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Ideology-Driven Telecommunications Market Leads to a Second-Rate Outcome

Editorial

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Abstract: Papers in the December 2020 issue of the *Journal* include a discussion about the parlous state of television broadcasting in Australia, 6G and the future of the National Broadband Network. The digital economy is a focus, with papers on tax risk assessment and assurance and the use of e-commerce by MSEs in Indonesia. Global telecommunications markets are struggling to move beyond the 20th century thinking and ideology-driven decision making that pervades many governments. Telecommunications use has surged as work from home has become normalised, yet the digital divide and second-rate outcomes abound as the result of poor decision making by government. Dr Leith Campbell takes over as the Managing Editor in January 2021. The *Journal* welcomes contributions on telecommunications and the digital economy.

In This Issue

In this issue of the *Journal* papers cover the NBN Futures Forum on a national broadband strategy for Australia, the state of television broadcasting in Australia and what should happen next, and a cyber and critical technology strategy towards 6G. The digital economy is a focus with a discussion on tax risk assessment and assurance reform and the use of e-commerce by MSEs in Indonesia. A review of network traffic anomaly detection is included, and historical papers look back at the Bellenden Ker television broadcasting station in north Queensland.

Should TV Move? provides a discussion about the unprecedented threats to broadcast television's business model, the global picture for terrestrial TV broadcasting and options for modernising the Australian system.

Gap between Regions in the Use of E-Commerce by MSEs examines the adoption of e-commerce by MSEs in different provinces in Indonesia.

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A Review of Current Machine Learning Approaches for Anomaly Detection in Network Traffic provides a comprehensive survey to give a broad perspective of recent research in the area of anomaly detection.

Tax Risk Assessment and Assurance Reform in Response to the Digitalised Economy focuses on the global reform that took place among tax authorities from a tax risk management and assurance perspective. The research results suggest an imbalance in reform among participants from developed and developing economies.

On Australia's Cyber and Critical Technology International Engagement Strategy Towards 6G reviews the most critical technologies; related risks and opportunities; best practices, policies and security frameworks in other countries; relevant government, industry, civil society and academia cooperation initiatives; and proposes how Australia may became a leader in the global Cyberspace.

The Bellenden Ker Television Project presents two historic papers from 1974/75 detailing the construction of the Bellenden Ker television broadcasting station in far north Queensland.

The NBN Futures Forum: Towards a National Broadband Strategy for Australia, 2020-2030 promoted the concept of an overarching National Broadband Strategy to achieve social, economic and governmental goals.

Towards a National Broadband Strategy for Australia, 2020-2030 examines the current state and desirable future of broadband services in Australia.

Ideology-Driven Telecommunications Market Leads to a Second-Rate Outcome

The Minister for Communications, Paul Fletcher, recently announced that the National Broadband Network (NBN) is built and fully operational. What this declaration does not say is whether the NBN is world-class and going to meet the nation's telecommunication needs for the 21st century.

The Minister's declaration is the first step required under the relevant legislation for the NBN to be sold off. It is reasonable then to reflect on the outcomes of the ten-year NBN rollout.

As nationally important infrastructure, the original goals for the NBN have not been met. Rather than providing a ubiquitous national fibre network, the NBN is now a patchwork of technologies, including copper-based technologies that are sub-standard, expensive and obsolete.

NBN Co, the government business enterprise, is responsible for the NBN rollout and its operation until the NBN is sold off. NBN Co has failed to achieve most metrics, and this failure

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has been brought on principally by the Coalition Government's decision in 2014 to force NBN Co to adopt an ideology driven business model and obsolete technologies. NBN Co has overspent, and continues to do so, and this growing debt means that the cost of the NBN to consumers is far higher than it should be. The Board of NBN Co now appears to be focused on enterprise products as a way to make up the shortfall; however, it is unlikely that any revenue gained will be directed to completing the original design.

It is anticipated that the Coalition Government will sell off the NBN after the next election, if it retains government, utilizing the disaggregation model that it favours. It has consistently said it will do so, but the ideology driving the Coalition government's decision making is wrong. There are times when the needs of the many should take precedence over the competitive and piecemeal business models for government services that appear to be favoured by conservatives globally, not just in Australia. As with the COVID-19 pandemic, an approach that favours lives (the many) over other considerations will require the Federal Government to inject the funds and resources necessary to ensure a successful outcome.

The Australian telecommunications market is dysfunctional, with unnecessary infrastructure duplication, over-pricing, poor reliability and a lack of world-class services. The digital divide continues unabated due to the failed telecommunication policies that have been a foundation of the telecommunications market since the deregulation process began in the early 1990s.

Whether it be a digital divide between urban, regional and remote areas, or the digital divide between those that can afford the exorbitant prices for telecommunications and those that cannot, Australia has little to show for a decade in which telecommunications was finally acknowledged to be an essential service.

Government intervention occurs in nearly every aspect of our lives, as it should. The key to successful government intervention is to be open about the desired outcome of the intervention and to willingly accept review, debate and criticism.

It is now more than six years since reviews and audits by the government and NBN Co were carried out in late 2013 and early 2014, yet the government and NBN Co are steadfastly refusing under FoI to make available the full reports, the input data and models. In a democracy this level of government obstruction is destructive.

Global telecommunication markets are evolving through the introduction of 5G, satellite constellations, AI/ML and edge computing.

The Australian telecommunications market needs urgent reform to ensure that it is open, fair and competitive. A good starting point, not just for the telecommunications market, would be to ensure that taxation is paid in Australia on transactions for products and services. It is vital that the offshoring of credit card transactions to avoid local taxation be prevented.

A model that places the focus on what is best for the nation and consumers, the motivation for the original NBN design, is required. A world-leading telecommunications market is a fundamental requirement for a nation to achieve societal and economic success in the 21st century.

The NBN is a fundamental enabler of our connected society in the 21st century. It is wrong to accept the Government's statement that the NBN is built and fully operational. It is not and will not be until the original design is completed and the government mandates an end to the digital divide.

Ideology is a poor platform for decision making.

The *Journal*, Looking Forward

Stepping down as Managing Editor

After 24 issues as the Managing Editor of the *Journal*, I have decided to step down. Over the past six years, the *Journal* has had a name change, moved to an online paper management system and streamlined processes. Successful inclusion in the Scopus journal index led to a Q2 ranking, an outcome that is welcomed and ensures that the *Journal* will continue to attract high quality papers from around the world.

I am pleased to note that Dr Leith Campbell, an Adjunct Professor at RMIT University, has agreed to take over as the Managing Editor of the *Journal*. Leith has kindly filled the role of copyeditor and Deputy Managing Editor for several years.

My heartfelt thank-you goes to the Editorial Advisory Board members, without whom the *Journal* would not have moved forward so successfully over the past six years. It is the positive support offered by the multidisciplinary and experienced Editorial Advisory Board that makes the *Journal* a key focal point for the reporting of research, discussion and public policy debate on telecommunications and the digital economy.

Looking forward

The *Journal* welcomes papers on telecommunications and the digital economy, including, theory, public policy, reviews and tutorials, and case studies.

Technological change is happening at a rapid rate and consumers anticipate that governments and industry keep pace to ensure that the benefits can be fully utilised. The *Journal* is calling for papers on how new technologies will affect Australian telecommunications consumers.

The topics of *International Telecommunications Legislation and Regulations* and *International Mobile Cellular Regulation and Competition* are set to continue for some time, as the opportunity to attract papers from around the globe continues. We encourage papers that reflect on where the global telecommunications market is now, how it got to where it is, and what is going to happen next.

Papers are invited for upcoming issues. With your contributions, the *Journal* will continue to provide readers with exciting and informative papers covering a range of local and international topics. The Editorial Advisory Board also values input from our readership, so please let us know what themes you would like to see in the coming year.

All papers related to telecommunications and the digital economy are welcome and will be considered for publication after the double-blind peer-review process.

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Should TV Move?

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Abstract: This article considers five options for the future of television transmission in Australia. We begin by describing the unprecedented threats to broadcast television's business model and power. We then set out the global picture for terrestrial TV broadcasting and options for modernising the Australian system. We do this within a framework that asks what now constitutes "television", because the services that viewers and users now treat as TV are broader than the subset that have carried most of the public policy freight for decades. The five options we consider are: first, do nothing much apart from adopting further improvements in compression technology; second, replace the current transmission system with a new, specialised terrestrial broadcast platform; third, migrate terrestrial TV to a direct-to-home satellite platform; fourth, move over-the-air TV online; fifth, design some sort of hybrid of Options 1 to 4. Finally, we arrive at some tentative conclusions.

Keywords: television, digital switchover, NBN, wireless broadband, spectrum auctions

Introduction

TV should move. So argued MIT Media Lab co-founder Nicholas Negroponte in the 1980s as part of a bigger idea he called "trading places". Most TV sets and telephones, at the time, were immobile. Switching television from over-the-air transmission to wired networks would enable it to offer viewers more channels and better quality pictures by deploying additional bandwidth. Telephone services were delivered over copper landlines to fixed locations in homes and businesses. Switching to wireless networks would enable callers to be mobile. Someone coined it the "Negroponte Switch" (Negroponte, 1995, p. 24).

The idea was never a comprehensive, global prescription. Much television was already delivered by cable in countries like the United States, Germany, Canada, The Netherlands, Belgium and Switzerland.[i] Most of the world's people had no telephones, landline or

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otherwise, so there was nothing to switch. When telephony finally came to them, it was born wireless (Ritchie & Roser, 2017). In Australia, the idea was real. Telephones meant landlines and almost all TV households received their service over the air. A very few received services retransmitted by cable in areas of poor broadcast reception. Many began subscribing to multichannel pay TV services from the mid-1990s: Optus and Telstra built hybrid-fibre coaxial cable (HFC) networks for that purpose in parts of the mainland state capitals and the Gold Coast (BIS, 2001, p. 14). Take-up of these pay TV services never exceeded about a third of households and a lot of customers—75% by one estimate—were served by satellite (Long, 2018).

So Australian TV was still predominantly delivered by wireless in 2009 when the National Broadband Network (NBN) was announced. Some were quick to see the new network as a potential delivery system for broadcast TV (Lohman, 2010; Morsillo & Barr, 2013), which was in the process of upgrading from one form of wireless signal (analogue) to another (digital). But the stated rationale for building an all-fibre – and later "multi-technology mix" – broadband network to more than 90% of households and businesses lay elsewhere. The option of building a so-called RF-layer into the NBN's architecture, which would have enabled free-to-air signals to be delivered over the fibre network, was rejected (Budde, 2012). Broadcast TV was well on the way to its own independent transmission future, all digital, and still all wireless, a destination it reached at the end of 2013 (Bunch, 2015).

The NBN is now mostly built. By June 2020, 11.7 million premises could order an NBN service, 99.7% of the total (NBN, 2020d). There is still a lot of work ahead to connect customers: 7.3 million had done so by June 2020. Even by June 2023, NBN estimates more than a quarter of premises that are "ready to connect" will not have activated a service (NBN, 2019, p. 49). Network usage was already heavy before the COVID-19 pandemic and has surged since, supported by additional Connectivity Virtual Circuit (CVC) capacity provided by NBN Co to service providers at no extra cost in March (later extended until November 2020) (NBN, 2020c) and a doubling of the Sky Muster satellite data allowance. From the pre-COVID baseline (week starting 24 February 2020) to 19 June 2020, peak downstream network throughput on NBN's main wholesale broadband service increased by 21% to 13.4 Tbps during the Evening Busy Hours (8pm to midnight). Peak Business Hours (Monday–Friday 8am-5pm) throughput increased 26% to 9.8 Tbps (NBN, 2020b).

One of the main reasons evening usage peaks higher than daytime, and post-COVID usage is up on pre-COVID, is video: video streaming, video conferencing and remote accessing of cloud-based office applications (NBN, 2020a). By early 2017, NBN was touting its role in "enabling the online video streaming revolution in Australia" (NBN, 2017). By late 2019, more than two-thirds of Australians aged 14+ used some kind of subscription video service.

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This was less than five years after the launches of the most popular streaming video-on-demand (SVOD) services, the international giant Netflix and Australian-based Stan. A quarter used the incumbent pay TV operator Foxtel (Roy Morgan, 2019). None of those video services use TV's digital broadcasting transmission platform. Nor do video sharing sites like YouTube, TikTok and Vimeo, online video games, or Disney+, the streaming video service launched in November 2019. If this is television, it has moved already.

Broadcast television, though, is still heavily used. Overall viewing has fallen in recent years, precipitously among younger viewers, though, like video streaming, it was boosted by COVID isolation. The switch to all-digital transmission made broadcast TV more technically efficient and enabled popular multichannels from the commercial and national broadcasters, but the upgrade in picture quality that came from the highest resolution HDTV formats did not provide a durable competitive advantage: it may have matched DVD, but not BluRay or the "4K"/ultra-high definition (UHD) streaming options that came later. The struggling financial performance of commercial TV broadcasters in the 2010s has been accentuated by the advertising decline that has inevitably accompanied the COVID-driven downturn in economic activity. Even with the abolition of broadcast licence fees in September 2017, which until 2010 required the big Sydney and Melbourne stations to pay 9% of their gross earnings before tax,[ii] and COVID-era holiday from the spectrum tax that replaced them, serious doubts about the economic viability of regional affiliates have been raised. Although other countries have upgraded their terrestrial TV distribution platforms, or are in the process of upgrading them, someone has to pay and the viewers have to be there when the job is done.

Is it time to revive the old idea that "TV" should move? This article considers five options. First, that we do nothing much, apart from adopting further improvements in compression technology. Second, that we replace the current transmission system with a new, specialised terrestrial broadcast platform. Third, that we migrate terrestrial TV to a direct-to-home satellite platform. Fourth, we implement the Negroponte Switch and move most over-the-air TV online. Fifth, we design some sort of hybrid of Options 1 to 4.

These options are considered as part of a wider analysis of the future of television transmission in Australia. We begin by describing the unprecedented threats to broadcast television's business model and power. We then set out the global picture for terrestrial TV broadcasting and options for modernising the system in Australia. We do this within a framework that asks what now constitutes "television", because the services that viewers and users now treat as TV are broader than the subset that have carried most of the public policy freight for decades. Finally, we arrive at some tentative conclusions.

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The State and Fate of Australian Broadcast Television

IBISWorld's July 2020 report on Free-to-Air Television Broadcasting in Australia portrays an industry "in the decline stage of its economic life cycle". Although barriers to entry into the narrowly-defined TV broadcasting industry are significant, competition from across the more widely-defined television and video market is high and increasing. IBISWorld estimates free-to-air broadcasting's revenue declined at an annual rate of 0.8% over the five years 2015–2020 and profits at an annual rate of 7.7%. Employment also declined, at an annual rate of 3.6% (Chapman, 2020a).

Broadcast television remains an extremely popular medium. Three-quarters of all Australians used it every week ("Weekly Reach") in the second half of 2019, and nearly 90%, 21.5 million people, used it every month ("Monthly Reach"). On average, they watched for just over two hours a day, around 65 hours per month (ThinkTV, 2020). But these figures have declined sharply in the 2010s and the averages mask big differences across age groups. A little over a decade ago, weekly reach was 95% (Screen Australia, 2013). Even six years ago, the average viewer watched for three hours a day, nearly 96 hours per month (OzTAM, 2013). Weekly reach remains at more than 90% for people aged 65 and over, but just 50% for 18–24 year-olds and 56% for teens (13-17 years). Those teens and 18–24 year-olds watch only half an hour per day. It is people aged 65 and over who bring up the average, watching more than 4.5 hours of broadcast TV per day, including live and playback up to 28 days later (ThinkTV, 2020).

The biggest programs still draw huge audiences but they are not what they were. In 2001, the finale of the hot reality show that year, *Big Brother*, drew 2.8 million viewers in the five main metro markets, and the AFL Grand Final 2.6 million (a Melbourne team, Essendon, against an interstate team, the Brisbane Lions). In 2019, the finale of *Married at First Sight* drew 2.1 million and the AFL Grand Final 2.2 million (again, a Melbourne team, Richmond, against the out-of-town Greater Western Sydney) (Screen Australia, 2020). Over the same period, the population grew by nearly a third (ABS, 2020).

These are seismic changes in a business that dominated the Australian media landscape in the last decades of the twentieth century. They were not, however, unanticipated. In the 1990s, TV broadcasters lobbied hard for spectrum arrangements and government funding to enable them to switch from analogue to digital transmission. This would provide them with flexible capacity to improve their picture quality, to add more standard definition channels, and to introduce forms of interactivity (ABA, 1997; Tanner, 2013). The first of these was under-utilised at first, though all networks now transmit their main channel in HDTV. The second, though delayed by complicated political deals, was eventually implemented successfully through services like Seven's 7TWO, 7flix and 7mate and the ABC's Kids/Comedy, ABC ME and News. The third also occurred, but less through the TV remote "red button" interactivity that broadcasters envisaged, and more through "multi-screening" with mobile phones, laptops and tablets, as part of a wider transformation of the media and communications landscape.

Television and "the TV" diverged. TV sets became displays for content from multiple inputs, not just from "TV stations", and they were no longer the only screens people watched. The industry's switchover pioneers had hoped to find themselves in the centre of the digital revolution: instead, they were "to some extent overrun" by it (Given, 2016). From 2001–2013, as the digital transmitters were switched on, a plethora of online and mobile digital platforms was launched that took audience attention and advertising dollars from existing media, especially television and print: Google News (2002, a few years after Google Search), LinkedIn (2003), Facebook (2004), YouTube (2005), Twitter (2006), Instagram (2010) and SnapChat (2011) (ACCC, 2019). They came "Over The Top", reaching users mainly over infrastructure that was built, maintained, upgraded and replaced by others. Older competitors also had an impact. Multichannel subscription TV did not become the dominant television force it was in Britain, but Foxtel got to all-digital transmission on its cable and satellite platforms well before broadcasters and deployed HDTV more aggressively. Since the mid-2010s, Foxtel has earned roughly the same amount in revenue as the three commercial networks combined (Chapman, 2020a; 2020b). For a time, DVD was another strong competitor: the market surged from an annual turnover of less than 20 million discs in 2000 to more than 80 million in 2009 but has declined since to around 30 million in 2018 (AHEDA, 2019, p. 7).

Better quality fixed and later mobile broadband, cheaper and eventually "unlimited" data plans, together with the rapid evolution of big screen TVs and mobile devices, then enabled video sharing and streaming to surge in the 2010s. Apple's iPhone was released in 2007, its iPad in early 2010. Internet-capable TV sets entered the Australian market early in 2011 (OzTAM *et al.*, 2017). Between March 2014 and March 2015, SVOD services were launched by Foxtel and SevenWest (Presto), Nine and Fairfax (Stan) and Netflix. Their impact was immediate. Paying for television, a minority practice through two decades of "pay TV", became a majority practice in 2016 (Roy Morgan, 2019). Three years later, the ACMA estimated 71% of adult Australians had access to some form of "pay TV" (ACMA, 2020, p. 92) According to Roy Morgan, in the three months to May 2020, 15.7 million Australians aged 14+ viewed some kind of subscription TV service. Netflix was by far the most popular, with 13.3 million viewers, followed by Foxtel (5.5 million including Kayo Sports) and Stan (4.4 million). New entrant Disney+ had nearly 2.5 million viewers within six months of its

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November 2019 launch, having reached 2 million even faster than Netflix. Households with multiple subscriptions are now common, especially Netflix/Stan and Netflix/Foxtel (Roy Morgan, 2020a, 2020b).

Television broadcasters adapted their activities and restructured their inter-firm relationships to deal with all this change. Initially, Seven and Nine took stakes in pay TV operators and created partnerships for their online activities with US tech giants, Yahoo! and Microsoft. Yahoo!7 and NineMSN were eventually unwound. Most, though not all, free-to-air broadcasters invested in the Freeview online platform. This was a hesitant move away from exclusively intra-network competition, towards a recognition that free-to-air TV in its entirety is in competition with other platforms. Freeview Plus now offers simplified access to catch-up TV and is supported by popular TV receiver, set-top box and personal video recorder (PVR) brands. All five national networks, however, have their own live streaming, catch-up and on-demand brands: ABC iView, SBS On Demand, 7plus, 9Now and 10play.

Mergers and acquisitions in the late 2010s were defensive: Seven and Nine merged with primarily print media companies, West Australian Newspapers and Fairfax Media in 2011 and 2018, respectively; Ten was placed into voluntary administration and sold to one of the original Big Three of US broadcast television, now ViacomCBS, in 2017 (Chapman, 2020a). In the national and community sectors, the National Indigenous Television Network (NITV) was merged into SBS in 2012 and, from 2014, the Federal Government encouraged the few community TV broadcasters to move online: the Sydney service (TVS) ceased all operations in 2015, the former Brisbane service rebranded itself as Hitchhike TV and moved online in 2017, while Melbourne station C31 continues to transmit on UHF at least until 30 June 2021 (Turnbull, 2014; Kalika, 2020).

In 2020, the COVID-19 pandemic initially boosted free-to-air viewing (Mason, 2020; Samios, 2020c) but hammered advertising expenditure. According to SMI AU/NZ data, ad spend across all media fell nearly 15% in 2019/20 (see Table 1). Managing director Jane Ractliffe said the level of confirmed future ad bookings was looking more positive in early August, but: “Never before have we seen a situation where all major media have reported significant declines in ad spend in the last month, quarter, half year and financial year as such large product categories significantly reduced their media investment” (Mediaweek, 2020). Seven West Media reported a statutory loss from continuing operations before tax of $294 million in 2019/20 (more than accounted for by significant items “including impairment of intangibles, other assets including fixed assets, restructuring costs and onerous contracts”), after reporting an equivalent loss of $444 million the previous year (Seven, 2020, p. 10). News Corporation announced a 14% fall in its “subscription video revenue” (which is mainly Foxtel) in the year to 30 June 2020, and a 12% fall in subscribers to Foxtel, Kayo and Binge (Kelly, 2020). In the UK, "changing behaviour during the pandemic appears to be accelerating the growth in viewing of online video", reported Ofcom, prompting "a surge in TV viewing that amplified the shift from broadcast to on-demand", while "reinforc[ing] the importance of public service broadcasters as trusted providers of news and information" (Ofcom, 2020a, p. 4).

Table 1. Ad Spend Trends, Australia, 2019/20

Media Type	Variance – FY2019/20 change on 2018/19, %
Television	-15.3
Digital	-8.0
Radio	-19.9
Outdoor	-19.0
Newspapers	-23.3
Magazines	-29.3
Other	-13.9
Cinema	-16.5
Grand Total	*-14.7*

Source: SMI AU (Standard Media Index, Australia), cited in *Mediaweek*, 4 August 2020. (Mediaweek, 2020).

Those who sensed immediately the scale of the social and economic crises ahead saw the possibility that this might be a time to ask the big, old question: Should TV Move?

The Global Picture for Terrestrial TV Broadcasters and Broadcasting

Terrestrial TV looks likely to remain an irreplaceable part of the communications infrastructure in most, though not all, comparable countries over the medium term. Longer term, beyond ten years, the outlook is less clear. Sources of uncertainty include, at the level of individual nations, the risk that other platforms will reduce the need for terrestrial broadcasting to the point where it is financially unsustainable. At a global level, the main uncertainty is potential competition from wireless broadband for broadcasters' UHF spectrum.

International generalisations about terrestrial TV viewing conceal big differences at the country level. Revenue models differ, including various combinations of public and/or advertiser-funded commercial broadcasting as well as free-to-air, receiver-licensed and subscription models. The historical level of competition from pay TV also varies widely. In countries with a strong tradition of public service broadcasters, the future of free-to-air TV is wrapped up with questions about the future of those institutions. In some other countries,

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however, public TV never existed, has disappeared, or now plays only a minor or specialised role. (See, for example, UK regulator Ofcom's work on the future of public service broadcasting and media (Ofcom, 2020b.))

To illustrate, overall viewing figures from the European Broadcasting Union (EBU) show a stable 29% of TV viewers in the EU-28 mainly reliant on digital terrestrial TV over the years 2014–17, almost level with satellite reception and well ahead of cable and IPTV (Broadband TV News, 2018). In two markets, Italy and Spain, twice that proportion, around 60% of households, mainly relied on a terrestrial signal to receive their television channels (Quijada, 2020). At the other extreme, Switzerland and Belgium had high penetration of cable and/or satellite TV and those mainly reliant on digital terrestrial TV had never exceeded 5%. Switzerland ended digital terrestrial transmissions by its public broadcaster, SRG, in June 2019. (An Austrian cable company got approval to reinstate them from a site in the Alps that reaches viewers in Austria. This preserved the cable company's regulated ability to carry the channels on its cable service, where they are popular with viewers especially in border regions. Similar arrangements are being contemplated along the French and German borders (Krieger, 2019).) Significantly, other options for the less than 2% of Swiss households seen as relying on DTT included free-to-air satellite DTH. Belgium too had high cable penetration and free-to-air DTH satellite options. Flemish public broadcaster VRT announced in 2017 it was turning off its digital terrestrial service (Broadband TV News, 2018).

Germany and the United States provide counterexamples illustrating the durability of terrestrial TV even when only a small minority relies on it. In these two countries, although most TV viewing is also via cable or satellite, significant investment is occurring in new digital terrestrial TV technology. Between 2016 and 2019, Germany progressively upgraded its digital TV network to DVB-T2/HEVC TV transmission and compression standards (discussed in the next section). The all-HD service offers unencrypted access to Germany's public broadcasters and access to commercial broadcasters for a monthly fee (Weidner, 2016). In the United States, reliance on terrestrial TV has bounced back in recent years (Perez, 2019). Following a two-sided "incentive auction" conducted by the Federal Communications Commission (FCC) in 2016/17, US broadcasters are currently migrating out of the 600 MHz band. This process is being funded by mobile network operators wishing to use the band for 5G telecommunications. In a series of recent decisions, the FCC has allowed existing TV operators to upgrade to the more advanced ATSC 3.0 TV transmission standard as they move from the 600 MHz band (Edgerton, 2018). ATSC 3.0 is able to support 4K/UHD picture quality. Nielsen found in May 2018 that the number of US television households receiving TV via an over-the-air antenna had nearly doubled over the previous eight years, to 14%: "As consumers look for more on-demand and cost-effective options, there has been a resurgence in this type of television household" (Butts, 2019). The US example also shows how the rise of Internet-delivered TV services may, by reducing the appeal of "traditional" cable or satellite pay TV, actually reverse the long-term trend away from the terrestrial TV service.

Despite its soaring uptake, Internet-delivered TV is not yet seen as a viable substitute for terrestrial broadcasting in any country. As early as 2014, the UK regulator Ofcom recognised an "emerging debate" about the right future delivery mechanism(s) for free-to-air television, driven by increasing viewer reliance on Internet delivery and "possible future demands" on the spectrum used by terrestrial TV, a reference to the re-farming of the UHF broadcasting bands for wireless broadband. Ofcom identified the Internet and satellite TV as the rival candidate platforms. It proposed some criteria for a migration of television to the Internet, including the availability and take-up of superfast broadband, the take-up of IP-capable receivers and the quality and reliability of the IP viewing experience. Ofcom's own, tentative conclusion was that the free-to-air terrestrial platform would be needed at least until "post-2030" (Ofcom, 2014).

Decisions to re-farm entire bands from broadcasting to telecommunications use are commonly taken supranationally, by a "critical mass" of countries. The development and subsequent global influence of the Asia-Pacific Telecommunity (APT) 700 MHz "digital dividend" from analogue TV closure shows how, by increasing the value of the relevant spectrum world-wide, these decisions tend to create their own momentum. Major changes in broadcasting delivery have historically been led by the most developed countries, suggesting North America, Europe and East Asia should be looked to for leads. The ACMA's 2019-23 *Five Year Spectrum Outlook* [*FYSO*] suggested "current thinking in Europe is that the remaining UHF TV spectrum will be needed at least until 2030" (ACMA, 2019b, p. 29), suggesting terrestrial TV is unlikely to face pressure to migrate out of UHF in the medium term.[iii] The picture is somewhat different in North America; the relevance of US moves to re-farm part of the UHF TV spectrum (600 MHz) is discussed further below.

Options for Modernising Terrestrial TV in Australia

One of the legacies of analogue to digital conversion in Australia was a ubiquitous, free-to-air TV service that was initially able to match its chief rival – cable or satellite subscription TV – on picture quality. By the 2013 completion of analogue switch-off, five digital TV networks offered seventeen streams of free-to-view audio-visual content, in a mixture of High Definition (HD) and Standard Definition (SD) formats (Tanner, 2013). The service was available everywhere for the price of a single, relatively cheap external antenna or – in remote areas and reception "black spots" – a satellite dish, after the government supported the creation of the Viewer Access Satellite Television (VAST) service. This provides satellite delivery of free-to-air television (FTA TV) to approximately 200,000 households, mainly in remote and regional areas, and 30,000 travellers, that are unable to receive reliable local terrestrial transmissions (DOCA, 2018b).

Digital TV in Australia launched using the European DVB-T *transmission standard* coupled with the MPEG-2 video and audio *compression standard* or codec. Each network obtained an entire, 7 MHz TV channel at every site, able to carry up to six standard definition (SD) video streams, or up to two high definition (HD) video streams, or a combination. Broadcasters have subsequently begun to deploy the more efficient MPEG-4 *compression standard* for some services in some markets. Consumers have needed newer, MPEG-4-compatible receivers to watch the services, so the upgraded compression standard has been used mainly to supplement the existing (MPEG-2) ensemble with new channels, like Racing.com on Seven, and to carry the HD versions of each broadcaster's primary channel. The number of MPEG-4 streams varies between networks and between metropolitan and regional services. The use of MPEG-4 for HD services may reflect the larger percentage of MPEG-4-compatible HD sets. There is as yet no stated industry plan or timetable for full migration, which would leave an unknown number of older MPEG-2 sets unable to receive services. Moving fully to MPEG-4 should permit a roughly two-thirds increase in the number of SD or HD streams broadcast (SBS, 2015, p. 11). It is debateable whether it can support 4K/UHD content: even if it is technically possible to carry a 4K/UHD picture, broadcasters could only do so by sacrificing multi-channel capacity, so it is very hard to see it happening.

Most public discussion to date has focussed on the option of updating the entire platform, both the transmission standard and the compression standard. But, as the deployment of MPEG-4 demonstrates, newer compression standards can be introduced with the existing DVB-T transmission standard to enable broadcasters to expand and improve services as viewer uptake of compatible receivers allows. MPEG-4's effective successor, HEVC, is already widely used, and the first version of its successor, VVC (Versatile Video Codec), was finalised by the Joint Video Experts Team in July 2020 (JVET, 2020; Ozer, 2019). Both would, in theory, considerably increase the carrying capacity of each DVB-T TV channel used for transmissions from existing multiplexes. By contrast, conversion to a more advanced transmission standard – which would incorporate a newer compression standard as well – cannot be achieved using current multiplexes. New transmitters would be required, with full conversion requiring sufficient viewer uptake of compatible receivers and the eventual switch-off of existing transmitters.

In theory, there is a choice of several terrestrial TV standard families in use globally: the others are ATSC (North America), DTMB (China) and ISDB (Japan), which has a Brazilian variant, SBTVD-T (Digital TV Status, 2017). The obvious choice for Australia is DVB-T2, the newer version of the DVB-T standard chosen initially. This was first deployed by Freeview in the UK in 2009 with MPEG-4 compression. (New Zealand, where digital services started later than Australia, uses DVB-T/MPEG-4.) The ATSC 3.0 standard, used in North America, is newer than the comparable European standard and is based on Internet Protocol (IP), which may confer an advantage in interactive use cases (Siebert, 2019). An updated version of SBTVD is still "evolving" (Forum SBTVD, 2018).

Australia's continuing use of DVB-T means DVB-T2 starts with several advantages. It would be easy to source affordable DVB-T2 receivers that are backwards-compatible to DVB-T, which is something consumers will require in any plausible migration scenario. The local TV industry has conducted trials of DVB-T2 and has consistently identified it as the likely future standard (Broadcast Australia *et al.*, 2019; Free TV Australia, 2020). While the early history of TV digitisation is littered with false starts, and numbers of countries have upgraded or augmented DVB-T networks with DVB-T2, we are not aware of any examples to date of countries where digital television services were established using one family of standards and subsequently changed to another.

A DVB-T2/HEVC TV channel would allow 4K/UHD pictures and carry about five times as much TV content as a DVB-T/MPEG-2 channel, as shown at Figure 1, or a little over three times as much as a DVB-T/MPEG-4 channel.

Complete migration of all five broadcast networks to DVB-T2 would be costly and complex, like the transition from analogue to digital. That experience, however, does not provide a precise template for digital-to-digital conversion. The net implications for government from additional expenditure and revenue raised from vacated spectrum are difficult to estimate, just as they were for digital switchover.

Between 2000 and 2014, digital switchover cost the Australian government $A2.4bn in 2018 dollars, a sum fortuitously exceeded by the amounts paid for wireless broadband licences in the vacated 700 MHz band (Given, 2018). The largest expenditure item (66% of the total), direct assistance to broadcasters, included the entire costs of digitising the transmission networks for the two taxpayer-funded networks and more than half the capital costs of digitising commercial TV transmission outside metropolitan areas. Assisting viewers with the cost of conversion, including establishing the VAST service, was the next largest item (27%). Government also funded the "restack" of digital TV services in preparation for the 700 MHz auction. This involved a large number of frequency shifts for transmitters at particular sites to create larger and more valuable contiguous blocks of spectrum for auction. It also ensured all TV services from each transmission site were delivered on either VHF or UHF frequencies, simplifying viewer reception.

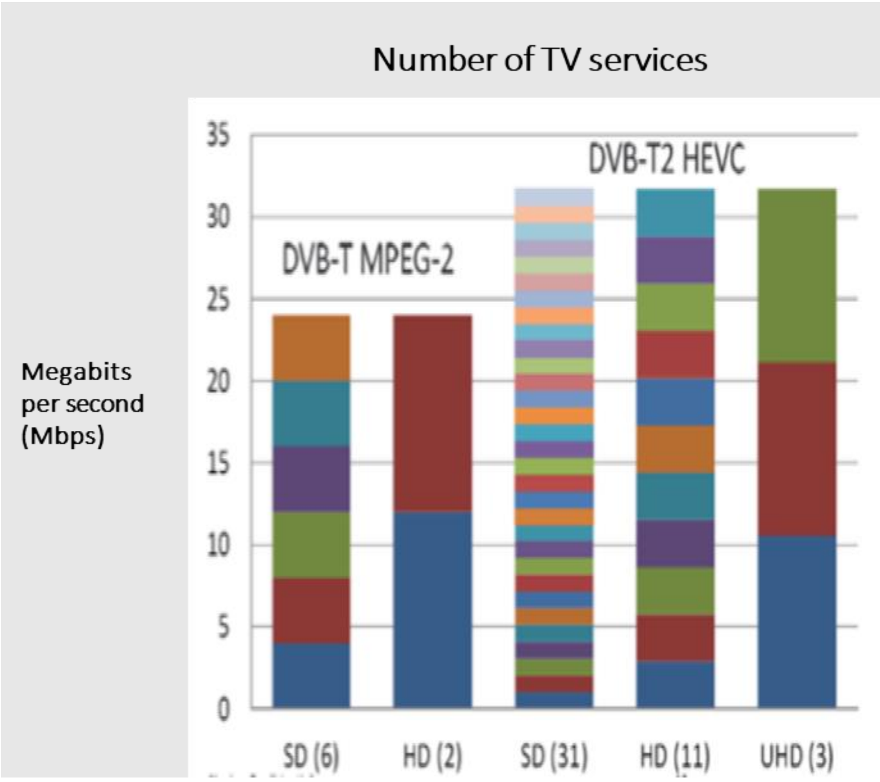

Figure 1. Comparison of DVB-T/MPEG-2 with DVB-T2/HEVC. The two columns on the left show alternative uses of the capacity of a 7 MHz channel using DVB-T/MPEG-2; the three on the right represent alternative uses of a channel using DVB-T2/HEVC. The DVB-T columns are lower than the DVB-T2 columns, because DVB-T can carry only up to about 24 Mbps compared to around 32 Mbps for DVB-T2. Source: Helge Stephansen's presentation at *VidTrans13*–Content in Motion, Annual Technical Conference and Exposition, February 26–February 28, 2013. Los Angeles, California, cited in Giles Tanner's Radcomms speech in 2018 (Tanner, 2018).

The most important extra complexity involved in a complete migration to DVB-T2 derives from the limited supply of TV channels. For digital switchover, each of the five analogue broadcasters in each area gained access to an entire, additional 7 MHz TV channel. This was possible because digital transmission allowed previously vacant frequencies to be used. For example, in metro areas, VHF Channel 8 could be used, previously a "taboo" frequency when used for analogue transmissions from the same sites as Channels 7 and 9. This meant each broadcaster was able to simulcast analogue and digital versions of their main services throughout the transition. Introducing further new digital transmissions using a different standard, DVB-T2, would not now create the same opportunity.

The current TV channel plan provides only a single spare channel at each site, the "sixth channel", which has been used in major cities and some regional areas by community TV stations. It could be used for DVB-T2 services but, if more than one broadcaster wished to use it, participants would need to consolidate their signals, as radio broadcasters are already

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doing for digital radio services transmitted on DAB+. (As DAB+ radio multiplexes can carry eighteen or more near-FM quality radio streams, two models were adopted in major city markets. ABC and SBS share one multiplex. One or two other multiplexes, as required, are shared by up to seven analogue commercial radio services, each qualifying for one-ninth of the capacity. The remaining two-ninths must be offered to community radio services.) Even with the increased efficiency of DVB-T2/HEVC, a single multiplex could not handle the existing free-to-air multi-channels in all the formats in which they are currently delivered. Some sort of progressive roll-out of services would be required, with extra frequencies becoming available only when existing services were turned off. This contrasts with the single switch-on date set in each transmission area for the launch of DVB-T services, which was easier to plan and especially to communicate to viewers.

On the other hand, several elements of the transition might be easier than analogue–digital migration. Because fewer people now rely on broadcast television, more may simply shrug at the prospect of losing over-the-air reception. They will not miss out on what they have come to think of as TV and their political representatives will not be as fearful. Those that do care may be more attuned to the relentless redundancy of media and communications devices, and less likely to blame governments for the expense of the new one(s) needed to receive familiar services. The legacy of rationalised TV transmission arrangements left by digitisation – including the current "block" channel plan and the neat sorting of households into terrestrial and satellite (VAST) audiences – would simplify planning for DVB-T2 services. Most people will already have the correct (VHF or UHF) rooftop antenna and a substantial but unknown percentage of viewers will be "DVB-T2-ready", having fortuitously acquired one of the many DVB-T2-comptible TVs already on the market. If the five national broadcasters consolidated transmissions onto less than five DVB-T2 multiplexes at each site, the total capital and operating cost of new transmission infrastructure would fall proportionately.

Auctioning any vacated spectrum might not attract the bonanza anticipated, and eventually delivered, by the first "digital dividend". While demand for spectrum for fixed and mobile wireless broadband from mobile network operators (MNOs) is the most plausible source of revenue to finance the migration, there is no current shortage of similar (sub-1 GHz UHF) spectrum in Australia (ACMA, 2020, pp. 29–30). Longer term, the value of TV spectrum will depend on international developments in spectrum harmonisation and telecommunications equipment availability. As discussed above, there is little sign of any global move to re-farm the remaining broadcasting bands. An important exception is that the US has identified a paired allocation for wireless broadband of 75 MHz of spectrum that corresponds to the top of Australia's UHF TV allocation (617–698 MHz). While Europe seems unlikely to follow any time soon, Australia's isolation frees it somewhat to pick and choose with whom it harmonises. Submissions to the draft *FYSO 2020–24* indicate there is growing medium-term mobile network operator interest in the allocation (AMTA, 2020; Telstra, 2020). If, in future, MNO demand grows strong enough, a TV upgrade might even be funded via a two-sided auction, as has happened in the US. In 2018, ACMA staff estimated that alignment with the US 600 MHz plan could be achieved if TV squeezed down to either four or "preferably" three channels at each site (Tanner, 2018).

Considering the Options

So, should Australian TV move? And, if so, where? We now consider five options:

1. Minimalist model: upgrade the current compression standard(s);
2. Replace the current transmission standard with a new, specialised terrestrial broadcast platform like DVB-T2;
3. Migrate terrestrial TV to a direct-to-home satellite platform;
4. Move over-the-air TV online;
5. A hybrid of Options 1 to 4.

The main issues raised in different ways and to different degrees by the five options are mostly familiar from the debates about analogue–digital switchover and the first digital dividend. First, transforming TV: the extent to which each option enables better picture quality and more channels, and delivers video services in the ways users want them. Second, freeing spectrum: how much might be vacated, how soon and what value might other spectrum users place on it. Third, economics: any migration will bring its own costs to operators, consumers and also governments, which fund two networks and subsidised the transmission infrastructure of the others outside of major cities. To some extent, these costs can be traded off between the stakeholders, but this risks leaving vulnerable consumers behind altogether or making them pay for a previously free service they regard as essential. Fourth, international trends: the extent to which Australia keeps pace with developments in major overseas countries, to ensure the supply of transmission equipment and domestic receivers that Australia does not produce itself. Fifth, competition: if broadcasters have to collaborate more closely with each other, and/or are compelled to migrate to a single fixed-line or satellite platform, might that result in unacceptable concentrations of power in the hands of the broadcasters or another entity, such as the NBN?

What is different from the debates about analogue–digital switchover is the smaller – though still large – place broadcast TV occupies in the social, political and economic landscape. The audience that actually still relies absolutely on "the TV" is increasingly mainly old, though, at particular times, it is much larger and more diverse. For that absolutely reliant audience, moving TV transmission is about the retention of a critical service, as telegrams once were, and petrol stations stocking gasoline might become.

The five options and the issues they raise are summarised in Table 2.

Table 2. Should TV Move? Comparison of Options

Option/Issue	Transforming TV	Freeing spectrum	Economics: costs for industry, consumers, government	International trends	Competition
1. Minimalist model – upgrade current transmission system	modest	modest or very long term	modest	common	preserves existing level; could involve consolidation among broadcasters
2. New specialised terrestrial platform like DVB-T2	potentially significant	potentially significant	complex, expensive	follows Britain and Germany on DVB-T2, US on 600 MHz band clearance	could involve consolidation among broadcasters
3: Migrate terrestrial TV to a DTH satellite platform	potentially significant – dependent on satellite/capacity chosen	potentially clears all terrestrial TV spectrum	complex, expensive, contentious	some use of satellite common but not complete migration	potentially significant
4: Move over-the-air TV online	most significant	potentially clears all terrestrial TV spectrum	*Industry*: depends on access pricing *Consumers*: may require viewers to acquire new services or upgrade existing ones to higher speed/price tiers *Government*: depends on scale of any direct or indirect subsidies, including via NBN	unprecedented at this stage	potentially significant
5: Hybrid of Options 1 to 4	depends on precise mix of elements	depends on precise mix of elements	depends on precise mix of elements	depends on precise mix of elements	depends on precise mix of elements

Option 1: Minimalist model: upgrade the current transmission system

Policymakers could choose to do nothing much. Those who think broadcast TV is dying anyway might just want to hang back and monitor the decline. Any action will cost money and risk alienating viewers. Why invest in a new, specialised broadcasting platform when other platforms exist – satellite everywhere, the fixed-line NBN in most places, and even mobile networks in and near major population centres, especially once 5G is widely deployed?

Upgrading the current transmission system, at this point, means each broadcaster fully converts all or most of its transmitters to MPEG-4. Longer term, it could mean upgrading to a still newer and more efficient compression standard like VVC while retaining the DVB-T transmission standard and transmitters. Full conversion to MPEG-4 would give broadcasters and their audiences the full benefit of the roughly two-thirds increase in capacity. The resulting greater efficiency would also create some possibilities — though not as large as those offered by DVB-T2/HEVC — for television broadcasters to consolidate their services onto shared multiplexes so as to reduce their transmission costs and spectrum use. Full migration to MPEG-4 by each broadcaster would not, of itself, free any spectrum, but opportunities would be created for further steps that would achieve this result. In 2016, the ABC's outgoing managing director, Mark Scott, highlighted the scope for savings through consolidation of transmission by the ABC and SBS, as part of a broader plan for the national broadcasters to co-ordinate activities while retaining distinctive brands (Knott, 2016). The SBS had previously identified practical problems with this approach (DOC, 2015, pp. 25–26; SBS, 2015, pp. 20–21).

Since then, the pressure on transmission costs for both national and commercial broadcasters has only intensified. In response to the COVID-19 pandemic, governments have shown themselves prepared to spend on an extraordinary scale, but the resulting deficits may sharpen the search for savings measures elsewhere. As TV advertising revenue has crashed, genuine doubts have been raised about the economic viability of regional commercial TV affiliates that earn much less revenue than their metropolitan counterparts but incur larger transmission costs to distribute their signals to more dispersed audiences (Samios, 2020a; 2020b). To illustrate, the Adelaide and Southern NSW/ACT aggregated TV markets each contain a little over 1 million viewers. Adelaide is served from a single transmitter at Mt Lofty plus a couple of small in-fill translators. Southern NSW requires separate high-power sites to serve Canberra, the Illawarra, Central Tablelands, Cooma/Monaro, Central Western Slopes, and South-Western Slopes/Riverina, plus literally dozens of medium- and low-powered sites.

Facing these and other pressures about the future of their medium, we should not assume that all five networks will share the same strategic vision or even that they will stick with their own individual vision over time as circumstances and perhaps owners change. They had quite different ideas about how to deploy the flexible extra capacity offered by DVB-T in the late 1990s and early 2000s. The national broadcasters and Seven were interested in multi-channels, while Kerry Packer's Nine and Ten wanted HDTV (Given, 2003, pp. 164–165). Those divisions declined after Packer's death in 2005 and Seven's rise to ratings leadership. It would not be surprising, for example, if the Ten Network, now owned by a US media giant, had different priorities from Nine and Seven, or the publicly-funded ABC and SBS. Nor would it be surprising if the larger ABC were more interested in consolidating transmission than the smaller SBS, which jealously guards its separate identity.

Even a minimalist model is likely to involve government. Leaving the future of terrestrial TV wholly in the hands of a potentially divided industry seems unlikely to be attractive to governments that pay the transmission costs of two of the five networks, receive revenue from reallocating any vacated spectrum and generally want to ensure Australia is at least a relatively fast follower of technical developments in comparable markets. It may be acceptable for the next few years, but less so for the longer term, especially if it leaves Australia significantly lagging the US and any other countries that follow it in clearing TV out of the 600 MHz band. The VAST service also sets decision points. It was initially funded for ten years to 30 June 2020. Reviewing the service in December 2018, the Department of Communications and the Arts recommended the current satellite delivery model should continue for five years, as it currently provides the only available cost-effective way of delivering free-to-air television in areas not served terrestrially. It also recommended a further review before the next funding service period (DOCA, 2018b). Releasing the Department's report in January 2019, the Minister for Regional Services, Bridget McKenzie, announced $10 million in additional funding to secure the VAST service "until 2021" (McKenzie, 2019).

Option 2: Replace the current transmission system with a new, specialised terrestrial broadcast platform like DVB-T2

Replacing the current transmission system entirely provides more advantages but some big disadvantages. It offers greater capacity to improve television, potentially a five-fold increase in the number of SD or HD channels, or three 4K/UHD channels, or some combination, per multiplex, compared to DVB-T/MPEG-2. (The percentage increase will be smaller, a little over three-fold, if TV has fully upgraded to MPEG-4 compression.) The scope for reducing transmission costs and enabling a second digital dividend is large, depending on how much of the increased transmission efficiency is harvested by reducing spectrum allocated for TV rather than allowing broadcasters to expand services. Replicating the steps taken in some major overseas markets – DVB-T2 in Britain and Germany, clearing TV from the 600 MHz

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band in the US – would help to minimise any unique technical features of industry and consumer equipment needed for the Australian market.

The disadvantages are that it would be complex and expensive, much more so than just upgrading compression standards on existing transmitters (Option 1). It would risk disruption and perhaps temporary or permanent loss of service to vulnerable, politically-sensitive viewers, but deliver capacity increases well short of the potentials offered by Options 3 and 4. As discussed in the previous section, the transition from DVB-T would be more complicated than that from analogue to digital. Like that process, however, viewers would need to buy set-top converters or new TV sets to receive the DVB-T2 transmissions (some sets on the market are already DVB-T2 compliant) and dispose of old ones at a time when concern about the environmental consequences of electronic waste has grown.

While presented as a single option, full conversion to DVB-T2 encompasses myriad sub-options with different levels of consolidation among broadcasters and different timeframes for switching transmitters on and off across the country. These set the actual levels of improvement in services that can be delivered, and when, as opposed to the theoretical improvements implied by each standard's maximum data rates. A crucial issue is the preparedness of the five broadcasters to consolidate transmissions onto four or perhaps three multiplexes, thereby vacating one or two sets of frequencies, then "restacking" to optimise the useability and value for incoming spectrum users. Any restack, too, would bring a range of options, costs and complications. The US incentive auction provided a government-structured bargaining framework through which incumbent broadcasters and aspiring mobile broadband operators negotiated the price of multiple strategic options. Something similar could be done in Australia, although the regulatory cost and complexity would need to be amortised against a much smaller pool of auction revenue (Tanner, 2018). As a "standards taker", Australia might instead choose to adopt a simpler format for a two-sided auction, where a single option is put to the market, such as whether to align with the US 600 MHz allocation.

While the TV networks are ferociously competitive, they are no strangers to collaboration where commercial imperatives justify it. Most are partners in Freeview Plus and several use the playout, live streaming, archiving, audio description, closed captioning and other facilities provided by Media Hub (Kelly, 2018). The three commercial networks pooled their transmission facilities into the jointly-owned TXA years ago. Seven and Nine bought Ten out of its share in 2019 when Ten shifted its transmission to BAI Communications (formerly Broadcast Australia and, long before that, the state-owned National Transmission Agency), which handles transmission for the ABC, SBS and Southern Cross Austereo. (Seven and Nine are currently looking to sell TXA (Samios, 2020d).) Radio broadcasters share DAB+

multiplexes for digital radio transmission and newspaper publishers now share printing facilities (Ryan, 2018).

A cost/benefit analysis could also be undertaken. This was done for digital switchover in some countries including New Zealand and the UK, though not Australia (Given, 2007). Any analysis would be contentious and incomplete, not least because of the difficulty of estimating the costs of technical equipment years in advance and the value to consumers of free, over-the-air reception in areas where a new transmission standard might result in poorer or no coverage. Cost/benefit analysis cannot be relied on to precisely evaluate options but it does force disciplined thinking about what each option involves, the nature and magnitude of costs and benefits, and where and when they occur. The analyses undertaken for digital switchover in New Zealand and the UK, for example, helped to identify the relative merits of partial and complete switchover, the optimal mix of terrestrial and satellite delivery for all-digital free-to-air TV, and who was best placed to bear the costs. Like digital switchover, most of the costs of a full migration to a new standard are likely to come early, the revenue much later. That experience shows that big, complicated shifts can occur over a long period and deliver net benefits, despite changing governments, industry disagreement and uncertainty about technology, costs, processes and timing.[iv]

Option 3: Migrate terrestrial TV to a direct-to-home satellite platform

Wholesale migration to a satellite platform has considerable technical and economic attractions and may seem conceptually straightforward – turn off terrestrial transmitters and allow viewers in all markets to acquire satellite receivers giving access to an enhanced version of the VAST service. Alternately, the potential for some future synergy with another government-supported satellite service, the NBN's satellite broadband service, has already been flagged for long-term future exploration in the 2018 review of the VAST service (DOCA, 2018b, pp. 32–34). In practice, any wholesale shift to satellite delivery would be costly for many households and require the current satellite DTH service to be fundamentally re-engineered and expanded to incorporate all TV networks and the separate programming and advertising break-outs they currently deliver terrestrially to discrete local service areas. It would therefore be extremely contentious with viewers and hence politicians.

On the question of cost, if the same satellite also carries pay TV and the householder is a subscriber, the conversion would not be complex. For other viewers, the $850+ indicative cost of a dish to receive VAST would compare poorly with the $350+ their standard VHF or UHF antenna probably cost them. Broadcasters could cut these costs by leasing capacity on more powerful satellites, but that would reduce the savings. Very few retail customers prefer satellite-to-terrestrial transmission for any kind of service. It is better than no service at all and was welcomed in remote areas when it brought broadcast TV, telephony, multichannel TV, the Internet and broadband for the first time. But it is never better than a service a customer is already receiving via terrestrial delivery with cheap, easily available equipment. Aspiring telephone users who had waited decades for landlines did not welcome a National Broadband Network that forced them to shift to fixed wireless or satellite.

On the question of distinctive programming and advertising break-outs, the VAST service is a workaround, not a complete solution. Though conceptually simple, it is operationally complex and a long way from replicating the full suite of separate TV services now delivered across all metropolitan and regional markets. It was designed in 2010 to preserve as much as possible of the distinctive local news, other programming and advertising break-outs offered by relevant non-metro TV broadcasters, but it has always been a compromise. The ABC and SBS carry distinct TV and radio services to five separate areas corresponding to the country's five summer time zones. These services include Indigenous services like ICTV supported by the Department of Prime Minister and Cabinet under its Cultural and Capability Program. Two different commercial joint ventures involving WIN, Prime, Imparja and Southern Cross Austereo provide three different service packages to three satellite coverage zones – broadly, Western Australia, Northern Territory and Queensland, and the states and territories of South Eastern Australia. Dedicated news channels are carried in the Northern and South-Eastern satellite areas. These rebroadcast nightly bulletins and updates from regional commercial broadcasters about half an hour after the original terrestrial broadcast, and include the same advertising.

Even the viewers VAST is designed for raised a range of concerns when the government reviewed the service in 2018: the cost and functionality of the VAST set-top boxes; the reliability of reception especially during heavy rainfall; the half-hour delay in broadcasting the commercial news bulletins; and the fact that "sport, advertising, metropolitan news and emergency information on commercial VAST channels [is] not as comprehensive as terrestrial channels or as relevant to viewers" (DOCA, 2018a, p. 13). These concerns, from the existing base of 200,000 households and 30,000 travellers, would be amplified many times over if millions of households were offered a similar substitute for their existing free-to-air services, although newer transmission and compression technology may increase the range of signals that can be economically carried, and broadcast/broadband integration may create new ways of delivering programming break-outs. This issue lies at the heart of the idea of television and the role it has come to play in the lives of dispersed audiences. It can be difficult for big-city viewers to appreciate fully the personal, social and economic impact of media messages aggregated in faraway places even within the same state – news from

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distant towns, ads for irrelevant businesses, results from meaningless sporting fixtures, forecasts of other people's weather.

Satellite would offer more potential capacity than an upgraded or new terrestrial platform, but the precise capabilities would depend on the satellite(s) chosen and decisions taken about how much capacity to buy or build. An optimistic view about the future of free-to-air TV might encourage ambitious capacity commitments, offering scope to expand the numbers and picture quality of services. But, if a central reason for the migration is to reduce overall transmission costs, an agenda more like the one chosen when VAST was created in 2010 seems more likely: "freeze-frame" the currently best-available free-to-air offering in metropolitan areas and equalise its delivery across satellite and terrestrial platforms. That makes satellite's theoretically unlimited capacity less of a practical advantage.

All the spectrum used by terrestrial broadcasters could be vacated if the migration to satellite was comprehensive, maximising the opportunities and value of reallocated frequencies. More likely, any migration would be staged, beginning in regional areas, optimising the trade-off between spectrum freed and viewers inconvenienced. The proportions of households served terrestrially and by satellite would shift again, as they did when VAST was established, and, before that, when commercial pay TV operators made their decisions about platforms. The boundaries of terrestrial service would be redrawn still closer to metro centres. Those with an eye for history might see this as a further step along the path proposed by Kerry Packer when proposing a domestic satellite system in the 1970s. Packer wanted the three metropolitan networks to beam their single channels direct to homes in the major regional centres, replicating the three-channel competition that Sydney, Melbourne, Brisbane and Adelaide had had since the 1960s. (His father, Sir Frank, had wanted the same thing when commercial TV services were first proposed for country areas, though with signals distributed by Telecom's cables.) Packer – unusually! – did not get his way. Regional TV resisted and country politicians and the whole Parliament chose to preserve a degree of independence for regional broadcasters. The large, aggregated regional markets created in the early 1990s are the result, with their attendant high transmission costs relative to revenues. That independence was always tendentious and has been progressively mugged by financial reality as the economics of the TV business have deteriorated.

Looking overseas for precedents and potential future moves, both New Zealand and the UK provide examples where the availability of satellite delivery options for free-to-air TV was an important factor that allowed many terrestrial analogue transmission sites to be shut down as part of the shift to an all-digital terrestrial platform. Satellite was already the platform of choice for the main subscription TV operators in those countries, so neither provides a neat precedent for the extreme version of this Option 3, a mandated shift from over-the-air to

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satellite for the large number of city viewers who depend primarily on broadcast reception for the many hours of TV they watch each week.

Any comprehensive consolidation of TV broadcast transmission onto a single platform may raise competition concerns, firstly about the level of collaboration required among ostensibly competing broadcasters, and secondly about the market power it would give to the satellite provider. These may be mitigated by the degree of competition already being provided to broadcasters by SVOD and other video services and apps, and by competition for distribution in geographic markets served by the fixed-line NBN. Given the long-running, rumbling government unease about BAI's power and pricing in terrestrial transmission, these competitive concerns may not be easily allayed.

Option 4: Move over-the-air TV online

This would be a big, bold strike, integrating broadcasters decisively into the distribution platform that is already carrying the video streaming and sharing services and apps whose rapid take-up is the story of the last decade. It is not exactly the Negroponte Switch, which was about shifting over-the-air TV to wires. Nor is it exactly just about shifting Australian TV to the NBN, which is a terrestrial wireless and satellite network for a small but significant proportion of customers, and is far from the only way users access video, now that mobile broadband in Australia is so fast and cheap. Indeed, some are already suggesting that TV broadcasters' real transmission future lies with 5G (Pennington, 2020).

The ongoing evolution of wireless broadband technology may well permit greater customisation of wireless broadband networks to substitute, rather than just complement, the existing broadcasting platform. For example, European initiatives under the rubric of Enhanced TV (EnTV) are exploring the holistic implementation of multicast/broadcast as a critical technology element in 5G systems in addition and as a complement to unicast (Gibellino, 2020). In the absence of a mature "5G EnTV option", however, we have focussed on the option of unicasting (i.e., point-to-point streaming) of TV to viewers using any existing (fixed or wireless) broadband platform (5G-Xcast, 2020).

Moving TV online would not remove capacity constraints, no transmission medium can ever do that, but it would extend to broadcasters the 4K/UHD capability that online video distributors are already enjoying. Free up spectrum? In theory, TV broadcasters would vacate the lot, all five sets of UHF and VHF frequencies across the nation. Over-the-air transmission costs would fall to zero and, while the fees broadcasters paid to stream all their services would rise with the increase in viewer numbers, a significant share of it would go to the state-owned NBN, helping to amortise the cost of its massive public investment, rather than to private transmission providers like BAI. The competition concerns might be significant, especially if the NBN is privatised and controlled by parties not yet known, but the arguments have been well-rehearsed by the ACCC, the industry, the NBN, and its shareholder and stakeholders. If comparable overseas markets choose this approach in the decade ahead, Australia may be tempted to follow.

Given the dramatic generational shift from broadcast to broadband video viewing, some might see it as inevitable that broadcast and broadband should converge. Henry Jenkins warned about this kind of thinking, which he called the “Black Box Fallacy”:

> Sooner or later, the argument goes, all media content is going to flow through a single black box into our living rooms (or, in the mobile scenario, through black boxes we carry around with us everywhere we go). … Part of what makes the black box concept a fallacy is that it reduces media change to technological change and strips aside the cultural levels. (Jenkins, 2016, pp. 14–15)

Television, and broadcasting more broadly, have never been just technologies. They are “a set of technologies, social practices, cultural forms, industries, institutions, words and ideas that constantly transform, finding new shapes that sometimes embody features of old ones” (Given, 2016, p. 119). Broadband network operators, especially the state-owned NBN, would need to demonstrate not just that they have the technical capacity to carry the extra traffic but that they could meet whatever social and cultural expectations remain implicit in the idea of television. This seems likely to include the reliability of the services, the range of content, and free-to-air accessibility.

Technical capacity should be an empirical question and answering it has been assisted by the unanticipated, real-time experiment forced by COVID lockdowns. It still requires assumptions to be made about what and when people will choose to watch, especially any viewing peak periods or programs. These can be unpredictable. In the UK, Prime Minister Boris Johnston’s messages to the nation in March and May 2020 were the UK’s most-watched broadcasts since the closing ceremony of the 2012 London Olympic Games (Ofcom, 2020a, p. 26). His 14-minute broadcast at 7pm on 10 May about the easing of lockdown plans drew an astounding 90% viewing share to the seven channels that carried it, 60% on BBC One alone. Such peaks can be technically challenging even when they are totally predictable. Governments will remember well Optus’s network meltdown after acquiring exclusive rights to transmit the 2018 FIFA World Cup finals to Australians via online streaming, a fiasco from which it was rescued by the SBS’s broadcast TV service (Pearce, 2018). One of broadcast TV’s great advantages – a declining asset, it seemed, as viewing preferences have atomised – is its capacity to absorb seamlessly those moments when, for whatever reason, everyone chooses to turn on the television.

The range of content that would need to migrate to the NBN and mobile broadband networks requires the same kind of decision canvassed under the previous option, to "freeze-frame" the current suite of free-to-air channels and set parameters around any future adaptation. When television began in Australia in the 1950s, it meant an ABC channel and two commercial channels delivered to audiences in Sydney, Melbourne, Brisbane and Adelaide. As TV expanded into regional centres, it meant an ABC channel and only one commercial service. From the mid-1960s, it meant a third service in the four biggest cities but not Perth. It was not until the 1980s that "equalisation" brought three commercial TV services to east coast regional markets. At the same time, a second national service, the SBS, was expanding across the country. Then pay TV rendered the service offerings in metropolitan and country areas unequal again, because there were (at least marginal) differences between the suites of channels available by cable and satellite and huge differences between the channels available to those who could pay and those who couldn't. The switch from analogue to digital terrestrial transmission provided the next moment when policy-makers equalised the services available, this time not just between viewers in metropolitan and major regional centres, but everywhere, via the VAST service and heavy government subsidisation of regional commercial TV.

Arguably the biggest transformation embodied in a complete shift to broadband delivery would be the loss of broadcast television's free-to-air accessibility. A service that is enduringly popular with older, potentially vulnerable consumers would change from a delivery mode that is effectively free at the point of consumption to ones that depend on a paid fixed or mobile broadband subscription. It seems unlikely that anything less than 100% network availability and take-up would be politically palatable as a replacement for terrestrial TV, especially when, as highlighted by Telstra's annual Australian Digital Inclusion Index, the gaps between digitally included and excluded Australians are still "substantial and widening for some groups" (Thomas *et al.*, 2019).

Option 5: A hybrid of Options 1 to 4

The practical reality is that none of the Options 1–4 are likely or even capable of being implemented in a simple, discrete way. Any realistic plan for the future of TV transmission is likely to involve elements of them all.

What we call "broadcast TV" is already a hybrid of terrestrial and satellite transmission, together with a small amount of cable retransmission. Similarly, "the NBN" is, and was always planned as, a mix of wire, terrestrial wireless and satellite, even in its original FTTP iteration, before the reorientation to a "Multi Technology Mix". The NBN's satellite segment did not converge with the spacecraft used to deliver the VAST free-to-air TV service; they are separate systems configured for different, but all-digital, demands. Viewers of "broadcast television" already watch a lot it online, receiving signals distributed through the NBN and in-home Wi-Fi or over 3G, 4G and 5G mobile networks.

If everything is negotiable, if the unthinkable has become thinkable – as pandemic-era policy-making has shown – then perhaps even such durable features of Australia's broadcasting policy landscape as the equalisation of services across metropolitan, regional and remote areas, and the very existence of regionally-based commercial TV operators, might be put on the table. Governments might decide to return to an older historical model, whereby regional services "cherry-picked" parts of the metropolitan area offering and regional audiences received fewer services than their metro area counterparts. Or they might conclude that the model of independently-owned regional affiliates is simply no longer viable, so Australia-wide carriage of TV defaults to a few national networks. Or they might come to the opposite conclusion: galvanised into building greater resilience and redundancy into communications and other networks due to health, environmental and global strategic crises, they might think a digital terrestrial transmission network independent of the NBN is a worthwhile investment. Meanwhile, in metropolitan markets, where the cost of terrestrial carriage remains comparatively small relative to revenue, commercial networks might decide the lack of an upgrade path to the all-HD or 4K/UHD picture quality that SVOD services are able to offer is a more pressing competitive concern than cutting transmission costs.

Conclusion

To the big question "Should TV Move?" we might start with an unhelpful answer: It is always moving. Each of the five options requires us, to some extent, to ask what television is. The easy answer, especially for the purposes of this article, is the five national broadcast networks that use radiofrequency spectrum to deliver services over terrestrial networks. Do we move them or don't we? But a more complicated answer is required if we are to deal with larger policy questions about what television broadcasting has come to represent, the cultural, social and economic policy ends it has served, and the ways those ends might best be pursued in the future.

"Equalisation" of media and communications services available to all Australian consumers is a potent aspiration, persuasive to politicians of any generation. The geographic dimension of it is very much alive in the architecture and funding of VAST, but Australian "television" today is not just the multichannel suite of channels available over that satellite platform. It is a sprawling, overlapping amalgam of the national and commercial broadcast services that founded the medium, the subscription broadcast and narrowcast services that joined it 40 years later, and the many types of online video that might be thought of as forms of television. Does this growth and diversification mean that television, and therefore the policy issues it raises, have got bigger? Or does it mean television has disappeared, absorbed into a wider technological and cultural ecosystem that means we should stop thinking and talking about it?

It is 25 years since Nicholas Negroponte wrote: "The future open-architecture television is the PC, period. [T]here is no TV industry in the future. It is nothing more or less than a computer industry" (Negroponte, 1995, p. 47). That is not what has happened. The "computer industry" has soared but parts of it have become TV-like: Amazon Prime, Apple TV, YouTube and Google Chrome, AT&T/WarnerMedia. Alongside it, the TV industry has survived but become more computer-like: Netflix and live-streamed and catch-up "broadcast" channels.

Australia's terrestrial TV transmission technology, DVB-T, is no longer state-of-the-art. It is unclear if and when a business case will emerge for the high cost of upgrading it. Since it was introduced, there have been dramatic changes in TV and video viewing practices and the revenues and profits derived from them. A new, national fixed-line broadband network is virtually complete. It is being used extensively for video, but the overall migration to online video viewing masks stark demographic differences. Over-the-air transmission is an occasional indulgence for teens and 18–24-year-olds while remaining hugely important for older viewers. For the most part, these groups are not geographically separated in any systematic way that can be mapped onto physically discrete communications networks.

Australia is a technology-taker, not a technology-maker. The overseas countries it turns to for its leads about TV transmission and reception, especially those with a relatively heavy reliance on over-the-air transmission, are reinvesting in a specialised TV platform that they anticipate will take them until around 2030. Beyond that, TV's transmission future is highly uncertain and COVID-19 has brought waves of new contingencies.

If Australia's terrestrial platform is to be upgraded, there are two broad options with myriad permutations. The existing DVB-T standard is already being upgraded to a more efficient compression standard. That could be extended, perhaps to all transmission sites and viewers (our Option 1), and perhaps further extended later by deploying a still newer compression standard. Alternately, a wholly new transmission standard, most likely DVB-T2, could be adopted (our Option 2). Introducing a new transmission standard would be more complex than the switchover from analogue to digital broadcasting undertaken between 2001 and 2013, and would virtually compel a degree of consolidation among incumbent broadcasters. The degree and timing of consolidation and any subsequent restack of the frequencies they use will be a crucial element of any options considered, because these would significantly affect the costs and the likely value of any second “digital dividend”.

Full conversion to DVB-T2 looks increasingly like a large investment for relatively little gain, especially if funded, in whole or in part, by a reduction in broadcaster spectrum, which would reduce the number of multiplexes in each market. The longer the future of DVB-T2 remains uncertain, the more attractive the option of pursuing further efficiencies with the existing DVB-T platform is becoming, especially if it enables broadcasters to reduce transmission costs. MPEG-4 conversion is a shorter-term, relatively low-gain option. The possibility of the ABC and SBS moving to share a single multiplex, potentially halving their current terrestrial transmission costs, has been extensively canvassed and some technical objections have been publicly raised. However, MPEG-4 might equally enable rationalisation of transmitter numbers in regional commercial TV markets. An area of future work may be to further investigate the costs and overall practicability of moving to a shared broadcaster multiplex model for all-MPEG-4 services using the current DVB-T technology. The feasibility of multiplex-sharing will also be critical to answer the question whether a second “digital dividend”, e.g. to free up 600 MHz TV spectrum for wireless broadband, is feasible based only on MPEG-4 conversion.

As with analogue-digital switchover, any new terrestrial standard might be supported by shifting the lines between terrestrial and satellite service areas, increasing the number of households receiving TV only by satellite. This leads to our Option 3 – a wholesale shift to a free-to-air satellite platform. Because a version of this, VAST, already exists, it presents as a conceptually neat option, with or without some sort of integration with NBN’s satellite segment. It would, however, be highly controversial because of the extra costs and complexity for so many metropolitan households and the risk of losing service altogether, including during heavy rain. The service offerings on VAST would need to be completely re-engineered, highlighting the challenges and costs involved in offering a true like-for-like alternative to location-specific terrestrial broadcasting services via satellite. Whatever its shortcomings, international experience, and the unique economics of satellite DTH transmission, suggest satellite is likely to retain a long-term role and may even end up as a “final safety net” in an otherwise all-online future.

A different wholesale migration, online – mainly to the fixed-line NBN – our Option 4, would be Australia’s 21st century version of Negroponte’s Switch. This would also be conceptually neat. Viewing preferences are shifting online and, in the places where the NBN is a fixed line platform – the overwhelming majority of households – it would offer enormous capacity for expansion. It might also do that in areas covered by 5G. But Internet-delivered TV is not yet seen as a viable substitute for terrestrial broadcasting in any country, its record with big, simultaneously-viewed events is not perfect, and it currently faces a fundamental objection that free-to-air TV would no longer be "free".

The likely reality is that Australian TV's transmission future is going to be a hybrid of these options, our non-specific Option 5. Both Australian broadcasting and broadband are already hybrids. This reflects one of the deepest and most durable truths that Australian communications policy has always had to deal with: the differences in the costs of serving viewers and listeners, customers, users, even readers, in inner metropolitan, outer metropolitan, regional, rural and remote areas. The differences rise and fall with different technologies, services and patterns of use, but they rarely disappear for long. There are destinations but no end game. Everything is a hybrid, always in transition. Considering Australia as a series of different TV markets – remote, regional and metropolitan – suggests the future may involve a mixture of short- and longer-term innovations in response to different pressures, with different, including "hybrid", solutions for each market segment.

In the late 1990s and early 2000s, TV was still king. Australia's federal government was delivering budget surpluses but prepared to spend whatever it took to shift the medium from its analogue past to a digital future. The "digital dividend" was going to pay for it anyway. In 2020, budget deficits are back, deeper than for decades. Governments are finding unimaginable sums to keep businesses, services and individuals afloat. TV, though, is no longer king. It already occupies much less spectrum than before analogue-digital switchover, and it does not have a spectacular, spectrum-efficiency-boosting rabbit ready to pull from its hat. Some efficiency gains can be achieved relatively easily; bigger gains will involve considerable complexity and cost. The value of any vacated spectrum is probably large but uncertain. This time, digital-digital switchover is not a moon shot for the future of television. It's fiendishly complicated and it's mainly about dollars, minimising costs in a still big and important but now mature industry. If Australians want to keep this much TV, and they want its costs to match its likely revenues, it is going to have to move: at least some of it, in some places, and sometime soon.

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Dedication

Remembering Liz Fell, 1940–2020 – peerless communications journalist, educator, activist.

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Endnotes

[i] The United States had 50.5 million cable subscribers in 1990, Germany 8.1m, Canada 7.1m, The Netherlands 4.1m, Belgium 3.7m and Switzerland 1.7m: Top six countries ranked by total cable TV subscribers (OECD, 1996, p. 19). US cable penetration increased from less than 1 in 5 homes in 1978, to more than half in 1990 and two-thirds in 2005 (Christensen, 2009, p. 197).

[ii] The earnings-based fees were reduced progressively from 2010 and then replaced by a tax assessed for each transmitter licence, based on the frequency band, location and power emissions. Commercial TV licensees paid $287 million in fees in 2008/09 and commercial radio licensees $24 million, a total of $311 million. In the first two years of the new arrangements, 2017/18 and 2018/19, they paid an average of $52.3 million per year (ACMA, 2010, p. 71; 2019a, p. 83).

[iii] In 2014, Pascal Lamy recommended a "2020-25-30" strategy under which, broadly, 700 MHz would be freed up by 2020, broadcasters below 700 MHz would have security until 2030 and, by 2025, the EU would reassess technology and market assessments (Lamy, 2014). An "inception impact assessment" published by the EU the following year outlined several options for the UHF band, including Lamy's (EC, 2015).

[iv] While our focus has been whether to upgrade the current platform, we note that Australian radio has seen an alternative approach, where a digital technology (DAB+) was used to augment, rather than replace, the existing platform. DVB-T2 could be used to augment the TV platform, e.g. by allowing three commercial broadcasters in an area to offer a 4K/UHD stream each, using the "sixth channel". A key difference with radio is the potentially high future value of UHF TV spectrum compared with the VHF used by DAB+. Even if UHF is

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excluded, however, there remains a high power, VHF TV channel vacant in each of the five mainland metropolitan markets.

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Gap between Regions in the Use of E-Commerce by MSEs

Macro-level Research Using Provincial Data from Indonesia

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Abstract: The availability of information and communication technology (ICT) has assisted companies to effectively produce and market their products and services in the global market. However, the majority of micro and small enterprises (MSEs) in Indonesia have not adopted such technology or e-commerce to support their business activities. Based on province data (cross-section data), this study aims to examine the adoption of e-commerce by MSEs in different provinces in Indonesia. It addresses two research questions. First, how many MSEs have adopted such technology? Second, what factors influence e-commerce adoption by MSEs? The study used multiple regression to estimate empirically the impact of selected factors as independent variables on the number of MSEs that use e-commerce. It shows at least three important facts: (i) the degree of e-commerce adoption by MSEs in Indonesia is still very low; (ii) there is a positive relationship between market size in a province and the number of MSEs in the province adopting e-commerce; and (iii) in a region where all residents or households have a computer or access to the Internet, it is not always that all business actors, especially MSEs, in that region adopt e-commerce.

Keywords: MSE, e-commerce, ICT, external factors, Indonesia

Introduction

It is undeniable that information and communication technology (ICT) has changed many things in business. It not only has changed the way businesses communicate to each other or deal with their customers, distributors and suppliers, but also through digital marketing or e-

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commerce it has changed the way they promote and sell their products or purchase their raw materials. Digital marketing has now become the trend in targeting both current and prospective customers. Most people now have daily access to the Internet via personal computers, laptops or smartphones. Social media is one of the best channels of online marketing, and Instagram is one of the fastest growing platforms available today (Balakrishnan & Boorstin, 2017). More businesses are now eager to establish a strong presence on this network and encourage their prospects' engagement. To be able to survive in this new business environment all companies, including micro and small enterprises (MSEs), are pushed to adopt this technology. Sooner or later, MSEs which do not adopt this technology and business practice will be displaced by their competitors and abandoned by their customers (Ahmad *et al.*, 2015; Bakos & Brynjolfsson, 2000; Barry & Milner, 2002).

Governments in many countries have given considerable attention to the utilization of ICT, particularly the adoption of e-commerce, by MSEs by issuing special policies and regulations to assist them. In Indonesia, despite the rapidly growing Internet media, the number and percentage of MSEs that have utilised the Internet or adopted e-commerce are still low. According to the 2016 Economic Census, only 563,000 enterprises or about 2.14% of total MSEs in all sectors have utilised such technology; although it varies by province (Figure 1) (BPS, 2017). Therefore, in the past few years the Indonesian government has taken many measures to encourage or support them to adopt such technology in order to expand their marketing. The measures include providing training for MSE owners in utilizing the Internet, Facebook, Instagram and other application systems, and to create their own websites; creating a special web portal (SMESCO Trade) by the Ministry of Cooperatives and Small Medium Enterprise (SME) that all micro, small and medium enterprises (MSMEs) can use for marketing their products; and issuing various regulations to provide a sense of security for business actors in adopting e-commerce and internet banking.

A review of the literature reveals that there is a growing body of literature on the adoption of e-commerce or online marketing by MSMEs. While these studies improve researchers' understanding of MSMEs' efforts to adopt e-commerce, they are all micro-level research: i.e., the theories and frameworks were empirically tested with data collected from interviews with the owners or managers of MSMEs on variables that were expected to influence their ability to adopt e-commerce, such as external factors, organizational barriers, technical barriers, environment barriers, perceived usefulness, perceived ease to use, and attitude. To the authors' knowledge, no attention has been given to macro-level research, i.e., the influence of regional factors such as poverty, income per capita, and the average education of the population, on differences in e-commerce adoption by MSMEs between regions.

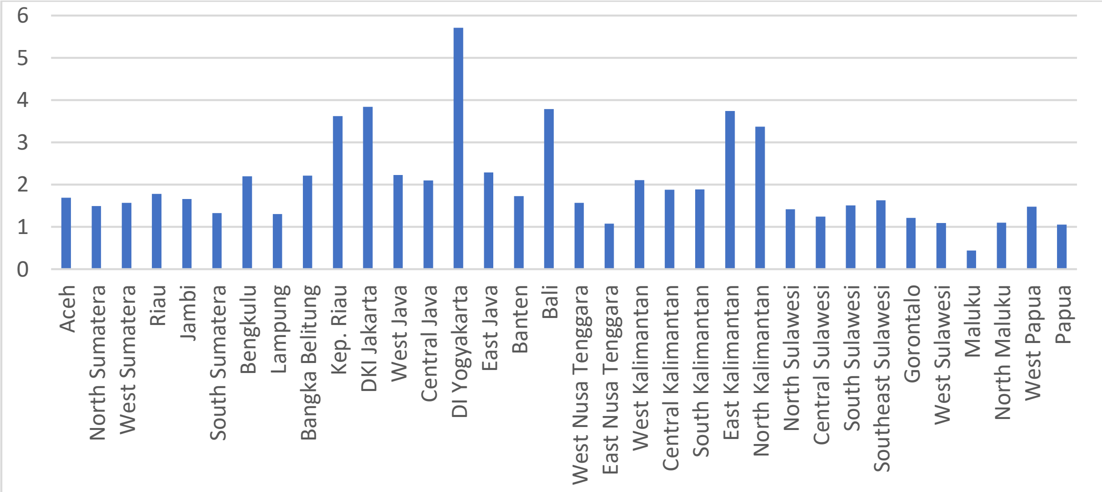

Figure 1. The Adoption of E-Commerce by MSEs in 34 Provinces in Indonesia, 2016 (%) (Source: BPS, 2017)

Therefore, by using statistical data from 34 provinces in Indonesia, this macro-level study tries to close this research gap. More specifically, it addresses the following two research questions. First, how many MSEs in Indonesia have adopted e-commerce? Second, what factors influence e-commerce adoption by MSEs? This research only focuses on MSEs, not including medium enterprises (MEs), because there is no province data regarding the adoption of e-commerce by MEs.

Literature Review

As the market competition becomes increasingly tight, it is vital for business actors to use modern technologies, including ICT, as among their key sources of competitive advantage. In many developing countries, although the need to have ICT is also apparent, there are still many companies, especially MSEs, that do not adopt this technology. For larger enterprises with ample human and financial resources, the adoption of ICT may not be a significant problem. But, for MSEs which face resources limitations, including lack of funds and skill, ICT adoption becomes a problem. Most MSEs do not consider IT as a strategic issue, but rather use it more opportunistically (Triandini, Djunaidy & Siahaan, 2013). Therefore, the adoption among MSEs in many developing countries, including Indonesia, is still very low.

Literature on e-commerce and MSMEs can be grouped into two categories, namely studies that focus on factors influencing e-commerce adoption, and studies that give more attention to the benefit of utilizing this technology. According to the title and purpose of this study, the focus of this literature review is on that first category.

Literature on Technology Acceptance Model

Many of the existing studies in this category that attempted to explain the barriers to e-commerce acceptance in MSMEs were based on the Technology Acceptance Model (TAM). It is one of the models that is used extensively for explaining the factors influencing the adoption of e-commerce or ICT. This model has many variables, including organizational barriers, technical barriers, environment barriers, perceived usefulness, perceived ease to use, attitude, intention and desire (intention to use), and behaviour (actual use). This model is known as a powerful model for predicting the acceptance of new technology by users.

In connection with the position of the current study, different studies have been conducted in many parts of the world and some of them can be mentioned briefly here. Nakhleh (2017) explored the practice of e-commerce among MSMEs in Al-Qassim region, Saudi Arabia and the obstacles to e-commerce faced by managers. In order to collect the required data, a questionnaire was developed on the basis of an extensive review of the literature, and this was distributed to a sample of 100 SMEs in the Al-Qassim region. The questionnaire comprised four main domains: the practice of e-commerce as a dependent variable, with organizational, technological and environmental factors as independent variables. The results supported the hypotheses that organizational factors (top management support, employee skills and experience, and business strategy alignment), technological factors (Internet service quality, information technology security, perceived benefits, e-payment services, and number of technical officers), and environmental factors (customer preferences, industry characteristics, socio-cultural factors, and competitor pressure) have significant and positive relationships with the practice of e-commerce in MSMEs. As stated by Nakhleh, the absence of these factors can therefore be regarded as a barrier to the practice of e-commerce.

Esmaeilpour, Hoseini & Jafarpour (2016) identified the main obstacles and challenges of e-commerce adoption by MSMEs. They collected primary data through interviews with 157 managers and company experts from 86 companies in the industrial city of Bushehr (Iran). The results showed that organizational barriers, technical barriers and environmental barriers as external factors on technology have affected two starter variables of the technology acceptance model, namely usefulness and perceived ease, and these predicted relationships are confirmed. In addition, expressed relationships in the TAM, including the impact of usefulness and perceived ease on attitude, impact of attitude on intention, and finally impact of intention on actual use, were confirmed.

Xiong, Qureshi & Najjar (2013) investigated what factors affect the acceptance of ICTs including e-commerce by small business owners in two provinces in China. They collected data through a survey of 118 different small businesses in two provinces. Factor analysis was conducted to examine how the responses on a number of measured variables influence each other by examining the patterns of correlations between the variables. Their analysis found that the factors that affect ICT adoption by small businesses in China are attitude toward using technology, perceived usefulness, facilitating condition, anxiety, perceived ease of use, and job-fit, which are different from the existing model. Perceived ease of use and attitude toward using technology are identified as the most important factors affecting the adoption of ICT among China's small business.

Looi (2005) developed a model of factors motivating and inhibiting e-commerce adoption among MSMEs in Brunei Darussalam. A qualitative research method, in the form of semi-structured interviews, was used to identify factors that are important and relevant to encourage willingness to adopt. Findings showed that owner characteristics, like lack of perceived benefits, lack of knowledge and skill, and perceived lack of trust, are significant inhibitors, while environment characteristics, like competitive pressure, government support and infrastructure, are significant motivators of electronic commerce in Brunei Darussalam.

Empirical results of other studies on the subject are summarized in Table 1. Together with recent studies briefly discussed above, this table shows a structured literature review by consolidating the growing body of academic literature in the field of the main important factors in determining or encouraging the adoption of digital marketing or e-commerce by MSMEs. This literature review provides an understanding of past research points and methodologies related to the studies of digital marketing by MSMEs to explore, analyse and develop a clear understanding about the different studies and methodology implemented relating to the field of digital marketing and MSMEs. Obviously, in this category of literature all existing empirical studies on the subject are based on micro data collected through interviews with selected respondents from different companies, mostly in one area/region.

Table 1. Selected Important Literature on the Adoption of E-commerce by MSMEs with the Technology Acceptance Model (TAM)

Researcher	Year	Findings: adoption determinants	Data	
			Type	Method of collection
Al-Bakri & Katsioloudes	2015	Readiness, strategy, managers' perceptions, external pressure by trading partners	Micro	Survey/Interviews
Ahmad *et al.*	2015	Perceived relative advantage, perceived compatibility, manager's/owner's knowledge and expertise, management characteristics. external change agents	Micro	Survey/Interviews
Lertwongsatien & Wongpinunwatana	2014	Organizational factors, technology factors, environmental factors	Micro	Survey/Interviews
Dlodlo & Dhurup	2013	Perceived ease of use, external pressure, mission, job performance, resource availability and compatibility	Micro	Survey/Interviews
Ghobakhloo	2013	Cost of ecommerce, incompatibility, risk, awareness of e-commerce, knowledge of	Micro	Survey/Interviews

Researcher	Year	Findings: adoption determinants	Data	
			Type	Method of collection
		information systems, external/government support, preparedness partners		
Poorangi &. Khin Poorangi	2013	Relative advantage, trialability, observability, company culture, complexity	Micro	Survey/Interviews
Cosgun & Dogerliogl	2012	Financial resources, organisational size, top management support, perceived benefits, industry characteristics, external pressure, and compatibility external IT support	Micro	Survey/Interviews
Das & Das	2012	Information exchange with customers, intense competition, government incentive schemes, enterprises sector, size, age	Micro	Survey/Interviews
Kenneth, Rebecca & Eunice	2012	Leadership style, resources, infrastructure, competition and positioning on the adoption of electronic commerce	Micro	Survey/Interviews
Zaied	2012	Technical factors, legal and regulatory, Internet security, organisational factors, economic factors, political factors, social-cultural factors, use of Internet banking and web portals	Micro	Survey/Interviews
Ghobakhloo, Arias-Aranda & Benitez-Amado	2011	Perceived relative advantage, perceived compatibility, CEO's innovativeness, information intensity, buyer/supplier pressure, support from technology vendors, and competition	Micro	Survey/Interviews
Jones *et al.*	2011	Perceived benefits, time consumed to develop an e-business operation, ICT skills, e-business deployment in a region (e.g. supplier usage), financial resources	Micro	Survey/Interviews
Arendt	2008	Proper knowledge, education and skilled owner-managers and employees	Micro	Survey/Interviews
Chitura *et al.*	2008	business opportunities, time, security, e-commerce acceptance among customers and suppliers, willingness of senior managers to use such technology, associated costs, communication, infrastructure, perceived benefits, complexity, type of products	Micro	Survey/Interviews

Researcher	Year	Findings: adoption determinants	Data	
			Type	Method of collection
Marasini, Ions & Ahmad	2008	Readiness for change, costs, basic skills, awareness of its benefits	Micro	Survey/Interviews
Saffu, Walker & Hinson	2008	Organizational support/pressure, managerial productivity, decision aids, perceived usefulness, compatibility, external pressure	Micro	Survey/Interviews
Chong & Pervan.	2007	Perceived relative advantage, trialability, observability, variety of information sources, communication amount, competitive pressure, and non-trading institutional influences.	Micro	Survey/Interviews
Alam & Ahsan	2007	Government support, understanding the importance of ICT adoption, manager's ICT knowledge and skills	Micro	Survey/Interviews
Aghaunor & Fotoh	2006.	Perceived complexity, perceived benefits, organizational competence, perceived compatibility, supporting industries e-readiness, management support, market e-readiness, IT capability, and government e-readiness.	Micro	Survey/Interviews
Migiro	2006	Associated cost, availability of funds, technical know-how, perceived benefits	Micro	Survey/Interviews
Molla & Licker	2005	Organizational factors, environmental factors, infrastructure, government supports	Micro	Survey/Interviews
Poon & Swatman	2005	Management enthusiasm, perceived benefits, industry and product specificity	Micro	Survey/Interviews
Ching & Paul	2004	Business value and system of business, perceived benefits, associated cost, customer pressures	Micro	Survey/Interviews
Scupola	2003	technology characteristics (e.g. benefits and barriers), organizational characteristics (e.g. slack resources), government intervention, public administration and external pressure from competitors, suppliers and buyers	Micro	Survey/Interviews

Literature on Digital Divide

The above literature review shows obviously that there are many studies on the adoption of ICTs or e-commerce by organizations/companies. However, rare are those that explore the topic using the concept of "digital divide". Digital divide (DD) is a term that refers to the gap between individuals, companies, regions and countries in accessing and using ICT. This technology can include the telephone, television, personal computers and the Internet.

Important studies on DD include Zhu, Kraemer & Xu (2003), Viswanathan & Pick (2005), Wielicki & Cavalcanti (2006), Arendt (2008), Fong (2009), Stiakakis, Kariotellis & Vlachopoulou (2009), Oliveira & Martins (2010), Wielicki & Arendt (2010), Srinuan & Bohlin (2011), and Bach, Zoroja & Vukšić (2013). Zhu, Kraemer & Xu (2003) developed a conceptual model for studying the adoption of e-business (EB) at the firm level, incorporating six adoption facilitators and inhibitors, based on the technology–organization–environment theoretical framework. Survey data from 3100 businesses and 7500 consumers in eight European countries were used to test the proposed adoption model. To examine whether adoption patterns differ across different e-business environments, they divided the full sample into high EB-intensity and low EB-intensity countries. The findings showed that: (1) technology competence, firm scope and size, consumer readiness, and competitive pressure were significant adoption drivers, while lack of trading partner readiness was a significant adoption inhibitor; (2) as EB-intensity increases, two environmental factors, i.e. consumer readiness and lack of trading partner readiness. become less important, while competitive pressure remains significant; (3) in high EB-intensity countries, e-business was no longer a phenomenon dominated by large firms — as more and more firms engage in e-business, network effects work to the advantage of small firms; and (4) firms were more cautious in adopting e-business in high EB-intensity countries,

Viswanathan & Pick (2005) analysed the growth of the e-commerce industry and its relationship with associated industries, such as telecommunications and software, in the context of the Indian and Mexican economies. In addition, they also examined factors impacting the adoption of e-commerce in different sectors of the economy. The major variables considered in their research included growth in the number of Internet connections, telecommunications infrastructure, attitudes and awareness of corporations and individual customers towards e-commerce, growth of the software industry in terms of its relationship to e-commerce, and the role played by the government. The two nations were compared on four groups of e-commerce factors. Based on existing trends, they also examined the major bottlenecks to future growth and presented a framework that may help explain the process of e-commerce diffusion in developing countries.

Wielicki & Cavalcanti's (2006) paper reported on findings of a study conducted among over 750 MSMEs in Central California regarding uses and application barriers for ICT. This study focused on the scale, dimensions and reasons for existence of a so-called digital divide. It showed that the primary reason for discrepancies in utilization of ICT among MSMEs and large corporations is not as much lack of funds or access to information technology as it is lack of proper management, education, training and skilled labour. Some comparative pilot data from Poland and Brazil indicate also that insufficient management, education and training may contribute to the existence of a digital divide, regardless of economic status of a country.

Arendt (2008) examined the use of ICT-based solutions by MSMEs in selected regions of Spain, Portugal, Poland, and California (USA), and digital divide phenomena which exist between MSMEs and large enterprises. He collected data from face-to-face interviews with MSMEs' owner-managers and employees from the regions and used it for making a comparative analysis based on descriptive statistical methods. He argued that the main barrier to better utilization of ICT and e-commerce, and thus the main reason why MSMEs faced a digital divide, was not the lack of access to information technology but the lack of proper knowledge, education and skilled owner-managers and employees within the enterprise.

Fong (2009) assessed the impact of ICTs on Gross National Income (GNI) per capita in developing countries using data from 2005. Her regression analysis showed a significant relationship between GNI per capita (in PPP international dollars) and adoption of each ICT (mobile phone, personal computer, and telephone), with the exception of Internet technology. Her study suggests that an increase in the adoption of mobile phone, personal computer, and fixed-line telephone by one percent will bring about an increase in average income per person in lower-middle-income and low-income developing countries of approximately 2.8 per cent, 4.1 per cent, and 6.3 per cent, respectively. The absence of a significant relationship for Internet technology may be the result of an absence of a critical mass in Internet adoption and usage. This warrants further investigation with a more robust analytical model.

The digital divide is nowadays evolving to digital inequality, i.e., the socio-economic disparities inside the ‘online population’. Stiakakis, Kariotellis & Vlachopoulou (2009) examined two main dimensions of digital inequality, namely ‘skills’ and ‘autonomy’ of Internet users. The level of formal education was selected as a representative variable for the skill dimension, as well as the density of population in different geographical areas as a representative variable for the autonomy dimension. The research was focused on the member states of the European Union (EU). The data, provided by Eurostat, included the daily use of computers for the last three months and the average use of the Internet at least once per week. The findings indicate that the EU already faces the problem of digital inequality to an extended degree, since there are significant disparities among the European countries with regard to the aforementioned variables.

Oliveira & Martins (2010) analysed the pattern of e-business adoption by firms also across European Union (EU) member states. They used survey data from 6,964 businesses in EU27 members. The choice of variables used in the analysis was based on the technology-organization-environment (TOE) theory. In the TOE framework, three aspects may possibly influence e-business adoption, namely technological context (technology readiness and technology integration), organizational context (firm size, expected benefits and barriers of e-business, and improved products or services or internal processes) and environmental context (Internet penetration and competitive pressure). They performed a factor analysis (FA) of multi-item indicators to evaluate the validity and to reduce the number of variables. They used the principal component technique with varimax rotation to extract four eigen values, which were all greater than one. The first four factors explain 72.4% of variance contained in the data. The four factors found were expected benefits and obstacles of e-business, Internet penetration, technology readiness, and technology integration. The findings suggest that in the European context the most important factor to characterize e-business adoption is the specific characteristics of the industry and is not the country to which the firm belongs.

Wielicki & Arendt (2010) explored a shift in the perception and ranking of barriers to implementation of ICT-based solutions among MSMEs in selected regions of Spain, Portugal, Poland and California (USA), which can be attributed to the degree of ICT readiness exhibited by a given country. They have verified a hypothesis that the more knowledge-based a given economy is (as measured by ICT indexes), the more likely it is that perception of the key ICT implementation barriers among MSMEs will shift away from mere lack of funds and technology toward lack of knowledge, education and information system planning. The conclusion of their study may well serve a better distribution of resources allocated by governments to overcome the business digital divide that limits productivity of so many MSMEs.

Srinuan and Bohlin (2011) presented a literature review and classification scheme for digital divide research. The review covered journal articles published between 2001 and 2010. The results showed that the digital divide is a multifaceted phenomenon, due to the many dimensions of determinant factors. Recent studies covered by their review have included socio-economic, institutional and physiological factors in order to gain a greater understanding of the digital divide. Among other findings, they showed that technological determinism is not sufficient to explain the emergence of the digital divide. Moreover, several types of technologies were investigated, both from empirical and conceptual standpoints. The divide in access and usage are discussed at the global, social and democratic levels by employing a quantitative method, either a survey or data analysis, as the main method. It revealed, however, that there is less discussion in developing countries and at the level of the organization (i.e., MSMEs, the private sector and the public sector).

Bach, Zoroja & Vukšić (2013) also presented a review of published papers on DD among corporations. Papers from the journals indexed in SSCI that investigate corporate DD were examined in order to compare the research on corporate DD in terms of: (1) geographical area, time frame of the study, sampled corporations; (2) phenomena used as the indicators/measure of DD, inequality type, ICT adoption cycle, determinants of DD; and (3) data collection approach, data sources, sample size and methodology used for investigation of DD determinants. Their research revealed that most of the papers on corporate DD investigate the first-order corporate DD and ICT use in developed countries, using a large number of phenomena as a proxy for corporate DD, ranging from general ICT use and Internet use to the specific ICT use, such as e-business. Most of the research revealed that internal factors in corporations are crucial for adopting and using ICT in order to increase business performance and competitiveness. Based on the results of their DD literature review, they concluded that future research should focus on ICT access and use in developing countries and more research should be conducted by using secondary data such as transactional data or national data, since it allows larger samples and a broader scope of corporations to be investigated.

Indonesian Case Studies

Literature on ICT or e-commerce adoption by MSMEs in Indonesia has been growing in the past decade. It includes Budiarto *et al.* (2018), Chairoel & Riski (2018) and Suhartanto & Leo (2018). The purpose of the former was to test the effect of both internal (owners' knowledge) and external (infrastructure) factors on the success of ICT implementation and MSMEs' performance. For that purpose, data was collected from 110 MSME owners with a mail questionnaire, and a regression model was used to test the hypothesis and to examine the effect of each variable. The result of this research showed that both internal and external factors have a significant impact on ICT implementation.

Chairoel & Riski (2018) aimed to identify internal and external factors of ICT adoption by MSMEs by conducting a survey of 146 selected MSMEs. The conceptual model in their research was the combination between Diffusion of Innovation (DOI) theory and the Technology-Organization-Environment (TEO) theory. The collected data was analysed using SEM/Smart-PLS program. The study has exogenous variables including technology, organization, managerial characteristic, and environment, and the endogenous variable is ICT adoption. The research found that ICT use was predicted by the characteristics of management, organization and technology.

Suhartanto & Leo (2018) examined small business entrepreneur resistances to adopting online store and website technology. Their qualitative study used the technology adoption model (TAM) as a theoretical basis. From their sample of 131 small entrepreneurs, they found that perceived lack of usefulness, perceived lack of ease to use, resources, and social influences are resistance factors for entrepreneurs to adopt online stores and websites. Among these factors, the perceived lack of usefulness and resources is considered the most substantial resistance factor for the entrepreneur to adopt the technology.

According to Julianto (2016), there were various obstacles faced by the Indonesian government (i.e., the State Ministry of Cooperative and Small Medium Enterprise) in encouraging or supporting MSEs' owners to utilise ICT or to adopt e-commerce, namely their low understanding of this kind of technology and its usefulness, their mindset, which is not in favour of adopting e-commerce, and their lack of knowledge on how to operate this technology. Especially MSEs located in isolated/rural areas, many of them were unfamiliar with the online marketing system. Therefore, they prefer to do marketing with conventional methods, by utilising the distribution networks that they have been using for a long time or involving many traders or collectors who have long been their key customers.

Rahayua & Day (2015) did a survey of more than 200 MSME owners/managers in 2015. In their study, MSME refers to a business which has less than 100 employees, assets less than 10 billion rupiah and total sales per year below 50 billion rupiah. They concluded that the adoption of e-commerce by MSMEs in Indonesia was affected by several factors, which are perceived benefits, technology readiness, owners' innovativeness, and owners' ICT experience and ability.

Triandini *et al.* (2013) investigated the opportunities provided by e-commerce adoption for MSMEs in Indonesia and potential factors that could influence their e-commerce adoption. Their study, however, was not empirical but rather a discussion of a conceptual model. It proposed six potential factors influenced the adoption of e-commerce, i.e., perceived usefulness, perceived ease of use, relative advantage, perceived risk, perceived trust, and compatibility.

Govindaraju & Chandra (2011) found that many MSMEs in Indonesia did have strategic plans to adopt a higher level of e-commerce, though the majority of them currently still adopt e-commerce at a lower level. They found eight essential variables which have no significant influences as the barriers of e-commerce adoption by MSMEs. Accordingly, these variables can be predicted as the factors that can support e-commerce adoption that need further analysis, namely financial, supply chain management, Internet services, market, source of information, enterprises association, e-commerce popularity, security and political.

Eva (2007) conducted a study on the application of e-commerce services for marketing MSME products. Five e-commerce services were communication interaction, access to information and data, transaction, remote control and decision-making, and application and other services. In general, she found that the adoption of these online-based business processes by MSMEs was still relatively low. Many MSME owners/managers faced a number of constraints, such as Internet access taking a long time, difficulties to switch to transaction-based technology, and many MSMEs, especially MSEs, still preferring the traditional ways of marketing (such as waiting for buyers to visit their shops, or selling their products to merchants to then sell to places that are farther away) even though they may have access to the Internet or Wi-Fi, . Likewise, in payment, most MSEs do not want to be paid by credit card but cash. So, generally, MSE owners/managers were difficult to change from their traditional behaviour of doing business, including marketing.

Hafied (2007) found that many MSMEs in Indonesia have already started to apply e-commerce adoption to increase or at least to maintain their revenues or profits, although the degree of adoption is different from one company to another. It was also revealed from his research that financing and customer service were the major driving factors in adopting e-commerce.

Kartiwi (2006) aimed to understand the factors and combinations of factors that MSMEs need to be considered before embracing e-commerce into their business, by providing a closer look at actual experience of Indonesian SMEs. For this purpose, two case studies (firms) were carried out to analyse and explain the underlying factors that are likely to determine the varying extent of e-commerce adoption in MSMEs, especially in the service sector. The findings of their case studies have been further extended into the development of a proposed practical framework to illustrate how e-commerce adoption should be carried out from a strategic perspective.

Finally, Vidi (2006) also used TAM to create an e-commerce adoption model in examining factors affecting the adoption of e-commerce by MSMEs in Indonesia for her thesis. She inferred that compatibility, top management support, organizational readiness, external pressure, and perceived benefits have significant positive effect on e-commerce adoption, and the adoption has significant positive effects on company performance. Data was collected from nine big cities in Indonesia, i.e., Padang, Jakarta, Cirebon, Yogyakarta, Jepara, Sidoarjo, Denpasar, Makassar and Balikpapan.

Theoretical Framework

As explained before, this study is based on the concept of digital divide, aiming to examine the influence of regional factors on differences in e-commerce adoption by MSMEs between provinces in Indonesia. The literature review reveals that the decision of a business owner to adopt e-commerce is influenced by many factors, directly or indirectly. These factors can be grouped into two categories of factors: internal factors and external factors. Internal factors are related to: (i) individual characteristics of the entrepreneur/business owner, which include education, age, strategic vision, business planning, ICT knowledge, expertise, and experience, confidence that the use of e-commerce can improve business (perceived usefulness), confidence that this new marketing system would deliver its functionality in expected quality and reliability (perceived trust), and willingness to adopt e-commerce as well as to adjust the way he/she does business with the related requirements; and (ii) characteristics of a company including size, organizational complexity, technology readiness, resources (i.e., availability of skilled labour in ICT and capital), company culture and level of innovativeness, and type of business. The first and second groups of factors can be said to be, respectively, the "entrepreneur" factors, and the "company" factors

External factors are related to the external environment uncontrolled by the company. They can be categorized into three sub-factors: (i) market factors (e.g., market size, location, degree of complexity and level of competition, and pressures from trading partners and customers to adopt e-commerce); (ii) policy factors (e.g., government regulation, laws, and incentive measures or facilities in the forms of, e.g., tax relief, specially designed ICT training programs for MSE owners and employees, and other facilities to ease the use of ICT for beginners); and (iii) supporting factors, such as the availability of ICT, infrastructure (e.g., electricity, software/hardware vendors, having a computer or smartphone, access to the Internet, universities and other training institutes providing ICT/e-commerce training, funding support by the bank, and active support by business associations and chamber of commerce).

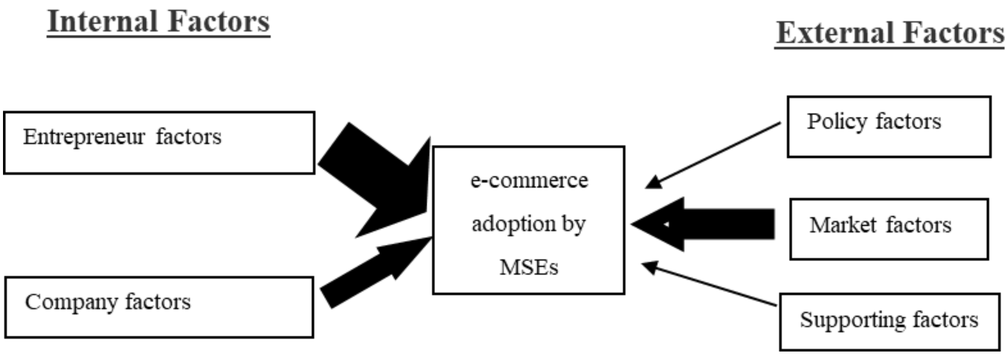

Figure 2. Theoretical Framework

Thus, as illustrated in Figure 2, generally, e-commerce adoption by MSEs is influenced by five main factors. From the literature there is no conclusion which of these five factors most influences the adoption of e-commerce by MSEs. But, because business decisions are in the hands of entrepreneurs or company leaders, especially things that have a serious consequence to the company, it can be hypothesized that the characteristics of entrepreneurs/business owners have the most influence, shown by the broadest black arrow. The second and third factors which also have big influences are, respectively, market and characteristics of company.

So, based on the theoretical framework, the general hypothesis is that all these five groups of factors have positive and significant influences on e-commerce adoption by MSEs, and the entrepreneur factors have the largest effect, followed by the market factors and company factors.

Methodology

Economic Method

In accordance with the research objective, the following functional form, i.e., a multiple regression at 0.05 level of significance, was used to estimate empirically the impact of determinant factors as independent variables on the number of MSEs in all sectors that use e-commerce. The definitions of operational independent variables are given in Table 2. Unfortunately, there is no province data for many determinant factors included in these two categories of factors illustrated in Figure 1. So, in this model the number of independent variables is very limited. For instance, local governments in many provinces have organized ICT training for MSMEs, which can actually be adopted as an independent variable that represents a policy factor.

$$\text{MSEs-e} = \alpha_0+\alpha_1 HH_1 + \alpha_2 HH_2 + \alpha_3 GW + \alpha_4 GRDP + \alpha_5 EDU$$

where MSEs-e = number of MSEs in all sectors that use e-commerce as a percentage of total MSEs per province.

Table 2. Definitions of Operational Independent Variables

Factor	Variable used	Definitions and Variable Units
Supporting Factor	HH_1	The number of households that have computers as a percentage of total households per province.
	HH_2	The number of households that have access to the Internet as a percentage of total households per province.
Company Factor	GW	Electricity flow from the electricity transmission system to the consumer (Gigawatts per hour) per province.
Market Factor	GRDP	Percentage distribution of Indonesia's gross domestic product by province.
Entrepreneur Factor	EDU	The number of MSEs whose owners have a college or university diploma as a percentage of the total MSEs per province.

E-commerce adoption was measured by Internet access, use of website, online marketing, use of the web for buying and selling, sending e-mail to communicate with business partners, using the World Wide Web to access information such as information about markets and competitors; and use of ICT tools for business information processing.

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Hypotheses

Based on the model and the number of independent variables, this study has five hypotheses:

H_1: in province with higher percentage of households having computer (HH_1), the percentage of MSEs adopting e-commerce is higher than in provinces with lower percentage;

H_2: in province with higher percentage of households having access to the internet (HH_2), the percentage of MSEs adopting e-commerce is higher than in provinces with lower percentage;

H_3: in province with higher percentage of households having access to electricity (GW), the percentage of MSEs adopting e-commerce is higher than in provinces with lower percentage;

H_4: in province with higher income per capita (GRDP), the percentage of MSEs adopting e-commerce is higher than in provinces with lower income per capita;

H_5: in province with higher percentage of highly educated MSE owners/entrepreneurs (EDU), the percentage of MSEs adopting e-commerce is higher than in provinces with lower percentage.

Data

This study used secondary data, i.e., 2016 cross-section data of 34 provinces published in *Indonesian Statistics* for all independent variables, and National Economic Census 2016 for MSEs (the only data available on MSEs using e-commerce by province). Both datasets are from the National Bureau of Statistics.

Results

Descriptive Statistics and Statistical Tests

Table 3 presents the outcomes of the descriptive statistics for the main variables involved in the regression model. Key figures, including mean, median, standard deviation, minimum and maximum value, are reported. This was generated to give an overall description of the data used in the model and served as a data screening tool to spot unreasonable figures.

Table 3. Descriptive Statistics of the Data

	MSEs-e	HH1	HH2	GW	GRDP	EDU
Mean	2.942	2.044	5.311	1.806	2.941	4.634
Median	1.195	1.920	5.372	0.370	1.215	4.200
Maximum	1.872	3.340	8.570	9.900	1.744	1.050
Minimum	0.120	1.224	1.976	0.010	0.230	2.500

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	MSEs-e	HH1	HH2	GW	GRDP	EDU
Std. Dev.	4.848	5.864	1.282	2.997	4.241	1.778
Skewness	2.494	0.883	-0.103	1.837	2.259	1.228
Kurtosis	7.936	3.146	3.915	4.962	7.168	4.635
Probability	0.000	0.108	0.537	0.000	0.000	0.002
Observations	34	34	34	34	34	34

Source: computed from SPSS

Various statistical tests were performed first, to determine the stability of the model, normality, multicollinearity and heteroscedasticity. The stability test (CUSUM and CUSUM SQ) shows the CUSUM and CUSUM of Squares lines do not cross the 5% significance line. So, it can be concluded that the model used is stable. The normality test results show that the prob. Jarque-Bera is more than 0.05 (i.e. 0.3558), which means that the data used are normally distributed (Figure 3). Based on the multicollinearity test (if a variable has a Variance Inflation Factor (VIF) value less than 10 (Table 4), then the variable does not have multicollinearity), it can be concluded that all independent variables in this model do not have multicollinearity. Finally, based on the heteroscedasticity test results that prob. Chi-Square is more than 0.05 (0.0532) (Table 5), it can be concluded that there is no heteroscedasticity.

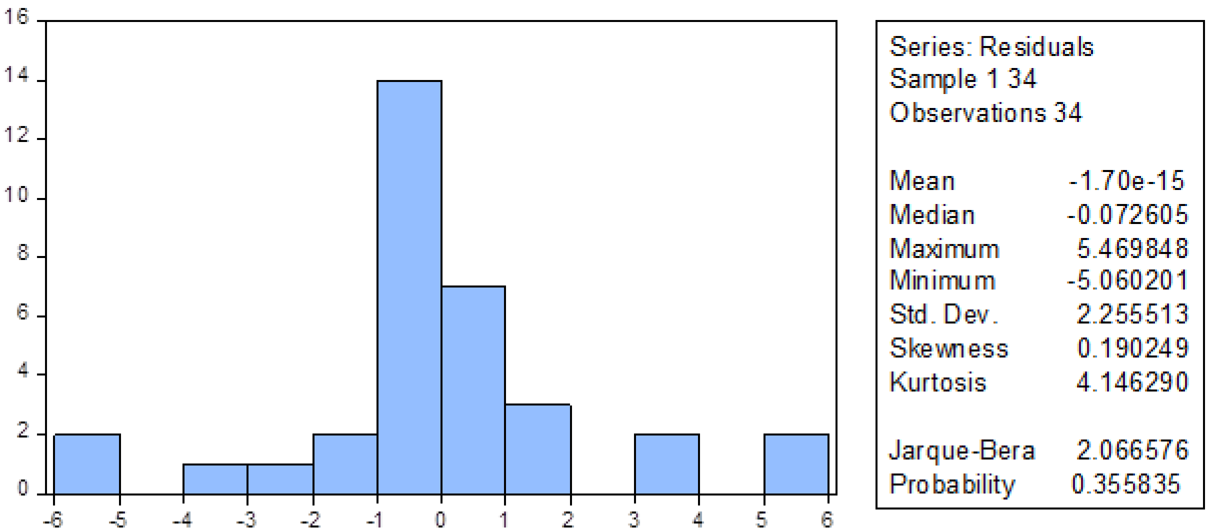

Figure 3. The Normality Test Results

Table 4. Variance Inflation Factors (N=34)

Variable	Coefficient Variance	Uncentred VIF	Centred VIF
α0	5.412694	30.69347	NA
HH_1	0.018718	47.88099	3.542982
HH_2	0.003982	67.29282	3.602590
GW	0.061185	4.156698	3.025185
GRDP	0.031128	4.608015	3.080821
EDU	0.092416	12.86317	1.608946

Table 5. Heteroskedasticity Test: Glejser

F-statistic	28.83459	Prob. F(21,11)	0.0000
Obs*R-squared	32.41122	Prob. Chi-Square(21)	0.0532
Scaled explained SS	42.34480	Prob. Chi-Square(21)	0.0038

Regression Results

For the purpose of determining the extent to which the explanatory variables explain the variance in the explained variable, regression analysis was employed. The *t*-test was used to determine the significance of the effect of each explanatory variable on the explained variable. According to the hypotheses given above, it is expected that all the explanatory variables, partially, have a significant effect on the explained variable at a significance level of 0.05. The results of such analysis are narrated in Table 6.

Table 6. Regression Results

Dependent Variable: MSEs-e						
Variable	**Coefficient**	**Prob.**	**Std Error**	**Hypothesis**	**t-Statistic**	**Conclusion**
α_0	2.667900	0.2612	2.326520		1.146734	
HH_1	0.052804	0.7024	0.136813	H_1 rejected	0.385956	Not significant
HH_2	0.044544	0.4861	0.063102	H_2 rejected	-0.705903	Not significant
GW	0.564949	0.0302	0.247357	H_3 accepted	2.283943	Positive significant
GRDP	0.697563	0.0005	0.176431	H_4 accepted	3.953748	Positive significant
EDU	-0.326206	0.2924	0.304001	H_5 rejected	-1.073046	Not significant
R-squared						0.783538
Adjusted R-squared						0.744884
S.E. of regression						2.448630
Sum squared residual						167.8821
Log likelihood						-75.39124
F-statistic						20.27058
Prob(F-statistic)						0.000000
Durbin-Watson statistic						2.081481

Discussion

The regression results show that not all independent variables have an impact on the use of e-commerce by MSEs as theoretically expected. For households that have computers (HH_1), the probability result is 0.7024 > 0.05, which means that it is insignificant: H_1 is rejected. This can be explained by the fact that e-commerce can also be done by a smartphone. In fact, a smartphone is more flexible and can be taken anywhere. It can be assumed that all MSE owners have a smartphone, as this has now become a necessity, no longer a luxury item. Meanwhile, in Indonesia, not all MSE owners, especially peddlers, roadside food stall owners, small grocery store owners, small motorbike repair shop owners, and craftsmen, do not have personal computers or laptops.

Likewise, with the percentage of households that have access to the Internet (HH_2), the result is 0.4861 > 0.05, not significant, and therefore H_2 is rejected. It is very likely that this variable does not have a positive and significant effect on the use of e-commerce by MSEs because the number of households in a region that have access to the Internet or have Wi-Fi at home is not always directly proportional to the number of MSEs that use e-commerce. An MSE owner may have Wi-Fi at home but does not use e-commerce in marketing his/her products. On the other hand, a shop owner may not subscribe to Wi-Fi at home, but has Wi-Fi in his/her shop or utilizes Wi-Fi for free in public places, or he/she buys a daily, weekly or monthly Wi-Fi package. So, actually the required variable in this particular case should not be the number of households that have access to the Internet but the number of MSE owners who have Internet access or a Wi-Fi subscription, for which there is no data available at provincial level. An earlier study by Govindaraju & Chandra (2011) reveals a number of essential variables which have no significant influence as barriers to e-commerce adoption by MSMEs. Therefore, they argued that these variables can be predicted as the factors that can support e-commerce adoption that need further analysis. The variables include Internet services, e-commerce popularity among MSMEs, and security in using e-commerce. In other words, it is still an open question regarding the significant influence of the Internet on the use of e-commerce by MSMEs, especially MSEs.

The effect of electricity flow to the consumer (GW) on the use of e-commerce by MSEs is positive and significant (0.0302 < 0.05), as generally expected; so H_3 is accepted. During the Covid-19 pandemic (March-May/June 2020) the Indonesian government required all schools and universities and companies in non-strategic sectors to close and school children and students learn and employees work from home. However, this 'anti-Covid impact' policy is not easy to be carried out in remote and rather isolated regions where most households are poor, especially in the eastern part of the country, because, besides the difficulty of accessing the Internet, there is also no electricity.

The effect of GRDP on the use of e-commerce by MSEs is positive and significant (0.005 < 0.05); so H_4 is accepted. Not only is the direction in accordance with the theory and the relationship is significant, but it also has the largest coefficient value among the independent variables. This independent variable represents the market size, and the result may confirm that the market size is an important (if not the most important) factor in influencing an entrepreneur or business owner to use e-commerce. Market size is not only determined by the number of buyers but also by the number of traders or suppliers that automatically increase the level of market competition. And, one way to stay in the market, besides improving the quality of goods or services, is to improve marketing efficiency and effectiveness by using an e-commerce system.

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The importance of the market size is also supported by the following figures. Based on the 2016 Economic Census, the distribution of MSEs in all sectors in Indonesia that adopt e-commerce by province, depicted in Figure 4, shows that MSEs using e-commerce are found mainly in Java island which consists of DKI Jakarta (the Capital City of Indonesia), the Province of Banten, the Province of West Java, the Province of Central Java, D.I. Yogyakarta, and the Province of East Java. Parts of Java with the highest proportion of MSEs that use e-commerce are the Province of East Java, with around 18.72 % of all MSEs adopting this technology in Indonesia, followed by the Province of West Java and the Province of Central Java with, 18.11 % and 15.41 %, respectively.

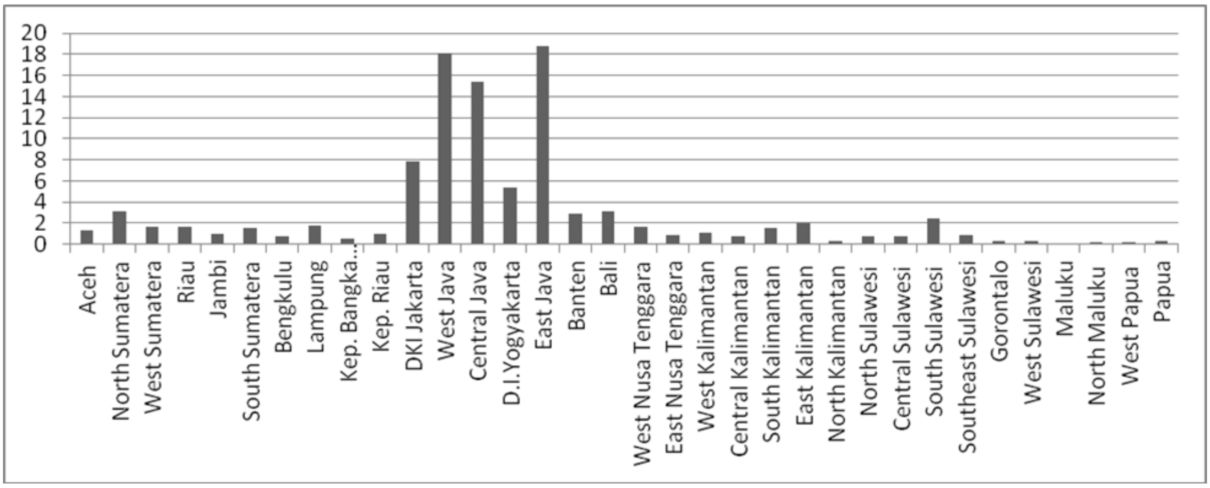

Figure 4. Percentage Distribution of Total MSEs Adopting e-commerce by Province, Indonesia, 2016 (Source: BPS, 2017).

Java is the centre of economic and financial activities in Indonesia, with DKI Jakarta, the Province of Banten and the Province of West Java together as the largest region in Indonesian GDP, followed by the province of East Java and the province of Central Java. Also, about 70 percent of the Indonesia population are found in this island; while, outside Java Island, especially in the eastern region where many poor provinces are found, the percentage of MSEs using e-commerce is much lower. Provinces that have the lowest percentage in this region are Maluku with only 0.12 %, North Maluku with 0.16 %, and West Papua 0.19 %.

The scatter diagram of MSEs-e and GRDP shown in Figure 6 may provide a clearer picture of the relationship between MSEs-e and market size, represented by provincial GDP.

Finally, the relationship between EDU and the use of e-commerce by MSEs is not significant (0.2924 > 0.05) and the coefficient is negative; so H_5 is rejected These results give the impression that conducting e-commerce is not affected by the level of formal education of the MSE owners. In Indonesia, MSE owners are generally poorly educated; in fact, most of them who are above 40 years old have only elementary school, or those who are still in their 20s only have a high school diploma. With low education, it is difficult for them to find jobs in the formal sector, for example, as employees in a big company. Therefore, they are forced to open their own businesses. So, there is a kind of negative relationship between the level of education of MSE owners and the existence of MSEs.

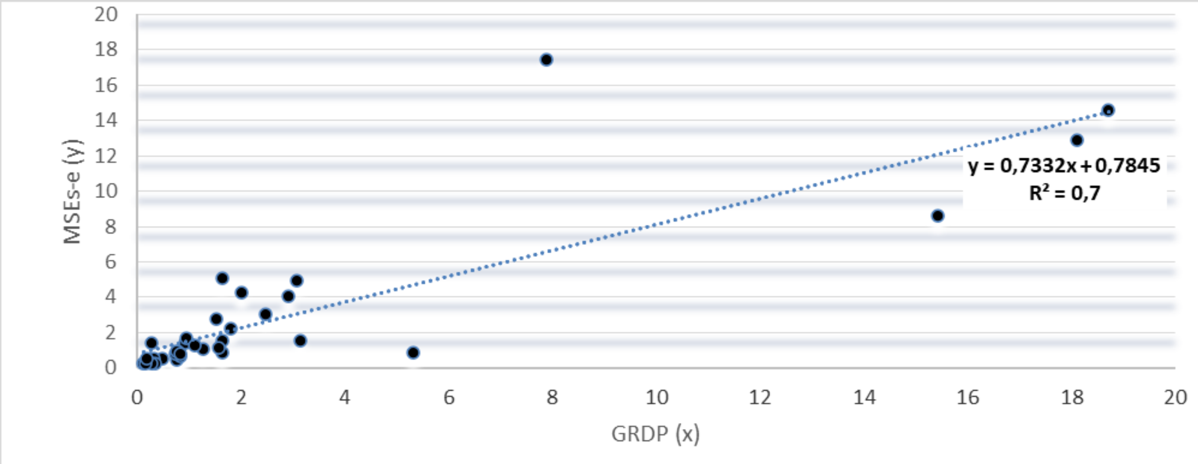

Figure 6. Scatter Diagram of MSEs-e and GRDP, Indonesia, 2016 (Source: BPS, 2017)

Conclusions

This study outlines some significant findings on the e-commerce adoption by MSE owners/entrepreneurs in Indonesia. It shows at least three important facts. First, the degree of e-commerce adoption by MSEs in Indonesia is still very low. The review of literature reveals several explanations, which include owners' low understanding of the importance of ICT or e-commerce for their businesses, their mindset, which is not in favour of using ICT or adopting e-commerce (i.e., they prefer to do marketing with conventional methods), lack of human resource capacity, and lack of owners' innovativeness.

Second, there is a positive relationship between the size of economic activities or market in a province and the number of MSEs in the province using the Internet or e-commerce. One explanation is that, in regions where market size is large, represented by many buyers and producers, usually the market competition among MSEs themselves as well as between MSEs and larger companies and imported goods is tight. Such market conditions force MSEs to be more aggressive and smarter in promoting as well as marketing their products, and, for that, they must utilise the Internet/ICT or adopt e-commerce.

Third, in a region where all residents or households have a computer or access to the Internet, it is not always that all business actors, especially MSEs, in that region utilize e-commerce technology. This suggests that there are many other factors, as already discussed in the literature review or described in the theoretical framework, which are far more important in influencing the decision of an MSE owner or entrepreneur to change his/her marketing system from conventional to e-commerce usage.

Limitation and Future Research

However, this study, which has tried to assess the impact of internal and external factors, as explained in the conceptual framework of this study, on the use of e-commerce by MSEs in Indonesia, based on secondary data, is not entirely successful. There are lots of factors, especially from the category of entrepreneur, company, policy and supporting factors, for which there are no province data.

Therefore, this research should be combined with primary data-based studies, that is, data collected from interviews with MSEs owners/entrepreneurs. And to get an idea of the differences (if any) between provinces and between sectors, the field survey must cover MSEs in various sectors and provinces. In the sample selection procedure, the priority sectors should be trade, agriculture and manufacturing industries, because usually the majority of MSEs are in these three sectors. The priority provinces are one or two provinces with the highest percentage of MSEs using e-commerce (e.g., East Java and West Java provinces) and one or two provinces with the least number of MSEs using e-commerce (e.g. Papua and West Papua provinces).

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A Review of Current Machine Learning Approaches for Anomaly Detection in Network Traffic

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Abstract: Due to the advance in network technologies, the number of network users is growing rapidly, which leads to the generation of large network traffic data. This large network traffic data is prone to attacks and intrusions. Therefore, the network needs to be secured and protected by detecting anomalies as well as to prevent intrusions into networks. Network security has gained attention from researchers and network laboratories. In this paper, a comprehensive survey was completed to give a broad perspective of what recently has been done in the area of anomaly detection. Newly published studies in the last five years have been investigated to explore modern techniques with future opportunities. In this regard, the related literature on anomaly detection systems in network traffic has been discussed, with a variety of typical applications such as WSNs, IoT, high-performance computing, industrial control systems (ICS), and software-defined network (SDN) environments. Finally, we underlined diverse open issues to improve the detection of anomaly systems.

Keywords: Anomaly Detection, Intrusion, Networks, Supervised, Unsupervised

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Introduction

The detection of anomalies and abnormal activity in the network have become the most common problem in the industrial research area (Larriva-Novo *et al.*, 2020; Kusyk *et al.*, 2018). Anomaly detection is widely used in different types of applications, such as health monitoring systems, fault detection in critical systems, fraud detection, crime investigation, and cyber-intrusion detection (Bauer *et al.*, 2019; Rettig *et al.*, 2015; Shukur & Kurnaz, 2019;Meng *et al.*, 2017; Mohammadi *et al.*, 2019). With the rapid development of extensive-scale network technology along with users and services, the security of information is becoming imperative for any network system. Therefore, many studies and researches took a broad scope in the security area, with various methods and techniques that helped many researchers to work on the development of algorithms and feasible methods in the detection of abnormal activities in network traffic. The machine learning (ML) concept has been actively present in the last decade in many applications to solve various problems in network security. The major problem to which ML techniques are applied is anomaly detection in the network. Many ML techniques have been used or proposed for this purpose in different aspects and different methods, but the most used techniques are categorized under supervised and unsupervised machine learning. Based on review studies in this area, these two types of ML have received considerable attention by researchers, who suggested these techniques to be used either separately or combined (Omar *et al.*, 2013). In fact, several researchers have used these two ML techniques and their results have led to improved performance of attack detection and increased anomaly detection efficiency. The question that remains is: how do researchers decide which ML (unsupervised or supervised) technique to use for a specific problem or dataset? In other words, how do we know which ML technique is going to fit better with our dataset and lead to better results?

These questions motivated us to investigate the differences between the supervised and unsupervised approaches in recent applications related to anomaly detection systems. The main aim of this survey is to review various ML techniques used for anomaly detection to provide maximal understanding amongst the existing techniques that may help interested researchers to boost their future work in this direction.

The paper is structured as follows. In section 2, we discuss the different types of anomalies. Section 3 describes the use of ML for anomaly detection. In section 4, we explain the significant types of network attacks. Sections 5 and 6 discuss the supervised and unsupervised techniques recently used and their variations are evaluated. In section 7, we compare the supervised and unsupervised techniques. Section 8 presents the work on semi-supervised techniques briefly. Finally, we conclude our work and highlight some open issues and challenges in section 9.

Network Anomalies Types

A computer network is a combination of many individual entities assembled together to provide complete and various communication services. Anomalies in these networks are network activities that differ from standard, usual or expected behaviour, and are suspected from a security perspective. They are also known as abnormal activities that attempt to disrupt the normal functions of the network.

Chandola *et al.* (2009) define anomalies as "patterns in data that do not conform to a well-defined notion of normal behavior". Ahmad *et al.* (2017) express the term as "a point in time where the behavior of the system is unusual and significantly different from previous, normal behavior". For a common network, Zhao *et al.* (2015) says “a traffic flow with unusual and significant changes is considered as an anomaly”. According to Zhang *et al.* (2017), "Network anomaly refers to the unusual behavior of network actions or suspicious network status, which can either be malicious or benign". Additionally, Lakhina *et al.* (2004) stated that “anomalies are unusual and significant changes in a network’s traffic levels, which can often span multiple links”.

Anomalies are also called abnormalities, outliers, or exceptions. They have been defined in many ways by different authors with different backgrounds, resulting in creating confusion of the terms related to anomalies. To understanding those definitions, the first step to knowing what is abnormal in a network system is understanding the normality. There are various types of network anomalies (Mohd Ali, 2018), which can be categorized into three types: point anomalies, contextual anomalies, and collective anomalies, as shown in Figure 1.

A point anomaly is considered as the simplest type of anomaly, where any single point of data has different attributes from its group of data. For example, in credit card transactions, the daily spend of money is a hundred dollars, but on a specific day the spending rises to four hundred dollars. This type of anomaly transaction is called a point anomaly.

A contextual anomaly is also known as a conditional anomaly, where the data behave anomalously in a specific context. However, conditional anomalies are usually applied to time-series data. For example, admission for short courses during summer takes typically 30 to 40 students for each course. If the admissions in some courses are below 15 students, we considered this as an anomaly.

A collective anomaly is detected when a collection of data groups behaves anomalously within the whole dataset. In this type, individual anomaly behaviour is not considered as anomalies. Nevertheless, the frequent occurrence in these data is considered an anomaly. For a better understanding of the concept, the following example is given: in the computer, there is a sequence of actions that occurs together, such as buffer-overflow, HTTP-web, FTP, HTTP-web, SSH, HTTP-web, SSH, buffer-overflow, HTTP-web. In this case, the sequence is called a collective anomaly (Fernandes *et al.*, 2019).

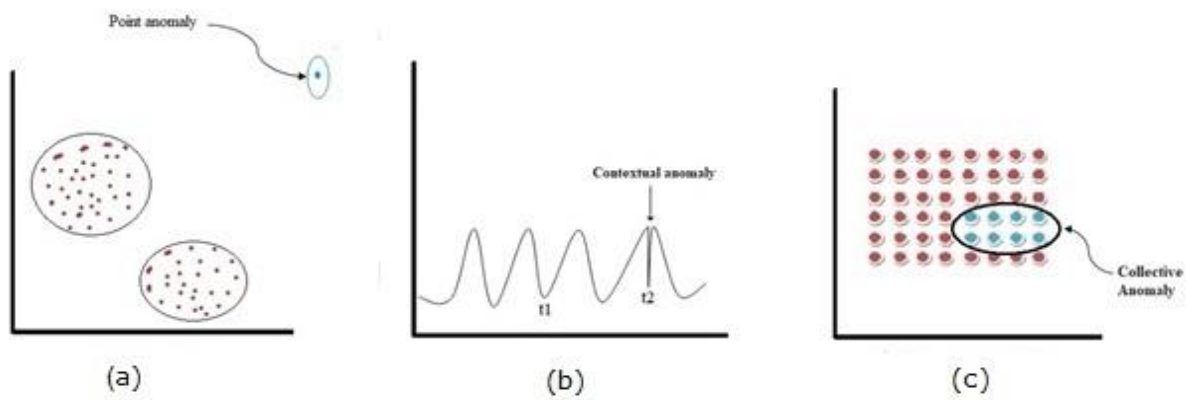

Figure1. Types of anomalies: a) point anomaly; b) contextual anomaly; and c) collective anomaly

Anomaly Detection Using Machine Learning

Anomaly detection is the process of finding an effective way to discover anomalous values in a dataset that behave abnormally in the system. The importance of this process lies in that anomalies in data are translated into important practical information in a wide range of application areas. Anomaly detection provides a method of identifying a possible threat behaviour and takes appropriate action when it occurs. Generally, the anomaly detection system is an automated security system used for monitoring, analyzing, and detecting abnormal activities within a network or host (Kotu & Deshpande, 2018; Omar *et al.*, 2013; Knapp & Langill, 2014). Besides, Lee & Stolfo (1998) report that there are four major elements to be considered when creating an anomaly or intrusion detection system: resources to protect, models to identify the typical behaviour of the resources, techniques that compare the actual activities of these resources with their healthy behaviours, and, finally, identifying what is considered anomalous or unwelcome objects. In this paper, we focus on anomaly-based intrusion detection systems (AIDS). However, the investigation of network intrusion using AIDS has been of interest to many researchers and authors. The researchers have presented a detailed description of various aspects and types of anomaly detection systems along with various models and techniques used to defend many attacks that we will discuss in detail later.

In any network computer system, there is potentially a large amount of activities, traffic, and log information available on it. The majority of activities are standard, but a tiny amount of activities may be outside the border of what is usual or expected. Those unexpected activities are potential anomalies or intrusions. However, as the dataset of such systems is extremely large, diverse, and ever-growing, the patterns of the anomaly may not be evident and easy to find. The ideas of the concept of machine learning may be an essential way to find potential intrusion patterns. Machine learning aims to extract valid, potentially helpful, and significative patterns to recognize intricate patterns in existing datasets to help to make intelligent decisions or predictions, by using a nontrivial learning mechanism (Bhattacharyya & Kalita, 2013). In general, all machine learning algorithms follow standard steps to classify the anomalies and intrusions, as follows:

Data Cleaning and Noise Removal: in this stage, the data is cleaned by removing outliers and unwanted data. This will improve the quality of the training data and lead to a better and more accurate prediction model.

Classification: classify or label the data into normal or abnormal.

Named Entity Recognition: it is necessary to know some entities to predict anomalies such as packets, IP address, time, size, and activity, then classify them as positive normal, or abnormal.

Subjectivity Classification: Subjectivity is a term referring to any attributes, events, or the properties of entities.

Feature Selection: the process of automatically selecting the features which are relevant to our data to predict the interested variables or output and help the system to detect anomalies (Manasa & Padma, 2019).

The basic idea of using a machine learning algorithm is to provide the ability to learn from a given dataset and address the problems in a similar dataset automatically without human intervention. Several algorithms and methods have been used by researchers and developers to overcome the network security challenges and avoid network attacks. Primarily, the machine learning approaches can be categorized into three main classes as shown in Figure 2: supervised learning, unsupervised learning and semi-supervised learning. Supervised learning is mainly used for classification or prediction, whereas unsupervised learning is used for clustering. The semi-supervised class is a hybrid approach between supervised and unsupervised classes. Figure 2 also shows some examples of well-known classification and clustering algorithms.

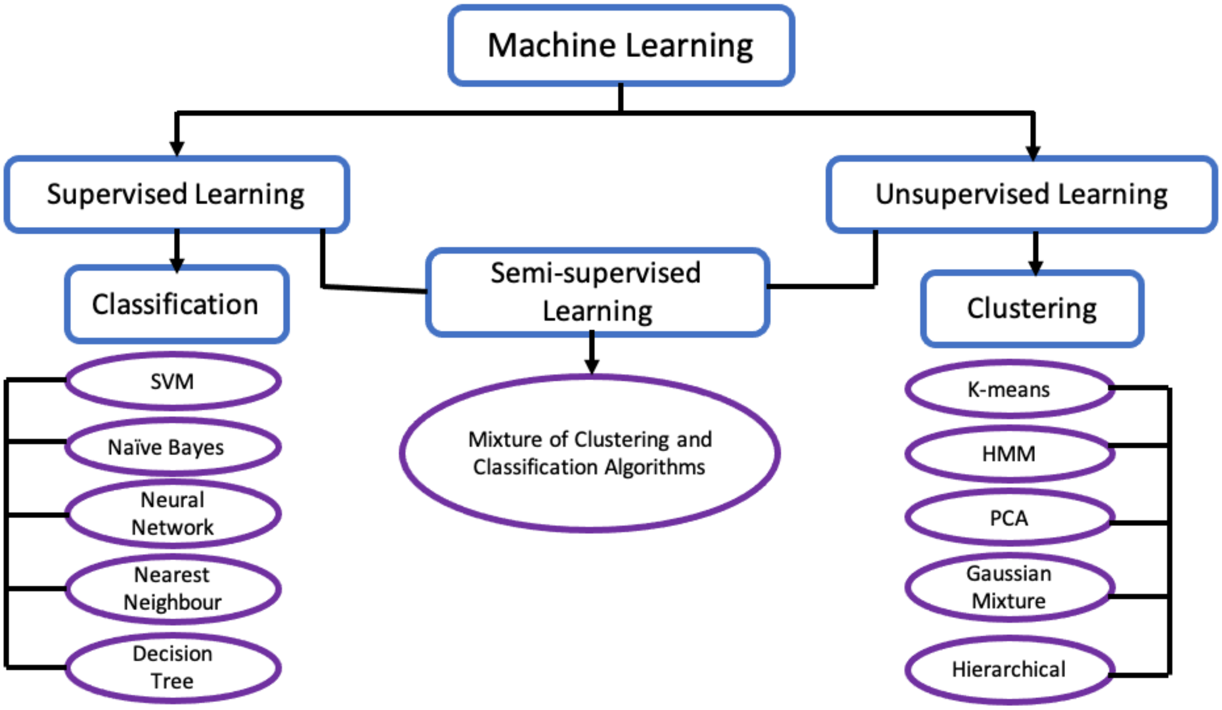

Figure 2. Machine learning techniques

In this paper, we will investigate different types of attacks handled by using supervised, unsupervised and semi-supervised algorithms. Moreover, we will review the most critical analysis methods which are related to anomaly detection techniques within the area of network traffic that have been proposed in the last five years.

Network Attacks

A network attack is an illegal attempt to avail of the vulnerability of a computer or network, attempting to break through the security of the network system. Anderson (1980) classifies attackers into two types: external and internal. External attackers are unauthorized users in the systems they attack, whereas internal attackers have the authority to access the system, but do not have access to the root or superuser. Bhattacharyya & Kalita (2013) classify attacks into seven main types based on the implementation of those attacks, as shown in Table 1.

In this survey, we will concentrate on the most critical and recent attacks from different categories with different examples. Also, we will highlight ML approaches and algorithms used to detect those attacks.

Table 1. Attack categories

Main category	Definition	Examples
Infection	Aim to infect the target system either by tampering or by installing evil files in the system.	Viruses, Worms, Trojans.
Exploding	Seek to explode or overflow the target system with bugs.	Buffer Overflow.
Prop	Gather information about the target system through tools.	Sniffing, Port sweep, IP sweep.
Cheat	Typical examples of this category include attempts to use a fake identity.	IP Spoofing, MAC Spoofing, DNS Spoofing, Session Hijacking, XSS Attacks, Hidden Area Operation.
Traverse	Attempts to crack a victim system through a dull match against all possible keys.	Brute Force, Dictionary Attacks, Doorknob Attacks.
Concurrency	Victimize a system or a service by sending a mass of identical requests which exceeds the capacity that the system or the service could supply.	Flooding, DDoS (Distributed Denial of Service).
Others	These attacks attempt to infect the target system by using system bugs or weaknesses directly.	

Supervised Learning

Classification is one of the terms which refers to supervised learning. Applying supervised techniques on the network data sets allows us to build a model, and the data instances can be labelled using a set of attributes. Many supervised algorithms are used to detect anomalies and intrusions in the network traffic and have proven effectiveness and efficiency, such as Support Vector Machine (SVM), Artificial Neural Network (ANN), Nearest Neighbour algorithm, Decision Trees, K-nearest neighbour, Ensembles classifiers, and Naïve Bayes classifier. These algorithms are more commonly used in the supervised learning approach. In the following, we summarize the research works that have been done using these supervised learning algorithms for anomaly detection in the past five years.

Support Vector Machine (SVM)

Chakir *et al.* (2018) introduced a new Intrusion Detection model based on a Particle Swarm Optimization algorithm (PSO), which joins a feature selection algorithm using information gain with a SVM classifier. The authors concluded that, by combining feature selection and parameter optimization for SVM, training and testing time are reduced and the effectiveness of the SVM Classifier is improved. The proposed model FS PSO-SVM results in obtaining a high detection rate and the lowest false positive rate. They tested the effectiveness of the proposed model by using the NSL-KDD Dataset, which includes 41 features, and by testing the model through 4 types of network attacks: DoS, R2L, U2R and Prob.

Recently, Gu *et al.* (2019) proposed an intrusion detection (ID) framework based on the SVM ensemble classifier with increasing features selection. Their idea is to integrate the powerful quality-improved transformation with the SVM ensemble. They built a robust intrusion detection framework with low training complexity, powerful performance, and high accuracy. However, they considered only the binary case of intrusion detection problems. They applied their proposal on the NSL-KDD Dataset and used a cross-validation (10-fold) method to train and test the model. The result of their experiment showed that the proposed framework could achieve robust performance, a high detection rate, and a low false alarm rate.

Weerasinghe *et al.* (2019) presented a novel framework to enhance the resilience of SVMs against training-data-integrity attacks. The proposed approach uses random projections on top of the learners. This makes it challenging for the attacker to guess the specific configurations of the learners. They introduce novel indices that ensure the shrinking of the data and increase the detection accuracy. Their contribution is characterized by the use of nonlinear random projections for defense techniques for learners (SVMs/One Class SVMs). Several datasets were used in this experiment, such as MNIST, CIFAR-10, and SVHN. The results indicated that SVM and OCSVM could be significantly affected if an attacker can manipulate the trained data.

Another approach using the SVM algorithm is proposed by Hu *et al.* (2019). To address the problem of the long training time of the prediction model, the authors proposed a prediction model based on the map-reduce technique and SVM classifier. They used an SVM classifier as a base classifier for the model and optimal parameters performed by the Cuckoo Search (CS). They used the Map Reduce (MR) technique and CS algorithm to enhance the SVM classifier to optimally solve the general problem of parameter optimization. They stated that the proposed model reached better results in terms of accuracy and it reduced training-time costs.

Naïve Bayes

Han *et al.* (2015) developed a Naïve Bayesian (NB) model for network intrusion detection based on PCA (Principal Component Analysis). The model utilized NB with PCA to extract new properties that helped them to improve the traditional NB algorithm, where traditional NB cannot consider the problem of weights in attributes. KDD CUP 99 was the experimental data set, and the type of attacks that dataset included were DoS, U2L, R2L, and Probe attack. This experiment has a good result in the detection rate with weighted Naïve Bayes classification, and it solves the problem of feature redundancy.

Swarnkar & Hubballi (2016) proposed a version of a Naïve Bayesian one-class classifier, OCPAD, for payload-based anomalies detection. OCPAD is a content method that identifies network packets with untrusted payload content. They have done many experiments with a large dataset showing that OCPAD can perform at an excellent level to detect anomalies with increasing Detection Rate as well as an agreeable False Positive Rate.

Kumar & Venugopalan (2018) introduced a novel algorithm based on the Naïve Bayes model to detect attacks in data training. In their study, they conducted four testing data stages on the Kyoto 2006+ dataset. The training dataset contained 5000 average records and 5000 attacks, and all the four tests were evaluated by the Naïve Bayes model, which resulted in higher accuracy and detection rate.

Recently, Mehmood *et al.* (2018) presented a new model of using the Naïve Bayes algorithm-based intrusion detection system. The proposed approach aims to protect the Internet of Things (IoT) infrastructure from Distributed Denial of Service (DDoS) attacks generated by the intruders and the complexity of IoT, where the data comes from heterogeneous resources that helped this type of attack to spread in the IoT network. The authors implemented a multi-agent-based IDS (NB-MAIDS). An NB classifier was applied with a multi-agent system (MAS) throughout the network and agents. They collected the information from sensors which help the system to report the activities of the abnormal nodes on the IoT network. This proved the efficiency of the NB classifier with multi-agents in the proposed approach, giving better performance to prevent attacks very quickly with low execution costs. The experiment of proposed classifier effectiveness was tested on the NSL-KDD dataset.

Nearest Neighbour

The nearest neighbour classifier is one of the supervised learning techniques that is widely used for anomaly detection. Xiao *et al.* (2015) introduced an effective detection technique based on CKNN to detect DDoS attacks. This method is applied across a data centre network by utilizing the training data correlation information and CKNN classification. Their contribution provided a novel approach throughout the use of a CKNN classifier with correlation information. This helped to reduce the size of training data and to improve the classifier accuracy in detecting DDoS attacks with low cost and minimum response time. In this work, the authors used three types of dataset: broad, real, and KDD99.

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Regarding the new type of Software Defined Networking (SDN) and their network flow problems, Peng *et al.* (2018) presented an SDN-based anomaly flow detection. This work was implemented for DDoS anomaly detection, where the K-nearest neighbour algorithm was the classification technique performed to detect flows using P-value. The results of the experiment showed that the DPTCM-KNN algorithm increases the detection accuracy rate of the anomalous flow detection, as well as reducing the false positive rate. This confirms that the algorithm has very good performance in SDN platforms.

An Industrial Control System (ICS) is a control system and related instrumentation developed to control and monitor industrial processes using cyber-physical systems. Abnormal behaviour in these critical infrastructures can cause a significant threat to society. In this area, Yun *et al.* (2018) implemented a statistical model that provides an intrusion detection technique to detect abnormal activities in ICS networks by using Nearest-Neighbour Search (NNS). The proposed model can identify the normal and abnormal traffic patterns in the network, even the small amount of traffic variation with the lowest false rate. The NNS algorithm works fast with time complexity analysis, which allowed the method to be used in real time in ICS. The experiment assured that small changes in the traffic could be detected by the method with fast execution. This speed can be used for real-time monitoring in any ICS network.

Anomaly detection systems were not only limited to computer networks but also included several networks such as WSN, IoT, Cloud, etc. Wang *et al.* (2019) proposed a method to detect anomalous values in a Wireless Sensor Network (WSN) environment by detecting the proximity of distance based on distance. The KNN (K-Nearest Neighbour) algorithm was used in the proposed approach to analyze the data first, then to detect the data anomaly in the WSN. The authors discussed the different types of applications in WSNs, which are repeatedly attacked along with the type of attacks in WSNs. They used the QualNet network simulation tool to analyze behavioural research and statistics of a wireless mobile network. QualNet helped to cover many models, algorithms, and protocols that are useful in learning, efficiency, speed, and accuracy of processing as part of a real network. The results of the paper prove that the KNN classifier can achieve a reasonable detection rate and a low error rate. The compressed proximity algorithm is used to minimize the massive dataset.

Decision Tree

Decision Trees are counted as one of the most common classification techniques. Khraisat *et al.* (2018) introduced a data mining technique that could minimize the false rate in the system. The proposed classifier is a C5 decision tree that was examined with different data mining techniques. The authors aimed to prove that the C5 algorithm obtains the best result of detecting abnormal activities. However, they examined 4 types of algorithms: SVM, Naïve Bayes, C4.5, and C5. The results showed that the C5 decision tree has reduced both false positive rate and false negative rate and the intrusion detection is improved effectively with high accuracy. The experiment was applied using the NSL-KDD dataset. Kevric *et al.* (2017) developed a combining classifier based on the decision tree algorithm for IDS. They selected a new version of a KDDCUP'99 data set that is NSL-KDD. A detection algorithm was used to classify the traffics of the network, whether it is normal or abnormal, based on 41 features describing all patterns of the network traffic. The authors stated they achieved outstanding detection rate accuracy by combining both Naïve Bayes Tree (NBTree) with random tree classifiers with a sum rule scheme, and it was better than the individual random tree algorithm.

Rai *et al.* (2016) worked on the decision tree classifier in terms of feature selection and split value. Those issues are essential to build the classifier; the Decision Tree Split (DTS) algorithm based on the C4.5 classifier was explicitly designed to address the two issues. The approach gives a novel method in selecting the split values. The algorithm is more efficient for signature-based intrusion detection with fast finding of attacks in the network with a small number of features and minimum cost of time to build the model. Through literature, comparing the proposed algorithm with others, it found that the DTS algorithm is efficient for constructing a decision tree that is used to detect intrusions. Experimentation is performed on the NSL-KDD dataset.

Chew *et al.* (2020) proposed a sensitive pruning model-based decision tree classifier to overcome the issues of the visibility of its tree rules in the Network-based Intrusion Detection System (NIDS). They modified the pruning algorithm based on the C4.8 decision tree. The pruning framework used in this work is the Weka J48 decision tree and tested on 6 versions of GureKDD Cup IDS datasets. Evaluation and results revealed two advantages of using a C4.8 decision tree. The first advantage is the ability to maintain privacy in the decision tree by hiding only sensitive rules selected. Secondly, any small changes in the proposed pruning of the decision tree structure during tree construction do not affect the process of feature selection.

Neural Network

A Neural Network can also be known as an Artificial Neural Network (ANN). Generally, an ANN uses constructs from the human brain system, consisting of significant parallel connections of many neurons. Usually, the neurons are related to each other in a complex manner. ANNs are built with several connecting nodes with activation functions (Akhi, 2019; Agrawal & Agrawal,

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2015). Neural Networks (NNs) can be used for supervised and unsupervised learning. However, in this section, the survey has been carried out through the latest published papers which focused on supervised learning only.

Hodo *et al.* (2016) presented an artificial neural network system to analyze threats in IoT networks. By using internet packet traces, ANNs are trained to learn the ability to detect and prevent DDoS attacks. The proposed model was able to identify several types of attacks and proved efficient results in the perspective of true-positive and false-positive rates.

Veselý & Brechlerová (2009) are in accord with Hodo *et al.* (2016) where they claim that an artificial neural network is an appropriate technique to increase the ability of anomaly detection systems to successfully detect attacks and abnormal activities. They present an overview of the previous work that showed the applicability of NNs for building anomaly detection systems and the ability to differentiate between normal and abnormal behaviour in the system.

Haripriya *et al.* (2018) proposed a novel ANN supervised classifier by applying the back-propagation algorithm to the intrusion detection system using the R tool. The KYOTO data set was used as a filtered version of KDD-CUP-99. The authors took advantage of feature selection techniques and applied them to this dataset to remove irrelevant features and duplicate data. They compared the proposed method with different models and the outcomes show that F-measure, accuracy, and recall are enhanced and increased.

However, Wu *et al.* (2018) used a different type of neural network, that is a Convolutional Neural Network (CNN), where the network intrusion-detection is proposed as a novel model. CNN has an ability to select traffic features automatically from the raw dataset, and that encourages them to use this type of NN. The main issue which needed to be solved is the imbalanced dataset problem. The proposed model improved the accuracy of detection in a big network and in real time, along with reducing the false alarm rate. The authors also proposed a model to convert the raw traffic vector into an image format, which facilitates reducing the cost of calculation. The standard NSL-KDD dataset is applied to evaluate the performance of the proposed model.

On the other hand, Vinayakumar *et al.* (2017) preferred to use another type of neural network, that is a Recurrent Neural Network (RNN). The authors have done a comprehensive review of various RNN networks and examined traditional machine learning classifiers to come out with a clear picture of RNN effectiveness. RNN is a subset of ANN that appeared as a powerful approach to learn temporal behaviours in large-scale sequence data. To examine this model, the authors model traffic of a network as a time series, especially TCP/IP packets in a pre-defined time range using a massive number of known strong and poor network connections. They used the existing datasets, DARPA, KDD-Cup-99, and UNSW-NB15, to display the power and efficiency of the RNN architecture. An RNN has the ability to store long-term information and is able to adjust with serial connection sequence information. Moreover, this work performed well with different types of high-frequency attacks such as DoS and Probe.

Deep learning (DL) is another machine learning method based on artificial neural networks with representation learning. Learning can be supervised, semi-supervised or unsupervised. The main difference between NNs and DL is in the number of node layers, or depth, of the neural networks. Therefore, an NN is a simple version of a DL. Recently, DL techniques have been widely used for detecting unauthorized logins into computer networks. DL techniques have stepped up to deal with the shortcomings of some automated learning techniques for dealing with large amounts of data that come from heterogeneous sources.

The use of DL techniques for anomaly detection is outside the scope of this study. We intend to extend our review to include DL-based anomaly techniques in our future work.

Ensemble Methods

Training a variety of ML methods to solve the same issue and then combining their performance to enhance accuracy is known as an ensemble method or a multi-classifier system (Aburomman & Reaz, 2017). Through the literature, we can see the progressive development of a variety of IDSs based on ensemble methods. In the following, we will summarize of these works.

Gu *et al.* (2019) proposed an efficient SVM ensemble-based intrusion detection system with feature augmentation. They implemented most powerful univariate classifiers marginal density ratios transformation on the original features, in order to obtain new and better quality training data. The results of the experiments show that the SVM ensemble can achieve reasonable and robust performance, which has a competitive advantage in terms of detection rate, training speed, accuracy, and false alarm rate compared to other established methods. The experiment was performed on the NSL-KDD dataset.

Pham *et al.* (2018) introduced an ensemble classifier and feature selection with the aim of improving the performance of the IDS. The ensemble classifiers were built based on two techniques, Boosting and Bagging, with a tree-based algorithm as a base classifier. These models were evaluated using NSL-KDD datasets. The results showed that the bagging technique with the tree-based classifier (J48) can improve the performance in terms of classification accuracy as well as a false alarm rate (FAR).

Bhati *et al.* (2020) proposed a new scheme of ensemble-based techniques to detect several types of attack classes, such as DOS, R2L, U2R, and Probing. The framework was implemented using MATLAB. The basic task of the proposed method is to create individual classifiers, then train them separately. The combination of classifiers leads to powerful decisions based on majority voting. The proposed framework consists of 4 major steps: Data Collection, Pre-processing, Training & Testing, Decision. As a result, the framework gives a high detection accuracy for DOS, Probing, R2L and U2R. The KDDcup99 dataset was used to evaluate the proposed scheme.

Rai (2020) examined ensemble learning methods for IDS that were boosting and bagging methods, such as XGBoost, Gradient Boosting Machine (GBM), and Distributed Random Forest (DRF). They were implemented using a Python library (H2O) for the new intrusion identification framework. A Deep Neural Network (DNN) is also executed using the same library and it was found that the model overcomes the past aftereffect of DNN after employing the genetic algorithm as a feature selection method. The proposed approach outcomes beat the diverse old-style ML models too. NSL-KDD dataset has been used for the experiment.

Table 2 shows a comparison between the above research works that used the different supervised learning algorithms for anomaly detection. The comparison is in terms of publication year, supervised learning technique used, type of anomaly detected, dataset used, and accuracy.

Table 2. Supervised Anomaly detection approaches

Authors	Year	ML Technique	Anomaly type	Dataset	Detection Accuracy (%)
Jingjing Hu *et al.*	2016	MR-SVM classifier	generic attack in network	KDD, DARPA	96.16%
El Mostapha *et al.*	2018	PSO - SVM classifier	DoS, R2L, U2R and Prob	NSL-KDD	99.5%
Jie Gu *et al.*	2019	SVM ensemble classifier	binary case of intrusion detection problems	NSL-KDD	99.36%
Sandamal *et al.*	2019	SVM and OCSVM	training-data-integrity attacks	MNIST, CIFAR-10, SVHN	97%
Han *et al.*	2015	Naïve Bayesian with PCA	DoS, R2L, U2R, and Prob	KDD CUP 99	87%

Authors	Year	ML Technique	Anomaly type	Dataset	Detection Accuracy (%)
Swarnkar & Hubballi	2016	Naïve Bayesian OCPAD	Generic attack	HTTP dataset.	100%
Kumar & Venugopalan	2018	Naïve Bayes (ANADA)	Generic attack	Kyoto 2006+	96.66%
Amjad Mehmood *et al.*	2018	NB-MAIDS	DDoS attack	NSL-KDD	90%
Peng Xiao *et al.*	2015	Nearest Neighbour CKNN	DDoS attack	KDD99	96.3%
Huijun Peng *et al.*	2018	K-nearest neighbour	DDoS attack	SDN environments	97.88%
Jeong-Han *et al.*	2018	nearest-neighbour	generic attack in ICS	ICS real-time	99%%
Wang *et al.*	2019	KNN	generic attack in WSN	WSN temporal data	99.7%
Kevric *et al.*	2016	NBTree algorithm	DoS, R2L, U2R, and Prob	NSL-KDD	89.24%
Kajal Rai *et al.*	2016	Decision Tree Split (DTS)	R2L, U2R	NSL-KDD	79.52%
Khraisat *et al.*	2018	C5 decision tree	Zero-day attack	NSL KDD	99.82%
Chew *et al.*	2019	Weka J48 decision tree	Generic attack	Gure KDD Cup	99.33%
Gu *et al.*	2019	SVM ensemble	Generic attack	NSL-KDD	99.36 %
Pham *et al.*	2018	Ensemble (Bagging and Boosting)	DoS, R2L, U2R, and Prob	NSL-KDD	84.25 %
Bhati *et al.*	2020	Ensemble techniques	DoS, prob, U2R, and R2L	KDDcup99	98.9 %
Ajeet Rai	2020	Ensemble Methods and DNN	DoS, R2L, U2R and Prob	NSL-KDD	92.7%

Unsupervised Learning

Unsupervised learning is namely clustering techniques or undirected classification. Unlike supervised learning algorithms, the training dataset (labelled data) is not required in unsupervised learning techniques. The idea of a clustering technique to group data into categories or sub-groups is known as a cluster based on similarity properties. It uses measurement or metrics to count the likeness between data instances. In brief, unsupervised techniques are an attempt to determine the hidden pattern in given data without training a model. Further, unsupervised Network Detection Systems (NDS) are used to overcome the limitation of the supervised anomaly techniques system. There are many unsupervised algorithms used to cluster given data and detect anomalous/abnormal activities in network traffic successfully, like the K-means algorithm, Hidden Markov Model (HMM), Gaussian Mixture, Hierarchical clustering, and Neural Networks (NNs) (Bhattacharyya & Kalita, 2013; Dua & Du,2016). In the following, we summarize the different research works that have used unsupervised learning algorithms for anomaly detection.

K-means algorithm

It was formally known as the most basic and straightforward algorithm in unsupervised learning, as well as a partition-based cluster and the most popular unsupervised approach. To solve clustering problems, k-means partition n observations into k clusters, where each n belongs to the k with the nearest mean, which acts as a prototype of the cluster (Karim *et al.*, 2019). According to Thakare & Bagal (2015), in K-means algorithm, k objects will be selected as initial cluster centres, then the distance between each centre and object will be calculated, and objects assigned to the nearest centre. After that, the mean of all clusters will be updated; finally, the process will be repeated.

With the need for mining big data sets, stream mining gains attention from researchers, and it causes different challenges, such as anomaly and outlier detection, fraud detection, etc. Chauhan & Shukla (2015) reviewed a different approach of outlier detection using the K-means cluster algorithm. The different areas of applications have been discussed, and this algorithm with stream data was used. Introducing different machine learning, feature selection and clustering methods have been used to give basics of the k-means concept in outlier detection for beginner researchers.

Network security is an important aspect of where this algorithm is applied. Münz *et al.* (2007) introduced a network data mining technique by proposing a novel anomaly detection method based on the K-mean cluster algorithm. The authors trained the unlabelled records in the dataset and divided it into clusters of regular traffic and anomalies using the K-means algorithm. The cluster cancroids have been used as patterns for efficient distance-based detection of anomalous traffic in new data. They concluded that the model resulted in fast anomalies detection and improving detection quality. They evaluated the capability of the model to detect DoS attacks and port scans.

However, the K-means algorithm is considered a basic algorithm for the clustering approach, where the integration with other algorithms will be more effective. Therefore, Aung & Min

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(2018) presented hybrid ML algorithms that contained a k-means algorithm to identify similar attack groups and a Random Forest algorithm to categorize the data into normal and attacks. The authors tested the proposed model on four categories of intrusion attacks, DoS, U2R, R2L, and Prob, in the KDD-Cup-99 dataset. Their experiments produced good results where the accuracy and recall of the normal and anomaly detection were perfect. The false-positive rate showed an enhancement result, nearly zero.

Hidden Markov Model – HMM

HMM is a statistical model used in data science and engineering as a state-based classification model. The first use of this model was in speech recognition. After that, many analysis applications were applied successfully. One of the most critical applications is anomaly detection. In this area, a lot of works have been done with very efficient results. We will discuss some of the recent research articles that used the HMM in terms of security and intrusion detection.

Chen *et al.* (2016) proposed an algorithm that can handle the massive size of data and event logs and recognize the temporal relation of unusual events. Besides, they proposed a state-based detection approach to recognizing multi-stage advanced attacks. The challenge for them was related to the large amount of data and how the big data will be handled to analyze for security purposes. Results showed that the proposed model has been active and successfully performed with a massive amount of event logs in the network.

Stefanidis & Voyiatzis (2016) have been interested in the security of Industrial Control Systems (ICS). They introduced the HMM model for intrusion detection systems in ICS. They applied the model on SCADA systems by using interconnected TCP/IP protocol. The evaluation part in their work was done by comparing the accuracy of detection with other researchers' systems which used the same datasets. The proposed system achieved a higher detection rate of the most attack vectors. They concluded that the system was more appropriate with real-time systems and high-speed environments.

Zegeye *et al.* (2019) had technical concerns about the security of 5G networks. For such a purpose, they developed a novel multi-layer approach based on the HMM model to defend the network against intruders and capture multi-phase attacks, where the CICIDS2017 dataset had been used. SVD and feature selection techniques were applied to this dataset to reduce the data. Further, K-means clustering labels were used to monitor the multi-layer HMM model. With the use of the proposed model, there is no requirement to use a big amount of training data. The layer in this model was trained in a small observation space, indicating the models were more stable and well trained.

Meanwhile, mobile networking security has unanticipated challenges. However, researchers are working hard to develop models that overcome these challenges. According to Liang *et al.* (2018), the traditional HMM algorithm used for predicting network security is not precise. Hence, they introduced a weighted HMM-based algorithm designed to predict mobile networking security. They used multiscale entropy to handle the problem of low speed of data training in the area of mobile networking, while the HMM transition matrix was optimized. Furthermore, the autocorrelation coefficient could be used in the connection between the characteristics of the given data to predict future security of the network. They implemented the model and applied the analysis on the DARPA2000 dataset to verify the effectiveness of the algorithm. The dataset contained DDOS attacks, lots of data, redundancies, and false alarm rates. The proposed model experiment showed that it is accurate and valid.

Principal Component Analysis – PCA

PCA is a statistical technique used to decrease the dimensionality of a dataset consisting of numerous variables related to each other, preserving the current variation in the dataset to the maximum extent. To apply PCA on a training set, there is no requirement for labelled data. For that, PCA is an unsupervised learning algorithm used for dimension reduction.

Ding & Tian (2016) explained how to apply the PCA algorithm to detect anomalies in Traffic Matrix (TM) analysis. The proposed approach may carry out an effective analysis of Origin-Destination flows by dividing network traffic data into a normal and anomalous subspace. The experiment on the proposed detection method was done on node disconnection and DDoS attacks in a backbone network. The proposed method could detect a single-node anomaly as well as multi-node anomalies. They used in the experiments the Abilene network dataset between 2003–2004.

Meanwhile, Vasan & Surendiran (2016) focused their work on the efficiency of PCA for anomaly detection, with the definition of the Reduction Ratio (RR), the number of Principal Components required to detect intrusions, and the noisy data effect on PCA. The experiments utilized different classifiers on two datasets, KDD-CUP and UNB-ISCX.

The experiments showed that the first 10 principal components were useful for classification. They concluded that the use of PCA to build an intrusion detection system would minimize system complexity and achieve a higher accuracy of classification.

Paffenroth *et al.* (2018) introduced Robust PCA as a new anomaly detection system. The proposed approach, RPCA, uses network packet captured data to show the impact in different network attack detection systems. The DARPA dataset has been used in their experiments with different attack scenarios, such as DDoS attacks, IP sweeps, and probing and breaking. The model achieved the lowest false positive rate with a reasonable correct positive rate and successfully detected network attacks. The used method detected packet stream attacks accurately which had not been encountered or trained previously.

Hoang & Nguyen (2018) probed a different way of PCA with IoT, where network platforms need effective tools to detect intrusions in traffic data swiftly and identify attacks. They mentioned a listing of issues in applying the PCA algorithm, for example, the choice of principal components for complexity reduction. Through previous literature, they proposed a new general formula for distance calculation as well as a new method based on PCA for detecting anomalies in IoT networks. Several experiments were conducted on the dataset Kyoto Honeypot that were collected from Honeypot university networks. Quick online detection and reduced complexity of computation are the results obtained from the experiment on three random Kyoto network datasets.

Gaussian Mixture Model (GMM)

The Gaussian Mixture model is “a probabilistic model which states that the entire generated data points are derived from a mix of a finite Gaussian distribution that has unknown parameters” (Technopedia, n.d.). Many researchers have worked on this model, and they have come up with excellent results. Therefore, the following survey covers a few recent papers using the GMM method.

Lalitha & Josna (2016) applied the GMM for network traffic verification. They captured the traffic data and fed it into the proposed model for verification. It supposed that the traffic which conforms to the model is reasonable and the traffic which does not conform to the model is an anomaly. Their analysis showed that the model has the best performance in terms of response time and the packet delivery ratio. Additionally, the model is effectively used with a Wireless Sensor Network (WSN) without any effect on the performance of the network.

Alizadeh *et al.* (2015) presented unsupervised GMMs for the production of application models via two scenarios: first, traffic classification; second, traffic verification. This work aims to confirm whether traffic flow generated by the claimed application conforms to the expected model or not. The authors used GMMs with automatic learning to build a traffic model to meet the real traffic and forming ANIDS. The experiments proceeded on the "UNIBS-2009" dataset where the obtained results are positive as the model was shown to be more effective in the abnormality detection of application traffic in multi-network.

Reddy *et al.* (2017) introduced a methodology using GMMs for outlier detection in univariate network traffic. The proposed approach is useful in big data concepts as it smoothly and efficiently delivers the required information. The GMM model divided all data points into normal and outlier data points. The algorithm can be implemented in several seasonal univariate big data sets. In this work, the authors use particularly time series network traffic data to test and validate their approach. There are two stages to detect outliers in this work. Firstly, GMMs are designed to train data in each time bin of the network time-series data. Second, GMMs are redesigned after removing outliers in the training data, and the re-computed GMMs were used in test data to detect the outliers. The proposed methodology showed the possibility of detecting outliers from various types of datasets and big data scenarios, and it can be easily modified for multi-variate datasets.

Not long ago, Blanco *et al.* (2019) proposed multiple simple GMMs that can model individual features in the dataset to be considered as normal according to the GMM. They tested the approach on the NSL-KDD dataset and formulated the normal behaviour models using samples labelled as healthy. They evaluated the model using the NSL-KDD testing set. The result indicated an F1-score above 0.9 and CAP over 0.49, which is considered better than other supervised and unsupervised proposals. The authors proved that using occurrence probabilities with the unsupervised algorithm will improve the performance and quality of the anomaly detection systems.

Hierarchical Clustering Algorithm

Similar objects in the hierarchical clustering algorithm are grouped into one form called clusters. An endpoint is a group of clusters where each one is diverse from another cluster, and each object in each cluster is widely similar to each other (Bock, n.d.). It is an approach of cluster analysis which tries to build a hierarchy of clusters. Recently, there are several works that have demonstrated the use of this algorithm and clarify it.

Kim & Kim (2015) introduced new IDS using a hierarchical clustering approach. The proposal is a combination of two models: misuse detection and an anomaly detection model. The objective of this work is to improve the detection rate in IDS and reduce the computational cost. In the proposed system, the model of misuse detection is used to remove the known attacks and to

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reduce the redundant features that help in the detection process. NSL-KDD dataset is used to evaluate the proposed hierarchical methods, and the results showed that detection accuracy and the speed improved, whereas the computational cost was reduced.

Similarly, Tang *et al.* (2016) developed a new intrusion detection model using the hierarchy approach, which also combines two algorithms, fuzzy c-means (GAFCM) and SVM. They used the NSL-KDD dataset to evaluate the model. The experiments showed that using a hierarchical clustering model extends the hard classification detection to the soft classification in the Fuzzy interval, enabling the model to give a high detection rate (DR) and low false alarm rate, whereas SVM classifiers reduce the computation time during model training.

Besides, Liu *et al.* (2017) proposed a dynamic hierarchical clustering approach. First, to reduce the feature dimension, they used feature selection based on information gain. Then, they defined the generalized Euclidean distance to measure the cross-domain data. After that, dynamic clustering accuracy was proposed to direct the dynamic hierarchical clustering. Finally, by using training data, the anomaly detection model was built. The experiment results determined that the proposed approach can achieve a high detection rate as well as a low false alarm rate on KDD-Cup-99 datasets.

The Internet of Things (IoT) is a rapidly growing network of devices that will cover billions of devices in the future. Therefore, researchers and industry are starting to deal with the IoT security issues seriously. Amangele *et al.* (2019) explored the use of the ML approach in IoT network traffic to detect anomalies that attack the Software Defined Network (SDN). SDN allowed hierarchical clustering intending to minimize the packet level processing of intrusion detection. For the evaluation step, they compared various supervised algorithms using a CICIDS2017 dataset. The results showed that the proposed model gives a drastic decrease in per-packet processing at the network edge in SDN.

Table 3 summarizes the above publications that used unsupervised learning algorithms for anomaly detection in the last five years. The table highlights the publication year, the unsupervised learning technique used, the anomaly type addressed, the dataset used, and the accuracy of the proposed approaches. Note that some papers did not report the accuracy achieved by their approaches: they only stated that they achieved better accuracy than the state of the art.

Table 3. Unsupervised anomaly detection approaches (SoA: State-of-the-art)

Authors	Year	ML Technique	Anomaly type	Dataset	Detection Accuracy (%)
Munz *et al.*	2016	k-means algorithm	DoS attacks and port scans	Cisco Netflow	Better than the SoA
Aung & Min	2018	k-means algorithm	DoS, R2L, U2R, and Prob	KDD CUP 99	99.9%
Chen *et al.*	2016	HMM	Generic network attack	Real-time network	93.2%
Stefanidis *et al.*	2016	HMM	Normal, DoS, MFCI, MPCI, MSCI, CMRI	Collected by researchers	93.4%
K. Zegeye *et al.*	2018	HMM	Benign, DoS Hulk, Port Scan, DDoS, DoS, FTP Patator	CICIDS2017	97.9%
Liang *et al.*	2018	weighted HMM	DDOS attacks	DARPA2000	Better than the SoA
Ding & Tian	2016	PCA	DDoS attacks	Abilene network dataset	93.33%
Vasan & Surendiran	2016	PCA	generic attack	KDD-CUP and UNB-ISCX	98.8%
Paffenroth *et al.*	2018	Robust PCA	DDoS attacks, IP sweeps and probing and breaking	DARPA	Better than the SoA.
Hoang & Nguyen	2018	PCA	Generic attack	Kyoto Honeypot	Better than the SoA
Lalitha & Josna	2015	Gaussian Mixture Model	Generic attack	WNS simulation	Better than the SoA
Alizadeh *et al.*	2015	Gaussian Mixture - GMMs	Zero-day	UNIBS-2009	98.7%
Reddy *et al.*	2017	GMMs	outliers	Collected by researchers	Better than the SoA
Roberto Blanco *et al.*	2019	GMMs	DoS, R2L, U2R, and Prob	NSL- KDD	Better than the SoA
Kim & Sehun Kim	2015	hierarchical approach	DoS, R2L, U2R, and Prob	NSL-KDD	96.1%
Tang *et al.*	2016	GAFCM + SVM	DoS, R2L, U2R and Prob	NSL-KDD	99.76%
Liu *et al.*	2017	dynamic hierarchical clustering	DoS, R2L, U2R, and Prob	KDD-Cup-99	98.2%

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Authors	Year	ML Technique	Anomaly type	Dataset	Detection Accuracy (%)
Amangele *et al.*	2019	hierarchical clustering	BOT, DoS, R2L, U2R, Prob, PSCAN, Web Attacks	CICIDS2017	99%

Comparison Between Supervised and Unsupervised Techniques

In SVM, for instance, combining feature selection and parameter optimization reduces training and testing time, as well as improving the effectiveness of the SVM Classifier. Additionally, according to the Naïve Bayesian model, combining NB with PCA to extract new properties helps to improve the traditional NB algorithm, which cannot consider the problem of weights in attributes. Based on previous studies presented in this survey, we can say supervised methods are commonly used with training data that are not real-time due to its simplicity and efficiency. Further methods employed are more flexible, with a high detection rate for known attacks. Also, by combining many classifiers, the methods can perform well, even if one is weak (Ensemble methods). However, supervised methods have some disadvantages addressed in this paper, such as the level of resource consumption and time complexity in terms of big data. Furthermore, real-time performance is not easy to acquire.

As seen in the survey, unsupervised learning does not require training data, as it is the first process for feature detection. Feature detection in unsupervised techniques is an attempt to determine the hidden pattern in given data without training data, so they are able to detect unknown attacks. For instance, in hierarchical clustering using the FCM approach, the membership function and the fuzzy interval are used both in the extended soft classification and the previous hard classification. This enables the model to detect unknown attacks. Moreover, in a robust PCA model, network packets are used to capture data which displays the effectiveness in different network attack detection systems. The method accurately detected an anomaly/attack that was not encountered or trained previously.

Given these studies in our survey, unsupervised learning techniques have been implemented in different areas and applications such as IoT, WSN, 5G mobile networks, and Industrial Control Systems (ICS), which primarily concern data all in real-time. Fast response and reduced computational complexity in large datasets are the most important advantages of unsupervised techniques, with the ability to achieve good results of accuracy combined with other classifiers in real-time networks. Detection rate is one of the essential limitations in anomaly detection, where it is dependent on proximity measures. It has a direct effect on the false alarm rate. As

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noted, time consumption in these algorithms is considered a problem that they have to overcome in future anomaly detection systems.

Semi-Supervised Learning

Semi-supervised machine learning could be a combination of supervised and unsupervised machine learning approaches (DataRobot AI Wiki). Typically, in semi-supervised learning, the algorithm learns from a dataset that contains both labelled and unlabelled data. Usually, the majority is unlabelled data. If there are insufficient labelled data to build an accurate model and insufficient resources to get additional data, semi-supervised techniques can be used to maximize the size of the training data. For that, we reviewed recently published papers which focused on using semi-supervised learning to detect anomalies in the network.

Aissa & Guerroumi (2016) proposed two-stage semi-supervised methods for anomaly detection. The aim of the first stage is to make a probabilistic model of normal samples and measure any deviation that exceeds an established threshold. This threshold is deduced from a regular discriminate function of greatest likelihood. The second stage is to minimize False Alarm Rate (FAR) through repetitions that reclassify anomaly clusters from the previous stage, employing a similarity distance and the anomaly's cluster dispersion rate. The authors evaluated the proposed method on NSL-KDD and Kyoto 2006+ datasets. The experimental results showed that the proposed approach outperforms the Naïve Bayes algorithm in terms of Detection Rate and False Positive Rate.

Ashfaq *et al.* (2017) designed a unique fuzziness-based semi-supervised learning method by using unlabelled samples with the assistance of a supervised learning algorithm to boost the classifier's performance for the IDS. The classifier is retrained when incorporating every class separately into the first training set. The experimental results using this method on the NSL-KDD dataset showed that unlabelled samples that belong to low and high fuzziness groups have a significant contribution to boost the classifier's performance compared to existing ones.

Borghesi *et al.* (2019) suggested a semi-supervised technique for anomaly detection in supercomputers. This approach is based on a type of neural network referred to as an autoencoder. This approach involves learning the normal state of supercomputer nodes and training them to discern anomalous conditions from normal behaviour. It is doing so to end up relying only on the availability of feature data and the standard system state. This is different from supervised techniques that require data sets with multiple examples of anomalous states.

The autoencoder-based method outcome was shown to significantly outperform the supervised method, where the accuracy was increased by 12%.

Idhammad *et al.* (2018) investigated the use of semi-supervised techniques in DDoS detection. Supervised techniques in DDoS detection frequently rely on the availability of labelled network traffic datasets, whereas unsupervised techniques detect attacks by evaluating incoming network traffic. This approach used an online sequential semi-supervised machine learning method for DDoS detection based on network entropy estimation, co-clustering, information gain ratio, and other trees algorithms. The unsupervised technique of this approach enables the reduction of irrelevant average traffic data for DDoS detection, allowing the reduction of false-positive rates and increasing accuracy. They performed the experiments on different datasets, UNSW-NB15, UNBISCX 12, and NSL-KDD, with high accuracy of 93.71, 99.88, and 98.23%, respectively.

Meanwhile, Yuan *et al.* (2016) proposed a novel semi-supervised AdaBoost technique for network anomaly detection. In this approach, a combination of a tri-training approach was used with AdaBoost algorithms. The boost samples were replaced with three different AdaBoost algorithms to provide adversity. Iterations were then run for each simulation to provide average results. The simulations showed that this approach is reproducible and consistent over various runs, outperforming other competitive learning algorithms. The proposed approach has a fast execution time, as well as providing a balance between detection rate and false-alarm rate. The CUP1999 dataset was used to evaluate the result of the proposed algorithm with different types of attacks, such as DoS, U2R, probing, and R2L.

Duong & Hai (2015) also proposed a semi-supervised model called M-PCA for network traffic anomaly detection. In this approach, modified Mahalanobis distance based on PCA is used for network traffic anomaly detection. This intends to explore the effectiveness of PCA in semi-supervised methods that use small training datasets. This approach employs a K-means clustering method to create a typical profile of traffic to improve the training dataset and weights that help to select principal components of PCA. The evaluation of the proposed algorithm is done on the NSL-KDD dataset with different types of attacks, such as DoS, U2R, probing attacks, and R2L.

Table 4. Semi-Supervised anomaly detection approaches

Authors	Year	ML Technique	Anomaly type	Dataset	Detection Accuracy (%)
Aissa & Guerroumi	2016	SSAD	DoS attacks and port scans	NSL-KDD + Kyoto 2006	90%

Authors	Year	ML Technique	Anomaly type	Dataset	Detection Accuracy (%)
Ashfaq *et al.*	2017	SLFN	DoS, R2L, U2R, and Prob	NSL-KDD	84.12 %
Borghesi *et al.*	2019	autoencoder	Generic network attack	Real-time data in network	93.8%
Idhammad *et al.*	2018	online sequential semi-supervised ML	DDoS	UNSW-NB15, UNBISCX 12, and NSL-KDD	93.71, 99.88, and 98.23%
Yuan *et al.*	2016	AdaBoost algorithms	DoS, U2R, probing, and R2L	CUP1999	96.63%
Duong & Hai	2015	M-PCA	DoS, U2R, probing, and R2L	NSL-KDD	87.8%

Conclusion and Open Issues

With our lives becoming more and more digitalized, computer networks are becoming more critical and dependable services. At the same time, they become more prone to anomalies and worse—malicious attacks. This motivates researchers to propose different solutions to the overarching issue of anomaly detection in network traffic, particularly machine learning techniques, whether supervised, unsupervised or semi supervised.

In this paper, we surveyed works in the field of anomaly detection using machine learning in the last five years. First, we defined the background related to our work: (i) types of network anomalies; (ii) categories of machine learning approaches; and (iii) types of network attacks. Then, we reviewed, categorized, and discussed the papers that used machine learning techniques for anomaly detection. Furthermore, we underlined some of the open issues to improve the detection of anomalies systems.

Based on our review, we are able to identify numerous aspects that require more attention from the research community within the anomaly detection area, such as detection rate, process complexity, and high false alarm rate. In addition, we identified a critical challenge of real-time anomaly detection, particularly when streaming data that is constantly shifting.

Finally, while there is a lot of work on anomaly detection in traditional computer networks, the emergence of the Internet of Things (IoT) and their pervasiveness is likely to exacerbate the need for more scalable and accurate anomaly detection techniques, that are able to deal with different data types. The security of IoT network infrastructure must be at the highest level.

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Tax Risk Assessment and Assurance Reform in Response to the Digitalised Economy

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Abstract: The digitalisation of the economy has increased tax administrations' traditional tax risks and introduced new tax non-compliance risks, such as the use of income suppression software and tax fraud associated with the use of alternative payment methods, such as cryptocurrencies. This study focuses on the global reform that took place among tax authorities from a tax risk management and assurance perspective. The study was executed in two phases, including a cross-national literature review to synthesise international reform regarding tax risk management and assurance in response to the digitalisation of the economy. This process was followed by interviews with risk, technology and data experts of 30 global tax authorities in order to evaluate the level of implementation of the global reform measures identified in the first research phase. The research results suggest an imbalance in reform among participants from developed and developing economies. An inability to optimise tax risk and assurance management within the digitalised economy will negatively impact the tax authorities' ability to maximise tax collection within the digitalised economy. This is especially concerning if the significant role of digital platforms on future global economic value creation is considered.

Keywords: Data science, digitalised economy, information technology audit, risk management, tax reform.

1. Introduction

Few other organisations besides tax administrations have to deal with such a significant number of risks, not only including the standard array of enterprise risks, such as economic, financial, strategic, operational, fraud, compliance and information technology risks, but also tax risks (Boitnott, 2019; European Commission, 2006). The digitalisation of the economy has increased the risk of tax fraud and tax evasion and, as such, an agile and innovative risk management approach has never been as important as it is now (Barbantini & Savini, 2018).

Digital tools that are specifically designed to defraud tax authorities, as well as to disrupt the economy, have increased the risk of anonymity and the non-detection of tax fraud and evasion (Ainsworth, 2016, ICAEW, 2019; OECD, 2013; OECD, 2017a; OECD, 2017b). The digitalised economy introduced new business models to the global economy. Highly digitalised multi-national entities' (MNEs) main generators of income have shifted from tangible products and services coupled with a physical presence in specific jurisdictions to intangible assets, intellectual property, globalised digital services and digital or crypto currencies that lack physical presence and substance (OECD, 2018). The biggest companies in the world used to be manufacturers, retailers and property investment companies, but digitalisation changed this reality. Today, some of the biggest companies in the world are platform providers, data collectors and digital advertisers – all with limited physical presence and alternative value creation models (ICAEW, 2019).

Risk management is the process of managing a range of uncertainties about the outcomes of situations that affect value creation. The process's objective is to manage and control uncertainty and threats to value creation. The latter ensures that the operational process continues and effectively manages the possible impact of risk on organisational achievement (Sithipolvanichgul, 2016). The organisational achievement or mandate of tax authorities worldwide is to administer and enforce the revenue laws, which generally results in the collection of the bulk of revenues required to support a state or country (Crandall, 2010). Inference can therefore be drawn that a redundant and outdated risk management process and approach will impact tax authorities' ability to optimise tax revenue collection. This statement is supported by the compliance risk management guidance issued by the OECD (2004).

The risk management process can be divided into four main categories, namely risk identification, risk prevention, risk detection and correction (Tripathi, 2013). An optimised risk management process assists tax authorities to achieve their mandate, but also to ensure the equal treatment of taxpayers, to focus the assurance process on non-compliant taxpayers, to utilise the available resources (human, technology and finance) effectively, to increase the level of voluntary compliance, to ensure agility within the risk management system and to evaluate the probability of compliant taxpayers becoming non-compliant (European Commission, 2006). It is expected that this risk management process will remain valid within the digitalised economy, because the objectives of the risk management process remain unchanged. However, the approach to identify, assess, prioritise and correct tax risks within the digitalised economy requires change. This required reform is mainly due to the way that highly digitalised enterprises create value and transact. These business models' global impact, and the strong reliance on and creation of data, further made tax risk management reform essential (European Commission, 2006).

Information sources that are used by tax authorities during the risk management process are increasingly based on data sourced from third parties and information generated in foreign jurisdictions. This data is often unstructured. The timing of tax risk management has also changed from ad-hoc, annual processes to (near) real-time (OECD, 2017c). The type of treatment changed along with simpler tasks becoming increasingly more automated and the application of methods to manage tax risk, where new tools and models are allowing administrations to manage "complete right datasets" rather than using risk-based approaches to allocate scarce resources (OECD, 2017c). The extent to which information or the collection of right data can be used during the tax risk management process is, however, limited by various factors. These factors include the tax authority's ability to ingest the information, the legality of the process, the value that new information or data can add in addition to what is already available (risk of information overflow), the capacity of information technology systems in use and the cost associated with obtaining new data (European Commission, 2006).

Although the pre-existing tax risk of non-registration, the understatement of taxable income, the overstatement of tax-deductible expenses and disguised transactions as a result of criminal activity remain relevant, the digitalisation of the economy has increased these risks significantly. This is mainly due to the business model changes and digital tools designed to manipulate taxable income. The literature, however, indicates that additional challenges were introduced with the digitalisation of the economy. The first challenge relates to tax authorities' legal right and ability to access and exchange data from digital platforms to enable them to identify and detect possible tax risks. Another challenge relates to the enforceability of country-specific tax legislation to non-registered international individuals or enterprises (Azam, 2007; European Commission, 2018).

Furthermore, tax authorities must ensure that they appropriately respond to identified and/or detected tax risks. Risk covering or the correction process focuses on non-compliant individuals or enterprises and usually results in the recovery of tax shortfalls to the tax authority in cases where an identified or detected tax risk was realised. Rectification can take place in monetary terms by issuing or amending a tax assessment to recover the evaded tax and related penalties. In some cases, other sanctions, such as criminal sanctions, are available (European Commission, 2006). Criminal sanctions as corrective measures usually fall within the assurance or audit ambit. If executed successfully, these sanctions might have a deterrent

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effect that not only applies to the behaviour of the individual or enterprise but, via its social and commercial network, influence other individuals or enterprises that have adopted similar tax positions (European Commission, 2006).

A tax audit or assurance is “an examination of whether a taxpayer has correctly assessed and reported their tax liability and fulfilled other obligations” (OECD, 2006). The assurance process of the majority of tax authorities can generally be divided into at least three categories. The first category refers to a verification process or single-issue audits where the verification is confined to only one potential non-compliance risk. These verifications take less time to perform and are used to review large numbers of taxpayers. The second category is “limited scope” audits where the assurance process is confined to specific risks per tax return submitted. The third category is “comprehensive/full audits”. The scope of these audits is all-encompassing and entails a comprehensive examination of all the information that is relevant to calculating the taxpayers’ tax liability and may include criminal investigations (OECD, 2006).

The World Economic Forum (WEF) (2020) estimates that 70% of new value created in the global economy over the next ten years will be based on digital platform business models. This change requires that reform takes place in not only international and domestic tax policy, legislation and the related systems to optimise tax administration, but it also requires a change in relation to the way that tax authorities manage tax risks and the related assurance process.

One of the questions that, however, arises is to what extent have tax authorities globally changed their risk management and assurance approach in order to optimise their ability to execute their mandate in response to the digitalised economy. The objective of this paper is to evaluate and analyse the reform of the tax risk management and assurance process of tax authorities, globally in response to the digitalisation of the economy.

Section 3 synthesises and evaluates the available literature in relation to international reform that took place regarding the tax risk assessment and assurance process in response to the digitalisation of the economy. The level of implementation of the main reform measures identified in section 3 are subsequently measured among selected international tax authorities. These research results and discussions are documented in section 4. The overall conclusion relating to global reform among tax authorities relating to tax risk management and assurance in response to the digitalisation of the economy is documented in section 5. Section 6 sets out the limitations on the scope of the study. Matters for future consideration and research are set out in section 7.

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2. Methodology

An inductive, qualitative, cross-national study was executed to collect data with the intention to build new knowledge with regards to the research topic. The study was conducted in two phases. The first phase of data collection comprised a semi-structured and integrative literature review in order to identify, collect and synthesise data regarding tax authorities' tax risk management and assurance reform in response to the digitalisation of the economy. The objective of the literature review was to synthesise the cross-national data that is available in order to identify the main tax risk management and assurance reform measures implemented in response to the digitalisation of the economy. These identified measures were subsequently used to inform and formulate interview questions posed to selected global tax authorities in order to evaluate the level of global reform of tax authorities on the subject matter. Sources identified for the cross-national, integrative literature review were balanced between international organisations, such as the Organisation for Economic Co-operation and Development (OECD) and the European Commission, as well as important stakeholders within the business sector. It was found that documented academic literature on the research topic was limited. The literature review results were synthesised, analysed and documented in section 3, as per the four tax risk processes identified in section 1: tax risk identification, tax risk prevention, tax risk detection and tax risk correction measures.

The objective of the second phase of the study was to evaluate the level of global tax risk management and assurance reform against the main technologies and data-related reform measures identified in the first phase of the study. The second phase of the study therefore comprised the collection of data and knowledge by means of semi-structured, qualitative interviews whereby open-ended questions were posed to selected tax authorities. Data was collected from conducting group interviews, one-on-one interviews and by means of direct observation. Manson (2010) confirms the relevance and applicability of interviews as a method of data collection. Secondary objectives of the interviews were to confirm the credibility and reliability of the data collected during the literature review. It was, furthermore, to collect rich and multi-layered data on the research topic that is not available from open source data resources.

Green and Thorogood (2004) indicate that limited value will be added to a qualitative study when more than 20 participants are interviewed. Ritchie *et al.* (2003), furthermore, state that researchers should not interview more than 50 participants in order to enable the researcher to manage the complexity of the analysis and the communication of research results. Based on the preceding literature, a sample size of 30 tax authorities was considered to provide a sufficient level of saturation that would provide reliable research outputs.

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The sample was selected by firstly identifying and specifically selecting the leading tax authorities with regards to tax risk management and assurance reform in response to the digitalisation of the economy, as identified during the integrative cross-national literature review. The sample was subsequently supplemented by random sample selection. In order to ensure that the sample was representative of the global country population, tax authorities from both developed and developing economies were selected. The classification of developed versus developing economies, as indicated by the United Nations (2020), was used. For the purpose of this study, one selected participant from a country classified as "economies in transition" in terms of the United Nations' (2020) classification was categorised under "developing economies" because it shared more characteristics with the participants of the developing economies. Further consideration was given to the fact that 36 countries from of a total of 195 countries globally are regarded as developed economies (United Nations, 2020; Worldometer, 2020). These 36 countries represent approximately 18% of the total geographical population. The sample of participating tax authorities consequently included five tax authorities from developed economies (18% of the total sample of 30 participants) and 25 tax authorities from developing economies.

The tax authorities selected for interview purposes are representative of Africa, Asia and Australasia, Europe and North America. The participants who were identified for interviews within the various tax authorities were key senior employees and experts within the field of tax risk management and assurance and were nominated by the tax authorities themselves. These participants were afforded the opportunity to respond in person, via digital platforms, telephonically or in writing. The preferred interview method of the interviewees was adopted, and the interviews were conducted in person, telephonically or per digital communication platforms. The interview questions, together with the purpose of the study, were circulated to the respective tax authorities prior to the interviews. A minimum set of open-ended questions was posed to all the interviewees to ensure a minimum amount of knowledge and data would be collected.

Tax authorities, globally, follow different approaches regarding the level of transparency relating to tax risk and assurance management processes and measures. Some follow a transparent approach where the various tax risk measures and processes are shared openly (through publications) with the public. Other tax authorities, however, restrict access to these measures and processes to approved employees within the tax authorities only. While respecting these vastly different internationally adopted approaches, cognisance was also taken of the fact that possible weaknesses in the general environment and internal controls shared during the study by participants might put the participating tax authorities in a

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compromised position in some form or another. In order to ensure a safe environment for the participants that allows for the collection of accurate data without publicly exposing the possible weaknesses of participating tax authorities, it was agreed that the participants of the study would remain anonymous.

The reliability and credibility of the research results were tested with three different triangulation methods. Supplementary literature reviews were conducted to verify the results, the research results were discussed with other international experts in the field, and different sources were used to collect and verify the research results. Observers were also invited to the interviews to ensure unbiased interpretation of interview results.

3. Literature Review Results and Discussion

3.1 Tax risk identification in response to the digitalised economy

In the literature, three main "platforms" introduced by the digitalisation of the economy are cited. These platforms are e-commerce, the shared or gig economy, and transacting with digital currencies or assets (Azam, 2007; OECD, 2020; PwC, 2018). It is suggested that the main tax risks associated with a digitalised economy include the fact that the taxpayer might not be registered within the tax jurisdiction where taxes are due. The lack of visibility of business activity within the digitalised economy increases this risk significantly (OECD, 2017b).

Another risk cited by the literature is the incomplete or inaccurate declaration of taxable income due to either a lack of knowledge of the specific tax requirements per tax jurisdiction or due to intentional tax evasion (European Commission, 2006). The utilisation of digital currencies or asset platforms also poses a major risk for intentional or unintentional tax evasion due to the (perceived) anonymous nature of the transactions and due to the uncertainty regarding the tax implications of these transactions (Smith, 2018).

Globally, there is a risk for either double or the non-taxation of businesses and individuals who operate within the digitalised economy (PwC, 2018). The current inconsistency among tax authorities globally regarding the legislative and administrative response to tax administration within the digitalised economy further increases the abovementioned tax risks (Ernst & Young, 2019b; OECD, 2017d).

The risk identification process is followed by the design and implementation of mitigating measures to prevent, detect or correct the identified tax risks (Frame, 2003). International reform and controls that are put in place in order to prevent, detect or correct the identified tax risks, as per the literature, are discussed in sections 3.2 to 3.4.

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3.2 Tax risk prevention reform measures in response to the digitalisation of the economy

The objective of preventative measures is to stop a threat from occurring and is specifically applicable to risks that are regarded as high priority with a major impact (Frame, 2003). While preventative measures are not always 100% effective, they do provide the tax administration with the first line of defence to prevent base erosion and profit shifting (BEPS) and/or possible tax fraud or evasion. From the literature, it is clear that the main preventative measures used by tax authorities in order to prevent the realisation of tax risks identified in section 3.1 include legislative reform, access to data of digital platforms, digital invoicing solutions and taxpayer education. These measures are discussed below.

Legislative amendments - direct and indirect taxes: Several countries either amended their tax legislation in order to make specific provision for tax within the digitalised economy and/or issued practice notes in order to address the identified tax risks associated with the digitalised economy. Examples of countries that made legislative amendments in relation to direct and indirect taxes in order to prevent the tax risks associated with the digitalised economy from occurring include Albania, Argentina, Armenia, Australia, Austria, Bangladesh, Belarus, Bulgaria, Botswana, Brazil, Canada, Chile, China, Croatia, Denmark, Finland, France, Germany, Ghana, Guatemala, Iceland, India, Israel, Italy, Japan, Kenya, Malta, Malaysia, Moldova, New Zealand, Nigeria, Norway, Pakistan, Philippines, Poland, Portugal, Romania, Russia, Serbia, Singapore, Slovakia, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Tanzania, Thailand, Turkey, United Kingdom (UK), United States of America (USA), Uganda, Uruguay and Zimbabwe (Ernst & Young, 2019b; Huang, 2019; IBFD, 2019; KPMG, 2019; Taxamo, 2019; The Law Library of Congress, 2018).

In the literature, however, it is cited that the legislative reform associated with the digitalised economy is complex and lacks uniformity (Ernst & Young, 2019b; European Commission, 2006; Katz, 2015; United Nations, 2019). The complexity of legislative reform might therefore have exacerbated the tax risk of non-compliance within the digitalised economy.

Access to data of digital platforms: Digital platforms are “systems that entities can build on, that are open and not proprietary” (Accenture, 2016). Digital platforms are foundational to the majority of digital retail enterprises and it can be expected that the extraction and analysis of tax-related data should yield a high level of success in preventing and detecting tax non-compliance and fraud.

Australia and Argentina amended their legislation in order to ensure access to tax related data and make electronic distribution platforms liable for the collection of VAT/GST with regards to specified digital goods and services (Musgrove, 2019; OECD, 2018). The European Union

(EU) submitted a proposal for an implementation regulation in order to achieve the same results, effective from December 2020. The EU also made provision that these digital platforms share tax-relevant information with them in order to assist with tax compliance (OECD, 2018). The province of Ontario in Canada partnered with Airbnb to launch a new pilot project where Airbnb will educate its hosts through an email notification during tax season to remind them of their tax obligations (OECD, 2017b). Withholding tax arrangements made with platform sellers in order to prevent tax evasion was also identified by the Italian and Mexican tax authorities (OECD, 2019).

In the literature it is suggested that the lines and responsibilities between government and business with regards to tax collection and tax risk prevention and detection are "blurring" due to the digitalisation of the economy. Limited literature could, however, be identified that communicates the successes of the implementation of the abovementioned preventative measures.

Electronic invoicing solutions: Electronic invoicing solutions are based on the "online" authorisation of invoices and other documents. The taxpayer has to apply to the tax authority for authorisation to issue the invoice before the approval of a business operation like, for example, the sale of goods or services. Authorisation is required by the tax authority in order for the invoice to be considered a valid invoice with fiscal value. The information is validated online and, if the invoice is authorised, an authorisation code or digital signature is allocated to it. Some models allow for the tax authority to store all the information entered on their database, while other models allow access to the information stored on the taxpayer's database.

These tools provide the tax authority with the information of the issuer and the receiver of the invoice, which, in turn, allows the tax authority to issue pre-populated tax returns based on verified transactions. It should be noted that the e-invoicing rules applied by the various tax authorities globally differ with regards to the method, tax types, taxpayers and parties of the business transactions (Czingege, 2019; Deloitte, 2017; OECD, 2017b; Palazzi, 2018). This is important to note as the application and implementation of e-invoicing as a preventative and detective measure will depend on the specific country's risk evaluation per tax type, industry and enterprise.

Examples of tax authorities cited to have implemented electronic invoicing solutions as a preventative tax risk measure include Albania, Argentina, Armenia, Austria, Belgium, Brazil, Chile, China, Czech Republic, Columbia, Greece, France, Germany, Hungary, Indonesia, India, Italy, Kenya, Mexico, Peru, Russia, Singapore, Spain, the Slovak Republic and the UK. France will implement mandatory e-invoicing and pre-populated VAT returns from 2023 onwards

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(Deloitte, 2020). E-invoicing varies at scale on implementation between these countries and the objective of the solution is not only to prevent tax fraud, but also to detect it in cases where the preventative measure was unsuccessful.

From the literature, it can be pointed out that the majority of the tax authorities introduced the new tool by means of a phased-in approach. Cognisance should furthermore be taken that this preventative tool will have to be evaluated and adapted continuously to adapt to new technology and related tax evasion or fraud risks. E-invoicing can, furthermore, not currently be legally enforced upon non-resident businesses operating within the digitalised economy (Deloitte, 2020; OECD, 2017b; Stanley-Smith, 2019).

Taxpayer education: From the literature, it was found that tax authorities in countries, such as Australia, Denmark, France, Greece, Hungary, Ireland, Italy, Japan, the Netherlands, Norway, Singapore and the UK, have launched comprehensive education campaigns as a preventative tax risk management measure. Various platforms and technologies are used in order to educate individuals, businesses and tax representatives regarding the various tax implications and considerations within the digitalised economy (OECD, 2019). New platforms used by these tax authorities include LinkedIn, Facebook, Twitter, digital webinars and online courses and workshops with relevant learning manuals.

3.3 Tax risk detection reform measures in response to the digitalisation of the economy

In the literature, it is highlighted that leading tax authorities rely heavily on Internet data collection or scraping tools, data science and analysis to detect tax risks within the digitalised economy. Tax risk detection reform measures that are cited in the literature follow in the discussion below.

Digital data collection tools: Examples of tax authorities cited in the literature that use tools to collect data from cyberspace include, but are not limited to, Austria, Belgium, Japan and the UK. These tax authorities monitor the Internet using different Internet scraping tools (web harvesting or web data extraction), some of which are open source and others that are custom-made tools. The intelligence that is gathered is fed into compliance projects, such as letters to presumptive taxpayers and information campaigns. The collected data is furthermore used to analyse and is matched to existing taxpayer information, records and registers (HM Revenue & Customs, 2018; OECD, 2017b).

The Belgium tax authority obtain the necessary data by either asking for data from the taxpayer or the owner of the platform on which the data is stored, or the data is “harvested” by the tax authority itself. According to the Belgium tax authority, the request for information from platforms is not necessarily a good approach, as the information that may be requested is limited to "power users", users with an extended amount of activity and users with a turnover of more than their VAT threshold (Dierickx, 2017). E-forensic techniques are used to collect data in cases where the platform or the taxpayer refuse to provide the requested data. According to Dierickx (2017), the harvesting of Internet data, even from compliant taxpayers, is not a "protection of privacy" challenge, because the data is publicly available and is therefore regarded as "open source intelligence data".

Data matching and predictive data analytics: Jacobs (2017) recommends strategies (from a digitalisation perspective) that can improve the tax risk identification and detection process. The first recommendation is the linking of data to the taxpayer's consumption. Tax authorities can obtain the data relating to taxpayers' consumption that is predicted to be digitalised to a large extent in the near future in order to project the possible income of consumers and compare it to the actual income that is declared for tax purposes. One foreseen challenge regarding this approach is the tendency of consumers to spend more than what they earn.

Another detection measure that is cited is to link taxpayer data to wealth and capital income. Assets, such as publicly traded assets, closely held assets, home ownership, pensions and bequests or estates can be used to analyse the overall wealth of the taxpayer against its tax records (Jacobs, 2017).

A third tax non-compliance detection measure that is recommended by Jacobs (2017) is the cross-border linking of data on wealth and capital. By way of global collaboration, taxpayer information in relation to asset ownership (shares, property and pensions) and capital income (interests, dividends, capital gains, property values and pension accrual) can be obtained for further analysis. Studies predict that, globally, we are headed towards a mainly cashless economy (Achord *et al.*, 2017). The utilisation of consumers as third-party reports might consequently also be a source of data that can be utilised to implement tax risk detection measures.

If the prediction regarding a cashless economy is accurate, the majority of consumer transactions will be in a digital format. Therefore, tax authorities can estimate the aggregate sales of particular businesses either through electronic payment information or with the use of information on consumption from digital platforms. The estimated revenue and taxable income can be predicted with data that is obtained according to the abovementioned recommendations and compared to declared tax returns and/or the taxpayer register in cases where the individual or enterprise is not registered for tax.

Some of the abovementioned recommendations have been actioned to some degree in terms of the country-by-country (CbC) reporting that forms part of action 13 of the OECD's BEPS initiatives. This enables tax authorities to exchange cross-border information in relation to company revenue, income, tax paid and accrued, employment, capital, retained earnings, tangible assets and activities (Deloitte, 2016). CbC reporting, however, only applies to multi-national entities with a revenue of €750 million and above. The current requirements therefore exclude high-net-worth individuals and enterprises that fall below the reporting threshold. Furthermore, not all countries currently participate in the initiative (KPMG, 2020).

Tax authorities that are cited in the literature that implement advanced data matching and predictive analytics as a tax risk detection tool in response to the digitalisation of the economy include, but are not limited to, Australia, Finland and Canada.

Australia makes extensive use of third-party data. The tax authority has access to information held in the Australian Transaction Reports and Analysis Centre (AUSTRAC), which is Australia's financial intelligence unit with a regulatory responsibility for anti-money laundering and counter-terrorism financing (Australian Taxation Office, 2020a). This information was used to trace the flow of funds to drivers and renters from abroad to local banks from where they are distributed.

The information is subsequently matched to the tax returns submitted by the businesses or individuals and other related information in order to detect any discrepancies in income declared for tax purposes (Australian Taxation Office, 2020a). As a result, the tax authority identified various unregistered business activities. In addition, the tax authority is working with major platform facilitators, such as Uber and Airbnb, in order to collect tax-related data (i.e. drivers and lessors of properties) (OECD, 2017b).

Finland utilises comparative data extensively to control both the digitalised and "traditional" economy. The data includes payment provider data that is received from credit card companies and other data from Finnish payment service providers. The tax authority also receives data from multiple digital platforms, such as digital currency brokers and intermediaries and sharing economy platforms (Ruuhonen, 2017). In this way, the Finnish tax authority is able to identify, detect and respond to the risks associated with VAT non-compliance by analysing credit card payment providers' data. They also implemented detective measures with regards to digital currency transactions that led to the identification of over 300 cases related to digital currencies, together with the personal income taxation process, in 2016 (Ruuhonen, 2017). In addition, they have increased the analytical ability concerning bitcoin blockchains by using software tools that are designed for the specific purpose. The main objective of the detection measure is to obtain an overall view of the

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taxpayer's cryptocurrency activity. The tool enables the tax authority to discover trade by Finnish bitcoin users in foreign markets (Ruuhonen, 2017).

Data visualisation: In the literature, it is cited that certain countries' tax authorities, such as Malaysia, New Zealand and Singapore, use social network analysis that includes the visualisation of connections between individuals and entities in order to detect tax fraud. The social network analysis also identifies links between taxpayers, joint bank accounts, addresses and/or shared telephone numbers that are used to detect possible tax non-compliance (Ernst & Young, 2016; OECD, 2017b).

Limited literature could be identified with regards to the specific use of artificial intelligence (AI) and machine learning as a tool for tax risk detection by specified tax authorities in response to the digitalisation of the economy.

3.4 Tax assurance reform measures in response to the digitalisation of the economy

Findings in the literature indicate that leading tax authorities reformed their assurance processes in response to the digitalisation of the economy by changing their assurance approach, digitalising assurance tools and utilising data analytics as an assurance tool. The reform measures that are cited in the literature are discussed below.

Standard audit file for tax: Angola, Austria, Czech Republic, France, Germany, Kazakhstan, Lithuania, Luxemburg, Netherlands, Norway, Poland, Portugal, Singapore and Slovakia have been cited as countries that have adopted the "Standard Audit File for Tax" (SAF-T) to either its full extent or according to a modified version (Gampl, 2019; Deloitte, 2017; Ernst & Young, 2019a). The standard was defined by the OECD in 2005 and the objective is to assist with the exchange of transactional data between tax authorities and taxpayers. It, furthermore, improves substantive testing within the tax authorities' audit and assurance units (Ernst & Young, 2019a).

Three implementation approaches were cited, which include data to be provided at the request of the tax authority (usually prior to the audit or assurance process), submission of data on a periodical basis in addition to the indirect tax return, and the submission of transactional data as a replacement of the periodic indirect tax return (Trowbridge, 2019).

Multi-disciplinary assurance teams: Belgium was cited as following an integrated audit approach with multi-disciplinary, digital teams. The teams consist of experts in five specialisations: e-commerce in order to obtain and analyse unstructured data from the Internet; e-audit in order to obtain and analyse structured data from digital bookkeeping systems (such as enterprise resource planning (ERP systems)), in most instances with the cooperation of the taxpayer; e-forensics, in order to obtain and analyse non-structured data in cases where there is a lack of co-operation of the taxpayer and/or in cases of serious fraud; e-cash registers, in order to obtain and analyse structured data from cash-registers; and e-audit mining that includes data analysis and the evaluation of electronic stored information for content and context, including key patterns, topics, people and discussions. Predictive analyses and AI are utilised in this latter process (Dierickx, 2017).

e-audits: e-audits were introduced in 2018 by the Australian taxation authority (ATO). An e-audit or information technology (IT) audit is a system-based auditing method that is used to understand the clients' business, systems and processes, governance and controls. The method extracts and analyses the client's data and obtains an understanding of the business using computer-assisted verification (CAV) methodologies. The ATO conducts e-audits as part of their "top 320 private groups and top 1 000 performance" programme (Australian Taxation Office, 2020b). An e-audit enables the ATO to assess and appropriately address the tax and audit risks that large market entities may pose from a tax perspective.

The e-audit process also adds value to taxpayers, as they receive a report with the outcome of the engagement, a risk rating that is assigned to their information technology systems, and recommendations to mitigate these risks. While the e-audits form an integral part of the ATO's assurance process, the results can be used by the taxpayer in order to address the vulnerabilities in their digital system(s) (Dyce, 2017). The ATO evaluates the accounting systems used by the taxpayer, the system architecture and how the data flows through the system(s), the format and extent of taxpayer electronic records, and the documentation available to assist in the auditors' analysis (Australian Tax Office, 2020b).

An e-audit generally has two objectives, namely: the review of the organisation's computer and information systems in order to evaluate the integrity of its production systems and potential security weaknesses; and, secondly, to undertake a tax audit where data analytics are used as a tool within the assurance process (Australian Taxation Office, 2020b).

Specialised assurance software and data analytics: In the literature, it is cited that the tax authorities of Austria, Australia, Denmark, Canada, Finland, Mexico, the Netherlands, New Zealand, Slovenia, Sweden, the UK and the USA have implemented advanced assurance and audit tools that harness the advantages of big data analysis, expert knowledge building, and sharing and digital customised audit software and toolkits (OECD, 2006). In this way, the traditional audit and assurance function has consequently been digitised, to a large extent.

3.5 Summarised results per integrative cross-national literature review

The tax risk and assurance measures implemented by leading tax authorities in response to the digitalisation of the economy, as cited in the literature, are synthesised in Table 1.

Table 1. Synthesis of identified tax risk and assurance reform measures in response to the digitalisation of the economy as cited per literature

Tax prevention reform measures	Tax detection reform measures	Tax assurance reform
Legislative reform	Digital data collection tools	Standard audit file for tax
Access to data: digital platforms and subsequent data ingestion and analytics	Data matching and predictive data analytics	Multi-disciplinary assurance teams
E-invoicing	Data visualisation	E-audits
Taxpayer education		Specialised assurance software and data analytics

Source: Authors' own (2020)

In order to test the extent of global reform and the implementation of the measures identified, as per the integrative literature review, selected international tax authorities were interviewed. The reform measures were limited to technology and data-related reform only. Legislative reform and taxpayer education were therefore excluded from the interview results. The results are documented in section 4.

4. Interview Results and Discussion

During the interviews, it became apparent that there is a major difference in the response levels among participating tax authorities from developed and developing economies. Due to the fact that, globally, there are more developing economies than developed economies and that this is reflected in the sample, there is a possibility that the interview results may be distorted if the results of the participating tax authorities from developed and developing economies are combined without first providing the reader with results that are categorised according to their economic classification. Consequently, the interview results were documented according to three categories, namely "participating tax authorities from developed economies", "participating tax authorities from developing economies" and "Combined: Developed and Developing economies". The combined results reflect the synthesized study results of the interviews of both the developed and developing economies. These results will not be discussed individually per interview question below, as it is a combination of the results of the participating tax authorities from developing and developed economies that are discussed in detail below.

4.1 Utilisation of data and technology as a tax risk management tool

Sections 3.2 and 3.3 highlight the critical role of technology and data in the tax risk management process. Measures identified in section 3 include data matching and predictive analytics, e-invoicing and data visualisation. In order to establish whether the participating tax authorities utilise technology and data as a tool for tax risk management, the following question was posed to the participants: "*To what extent does your tax authority use technology and data in order to identify, prevent and detect tax risks within the digitalised economy?*" The results are illustrated in Figure 1.

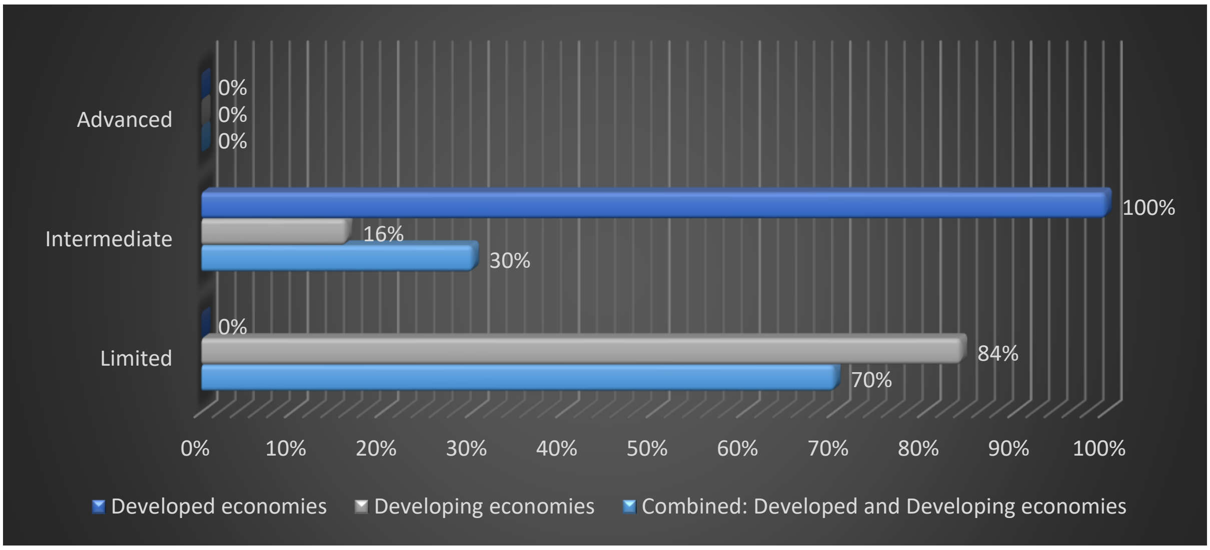

Figure 1. Extent to which participating tax authorities use technology and data in order to identify, prevent and detect tax risk within the digitalised economy
Source: Authors' own (2020)

An "advanced" response was allocated to participants where an array of data sources was utilised to identify tax risks. These sources included, but were not limited to, digital and cryptocurrency platforms, payment intermediaries, financial institutions, data collected with the use of web crawlers, internally collected data through the tax submission and payment process, as well as international data sharing programmes. Data is accurate, complete and consolidated into one database or data warehouse and is used across the organisation. The use of tools, such as data matching, predictive analytics and data visualisation, was optimised. Automation and AI were also used to their full extent in order to identify tax risks.

An "intermediate" response was allocated to participants who collected data from an array of sources associated with the digitalised economy, such as digital platforms and utilised tools, including automation, data matching, analyses and data visualisation tax risk management tools. However, AI was not implemented in full and data was not in all instances consolidated but, in some instances, used in siloes.

A “limited” rating was allocated to tax authorities that utilise older versions of technology and data science in order to identify risk with the utilisation of data and information. These tax authorities also store and have access to various sources of data and information, but do not utilise it optimally for tax risk management purposes. An example where data is not utilised optimally is where data is collected from various sources, but not fully integrated into the risk management process. A “limited” rating was also allocated to tax administrations who have not yet digitalised their tax risk management process or are in the process of digitalisation. Furthermore, a “limited” rating was allocated to tax authorities who initiated the implementation of tools and data in order to manage risk and where the data utilised for this purpose was limited.

None of the participating tax authorities demonstrated an “advanced” use of technology and data in order to identify, prevent and detect tax risk within the digitalised economy. All the participants from developed economies and 16% of participants from developing economies use technology and data on an “intermediate” level to manage tax risks within the digitalised economy. Eighty-four percent of the participating tax authorities from developing economies utilise technology and data for tax risk management purposes, to a limited extent. Some observations in this regard follows.

One of the participants buys data from data collection enterprises and makes use of these businesses to identify, for example, high volume transactions exceeding a certain amount of bandwidth. This data is then used to identify and detect tax risks. Customs data is also extracted by two of the participating tax authorities where a specific focus is placed on large consignors with low value imports to identify possible digital sales rendered within the country. This data was not only used to identify and detect possible tax risks, but also to educate the identified enterprises on a one-on-one basis in relation to the tax consequences and tax liabilities associated with the identified transactions.

Another participant demonstrated the extent to which they use technology and data in order to identify tax risks within the digitalised economy. Risks are assessed on a (near) real-time basis, predictive analytics are utilised, risk scoring is used to identify high-risk taxpayers, benchmarking and dynamic benchmarking are also done with the use of technology and data. Two of the participants stressed the importance of the integrity of data used during the tax risk management process and confirmed that they use the taxpayers themselves in order to verify the accuracy of their data, which not only confirms the accuracy of taxpayer data, but also builds the trust relationship between the taxpayer and the tax authority. They also utilise third-party information and match it to the in-house data to perform “test audits” on the data in order to ensure the accuracy and completeness.

Finally, data visualisation is also used by most of the participating tax authorities from developed economies in order to identify and detect tax risks. Although some participating tax authorities from developing economies also make use of data visualisation, the results of the visualisations are not in all instances actioned into risk identification, prevention and detection tools. Reasons for low digital maturity levels and limited utilisation of technology and data as a risk management tool include the lack of political support, political interference, budgetary constraints and a lack of the required skills and experience.

4.2 Data and information collection from cyberspace

In order to identify non-compliant individuals and enterprises that operate within the digitalised economy, the use of digital data collection tools as a critical tax risk detection measure is identified in section 3.3. In order to assess to which extent technology is used to monitor and gather data from the Internet and related platforms, the following question was posed to the participants: *"Does your tax authority survey transactions within the digitalised economy for purposes of effective and efficient tax risk management?"* The results are demonstrated in Figure 2.

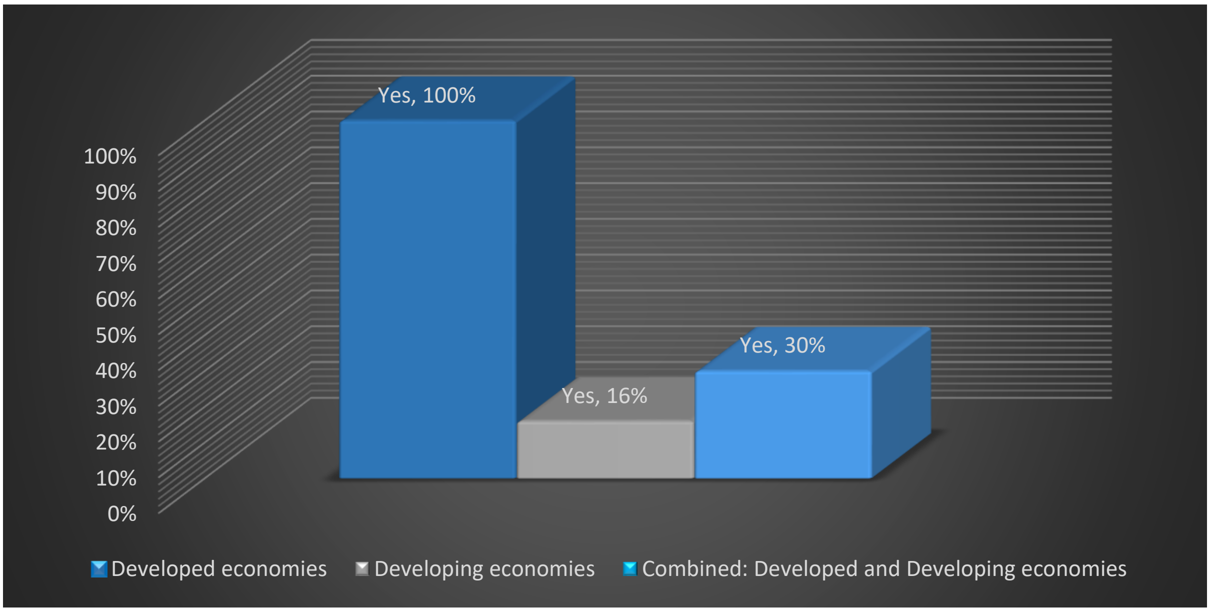

Figure 2. Utilisation of technology in order to collect data and information from cyberspace
Source: Authors' own (2020)

All participating tax authorities from developed economies use software to obtain data and information from cyberspace. Only 16% of the participants from developing economies obtain information and data from cyberspace for tax risk management purposes, while 84% do not currently utilise technology at all in order to obtain information and data from cyberspace.

One of the participants from a developing economy established an e-commerce department that only focuses on the identification and detection of tax risks within the e-commerce environment. The tax authority uses various Internet scrapers and web crawlers to identify taxable activity and utilises technology and data techniques in order to process the data into usable information and knowledge. The collected data is used in order to register the identified individuals and enterprises who are not registered for tax and/or to issue revised tax returns through the assurance process where discrepancies are identified.

The use of open source versus custom-made Internet scrapers varied among the participants. A challenge identified by participants from developing economies is legislative constraints (privacy concerns) with regards to taxpayer data collection within the digitalised economy.

4.3 Extent and source of data used during the tax risk management process

In sections 3.2 and 3.3 it is indicated that various new data sources are used in response to the digitalisation of the economy in order to manage tax risks. In order to establish what reform took place with regards to the access to data, data types and sources used in the tax risk management process, the following questions were posed to the participants: "*What type of data and information sources are used by your tax authority for tax risk identification and analysis*? *Is the data limited to taxpayer and return data collected internally or are other data sources, such as third-party data, accessed and utilised as well?"* The results are illustrated in Figure 3.

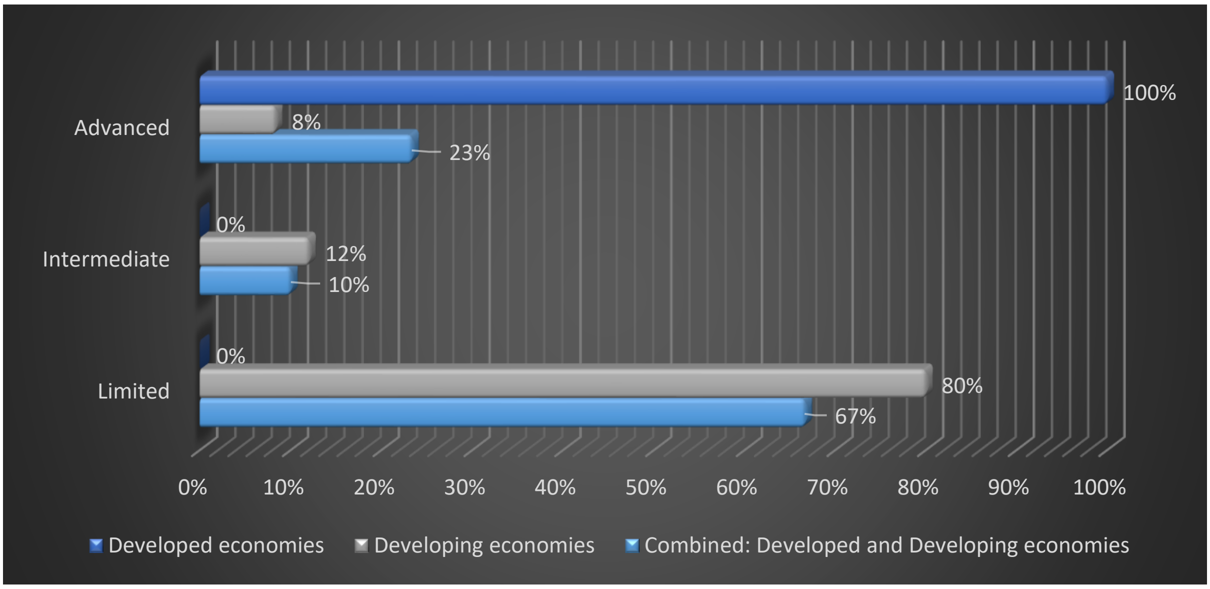

Figure 3. The extent and source of data and information utilised during the tax risk management process
Source: Authors' own (2020)

Data wrangling encompasses the technical and business processes that are used to generate valuable insights from disparate data sources, including extraction and transformation from structured, semi-structured and unstructured data sources (Altair, 2020). In cases where this process is applicable to the participating tax authority, an "advanced" rating was allocated.

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All the participating tax authorities from developed economies extensively utilise data and information from disparate data sources during the risk management process. Eight per cent of participating tax authorities from developing economies apply data wrangling. The data sources in these instances include data from online platforms, payment intermediaries and some also collect data from digital currency platforms.

An "intermediate" rating was allocated in cases where internally generated data was utilised during the tax risk management process, and data from third parties was obtained, but not utilised to its full extent. Twelve per cent of participating tax authorities from developing economies utilised data that was generated externally and collected third-party data, but its usage was not optimised.

In cases where a "limited" response was allocated to the tax authority, the utilisation of internal data for tax risk management was limited and, in cases where third-party data and information was available, it was not utilised optimally. Most of the tax authorities that were interviewed and are at least on an intermediate level of digital maturity collect data from traditional financial institutions, but do not use this data optimally in order to identify and detect tax risks. It should be noted that, essentially, the absence of data collection from digital platforms implies limited reform in relation to the digitalised economy and would imply a weakened tax risk management process.

Two of the participants indicated that the significant increase of collection and storage of taxpayer data drastically increased the tax authority's cyber-security risks. One of these participants also implemented e-invoicing and stores all e-invoicing data.

4.4 Utilisation of automation and AI during the tax risk management process

One of the benefits associated with the digitalised economy is the utilisation of AI and machine learning. This capability enables tax authorities to continuously build new intelligence and knowledge based on data and information collected from various parties and platforms with limited human intervention and cost. In order to establish the extent to which tax authorities are utilising AI and machine learning in the tax risk management process, the following question was posed to the participants: "*To what extent does your tax authority use automation and advanced applications, such as artificial intelligence, to identify and analyse risk?"* The results are demonstrated in Figure 4.

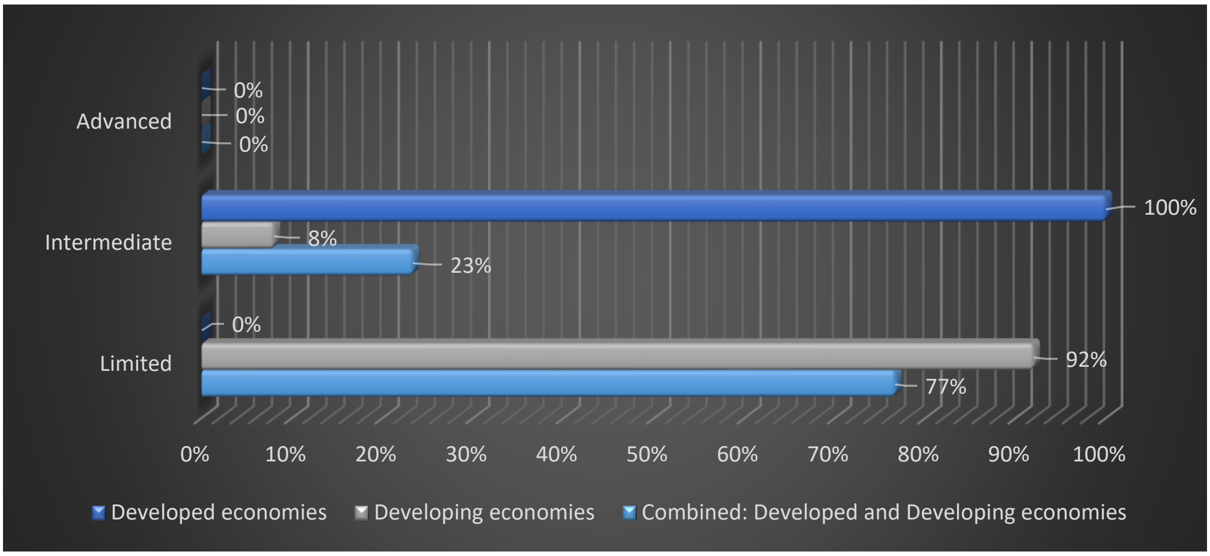

Figure 4. The extent of automation and AI utilised during the risk management process
Source: Authors' own (2020)

The research results reflect that none of the participating tax authorities utilise AI and machine learning to its full extent. An environment where AI and machine learning is used to such an extent during the tax risk management process that it requires only human oversight with maximum risk identification, prevention and detection outputs would be regarded as an "advanced" application.

An "intermediate" response was regarded as one where the use of AI and machine learning or segments of machine learning are utilised in some instances, or in parts of the tax risk management process. All the participating tax authorities from developed economies (100%) and 8% of participants from developing economies utilised AI and machine learning to some extent.

A "limited" response was allocated in instances where AI and machine learning were not used at all. Ninety-two percent of the interviewed tax authorities in developing economies do not make use of AI or machine learning in any form. The optimised utilisation of AI and machine learning requires accurate and complete datasets that are currently not present at the majority of participating tax authorities from developing economies. This was confirmed as one of the reasons for the low implementation rate by participants from developing economies, at this stage.

4.5 Change of tax audit approach in response to the digitalisation of the economy

Section 3.4 indicates that leading tax authorities have changed their audit approach and methodology in response to the digitalisation of the economy. Identified measures include the use of multi-disciplinary audit teams, the implementation of e-audits, audit software and the application of data analytics as an assurance or audit tool. In order to establish the reform that took place with regards to the assurance process among the participating tax authorities, the following question was posed to the participants: *"To what extent did your tax authority change your audit or assurance approach in response to the digitalised economy?"* The results are illustrated in Figure 5.

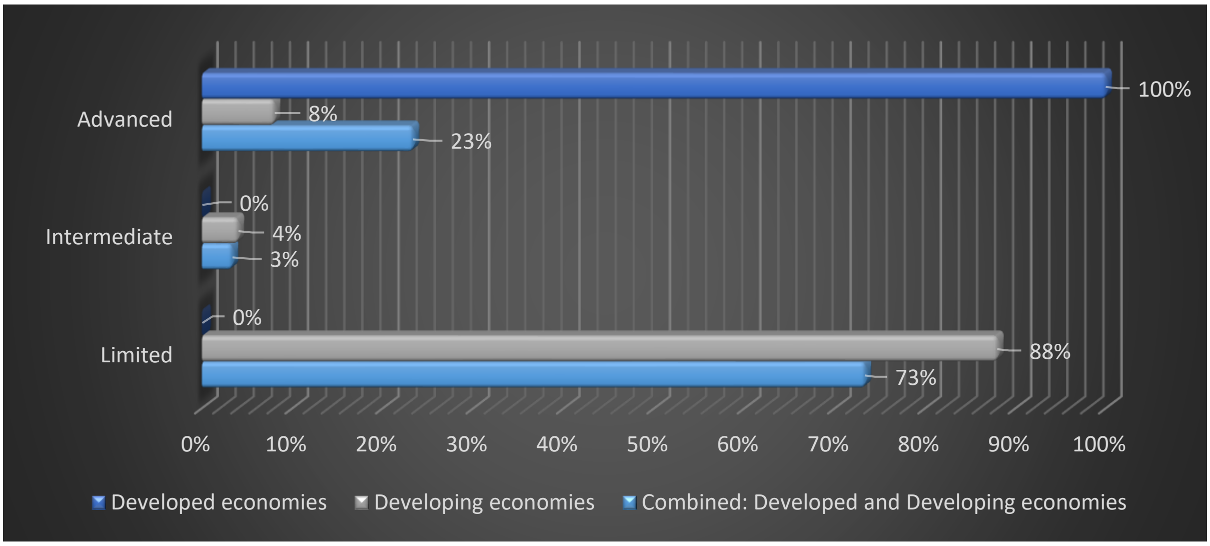

Figure 5. Participating tax authorities' response from an audit/assurance approach and methodology perspective
Source: Authors' own (2020)

An "advanced" response from a tax assurance perspective was allocated to cases where the audit approach and methodology were changed in order to consider the IT environment of the taxpayer, audit or investigation software is utilised and if the utilisation of data science was introduced as an integral part of the assurance process. An advanced response was observed among 100% of the participants from developed economies and among 8% of the participants from developing economies.

An "intermediate" response was allocated where tax authorities did not change their audit approach, but only their methodology. Of the interviewed tax authorities from developing economies, only 4% changed the methods used during the audit and assurance process in response to the digitalised economy, while 88% of tax authorities interviewed did not make any changes to their audit approach or methodology. A "limited" response was allocated to these tax authorities.

Some of the participants from developing economies indicated that they use "paper-based" audits in the absence of audit software. A lack of audit software is associated with risks, such as the loss or tampering with audit evidence. A paper-based audit is also not regarded as an optimised audit method within a highly digitalised environment associated with high data and transactional volumes.

One of the participants noted that the increased access to open source data and information enhanced the assurance process significantly. The tax authorities that conducted audits for highly digitalised multinational entities raised a concern regarding the accessibility to accounting data across borders. In order to assess the completeness and accuracy of, for example, declared taxable revenue, the ideal is to have access to the population of, for example, sales, and to calculate the amount of taxable sales that took place within a specific jurisdiction. However, challenges exist regarding the legality to request the population of sales in cases where this data is hosted in a different jurisdiction. The participants further stated that, although the exchange of information among tax authorities is possible, such requests in terms of the current methods and channels are time consuming and impractical within a digitalised economy.

One of the tax authorities is in the process of migrating the assurance process and related tools and data to a cloud application, as they are of the view that it would streamline the process. Seven of the tax authorities that were interviewed indicated that they make use of multi-disciplinary teams during the assurance process.

4.6 IT audits or e-audits

In section 3.4, the implementation of e-audits in response to the digitalisation of the economy is identified. In order to assess to which extent tax authorities have adopted the use of information technology or e-audits, the following question was posed to the participants: *"Does your tax authority execute information technology audits/e-audits?"* The results are demonstrated in Figure 6.

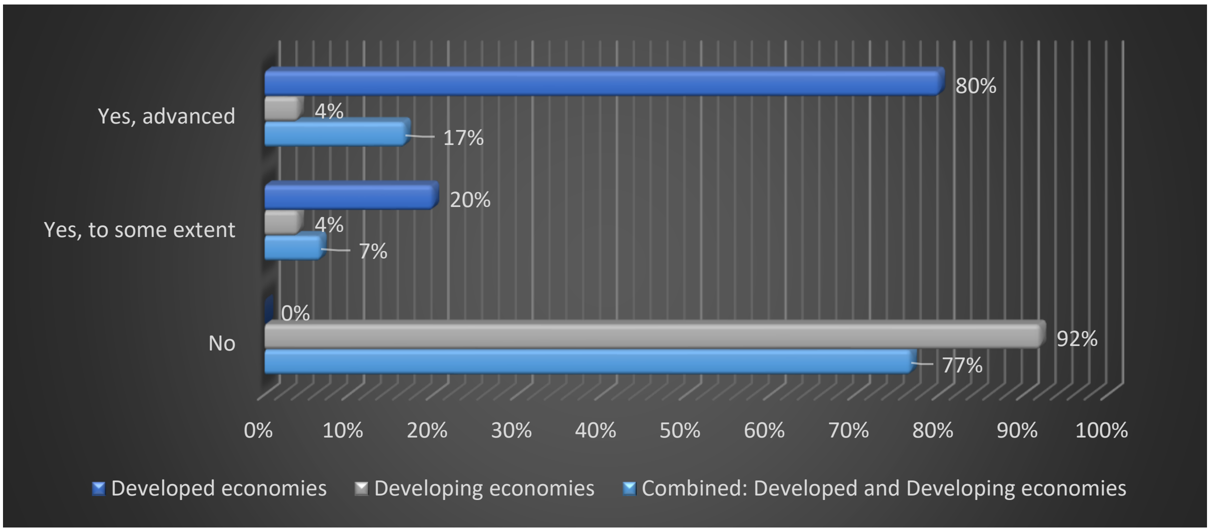

Figure 6. The application of information technology audits/e-audits
Source: Authors' own (2020)

Eighty percent of participating tax authorities from developed economies indicated that they have introduced IT audits or e-audits as part of the assurance process, while 4% of participating tax authorities from developing economies implemented IT audits. These audits are based on the risk profile of the taxpayer and the approach is consequently not applicable to all taxpayers under audit.

Twenty percent of participating tax authorities from developed economies and 4% of interviewed tax authorities from developing economies indicated that they implemented IT audits to some extent. In these instances, the tax authorities implemented computer-assisted audit techniques, but not the evaluation of the general IT and security environment of the taxpayer.

Ninety-two percent of participating tax authorities from developing economies did not implement IT audits as part of the assurance process. The lack of IT audits or e-audits is associated with an increased risk of inaccurate and/or incomplete financial information provided for audit and assurance purposes (Deloitte, 2018).

4.7 Data analytics as a tax audit/assurance tool

Section 3.4 indicates the use of data analytics as an assurance tool in response to the digitalised economy. In order to assess whether tax authorities use data science during the assurance process, the following question was posed to the participants: *"Does your tax authority use data analytics during the assurance processes?"* The results are illustrated in Figure 7.

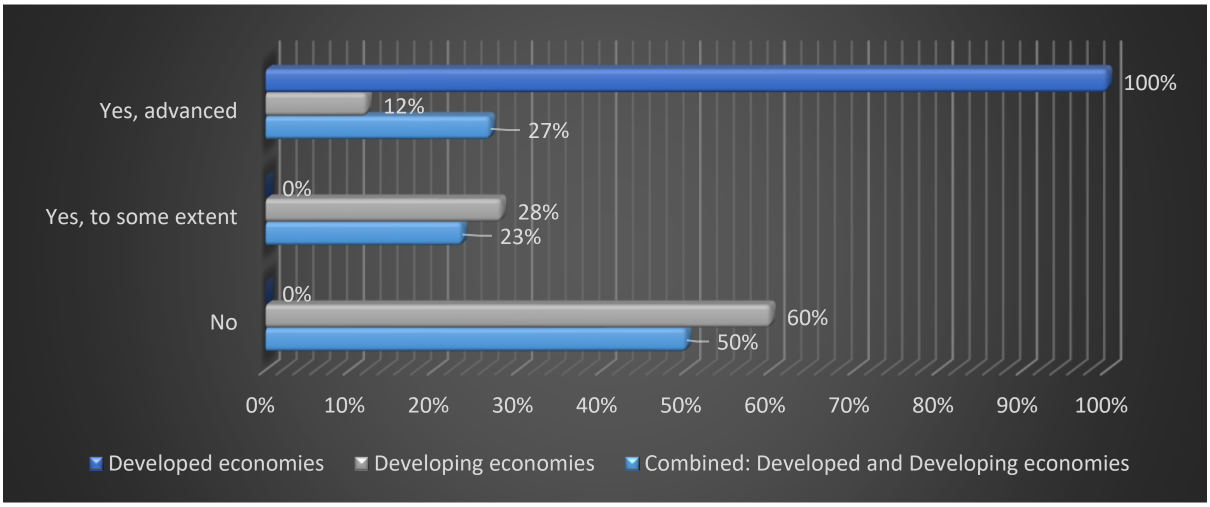

Figure 7. Utilisation of data analytics during the assurance process
Source: Authors' own (2020)

The research results reflected that all participating tax authorities from developed economies and 12% of participants from developing economies make extensive use of data analytics during the assurance process. Twenty-eight percent of participants from developing economies indicated that they make use of data analytics as an assurance tool, to some extent, while 60% of them indicated that they do not make use of it at all.

One of the participants indicated that pre-built analytical tools are provided to the assurance teams in order to optimise the use of data analytics during the assurance process.

5. Conclusion

The research results suggest that some international tax authorities responded to the changing global external environment which, in this case, is the digitalisation of the economy. These tax authorities are embracing the benefits of digitalisation in order to address the tax risks associated with the digitalised economy, although there is certainly scope for enhancement. The identified measures that were put in place by some international tax authorities include legislative reform, e-invoicing, taxpayer education, access to data of digital platforms, advanced application of data science, analytics and visualisation.

A significant amount of reform with regards to tax assurance was also identified and includes, but is not limited to, the implementation of assurance software, e-audits, the use of multi-disciplinary audit teams and the application of data analytics as an audit tool. The research results, however, indicate that the level of implementation of the identified tax risk and assurance measures are inconsistent if they are evaluated from a global perspective. The research results, as per section 4, highlight the fact that there is a sharp contrast between the level of tax risk management and assurance reform between participating tax authorities from developed and developing economies.

The research results indicate that the reform that took place to date among the participating tax authorities from developed economies was, overall, on an intermediate to advanced level. Advanced utilisation of AI and automation could, however, be considered as a further advancement to the current tax risk and assurance measures in place. In contrast, the research results reflect that, in general, participating tax authorities from developing economies find tax risk management and assurance within a changed digitalised landscape challenging. Their response in order to keep up with an exponentially changing digitalised economy therefore remains limited in most instances.

The fact that participants from developing economies' response, in relation to the tax risk management and assurance process, was, in general, rated as limited, raises concerns relating to these tax authorities' ability to protect their tax base and recover tax losses from highly digitalised MNEs that create value within their respective jurisdictions. It further raises concerns regarding these tax authorities' current and future ability to successfully deliver on their mandate as national revenue collectors. This concern is especially raised in light of the WEF's (2020) estimate that 70% of the new global economic value created over the next ten years will be based on digital platform business models.

6. Limitations

The scope of the research was limited to the tax risk management process and full-scope audit and assurance process. Although tax authorities manage an array of risks and conduct various levels of assurance, as per the introductory discussion in section 1, this study and the related literature review were limited to the tax risk management process and the full-scope or comprehensive audits or assurance processes due to the significance of their impact on the tax authorities' ability to fulfil their mandate as revenue collectors.

The scope of interviews with tax authorities to measure tax risk and assurance reform in response to the digitalisation of the economy, as documented in section 4, was, furthermore, limited to technology and data reform only. Tax legislative as well as digital tax administrative reform in response to the digitalisation of the economy, as identified in section 3, will be addressed in a separate study.

7. Further Consideration and Studies

Studies in human behaviour and psychology with regards to cyberspace suggest that human behaviour within this environment differs in some instances and under certain circumstances (Amichai-Hamburger, 2005). It further suggests that an array of new tools and techniques are used in order to commit various criminal offences, which include but is not limited to tax fraud (Goodman, 2016).

Limited literature could, however, be identified regarding taxpayer behaviour within the digitalised economy and their propensity to commit tax evasion within cyberspace. Research regarding taxpayer behaviour within the digitalised economy and their inclination to commit tax fraud or tax evasion will thus contribute richly to the business community and academia alike.

Further research with regards to the development and utilisation of software and tools such as AI and machine learning in order to identify possible "high-risk" non-compliant taxpayers within the digitalised economy might further enrich the scientific and business community.

8. Acknowledgements

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On Australia's Cyber and Critical Technology International Engagement Strategy Towards 6G

How Australia may become a leader in Cyberspace

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Abstract: In response to the call by the Australian Department of Foreign Affairs and Trade for submissions on the development of Australia's Cyber and Critical Technology International Engagement Strategy, this paper reviews the most *critical technologies*; related risks and opportunities; best practices, policies and security frameworks in other countries; relevant government, industry, civil society and academia cooperation initiatives; and proposes how Australia may became a leader in the global Cyberspace. To realise this vision, Australia should play a major role among selected international organizations; support the continuous evolution of *critical technologies*; adopt a proper technology security assurance scheme; and enforce a certification and accreditation process – against a predetermined set of appropriate security standards and policies – for security authorisation in Australia. This could be achieved with the formulation and implementation of an *Australia's defence-in-depth strategy*, augmented by a *Zero-Trust model*, which enhances security for untrusted domains, and within trusted domains, and meets the baseline requirements of cyber security for the Internet of Things.

Keywords: 5G, 6G, Cyber Security, Cyber defence, Zero Trust.

Introduction

This paper responds to the call by the Department of Foreign Affairs and Trade (the Department) for submissions on the development of Australia's Cyber and Critical Technology International Engagement Strategy (CCTIES) (Australian Government, 2020a).

The Department requested respondents to consider at least one of the following questions:

1. What should Australia's key international cyber and critical technology *objectives* be? What are the *values and principles* Australia should promote regarding Cyberspace

and critical technology?

2. How will *Cyberspace and critical technology* shape the international strategic/geopolitical environment out to 2030?
3. What *technological developments and applications* present the greatest risk and/or opportunities for Australia and the Indo-Pacific? How do we balance these risks and opportunities?
4. How should Australia pursue our *cyber and critical technology interests* internationally?
5. How can *government, industry, civil society and academia cooperate* to achieve Australia's international cyber and critical technology interests?
6. What *policies and frameworks* exist in other countries that demonstrate best practice approach to international cyber and technology policy issues?

The following sections touch upon all the above requests with a somewhat greater focus on Questions 2, 4, 5 and, especially, Question 6. The focus of the questions is on Australia's development and cooperation in the *global Cyberspace*.

The article sheds light on key areas the Department should focus on, and the international organisations to collaborate with: this, in respect of the security of *critical technologies*, and in doing so to take the necessary joint actions with likeminded countries. This will ensure these *critical technologies* are not manipulated and deployed for nefarious purposes in Australia (Australian Government, 2020b).

Objectives, Values and Principles

Cybersecurity ensures the Confidentiality, Integrity and Availability (CIA) of information[i]. Australia should strengthen its approach by including cybersecurity at the heart of its political, economic and safety priorities. *Trust*, *security* and *fight against cybercrime* should be at the core of Australia's 2020 Cyber Security Strategy in order to counter the rapidly evolving cyber threat environment (Australian Government, 2019).

In order to realise this vision, the Department should consider following in the footsteps of the European Union (EU) (European Commission, 2017), and take the following actions that will set Australia apart, overtaking the EU, and make it a leader:

- *Increase cybersecurity capabilities and international cooperation* by raising Australia's cybersecurity competences to the same level of development as other countries leading in this field and ensuring efficient exchanges of information and cooperation at cross-border level, especially in the Association of Southeast Asian

Nations (ASEAN) markets, where there is a strong demand for cybersecurity solutions.

- *Make Australia a strong international player in cybersecurity* and ensure that consumers, enterprises (including SMEs), and public administrations have access to the latest *digital security technology*, which is interoperable, competitive and trustworthy; ensures resilience and transparency; and respects fundamental human rights, including privacy preservation, taking advantage of the booming global cybersecurity market.
- *Pursue a collaborative and information sharing, risk management framework and labelling scheme that provides an objective and transparent basis for knowing which products and services are worthy of trust*: in particular, with regard to new technologies and emerging sectors – such as 5G, 6G, Artificial Intelligence (AI), Cellular Vehicle to X (C2X), Internet of Things (IoT), Industrial IoT (IIoT) and Consumer IoT (CIoT) (5G Americas, 2020a; European Commission, 2020b). Australia should adhere to the principle of "*openness and transparency*" and explore strategic and fundamental solutions based on facts with international stakeholders.

Cyberspace and Critical Technology

Devices and systems increasingly become more intelligent and more connected in many business processes and cross-sector industrial applications, such as transport, finance, healthcare, energy, agriculture, mining and manufacturing (Batas, Men & Smitham, 2020).

As more devices connect to the Internet, cyber security of Consumer IoT becomes a growing concern. People entrust their personal data to an increasing number of online devices and services. Products and appliances that have traditionally been offline are now connected and need to be designed to withstand cyber threats. For example, the baseline requirements for the cybersecurity of Consumer IoT are reported in ETSI (2020).

Fifth-generation wireless communications technologies (5G) will enable vastly more smart devices to connect to the Internet and among themselves, thereby accelerating the digital transformation that is already underway in manufacturing, transportation, education, healthcare and government. Some use cases and applications supported by 5G are depicted in Figure 1. Consumer devices from vehicles to medical implants will become more capable via 5G connections to new multi-access edge computing (MEC) servers and cloud services, algorithms and applications.

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Figure 1. Example of use cases and applications supported by 5G.

In short, 5G deployment will enable a *new generation of the knowledge economy, increasing productivity, growing new businesses and spurring innovation*. As a result, those nations and countries that master the advanced 5G technologies will have a long-term economic advantage as 5G systems and related capability enable digitised government and industry (US Department of Defense, 2020).

5G will bring computing power to the end user. It will increase the use of sensors and machine-to-machine communications to enable, smarter faster decisions, sometimes implemented automatically. This will make us increasingly dependent on technologies in a manner and to a degree that we have never experienced before, making two things much more important in security deployment than ever before:

- *Availability,* as we need to know these services will be there when we need them.
- *Integrity*: data, on which the analysis and decision-making depends, are accurate.

Three-hundred-and-ninety-two operators in 126 countries are investing in 5G, and 92 carriers in 38 countries have already launched one or more 5G services (GSA, 2020a), as illustrated in Figure 2.

China is said to more than double the number of its 5G base stations and will have 600,000 5G operational nodes. One year after 5G spectrum licenses were allocated there are already 36 million 5G end-users in the Chinese market (CGTN, 2020).

Comparatively in Australia, Telstra has more than 1,500 5G sites on-air across selected areas of 53 Australian cities and towns. Optus has more than 860 5G sites live across six major cities and several major towns.

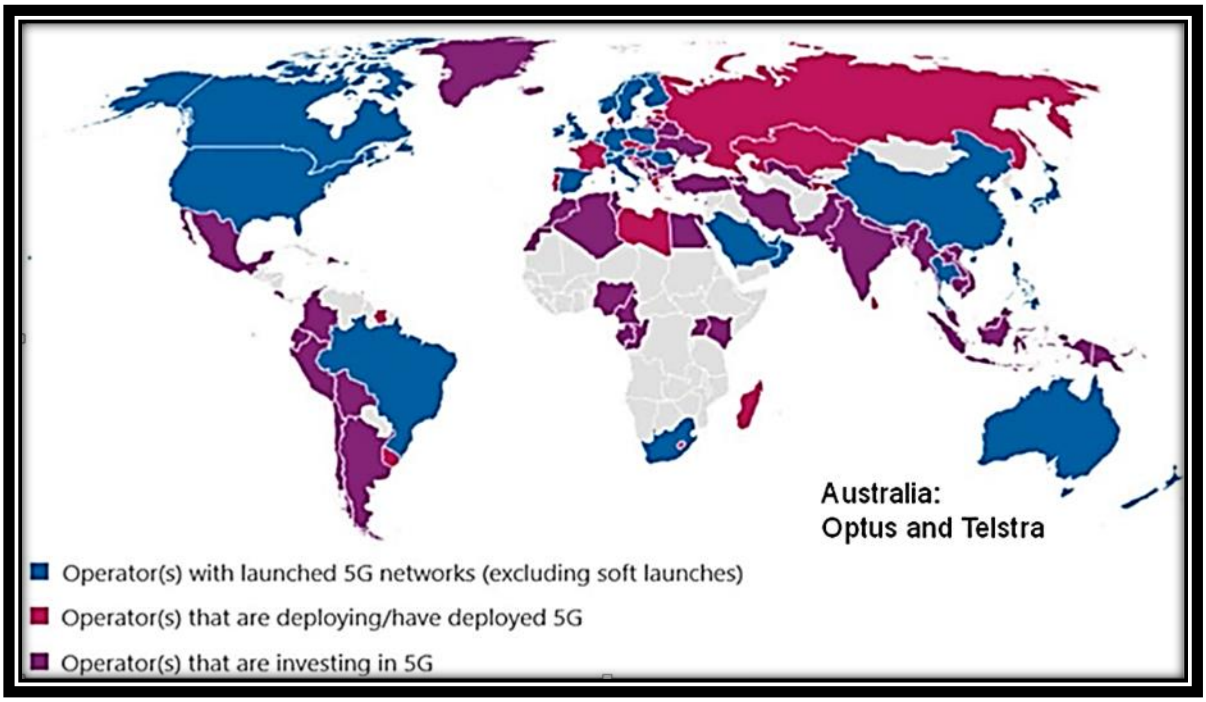

Figure 2. Map of global operator investments in 5G (GSA, 2020a).

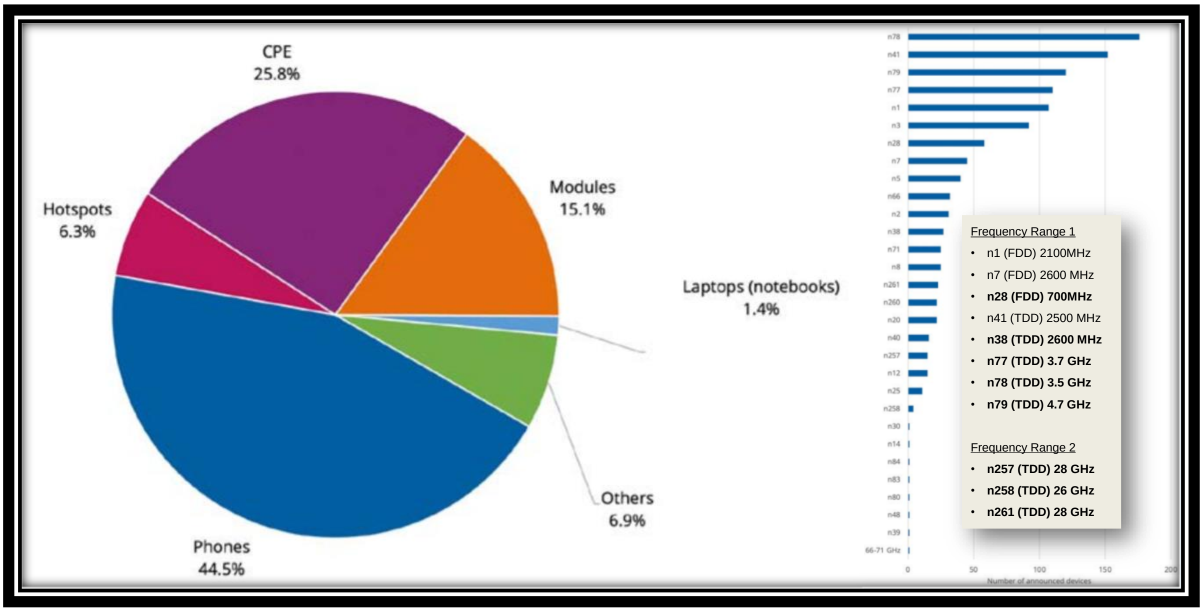

Figure 3. Announced 5G devices, by form factor and spectrum support, by specific band (GSA, 2020b).

Looking at the 5G ecosystem, by the end of July 2020, 18 form factors were announced. These included phones, head-mounted displays, hotspots, indoor CPE, outdoor CPE, laptops or notebooks, modules, snap-on dongles or adapters, industrial grade CPEs or routers (also referred to as gateways or modems), drones, robots, tablets, TVs, cameras, USB modems, a switch, a vehicle on-board unit (OBU) and a vending machine. A total of 91 vendors announced available or forthcoming 5G devices. The devices include a total of 364 regional variants, and phones that can be upgraded using a separate adapter. Excluded from this list are operatorbranded devices, which are essentially rebadged versions of other phones. Over 162 of these devices are said to be commercially available (GSA, 2020b).

The architecture of 5G is constantly evolving and will continue to evolve over the next decade until 6G is developed (Soldani *et al.*, 2018; Nokia, 2020; Ericsson, 2020). Whereas the first 5G release (Release 15) predominantly addressed the immediate needs of enhancing the mobile broadband experience, the release of the 16th and the 17th versions take 5G toward the full 5G vision, balancing the needs of mobile broadband operators with expanding into new markets, including vertical players. The second phase of 5G has been finalised in 3GPP with the anticipated release of the 16th version (Release 16) of the technical specifications (3GPP, 2020a). The 18th releases and beyond will focus on the definition of new use cases, study items (SI) and work items (WI) towards 6G, which is expected to be specified by 2030 (Soldani, 2020b). The 3GPP 5G high level roadmap is depicted in Figure 4.

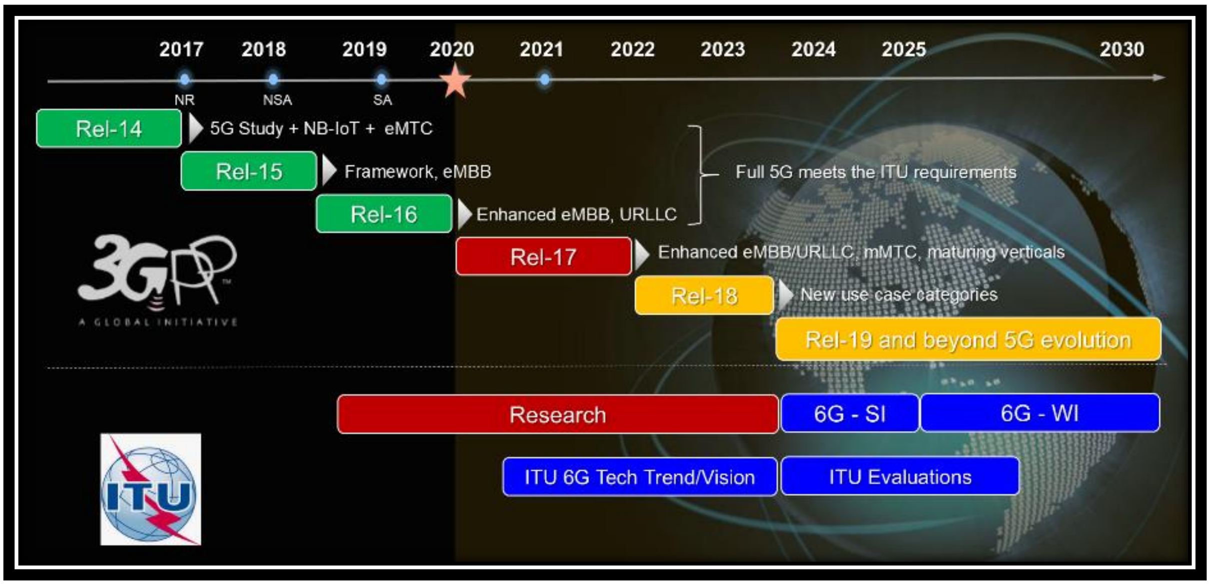

Figure 4. 3GPP 5G roadmap (Soldani, 2020b).

Release 16 forms the foundation for supporting Industrial IoT. It has an Ultra-Reliable Low-Latency Communications (URLLC) functionality that has the ability to achieve unprecedented levels of reliability, down to packet error rates of 10^{-6} ("six nines"). It boasts integration with IEEE Time-Sensitive Networking (TSN). It supports Private Networks, which are also known as Non-Public Networks (NPN), with both an NPN-specific authentication mechanism for User Equipment (UE) without a Universal Subscriber Identity Module (USIM) and an Authentication and Key Agreement (AKA) mechanism for the UE with a USIM card. It has a New Radio (NR) in Unlicensed (NR-U) spectrum in the 5 GHz and 6 GHz frequency bands, which may coexist with other systems such as IEEE 802.11 variants or LTE Licensed-Assisted Access (LAA). Vehicular communication ("V2X") features a *sidelink* for direct communication between devices. Beyond this, Release 16 supports Full 5G System Resilience with security features for service-based interfaces (SBI), Transport Layer Security (TLS) and Token-based

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authorization; Authentication and Key Management for Applications (AKMA), such as IoT over 5G; and Network Slice-Specific Authentication and Authorization (NSSAA). It also supports Wireless-Wireline Convergence (WWC) and Future Railway Mobile Communication System (FRMCS – Phase 1). The support extends to Network Automation Phase 2; Integrated Access & Backhaul (IAB); Device Power Saving; Mobility Enhancement and Enhanced Massive MIMO with multiple Transmission and Reception Points (TRP) (3GPP, 2020a).

As regards Release 17, the features to be included in this version have been agreed to and are scheduled for completion by the end of 2021 (3GPP, 2020b). Release 17 targets an even wider ecosystem expansion, particularly Consumer IoT. It will support native Time Sensitive Communication (TSC); High-Accuracy Positioning (cm-level); Sidelink enhancement for public safety and pedestrians; Multicast; Non-Terrestrial Networks (NTN), such as GEO and LEO satellites; and FRMCS enhancements (FRMCS – Phase 2). Further support will be provided to Network Slicing enhancements; Network Automation enhancements; New Radio in the 52–71 GHz frequency range; Device Power Saving enhancements; Further enhanced MIMO; Multiple USIMs; Cloud gaming QoS; and "NR-light" for IIoT and CIoT, particularly suitable for industrial cameras, high-end wearables, smart grid applications, high-end logistic trackers, and healthcare monitoring. This is illustrated in Figure 5 (3GPP, 2020b).

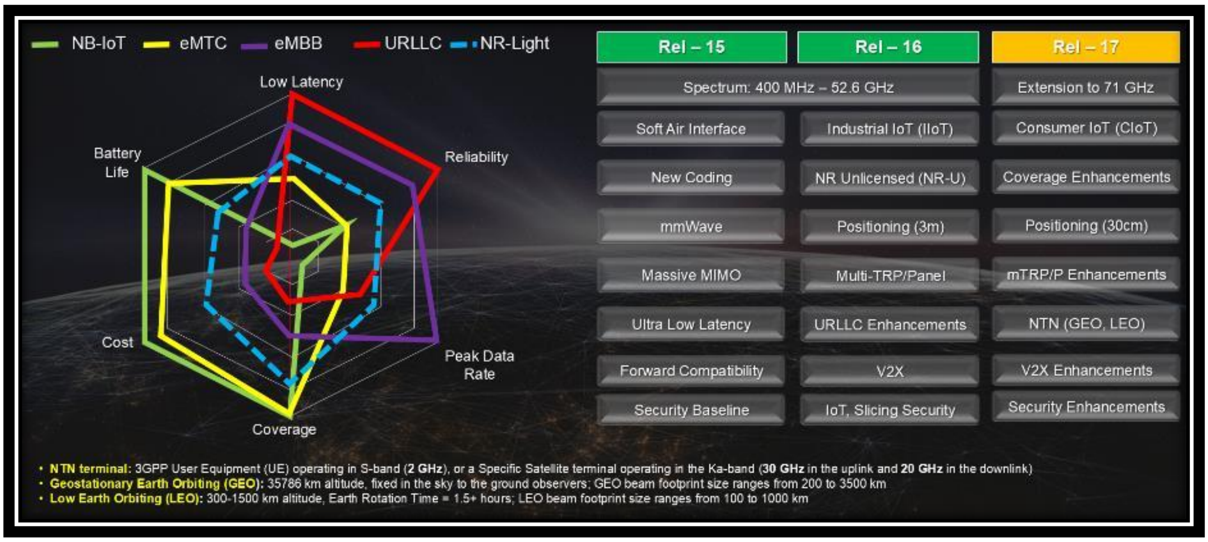

Figure 5. 3GPP R15, 16 and 17 supported spectrum and key features (3GPP, 2020b).

The release of versions 16 and 17 will witness an expansion of the ecosystem that can take advantage of 5G. As depicted in Figure 5, it will do so by adding many features to provide the full range of functionality required by new industry segments. It will make 5G networks easier to deploy and operate end to end. The progression of 5G with Release 18 and beyond will meet the needs of new market opportunities and deliver great value, towards 6G, which is expected to be specified by 2030.

The 6G wireless architecture will be shaped by five key constituents (Figure 6): *virtual-X*, *tactile*, *inferencing*, *sensing* and *learning*. AI will be the dominant service and application. The primary spectrum will be millimetre and terahertz waves, which lie at the far end of the infrared band, just before the start of the microwave band (Tong, 2020). This will allow us to apply wireless sensing capabilities; and 6G wireless will operate as a sensor network. The network and devices can perform real-time (RT) sensing, which will be the fabric to link the physical world and the cyber world.

The primary service will be virtual reality (VR) for everything. The virtual-X channel will allow access to digital content in the cyber world; the augmented tactile channel will carry haptic feedback, as the augmented neural system for the physical world; and the inference channel will exchange services between the AI engine and the end user.

From the physical world to the digital world, the primary applications are sensing and collecting the big data for machine learning (ML) (Soldani, 2020a). New compression technologies will be required to train the neural networks.

On the network side, we have the 6G Base Station (BS) node and 6G Edge Node. The BS will have all sensing capabilities to sense the environment in RT and for the ML capabilities. The Edge Node will be mostly used for ML, so the classical data centre at the edge will become the Neural Edge, and the BS will become the neural node.

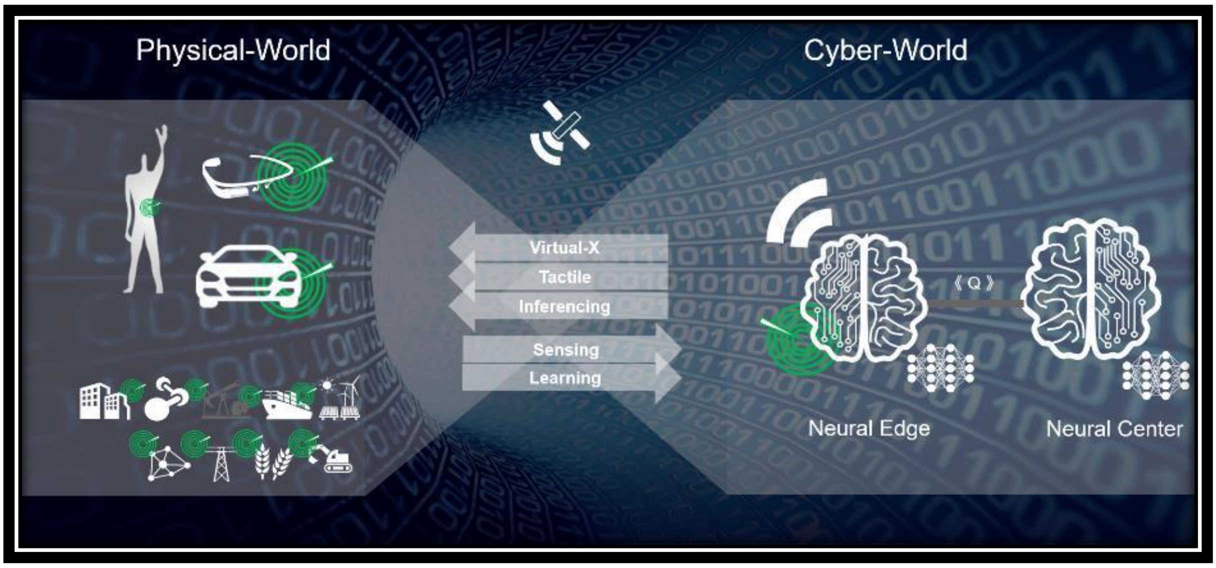

Figure 6. 6G Wireless network architecture (Tong, 2020).

Quantum (Q) key distribution technology can be deployed for the fibre-optic link between the Neural Centre and the Neural Edge. NTN is an integral part of the 6G wireless system, and a massive LEO satellite constellation will integrate traditional and non-traditional networks aiming at ultimately full earth coverage.

In a nutshell, 6G wireless is transforming from *connected everything* (information world) to *connected intelligence* (intelligent world). 6G wireless is the technology to deliver artificial intelligence to everyone, anywhere and at any time (Tong, 2020).

A high-level roadmap on how connectivity will evolve is depicted in Soldani (2020b). Today, we dwell in an *information world* characterised by remote control of digital devices, connected with 5G, IPv6+, Fixed 5G, and WiFi-6 technology, supporting 1-10 Gbps speeds, 10 ms latency, five nines reliability, and 1 million connections per square kilometre.

This is followed by an *intelligent world* featured by intelligent exoskeletons, 360° high-definition AR/VR and mixed reality (MR), provided by enhanced versions of the technologies available today.

We will arrive in the *holographic world* by 2030, characterised by unmanned robotic platforms and true-to-life holography (i.e. fully immersive interactive experience), only possible with the deployment of 6G, New IP, Fixed 6G, and WiFi-7 technologies, supporting 100 Gbps speeds, 1 Tbps anywhere transmission, both on the ground and via satellites, latency below 1 ms, "seven nines" reliability, and 10 million connections per square kilometre (Soldani, 2020b).

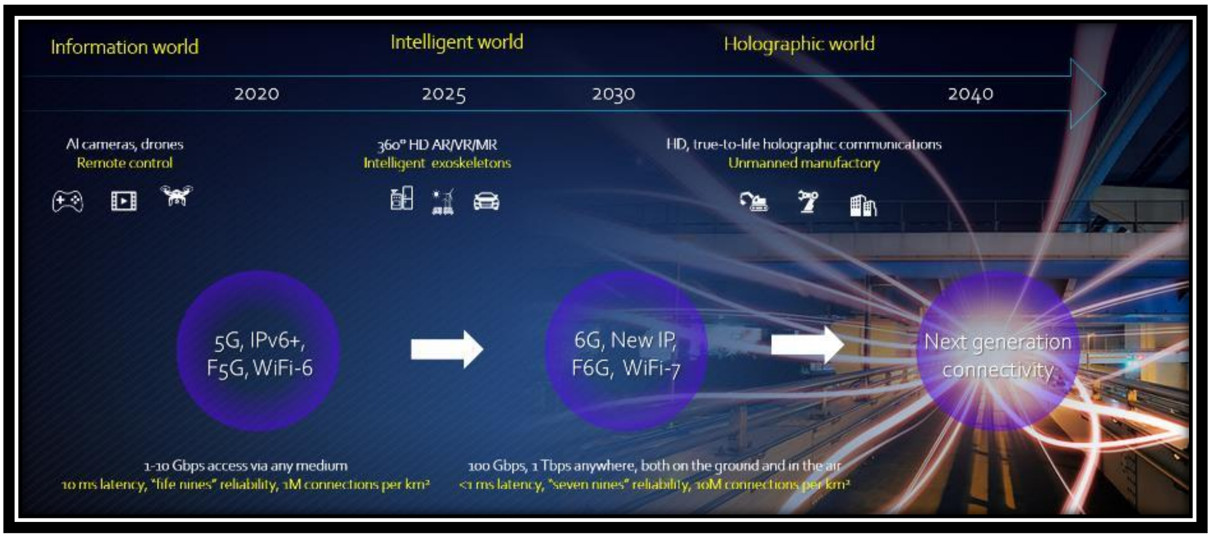

Figure 7. 6G Wireless network architecture (Soldani, 2020b).

Greatest Risk and/or Opportunities

There is a *shared responsibility* for risk management between information and communication service providers, equipment vendors and third-party suppliers. Market forces must be leveraged to drive greater assurance and transparency. *Procurement requirements* for buyers of ICT must be risk informed. Telecom equipment suppliers must be encouraged to develop *minimum industry standards* for assurance and transparency. There is a need to support *conformance programmes* and *independent testing;* and *effective risk*

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mitigation plans are necessary to address current and new emerging threats (Batas, Men & Smitham, 2020).

5G will progressively support essential services. This demands greater *cross-sector collaboration* between operators and suppliers – more than the partnership it seeks within the Telecoms field. As a result, building trust in Cyberspace is another important requirement (Batas, Men & Smitham, 2020; European Commission, 2020b).

Trust goes beyond technical or operational measures. Trust requires a dialogue between nations to set up *diplomatic norms* for acceptable state and state-sponsored behaviour in Cyberspace. Suppliers can build greater trust through *cooperation*, *openness* and *transparency*, ensuring a culture of security across sectors vital for our economy and society, which rely heavily on the use of information and communication technology (ICT).

Digital technologies and infrastructures, like 5G, present many new opportunities for economic growth and threats to the security of information and communications. The Department should work together with *industry* to build these technologies *in a way that ensures trust, security, safety* and *the protection of fundamental human rights*.

Since currently there are no relevant initiatives is place in Australia, it is vital that the Department and its agency partners, especially the Australia Cybersecurity Centre (ACSC), develop and fully implement a *Standards Engagement Plan* and actively participate in the 3rd Generation Partnership Project (3GPP) and Global System for Mobile Communications Association (GSMA) initiatives; for this engagement, it should have specific and prioritised outcomes, and deliverables, in Australia's interest, including strengthening the Australia's requirements and influence in those key organizations, and promoting high-quality contributions to 5G, 6G, and beyond, technologies and corresponding network equipment security assurance schema (discussed below).

Cooperating and collaborating at international level is essential for the Department in order to engage and drive towards a *trustworthy foundation* to enhance the security both of 5G networks and of technology built upon them, in a reliable, secure, resilient, and transparent manner (Soldani, 2019).

Cyber and Critical Technology Interests Internationally

Despite their advanced functionalities, 5G technologies pose several security challenges. This is essentially due to their innovative, software-driven nature and their use in a wide range of services and applications (Batas, Men & Smitham, 2020). The security challenge is exacerbated by the fact that the ecosystem is becoming increasingly dependent on the confidentiality, integrity and availability of data (the CIA triad). The EU Network and

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Information Security (NIS) Cooperation Group published its EU-wide Risk Assessment on 5G security that highlights shared technical and non-technical concerns (European Commission, 2019a). Conclusions were drawn based on the capabilities and the motivations of a potential attacker. *Integrity* and *availability* of 5G were of major concern, on top of the existing *confidentiality* and *privacy* requirements. Severe threats included compromised confidentiality and availability associated with an insider within a telecom operator or subcontractor, and associated with an *organized crime group*. Most critical 5G assets were Core Network Functions (5G Core), Network Function Virtualisation (NFV) and Management, and Orchestration (MANO).

The European Commission, the Member States and corresponding cybersecurity agencies are working together with Communication Service Providers (CSPs) and technology suppliers in order to provide continuity of mobile network services while managing cyber risks and concerns relating to these mobile networks and their underlying technologies.

To address the challenges to enhance cybersecurity, the European Union Agency for Network and Information Security (ENISA) published an analysis report of telecom security incidents, which the organisation has been collecting from all Member States (including the UK) and consolidating since 2012 (ENISA, 2019). *System failures* are the most common root cause, constituting roughly two thirds every year. In total, system failures account for 636 of incident reports (68% of the total). For this root cause category, over the last 7 years, the most common causes were *hardware failures* (36%) and *software bugs* (29%). The second most common root cause over the 7 years of reporting is *human errors* with nearly a fifth of total incidents (17%, 162 incidents in total). *Natural phenomena* come third at just under a tenth of total incidents (9%, 89 incidents in total). Only 4% of the incidents are categorised as *malicious actions*. In the period 2012-2018, two thirds of the malicious actions consist of *Denial of Service* (DoS) attacks, and the rest are mainly *damage to physical infrastructure*.

System failure and human error constitute the greatest risk and should be the focus of risk evaluation. The potential risks in any given product should be evaluated based on *factors* having a material effect on product security, such as the product security architecture, security mechanisms, and security features.

On the basis of the EU coordinated risk assessment of the cybersecurity of 5G networks that followed (European Commission, 2019a) – from the EU Network and Information Security (NIS) Cooperation Group – mitigation measures aim to *reinforce cross-sector collaboration between suppliers, operators, and service providers*, and also to raise the *transparency and openness of the suppliers* towards EU Member States.

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Governments in EU Member States can drive toward a *trustworthy foundation* to enhance the security of EU 5G networks addressing technical and non-technical risks through greater *public-private sector collaboration*, such as in the definition of security requirements; development of unified, international, globally recognised standards for network equipment security assurance scheme and compliance, as discussed in detail in the following sections; and promoting the widespread acceptance and implementation of international norms of responsible behaviour as well as confidence-building measures in Cyberspace.

The Department should work closely, at international level, with all relevant industries and partners to deliver a consistent set of regulations, and use market forces to incentivise greater assurance and transparency, to address 5G security that allows operators to take responsibility for the overall implementation (Huawei, 2019).

Cooperation between Government, Industry, Civil Society and Academia

Singapore, Indonesia and Thailand signed a Memorandum of Understanding (MoU) with Australia, which outlines cybersecurity cooperation in key areas. Those initiatives form a very good base for international companies to springboard into ASEAN markets, where there is strong demand for cybersecurity solutions (Barton, 2020).

Also, in Australia, there are many ongoing collaboration programs, such as, but not limited to, the list below (Barton, 2020):

- Cyber Security Cooperative Research Centre[ii], which encourages collaborations between industry, researchers and governments. Research programs include critical infrastructure security and cybersecurity as a service.
- Cooperative Research Centre Grants[iii] (CRC) and Project Grants (CRC-P), which provide funding for industry-led research collaborations.
- Next Generation Technologies Fund[iv] (NGTF), a government initiative with an investment of $730 million over the decade to June 2026. A forward-looking program focusing on research and development in emerging and future technologies.
- Australian Cyber Collaboration Centre[v] (A3C), which raises the awareness for business and acts as the translator between business, Government, industry and cyber specialists within the ecosystem.

However, we would need more investments in developing more *rigorous engineering practices* and move towards high-quality security software and hardware components by design, in compliance with standardised security requirements and fit-for-purpose testing for technology (Soldani, 2019).

In Australia, the Common Criteria (CC) regime and Australasian Information Security Evaluation Program (AISEP) have not met the expected results and little of the government technology in use today has common criteria certification. For example, the AISEP scheme should be revamped together with the Protective Security Policy Framework (PSPF) into a program that can achieve a real step up for government and critical-infrastructure systems (Moore, 2020).

In Europe, to this end, many successful initiatives are ongoing, looking at trustworthy technology to increase the level of customers' confidence in products and services, and, especially, for development and deployment of resilient ICT infrastructures.

The Department should ensure cooperation with the European Commission (EC) and other Member States, their partner cyber security agencies – such as ENISA, the Federal Cyber Security Authority in Germany (BSI) and the National Cyber Security Agency of France (ANSSI) – and a closer collaboration with international industry partners (Huawei, 2019), such as 3GPP and GSMA – on 5G *security specifications* (3GPP, 2020c) and *network equipment security assurance scheme* (GSMA, 2020).

This could be achieved by setting up an international "*Collaboration Working Group*", comprising public and private parties, and under the Department supervision, in order to support and facilitate strategic collaboration and exchange of information between partners and promote swift and effective operational cooperation on specific cyber-security labelling schemes, incidents and sharing information about identified threats and vulnerabilities. To this end, it is important to involve all suppliers and service providers in relevant industry sectors, in order to enable a much greater accountability of cyber incidents (Bartock, Cichonski & Souppaya, 2020).

For instance, in Singapore, the government, in collaboration with industry, will work with likeminded international partners to establish mutual recognition arrangements for a Cybersecurity Labelling Scheme (CLS), as Singapore, similar to Australia, is a small market with limited ability on its own to shift the global IoT device market toward an enhanced security standard. This will involve aligning the CLS with widely accepted global security standards for consumer IoT devices (Singapore Cyber Security Agency, 2020).

It also requires a broad and *well-trained workforce* (Industry Advisory Panel, 2020). The Department, in collaboration with academia, industry and interagency partners, should identify the necessary skills and develop a human capital plan that assembles distinguished experts, and extends to the next generation of talent, who will be needed to formulate a *strategic research and innovation agenda* (SRIA) for Australia, and design, develop and operate advanced technologies for 5G, 6G and beyond.

Policies and Frameworks in Other Countries

Ensuring cyber security throughout international collaboration and finding a balance between technology integration, human capital investments and the innovation ecosystem will be critical to enhancing productivity in the next decade (Soldani, 2019).

Since the telecom sector today is an enabler for the entire digital economy and society, Australia needs to act quickly with new policies and regularity frameworks to secure its global competitiveness and prosperity in the near future (Huawei, 2019).

In numerous countries, such as Europe, China, South Korea, Singapore and Japan, significant changes have taken place within the ICT field, and patterns of consumption and needs have been radically shifting, demanding access to an ever-increasing array of *digital services*, which place an ever-increasing demand on the *ICT infrastructure* across which they are provided. Even more performance and security requirements will be placed on the ICT infrastructure in the years to come, as service applications based on the IoT, artificial intelligence, distributed computing and extended reality (ER) will further develop and grow (European Commission, 2019b).

The full economic and social benefits of this digital transformation may be achieved only if the Australian Government can ensure widespread deployment and take-up of very high capacity networks, in rural as well as urban areas and across all of society.

Australia needs an effective technology-focussed industrial strategy, and it is essential that policymakers and industry leaders get the CCTIES right and invest in developing skills and local industrial capacity if they want to provide opportunity for all in the era of the 4th Industrial Revolution.

A close EU-wide and Australia cooperation is indispensable, both for developing strong international *Cyberspace* and for reaping the full benefits that 5G will have to offer for people, businesses and government services.

The "*Recommendation on Cyber Security of 5G Networks*" (European Commission, 2019c), "*Cyber Security Certification Framework*" (European Commission, 2019d), and "*Connectivity for a Competitive Digital Single Market – Towards a European Gigabit Society*" (European Commission, 2019b) are examples of relevant policies directed at improving security and ensuring future prosperity of all member states (including the UK) in Europe, and gaining trust from people, homes and organisations within the Union.

Following the Commission Recommendation for a common European approach to the security of 5G networks, 24 EU Member States completed the first step and the EU-wide risk assessment in October 2019 (European Commission, 2019a). The completion of the risk

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assessments underline the commitment of Member States not only to set high standards for security, but also to make full use of this ground-breaking technology. Europe wants all key players, big and small, to accelerate their efforts in building a common framework aimed at *ensuring consistently high levels of security to develop a European approach to protecting the integrity of 5G*.

Within the above framework, in January 2020, the Network and Information Systems (NIS) Cooperation Group, which leads the cooperation efforts together with the Commission, output a "*Toolbox of Mitigating Measures*" to manage the risks identified in the risk assessments at Member-State and EU level (European Commission, 2020a).

Following the entry into force of the "*EU Cyber Security Act*" (European Commission, 2019e), the Commission and ENISA have set up an *EU-wide certification framework* (European Commission, 2019d), in collaboration with industry; and Member States are collaborating with the EC and ENISA to prioritise the certification scheme covering 5G networks and equipment.

The "*EU Cyber Security Act*" establishes an *EU certification framework for ICT digital products, services and processes* that enables the creation of *a tailored and risk-based EU certification scheme*.

Certification plays a critical role in increasing trust and security in products and services that are crucial for digital markets. Today, a number of different security certification schemes for ICT products exist in the EU, and globally. But, without a common framework for a *global valid cyber security certification protocol or programme or ecosystem*, there is an increasing risk of fragmentation and barriers towards a Global Digital Single Market.

The EU certification charter will provide the "*EU-wide certification scheme*" as a comprehensive set of *rules, technical requirements, standards and procedures*. This will be based on agreement at EU level for the evaluation of the security properties of a specific ICT-based product or service, e.g., smart cards. It will attest that ICT products and services which have been certified in accordance with such a scheme comply with specified requirements.

In particular, each European scheme will specify:

- The categories of products and services covered.
- The cyber security requirements, for example by reference to standards or technical specifications.
- The type of evaluation (e.g., self-assessment or third-party evaluation).
- The intended level of assurance (e.g., basic, substantial and/or high).

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To express the cyber security risk, a certificate may refer to *three assurance levels* (basic, substantial, high) that are commensurate with the level of the risk associated with the intended use of the product, service or process, in terms of the probability and impact of an incident. For example, a high assurance level means that the product that was certified has passed the highest security tests. The resulting certificate will be recognised in all EU Member States, making it easier for businesses to trade across borders and for purchasers to understand the security features of the product or service.

At the same time, the industry is actively contributing to integrate the 3GPP Security Assurance Specifications (SCAS) (3GPP, 2020c) and Network Equipment Security Assurance Scheme (NESAS), jointly defined by 3GPP and GSMA (GSMA, 2020), certification and accreditation frameworks with the upcoming EU Toolbox, and the new Certification Scheme.

In particular, the German national cyber security authority (BSI) is working together with ENISA to adapt the 3GPP SCAS-GSMA NESAS model to the new European Cyber Security Act and set up an *EU 5G regulatory framework*, in cooperation with the industry, as detailed in the next section.

Also, in Germany, the Federal Network Agency has recently published the draft of the catalogue of security requirements for the operation of telecommunications and data processing systems, as well as for the processing of personal data (Bundesnetzagentur, 2020). The catalogue forms the basis for the security concept and for the technical precautions and other measures to be taken to increase the security of the networks and services. The catalogue requires in particular that (Bundesnetzagentur, 2020):

- Critical components are certified.
- Trustworthiness declarations are obtained from manufacturers and system suppliers.
- Product integrity is ensured.
- Safety monitoring is introduced.
- Only trained specialists are used in safety-relevant areas.
- Sufficient redundancies are available.
- Monocultures are avoided.

The catalogue has been submitted for notification to the EC and is also be available in English. Changes may occur until this process is completed, as, at the time of writing, a public consultation on the draft catalogue is ongoing in Germany.

GSMA NESAS Model

The GSMA NESAS is an industry-defined voluntary scheme through which vendors subject their product development and lifecycle processes, and network equipment, to a comprehensive security audit and testing against the currently active NESAS 1.0 release and its security requirements (GSMA, 2020).

The NESAS, jointly defined by 3GPP and GSMA, provides an *industry-wide security assurance framework* to facilitate improvements in security levels across the mobile industry. It defines security requirements based on 3GPP technical specifications and an *assessment framework* for secure product development and product lifecycle processes; and a *security evaluation scheme* for network equipment, using the 3GPP defined security specifications and test cases, i.e., 3GPP SCAS (3GPP, 2020c).

Figure 8 presents the roles and work split between the two organisations:

- GSMA defines and maintains the *NESAS specifications*, which cover assessment of Vendor Development and Product Lifecycle processes, NESAS Security *Test Laboratory accreditation*, and *Security Evaluation* of network equipment. (GSMA also defines a *dispute resolution* process and governs the overall scheme.)
- 3GPP defines *Security Requirements and Test Cases* for network equipment implementing one or more 3GPP network functions – defined in the Security Assurance Specifications (SCAS): 3GPP TS 33.X (3GPP, 2020c).

The NESAS approach consists of the following steps (see Figure 9):

- Equipment Vendors define and apply secure design, development, implementation, and product maintenance processes.
- Equipment Vendors assess and claim conformance of these processes with the NESAS defined security requirements.
- Equipment Vendors demonstrate these processes to independent auditors that GSMA has selected.
- The level of security of network equipment is tested and documented. (Tests are conducted by accredited test laboratories.)

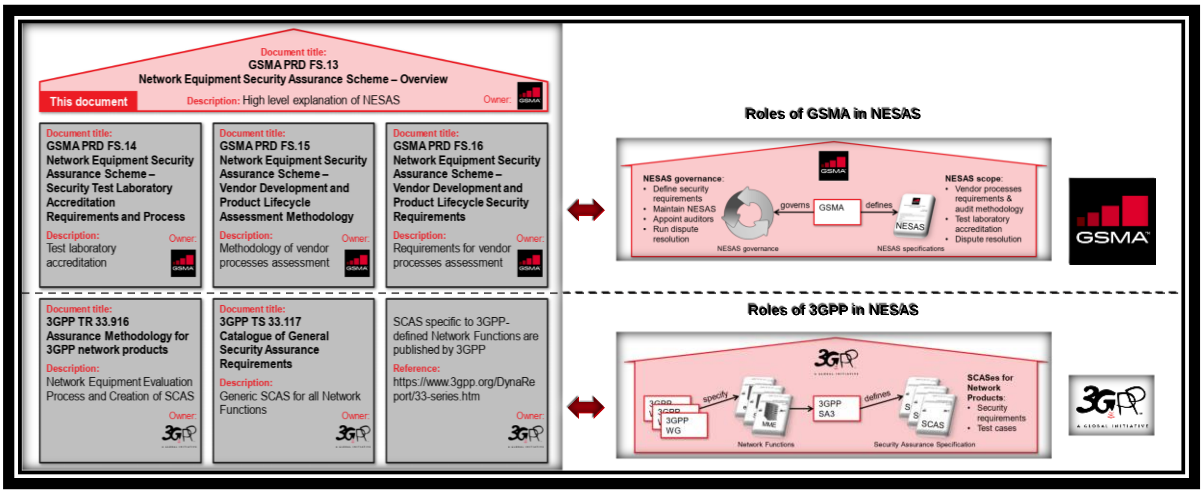

Figure 8. 3GPP and GSMA deliverables, roles and work split (GSMA, 2020).

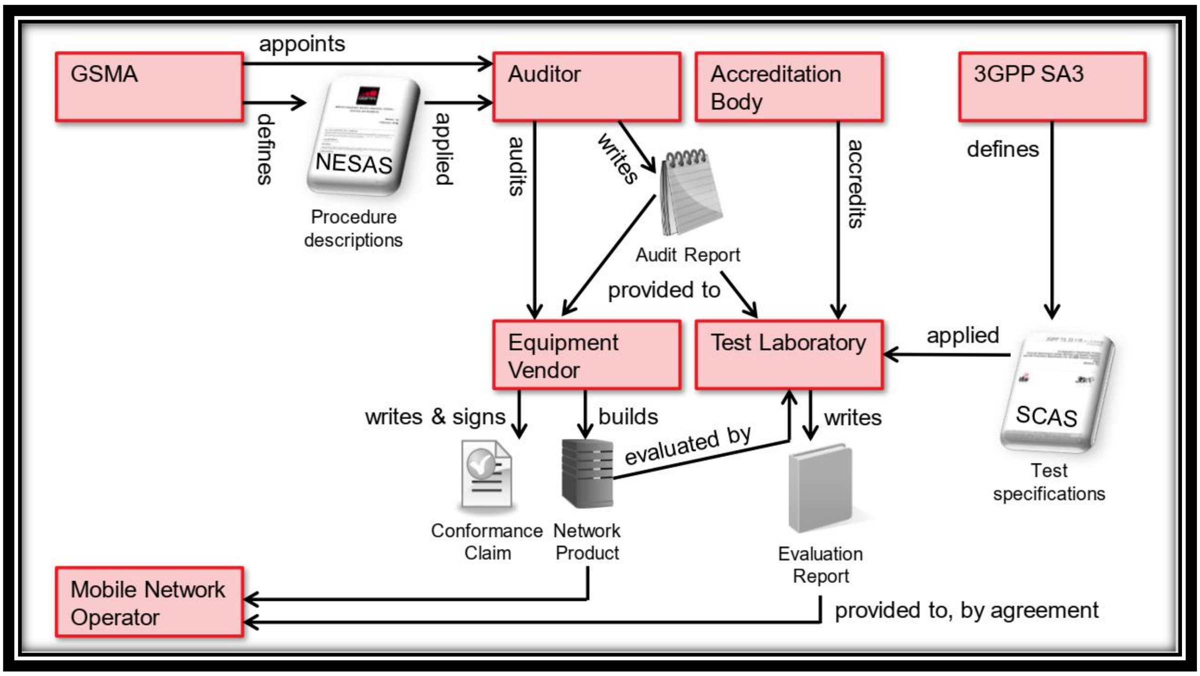

Figure 9. NESAS high level process (GSMA, 2020).

Figure 10 illustrates the involvement of many public and private organisations in the NESAS process. The NESAS is widely supported by security authorities (such as ENISA in EU, ANSSI in France and BSI in Germany) and industry organisations, globally. The NESAS 1.0 release was finalised in October 2019. Since then, two European firms (ATSEC and nccgroup) were selected by GSMA; Ericsson, Nokia and Huawei openly support NESAS as a unified cyber security certification framework for mobile network equipment, and more than ten operators have requested NESAS compliancy, before deploying 5G equipment in their countries.

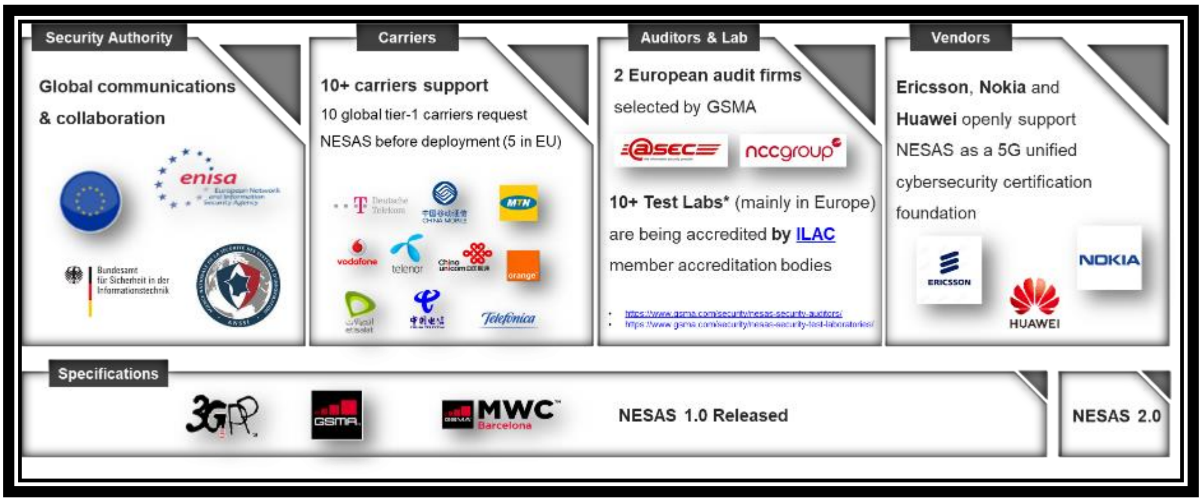

Figure 10. NESAS process widely supported by security authorities and industry organisations, globally.

GSMA appoints the Audit Firms and recognises the competency of the International Laboratory Accreditation Cooperation ([ILAC](#)) member accreditation bodies to assess and accredit security test laboratories.

Security test laboratories that are deemed by an ILAC member to have satisfied the ISO 17025 and NESAS requirements, and that have been ISO 17025 accredited, will be considered to have achieved NESAS accreditation.

The NESAS 1.0 framework was approved in October 2019 and comprises the technical specifications depicted in Figure 8.

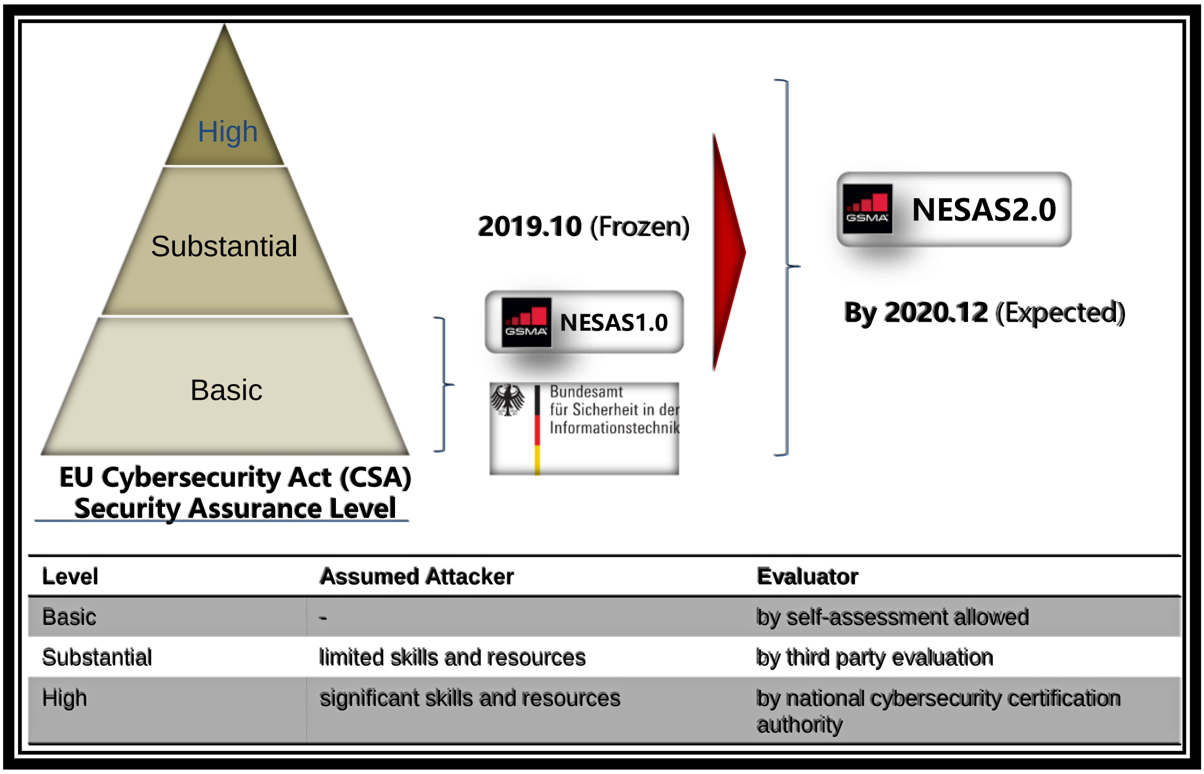

Figure 11. NESAS Evolves as a solid security assurance basis.

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The NESAS specifications will be further improved by the end of this year to meet the security assurance level in compliance with the EU Cyber Security Act (European Commission, 2019e). This will possibly encompass: *Penetration Tests*, *Cryptographic Analysis* and *Software Engineering*, as exemplified in Figure 11, in alignment with the best industry standards and practises, as depicted in Figure 12.

Furthermore, the NESAS – defined for mobile systems security – fully validates the characteristics of mobile communication services, in terms of threat analysis and modelling, and significantly simplifies the Common Criteria (CC), featuring short accreditation and evaluation time, and low cost, and meeting the development needs of new technologies, such as cloud, digitisation, and software-defined everything.

The CC and companion Common Methodology for Information Technology Security Evaluation (CEM) are intended for the IT industry and define no equipment test specifications for mobile communication in product process (PP).

Moreover, the CC cover the general R&D process and lifecycle management audit, but lack of specialty on telecommunication such as 5G, and also suffer from complicated accreditation, long period, and high cost.

A comparison between the NESAS and CC frameworks is shown in general terms and in terms of technical requirements in Figure 13 and Figure 14, respectively.

NESAS 2.0	Penetration test	Cryptographic analysis	Software engineering capability
Industry Benchmarking	1. BSZ 2. CSPN 3. CPA 4. CC AVA (bypassing, tampering, direct attack, monitor, misuse) 5. MSDL/BSIMM/OWASP SAMM	1. BSI TR 02102 2. ANSSI RGS_B series 3. NCSC CPA 4. NIST FIPS140-2, NIST SP800-90A 5. NDcPP (ISO19790:2012, NIST SP800-90A)	1. NCSC Secure development and deployment 2. MSDL 3. BSIMM 4. OWASP SAMM 5. NIST standards 6. ISO standards

Figure 12. How the NESAS is expected to evolve according to stakeholders' requirements.

Accreditation/ Evaluation System	NESAS	CC
Organization owner	GSMA/3GPP	CCRA (Common Criteria Recognition Arrangement)
Standards scope & completeness	Audit/Evaluation report (Not certificate)	1~7 EALs (Evaluation Assurance Levels)
Standards progress	NESAS/SCAS standard/specifications (2019.10)	CC released years ago, **operated maturely**
Number of accredited labs & auditing companies	Several labs and 2 auditing companies now	About **77** labs globally
Operators' recognition	**High**	**Low**
Telecommunication Assurance	Only one professional standard	N/A
Process & TTM	Simple processes & 3-6 months	Complex processes & 12-18 months (EAL4+)

PP: Protection Profile; CC: Common Criteria

Figure 13. Comparison in general terms between NESAS and Common Criteria (CC).

On 24 August 2020, the GSMA announced that the world's leading mobile network equipment vendors, Ericsson, Huawei, Nokia and ZTE, had successfully completed an assessment of their product development and lifecycle management processes using the GSMA's NESAS (GSMA, 2020). The process audited, the products developed under the audited process, and a summary report for each vendor are reported in Figure 15.

NESAS Product Development & Lifecycle Audit		CC Product Development & Lifecycle Audit	
1	Security by design	ADV_ARC/FSP/HLD/LLD/ST	√
2	Version control system	ALC_CMC (on-site audit)	√
3	Change tracking	ALC_CMC (on-site audit)	√
4	Source code review	-	×
5	Security testing	ATE_COV/DPT/FUN	√
6	Staff education	-	×
7	Vulnerability remedy process	ALC_FLR (Flaw Remediation)	√
8	Vulnerability remedy independence	-	×
9	Information security management	ALC_DVS (Developer Security)	√
10	Automated build process	ALC_CMC (on-site audit)	√
11	Build environment control	ALC_CMC (on-site audit)	√
12	Vulnerability information management	-	×
13	Software integrity protection	ALC_DEL (Delivery with DS)	√
14	Unique software release identifier	ALC_CMC (CI Identification)	√
15	Security fix communication	-	×
16	Documentation accuracy	ALC_CMC (on-site audit)	√
17	Security point of contact	-	×
18	Source code governance	ALC_CMC (on-site audit)	√
19	Continuous improvement	ALC_CMC (on-site audit)	√
20	Security documentation	AGD_OPE/PRE	√

Test	Contents of equipment evaluation test	SCAS	CC
SCT (security compliance test)	Sensitive info. storage, transfer, protection during access to system, privacy protection (FDP/FCS/FPR)	√	√
	System overflow, secure start-up, robustness of data input, software integrity (FRU/FPT)	√	√
	Authentication (credential/password), token policy, account lock, principle of least authority (FIA)	√	√
	Log out, overtime auto protection (FTA)	√	√
	Security log, log rotate, log access authorization (FAU)	√	√
	Admin account, user account, IP/ICMP Process (FIA)	√	√
	https, web server log, session ID, input examination	√	√
	Message filtering, robustness of protocol, GTP-C/U filtering	√	√
	Security enhancement of baseline requirement	√	×
	OS Security enhancement	√	×
	Webserver Security enhancement	√	×
	Management/User plane separation (FDP/FPT)	√	√
	FCS (cryptographic algorithm implementation check, random number generator, etc.)	×	√
BVT (basic vulnerability test)	Port scan	√	√
	Known vulnerability scan	√	√
	Robust test for interface protocol	√	√
EVA (enhanced vulnerability analysis)	**Penetration test**	×	√
	Source code scan	×	√

Figure 14. Comparison in terms of technical requirements between NESAS and Common Criteria (CC).

Company	Month of Audit	Process Audited	Products Developed Under Audited Process	Summary Report
Huawei Technologies Co. Ltd.	March 2020	Huawei Integrated Product Development (IPD) – 10.0	LTE eNodeB and 5G gNodeB Product Lines	https://www.gsma.com/security/wp-content/uploads/2020/08/Huawei-RAN-NESAS-Audit-Report-Summary-Report-Mar-2020.pdf
Huawei Technologies Co. Ltd.	May 2020	Huawei Integrated Product Development (IPD) – 10.0	5G Core product line for UDG, UDM, UNC, UPCF	https://www.gsma.com/security/wp-content/uploads/2020/08/Huawei-RAN-NESAS-Audit-Report-Summary-Report-Mar-2020.pdf
Nokia Solutions and Networks Oy	May 2020	Nokia MN CREATE Process v18.3	LTE eNB (SRAN) and 5G gNB Products	https://www.gsma.com/security/wp-content/uploads/2020/08/Nokia-NESAS-Audit-Summary-Report-May-2020.pdf
Ericsson	June 2020	Ericsson DNEW Development Framework	eNodeB and gNodeB Product Lines	https://www.gsma.com/security/wp-content/uploads/2020/08/2-Ericsson-NESAS-Audit-Summary-Report-Jul-2020.pdf
ZTE Corporation	July 2020	High Performance Product Development (HPPD) Process 2017	5G NR and ZXUN USPP Product Lines	https://www.gsma.com/security/wp-content/uploads/2020/08/ZTE-NESAS-Audit-Summary-Report-Jul-2020.pdf

Figure 15. Audited process, audited products developed and summary report for all vendors (GSMA, 2020).

As described above, the NESAS is focused on the *vendor aspects of the supply chain*, and thus provides a *security assurance framework to improve security levels across all the mobile industry*, because it has been developed following established practices and schemes that provide *trustworthy security assurance* (GSMA, 2020).

Zero Trust Model

Zero Trust is a cyber security paradigm focused on security controls to prevent unauthorised access to data (resources) and services coupled with making the access control enforcement as grainy as possible, as defined in Rose *et al.* (2020). This could be achieved by policy enforcement of geo-location, and mandatory authentication and authorisation of peer entities to establish the needed verification. For instance, in 5G, each element should utilise a robust code signing stack at both the silicon and software layers, so that all the layers involved can be trusted (5G Americas, 2020b).

To achieve Zero Trust, operators need to adapt a default "deny all" mentality and start opening up network lanes and endpoints according to the least privileges principle.

This new paradigm will allow the replacement of hardware and software in the network — with low quality implementations — with physical and logical elements with substantially more trust built into the product(s) from the supply chain perspective.

Since Zero Trust is an iterative process, operators must put in place proper network operations – including in both centralised and distributed locations – to log and inspect all traffic across user, control and management planes; and, especially, monitor both virtual network (slice) and physical and infrastructure on an ongoing basis.

Zero Trust augments a *defence-in-depth security strategy* – also known as layered defence, where controls of various types and kinds overlap each other in coverage – and cannot be achieved without the full participation of all the elements in the trust chain for a network.

An example of the defence-in-depth approach augmented by a Zero Trust model for 5G security deployment, is shown in Figure 16 (Soldani, 2019). The 5G system supports:

- All 3GPP SCAS requirements and fundamental security control enhancements, such as, but not limited to, the following: user plane (UP) integrity protection, UP security policy, roaming security, user privacy preservation (encryption of international mobile subscriber identity), unified authentication and 256-bit encryption algorithm.
- Equipment security (3-plane isolation, data security, host intrusion detection and Trusted Execution Environment, TEE).
- Sub-solutions to Radio Access Network (RAN) security (e.g. rogue base station detection, secure transmission), Multi-Access Edge Computing (MEC) security (MEC platform hardening, MEC security operations, e2e encrypted local network), Core Network security (multi-layer isolation and hardening, disaster and elastic recovery), Network Slicing security (slice isolation, encryption and protection, differentiated slice security), and Massive Connectivity security (signaling domain anti-DDoS and date

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domain anti-DDoS).

- Security management, which includes an Element Management System (EMS) layer, for situational awareness, anomaly detection, trusted integrity measurements, certificate management, log auditing, and Network Element (NE) vulnerability management; and an end-to-end (e2e) Security Operation Centre (SOC), for security situational awareness, AI-based threat analysis and detection, security orchestration and Network Element (NE) vulnerability management.

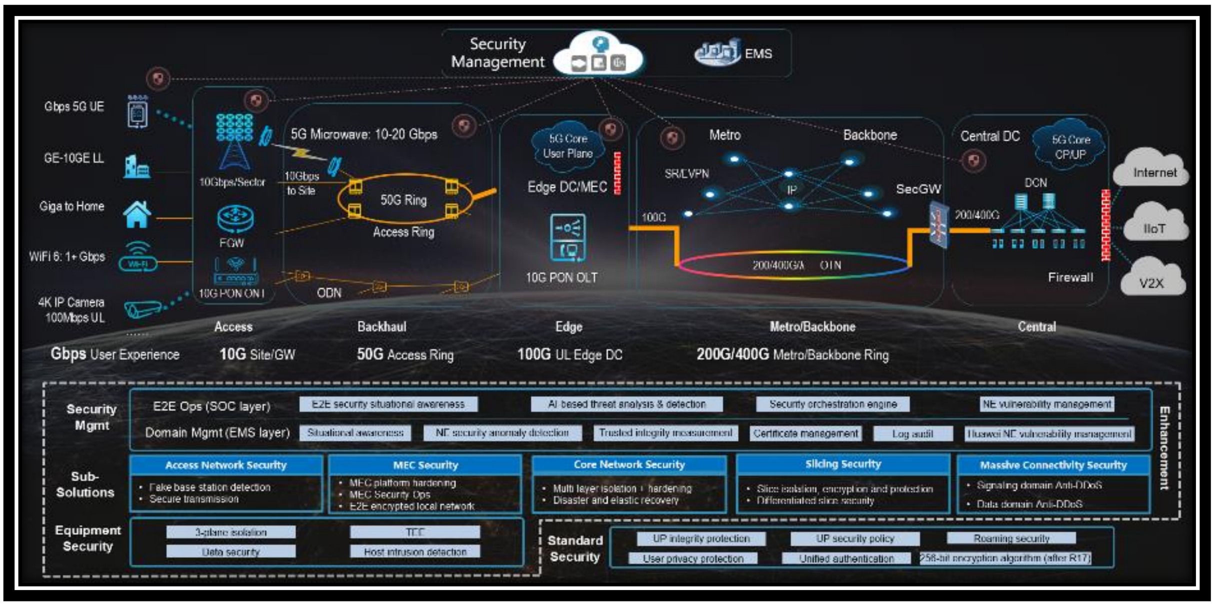

Figure 16. Example of defence-in-depth, Zero Trust, solution for 5G security deployment (Soldani, 2019).

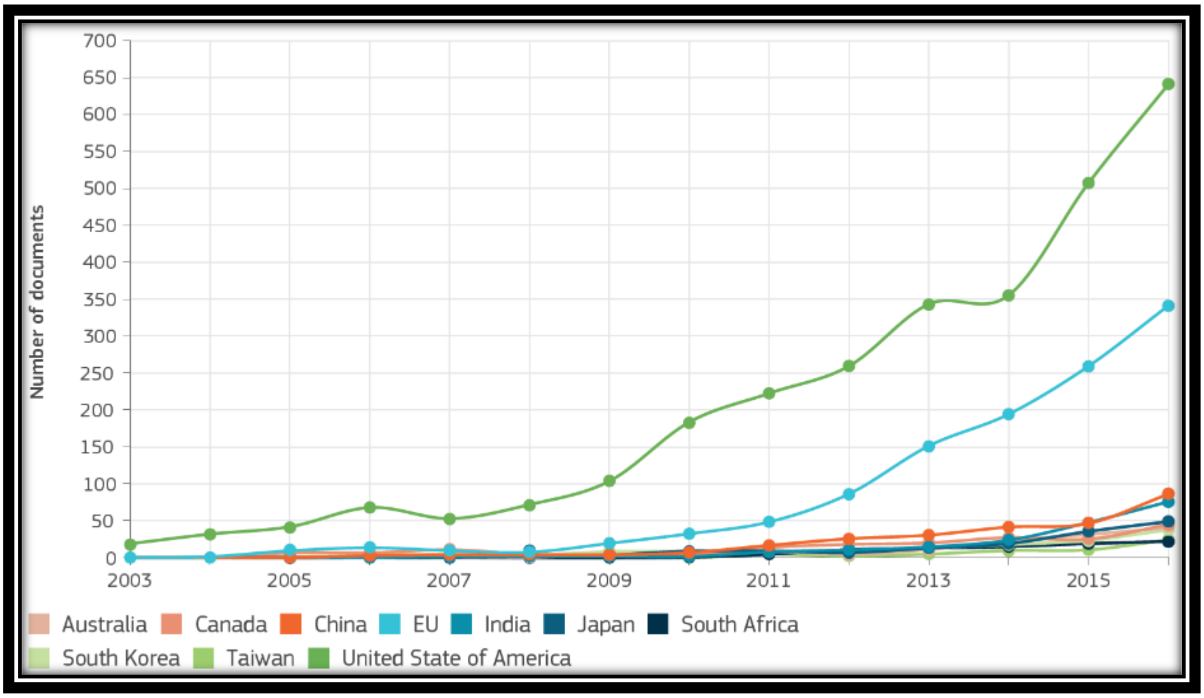

Figure 17. Scientific publications in cyber security per country ([Joint Research Centre, 2020](#)).

Australia Competitiveness and International Collaboration

As presented in Joint Research Centre (2020), research and development are primary indicators of the liveliness and competitiveness of a sector and its capacity to stay abreast of a given field.

Analysis of the cyber-security scientific literature indicates that the USA leads scientific research in cyber security, with half the publications. The EU is in second place with a quarter of the total number of publications, while the remaining quarter aggregates the scientific production of all the remaining non-EU countries (dominated by China, Canada and Japan), as shown in Figure 17. The majority of publications are concentrated in the security management, network security, data security and privacy, and cryptography domains (Joint Research Centre, 2020).

An analysis of the collaboration networks (see Figure 18) shows how the USA is the EU's strongest partner as regards its overall scientific production in cyber security, followed by China and Canada.

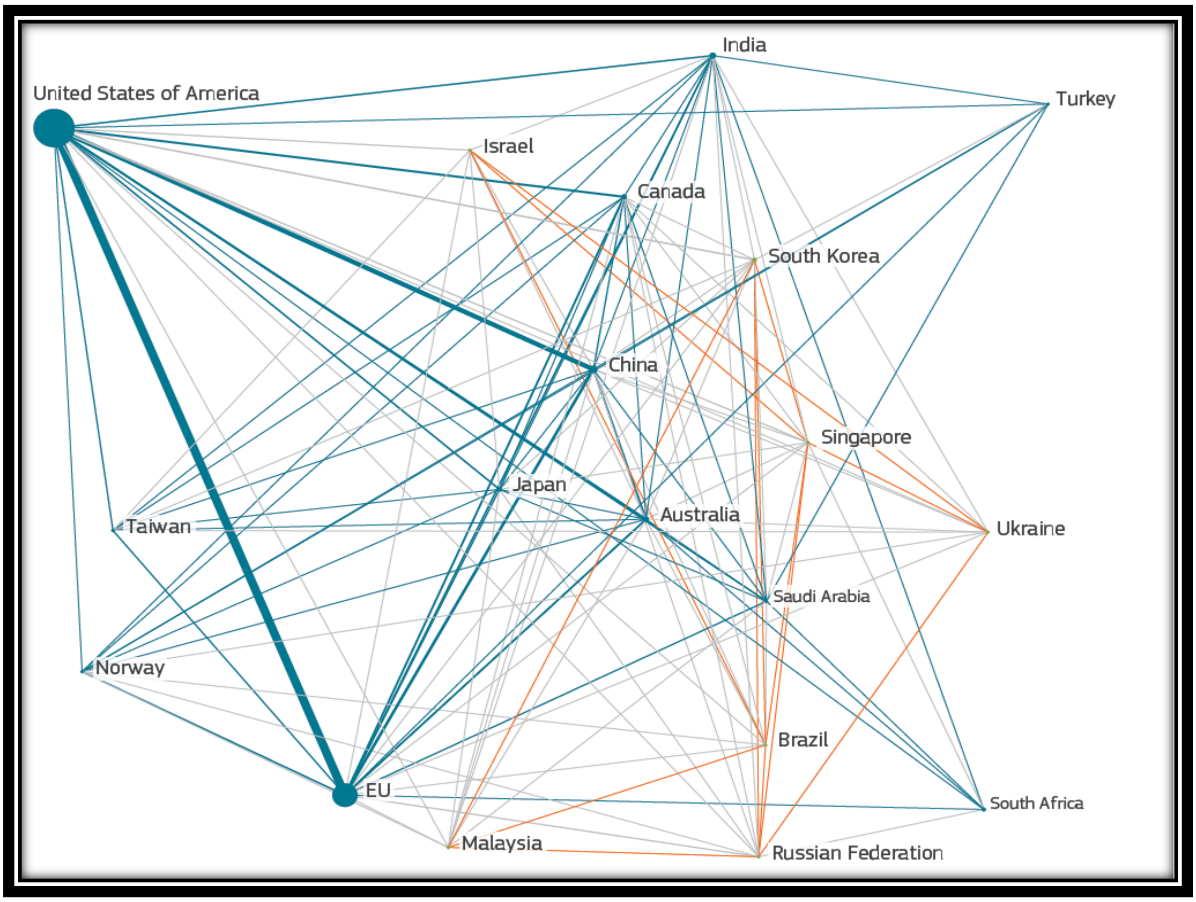

Figure 18. Country share of scientific publications in cyber security (size of nodes = number of projects, edge between nodes = project(s) in common, colours identify communities of countries collaborating more often) (Joint Research Centre, 2020).

Figure 19 gives a picture of patents in the cyber security sector where patent filing is dominated by China, followed by the USA, while Australia does not have a prominent position (Joint Research Centre, 2020).

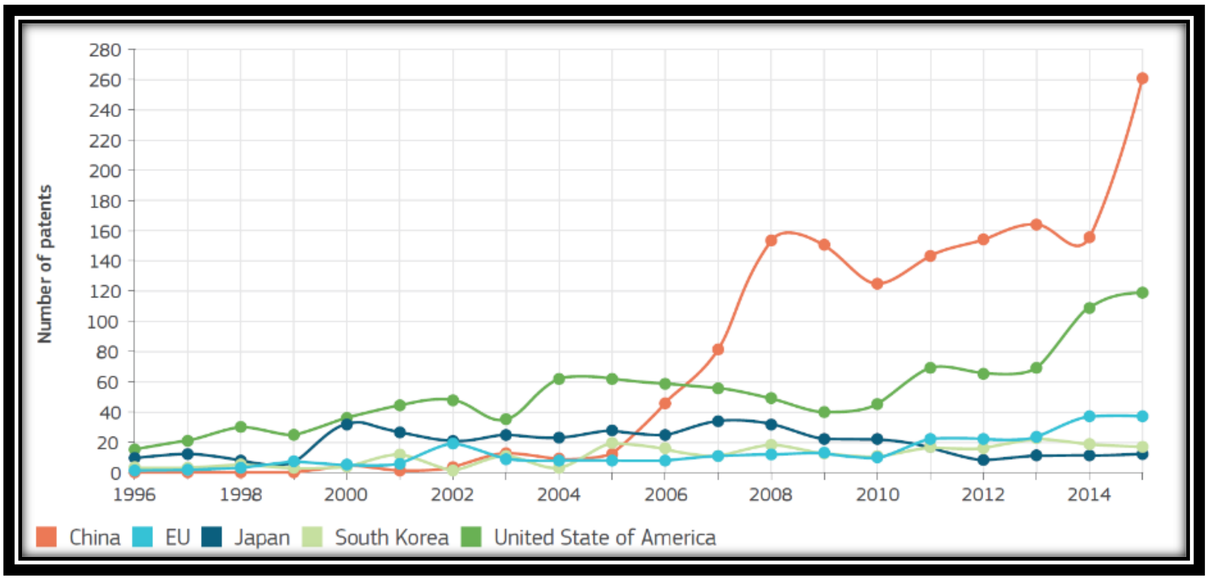

Figure 19. Patents in cyber security per country (Joint Research Centre, 2020).

The overall picture provided by this analysis shows that the Australian research landscape could be much more vibrant, productive and recognised at the global level. This could be improved by:

- Strengthening and enlarging the collaboration of cyber security research organisations across States/Territories and with the European Commission.
- Streamlining and stabilising the R&D cooperation between industry and academia.
- Better coordinating research funding across Australia and involvement in Horizon Europe[vi] – an ambitious €100 billion research and innovation program to succeed Horizon 2020.
- Co-designing research plans between funding bodies and recipients.
- Supporting the sharing of highly expensive infrastructures (in an Open Laboratory Initiative approach).
- Setting up an Australian Cybersecurity Industrial, Technology and Research Competence Centre and a Network of National Coordination Centres, aiming to create a more collaborative and synergetic Australian cyber security competence ecosystem.

Discussion and Recommendations

The Australia's 2020 Cyber Security Strategy (Australian Government, 2020b) has been recently unveiled and, while it delivers a reasonable foundation on which to build, there is still clearly much work to be done to deliver a truly comprehensive strategy for Australia (Moore, 2020).

A huge amount of work went into crafting this strategy with recommendations being delivered from many public and private organisations and individuals. Some of the key recommendations from the Industry Advisory Panel (Industry Advisory Panel, 2020), led by Andy Penn, Telstra CEO, were incorporated into the new 2020 Cyber Security Strategy. This includes, but is not limited to, the following:

- Strengthening the pipeline of skilled cyber security professionals.
- Clearly defining all critical infrastructure and systems of national significance.
- Appointing an Industry Advisory Committee to guide the Government on cyber security, including on implementation of current recommendations.

Yet, experts bemoan a lack of detail in the "what" and "how" of the cyber strategy (Smith, 2020). For example, some of the most important recommendations of the Industry Advisory Panel that would need further consideration are:

- Proactive mitigation strategies and strengthening of systems essential for end-to-end resilience of critical infrastructures.
- Measures to build trust in technology markets through transparency, such as product labelling.
- Promoting international law and increase operational-level cooperation with international partners.
- Getting major vendors to sign up to a voluntary 'secure by design' charter to leverage international best practice.
- Working with industry to increase Australia's role in shaping international cyber security standards.
- Encouraging diversity, transparency and competition in digital supply chains.
- Accelerating the adoption of appropriate standards to ensure digital products and services are 'secure by design'.
- Implementing a dynamic accreditation or mandatory cyber security labelling scheme.

We recommend that the Department of Foreign Affairs and Trade works closely with the European Commission (EC) and other Member States, and their partner cyber security agencies – such as the EU Agency for Network and Information Security (ENISA), the Federal Cyber Security Authority in Germany (BSI) and the National Cybersecurity Agency of France (ANSSI) – and establishes a close collaboration with international industry partners – such as the 3rd Generation Partnership Project (3GPP) and GSMA Mobile for Development Foundation (GSMA) – on 5G *security specifications* (3GPP, 2020c) and *network equipment security assurance scheme* (GSMA, 2020).

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This will make it possible for Australia to:

1. Promote *market forces*, risk-informed procurement *requirements* for assurance and transparency and development of supplier-focused minimal industry *practices* to meet those requirements.
2. Deliver a consistent set of *regulations* and additional recommended *practices* to address 5G security that allow the corresponding stakeholders to take responsibility and action for its overall implementation, and adhere to the principle of openness and transparency.
3. Show willingness to explore strategic and fundamental solutions with all relevant stakeholders and establish *flagship projects* aimed at attesting how 5G commercial products can leverage cyber security standards and recommended practices for relevant 5G use cases and scenarios, as well as showcase how 5G security features can be properly utilised.

This *iterative approach* will provide the indispensable *flexibility* to take advantage of newly introduced 5G security capabilities to deliver proper *cyber security practice guides* with the necessary standard of quality for their intended use.

Furthermore, the Australian Government and private sector should collaborate with the following organisations and promote:

1. *Recommendations* from the Global Commission on the Stability of Cyberspace (Global Commission, 2019), which builds on, e.g., UN work on norms.
2. *Contributions* of the Global Forum on Cyber Expertise (GFCE, 2020) for cyber capacity building and support for Confidence Building Measures (CMB).
3. The Commission *recommendations* from November 2019 (Global Commission, 2019) and the recommendations of the Paris Call in 2020 (Paris Call, 2020).

In order to realise this vision in Australia, the Federal Government should establish a close collaboration with international industry partners, such as the 3rd Generation Partnership Project (3GPP) on 5G security assurance specifications (SCAS) and GSMA Mobile for Development Foundation (GSMA) on network equipment security assurance scheme (NESAS) (GSMA, 2020).

The Australian Federal Government should be a major player among those organisations, support the continuous evolution of the 3GPP 5G technical specifications with evolving usage scenarios, adopt the GSMA NESAS/3GPP SCAS for testing and evaluating telecoms equipment, and enforce a certification and accreditation process (Industry Advisory Panel, 2020), against a predetermined set of security standards and policies, for security authorisation in Australia.

Furthermore, we advocate for a *Zero-Trust approach* to developing a Cyber Security framework – everything and every element should be checked and vetted thoroughly, no matter where it comes from (Soldani, 2020).

Our position is that adopting a Zero-Trust model can not only enhance security for existing 5G networks but also provide the framework for security architectures, as detailed by 5G Americas, in their recent white paper on "Security Considerations for the 5G Era" (5G Americas, 2020b).

5G brings about virtualisation, slices on private cloud, public cloud, and hybrid models, including data centres located even in different jurisdictions. This concept of "*5G without borders*" could bring security concerns and the Zero-Trust model may mitigate them to an acceptable level.

Zero Trust ensures that security is in place from untrusted domains (e.g., supply chain, Internet, user devices, other operators and partners) to and from within trusted domains (carrier networks).

Also, the Zero-Trust model meets the ETSI baseline requirements of cyber security for the IoT (ETSI, 2020).

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Endnotes

[i] This is true for data in use, at rest and in motion (transit). It also applies to any system and technology – such as AI, Cloud, IoT, 5G, 6G and beyond – used for processing, transmitting, manipulating and/or storing that data.

[ii] https://marketplace.service.gov.au/

[iii] https://www.business.gov.au/Grants-and-Programs/Cooperative-Research-Centres-CRC-Grants

[iv] https://www.dst.defence.gov.au/NextGenTechFund

[v] https://a3c.co/

[vi] https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme_en

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The Bellenden Ker Television Project

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Abstract: Two historic papers from 1974/75 detailing the construction of the Bellenden Ker television broadcasting station in far north Queensland.

Keywords: history, telecommunications, broadcasting, Mt Bellenden Ker

Introduction

Flying into Cairns is a wonderful experience with the Bellenden Ker Range (part of the Great Divide) to the west, separating the narrow wet tropical coastal plains from the rolling Atherton Tablelands inland. This mountain range is the highest in Queensland with two peaks over 1,500 metres above sea level, namely Bartle Frere South Peak at 1,615 metres and Bellenden Ker Centre Peak at 1,582 metres.

The range is aligned in such a way as to intercept the prevailing south-easterly winds, resulting in the highest average rainfall in Australia. Mt Bellenden Ker has recorded an average of over eight metres of rain annually and a maximum annual rainfall of more than 12 metres (Lavarack, 2015).

If the weather is clear, you may catch a glimpse of the communications tower on Mt Bellenden Ker as you descend into Cairns. This is one of the most unique television broadcasting stations in Australia. For those of us who were lucky enough to work in broadcasting in the 1970's, the station on Mt Bellenden Ker has an almost mythical status.

Purpose-built in the wettest place in Australia, capable of withstanding tropical cyclones with winds over 200 km per hour, it is fully remote controlled from Cairns (the first of its kind) and only accessible by helicopter or its own private aerial cableway, which rises 1,500 metres from the coastal plain over a run of 5km.

In the 1960's, the Australian Government had a policy of providing television as widely as possible. The capital cities were provided with services in the first two stages of development. In the third stage, services were provided to 13 of the highly developed and populated country

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areas and in the fourth stage a further 20 country areas were approved, including the Cairns region (Public Works, 1968).

By the mid 1960's, television had been provided in all the approved areas with the exception of the Cairns region. Temporary national and commercial television stations were established in the city of Cairns and had been operational since 1966, but only served about 40,000 people in a limited area around the City of Cairns.

Complex problems in finding a site and providing access due to the rugged surrounding country had delayed the establishment of a permanent station. The decision to establish a permanent station on Mt Bellenden Ker with access provided by an aerial cableway was made in 1968. The permanent transmitters would then serve about 90,000 people on the coastal plain north of Cairns to Mossman, south to Tully, and west to the Atherton Tableland (ABCB, 1970).

Prior to construction, the proposed design was referred to the Parliamentary Standing Committee on Public Works for investigation and report on the construction of a television transmitting station at Mt Bellenden Ker, by resolution on 11 September 1968 of the House of Representatives (Public Works, 1968).

This investigation looked at several alternate ways for providing television coverage in the Cairns region and confirmed that Mt Bellenden Ker was the optimal site for the station. It also verified the support of the relevant government departments, given the preferred design necessitated the establishment of an aerial cableway through a national park with minimal environmental impact.

The first historic paper (Poulson, 1974) details the propagation surveys, site selection, access cableway, transmitter building and installation. The second historic paper (Poulson & Reed, 1975) details the television & radio equipment, remote control and operation.

The first historic paper eloquently describes the significant logistical challenges of establishing a television station on Mt Bellenden Ker and details below are taken directly from that paper.

All civil engineering work associated with the project was carried out by the Australian Government Department of Housing and Construction. This included the bottom station access road, the transmitter building and the aerial cableway itself. The actual construction work relied almost entirely on the use of helicopters for transporting men and material to all of the cableway tower sites and to the top station on the mountain.

All of the material for the aerial cableway and the transmitter building was carried in this way. In addition, the helicopters were used as "flying cranes" for a large proportion of the rigging work, and it is a tribute to the skill of the pilots and riggers that the work was completed

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without any major accident. A total of some 2,000 flights were made during the course of construction, using up to three helicopters during the peak periods, and it is doubtful if the project could have been completed at all in any other way.

When the Austrian designed and manufactured aerial cableway was completed, it was subjected to inspection and test by the head of the Austrian Government Department responsible for licencing such installations in Europe and certified as to the safety and quality of construction.

As would be expected, the location and mode of access to the station led to some unique problems in the physical task of transporting all the required items to the site. The aerial cableway design had been based on a maximum net load of 1,000 kg, which was determined by the heaviest packed item of transmitting equipment and the heaviest items of a dismantled emergency engine alternator, these being the engine block and the alternator rotor.

This maximum load could only be carried by removing the construction car and slinging the load directly from the carriage hanger on the aerial cableway. An auxiliary carriage and hanger were necessary for long items such as tower leg members. Operation in this manner was time-consuming because of the difficulties involved in lifting and slinging the load at the bottom station and then removing it at the top, and was restricted to the large tower members and large heavy crates, which could not be fitted into the construction car.

A number of mechanical aids were essential throughout the transportation period. These included a mobile crane at the bottom station, hydraulic scissor lift tables at both stations, and a front-end loader used as a 1000 kg mobile crane at the top station. This loader was itself taken to the top in stripped-down form and reassembled on site by a motor mechanic.

Despite the logistic difficulties of material transport, all installation work, including the microwave links, transmitting tower and antenna and transmitters themselves, were completed in time to allow half power operation by Christmas 1972, less than eight months after the aerial cableway was made available to the broadcast installation team. Full power operation was not commenced until February 1973 after the existing channel diplexer for the temporary service had been shifted from Cairns to Mt Bellenden Ker and re-installed there.

The extreme design and construction challenges of this remote and wet location are the reasons why the television broadcasting station on Mt Bellenden Ker in far north Queensland has taken on an almost mythical status amongst broadcasters in Australia. It is my pleasure to provide the two historic papers below.

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The Historic Papers

The Bellenden-Ker Television Project – Part 1

A. B. POULSEN, B.Sc.,

The selection of Bellenden Ker as a television transmitting site for the Cairns region of North Queensland was a decision of some moment, necessitating the construction of a passenger cableway to the top of the Bellenden Ker Range for site access. Part 1 of this article outlines the factors leading to this decision, and describes the construction and operation of the cableway. Part 2 in the next issue of the Journal will describe the equipment installed in the transmitter building, and the operation of this equipment by remote control. This was the major factor permitting the integration of all radio operations in the Cairns area into a functional Radio District.

INTRODUCTION

This project had its genesis in the decision by the Australian Government in 1962 to provide a television service for the Cairns area in Phase 4 of the television expansion programme. The television transmitters installed were similar to those which had been provided at many other stations in Australia. The particular factors which made this project noteworthy were the difficulty of selection of a suitable site, and that the only practicable access to the site chosen was through a National Park. This required the provision of the most sophisticated cable-car system which had been provided in Australia at that time. As this mode of access would not be available in the extreme weather conditions which frequently prevail at the site, it was necessary to remotely control the television transmitters from the radio-communications terminal in Cairns, approximately 50 km from the site. This centre is the terminal of the Brisbane-Cairns microwave systems and also remotely controls three sound broadcasting stations located within the region.

Survey

From a general consideration of the parameters of propagation in the VHF spectrum, practicable transmitter powers and aerial gains, and community factors, it was decided that the area to be served should be as shown in Fig. 1. This area is bounded by the Cardwell Ranges in the south, includes the towns of Tully, Innisfail and Cairns along the coast and extends to Mossman in the north. Inland it encompasses the Atherton Tableland and the towns of Atherton, Mareeba, Herberton and Ravenshoe. The most significant feature of this region from a propagation viewpoint is the extremely rugged

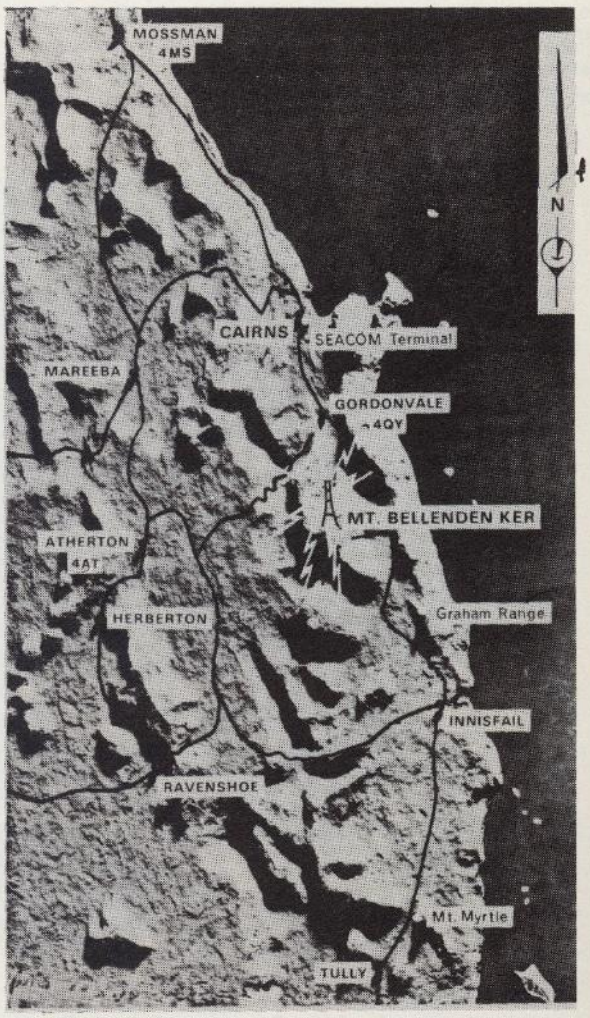

Fig. 1 — Topographic Model of the Region.

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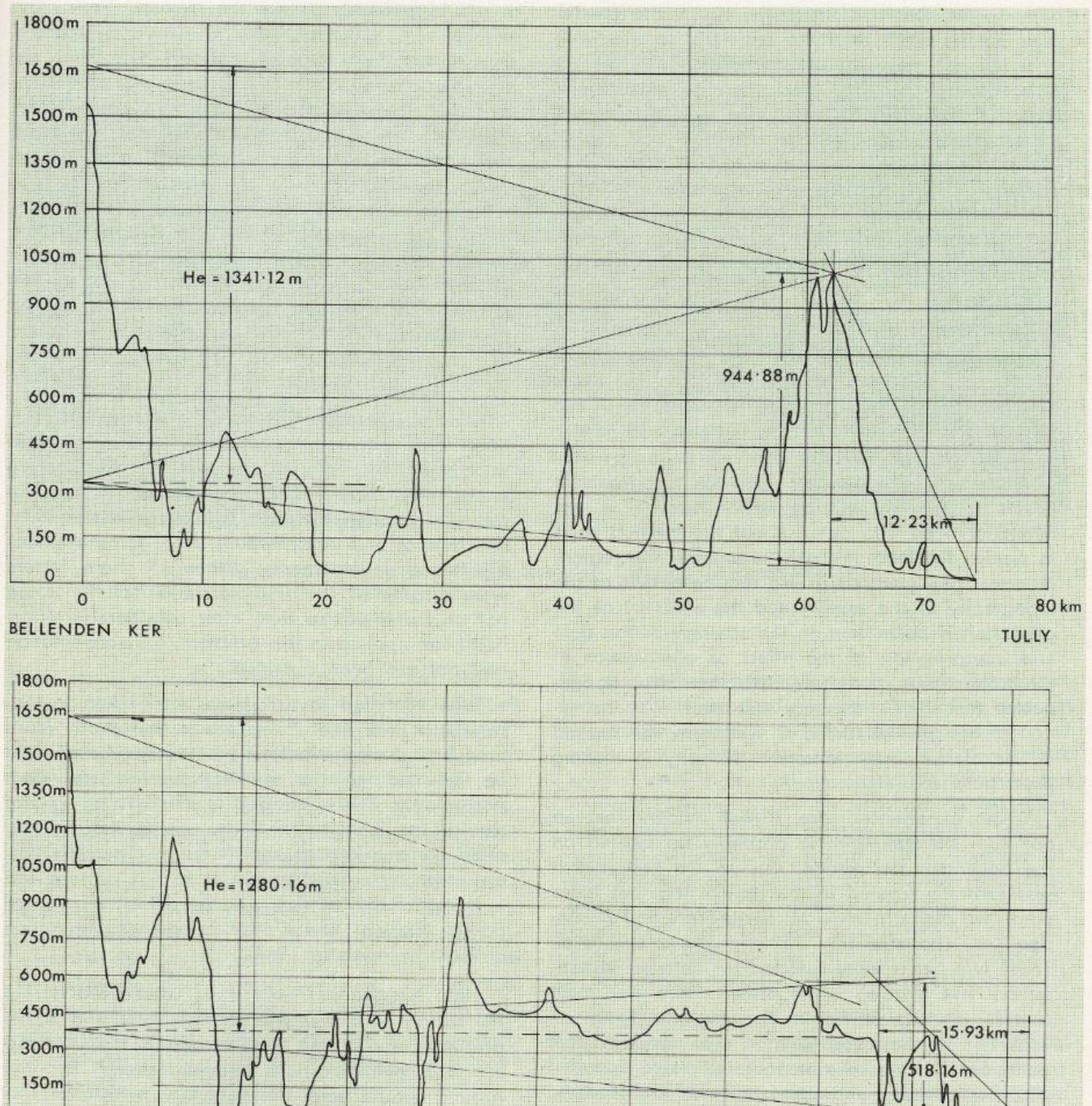

Fig. 2—Typical Profiles from Bellenden Ker to Towns of Interest.

nature of the terrain. In the centre of the region is the Bellenden Ker Range with peaks over 1500 m, dividing the region into three separate areas, namely, the coastal plain to the south, the coastal plain to the north, and the tableland to the west at a general elevation of over 600 m. However, in each of these subdivisions there are local topographical variations. Some idea of the rugged nature of this region can be obtained from Fig. 1 which is a photograph of a model of the region. Although it is a convenient simplification to refer to the main centres of population, it was necessary to consider most parts of the region in some detail due to the generally closely settled rural areas.

Site Selection

A suitable site for a television station is one which allows propagation conditions to the areas of interest such that a value of signal strength can be maintained which will give the required picture quality. The field strength received at any particular place will be dependent upon the topographical profile to the transmitting station site. It is not intended to go into detail about the method used to predict the field strength throughout the region. However, the methods in use require details of the topography of the region, and the accuracy of the prediction is dependent on the accuracy of this data and interpretation of the effect of obstructions in the transmission path. It must, therefore, be expected that some inaccuracy will result. An inspection of the profiles in Fig. 2 will show the rugged nature of the terrain and the difficulty in making predictions accurately.

To an experienced eye, it was evident that an optimum site would most probably be located on the Bellenden Ker Range, due to the fact that it was centrally located in the region and that there were two peaks, namely Mt Bartle-Frere and Bellenden Ker, approximately 1525 m above sea level. These two peaks were selected for detailed investigation and profiles were drawn from the main centres of population in the region. From an analysis of these profiles, it was evident that Bellenden Ker was the best site available and that Mt. Bartle-Frere, although generally satisfactory, would give obstructed transmission into the southern portion of Cairns, increasing the probability of "ghosting" due to multi-path transmission.

It was then necessary to investigate the establishment costs of each site. At this stage it was found that the eastern slope of the Bellenden Ker Range was a National Park, and, although the proposed site was not in the Park, the only practicable access would be through the Park. It was also evident that the construction of a road in such steeply sloping mountain country would be very expensive, maintenance would be costly, and that it would seriously deface the National Park. The responsible authority, the Queensland Forestry Department, very properly refused permission for an access road through the Park. Consideration was then given to Mt. Bartle-Frere as road access appeared practicable from the Atherton Tableland to the west at an elevation of approximately 600 m which could result in a decrease in the cost of road construction. It was considered that the problem of the propagation path into Cairns could be solved by the use of a low-powered translator suitably located in Cairns. An investigation of this proposed access road revealed that it would be exceedingly difficult and expensive to construct due to the complex geology of the mountain caused by its volcanic history.

Consideration was given to multiple station solutions. However, it became evident that this would be expensive and only partially effective. More importantly, there would be a problem in the allocation of frequencies which would not cause mutual interference and which would allow some channels for future developments. When all these factors were considered, the multiple station solution could not be sustained; so that, after considerable effort had been applied to this problem, a viable solution had not yet been obtained.

These detailed investigations had taken a considerable time and it was clear that much more time would elapse before a satisfactory site could be selected and a working service provided. Accordingly, it was decided to establish an interim service for the city of Cairns, using the existing radio communications centre there. The Commercial company agreed to join us in this venture and a low-powered service with an effective radiated power (ERP) of about 6kW commenced operation on both channels in 1966.

Light aircraft and helicopters were used during the survey to investigate possible sites and access problems, and during these operations it was apparent that communications between aircraft and the ground control were unsatisfactory, which was not surprising as those channels are also in the VHF band. At this time jet aircraft were being introduced for civil use and the Cairns Airport was being upgraded. It was clear that the proximity of high mountains to the Cairns Airport was a hazard which would require the upgrading of navigational aids and air-ground communications. It was also evident that Bellenden Ker, with an unobstructed "line of sight" to the Cairns Airport

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Fig. 3—Bellenden Ker Range, Showing Clearing Towards Top Site.

and its commanding view over all other obstructions, would be ideal for siting these facilities. This matter was discussed with the Department of Transport and an agreement was reached on the need to accommodate such services.

At this time, the Australian Post Office, in its general communications role, was proceeding with the introduction of Subscriber Trunk Dialling, and it was apparent that a considerable increase in trunk channels would be required between Cairns and the other towns in the region. These could be provided by coaxial cable systems, but, if a site at Bellenden Ker were available, considerable economies would be made by using microwave radio equipment. It was also evident that other services in the VHF band could be improved by location on this site.

All these factors caused a reconsideration of Bellenden Ker as a site and an attempt was made to find a way to develop it without affecting the National Park. It was evident that our need to serve the public interest in the provision of television services with conservation of the frequency spectrum was in conflict with the responsibility of another authority to serve the Public Interest by conserving the environment. As neither need could be said to have primacy over the other, some compromise was required between them. The decision was then made to investigate the feasibility of constructing a cableway across the National Park so that only a few points would be affected and minimal clearing would be required. A feasibility study was carried out by the Australian Government Departments of Housing and Construction, and Services and Property and it was established that a cableway could be constructed with long spans over the Park; this would require the location of a small number of trestles in the Park at a cost which would allow the project to proceed.

Negotiations were re-opened with the Forestry Department, who were the guardians of the National Park. The officers of this Department took their responsibilities for conservation seriously and had to be assured of the lack of a suitable alternative solution, and that the proposed cableway would not cause damage to the National Park. Ultimately, it was agreed that the proposal to locate the television station on Bellenden Ker with access by cableway could be agreed to by the responsible authorities and that they would each be able to discharge their specific responsibilities to the community.

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It should be recognised that the assessment of Bellenden Ker as the site was based on a method which required accurate topographical survey information. It was known that the available survey information was inaccurate and that the method of interpreting the effect of it required a good deal of judgment. Bellenden Ker was chosen with a knowledge of the probable imperfections from a transmission viewpoint, but with the surety that it was the best site available and that those imperfections in the service which would be provided could be corrected at some future time by the use of translators. The steeply sloping eastern face of the Bellenden Ker Range is shown in Fig. 3, which gives some indication of the rugged terrain typical of the region. It also shows the clearing made through the Park for the construction of the cableway. This clearing is now overgrown and is not visible at any distance.

System Design

This required that a transmitting station be constructed with access by cablecar. The station building was to house television transmitters for a National and Commercial service which were to be remotely controlled from the radio communications terminal at Cairns. The remote control system was also to cater for the operation of the 2 kW sound broadcasting stations at Atherton, Mossman and Gordonvale. In addition, the television station building would house microwave terminal equipment for the vision links, a repeater on the microwave system from Cairns to Atherton, air-ground communication systems for the Department of Transport and communication equipment for other services. A general outline of the radio and television facilities for the whole Cairns area, based on this concept, is shown in Fig. 4.

ACCESS CABLEWAY

General

The site finally chosen for the station was just south of Centre Peak in the Bellenden Ker Range. The cableway bottom station was located some 2 km west of the Bruce Highway and about 50 km south of Cairns. Climatic conditions in the area are severe; the average annual rainfall is approximately 4000 mm on the coastal plain and exceeds this in certain

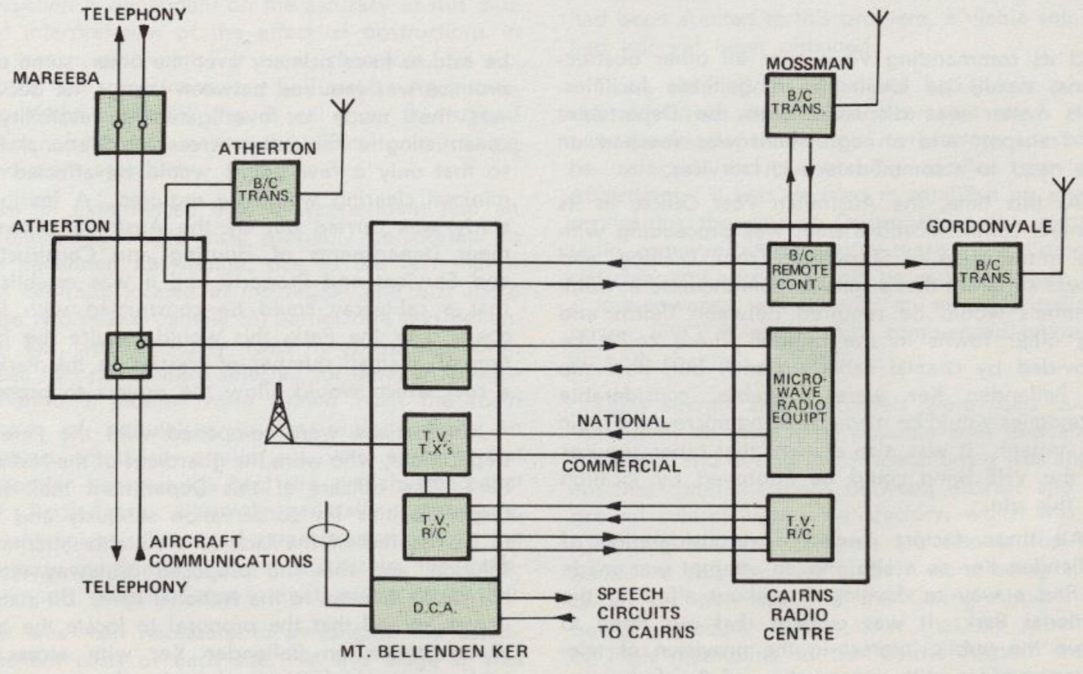

Fig. 4 — Communications Facilities Planned for the Area.

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elevated areas on the mountain ranges. Cloud cover on the peak is about 50% for more than half of the year and about 25% for the remainder. Although the general area enjoys a hot wet tropical climate, temperatures on the mountain top site frequently do not exceed 5°C for days on end, even in the summer months. The lower slopes are covered with dense tropical rainforest, while in higher areas the vegetation, although different in nature, still forms a thick cover. These conditions contributed in no small measure to the difficulties of the project.

In accordance with normal practice all civil engineering work associated with the project was carried out by the Australian Government Department of Housing and Construction (AGDHC). This included the bottom station access road and the transmitter building as well as the cableway itself. The AGDHC enlisted the aid of a consulting engineer in the design and specification of the cableway and a contract was ultimately let in April 1970 for the construction of the cableway bottom station and transmitter building on the mountain. The successful tenderer was McNamee Industries of Sydney, in association with the Austrian firm of Waagner-Biro, who provided the expertise necessary for the cableway itself.

Design

The cableway is described as a bicable to and fro system and consists of a track rope with a separate haul rope, all supported on nine steel towers on the eastern face of the mountain, rising from an RL of 90 m at the bottom station to 1550 m at the top. A profile of the cableway is shown in Fig. 5.

The steel wire track rope is 36 mm diameter, weighs 29.5 tonnes, and is manufactured and erected in one continuous length of some 5.3 km. As such, it is the longest cableway of its type in the world. The track rope is anchored at the top station by a number of turns around a large wood-rimmed concrete bollard, and is tensioned at the bottom station by a counterweight of 18 tonnes supported on a 27 m steel tower. The rope is supported at each intermediate tower on steel saddles with bronze lining inserts, which allow it to slide over the saddles as the catenaries change with temperature and movement of the cableway vehicles. The rope is kept well greased to assist this movement and as a corrosion preventative measure. The intermediate towers vary in height from 11 to 41 m, depending on span and location. Two of the spans are over 1.2 km long and the height of the track rope above the ground reaches 190 m in some places. Fig. 6 shows a typical cableway tower, looking up along the track.

The cableway carriage rides on the track rope and is moved to and fro between the top and bottom stations by a hauling rope. This is a steel wire rope 22 mm diameter, weighing 14.2 tonnes, and is in one continuous length of approximate 10 km. It is supported at each tower on rubber

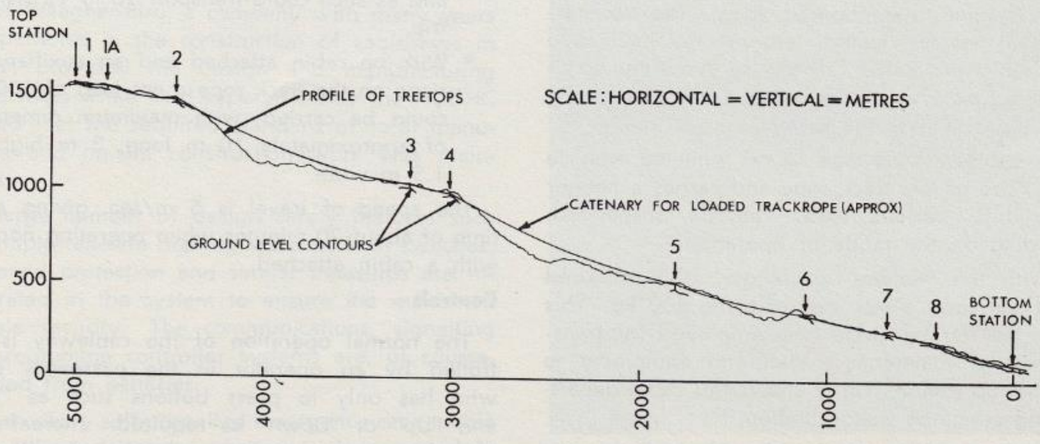

Fig. 5 — Profile of the Bellenden Ker Cableway.

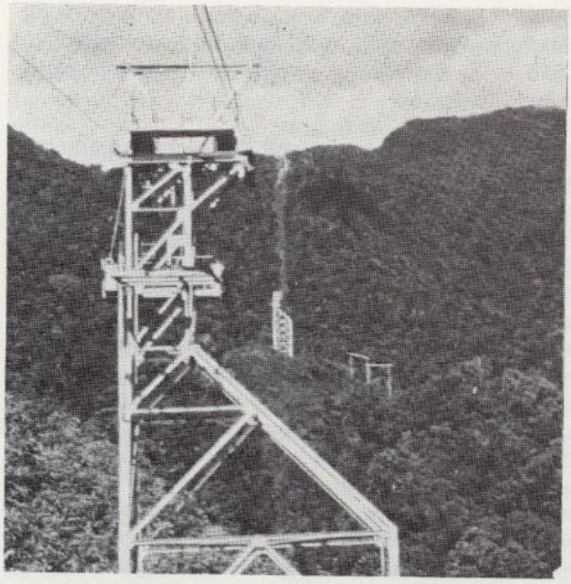

Fig. 6 — Typical Cableway Tower.

Fig. 7 — Cableway Passenger Cabin.

lined sheaves; this is necessary to insulate the haul rope so that it may be used for signalling purposes. The rope is driven by a large sheave 2 metres in diameter, known as the bull wheel, which in turn is directly driven by two hydraulic motors, powered by a pump from a 150 kw electric motor. The haul rope has one end attached to the cableway carriage, passes up over all the towers on sheaves on the northern side, around a counterweight carriage at the top station, down again on the return or southern side of the towers, around the bull wheel and is attached to the cableway carriage again, forming a continuous loop. The counterweight at the top station tensions the haul rope and is on a moveable carriage to allow for acceleration surges and sudden tension changes as the carriage passes over the towers.

The cableway carriage is a wheeled vehicle which rides on the track rope and carries a hanger from which various loads can be suspended, depending on the mode of operation:

- With the "deluxe" passenger cabin attached it can carry a net load of some 800 kg. This is the normal mode now employed for transport of maintenance staff and equipment to the top station. Fig. 7 shows this cabin departing from the botton station.
- With a construction cabin attached the net load is 900 kg. This was the mode mostly used for installation work at the top station and as such could transport 10 to 12 staff per trip.
- With no cabin attached and an auxiliary carriage on the track rope a net load of 1000 kg could be carried, with maximum dimensions of approximately 10 m long, 3 m high and 1.5 m wide.

The speed of travel is 5 m/sec, giving a trip time of about 20 minutes when operating normally with a cabin attached.

Controls

The normal operation of the cableway is controlled by an operator in the passenger cabin, who has only to press buttons such as "Start" and "Up" or "Down" as required. Thereafter an electronic programmed controller provides all necessary signals to the drive system to ensure a complete trip in the required direction, including reduced speed over towers and controlled deceleration and final stop at the terminal station. This is done by continuously monitoring the carriage position throughout the trip and generating the necessary control signals at a number of points as selected in the programme. Operation of the cableway can also be carried out from a control panel in the top station or the main control console in the bottom station. Manual control of the drive system can be exercised from any of these control points should the programmer become faulty.

All drive and programme control equipment is installed in the bottom station; there is also an emergency diesel engine and hydraulic pump which can operate the system at reduced speed under the manual control of an operator in the bottom station. This could be used, for example, in the event of a prolonged interruption of the primary AC power supply.

Communication between passengers in the cabin and the top and bottom stations is provided by a telephone circuit which operates by induction on the electrically insulated haul rope. This system is also used to provide VF control and monitor signals between the cabin and top station control panels and the bottom station equipment. In addition, FM transceivers have been provided for emergency communications between the passenger cabin, the top and bottom stations and the radio control centre in Cairns.

Safety Provisions

The basic safety of a cableway such as this is, of course, dependent on the initial specification and design of the system, which must be coupled with meticulous manufacture of critical components and careful installation of the whole system. The Austrian firm of Waagner-Biro, a company with many years of experience in the construction of cableways in Europe, provided the design and manufacturing competence, while field supervision by the AGDHC ensured that the required standard of local manufacture and on-site construction work was maintained.

A large number of design safety features such as multiple fail-safe braking systems, limit switches, overspeed protection and similar measures are incorporated in the system to ensure the maximum possible security. The communications, signalling and programme controller systems are, of course, operated from batteries.

An auxiliary self-propelled emergency car capable of travelling along the track rope is provided in the bottom station for rescue purposes or for inspection of the installation, for example, after a cyclone. In this context it is relevant to point out that the cableway system is designed to be operational in wind velocities of up to 80 km/hr, and to safely withstand a wind velocity of 225 km/hr.

Construction

It can be appreciated that a project of this magnitude, the first of its kind in Australia, was made even more difficult by the climatic and topographical conditions in the area.

Before any construction work could commence, it was necessary to clear a swathe along the cableway track from bottom to top of the mountain. The width of this had been strictly limited to 6 m by the Queensland Conservator of Forests, and clearing a track 6 m wide and 5 km long in a straight line over ridges and gorges was one of the many difficult tasks in the project. Part of this cleared track is shown in Fig. 8.

Fig. 8—Cleared Cableway Track to Top Site.

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The actual construction work relied almost entirely on the use of helicopters for transporting men and material to all of the tower sites and to the top station on the mountain. All of the material for the cableway and the transmitter building was carried in this way. In addition the helicopters were used as "flying cranes" for a large proportion of the rigging work, and it is a tribute to the skill of the pilots and riggers that the work was completed without any major accident. A total of some 2000 flights were made during the course of construction, using up to three helicopters during the peak periods, and it is doubtful if the project could have been completed at all in any other way.

The cableway towers, although relatively simple to erect, required considerable care in placement, since the track rope saddles at the top had to lie within ± 20 mm of a defined straight line along the cableway. In a track length of some 5 km, this necessitated precise surveying and positioning.

Hauling the track rope from the bottom to the top of the mountain was without doubt the most difficult task in the construction. This was done by first flying a number of drums of small diameter wire rope to various locations on the mountain, laying and joining these lengths by hand and using this rope and a winch at the top station to haul a larger wire rope into position. This was in turn used to finally haul the 36 mm track rope. Although the principle sounds elegantly simple, constraints such as ensuring that the 5 km of track rope was always kept under tension and not allowed to rotate, along with the very limited amount of clearing permitted along the track in the National Park, made the job both difficult and prolonged.

When the cableway was completed it was subjected to a searching inspection and test by the head of the Austrian Government Department responsible for licencing such installations in Europe, and certified as to safety and quality of construction.

Operation

The facility was made available to the APO for equipment and personnel transport in May 1972. For contractural reasons it was operated by the AGDHC during the first 12 months, during which time it was in use at least 6 days per week for the APO or by the AGDHC in site clearing work and the completion of certain building construction work. As would be expected with such a complex and unfamiliar facility, there were the usual initial operational problems, but in general these were not serious and were gradually resolved and eliminated during subsequent operation.

TELEVISION FACILITIES

Building

The top station transmitter building was designed in Queensland to suit all the known requirements of the site and equipment. Because of the difficulties and cost of material transport to the top station, a normal reinforced concrete building as used in other areas was not suitable. Instead of this a steel framed building using prefabricated insulated units for walls and pre-treated steel ribbed panels as external cladding was designed by the APO. The roof was of conventional steel decking, while the floors were constructed of steel decking topped with concrete. This method of floor construction meant that all holes for ducting and ventilation had to be detailed in advance so that suitable steel framing could be provided in the construction. Since the transmitter types had not been finally determined during the building design and documentation stage some educated guesses were necessary for such details. The layout of the building floors is shown in Fig. 9.

Because of the weather conditions at the site, namely up to 100% relative humidity and a large proportion of the time in fog and cloud, it was necessary to provide special treatment for the transmitter cooling air. With the two national and two commercial transmitters operating, an air change of 170 cubic metres per minute is required. The initial air intake is through a large bank of fibreglass filter panels, which remove most of the airborne droplets and fog. Behind these filters is a basement plenum chamber where hot exhaust air from the transmitters can be mixed with the inlet air. This mixture is warmed and dehumidified as a result and is then circulated through a secondary filter bank to the transmitter air blowers and returned by ducting to the plenum chamber where it can be either mixed with the incoming air as previously described or vented under the building. This process is controlled by a thermostat in the transmitter air inlets which operates control motors and vanes in the return air duct to vent the hot air instead of mixing it with inlet air. The design of the system is such that failure of a control motor will vent the return air thus ensuring that such a failure will not lead to transmitter overheating. When the transmitters are not operating small radiant heaters in the bottom of the inlet air ducts dehumidify any convected air and prevent condensation within the transmitter cabinets. This simple system has proven very satisfactory in practice and corrosion problems in the transmitters are expected to be minimal.

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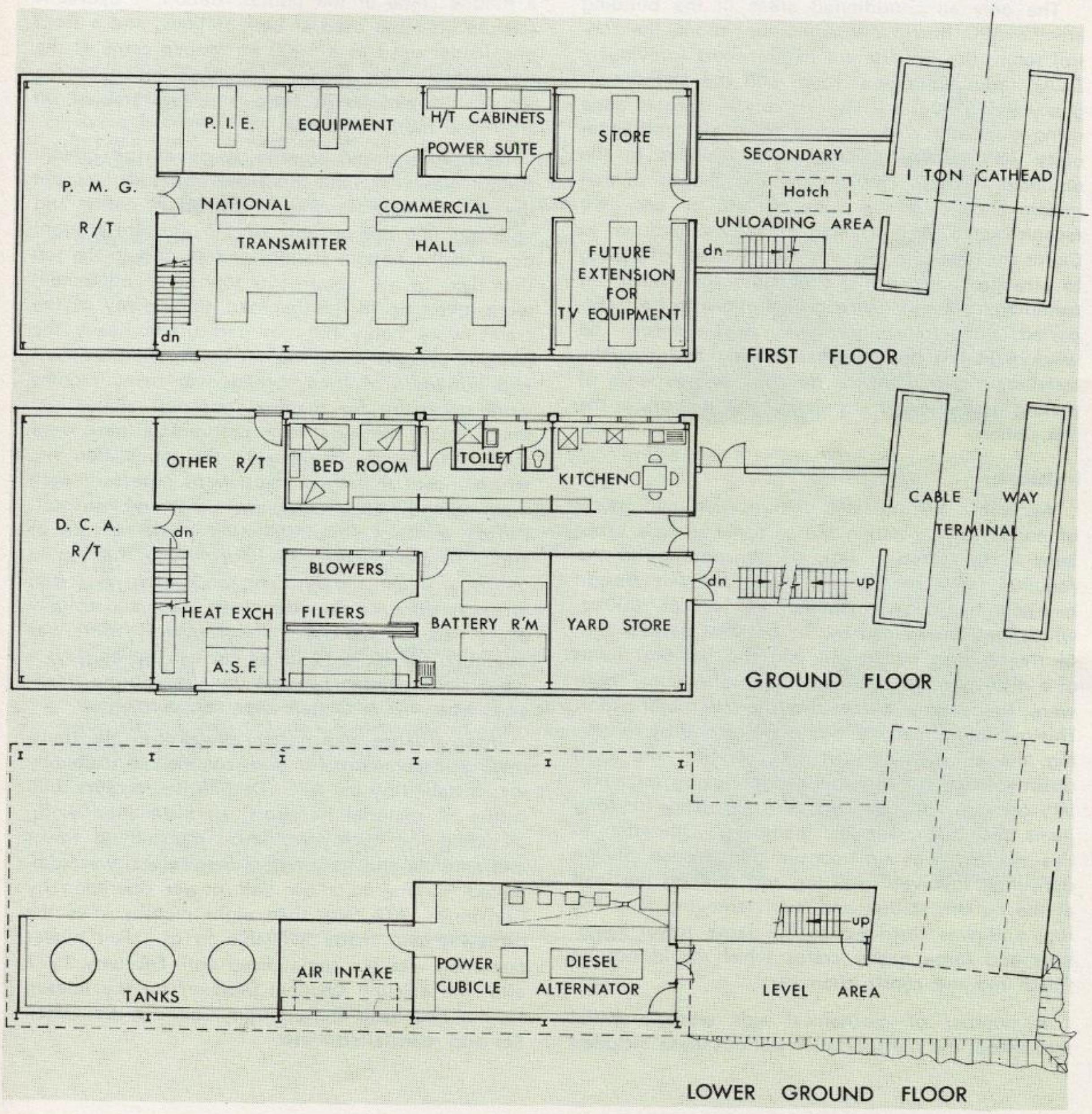


Fig. 9 — Floor Layout of Top Station Transmitter Building.

The only air conditioned areas in the building are the APO microwave equipment room, the control room, the Department of Transport (previously DCA), radio equipment room and the staff emergency living quarters. All air conditioning is done using duplicate wall-mounted room air conditioner units with automatic changeover facilities in the equipment areas. This system was chosen so that maintenance could be done on site by our own technical staff, or by taking a faulty unit down to Cairns for repair. In this way the necessity of having to arrange for specialist staff from commercial air conditioning maintenance organisations to be transported to the transmitter station was avoided. The wisdom of this decision was borne out during the installation period by the difficulty and expense of getting tradesmen of any description to work at the top station.

Installation

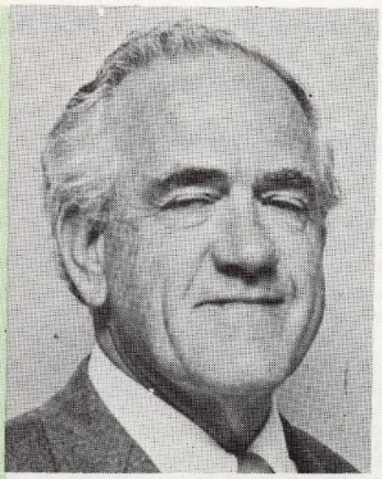
As would be expected the location and mode of access to the station led to some unique problems in the physical task of transporting all the required items to the site. The cableway design had been based on a maximum net load of 1000kg, which was determined by the heaviest packed item of transmitting equipment and the heaviest items of a dismantled emergency engine alternator; these were the engine block and the alternator rotor. This maximum load could only be carried by removing the construction car and slinging the load directly from the carriage hanger, using an auxiliary carriage and hanger where necessary for long items such as tower leg members. Operation in this manner was time-consuming because of the difficulties involved in lifting and slinging the load at the bottom station and then removing it at the top, and was restricted to the large tower members and large heavy crates which could not be fitted into the construction car.

A number of mechanical aids were essential throughout the transportation period; these included a mobile crane at the bottom station, a hydraulic scissors lift table used at both stations, and a front end loader used as a 1000 kg mobile crane at the top station. This loader was itself taken to the top in stripped down form and reassembled on site by a motor mechanic.

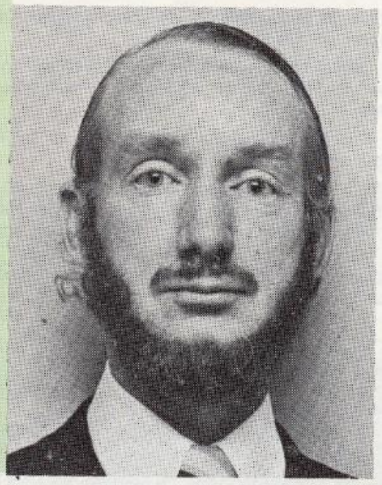
Because enclosed storage space at the bottom station was very limited all the equipment except the tower steelwork was stockpiled in Cairns and each morning one or more truckloads were brought down to the bottom station for transport to the top that day. In all, about 150 tonnes of equipment were taken up in this manner; since many of the crates were bulky but not particularly heavy the payload on most trips was far below the maximum and hundreds of trips spread over many months were necessary for material transport alone. At times during the installation programme there were almost 30 people working on the top station site which meant that three trips were necessary each morning and each afternoon for personnel transport. During most of the installation phase a core of about 10 staff worked 12 hours a day, starting in Cairns at 7 am and finishing back there at 7 pm; this was done on five days per week and usually every second Saturday. The cableway itself was operating for 10 to 12 hours per day, seven days a week since maintenance was done during the weekends when the APO staff were not working.

In accordance with normal practice, all the transmitting equipment for the commercial company was installed by the APO. Despite the logistics difficulties of material transport, all installation work, including the microwave links, transmitting tower and antenna and transmitters themselves, was completed in time to allow half power operation by Christmas 1972, less than eight months after the cableway was made available to us. Full power operation was not commenced until February 1973 after the existing Channel Diplexer for the interim service had been shifted from Cairns to Bellenden Ker and re-installed there.

A. B. POULSON graduated as an Engineer through the Cadet Engineer training scheme in 1949. After some years of general engineering experience he joined the Radio Section in the Queensland Administration and became Divisional Engineer, Broadcasting, in 1956. He subsequently became Divisional Engineer, Television, and was responsible for the implementation of the Television installation programme from its inception until 1969, during which period this project was planned. He is at present Superintending Engineer, Regional Operations Branch.



P. J. REED joined the APO in 1956 as a Cadet Engineer and graduated as a Bachelor of Electrical Engineering from the University of Queensland in 1960. After a year in the Radio Section he spent sixteen months in the Materials Division being responsible for the Materials Testing Laboratory. Following this he returned to the Radio Section and was involved in several areas before joining the Television Division in 1963. During the next ten years he was responsible for the planning and installation of most of the high-power television transmitting stations in Queensland. In 1973 Mr. Reed transferred to the Metropolitan Operations Branch, where his present position is Acting Engineer Class 3, Switching and Transmission, City Operations Section in Brisbane.



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The Bellenden Ker Television Project (Part 2)

A. B. POULSEN, B.Sc., Dip P.A., M.I.E. and P. J. REED B.E.

Part 1 of this article, in the previous issue of the Journal, outlined the background to the Bellenden Ker television transmitter and radiotelecommunications project, and described the construction of a passenger cableway to the top of the Bullenden Ker range for site access. This second part of the article describes the equipment installed in the transmitter building and the operation of this equipment by remote control. This was the major factor permitting the integration of all radio operations in the Cairns area into a functional Radio District.

TELEVISION AND RADIO EQUIPMENT

Reliability was of course the primary consideration for equipment to be installed in such an isolated location, and this was achieved in general by the selection of high quality equipment of known performance and stability, and the use of solid state design wherever possible.

The microwave radio installation carries the two television programmes, National and Commercial, from Cairns to Bellenden Ker and also some 600 bothway channels of telephony between Cairns and the Atherton Tableland. In addition to this, a number of VF channels are available between Cairns and Bellenden Ker for such purposes as remote control channels, order wires and for use with VHF base stations for "Other Services" such as Police and Ambulance. The Cairns to Bellenden Ker hop is in the 2 GHz band to minimise fading attenuation from heavy tropical rainfall, while the remainder of the link to the Tablelands is in the normal 4 GHz spectrum. Equipment installed by the Department of Transport includes a number of transmitters and receivers in the 120 MHz band for air-to-ground communications, together with associated VF channels to Cairns.

The television equipment itself is fairly conventional and comprises a "shared" installation such as has been put into operation at many other places in Australia. The sharing concept implies that as much common equipment as possible is used by both National and Commercial interests and includes items such as the building itself, test equipment, the transmitting antenna tower and in this case the transmitting antenna as well. Under such an arrangement the APO also carries out all operational and maintenance activities on the commercial transmitting equipment. The main factor distinguishing the transmitting equipment from other similar installations is that it was designed and installed to be suitable for colour transmission which, at the time of planning, was some years in the future.

A block diagram of the national television facilities for Channel 9 is shown in Fig. 10. The commercial facilities for Channel 10 are similar, except that the test equipment and similar items are not duplicated. Each channel consists of twin 5 kW vision and 500 W sound transmitters operating in parallel. These outputs are then combined in a Channel Diplexer so that a common transmitting antenna may be used. This antenna itself consists of two halves which are fed from a power splitting transformer. Parallel transmitter operation guards against programme breaks in the event of a fault in one unit, while the use of a common antenna results in considerable economies in capital expenditure for antennas and the supporting tower. The programme input equipment for the transmitters has been kept as simple as possible to minimise maintenance problems on site. The video and audio channels are duplicated; complex devices such as stabilising amplifiers are not provided but may be inserted in the programme chain at Cairns if required at any time. In addition to the normal programme, a video and audio test signal source or an emergency slide and music may be selected for transmission.

A transmitting tower near the eastern face of the building carries all antennas for the complex.

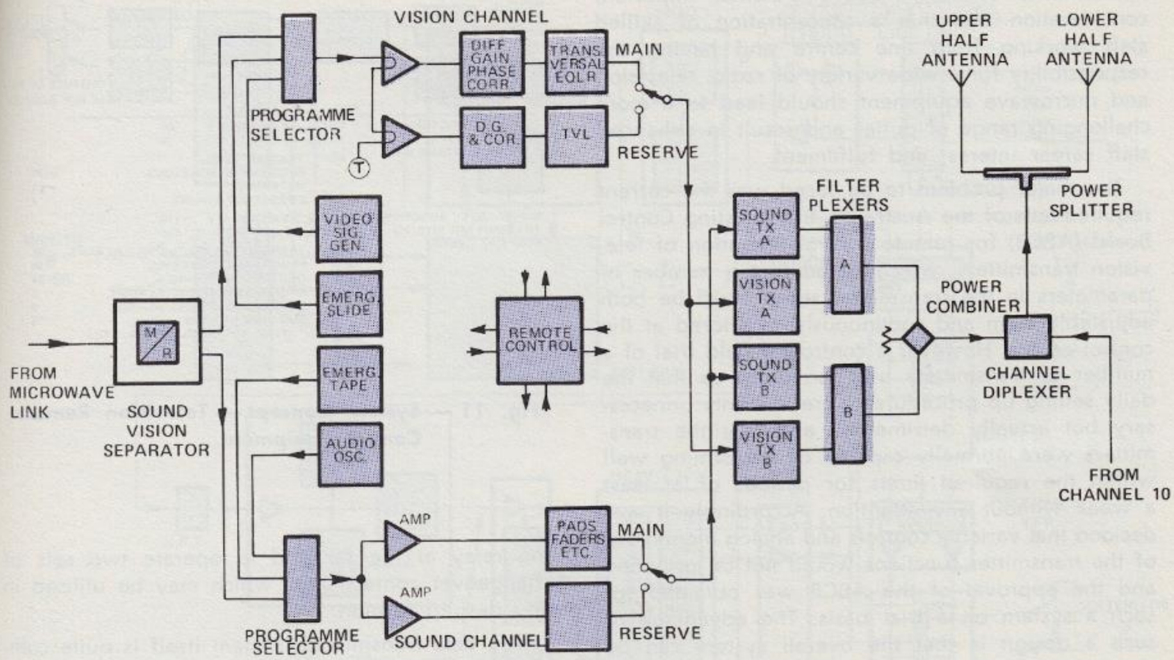

Fig. 10 — Channel 9 National Television Facilities.

This tower consists of a standard 60 m extreme duty microwave link tower modified with offset footings to suit the site and a 25 m extension to carry the two-section television transmitting antenna which consists of six bays of double-dipole panels. In addition to this, a number of 3 m parabolas for the microwaves links, and discone antennas for the air-ground communication links are mounted on this common tower, which is designed to resist winds of 225 km/hr.

All equipment in the building is supervised by a special fire protection system. This consists of smoke detectors installed in strategic areas of the transmitters and equipment rooms, backed up with thermal detectors and BCF pressure sprays. Operation of a smoke detector in a transmitter causes circuit breakers to remove all primary AC power from that transmitter and transmission of an alarm to the control centre. Should combustion continue in any cabinet a thermal detector actuates a BCF pressure spray in the cabinet. Equipment areas have smoke detectors for early warning alarms, backed up by a number of BCF bottles with thermal heads.

Emergency power for the building and equipment is provided by a 170 kVA diesel alternator, arranged for automatic start and load transfer should the incoming AC mains vary outside preset limits. The plant runs until normal mains have been restored and then closes down automatically in a controlled sequence. Starting and stopping of the plant may also be done by remote control if required for any reason. Sufficient fuel is stored on site in service tanks to enable the station to run for at least one week on full load during prolonged interruptions to the commercial mains supply.

REMOTE CONTROL EQUIPMENT

The whole design philosophy of the equipment installation was based on the plan to operate by remote control from Cairns. Factors which influenced this decision were mentioned previously and included the isolation of the station as well as the possibility of considerable savings in operational costs by having an integrated radio control and maintenance centre in Cairns. Another important consideration was that a concentration of skilled staff working from one centre and having the responsibility for a wide variety of radio, television and microwave equipment should lead to a more challenging range of duties and result in enhanced staff career interest and fulfilment.

The major problem to be faced was the current requirements of the Australian Broadcasting Control Board (ABCB) for remote control operation of television transmitters, which stated that a number of parameters in the transmitted signal must be both adjustable from and continuously monitored at the control centre. However a controlled field trial of a number of transmitters had convinced us that the daily setting up procedures were not only unnecessary but actually detrimental, and that the transmitters were normally capable of performing well within the required limits for periods of at least a week without any attention. Accordingly it was decided that variable controls and analog monitoring of the transmitter functions would not be provided and the approval of the ABCB was obtained for such a system on a trial basis. The advantage of such a design is that the overall system can be less complex, thus lowering the capital cost and reducing maintenance problems.

Once such a system was defined and the details of the equipment to be installed were known it was possible to specify how many bits of data were necessary for satisfactory operation between the control centre and the station. This consisted of a number of "On", "Off", "Select" and similar functions to control the transmitting equipment together with similar status indications at the control centre to monitor the equipment functions and alarms. Previous experience at another station had convinced us that the most satisfactory method of installing remote control equipment was to buy the data transmission system as a "black box" with the required number of bits and to design and install any necessary interface equipment to suit our own requirements. This concept has particular relevance where a complex system of controlled outstations is involved. The system design was for a control centre in Cairns to control and monitor the two sets of television transmitters on Bellenden Ker and the three MF broadcasting transmitters at Mossman, Gordonvale and Atherton. After careful consideration the data transmission system finally chosen was a two-address system for the TV control and a separate three-address system for the broadcast control. A block diagram of the basic system concept is shown in Fig 11, which also specifies in general terms the allocation of data bits to the various functions in each direction. An earth on any input at the data transmitter will cause a corresponding relay at the far end to operate two sets of changeover contact units which may be utilised in any desired fashion.

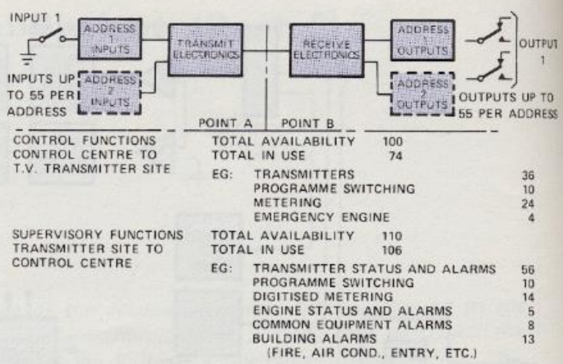

Fig. 11 — System Concept — Television Remote Control Equipment.

The data transmission system itself is quite complex and a simplified functional diagram is shown in Fig. 12. Input data is supplied in parallel form and each address block has 55 available inputs. The transmitter scans each input of address A in sequence and the input data is converted to a serial form of short pulses (SP) or long pulses (LP) corresponding to open circuit or earth on the inputs. This pulse train is used to phase reversal modulate a VF carrier generated in the equipment and this carrier is sent to line after suitable filtering and processing. The pulse train consists of 64 bits; the first five bits carry the address information in binary coding; the 55 data bits follow; then comes 2 bits for system alarms, a parity check bit and finally an "extra long" synchronising pulse (ELP) which updates the memory and prepares for the next pulse train. When the first pulse train is completed, a programmer steps the scanner to address B, which has another 55 inputs but is identified by a different binary coding of the 5 address bits. These inputs of the second address are similarly encoded and transmitted and the process continues, stepping around as many addresses as are provided before returning to the first. The speed of transmission is set by the clock pulse generator and may be varied from 50 to 1200 bauds depending on requirements and the availability of a suitable VF signalling channel. In the Bellenden Ker system a speed of 200 bauds was chosen. This ensures that the maximum response time from the initiating of a command in the control centre to the receipt of an acknowledgement from the transmitter is about 2.5 seconds.

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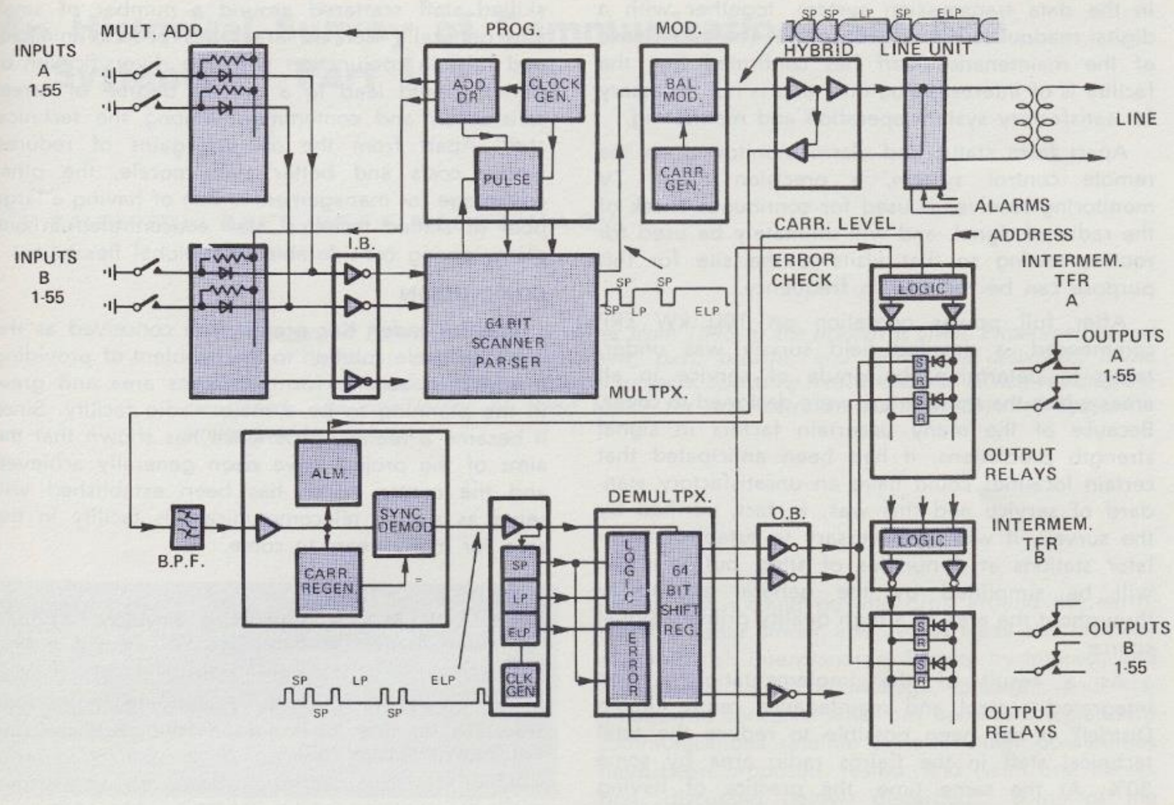

Fig. 12 — Data Transmission Equipment — Transmit and Receive Electronics.

At the receiver, the input carrier is filtered, amplified, clipped, synchronously demodulated and processed to give a pulse sequence identical to that originating in the transmitter. For each transmitter address there is a corresponding intermemory transfer circuit and set of output relays in the receiver which form a latching permanent memory. As a pulse train is received the condition of each pulse (long or short) is stored in a temporary memory and converted from serial to parallel form again. During the last extra long synchronising pulse the contents of this temporary memory store are transferred to the permanent memory relays of the corresponding address provided a number of message checks are valid. These include—

- Input signal level
- Total number of pulses
- Correct parity
- Correct sync pulse length
- Correct address coding.

If these checks are verified the data is transferred to the appropriate permanent memory relays as determined by the address bits at the beginning of the pulse train. The numerous checks applied to each message ensure the system is very reliable even when channels with poor signal/noise ratio are used. Extensive use of integrated circuits is made and the system has been very reliable in operation.

Operation

At the control centre in Cairns control panels are provided with push-buttons for operation of all required facilities. Integral status indication lights are provided to give continuous indication of all monitored functions and alarms. As stated previously, analog monitoring of such functions as vision transmitter power is not part of the system design; instead two preset alarms for "power high" and "power low" are provided; each of these needs only 1 data bit for transmission. However, in order to assess the usefulness or otherwise of such a facility, provision was made for analog monitoring of selected quantities using an analog-to-digital converter at the transmitters and a number of bits in the data transmission system, together with a digital readout at the control centre. The experience of the maintenance staff has confirmed that the facility is of interest value only and is not necessary for satisfactory system operation and monitoring.

Apart from status and alarm monitoring on the remote control system, a precision off-air TV monitoring receiver is used for continuous check of the radiated signal, and will ultimately be used for routine testing so that visits to the site for this purpose can be reduced in frequency.

After full power operation on 100 kW ERP commenced, a detailed field survey was undertaken to determine the grade of service in all areas which the transmitters were designed to cover. Because of the many uncertain factors in signal strength predictions, it had been anticipated that certain localities could have an unsatisfactory standard of service and this was, in fact, verified by the survey. It will be necessary to establish translator stations at a number of sites, but this task will be simplified by the general availability throughout the area of a high quality primary signal source.

As a result of the implementation of an integrated control and maintenance centre (Radio District), it has been possible to reduce the total technical staff in the Cairns radio area by some 30%. At the same time, the practice of having skilled staff scattered around a number of small and generally isolated areas has been eliminated, and this, in conjunction with the diversification of duties should lead to a greater degree of career satisfaction and contentment among the technical staff. Apart from the obvious gains of reduced labour costs and better staff morale, the other advantage for management is that of having a large pool of skilled technical staff concentrated in one place, giving considerable operational flexibility.

CONCLUSION

The Bellenden Ker project was conceived as the best realisable solution to the problem of providing a television service for the Cairns area and grew in the planning to be a major radio facility. Since it became a reality, experience has shown that the aims of the project have been generally achieved and the centre which has been established will serve as a vital telecommunications facility in the area for many years to come.

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The NBN Futures Forum

Towards a National Broadband Strategy for Australia, 2020-2030

Leith H. Campbell
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Abstract: On 24 November 2020, TelSoc hosted the fifth NBN Futures Forum, held online, to launch the first major report, *Towards a National Broadband Strategy for Australia*, from the NBN Futures Group. The report, which summarized nearly two years of deliberations by the NBN Futures Group, contained 13 conclusions that were presented and discussed at the Forum. These conclusions supported the view that broadband is an essential service for Australia's digital economy and society and that Australia's National Broadband Network (NBN) is central to broadband provision. They promoted the concept of an overarching National Broadband Strategy to achieve social, economic and governmental goals. In addition to the main speech presenting the report's conclusions, there were written statements from the Minister and Shadow Minister, supplementary remarks from two members of the NBN Futures Group, commentary from three panellists on consumer, policy and governmental perspectives, and general discussion. This paper summarizes the full content of the Forum.

Keywords: NBN, public policy, national strategy

Introduction

The NBN Futures Project (Holmes & Campbell, 2019) has been organizing a series of public forums under the title NBN Futures to encourage debate, and potentially to build consensus, about the future of Australia's National Broadband Network (NBN). The forums are hosted by TelSoc (the Telecommunications Association Inc, publisher of this *Journal*). The first forum was held in July 2019 (Campbell & Milner, 2019), the second in October 2019 (Campbell, 2019), the third in February 2020 (Campbell, 2020), and the fourth in August 2020 (Campbell, Smith & Brooks, 2020).

The fifth forum, held online on 24 November 2020, was to launch the report, *Towards a National Broadband Strategy for Australia*, from the NBN Futures Group. The report, published elsewhere in this issue (Holmes *et al.*, 2020), summarizes the deliberations of the NBN Futures Group in 2019 and 2020 on broadband access in Australia and the role of Australia's National Broadband Network (NBN). It argues for an overarching National Broadband Strategy for the decade to 2030.

The Forum was structured as follows:

- Introductory remarks by Mr John Burke, convenor of the NBN Futures Group;
- The main presentation on the report, focussing on the conclusions, by Dr Jim Holmes, President of TelSoc and a member of the NBN Futures Group;
- Short supplementary remarks by Dr Leith Campbell and Dr Murray Milner, members of the Group;
- A summary of written statements received from Australia's Minister of Communications (The Honourable Paul Fletcher MP) and the Shadow Minister (Ms Michelle Rowland MP);
- Brief comments from panellists Ms Teresa Corbin, Ms Deena Shiff and Dr Helen Haines MP;
- General discussion, introduced by Mr Allan Horsley, a member of the NBN Futures Group.

The remainder of this paper summarizes the content of each part of the Forum.

The NBN Futures Forum

The Forum was conducted online via Zoom. There were more than 80 people registered to attend and at least 54 of them were online for all or part of the session.

Introduction and context

Mr John Burke, the convenor of the NBN Futures Group, described how early discussions on the future ownership of NBN Co had led to a realisation that broader considerations were required and decisions about broadband, fixed and mobile, and the NBN needed to be put in a proper context. The aim of the Group was to promote discussion of broadband and NBN issues within the framework of a broader strategy to realise social and economic benefits. Previously, four Forums have been held and 10 related articles published in the *Journal of Telecommunications and the Digital Economy*.

He noted that there had been significant change over the past two years. The Covid crisis, especially, had changed perspectives about the value and necessity of broadband access in the home and for business. There had been new government initiatives, such as the formation of the Australian Broadband Advisory Council and the Digital Technology Taskforce, and new

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announcements from NBN Co about network upgrades and further support for wholesale prices. These initiatives were welcomed by the Group.

Finally, John Burke noted that the report to be discussed in this Forum was not a conclusion but, rather, part of a process to develop a broadband strategy and realise the benefits of broadband and the NBN for Australia.

Launch of the report

Dr Jim Holmes, TelSoc President and member of the NBN Futures Group, launched the new report, *Towards a National Broadband Strategy for Australia*, by outlining what is hoped to be achieved and describing each of the 13 conclusions in the report. The full report is published elsewhere (Holmes *et al.*, 2020) in this issue.

He indicated that the Group hoped to achieve the following outcomes:

- A recognition of broadband as an essential service for Australia's digital economy and online society;
- The nomination of the NBN, which is central to broadband provision, as long-term National Critical Infrastructure;
- Ongoing support for the NBN including through continued investment in its development, so that it can realise its full potential for all Australians;
- An understanding of the role of 5G technology as both a complement and a competitor to NBN infrastructure;
- The development of a long-term National Broadband Strategy to achieve social and economic goals, through a coordinated whole-of-government approach and with engagement of all stakeholders;
- A bipartisan approach to the strategy so that it can continue beyond commercial planning and electoral cycles.

He suggested that the report specified only the minimal essential items that should be included in a National Broadband Strategy. There are multiple aspects, described in the annexes to the report, that are all interconnected and should be considered as a whole.

Jim Holmes then discussed each of the conclusions in the report. They are as follows (with emphasis added in the presentation):

1. Australia needs to have a *National Broadband Strategy* reflecting national broadband policy settings and providing long-term guidance for the development of infrastructure and services and for ensuring that all Australians enjoy the full potential social and economic value of broadband (fixed or mobile).
2. The National Broadband Strategy must:

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a. articulate that Australia is committed to continuously developing and maintaining *world-class broadband* infrastructure and services that will be provided to *maximise social and economic inclusion*, and to express in detail what this means at nominated points in the timescale covered by the Strategy;
b. be *longer-term in its perspectives*, and initially provide a clear roadmap for the next 10 years;
c. be broadly based and broadly supported, seeking the *bipartisan support* necessary for certainty, continuity and consistency across the life of multiple parliaments;
d. be concerned to ensure that the network benefits from broadband investment – that is, benefits to society at large, not realisable at the enterprise level – are identified, assessed and realised;
e. emphasise the *demand-side aspects of broadband service*, and the need to maximise economic and social inclusion through policies that deliver high quality affordable broadband services to all areas, sectors and customer segments;
f. recognise that broadband infrastructure and services will be provided by *many vendors on many platforms*, but also that the NBN will have a central part to play for at least the next 5-10 years in Australia; and
g. establish a *Universal Broadband Service roadmap* with clear download and upload targets and intermediate milestones, while recognising that flexibility to address future unknown application innovation will be a critical success factor.

3. The National Broadband Strategy needs to outline the *policy and regulatory settings*. NBN Co should not enjoy any form of statutory monopoly in broadband access service provision, subject to the existing time-bound prohibitions on Telstra running their course.
4. The Strategy should make provision for *regular assessment of broadband needs and demand* to guide national policy. It is the role of the Strategy to ensure that social and economic development will not be unduly constrained in future by a lack of capacity.

   We recommend that *all* premises connected via fixed network technologies should be uprated to 100/50 Mbps service capability as soon as possible in the next five years and to 1000/500 Mbps service capability everywhere by the end of 10-years.

On this conclusion, Jim Holmes noted that the NBN Futures Group had not been able to discover detailed time-series data on broadband usage, needs and demand. He suggested that more work is required on understanding future household needs and the impact of broadband

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on future economic growth. The recommendation on upgrading service capability is in line with the Government's recent announcements but proposes extending this capability to all premises. The target of 1 Gbps may seem fanciful now but may seem insufficient in a few years' time.

5. The Commonwealth must be prepared to make *further investments in NBN Co*, especially in relation to *specific-purpose infrastructure development* programs that are needed for high quality broadband to be affordable in high cost areas and for currently underserved communities and population segments, e.g. to encourage greater decentralisation of population.
6. The Commonwealth must be prepared to promote and sponsor *applications development and research* to ensure the best possible working arrangements are in place in the residential, small business, enterprise and government spaces to bring about maximum benefit.

On this conclusion, Jim Holmes noted that the Government has taken some important steps in this regard, including the creation of the Broadband Advisory Council, which will focus on demand-side issues.

7. The *charter for NBN Co* needs to be clarified as part of the National Broadband Strategy and revised to reflect current industry needs and developments. In particular, its charter needs to explicitly reinforce its essentially wholesale role, but also be reviewed in the light of current circumstances and likely future developments. As part of that review the following extensions of the charter should be considered:
    a. enable NBN Co to provide wholesale services *to industry verticals* and full participation in the *Internet of Things*;
    b. enable the adoption of *new technologies*, such as 5G, and to become a *5G network wholesaler*; and
    c. allow for the provision of *wholesale transmission generally*.
8. In pursuing the major objective of extending the social and economic benefits of broadband services, the Commonwealth should support programs *to overcome digital exclusion* and establish effective levels of *digital capability*, and to scale up the usage in a range of activities that has been demonstrated during COVID-19. These programs will require substantial research and project support.

In speaking to this conclusion, Jim Holmes acknowledged the work of the Australian Digital Inclusion Alliance towards developing a roadmap and its recent submission to the Government. He also referred to the previous Forum discussing digital inclusion and telehealth (Campbell, Smith & Brooks, 2020).

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9. NBN Co should be set goals in a *new Statement of Expectations for NBN Co* covering the next 5-year period, and this statement should be reviewed at regular intervals to guide NBN Co's rolling investment and operating plans.
10. NBN Co must take action to deliver the *efficiency gains associated with its transition* from a mostly construction organisation to an ongoing operational entity following the completion of the initial NBN rollout, and also:
    a. Address the 100,000 premises outstanding at June 2020;
    b. Implement over the next 5 years the capacity uprating plans outlined in its Corporate Plan; and
    c. *Develop cost-effective capacity uprating plans for Fixed Wireless and Satellite access*, including, for Fixed Wireless Access, the use of aerial fibre and other means to support more effective wireless nodes.

On this conclusion, Jim Holmes noted that the plans for uprating Fixed Wireless and Satellite services should look beyond the needs of rural and remote households to cover a range of regional and remote industries.

11. NBN Co should publish much *more detailed dissections and analysis* of its existing and forecast costs, consistent with its role as an accountable public enterprise in a quasi-monopoly position, to facilitate a broader discussion on its performance, plans and options.
12. NBN Co should undertake a number of *initiatives to improve its medium-term financial position* and its ability to fund capacity improvements and technology upgrades, including:
    a. securing new revenues through effective programs to connect a substantial portion of the *4 million premises that are ready to connect but remain unconnected* as at June 2020;
    b. plan and implement over the next 5 years (2021-2025*) uprating the capacity of the technologies in the MTM* [multi-technology mix] to meet the service capacity targets referred to earlier; and
    c. establishing *private loan facilities* at lower cost and extinguishing its Commonwealth loan facilities before June 2024, and expanding debt financing as a source of capital, as appropriate.
13. There is a strong case for *NBN Co remaining in public ownership* for as long as it retains a central role in the provision of National Critical Infrastructure-based services. NBN Co should remain in public ownership for *at least 5 years* to enable it to develop into a sustainable enterprise. Thereafter, ownership might be reviewed in the light of changing circumstances as required.

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Jim Holmes indicated that , following release of the current report, the NBN Futures Group will continue to promote constructive public discourse on the issues raised, including engaging with Government and other leaders to commit to a robust bipartisan plan for a strong and successful broadband future for Australia. The Group's agenda for 2021 included considering Universal Service requirements for Australia in the era of 5G and the NBN.

Supplementary remarks

Two members of the NBN Futures Group made short supplementary statements. Dr Leith Campbell drew attention to the annexes of the report dealing with access technologies and 5G. He suggested that an early upgrade to 100 Mbps downstream for the NBN was achievable everywhere, but only with the participation of other parties, which would raise issues of accountability and regulation. On 5G, he outlined the reasoning that led to the conclusion that NBN Co could become a 5G wholesaler and would, in any case, benefit from 5G advances.

Dr Murray Milner spoke about the seemingly "bipartisan" approach to broadband policy in New Zealand. He pointed out that there had not always been policy alignment between the two major parties but the combination of incremental steps and fortuitous timing of success had led to continual broadband enhancements over the past 15 years.

The broadband policy had been started in 2006 by the Labour Government with the operational separation of Telecom New Zealand and a related policy of driving Fibre to the Node (FTTN) to 80% of premises by 2011. This was a low risk venture. While the National Party opposition agreed with the government that the quality of broadband access needed improvement, it had a more ambitious policy of Fibre to the Premises (FTTP) to 75% of premises through a Public-Private Partnership. When the Nationals came into government in late 2008, they continued the FTTN rollout while beginning in parallel the FTTP policy through a new entity, Crown Fibre Holdings. By 2016, the FTTP rollout was showing success and it was extended to cover 87% of premises by 2022 and, in addition, a Rural Broadband initiative was begun. By the time the Labour party came back into government in 2017, the FTTP rollout was about 80% complete. The new government has continued the policy to completion.

Considering the situation in Australia, Murray Milner considered that, despite the partisan history, there is an opportunity to align the policies of the major parties by building on the success of the NBN, taking positive incremental steps to further enhancement, and properly managing the risks.

Statements from the Minister and Shadow Minister

The Minister and Shadow Minister had both provided supportive statements. The Minister noted the benefits of ubiquitous broadband to economic sectors such as agriculture, construction, education, health, tourism and media. These are the sectors that the Australian Broadband Advisory Council had been asked to consider. The Minister described the current strong state of NBN Co, noting its ability to handle the surge in demand caused by the Covid pandemic. He noted that the newly announced network upgrades, to cost $4.5B, would be financed without further Commonwealth contribution. He suggested that NBN Co had been given the ability to adapt to new technological advances and that a demand-driven approach would be the basis of future network planning. The policy is to create a leading digital economy by 2030.

The Shadow Minister welcomed the report and encouraged policy experts to continue the discourse about future planning. She noted that policy and investment certainty would be required for the continuing enhancement of broadband capabilities. She advocated a dual approach of supply-side and demand-side consideration. Noting that the NBN rollout had never been an end in itself – rather, it was a means to an end – she suggested that the end result should be a vibrant and interconnected nation.

Brief comments from panellists

Three well-known panellists had been invited to comment on the report.

The first was Ms Teresa Corbin from the Australian Communications Consumer Action Network (ACCAN). She indicated that the NBN has become pivotal to ACCAN's concerns, with frequent interactions with the ACCC, the Department of Communications, NBN Co, and Retail Service Providers. ACCAN's policy is that there should be trusted, inclusive and available communications for all Australians. In this regard, she supported the need for a broadband strategy and the designation of the NBN as critical national infrastructure. At the genesis of the NBN policy, ACCAN had proposed that no consumer should be worse off during the transition and that there should be a competitive and fair market in broadband. Now, 10 years further on, ACCAN is developing an assessment framework to evaluate if the NBN is meeting its requirements.

Teresa Corbin described four aspects of the assessment framework. The first, related to the digital divide, proposes affordable, guaranteed access to data and voice services. There should be equitable access to broadband, not necessarily just fixed broadband, to improve overall social inclusion and to support SMEs. The second aspect is regulation appropriate to an essential service. There should be minimum network standards in terms of speed, reliability, latency, jitter and packet loss. There should be pricing measures including a government-subsidised low-cost service. ACCAN supports the Statutory Infrastructure Provider regime, which commenced in July 2020, and the Regional Broadband Scheme, which is to commence in January 2021. ACCAN is also seeking greater clarity on a future universal service obligation. The third aspect is competition. ACCAN desires strong retail competition for network access, with transparency in pricing to prevent anticompetitive behaviour. The fourth aspect concerns the Budget: when NBN Co is eventually sold, ACCAN is concerned that the revenue received should be balanced by the long-term interests of end users.

The second contributor was Dr Helen Haines, Independent Member for Indi in the Australian Parliament, a member of the parliamentary Joint Standing Committee on the NBN and a member of the House Select Committee on Regional Australia. Her electorate covers 29,000 km^2 of regional Victoria. As an Independent member, she supports bipartisanship and collegiality as a means of developing good public policy through collaboration. Her predecessor had founded the Indi Telecommunications Action Group, which she has continued, dealing with mobile blackspots and NBN connectivity. She works with the Ovens and Murray Digital Futures Group to strengthen digital connectivity and digital literacy in the area. She cited several examples of groups and businesses whose growth has been limited by inadequate NBN connectivity. On health, in which she had worked, she noted that telehealth had been taken up during the Covid crisis but most consultations were undertaken by telephone, due to poor access to the NBN or affordability issues. In all this, she claimed, a broadband strategy is a missing link. She had been surprised to learn that the regular assessments of usage and demand did not separate out data on regional and rural access. The NBN was an important integrator of services and its availability is a key attractor of young people (Gen Y and Gen Z) to regional areas.

The third contributor was Ms Deena Shiff, the chair of the Australian Broadband Advisory Council, which was set up in July 2020 and has just published its first report describing its work program for the next six months. The report reflects on what has been learnt from the Covid crisis. On the whole, the network has been remarkably resilient. Broadband, however, has not just been about fixed access but also about mobile services and access. A focus of the Council is on national infrastructure needed to deliver the same capabilities in the regions as in cities, to ensure that there is no geographical digital divide. There is a need for further evidence on what is happening in regional Australia. The Council will help to establish more local planning tools to drive delivery of the digital skills and digital capabilities that reflect the aspirations of regional areas. There will be a focus to drive productivity in sectors with high, but difficult to realise, potential. Two sectors have been identified for initial attention: eHealth, starting from telehealth but expanding to provide capabilities matching desired health outcomes; and agritech to exploit new digital capabilities for agriculture. In reflecting on weaknesses shown up by the Covid crisis, the Council has identified digital inclusion, which has become even more important than before, and digital skills as in need of attention. For the currently unconnected and the requirements for vulnerable groups, the Council will consider affordability issues, but also the role of public Wi-Fi as a potential means of connectivity. To improve digital skills, the Council will collaborate with the Digital Skills Organization and others to develop a pathway curriculum for upskilling, reskilling and life-long learning. The focus will be on regions and SMEs to identify pilot initiatives and digital clusters, where people can learn from one another.

General discussion

Mr Allan Horsley, a member of the NBN Futures Group, offered some reflections on the report and the topics that had been discussed in the Forum. He identified five issues of vital importance. The first is that the NBN is a piece of critical national infrastructure. As a critical piece of infrastructure, like electricity, gas or water, the NBN should have clear definitions of availability and reliability, especially during emergency periods and at times of heavy traffic. The second important issue is applications development. There have been recent rapid developments in telehealth, home schooling and working from home, for example. Further development is required to make them robust and have longevity. This could be accomplished by a government-funded research and development program. The third issue is inclusion, where a really practical program is required to improve digital skills. Here, an education program delivered through municipal libraries could be funded. The fourth vital issue is bipartisanship. Allan Horsley reflected on the 10 years of policy alignment that occurred in Australia from 1987, as the telecommunications sector was opened up to greater competition. Finally, the fifth issue concerned coordination of Commonwealth government initiatives on delivery of government broadband services. There was little evidence of such coordination and Allen Horsley suggested that a subcommittee of Cabinet would be appropriate to oversee this issue.

A question had been asked about the market failure that would lead NBN Co, a government-owned enterprise, to expand into wholesale 5G and wholesale transmission. Leith Campbell explained that it was less about market failure and more about technology change and competition. As an importer of technology, Australia will gain equipment, systems and processes that address the fixed-mobile convergence concerns of the big telcos. For NBN Co, this will lead to greater automation of processes and will open up new opportunities. If NBN Co became a 5G wholesaler, it would enliven competition in the Australian mobile market. If

NBN Co were to enter the wholesale transmission market, it would simplify the provision of services for some retail service providers and increase competition in broadband.

Reg Coutts, Vice-President of TelSoc, remarked that it had been a mistake to politically "weaponise" the NBN from the beginning. He believed then and now that the only path to success was through bipartisanship. His main point, however, was that mobiles, especially with 4G, has always been part of the broadband picture. A combination of fixed and mobile broadband would be needed. It would not be possible to do everything just with wireless and mobile. He suggested that Australia was unique in the world in debating if all broadband provision could be mobile.

In concluding remarks, John Burke outlined four topics that the NBN Futures Group would pursue in 2021, among others. The first is universal service, especially to clarify the issues of aspiration and guarantee. The second is rural access technologies, on which a future forum is planned. The third is digital inclusion, to understand the scale and cost of various programs. The final topic is continuing consideration of ownership of NBN Co.

Finally, John Burke suggested that attendees should take away three messages about a broadband strategy: it should be long-term; it should be bipartisan, so that it survives beyond a single electoral cycle; and it should emphasise demand-side social and economic benefits.

Conclusion

This was the fifth of a planned series of forums related to the future of the NBN. The release of the report, *Towards a National Broadband Strategy for Australia*, is a major milestone in the deliberations of the NBN Futures Group. It is hoped that, with further discussion and lobbying, it will lead to the development of a national strategy for guiding and coordinating the continuing enhancement of broadband provision in Australia to the benefit of the digital society and the digital economy.

Australia has found itself in a unique position where most of the fixed broadband access is in the hands of a government-owned commercial entity, while mobile broadband is provided by competitive commercial operators. Navigating the way from here to "create a leading digital economy by 2030" (the Minister's aspiration) will require coordination between the actions of government and commercial providers if no-one is to be left behind and the full benefits of a digital society are to be realised. An overarching and agreed strategy supported by a whole-of-government approach is a vital guide for this coordination. Recognising the NBN as a piece of national critical infrastructure will be important to ensure that it continues to meet the needs of Australians in all circumstances.

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Towards a National Broadband Strategy for Australia, 2020-2030

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Abstract: This Report has been developed by the TelSoc National Broadband Network (NBN) Futures Group, drawing on substantial work since early 2019 to examine the current state and desirable future of broadband services in Australia. The purpose of the Group and this Report is to ensure Australia's broadband infrastructure and services continues to develop in a financially responsible and timely manner, delivering value, economic benefit and new services to all Australian residents in all locations and in all economic circumstances. Broadband infrastructure, including the NBN in particular, represents National Critical Infrastructure providing essential services important for the development of a digital economy and online society. All Australians should benefit to the maximum extent in realising the social and economic potential of broadband. Large, long-term investments and programs that address the demand side, as well as the supply side, of broadband require a clear long-term vision and plan (the National Broadband Strategy), supported by a robust bipartisan commitment that endures beyond electoral cycles. The Report is not such a Strategy but is a major contribution towards it. It is addressed to all stakeholders, especially to the Commonwealth Government which has leadership responsibility, and to industry organisations whose involvement is important for success.

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Australia’s National Broadband Strategy: An Overview

1. Executive Summary

This Report has been developed by the NBN Futures Group, with support from TelSoc, and draws on the substantial work that the Group has undertaken over the past two years to examine the current state and desirable future of broadband services in Australia. Our work includes conducting four public forums on various aspects of broadband policy and on the future of the National Broadband Network (NBN), which is central to broadband infrastructure and services both now and into the immediate future. The purpose of the extensive work program of the NBN Futures Group and this Report is to ensure Australia’s broadband infrastructure and services continues to develop in a financially responsible and timely manner delivering value, economic benefit and new service experience opportunities to all Australian residents in all locations and in all economic circumstances across Australia.

Our proposals in this Report have been developed in a rapidly changing environment. This period has seen significant shifts in the policy context for broadband networks — with the remarkable dependence on them during COVID-19, the completion of the NBN build and projections of upgrade, the rollout of 5G and other initiatives. It is timely to form a common understanding of future directions.

We recognise that broadband, and the NBN in particular, represents National Critical Infrastructure (“Critical Infrastructure”, n.d.) providing essential services that are fundamentally important for the development of a digital economy and online society in Australia. Broadband services provided over mobile networks are also increasingly important for Australian users, and this is being reinforced with the introduction of 5G technology. It is important that all Australians benefit to the maximum extent in realising the social and economic potential of broadband. The investments that have been made to date and which still need to be made are very large and are for the long term.

Large, long-term investments and programs that address the demand side, as well as the supply side, of broadband require a clear long-term vision and a long-term plan (which we have called the National Broadband Strategy), and need to be supported by a robust bipartisan commitment from all leaders that endures beyond commercial and electoral cycles.

In this Report we have outlined the requirements and essential content of a National Broadband Strategy together with conclusions relating to specific issues that need to be addressed. Our main conclusions are set out in Section 10 of this Overview and are supported by the various Annexes that make up the Report. In summary, they are:

- That there needs to be a National Broadband Strategy with a clear vision for Australia's broadband future.
- The NBN needs to be recognised as National Critical Infrastructure.
- The Strategy needs to have bipartisan support.
- The Strategy needs to be long-term covering a rolling 10-year horizon.
- The Strategy needs to address supply-side and demand-side goals, with a view to maximising social and economic benefits through digital inclusion and by scaling up applications development and use.
- The Commonwealth Government must take the key leadership role in developing the Strategy, but must engage widely in the process, given the broad social and economic consequences of broadband.

This report is addressed to all stakeholders in Australia's broadband future, but especially to the Commonwealth Government which has leadership responsibility, and to the industry organisations whose engagement and involvement is so important to success.

2. Introduction

Australian Governments and industry have long recognised that, for Australia to develop as a modern digital economy and society that is inclusive nationally and competitive globally, it will need to have modern broadband infrastructure and appropriate settings in its national policies, including direct intervention when required. Broadband planning needs to be guided by a robust national broadband strategy that has a longer-term horizon than current

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commercial planning perspectives or election cycles, and which has broad and consistent bipartisan support.

The NBN Futures Group, with support from TelSoc (the Telecommunications Association) (both of which are described in the Annexes to this Overview), are of the view that it is now timely for renewed national discussion and action to develop a comprehensive National Broadband Strategy for Australia to cover at least the next 10 years, and to plan the future for the National Broadband Network, which will have a central role in the National Broadband Strategy during that time.

3. This Report

This Report documents the work of the NBN Futures Group (supported by TelSoc) since the beginning of 2019 on national broadband issues. The work commenced with consideration of the ownership options for NBN Co, but quickly developed to address a range of issues associated with broader broadband strategy and policy.

This Report is intended to be a thoughtful and deep analysis of issues that need to be reflected in Australia's National Broadband Strategy for the longer term. It does not purport to be that Strategy. The Report is addressed to policy makers and those with the power and duty to act as leaders in this field. Our key audience is therefore the Commonwealth Government and the Commonwealth Parliament, where responsibility resides for communications services, national social welfare and the national economy.

However, there are stakeholders who have important leadership roles in this field – including NBN Co itself, other telecommunications service providers, users of telecommunications services, the media and the general public – and all of these are important audiences addressed through the document.

This Report consists of a short overview, with annexes dealing with each of the main themes numbered 4–8 below.

The conclusions have been made as concrete as the information available allows.

4. Vision and Objectives for the Strategy

TelSoc's values

The primary focus of TelSoc is on the development of telecommunications and with realising the potential of telecommunications for social and economic development. Insofar as it has any advocacy role, TelSoc is limited to that. Through the *Journal for Telecommunications and the Digital Economy*, TelSoc aims to promote reasoned discussion on technology, social and economic issues and on themes associated with the sector and with its wider impacts. This Report is a further initiative in that tradition.

Vision for the National Broadband Strategy

The National Broadband Strategy should encompass all public access networks, both fixed and mobile. The National Broadband Network operated and managed by NBN Co is very central to the strategy, especially in the near term, but is not the entirety of the issues that need to be considered.

The National Broadband Network and other broadband infrastructure is fundamental infrastructure secured though substantial investments in long-term assets in a time of rapid technology change and of uncertainty in demand preferences and patterns. This is potentially therefore an area of substantial commercial risk.

The vision for the national broadband strategy recognises that long-term national investment must be supported by an equally long-term national broadband strategy based on robust, inclusive planning work and sustained by bipartisan support. In substantive terms, the vision is for the reliable delivery of accessible, affordable and appropriate broadband services nationally to support Australia's development as a competitive and leading digital economy and as an inclusive digital society. The vision further recognises the potential of high-performance broadband capability to support innovative new services and employment opportunities associated with growing social and economic structural change. It is both long-term and continuing, but needs to be translated into instalments capable of short-term realisation.

Principles for the National Broadband Strategy

Bearing in mind that the National Broadband Strategy will be critical for the development of the national economy and for national economic and social inclusion:

- the strategy needs to recognise the role of broadband and of the NBN in particular in supporting Australia's evolution to a digital society and digital economy;
- the strategy needs to incorporate technical performance and service quality goals over at least the next 10 years and be subject to periodic review and refreshment;
- the strategy can only deliver over multiple electoral and economic cycles if it has widely-based, bipartisan support;
- the strategy must reflect a whole-of-Government, whole-of-economy and whole-of-society approach, with net benefits of specific initiatives considered on that basis, rather than purely in commercial terms; and

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- the strategy needs to be underpinned by the values that Australia espouses as an inclusive liberal democracy and must not only seek to extract full value from the national investment in the NBN, but must ensure that the benefits are fairly, widely and reasonably shared.

5. Social and Economic Benefits of National Broadband Networks

Broadband capability has become critical for the evolution of the online society and the digital economy in Australia and globally. This process has been ongoing for some time, but has now been given further impetus and attention because of the imperatives of online interactions in response to the COVID-19 pandemic. The pandemic has dramatically highlighted the importance of national telecommunications networks, and of the NBN in particular, in delivery of services ranging from telehealth and tele-education, through to supply chain management and fulfilment, working from home, maintaining community cohesion and personal relationships. There is a substantial body of opinion that many of the social and economic adaptations made in response to the pandemic will remain as a 'new normal' in a post-crisis world. It is not the purpose of this Report to speculate on what that new normal might be in any detail, other than to note that ubiquitous broadband access will be a central requirement.

Obtaining value

A major component of the next phase of broadband network development in Australia, post the completion of the initial build of the NBN, will be an emphasis on realising the full social and economic benefits of such networks, both fixed and mobile.

This is a view given strong support in statements of the Minister, Paul Fletcher, and Shadow Minister, Michelle Rowland. At the NBN Futures Forum in July 2019, Minister Fletcher emphasised the need to "get the maximum social and economic impact from the $51B taxpayers' money" and to understand "how best to leverage this extraordinary national investment". Shadow Minister Rowland identified "the task of public policy will be to maximise the benefit of that investment [in the NBN] now and into the future" (Campbell & Milner, 2019).

Essential Service and Universal Access

Broadband access has become an essential service, similar to other utilities. Life is certainly possible without such services, but full inclusion and interworking makes access necessary for all intents and purposes. As society and the economy are transformed by greater and greater

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online presence, the essential nature of broadband services will become more and more manifest. The important point is not to be concerned about how true this might be at any time and for any set of activities, but to plan on the basis that it is so in the national broadband strategy.

The consequences of essential service status include setting and planning for a ubiquitous, minimum level of universal broadband service, noting that the minimum will increase over time. It is a tenet of the social benefits of broadband that a minimal offer should be available to every premises. The strategy should be based, in part, on a minimal broadband service available to everyone and incremental improvements in that minimum standard over time. Flexibility to respond to future needs will be an essential aspect of any universal access policy.

Future demand

Devising a long-term strategy in an era of rapid technological development and innovation is difficult, with penalties for providing inadequate capacity and for building infrastructure that may be stranded. We note that, to this point, the construction of much of the broadband infrastructure through NBN Co has responded to bottom-up demand estimates based on the requirements of "applications stacks" relating to multiple simultaneous usage in households and small businesses. We consider that this approach is dependent on having reasonable knowledge of the applications that might arise in the longer term and of their data rate requirements. However, the approach is useful in setting a minimum requirement and will also be useful in determining minimum capacity requirements for universal service. However, on its own it will not lead to a responsive approach to meeting future demand, which is highly uncertain due to the impact of unpredictable innovation in the ways that communication technology and applications will evolve.

The approach that we believe ought to be adopted in the national broadband strategy is to favour technologies that are capable of rapid upscaling to provide substantial additional capacity for relatively little incremental cost. Clearly FTTP (fibre to the premises) delivers on this, but will not be feasible in all customer settings. As discussed in section 6 below, progressive implementation pathways are available for upgrading existing technologies in ways that enable increased capacity to be delivered progressively to almost all Australian customers.

Inclusion and Access

There are substantial social and economic costs that are incurred through non-inclusion and these need to be studied and measured more comprehensively than they are at present. They form part of the broader picture of costs that are not taken into account when the focus is the commercial feasibility of broadband delivery at the level of the enterprise – including at the NBN Co level.

For Government, community and commercial organisations, the costs incurred are in terms of multiple service delivery modes, in the absence of ubiquitous broadband access. At the level of the individual and of commercial enterprises, the losses from non-inclusion are in terms of lost amenity, lost potential and, ultimately, the possible costs of expensive workarounds. The social and economic costs where inclusion is inadequate or non-existent is not only a cost on those directly affected, but on all who seek to transact or engage with them.

For these reasons, regional equity in access to affordable high-speed broadband services is recommended as a good national investment, supported by an upgraded Universal Services Obligation for communications services.

We agree with the Australian Digital Inclusion Alliance (ADIA) that a National Digital Inclusion Roadmap should be developed by Government providing for a coordinated approach to access and affordability of broadband services, development of digital capabilities and for accessibility by all sectors and community groups (ADIA, 2020).

Applications development and scaling

In the course of its work the NBN Futures Group has identified substantial numbers of online developments and initiatives, often commenced as pilots, trials or small-scale projects. To be viable many of these developments need to gain scale and thereby gain traction. To date this has been a commercial process, with hit-and-miss outcomes dependent on many factors, including chance. While that will continue to be a mainstream process for applications development, particularly outside those required by large corporations and Government, the scaling up of the use of online applications in key sectors – telehealth, online learning, access to government services, etc. – is a major challenge requiring substantial demand-side, user focused policies and programs to tackle the underlying issues of digital capability, culture and economics. This will need cross-portfolio leadership within Government.

Research and databases

Systematic research, regularly updated, into the broader social and economic impacts is needed to provide a wider base of knowledge for all in the sector, and also to enable evidence-based policy settings to be established and reviewed as part of the National Broadband Strategy. The research that we envisage is needed to provide an ongoing demand-side focus, to offset the substantial attention given to supply-side issues associated with NBN rollout and technical characteristics of the broadband capacity and services.

Demand-side areas of focus will include:

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- the contribution to the macro economy;
- expansion of Internet use in a broad range of information, communication, transaction and entertainment applications;
- specific socially valued application areas, such as government services, education, health, banking and public broadcasting;
- specific economic development areas, such as business (corporate and SMEs), agriculture, tourism;
- broader social impacts, such as decentralisation; and
- possible benefits of future application areas, such as the Internet of Things, driverless vehicles and augmented reality.

Our work, and that of other groups such as the Australian Digital Inclusion Alliance, strongly suggests that in every sector and applications field there are many initiatives, trials and localised projects. Broadband usage and applications reflect a patchwork. This is not surprising and is expected to continue. The social and economic value of the investment of resources would be substantially improved if the Commonwealth Government were to take a lead in developing either directly or through a university or other institutional form, a database of such initiatives and improved connectivity between the participants.

6. Technologies and Technical Pathways

In 2014 NBN Co adopted a MTM (Multi-Technology Mix) approach to the rollout of broadband access, in lieu of the previous approach that concentrated on FTTP (fibre to the premises) for all wired connections. The MTM approach was designed to deliver broadband faster and at lower overall cost. NBN Co uses a variety of access technologies to reach customers' (end-users') premises, namely:

- FTTP, Fibre to the Premises (NBN Co distinguishes between FTTP installation in 'brownfields' areas – that is, areas where a telecommunications access network already exists – and 'greenfields' areas, usually newly built housing estates or industrial parks);
- HFC, Hybrid Fibre-Coax, based on the Telstra HFC network for Foxtel and Internet access;
- FTTN, Fibre to the Node, where an active node, fed by fibre, replaces a pillar or other junction point in the existing copper-line access network;
- FTTB, Fibre to the Building, for multi-tenant buildings, in which fibre is run to the building's communications point and the existing inside wiring is used for access to each individual premises;
- FTTC, Fibre to the Curb, for which fibre cables run to just outside property boundaries and a small active node is used to terminate the fibre and provide a connection to the existing copper lead-ins to the premises;

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- Fixed Wireless, where a microwave radio link is established between an NBN Co site and an antenna installed on the outside of a premises; and
- Satellite, NBN Co's SkyMuster service, where access communication is between NBN Co's geostationary satellites and an antenna mounted on the outside of the premises.

NBN Co has recognized that future technology upgrades will be necessary to provide higher speed services. In its *Corporate Plan 2020-23*, NBN Co provides a "Future technology roadmap" (pp. 29-32) for uprating each of these technologies (except for Fixed Wireless[1] and Satellite).

Our conclusion has been that the NBN fixed line services should be uprated to at least 100/50 Mbps service capability[2] as soon as possible in the first five years of the initial National Broadband Strategy and to 1000/500 Mbps service capability[3] everywhere by the end of the 10-year period, prioritised as appropriate in terms of commercial benefit. We therefore welcome the recent announcements by NBN Co that 72 per cent of its fixed line network is currently capable of delivering speeds of 100/40 Mbps and the company's estimates that its highest peak wholesale speed tiers of 500 Mbps to close to 1 Gbps downstream will be available on demand to an estimated 75 per cent of homes and businesses on the fixed line network by 2023 (NBN Co, 2020). Target dates should be established for the remainder of the fixed line network, thereby minimising lost opportunities for society and the economy.

Fixed wireless and satellite services pose a greater challenge because of user contention for system-limited capacity. Nevertheless, even fixed wireless systems can provide improved capacity in many circumstances if they are supported by aerial fibre links to the wireless nodes in rural communities.

5G technology

Much discussion of 5G technology is about its application as a wireless service, and specifically about the rollout of 5G cellular mobile services. All mobile network operators in Australia are now rolling out 5G services.

The international Broadband Forum (n.d.) is currently developing standards for the delivery and management of 5G services over fixed networks, mainly in the context of combined fixed and mobile operators. With appropriate system and software developments, these standards would enable the provision of 5G services over the NBN, both by Retail Service Providers and, potentially, by NBN Co itself.

The National Broadband Strategy needs to take account of 5G mobile services as an alternative, and therefore as competitors, to fixed broadband access provided by the NBN. In addition, it needs to endorse NBN Co using 5G technology to provide a range of wholesale services, including to support 5G mobile and radio networks. Our work recognises that 5G is an opportunity for NBN Co to develop a more sustainable business in the future. Leveraging 5G technology in a fixed wireless configuration will enable services at rates of 100/50 Mbps to be provided more cost effectively in the near future.

7. Financial Considerations

At the end of the initial rollout in June 2020, NBN Co was funded from the Commonwealth via $29.5B in equity and a $19.5B debt facility. NBN Co is not paying a dividend on the equity and is being charged 3.96% per annum interest on the debt facility funds drawn down. In 2019-20 NBN Co generated total revenue of $3.8B and earnings before interest, tax, depreciation and amortisation of $1.8B before subscriber costs, and -$0.6B (negative) after including those costs. NBN Co is required to substitute private borrowings for its Commonwealth debt facility by June 2024, and in 2020 was able to establish an initial facility of this kind for $6.1B. NBN Co has not released details of the interest rates that it has negotiated for its private debt facility. Debt capital is readily available below the Commonwealth's 3.96% rate, however.

The financial information available from NBN Co, especially the forecasts in its Corporate Plan 2021-24, is high level and averaged to a level that precludes detailed analysis.

For the purposes of future financial expectations of NBN Co and for the National Broadband Strategy, the following key points need to be taken into account:

- With the initial rollout completed in 2020, NBN Co will be transformed from an organisation with a largely construction focus into an ongoing operational enterprise, but with some specific construction tasks to complete and future upgrades to support. This will require NBN Co to adjust its resource levels accordingly.
- With the ready availability of low-interest, long-term debt funding, NBN Co should be able to profitably retire its current Commonwealth debt facility by 2024, but also to consider debt funding for new infrastructure investment and upgrades. This is supported by NBN Co's announcement on 23 September 2020 that its $4.5B fibre extension program will be debt funded, with debt expected to rise to $27.4B by June 2024.
- The Commonwealth Government has stated on many occasions its reluctance to make further equity contributions to meet NBN Co new investment requirements. However, it should be prepared to consider specific cases for funding where the national interest requires it. This means a perspective that is beyond the commercial boundaries of enterprise-level economics. A clear example is with satellite-based services, but all NBN services have substantial externalities in terms of economic benefits and should be viewed in a wider context.

- The individual MTM technology uprating paths set out in the NBN Co Corporate Plan need to be pursued with a view to implementation in the first five years of the National Broadband Strategy. The capital cost of doing this for all FTTP, FTTN (and Curb) and HFC connections is estimated by the authors at approximately $7B (see Annex D, section 3), some of which will have been covered in the fibre extension program announced by NBN Co on 23 September 2020. NBN Co has not provided enough information to estimate uprating costs for Fixed Wireless and Satellite connections.
- In the case of Fixed Wireless services, NBN Co should be prepared to improve fibre support to Fixed Wireless nodes using aerial cable and other delivery modes.
- Revenue estimates will be affected by the extent of connection of the 4.4 million premises that are passed by the NBN and are ready to connect as at June 2020, but are not yet connected. Essentially, the potential benefit is a low incremental cost for a full per-premises revenue gain, assisted by third-party investments in some cases.[4] Some of these unconnected premises will be connected during the 18-month transition period that NBN Co provides, some may remain or become all-mobile data services, others will be affected by affordability and other digital inclusion issues, and there may be some residual who do not take up any broadband service option. NBN Co estimates take-up of around 73% by 2024. We consider that NBN Co should establish the programs it will undertake in conjunction with retail service providers to achieve and potentially exceed this take-up, provide estimates of revenue impacts for different levels of take-up, and regularly report results achieved.

8. NBN Ownership Options

We have examined the cases for and against various ownership options in this Report, ranging from various sale options to various options for retention in public ownership. In conducting this examination, we have recognised that the NBN is a crucial component of National Critical Infrastructure.

NBN Co should not be protected as a legislated monopoly. It needs to be competitive and to remain open to all modes of broadband competition with the exception of the time-bound fixed network service prohibitions which currently apply to Telstra. In addition, the arrangements currently in place to constrain arbitrage that is not in the overall public interest should be maintained, and be subject to regular review to ensure that they are as “light touch” as possible while remaining effective.

The key principle in this Report about NBN Co ownership is that it should not be a matter of ideological preference, but should reflect the role of providing fixed wholesale broadband as an essential service and how that might be best guaranteed under the circumstances that apply from time to time. Important considerations will be the policy and regulatory settings and the level of effective competition from services provided using alternative technologies and infrastructure.

We have concluded that sale of NBN Co is not a realistic option for at least the next five years and possibly for the whole 10-year period of the initial National Broadband Strategy. However, the issue of whether and, if so, how NBN Co might implement a greater charter opportunity by becoming a 5G wholesaler and having appropriate opportunities to engage in greater wholesale transmission opportunities (not only access services) needs to be addressed.

9. Developing a Bipartisan National Broadband Strategy – Next Steps

We have argued the case that Australia needs a National Broadband Strategy, which addresses in a bipartisan manner the longer-term considerations for ubiquitous availability and use of broadband services needed for Australia to become a successful digital economy and society. We have outlined some of the key issues that need to be included in the Strategy. But developing the actual Strategy and achieving a broad-based consensus that will guarantee robustness and effectiveness is a matter for national leadership, and particularly for leadership by the Commonwealth Government.

The breadth of considerations and issues means that many, possibly most, Government portfolio areas will be involved. A coordinated approach will clearly be necessary. A Sub-Committee of Cabinet may well be an appropriate way to lead and manage this development process.

We also note the recommendation by the Australian Digital Inclusion Alliance in September 2020 that "a single department could be appointed to lead [on developing] a National Digital Inclusion Roadmap" (ADIA, 2020). The proposed Roadmap needs to be part of the larger National Broadband Strategy now being proposed, and the approach of a single lead department may have merit as an alternative.

Before finalising a firm policy, the Government needs to consult widely in the case of the National Broadband Strategy to ensure that it reflects appropriately the diverse range of interests at stake and issues in play, and has legitimacy, robustness and relevance as a result.

10. Conclusions and Recommendations

From our work since the beginning of 2019 we have arrived at the following conclusions, which we encourage the Commonwealth Government, and all who seek to shape Australia's broadband future, to adopt:

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1. Australia needs to have a National Broadband Strategy reflecting national broadband policy settings and providing long-term guidance for the development of infrastructure and services and for ensuring that all Australians enjoy the full potential social and economic value of broadband, both fixed and mobile.
2. The National Broadband Strategy must:
    a) articulate that Australia is committed to continuously developing and maintaining world-class broadband infrastructure and services that will be provided to maximise social and economic inclusion, and to express in detail what this means at nominated points in the timescale covered by the Strategy;
    b) be longer-term in its perspectives, and initially provide a clear roadmap for the next 10 years;
    c) be broadly based and broadly supported, seeking the bipartisan support necessary for certainty, continuity and consistency across the life of multiple parliaments;
    d) be concerned to ensure that the network benefits from broadband investment – that is, benefits to society at large, not realisable at the enterprise level – are identified, assessed and realised;
    e) emphasise the demand-side aspects of broadband service, and the need to maximise economic and social inclusion through policies that deliver high quality affordable broadband services to all areas, sectors and customer segments;
    f) recognise that broadband infrastructure and services will be provided by many vendors on many platforms, but also that the NBN will have a central part to play for at least the next 5-10 years in Australia; and
    g) establish a Universal Broadband Service roadmap with clear download and upload targets and intermediate milestones, while recognising that flexibility to address future unknown application innovation will be a critical success factor.
3. The National Broadband Strategy needs to outline the policy and regulatory settings that will operate for the next 10 years, subject to regular monitoring and refinement. NBN Co should not enjoy any form of statutory monopoly in broadband access service provision, subject to the existing time-bound prohibitions on Telstra running their course.
4. The National Broadband Strategy should make provision for regular assessment of broadband needs and demand and for the broader economic assessments needed to guide national policy. In particular, the Strategy must favour broader assessment of capacity needs that allow for unanticipated step-function changes in the requirements

of applications. It is the role of the Strategy to ensure that social and economic development will not be unduly constrained in future by a lack of capacity. We recommend that the NBN access service for all premises connected via fixed network technologies should be uprated to 100/50 Mbps service capability as soon as possible in the first five years of the initial National Broadband Strategy and to 1000/500 Mbps service capability everywhere by the end of the 10-year period.

5. The Commonwealth should be prepared to make further investments in NBN Co, especially in relation to specific-purpose infrastructure development programs that are needed for high quality broadband to be affordable in high-cost areas and for currently underserved communities and population segments, e.g., to encourage greater decentralisation of population.
6. The Commonwealth must be prepared to promote and sponsor applications development and research to ensure the best possible working arrangements are in place in the residential, small business, enterprise and government spaces to bring about maximum benefit.
7. The charter for NBN Co needs to be clarified as part of the National Broadband Strategy and revised to reflect current industry needs and developments. In particular, its charter needs to explicitly reinforce its essentially wholesale role, but also be reviewed in the light of current circumstances and likely future developments. As part of that review the following extensions of the charter should be considered:
    a) enable NBN Co to provide wholesale services to industry verticals and full participation in the Internet of Things;
    b) enable the adoption of new technologies, such as 5G, and to become a 5G network wholesaler; and
    c) allow for the provision of wholesale transmission generally, not necessarily limited to fixed access services.
8. In pursuing the major objective of extending the social and economic benefits of broadband services, the Commonwealth should support programs to overcome digital exclusion and establish effective levels of digital capability, and to scale up the usage in a range of activities that has been demonstrated during COVID-19. These programs will require substantial research and project support.
9. The Government should set goals in a new Statement of Expectations for NBN Co covering the next 5-year period, and this statement should be reviewed at regular intervals to guide NBN Co's rolling investment and operating plans.
10. NBN Co must take action to deliver the efficiency gains associated with its transition from a mostly construction organisation to an ongoing operational entity following the completion of the initial NBN rollout. In particular, it should:

a) Address the 100,000 premises identified as difficult to serve and which are outstanding as at June 2020;
b) Implement over the next 5 years the capacity uprating plans outlined in its Corporate Plan 2020-23 for each of the technologies in the Multi Technology Mix; and
c) Develop cost-effective capacity uprating plans for Fixed Wireless and Satellite access, including, for Fixed Wireless Access, the use of aerial fibre and other means to support more effective wireless nodes.

11. NBN Co should publish much more detailed dissections and analysis of its existing and forecast costs, consistent with its role as an accountable public enterprise in a quasi-monopoly position, to facilitate a broader discussion on its performance, plans and options.
12. NBN Co should undertake a number of initiatives to improve its medium-term financial position and its ability to fund capacity improvements and technology upgrades, including:
    a) securing new revenues through effective programs to connect a substantial portion of the 4 million premises that are ready to connect but remain unconnected as at June 2020;
    b) plan and implement over the next 5 years (2021-2025) uprating the capacity of the technologies in the MTM to meet the service capacity targets referred to earlier; and
    c) establishing private loan facilities at lower cost and extinguishing its Commonwealth loan facilities before June 2024, and expanding debt financing as a source of capital, as appropriate.
13. There is a strong case for NBN Co remaining in public ownership for as long as it retains a central role in the provision of Critical National Critical Infrastructure based services. NBN Co should remain in public ownership for at least 5 years to enable it to develop into a sustainable enterprise. Thereafter, ownership might be reviewed in the light of changing circumstances as required.

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Endnotes

[1] In the plan it is stated that the Fixed Wireless will be upgraded to support 50 Mbps downstream services where possible. NBN Co has implemented a Fixed Wireless Plus service which aims to deliver the maximum potential wholesale speeds that the network is capable of delivering to that premises at the time of use. It is understood that this addresses the fact that spectrum over which wireless services operate is shared and finite, so the aim is to optimise the experience around the available radio capacity. NBN Co currently provides the following Fixed Wireless services: 12/1, 25/5 and Fixed Wireless Plus. Fixed Wireless Plus replaced the previous ranged tier 25-50/5-20**.** Wireless services are considered in speed ranges by NBN Co due to the shared spectrum resource.

[2] 100 Mbits per second downstream capacity and 50 Mbits per second upstream capacity. The choice of 100/50 is proposed as the reference service, as it is the default service delivered by GPON technology when configured for use with 24:1 passive splitters, which is the predominant technology used for the delivery of FTTP.

[3] 1 Gbit per second downstream capacity and 500 Mbits per second upstream capacity

[4] Such as, for example, from State and Local Government, retail service providers and other co-investors

Annex A: TelSoc and the NBN Futures Project

TelSoc

TelSoc is the operating name of the Telecommunications Association Inc., a voluntary membership-based association of interested individuals, who seek to discuss, research and advance issues associated with telecommunications and the digital economy. TelSoc and its predecessor organisations have served as the learned society of the Australian telecommunications industry continuously since 1874 (initially as the Telegraph Electrical Society), convening regular talks by experts and publishing papers and monographs on Australian telecommunications for more than a century. Most of our individual members are professionals who have worked in the sector, including those with academic, research, regulatory and operational interests in the industry.

TelSoc seeks engagement with policy makers and other stakeholders on telecommunications issues via its quarterly publication, the *Journal of Telecommunications and the Digital Economy* ("the *Journal*"), and through the policy forums and other events that it organises. The *Journal* and its predecessor, the *Telecommunications Journal of Australia*, have been published continuously since 1935, initially in print and since 2007 online.

NBN Futures Project

The NBN Futures Project began as an idea put forward at the TelSoc Journal's Editorial Advisory Board in February 2019: that the options for the future ownership and enhancement of the National Broadband Network should be researched and debated in a systematic way, through public lectures and policy articles published in the *Journal*.

This proposal was enthusiastically supported by all present, who held a series of subsequent meetings to work out project objectives and plan actions. In the course of these, additional TelSoc members and others with useful skills and knowledge were invited to join the project.

On time frame, it was decided to develop, by early 2021, some well supported policy options that might influence both of the major political parties in the lead-up to the forthcoming federal election. Best endeavours are being made to seek bipartisan support for the project's recommendations.

To help develop these ideas it was decided to hold a series of public policy forums, under the TelSoc banner, and to transform as many of the presentations as possible into papers of record, published in the TelSoc Journal (the *Journal of Telecommunications and the Digital Economy*). The Project Team also made a submission in January to the federal Parliamentary

Joint Standing Committee on the NBN, to alert relevant political advisors to the existence and potential of this project.

The first NBN Futures public forum, held at RMIT University (courtesy of Mark Gregory) on 31 July 2019, concentrated on examining the options for eventual ownership of the completed NBN. Chaired by John Burke, it included presentations by Peter Gerrand, Jim Holmes, Graeme Samuel AC and Michael Cosgrave (ACCC). A report on the forum appears in Campbell & Milner (2019).

The second NBN Futures public forum, held at RMIT on 22 October 2019, focussed on realising the user potential of the NBN. It featured presentations by Teresa Corbin (CEO, ACCAN), Chris Wilson (on the Australian Digital Inclusion Index) and Murray Milner (on the New Zealand broadband market experience). A report on the forum appears in Campbell (2019).

Details on the broad scope of the project as at December 2019 can be found in Holmes & Campbell (2019).

The third NBN Futures public forum, *Learning from International Experience*, was held on 25 February 2020, again at RMIT, featuring Richard Ferrers (on OECD comparisons) and Murray Milner (on lessons from the successful New Zealand Ultra-Fast Broadband program), with discussion from Jim Holmes (Incyte Consulting). A report on the forum appears in Campbell (2020).

The fourth NBN Futures public forum, *Social and Economic Considerations: Digital Inclusion and Telehealth*, was held on 18 August 2020 via videoconference. It was chaired by Jim Holmes and included sessions on Digital Inclusion by Ishtar Vij, coordinator of the Australian Digital Inclusion Alliance, and on telehealth by Professor Anthony Smith of the University of Queensland Telehealth Centre and Professor Peter Brooks of Northern Health, Victoria. A report has been published in the *Journal* in Campbell, Smith & Brooks (2020).

Project Membership: Active members of the NBN Futures Project, in alphabetical order, have been: Trevor Barr, John Burke (convenor), Leith Campbell, John Costa, Richard Ferrers, Peter Gerrand, Andrew Hamilton, Peter Hitchiner, Tim Herring, Jim Holmes, Allan Horsley, Murray Milner and Craig Watkins.

Articles in the *Journal of Telecommunications and the Digital Economy*:
Covering content presented in the first forum:

Leith Campbell and Murray Milner, "The NBN Futures Forum" (Campbell & Milner, 2019).

Peter Gerrand, "NBN Futures: The Option of Merging NBN Co with InfraCo, as a Benefit to the Digital Economy" (Gerrand, 2019).

Jim Holmes, "Getting the NBN Infrastructure We Need" (Holmes, 2019).

Project overview:

Jim Holmes and Leith Campbell, "The NBN Futures Project" (Holmes & Campbell, 2019).

Covering content presented in the second forum:

Leith Campbell, "The NBN Futures Forum: Realising the User Potential of the NBN" (Campbell, 2019).

Teresa Corbin, "Promoting Digital Inclusion Through the NBN" (Corbin, 2019).

Covering content presented in the third forum:

Leith Campbell, "The NBN Futures Forum: Learning from International Experience" (Campbell, 2020).

Richard Ferrers, "Enhancing NBN's Value: Comparing NBN with Australia's Top 10 Trading Partners and OECD" (Ferrers, 2020).

Murray Milner, "Ultra-fast Broadband" (Milner, 2020).

Covering content presented in the fourth forum:

Leith Campbell, Anthony Smith and Peter Brooks: "The NBN Futures Forum: Social and Economic Benefits of Broadband for Digital Inclusion and Telehealth" (Campbell, Smith & Brooks, 2020).

Submission to the Joint Standing Committee on the National Broadband Network: https://www.aph.gov.au/Parliamentary_Business/Committees/Joint/National_Broadband_Network/smallbusinessandcase/Submissions (Submission 20)

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Annex B: Vision and Objectives

1. Vision

The vision that has been the focus of the work over the last two years and the preparation of this Report is of ubiquitous, high quality, high speed broadband that is affordable to all in Australia and which will provide an essential service needed for Australia to develop and remain an inclusive online society and a competitive online economy into the future.

This vision is continuing – and needs to be agreed and given substance in terms of national broadband infrastructure and services with regard to evolving technologies, market circumstances and national needs.

2. Objectives

The vision needs to be given substance and be realised through:

1. Longer term substantive objectives;
2. Medium-term substantive objectives for the national broadband infrastructure, and for the NBN in particular; and
3. Process objectives in relation to how Australia should seek to achieve its substantive objectives.

Longer term substantive objectives

These objectives are:

- **Digital Society**: to provide all residents and visitors with affordable, reliable network access to all essential services, high and low speed, across Australia.
- **Digital Economy**: to provide all Australian businesses with internationally competitive network access to their customers, suppliers, staff and collaborators across the world.
- **National Infrastructure**: to provide reliable and economical broadband access to fixed and mobile networks, transport infrastructure, emergency services, education, health and public broadcasting networks.

It should be clear that these objectives cover more than the role of NBN Co. All broadband providers in Australia contribute to the national broadband infrastructure.

These objectives need to be given specific meaning for each planning period, to reflect changing expectations and requirements. However, they are likely to be enduring at the higher level expressed above in the long term.

Medium term substantive objectives

These are objectives for the national broadband infrastructure, and for the NBN in particular.

These objectives are best expressed in a National Broadband Strategy that provides direction and some certainty about the priorities that need to be met over the next 10 years. The Strategy will need to be reviewed and, as needed, revised to remain current.

The National Broadband Strategy, to do the work required of it, will need to:

- Be authoritative, reflecting the commitment of the Commonwealth Government as the institution with the key leadership role in relation to broadband infrastructure and services;
- Be comprehensive, covering both supply-side and demand-side targets for broadband;
- Recognise that broadband access services at both wholesale and retail levels in the market will be provided by many providers on a multi-modal platform and network basis, but that the role of the NBN and of NBN Co will be central for fixed access, at least for the 10 years covered in the initial Strategy;
- Identify the performance levels that are planned to be available to residential and enterprise customers served by each of the mix of technologies at the end of each period within the Strategy (at least by the end of the first five-year period, from 2021 to 2025); and
- Incorporate a Statement of Expectations for NBN Co.

Process objectives

These are objectives in relation to how Australia should seek to achieve its substantive objectives.

Australia's national broadband infrastructure and the NBN in particular are long-term, high-cost assets that reflect a very large national investment of public and private resources. As recent developments, and particularly the impacts of the COVID-19 pandemic, show, reliance on ubiquitous broadband services is effectively entrenched. Broadband access needs to be viewed and planned as an essential service, broadly similar to any other utility that is regarded as essential for modern living.

This means that there needs to be a robust level of bipartisan support for national broadband policy and for the key settings in the National Broadband Strategy. The Strategy needs to provide for a consistent approach over long-term investment cycles to provide some certainty for all investment in this field. These cycles and the perspective they require are well in excess of political or electoral cycles and short-term business cycles.

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Other process objectives are driven by the enduring values that Australia espouses as an egalitarian, inclusive liberal democracy – including an agreed minimum level of service coverage to all communities and areas of the country, and affordable access by all.

The process objectives that result from the above considerations are:

- Transparency in developing and approving the National Broadband Strategy and in monitoring and assessing implementation;
- Processes that maximise bipartisan support;
- Establishing affordable access options for all Australians in all geographic locations; and
- Regular reviews of the national Broadband Strategy and of Statements of Expectations for the NBN to ensure they remain current and reflective of dynamically changing circumstances.

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Annex C: Extending the Social and Economic Benefits of Broadband

1. Summary

The major goal of the next phase of broadband development in Australia, following the completion of the initial build of the NBN, should be achieving the full social and economic benefits of broadband networks and delivering value to end users.

The present COVID-19 crisis has demonstrated the benefits of broadband networks in supporting many vital online activities. It has also highlighted the negative impact of digital exclusion on the ability of some citizens to participate in those activities.

Australia needs a substantial and focused approach to pursuing these benefits. Developing this approach will require a contemporary policy focus to embrace a demand-side, user- focused perspective. Significant initiatives have recently been undertaken.

This paper identifies a number of important components for the next phase of broadband development.

2. Situation

A major component of the next phase of broadband network development in Australia will be an emphasis on realising the full social and economic benefits of such networks, both fixed and mobile. This is a view given strong support in statements from both the Minister Paul Fletcher and Shadow Minister Michelle Rowland. At the NBN Futures Forum in July 2019, Minister Fletcher emphasised the need to "get the maximum social and economic impact from the $51B taxpayer's money" and to understand "how best to leverage this extraordinary national investment". Shadow Minister Rowland identified "the task of public policy will be to maximise the benefit of that investment [in the NBN] now and into the future" (Campbell & Milner, 2019).

The current experience of COVID-19 has significantly changed perceptions of these benefits. For many, broadband networks have enabled working at home, studying and communicating in various forms. Many innovative instances of "living online" are revealed each day, at the same time as there are major social innovations such as broad-based telehealth, to which there have been long-standing barriers.

During the course of this project, the NBN Futures Group has given continuing attention to the ways to fully recognise and achieve these social and economic benefits, through two forums

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– *Realising the User Potential of the NBN* (Campbell, 2019) and *Social and Economic Benefits of Broadband Networks: Telehealth and Digital Inclusion* (Campbell, Smith & Brooks, 2020) which attracted over 100 participants in total – as well as a Discussion Paper (NBN Futures Group, 2020), which went through several phases of review by experts external to our group.

Our early considerations occurred in a context in which there had been limited attention to these issues for many years and our Discussion Paper consequently sought to generate active discourse and specific proposals for action. The Paper recognised two major themes in achieving these benefits — given an extraordinarily heightened awareness due to the COVID-9 situation — namely:

- a focus on better understanding and scaling up beneficial online activities, including:
    - online learning;
    - personal communications;
    - working from home;
    - small business processes;
    - creative and cultural activities;
    - online interaction with government;
    - telehealth, which we have chosen to take as a particular case study of activity;
- digital inclusion programs to ensure citizens have the capability to engage with these and other online activities through increasing access, affordability and personal abilities, as examined in detail by organisations such as the Australian Digital Inclusion Alliance, the Australian Communications Consumer Action Network and the Australian Digital Inclusion Index.

The Discussion Paper emphasised the need for long-term, coordinated action focused on these linked themes, possibly through the establishment of new entities.

3. Recent Initiatives

During the last year, practical initiatives have been undertaken by the Commonwealth Government and NBN Co. These include:

- The establishment of the Digital Technology Taskforce, as a cross departmental body coordinated by the Department of Prime Minister and Cabinet with an external Experts Advisory Committee and including a specific area of focus on digital skills and inclusion ("Digital Technology Taskforce", n.d.).
- The establishment of the Australian Broadband Advisory Council to provide advice and recommendations to the Minister, Paul Fletcher, on matters including:

  - ways in which the NBN and 5G can be used to lift Australia's economic output and the welfare of Australians more generally;
  - opportunities to increase the use of the NBN, 5G and other broadband networks, including by small and family businesses;
  - barriers to using the NBN and 5G, including financial and cultural/behavioural issues and cost-effective strategies to reduce such barriers;
  - potential implementation, communication and outreach strategies.

Over an initial 2-year period, the Council will develop digital connectivity strategies for the agriculture, education, tourism, media and digital content, and health sectors ("Broadband advisory council established", 2020).

- Increasing emphasis by NBN Co. on pursuing social and economic benefits through its corporate plans and actions in relation to affordability and inclusion, including:
  - A $150m COVID-19 response package to help Internet providers "to connect low-income families with home schooling needs and assisting small and medium businesses and households facing financial hardship" ("COVID-19 relief", 2020);
  - a process of codesign with Internet service providers and community groups on approaches to increasing connection of older Australians ("Media Statement", 2020).

We welcome these initiatives and recognise the importance of seeing how they develop over time. At the same time, we identify some of the matters that we consider need to be taken into account in considering how a long-term emphasis evolves from these initiatives.

4. Components of an ongoing process

The following components of the ongoing broadband development process arise from our understanding of the social and economic benefits achieved (or not) by broadband networks over the last several decades. Key sources are our Discussion Paper, our NBN Futures Forums and our interactions with experts in relevant fields.

4.1 A continuing "demand side" policy focus

We need to recognise enhancement is required to the National Policy focus. For a considerable period, debate about national broadband network development in Australia has focused on the technical and ownership aspects of the relevant infrastructure. The social and economic benefits of this infrastructure are, however, derived from the ways in which it is put to use by a wide variety of users — residential, small business, corporates, government agencies and other service providers. This user focus, or demand-side perspective, requires a quite different orientation than that of the supply-side perspective on technology and services. Globally, research is identifying that, once the infrastructure is substantially in place, nations are increasingly starting to take a demand-side focus on policy development:

> "Theoretical research and international experiences have demonstrated that, while both supply-side and demand-side policies have a positive effect on broadband diffusion at the initial stage of broadband adoption, only demand-side policies appear to generate a positive and increasing effect after one has reached a certain degree of broadband penetration" (Liu, 2016, pp. 177-178, 183).

This user-focused perspective brings in elements of social, economic and policy research and development on which we have had relatively little emphasis in our national policy debate.

Taking Telehealth as an example, we have been advised that major factors in scaling up applications so apparently beneficial during COVID-19 include the comfort of patients with the approach and their easy access to and capability with technology, cultural acceptance within the health profession, and economic aspects such as the provision of Medicare items. While massive increases in Telehealth consultations have occurred, the fact that about 90% of these have been by telephone indicates the need for a focus on factors limiting the use of video consultation ("Telehealth and coronavirus", 2020).

Clearly, the influencing of all factors such as these which are across many sectors is within the remit of a number of Ministers — Communications, Health, Education, Government Services, Agriculture and others — making appropriate policy development a cross-portfolio matter.

4.2 A broad consideration of social and economic benefits

While it makes a great deal of sense to focus in the short term on sustaining and scaling up the clearly observable benefits of online activities since the advent of COVID-19, over time a broader approach will be desirable, including:

- Identifying areas of focus such as:
    - Assessment of macro-economic benefits;
    - Expansion of Internet use in a broad range of information, communication, transaction and entertainment applications;
    - Specific socially valued application areas, such as government services, education, health, banking;
    - Specific economic development areas, such as business (corporate and SMEs), agriculture, tourism;
    - Broader social impacts, such as decentralisation;
    - Possible benefits of future application areas, such as Internet of Things and augmented reality;
- Developing a framework for the recognition of benefits as they apply to users, service providers, and society broadly;

- Recognising the critical underlying requirement of digital inclusion and broader activity-oriented capabilities.

4.3 Generating discourse

There have been claims about the social and economic benefits of broadband networks over the years, but little apparent sustained, interrogating discourse or research in Australia:

- There have been limited generators of wide-ranging discourse since such activities as the University of Canberra hosting a symposium, *Converging on an NBN Future: Content, Connectivity, and Control* in 2012 ("NBN future", 2012), and the Institute for a Broadband-Enabled Society and its now-defunct successor, the Networked Society Institute, conducting a range of public seminars and forums from 2009 to 2019.
- There are more niche, sector-based approaches such as the University of Queensland's Centre for Online Health's public seminars, and the Australasian Telehealth Society's annual conferences on *Successes and Failures in Telehealth* ("SFT-19", 2019).

Our experience of conducting the NBN Futures Forums has shown the merit of cross-disciplinary public discourse, which could be greatly expanded to an extensive inclusion of policymakers, practitioners and researchers.

4.4 Long-term coordinated activity

In contrast to some other countries with advanced broadband infrastructure, which have long-established plans and central agencies to guide demand-side development, Australia has a patchwork history of policy and research activities. Research and policy development bodies with a demand-side emphasis must have longevity to ensure the building of intellectual capital.

These latest initiatives provide an opportunity to adopt a long-term strategic understanding and consequential plans.

4.5 Scale requirements of programs

In relation to Digital Inclusion/Capability

A common estimate of the number of people in Australia who are not accessing the Internet on any regular basis is 2.5m, with 2m being over 55 (ABS, 2018, Table 1). In contrast, the Commonwealth-funded *Be Connected* program, specifically directed at older persons, aims to reach up to 100,000 people annually (eSafety Commissioner, 2018, p. 2). A more robust approach to digital inclusion and enhanced digital capability will be required to ensure significant scaling up of current activities.

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The Australian Digital Inclusion Alliance identifies more than 50 current projects operating in an uncoordinated fashion and not embracing all the groups with most exclusion – such as those on low income, people with disabilities, and also Indigenous people. They propose the development of a Digital Capabilities Framework and a National Digital Inclusion Roadmap to be driven by a single government department (ADIA, 2020).

Table C-1. National Digital Inclusion Roadmap (Source: ADIA)

Affordability	Ability	Accessibility
Addressing availability and affordability of Internet services	*Ensuring everyone has the capabilities and confidence to benefit from and complete activities on the Internet*	*Allowing everyone to use the Internet including those living with disability, from culturally or linguistically diverse backgrounds, or with other needs*
Access to devices and the Internet	Analysis of digital capability programs being provided to understand gaps and overlaps Creating a Digital Capabilities Framework to provide a common understanding of what it means to be a digitally capable individual	Ensuring websites are compliant with the latest accessibility standards
Removing cost as a prohibitive barrier	Implementing a consistent way for individuals and community organisations to find out what is available locally by way of programs and resources to encourage digital inclusion	Ensuring whole of government adherence to accessibility requirements suitable for public procurement of ICT products and services

In activity areas

Similarly, the scale of actions required in particular activity or sectoral areas will be significant, including greater skilling in using online capabilities and techniques in professional training programs and with current practitioners and the introduction of new supportive roles such as the Digital Health Navigators suggested in the Telehealth area (Brooks, Duckett & Oldenburg, 2020).

Required action includes fully encouraging the engagement of small businesses which may require expanded training programs to expand capabilities and incentive structures, such as grants for equipment, specific training and business restructure. The recently announced Jobmaker Digital Business Plan (n.d.) recognises the need for encouragement of this nature, although full details are not readily available at the time of publication of this document.

4.6 Opportunities from higher speed infrastructure

We have focused initially on the significant benefits that can clearly be obtained by scaling up current applications in a wide range of activity areas – through focusing on the issues of digital inclusion, culture and economics of particular sectors, and ensuring existing technologies meet reliability and common speed requirements, as far as possible. The capacity for visual communications provided by the broadband infrastructure underlies many of these applications. Other applications are likely to emerge with higher speed infrastructure, particularly through the increasing capacity for transfer of large data files. Ongoing development processes should include the capacity to nurture these initiatives.

4.7 Universal Service

Australia has a long tradition of recognising the social benefits of a standard telecommunications service, available universally at reasonable cost throughout the country. Currently, the concept of universal service, originated in 1996 in its present form, applies to fixed telephony and payphones. But in the 2020s the mobile phone has become the near-universal telecommunication device on which virtually all consumers depend, and is the device most used by Australian adults to access the Internet (ACMA, 2020a) particularly by people of low income. In a country with a significant number of homeless people (most of whom do use and depend upon mobile phones), an updated definition of universal service – necessarily a broadband service – must include serving those without fixed addresses.

The 2014 Statement of Expectations for NBN Co contains a policy objective of at least 25 Mbps downstream to all premises, but the service to many regional and rural premises falls well below this speed, particularly in peak periods. The Regional Broadband Scheme, which is due to commence on 1 January 2021, provides for a shared funding scheme between fixed-line broadband carriers to support NBN's fixed wireless and satellite service provision.

A fundamental question to consider further is whether the universal service should be that which is desirable to have in all premises for full social and economic participation – considered to be 100 Mbps by 2025 – but which may not be fully technically feasible, or whether it constitutes a more basic standard service that should be available to all areas. Closely associated with this question is that of how the service level is to be funded – on a commercial, cross-industry or government-supported basis.

A standard broadband service would reasonably need to be at the level of NBN Co's 2014 objective and be at least 25 Mbps download speed and 5 Mbps upload speed, and should include access by mobile devices through radio access links. Consideration of universal provision will therefore need to take into account:

- the significant access to broadband service through mobile phones and hence the provision of the universal service by fixed or mobile means;
- provision of free Wi-Fi at various locations;
- provision of the service by carriers other than NBN Co;
- the timeframe of progressive implementation;

- cross-industry funding support including mobile as well as fixed-line carriers; and
- the need for continual review and likely extensions to 50 Mbps download and 20 Mbps upload speed and beyond over time.

4.8 Organisational supports

Policy and project development to achieve social and economic benefits is likely to require particular supports, including:

- Social and economic research, preferably through structures that enable the continual building of understandings;
- Easily accessible national data: This will require, firstly, the identification of necessary measures and procedures to capture a broad cross section of data; and, secondly, a more consolidated database than currently exists through the Australian Digital Inclusion Index and the private survey work by the Australian Communications and Media Authority (ACMA, 2020b) and for other purposes. ACMA might be this ongoing repository of information. South Korea's National Information Society Agency, created over 30 years ago, collects and publishes extensive annual statistics (Park & Kim, 2012).
- Possibly a purpose-built organisation to drive the understanding and development of social and economic benefits of broadband networks, and provide ongoing policy and project support and research, such as a Broadband Institute proposed in the earlier Discussion Paper (NBN Futures Group, 2020).

5. Conclusion

Dramatic change has occurred in the use of broadband-based online services as a consequence of the COVID-19 pandemic, now supported by the completion of the NBN rollout. These circumstances must be seized upon and further developed to maximise the benefits to end users and the national economy.

The current initiatives by government and NBN Co are important but not necessarily sufficient. They should be placed within a vision of possible benefits, with a clear understanding of the long-term requirements for policy development, social and economic research and project support.

Scaling up the many applications flourishing during COVID-19, actively pursuing other opportunities that the technology provides, and thoroughly focusing on the requirements of digital inclusion and capability building is a major task requiring significant investment. A particular focus needs to be given to the development of the personal skills of all end users to maximise effective participation. These investments will be justified by the benefits to the whole of society beyond the specific commercial interests of NBN Co.

This necessary, but so far not fully explored, demand-side perspective on policy needs an informed discourse of all relevant parties. The establishment of a national cross-portfolio activity to ensure the efficient and effective development of online services is urgently needed.

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Annex D: Technology Pathways and Development

1. Overview

This Annex provides an overview of the access technologies used in the NBN and the proposals for how they may be enhanced to provide greater communications capability in response to user demand. The first part summarizes some of the evidence that indicates user demands for increased access speeds over time and makes a comparison with planned 5G performance. The second part considers each access technology in turn and describes the pathway to "uprating" that technology. Where possible, the description supports NBN Co's own plans for increasing the technology capability.

2. Demand for High-Speed Services

In designing a multi-technology mix for the NBN, the government depended on a bottom-up estimate of the 'need' for broadband speeds (Vertigan, 2014). This suggested that 25 Mbps would be an adequate downstream speed for most households for some years into the future. While there may or may not be little 'need' for higher speed services, there is clear evidence that a significant number of users desire speeds at or above 100 Mbps downstream, and even at 1 Gbps or higher, and are willing to pay for them.

This Annex considers the actual market demands and demand estimates that indicate a desire for higher downstream speeds to demonstrate that there will be demand to upgrade the services of the NBN beyond the capabilities of the initial deployment. It does not examine how such upgrading could be paid for: this is recognised in Annex C, Section 4.7 as a core question in considering future universal service requirements and in Annex F in seeking to understand how NBN Co will be able to fund infrastructure investments.

It is important to note that, apart from perceived market demand outlined here, there may be other drivers for upgrades. In the policy sphere, for example, consideration of social equity may lead to a general upgrade to a common performance standard across all accesses. Treating the NBN as a household utility (like water or electricity) may lead to a common and improving performance level. There may also be commercial drivers. Improved performance could lead to NBN Co selling more services at higher prices, thereby improving its average revenue per user. A wider deployment of fibre to the premises or to the kerb would lead to lower operational costs per line, improving NBN Co's earnings. Some of these matters are taken up elsewhere in this report.

NBN Co (2019) has recognized that future technology upgrades will be necessary to provide higher speed services. In its latest *Corporate Plan 2020-23*, it provides a section on "Lifting Australia's digital capability" (pp. 22-32). NBN Co says (p. 30): "This approach includes a commitment to continually evolve the product portfolio to meet changing customer demands."

The New Zealand experience

The New Zealand experience is enlightening. Milner (2020) has reported that in mid-2019 services at 100 Mbps downstream (and 20 or 50 Mbps upstream) make up 69% of subscribed accesses to the Ultra-Fast Broadband (UFB), with only 16% at 50 Mbps or lower. Access at 200 Mbps symmetrical makes up 6% of accesses, while 9% of accesses are at 1 Gbps (1,000 Mbps).

International comparisons

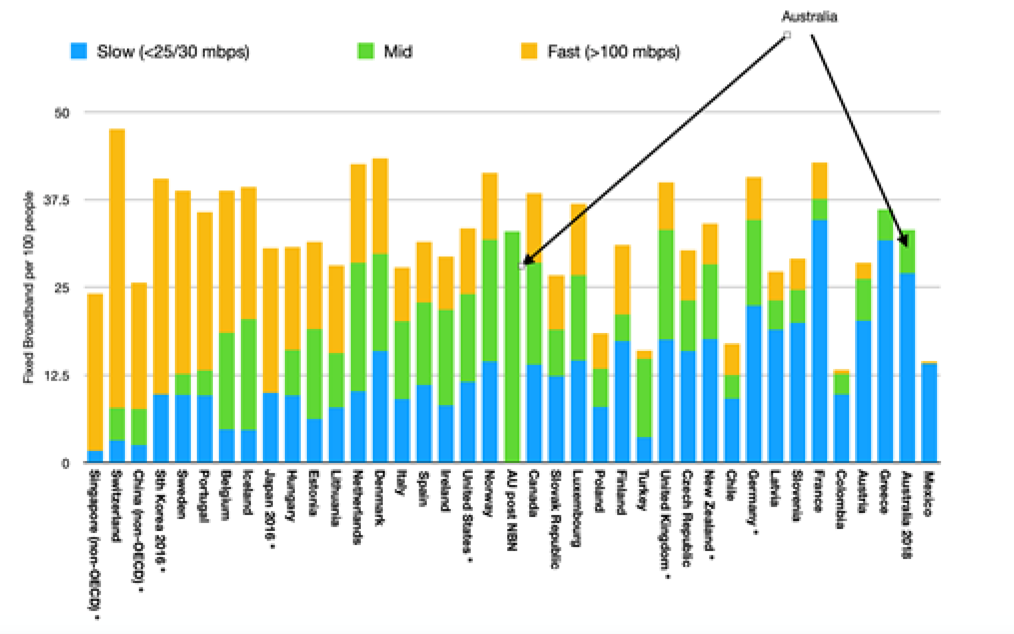

Figure D-1. Australia broadband download speeds compared with OECD and other countries in 2018
Source: Ferrers (2020), Figure 2.

Ferrers (2020) has identified that in comparable countries there are a significant number of services at 100 Mbps or greater. Figure D-1 reproduces a graph from Ferrers (2020) indicating the proportion of accesses subscribed to per 100 people at several speed bands. The countries have been sorted into decreasing order of average access speed. The graph shows, for example, that the top ten countries have significant numbers of subscribed accesses at 100 Mbps or higher. If the NBN *only* delivered 50 Mbps services, Australia would still only be in the middle of the pack. In addition, Ferrers (2020) provided data to show that average broadband speeds in other countries increased by 20-30% from 2018 to 2019.

Ferrers (2020) also noted that there is demand for services at 1 Gbps. He highlighted an offering in Thailand (a country many Australians would not consider technologically advanced), where True Corp. has offered 1 Gbps service at less than $140 per month.

It is important to note that the figures quoted above are *subscribed* speeds: that is, customers are willing to pay for them and are doing so. The evidence is clear: there is significant demand for services at 100 Mbps and above at affordable prices. Both Ferrers (2020) and Milner (2020) suggest that access at 1 Gbps or higher will be taken up if offered at reasonable prices.

Comparison with mobile broadband

For IMT-2020 (the 5G standard), the ITU-R has set *minimum* performance standards for enhanced mobile broadband service (Mohyeldin, 2016). Peak data rates are downstream 20 Gbps and upstream 10 Gbps. In a dense urban environment, users 95% of the time should be able to access 100 Mbps downstream and 50 Mbps upstream. These are "user experienced" data rates, that is, user data exclusive of transmission and control overheads.

The 3rd Generation Partnership Project (3GPP), the main standardisation body for 5G, has defined the performance requirements for 5G mobile services (3GPP, 2019) in a number of scenarios, some of which are shown in Table D-1. As a result of these requirements, it is likely that users will come to expect 50 Mbps downstream and 25 Mbps upstream as a *minimum* in almost all circumstances.

Table D-1. 5G Performance Requirements

	Scenario	Experienced data rate (DL)	Experienced data rate (UL)	Area traffic capacity (DL)	Area traffic capacity (UL)	Overall user density
1	Urban macro	50 Mbit/s	25 Mbit/s	100 Gbit/s/km²	50 Gbit/s/km²	10 000/km²
2	Rural macro	50 Mbit/s	25 Mbit/s	1 Gbit/s/km²	500 Mbit/s/km²	100/km²
3	Indoor hotspot	1 Gbit/s	500 Mbit/s	15 Tbit/s/km²	2 Tbit/s/km²	250 000/km²
4	Broadband access in a crowd	25 Mbit/s	50 Mbit/s	[3.75] Tbit/s/km²	[7.5] Tbit/s/km²	[500 000]/km²
5	Dense urban	300 Mbit/s	50 Mbit/s	750 Gbit/s/km²	125 Gbit/s/km²	25 000/km²

Source: Table 7.1-1 (part only) in 3GPP TS 22.261 V17.1.0, p. 48 (3GPP, 2019)

While 5G deployments in Australia may not deliver these data rates on a wide scale, they set an expectation among users. If fixed access cannot match or exceed the performance of enhanced mobile broadband, users will prefer the mobile solution, if the price is satisfactory.

Bottom-up service estimates

There have been many bottom-up estimates of the 'need' for broadband, where the estimated requirements of individual services are aggregated to calculate the required downstream and upstream access speeds. These estimates vary greatly, as the following examples show.

A relatively recent one from WIK Consult is quoted by Telstra (2020) in its submission to the Parliamentary Joint Standing Committee on the National Broadband Network. Telstra provides the following commentary (Telstra, 2020, p. 5):

> In 2018, WIK forecast the expected demand for bandwidth in the UK by 2025 on behalf of Ofcom (the UK's communications regulator). As illustrated in the table below, WIK expects that consumer demand will be driven by the parallel usage of several applications with higher requirements for download, upload and quality parameters compared to today. Telstra's experience suggests these to be equally applicable in Australia.

Telstra (2020, p. 6) then includes the following table of requirements.

Table D-2. [Telstra] Estimation of bandwidth requirements by application (Mbps)

Application category	Downstream bandwidth in 2015	Assumed CAGR (%)	Downstream bandwidth in 2020*	Downstream bandwidth in 2025
Basic Internet	2	25	~6	~20
Home Office/VPN	16	30	~60	~250
Cloud computing	16	30	~60	~250
State-of-the-art media and entertainment (4k, 3D, UHD)	14	20	~40	~90
Progressive media (8k, VR)	25	30	~100	~300
Communication	1.5	20	~5	~8
Video communication (HD)	8	15	~10	~25
Gaming	25	30	~100	~300
E-Health	2.5	30	~10	~50
E-Home/E-Facility	2.5	30	~10	~50
Mobile Offloading	2	30	~10	~15

Source: WIK. *Calculated by Telstra from WIK data

In its report, WIK forecasts demand of households in 2025 under a range of scenarios as:

- 'Top Level' demand (1 Gbps+ downstream, 600 Mbps+ upstream): 8%–40% of households;
- 'High Level' demand (300 Mbps–1 Gbps downstream, 300 Mbps–600 Mbps upstream): 49%–42% of households;
- 'Low to High Level' demand (up to 300 Mbps downstream, up to 300 Mbps upstream): 35%–10%;
- No broadband/refusal: 8%.

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From this material, we could estimate that downstream speeds of 300 Mbps or more would be required by more than 50% of households in 2025. While we may question whether this represents an estimate at the high end of useful forecasts, we can take it as evidence that there will be significant demand beyond 100 Mbps downstream in the next 5 years. NBN Co itself has recognized this with a wholesale service at 250 Mbps downstream ('Home Superfast', NBN Co, 2020b, p. 18).

The Bureau of Communications and Arts Research (BCAR) in the Australian Department of Communication and the Arts has forecast household consumption of fixed broadband services first (BCAR, 2018) up to 2026 and recently (BCAR, 2020) up to 2028. BCAR has considered the demographics and usage patterns of Australian households and small businesses and has classified Internet applications into groups based on common drivers (such as streaming for video, gaming and virtual reality). From this analysis and various assumptions about simultaneous use of applications, BCAR produced estimates of the cumulative density function of the maximum household requirement for download speed. The traffic is dominated by streaming video but, importantly, BCAR took account of emerging household applications such as virtual reality and the proliferation of Internet-of-Things devices.

The BCAR estimates have become somewhat more optimistic in the latest report. In its 2018 forecast, average monthly data usage increased from 95 GB in 2016 to 420 GB in 2026. In its current forecast (BCAR, 2020, p. 43, Figure 22), average monthly data usage in 2026 is about 600 GB, climbing to near 800 GB by 2028.

In BCAR's base case, 95% of households will require 56 Mbps or less at peak times in 2028, and only 0.1% will require download speeds above 78 Mbps (BCAR, 2020, p. 77). This should be well within the deployed capability of the NBN by that year.

The BCAR base case appears to be a conservative view for two main reasons. The first is that the growth in downloaded data is low – only 14% per annum to 2028, while the observed growth was about 42% per annum in the period 2010–2018 (BCAR, 2020, p. 38). BCAR notes that growth rates are declining over the long term, but the estimated decline seems excessive, especially given the step change in demand observed by NBN Co during the Covid crisis (NBN Co, 2020b, p. 30): this may represent a 'new normal' for working from home. The second reason is that demand may be affected by characteristics of Internet use other than download speed: BCAR notes this on p. 76. Higher download and upload speeds may well produce a more positive perception of Internet performance and hence lead to greater 'demand' for broadband. Indeed, the current market demand for accesses at 1 Gbps may well be partly driven by a perceived overall benefit to Internet usage from this high speed.

3. Uprating the NBN

In this chapter, we consider the issue of how to make the NBN responsive to customer demand for higher speed services. We call this 'uprating' the NBN, to distinguish it from 'upgrading' the NBN, which probably involves a wholesale replacement of technology, such as 'upgrading' to Fibre to the Premises. We outline the methods by which NBN Co can deliver higher speed services from the current multi-technology mix.

Our aim is to demonstrate that the NBN in its current configuration can be responsive and agile in service delivery in many areas without necessarily a wide-area upgrade of technology. An important consideration is to avoid the need, where possible, of a new installation in a customer's premises. Such installations are time-consuming and costly. We do assume, however, that it would be possible for a customer to make a simple change like swapping out an old modem for a new one.

NBN Co (2020b) has recognized that further technology upgrades are necessary to provide higher speed services. In its latest *Corporate Plan 2021*, it provides a section on "NBN Co's high-speed future" (p. 18), describing residential accesses up to 1,000 Mbps, and a "$4.5 billion network investment plan" (pp. 40-44) including an investment of $3.5B for direct network upgrades. NBN Co says (p. 40): "The plan will deliver targeted and demand-driven investments to ensure the network keeps pace with increasing demand for higher broadband speeds and greater capacity."

The initial technology mix

NBN Co uses a variety of access technologies to reach customers' (end-users') premises:

- FTTP, Fibre to the Premises, also known, in the domestic sphere, as FTTH, Fibre to the Home. NBN Co distinguishes between FTTP installation in 'brownfields' areas – that is, areas where a telecommunications access network already exists – and 'greenfields' areas, often newly built housing estates or industrial parks.
- HFC, Hybrid Fibre-Coax, based on the Telstra HFC network for Foxtel and internet access, suitably upgraded.
- FTTN, Fibre to the Node, where an active node, fed by fibre, replaces a pillar or other junction point in the existing copper-line access network.
- FTTB, Fibre to the Building, for multi-tenant buildings, in which fibre is run to the building's communications point and the existing inside wiring is used for access to each individual premises. For NBN Co, FTTB is similar to FTTN with the node placed in the building.
- FTTK, Fibre to the Kerb. (NBN Co uses "FTTC", Fibre to the Curb, but we prefer the Australian spelling to avoid confusion with FTTC meaning Fibre to the Cabinet or other uses. In the UK, BT uses "FTTC" to describe what we mean by FTTN.) In FTTK, fibre cables run to just outside property boundaries and a small active node is used to

terminate the fibre and provide a connection to the existing copper lead-ins to the premises.

- Fixed Wireless, where a microwave radio link is established between an NBN Co site and an antenna installed on the outside of a premises.
- Satellite, NBN Co's SkyMuster service, where access communication is between NBN Co's geostationary satellites and an antenna mounted on the outside of the premises.

For all technologies except FTTN and FTTB, an NBN NTD (Network Termination Device, an NBN-supplied modem) is installed in the premises to terminate the NBN connection. This, in turn, is connected via Ethernet cable to a service modem provided by a Retail Service Provider, and thence to whatever customer equipment – computers, television sets, telephones, alarms – is required.

NBN Co, in its latest plan (NBN Co, 2020b), has provided the numbers of premises passed by each access technology at 30 June 2020, at the end of the initial rollout. After this time, according to the previous plan (NBN Co, 2019), once some hard-to-reach premises have been passed, all future growth in premises passed will be handled with FTTP.

Table D-3 shows the technology mix at the end of the initial rollout. Also shown, because this is important for uprating the NBN, is the proportion of accesses based on each technology that are capable of providing 100 Mbps or higher downstream. These numbers are taken from NBN Co (2020b), p. 41, "Current network enabled speed", except for the separation of FTTP into 'brownfields' and 'greenfields', which is taken from NBN Co (2019).

Table D-3. NBN technology mix at end of initial rollout

Access Technology	**Premises Passed (“RTS — Ready for Service”)**		**Capable at 100 Mbps or above**
	Number (million)	**Proportion of total premises (%)**	**Proportion (%)**
FTTP (brownfields)	1.1	9.5%	100%
FTTP (greenfields)	0.9	7.5%	100%
HFC	2.5	21%	100%
FTTB	0.6	5%	100%
FTTN 100	1.2	10%	100%
FTTN 50	1.9	17%	0%
FTTN 25	1.0	9%	0%
FTTK	1.5	13%	100%
Fixed Wireless	0.6	5%	0%
Satellite	0.4	3%	0%
Total	11.7	100%	

Sources: Premises Passed – numbers from NBN Co (2020b), p. 41, "Current network enabled speed".

In this table, 'FTTN 100' refers to accesses that are capable of delivering 100 Mbps or more downstream; 'FTTN 50' refers to accesses that are capable of delivering 50 Mbps downstream but not 100 Mbps; and 'FTTN 25' refers to access that are capable of delivering 25 Mbps downstream but not 50 Mbps. This is the first corporate plan in which NBN Co has separated FTTB from FTTN and provided details of the range of download speeds available on FTTN.

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Within the FTTN footprint, 29% (1.2M premises) of accesses are capable of 100 Mbps or higher downstream. (This is higher than the 24% estimated in Gregory (2018).)

Outside the fixed-line footprint, NBN Co claims that all Fixed Wireless accesses are capable of delivering 50 Mbps downstream, but not 100 Mbps. Similarly, Satellite can deliver only 25 Mbps.

NBN Co's stated aims are to provide at least 50 Mbps downstream to 90% of premises in the fixed-line footprint of the NBN (i.e., excluding Fixed Wireless and Satellite areas) and at least 25 Mbps downstream to all premises. NBN Co is careful to note that its quoted speeds are *wholesale* speeds; the actual speed delivered to a customer will also depend on other factors, including the equipment of the Retail Service Provider.

Table D-3 shows that NBN Co has achieved its aims. In the fixed-line footprint, almost 91% of premises passed, excluding only the 1.0M passed by 'FTTN 25', can be provided with at least 50 Mbps downstream. All premises passed can have at least 25 Mbps downstream.

Attributes of the technology mix

Apart from maximum download speeds, which we focus on in this chapter, there are many other attributes for each technology, including minimum latency, availability, and reliability. We can make general statements about each technology – for example, FTTP is probably the most reliable access technology; satellite suffers from a minimum latency of 400 ms, because of transmission to and from geostationary orbit – and NBN Co publishes a "dashboard" of general performance measures. However, aside from Fixed Wireless and Satellite accesses, we have no technology-specific information on performance.

NBN Co reported in February 2020 (NBN Co, 2020a) that the access network was available 99.92% of the time. This is in line with operations for a well-managed copper access network.

Availability of broadband services also depends on the availability of mains power, for both customer premises equipment and active equipment in the access network. Some residential and business customers will invest in battery backup to provide short-term continuity of service after a power failure. Within the network, NBN Co provides battery backup for active equipment, except for HFC and FTTK accesses. HFC and FTTK access may therefore be seen as less reliable, especially for business services.

Bandwidth on the NBN

The actual speeds available on the NBN are shaped by NBN Co according to its pricing model. This means that, on average, users do not experience the maximum speed available on their access technology.

There are two components of bandwidth purchase:

- AVC (Access Virtual Circuit), which sets the maximum download and upload speeds available to the end user (at the wholesale level – information rates will be lower). AVCs come in discrete value pairs, from 12/1 (12 Mbps downstream; 1 Mbps upstream) through 50/20 and 100/40 to 1000/400. NBN Co provides download speeds 10-15% higher than the nominal maximum speed, to bring actually measured downstream speeds closer to the nominal maximum.
- CVC (Connectivity Virtual Circuit), which sets the maximum downstream rate for all the subscribers of a Retail Service Provider (RSP) at an NBN Point of Interconnection. The CVC can be any integer value of Mbps. Presumably, each RSP purchases an amount of CVC capacity that matches its backhaul capacity at the Point of Interconnection. Total CVC capacity purchased by an RSP can be shared across the Points of Interconnection.

An RSP will usually purchase less CVC capacity than the sum total of the AVCs for all its subscribers at the Point of Interconnection. This is because not all the access network capacity is used all the time, even in the busy hour. Contention ratios of 10:1 (that is, the CVC and backhaul capacity is only one-tenth of the total AVC line rates) or higher have been common and, averaged over a sufficiently large and diverse user base, have no noticeable effect on service quality. However, this is almost certainly not appropriate when the user base is small or becomes less diverse (for example, with everyone streaming videos during the busy hour in the evening).

Uprating the NBN technologies

In this section, we consider for each of the NBN access technologies in turn the capabilities to deliver downstream access speeds of 100 Mbps or greater and up to 1 Gbps (1000 Mbps).

FTTP

FTTP is used to pass about 17% of premises. It is often seen as broadly capable of any access speed. While this is generally true of direct fibre to the premises, most of the NBN's FTTP is delivered through GPON (Gigabit Passive Optical Network). That is, one fibre from an NBN site is 'split' by a passive optical splitter nearer to the end-customers' premises into at most 32 accesses to individual premises. A total of 2,488 Mbps is shared among these accesses downstream and half that upstream. The maximum split ratio of 32:1 is probably rarely used in the NBN and lower split ratios (24:1 or lower) are likely for the relatively spread-out households of the Australian suburbs.

In a standard GPON configuration, 24 premises could have a 100/50 service (100 Mbps downstream, 50 Mbps upstream) without contention. In operation, some contention is probably not noticeable, so 28 or even 32 premises could perhaps subscribe to 100/50 service.

Delivering 1 Gbps service in a standard configuration is also possible, but only for one or two accesses without contention on each PON. NBN Co has reportedly installed additional fibres to each splitter site, so a reconfiguration at the splitter site to provide a direct fibre connection for a 1 Gbps service (or higher) is possible. Importantly, this involves no change at the customer's premises and only a brief interruption to the service.

Enhancements to the GPON standards will also deliver standard configurations with higher speed accesses. The ITU-T has standardised a PON, XG-PON (ITU-T, 2012), that is capable of delivering 10 Gbps downstream. A symmetrical configuration, with 10 Gbps in both directions, is included in the standard, but it may require a significant upgrade to the customer premises termination.

HFC

HFC is used for about 21% of premises passed. NBN Co says (NBN Co, 2020b, p. 41) it can deliver up to 100 Mbps downstream everywhere in its footprint; 70% of accesses are capable of 250 Mbps; and 7% can achieve 500 Mbps to 1000 Mbps. NBN Co does not appear to publish information on how many premises are passed by a typical coaxial cable run, so the maximum number of high-speed services that can be delivered in each area is not publicly available. However, it is clear that NBN Co has been introducing fibre further into the network and reducing the length of the coaxial cable runs than was typical for delivery of cable TV.

HFC is used by the large cable-TV companies in the US and is thus on an upgrade path to higher speed services. Cable Labs (2019) has announced a '10G' project to specify the technologies for an upgrade path for HFC to deliver 10 Gbps downstream services. These technologies will be progressively available to NBN Co. It is likely that a concentrated adoption of 10G services in an area would require some further network reconfiguration – more fibre and shorter cable runs. NBN Co has already announced plans (NBN Co, 2019) to move progressively to DOCSIS 3.1 and DOCSIS 4.0, both Cable Labs standards, to provide the capability for higher speed services.

NBN Co has announced (NBN Co, 2020b) a $3.5B upgrade plan that includes $0.4B "for new capacity investments in the HFC network to enable access [to the] highest wholesale speed plans" (p. 41). This would appear to be a DOCSIS 4.0 upgrade for the network to provide downstream speeds up to 1000 Mbps.

FTTB

FTTB passes about 5% of premises. The delivery of access to individual premises depends on the building's inside wiring. For many older buildings, this will just be telephony twisted pair, in which case access using VDSL could deliver a few hundred Megabits per second downstream and somewhat less upstream. For more modern buildings with cat6 cables or even fibre in their risers, download speeds up to 1 Gbps should be easily achievable. Table D-3 shows that all FTTB accesses are capable of 100 Mbps downstream. For NBN Co, upgrading the connection to the building by direct fibre is essentially the same as for FTTP.

FTTN

FTTN passes about 36% of premises, that is, more than one-third of the total. This is a large proportion of suburban homes. The key issue for FTTN is that it is strongly distance-dependent, which is why only 29% of FTTN accesses (see Table D-3) can deliver 100 Mbps downstream. The maximum download (and upload) speed falls away rapidly along the length of the copper cables from the node to each premises.

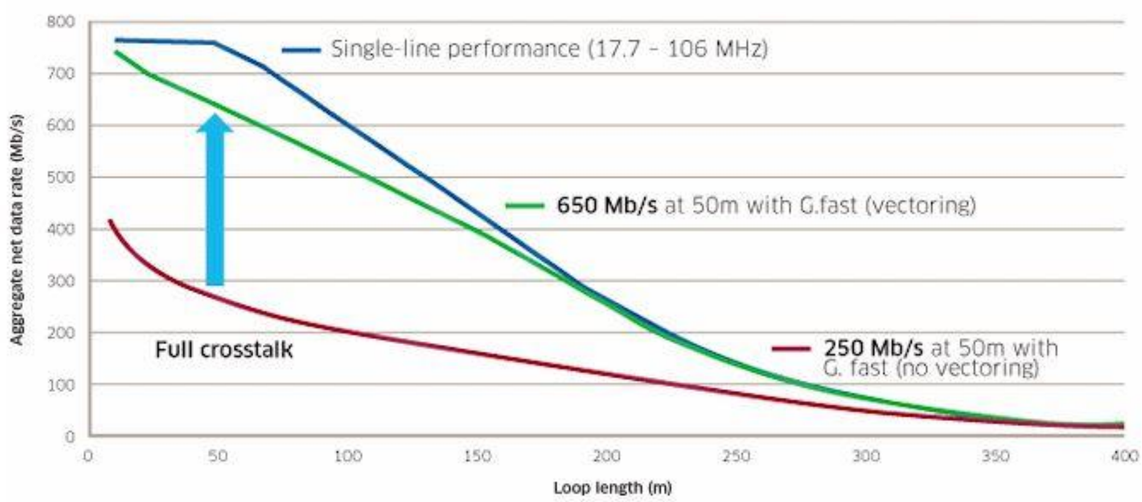

Figure D-2. Data rate as a function of cable length
Source: Jackson (2013), Figure 3.

Figure D-2 is an old chart reporting G.fast line results from Austria on "good quality cable" (Jackson, 2013). G.fast is a high-speed DSL standard. It can be used with vectoring, essentially the coordination of signals within copper cable bundles to increase data rates. Currently, NBN Co is deploying VDSL, a slower DSL standard, on the copper cables of the NBN. The speeds shown in Figure D-2 would only be available after an upgrade to G.fast. NBN Co will be making G.fast available in its FTTK deployments (NBN Co, 2020b, p. 41).

If only 29% of premises supplied by FTTN could get 100 Mbps or more downstream, it suggests that no more than 29% of premises are within about 200 m of a node and 71% of premises are at longer distances. For those within 200 m, the deployment of G.fast and other technical possibilities can deliver speeds up to 250 Mbps or more; for those beyond 200 m, the possibilities are severely limited without a change of access technology.

In some cases, the legacy DA design does not lend itself to high-speed DSL services, usually because the distribution cables are too long. For these cases, NBN Co can use micronodes that can terminate up to 48 cable pairs: see Figure D-3.

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Figure D-3. An NBN micronode during installation (Credit: Tim Herring)

NBN Co has announced (NBN Co, 2020b) a $3.5B upgrade plan that includes $2.9B "to take fibre deeper into the FTTN footprint, enabling premises to move to an FTTP service when they order a higher speed plan" (p. 41). If NBN Co is to achieve its aim of making "its highest wholesale speed plans available to up to 75 per cent of households and businesses in the fixed-line network", then about 1.5M accesses on FTTN will be affected by this upgrade investment. About half the investment will probably be for new FTTP lead-ins (that is, fibre connections into premises); the remainder will add more fibre in the access network through local fibre networks (p. 44).

After this upgrade, there will still be about 2.6M premises passed (about 21%, or one in five, of all premises) in the FTTN footprint that cannot get at least 100 Mbps downstream.

It appears that NBN Co is not considering an upgrade to FTTK within the FTTN footprint as an interim step towards eventual FTTP.

FTTK

FTTK is used to pass about 13% of premises in the initial rollout. FTTK (called 'deep-fibre FTTdp') and surrounding issues are well described in two papers by Watkins & Lillingstone-Hall (2014a, 2014b). FTTK can provide 100 Mbps or more and, with an upgrade to G.fast (see Figure D-2), can provide 1 Gbps downstream over the tens of metres of cabling from the street to a customer's premises. NBN Co has been deploying G.fast-capable units in the FTTK footprint since the end of 2018 (NBN Co, 2019, p. 31) and has now announced (NBN Co, 2020b) a $0.1B "uplift program to provide 100Mbps line speeds for premises on the [FTTK] network and enable access to [the] highest wholesale speed plans" (p. 41). This involves the "on-demand … deployment of G.fast capability or the provision of fibre lead-ins" (p. 41). Given the size of the investment, this is expected to be mostly G.fast deployment.

FTTK can be upgraded relatively easily to FTTP but, importantly, this involves a new fibre installation at customers' premises and hence is relatively expensive. FTTK is, on a world scale, a niche technology and so is unlikely to benefit over time from greater volume production or global technology advances.

Fixed Wireless

Fixed Wireless, installed for about 5% of premises, is used when it is not economical to lay cables from an NBN Co site to a customer's premises. This is predominantly in low-density regional areas (with property frontages of 50-60 m and more). Fixed Wireless, like all radio technologies, can suffer from fading by obstacles or atmospheric conditions. Because the endpoints are not moving, fading in Fixed Wireless can be significant and long-lasting. Some degree of individual design, in, for example, antenna placement or alignment, is required for each Fixed Wireless installation.

Upgrades to Fixed Wireless were described by NBN Co as "[f]uture capability being explored" (NBN Co, 2019, p. 29) but are described only as "[c]ontinued investment to help manage capacity and performance" in the latest corporate plan (NBN Co, 2020b, p. 16). Fixed Wireless benefits from the same technology advances as cellular mobile but, as it is a niche technology compared to mobile, it lags somewhat.

Upgrading Fixed Wireless to FTTP may be economically feasible in some circumstances. The New Zealand experience suggests that, if directional drilling can be used where there are no hard-surface paths, FTTP installations in areas with street frontages up to 100 m may be cost-effective. This could substantially expand the FTTP footprint in regional areas.

FTTP expansion is also possible if the initial installation costs can be spread over a sufficient user community or there is co-investment by other parties. For example, SmartFarmNet is planning to provide symmetrical, high-speed broadband services via FTTP to 650-1000 premises in the Wamboin, NSW, area (SmartFarmNet, n.d.). This would replace Fixed Wireless and Satellite services provided by NBN Co. NBN Co itself has announced (NBN Co, 2020b, p. 40) a $0.3B fund for co-investment with governments or local councils.

In any case, NBN Co's installations are rather under-dimensioned. NBN Co says its sites have a "design threshold of a 30-day average of 6 Mbps download throughput in the busiest hour of the day … (averaged across all active services connected …)" (NBN Co, 2019, p. 32). High throughput services cannot be maintained.

It is unclear what factors, other than cost, drive the low performance level of the Fixed Wireless installations. NBN's Fixed Wireless may be limited by the spectrum available to NBN Co, which was given access to spectrum used for Time-Division Duplex (TDD) services. This would limit the maximum transmission capability of the radio link. It stands in contrast to the Turkcell experience (Ericsson, 2019) using the same vendor (Ericsson) but with several frequency bands with Frequency-Division Duplex (FDD). The *minimum* download speed to be deployed in the Turkcell case is 100 Mbps. It is likely that NBN Co's Fixed Wireless

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installations will in time be upgraded to 5G multi-input, multi-output (MIMO) transmission, which may provide some higher transmission speeds downstream and upstream.

Bob James – quoted in Campbell (2019) – has suggested that Fixed Wireless will never be competitive with cellular mobile and that a combined mobile and fixed wireless network in regional areas would make better economic sense. This would appear to be a good technological option but how it could be achieved in the Australian context requires further consideration. It seems likely in any case that customers will prefer high-throughput mobile services, when they are available, over a limited fixed wireless service without mobility.

Satellite

Satellite, used for 3% of premises, is the least capable of the NBN access technologies. It does not provide downstream speeds above 25 Mbps and, although it can provide telephony, it does so with noticeable transmission delay. Subscriber charges are also higher than for other access technologies. There is evidence – cited in Corbin (2019) – that some customers would prefer to keep their DSL services rather than move to the NBN satellite access. (Most potential satellite customers, however, are beyond the reach of terrestrial broadband. Telstra, for example, advertises that it covers 99.5% of the population with its mobile services, suggesting that there are between 300,000 and 400,000 premises that are not covered).

The future of satellite service was marked by NBN Co as "[f]uture capability being explored" (NBN Co, 2019, p. 29). Satellite technology continues to evolve, with higher power geostationary satellites and new spectrum options. All such advances exclude acceptable telephony because of the transmission delay. There is also the promise of future low-Earth-orbit satellites (LEOs) providing high-speed internet access, including telephony. It is unlikely that NBN Co would launch its own LEOs for service in Australia, since the satellites would, of necessity, spend most of their orbits outside Australian range.

As with Fixed Wireless, the best technological option would seem to be some combination of NBN services with cellular mobile or other offerings but, again, how this could be achieved in the Australian context is open to question. There may always remain some very hard-to-reach premises for which satellite service is the only or best option, but many fewer than the current 400,000 planned to be served by satellite.

Cost of Uprating

The announced spend of $2.9B for fibre upgrades to the FTTN footprint, which we estimate will affect 1.5M premises, gives some insight into the cost of uprating the FTTN to FTTP.

The average cost per premises in this upgrade is about $1,900. This is made up of the cost of new fibre installations in the access network and, importantly, the cost of new fibre lead-ins at premises that request the highest speed services. The New Zealand experience, together with a high-level analysis of NBN Co's reported access costs, suggests that the installation of fibre lead-ins costs about $1,000-1,500 per premises, which leaves about $500-900 per premises passed for upgrades in the local fibre network. This is consistent with the costs per premises reported by NBN Co (2020b, p. 55).

The announced network upgrade costing $3.5B includes not only $2.9B spent on fibre upgrades, but also $0.4B for HFC upgrades and $0.1B for G.fast installations in FTTK. The total upgrade brings all of FTTP, HFC, FTTK, FTTB accesses, and 1.5M FTTN accesses up to the capability for more than 100 Mbps downstream. This still leaves 2.6M premises passed by FTTN, plus the 1M premises served by Fixed Wireless and Satellite, with lesser capability.

Using the average costs for the fibre upgrades, we can estimate that bringing the remaining 2.6M premises in the FTTN footprint up to the standard of FTTK with G.fast would cost about $900+$100 per premises passed, or approximately $2.6B. Adding an allowance to uprate the Fixed Wireless network (whose total cost to date is less than $2B – 600,000 premises passed at $4,315 cost per premises) of another $1B (and likely to be less) leads to a total cost of uprating the whole network to 100 Mbps or higher (excluding the Satellite component) of about $7.1B. Of this, $3.5B has already been budgeted.

In all these uprating calculations, the Satellite component (400,000 premises passed or 3% of the total) remains with the minimal capability of 25 Mbps downstream. NBN Co is expecting that the take-up of the Satellite service will remain steady at 100,000 premises connected up to 30 June 2024 (NBN Co, 2020b, p. 53, Table 2: Premises Activated).

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Annex E: The NBN in the 5G Era

1. Introduction

The abbreviation '5G' refers to the 5th generation of mobile (cellular) communications, offering many enhancements over the current 4th generation. 5G is an important contribution to a National Broadband Strategy. It can enhance the capabilities of the NBN as well as providing infrastructure competition in broadband access.

The performance standards for 5G have been set by the ITU's IMT-2020 project and technical standards are being developed by the 3rd Generation Partnership Project (3GPP). Equipment based on 5G radio standards is now being deployed. Related standards are still in development.

On 13 August 2020, the Chief Executive of Telstra Corporation Ltd, Andrew Penn, released Telstra's results for the 2020 financial year (Telstra Corporation Ltd., 2020). He sees a future that belongs to 5G:

> "Earlier this year we decided to bring forward $500 million of capital expenditure planned for the second-half of FY21 into calendar year 2020. This is enabling us to accelerate our 5G rollout further while injecting much needed investment into the economy. As a result, late last month I announced that we have increased our ambition and plan to cover 75 per cent of the population with our 5G network by June next year."

What is so significant about 5G that Telstra (and also Optus and Vodafone TPG) are investing so much in it? There are user benefits (higher data speeds, low latency and a much greater range of applications), cost benefits to the carrier (greater spectrum efficiency in transmitting large quantities of data) and simply "being on the right side of history" with all the marketing benefits of being supported by the 5G mobile phone manufacturers. However, the much broader potential of 5G can be explained in terms of its architecture and functionality.

There are four significant ways in which 5G differs from 4G:

1. the specification of distinct usage scenarios
2. network virtualisation
3. new radio (NR)
4. wireless-wireline convergence (WWC).

Usage Scenarios

IMT-2020, the International Telecommunication Union's "overall roadmap for the development of 5G mobile" (International Telecommunication Union, 2015) defines three distinct usage scenarios for 5G networks (International Telecommunication Union, 2017, p. 1):

1. eMBB—enhanced Mobile Broadband
2. URLLC—Ultra-Reliable and Low-Latency Communications
3. mMTC—massive Machine-Type Communications

These scenarios place differing demands on a 5G network: eMBB requires greater data rates, URLLC lower latency, and mMTC, which is designed for the Internet of Things, much greater numbers of connected devices than 4G.

To satisfy these demands, 5G has a flexible network architecture that allocates to each service the resources appropriate to its requirements. For example, URLLC services might need their data to follow the shortest path through the network to minimise latency; eMBB services might require a path with greater capacity.

Network Virtualisation

The most important aspect of the 5G architecture is network virtualisation.

The core of a 5G network (5GC) consists of network functions, such as the user plane function (UPF), which directs the flow of user data through a 5G network, and the access and mobility management function (AMF), which controls user access, connected together by a network that supports the 5G usage scenarios. The 5G standards define a protocol that the network functions use to communicate with each other.

The network functions are designed to be virtual: software that runs on virtual machines in the cloud. Because there can be multiple virtual machines on the same hardware, multiple network functions can share the same server in a data centre. Unlike physical hardware, they can be easily relocated if necessary.

The network can also be virtual and share a common physical network with other virtual networks, 5G or otherwise. The underlying physical network must, of course, support the 5G usage scenarios. The overlay virtual networks then inherit this capability.

Consequently, the whole 5GC, both network and functions, can be virtual: it is not tied to dedicated hardware.

New Radio

5G new radio (5G NR) is the air interface for 5G networks. An air interface specifies the format (modulation) of a wireless signal. The big difference from 4G is that, in addition to frequencies below 6 GHz, 5G NR will use spectrum with wavelengths of about a millimetre, in particular at 26 GHz and at 28 GHz. The benefit of using this spectrum is that it can support very high data rates. The trade-off is that its range is very limited.

The new frequency bands are well suited to indoor use. The Australian Communications and Media Authority is planning to auction spectrum in the 26 GHz band commencing in late March 2021 (Australian Communications and Media Authority, n.d.).

Wireless-Wireline Convergence

While we naturally think of 5G in a wireless context, the Broadband Forum is currently finalising standards that specify how a router can connect to a 5G network over a wired connection. It is defining interfaces for both 5G-capable routers and legacy routers (such as those in service today). These standards will enable the provision of 5G services over the NBN. Telstra is heavily involved in their development.

2. What Can NBN Co Do?

Can NBN Co play a role in the roll-out of 5G networks?
Broadly, it has five options:

1. Do nothing.
2. Uprate the NBN so that it can support the full range of 5G services.
3. Allow 5G carriers to use its dark fibre as backhaul from base stations.
4. Upgrade the NBN so that it supports Network as a Service (NaaS).
5. Provide a wholesale 5G service.

Do Nothing

It is possible for a 5G carrier to use an existing NBN fibre-to-the-premises (FTTP) service to connect to a (wireline) router or a (wireless) femtocell located at a subscriber's home or business.

5G Wireline

Why would a 5G carrier prefer providing a wireline 5G service instead of just a standard Internet access service? There are three reasons: (1) so that it can use its 5G wireless network for backup, (2) so that it can transfer fixed-wireless subscribers to wireline, and (3) so that it does not have to operate separate networks for wireless and wireline subscribers.

The first reason is obvious: if an NBN service were to go down, a subscriber's router could maintain connectivity by swapping over to a 5G wireless network. The second would give the 5G carrier a tactical advantage in acquiring subscribers in an area where the NBN was about to roll out, e.g., in a new housing estate. It could provide fixed-wireless service before its competitors and then cut over to the NBN when it became available.

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The third reason might be the most significant in that it affords a 5G carrier the opportunity to reduce its costs by eliminating the system that delivers fixed services and using the 5G system for both wireless and wireline services.

5G Wireless

A femtocell is the cellular analogue of a Wi-Fi access point. It would use spectrum in the 26- and 28-MHz bands to provide a 5G service over a limited range, for example, indoors or around a homestead. Femtocells can act as (limited) wireless extensions of NBN wired connections.

The advantage over a Wi-Fi access point is that it would allow smartphones to connect to it in preference to a base station, providing better service over a shorter radio link. However, the quality of a femtocell service would depend on that of the underlying NBN service.

Uprate the NBN

It would be perverse if the NBN, a wireline network, could not meet the IMT-2020 targets for bandwidth and latency. Does it? The IMT-2020 targets for minimum *peak* data rates are:

- downlink—20 Gbit/s
- uplink—10 Gbit/s

The NBN uses many technologies to provide service: fibre to the premises (FTTP), hybrid fibre (coaxial and fibre to the building, kerb, and node), fixed wireless (4G), and satellite (Sky Muster).

Passive Optical Networks (PONs)

The equipment that NBN Co currently uses for its FTTP service complies with the G-PON standard (International Telecommunication Union, 2008) and allocates a nominal peak data rate of 2.4 Gbit/s across up to 32 premises. *Prima facie*, it falls far short of meeting the 5G targets. The other NBN technologies are worse.

However, data rate requirements differ depending on the usage scenario. The maximum data rates above are most relevant to an eMBB service, and, even then, “the more relevant data rate will be the target average rate of 100 Mb/s per user in densely populated areas”. For URLLC and mMTC services the “bandwidth requirements are in the kilobits-per-second to low megabits-per-second range per user equipment (UE), in many cases even only burst-wise” (Wey, Luo & Pfeiffer, 2020, p. 51).

However, it is possible to upgrade the NBN FTTP equipment to comply with a more recent standard that provides much better performance. The NG-PON2 standard (International Telecommunication Union, 2013) provides for an aggregate of 40 Gbit/s downstream and of

10 Gbit/s upstream, which would be sufficient to meet the IMT-2020 bandwidth targets. The 50G-EPON standard (The Institute of Electrical and Electronics Engineers, Inc., 2020), which has just been approved, would also suffice. OptiComm Ltd, an NBN Co competitor, has just announced (Dinham, 2020) that it will soon deploy equipment that complies with the XGS-PON standard (International Telecommunication Union, 2016), which provides for 10 Gbit/s symmetric (i.e., both upstream and downstream) service.

Latency is different from bandwidth in that it is cumulative. Therefore, it is necessary to examine the contribution of each link in a network. One of the fundamental innovations of 5G is the separation of a mobile base station, also referred to as a gNB, into three parts: a centralised unit (CU), a distributed unit (DU), and a radio unit (RU). The purpose is to minimise the amount of equipment at the top (radio unit) and at the base (distributed unit) of a mobile tower. However, it also applies to femtocells. The 5G core (5GC) network connects to the centralised unit and the radio unit connects wirelessly to users.

The links between the 5GC and these units are referred to as backhaul (5GC–CU), midhaul (CU–DU), and fronthaul (DU–RU), or generically as x-haul.

As with data rates, latency requirements differ depending on the type of service: "the latency requirements for eMBB are in the range of multiple tens of milliseconds end-to-end (e2e), which leaves time of the same order for transport on the backhaul or on the F1 [midhaul] interface" (Wey, Luo & Pfeiffer, 2020, p. 51) and "With latency-critical services such as URLLC, the F1 [midhaul] and Fx [fronthaul] latency may both be in the <100 µs [0.1 ms] range" (Wey, Luo & Pfeiffer, 2020, p. 54).

A PON has a typical latency of the order of 10 ms and a best case of about 3 ms (M. Ruffini, personal communication, July 28, 2020), so, while there is no problem supporting eMBB and mMTC services, URLLC would appear to be out of the question (by an order of magnitude).

The most significant source of latency in a PON arises from the way in which it assigns the aggregate bandwidth across the premises connected to it. It uses a mechanism called dynamic bandwidth assignment (DBA) to implement this process, the aim being to maximise the utilisation of the shared network. A method of reducing this latency is cooperative (CO) DBA, which synchronises DBA with the scheduling process of the baseband unit of a 5G network. This would be implemented in the form of a cooperative transport interface (CTI), which is currently in the process of being specified (Wey, Luo & Pfeiffer, 2020, p. 55).

Digital Subscriber Lines (DSL)

The focus in this discussion so far has been on FTTP because it is the technology with the best performance and, hence, the one most likely to meet the IMT-2020 targets. However, recent work by Cioffi *et al.* (2020) suggests that DSL could also support 5G service. They call this cellular subscriber line (CSL).

This is possible because both 5G and DSL use the same type of modulation: orthogonal frequency division multiplexing (OFDM). Consequently, both use similar mechanisms to correct for interference. The difference is that 5G shifts the frequency of the signal to, for example, 26 or 28 GHz before transmitting it.

Cioffi's idea is to split that frequency shift in two: the first so that the signal best matches the frequency characteristics of a copper cable, the second to change it to the frequency of the transmitted signal. The 5G system can then correct for errors induced in the copper cable using the same mechanism that it does for interference in the wireless signal. It is not aware that there is a copper cable present.

The catch is that the range of 5G signals over copper cables is quite limited, and hence CSL cannot meet the IMT-2020 targets other than over very short distances. However, CSL makes up for this by providing an economical means of implementing a much greater density of base stations, which share the demand for bandwidth. This makes it well suited to the 5G mMTC usage scenario.

CSL is still being developed, and there is not any CSL equipment yet. However, it needs to be considered in planning for the future of the NBN.

Use Dark Fibre for Backhaul

An obvious way in which NBN Co could support the roll-out of 5G services is by allowing 5G carriers to use its dark fibres for backhaul. Dark fibres are optical fibres that NBN Co has installed along streets but has not yet lit up: there is no equipment connected to them. Consequently, they are not generating any income.

If a 5G carrier were planning to install a base station at a location close to a cable that contains dark fibre, the carrier could conceivably use that dark fibre for backhaul. However, NBN Co might be reluctant to offer this, as the dark fibre is there to cater for expansion and to replace fibres that are damaged.

Network as a Service (NaaS)

The core of a 5G network can be entirely virtual. This opens the potential for NBN Co to provide the virtual machines and networks necessary to host a virtual 5G core or other virtual network. The hardware for the virtual machines could be established in fibre access nodes (FANs) and points of interconnect (PoIs), which are linked by optical-fibre rings (NBN Co Ltd., 2018). Such a network as a service (NaaS) would be like Amazon Web Services for NBN RSPs.

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There are two components of 5G that support this: multi-access edge computing for virtual machines and slicing for networks.

Multi-access edge computing (MEC) is "cloud computing at the edge of the network" (European Telecommunications Standards Institute, n.d., p. 3). The edge part of MEC refers to locating computing applications, including virtualised network functions, at the edge of the network in order to reduce latency, which is one of the primary objectives of 5G.

This is of particular benefit for the Internet of Things (mMTC) because having access to MEC applications in the network means that "things" do not (necessarily) require access to the Internet, which provides a measure of security.

Although NBN Co could provide MEC service at both FANs and at PoIs, the most benefit comes from doing so at FANs because service providers cannot install their own equipment there.

Slicing

A 5G slice reserves capacity for a specified group of applications or users. The classic example is a slice for emergency services, providing emergency services communication over a public network as if it were a dedicated private network. Everyone agrees that slicing is important (Higginbotham, 2020), but there is some variation in the specifics of definition (Magretta, 2002, p. 71).

It is necessary to distinguish between two types of slice that are closely related: transport slices and 5G slices, which are similar to virtual paths and circuits in Asynchronous Transfer Mode (ATM).

A physical network uses transport slices to implement the different 5G usage scenarios. A transport slice is a reservation of bandwidth along a path across a network that satisfies the latency constraints for a usage scenario. For example, a direct path is best for URLLC slices because it minimises latency (LL = Low Latency). If a physical network has multiple virtual networks, a transport slice would typically be specific to one of them, but multiple virtual networks could share a transport slice.

There is no specific standard for transport slices; however, segment routing is emerging as the preferred method (Filsfils *et al.*, 2019, ch. 5). This uses a colour to identify each transport slice and associates each colour with a sequence of waypoints in the network, thus specifying a path. This is similar to integrated services (Braden, Clark & Shenker, 1994) but does not require the network to keep track of all the paths.

The 5G core uses transport slices to implement 5G slices: one transport slice can support multiple 5G slices, each being associated with a particular application. For example, there

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might be separate 5G slices for Internet access and for Netflix, each using the same eMBB transport slice across the physical network.

Offer a 5G Wholesale Service

The discussion to this point has been on the basis that NBN Co provide facilities that allow service providers to implement 5G services over the NBN. However, NBN Co could, if its remit permitted, offer a wholesale 5G service.

This would not preclude NBN Co's still offering MEC and slice services to RSPs, which they could use to construct 5G and other services. There are no technical barriers to prevent NBN Co offering either or both.

Problems

Allowing NBN to offer a wholesale 5G service would address two issues that arise if only 5G network operators can provide femtocells:

- the potential market failure of slicing;
- subscribers' inability to roam between premises served by different 5G carriers.

Slicing is intended to be an improvement on the one-size-fits-all approach of the Internet. Because the Internet cannot distinguish between applications, it treats them all the same, irrespective of their bandwidth and latency requirements. Of course, some of these applications, such as Netflix, are subscription services and, if you want to use them, you have to pay for them. Consequently, the consumer in this situation will pay for two separate types of service: network access and applications.

For slicing to be of any benefit, the provider of an application has to buy a slice from the operator of a 5G network. In the case of Netflix, the benefit from doing so would be encountering less buffering on that network.

If there were only one 5G network in Australia, an application provider might consider buying a network slice. However, Australia will have multiple 5G networks, and it would not be worthwhile for an application provider to buy slices from the operators of every 5G network in Australia. It would be far easier and cheaper to continue the current arrangement and keep going "over the top."

This is a particular problem for the Internet of Things, which requires femtocells in order to cope with the enormous number of connected IoT devices, which will only have sufficient power to transmit over a limited range. A provider of IoT applications needs to be able to deal with a single RSP to purchase an mMTC slice that covers every femtocell connected to the NBN.

The second issue is similar but applies to the subscribers of 5G carriers rather than to application providers.

Ideally, a subscriber to a 5G wireline service would like to take his 5G router—and the applications associated with it—from premises to premises. For example, if he rented a beach house for his summer holidays, he may like to take his 5G router with him, plug it in, and have all the 5G applications that he had subscribed to, including Internet access, work seamlessly. Unfortunately, the initial version of the BBF standards for wireline 5G access does not provide for roaming between carriers, so this scenario could only happen if the same 5G carrier connected both premises.

Landlords of short-term rentals would want as many potential tenants be able to use their 5G routers as possible. Consequently, they would tend to purchase 5G connections from the carrier with the most subscribers.

A Potential Solution

There are two possible solutions: mandate roaming between 5G carriers that use the NBN for 5G backhaul or allow NBN Co to provide a 5G access service onto which other 5G carriers could roam.

The problem with mandating roaming is that it will not be viable until the BBF standards allow for it (if ever). This leaves the option of NBN Co providing a 5G access service, which would confer three policy benefits:

1. maintaining the Internet's distinction between access and applications;
2. simple interconnection between 5G carriers and the NBN, thus enabling both synergies and retail competition;
3. defining the universal-service obligation (USO) as a bundle of applications deliverable over either fixed or mobile networks.

If NBN Co were to become a wholesale 5G provider, it would sell three types of 5G service: access, slices, and interconnect.

A 5G access service would be analogous to an AVC. It would provide access to the NBN 5G network from a particular premises. RSPs could buy 5G AVCs from NBN Co and bundle them with Internet access for sale to their subscribers in the same way as today.

A slice would be equivalent to a CVC. It would be accessible from any 5G access service, irrespective of the RSP. However, in addition to RSPs, the customers for this service would include application providers, as each application would have its own slice.

Keeping access separate from applications would make a multitude of applications available independently of the RSP providing the access service. For example, a manufacturer of "things" could purchase an mMTC slice from just the one RSP to monitor them remotely anywhere on the NBN. It would not have to enter into an interconnect agreement with every RSP. A landlord could purchase a 5G access service with a certain bandwidth, but not the Internet access that would normally go with it. Instead, the tenant would have to subscribe to his own applications, which would be associated with his 5G router.

5G interconnect service would correspond to a network-network interconnection (NNI). Interconnecting with the NBN 5G network would allow 5G network operators to construct slices that encompassed both the NBN network and their own.

Unlike the Internet, a 5G network can distinguish between different applications if each occupies a separate slice. Consequently, 5G offers the potential to provide a universal-service obligation (USO) service that is defined in terms of a bundle of applications, such as:

- government services (e.g. myGov)
- education
- public broadcasting
- limited Internet access
- telephony.

The advantage of this approach is that it can provide unlimited access to essential services without providing unlimited Internet access. Obviously, the USO would have to include a 5G access service as well. USO services would be available at no charge from any premises connected to the NBN.

3. Recommendations

We recommend that:

1. all relevant equipment in the NBN be upgraded only if it meets the data rate and latency requirements for 5G networks.
2. NBN Co offer multi-access edge computing and transport slice services to retail service providers.
3. NBN Co consider providing wholesale 5G wireless and wireline services over its fixed access network.

Data Rates and Latency

Our first recommendation arises from our view that the performance of the future NBN must be at least as good as that of a 5G network. It applies primarily to PON equipment: OLTs and ONT/ONUs. For example, both NG-PON2 (G.989) and 50G-EPON (802.3ca) are capable of providing the data rates necessary to support 5G services.

However, meeting the low latency of URLLC services requires that any future PON also implement the cooperative transport interface (CTI).

5G Substrate Network

Our second recommendation arises from our view that the NBN and 5G networks are complementary and that the NBN has a significant role to play in the rollout of 5G services in Australia.

Making the NBN a network platform of MEC virtual machines connected by slices would not only support the rollout of 5G services but enable RSPs to provide non-5G services that had to meet stringent latency requirements.

In addition to broadening the scope of services, it would also broaden the scale of service providers by making it easier for them to offer services.

5G Wholesale

Our final recommendation addresses our concern that there are potential technical and economic issues that can arise from having separate carriers independently providing 5G service over the NBN.

We take the view that allowing NBN Co to offer a wholesale 5G service would neatly overcome these problems but acknowledge that mandating roaming between 5G carriers might also suffice.

26-GHz Spectrum

If NBN Co were to offer a wholesale 5G femtocell service, it would require short-range spectrum in the 26-GHz (n258) and 28-GHz (n257) bands for femtocells. Consequently, consideration would need to be given to allocating spectrum to NBN Co for this purpose.

4. Conclusion

Any plan for the NBN must take account of 5G networks—and vice versa. 5G and the NBN are complementary: NBN Co can make a significant contribution to the roll-out of 5G networks in Australia. As the example of slicing demonstrates, it is even possible that 5G might not fulfil its full potential *without* the NBN.

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Annex F: Financial Considerations

1. Introduction

The purpose of this Annex is to examine, so far as available information will permit, whether NBN Co will be able to fund the infrastructure investments that it must make from mid-2020 onwards, and the sources of funds that realistically are available to NBN Co to do this.

2. Information available

The discussion that appears below is based on financial information that has been made publicly available by NBN Co, particularly in its corporate plans, annual reports and various public statements. This information is at a high level of aggregation and lacks the detail and dissections that would materially assist analysis and review. The latest public statements of financial import by NBN Co – the fibre zones announcement of 22 September 2020, the fibre extension program of 23 September 2020, and the Corporate Plan 2021-24 published on 23 September 2020 – are all of this kind.

As a result, the NBN Futures Group has sought answers from NBN Co to a number of questions, but without success to date. The Group is aware that others have also sought more detailed information on important financial and other aspects of NBN Co's operations, also without success. We consider that, as a public enterprise without any material competition in the fixed wholesale broadband access market, and with limited modal competition in the short to medium term, NBN Co should be accountable to a greater degree than current reporting suggests, and that future Statements of Expectations incorporated in the National Broadband Strategy should make this explicit.

3. Questions for NBN Co

The following questions are some of those that we have sought to put to NBN Co without response to date. They predate 23 September 2020 and therefore might be updated to reflect the same questions that might be asked in the context of the latest Corporate Plan.

(1) Interest rate on private loan facility: What rate of interest applies to the facility?

(2) Retirement of Government loan facility:

a. What was the rate (or average rate) payable on the private loan facilities established by NBN Co in May 2020?

b. Does any plan to pay back the amount borrowed from the Government depend in any way on the interest on private loan facilities being less than the 3.96% rate applicable to borrowings from the Government?

c. Are there any circumstances in which NBN Co might borrow additional amounts using the Government's facilities or relying on the any implicit or explicit Government guarantee, and, if so, what are they?

(3) **Government equity in NBN Co:** Does NBN Co have any plans to pay a dividend to the Government in the future in relation to the Government's equity of $29.5 billion in NBN Co?

(4) **CAPEX:** By way of context, the purpose of specific questions a) and b) below is to better understand how capital costs might be incurred in future, particularly as the NBN is extended to existing greenfield locations and as existing 'ready to connect' premises are connected**.**

a. In the Corporate Plan, 2020-23, at page 52, NBN Co sets out the average cost per premises for each access technology for FY19 and FY20: what are the constituent components in relation to each access technology for making each premises ready to connect, and for actual connection of each premises?

b. The figures referred to above on page 52 are expressed to be "incremental": (i) incremental on what base? And (ii) what categories of cost are not included and what is their value?

c. What is the capital cost of the satellites and what other capex has been allocated to the satellite service?

d. In the Corporate Plan, 2020-23, at page 48, CAPEX is stated to be $1.4 billion for FY21 and $1.4 billion for later years. What planned capital works are included in these estimates? Do they include any network upgrading, and, if so, what?[1]

e. What are the total costs associated with the upgrade pathways for each technology in the MTM that have been previously identified by NBN Co?

(5) **OPEX:**

a. In an overall sense, the question is what changes will occur, especially to OPEX and to overall financial settings as NBN Co moves from the initial construction phase of its operation prior to July 2020 to being more of an operating and maintenance business thereafter?

b. In the Corporate Plan, 2020-23, at page 51, a category of operating expenditure called "Other OPEX" is identified which, based on the description in the Plan, covers many different cost categories: What is the dissection of the figure for each of the years from FY19 to FY23 into the constituent cost categories listed at page 51?

c. At page 51, "Other OPEX" is shown as reducing each year from $2.3 billion in FY20 to $1.7 billion in FY23: Why will the annual total OPEX be reducing year on year in this way, given that the premises connected and new coverage is expected to increase and also given that the fault rate of 0.7 faults per 100 premises, driven largely by the copper cable network, will not change much over time in any of the current plans?
d. What is the direct OPEX incurred each year on a per premises basis in relation to each of the access technologies?
e. What is the expected cost saving that NBN Co will achieve as a result of anticipated workforce changes?

4. NBN Co Corporate Plan 2021-24

At the end of the initial rollout in June 2020, NBN Co was funded from the Commonwealth via $29.5B equity and a $19.5B debt facility. The Corporate Plan 2021-24 anticipates that the Commonwealth equity of $29.5B (which it notes has been capped since 2013) will continue at the same level for the next three years, and that debt funding will be increased by $8B to $27.5B over the period, with the Commonwealth debt facility being withdrawn in favour of private debt facilities by June 2024 (p. 52, 'Funding our Future Strategy').

The Corporate Plan indicates that funding task will be achievable "based on expectations of an investment grade credit rating, strong outcome in the recent bank financing transaction and overall favourable debt capital market conditions for infrastructure borrowers like NBN Co" (p. 52). However, the rates that NBN Co has achieved in its private borrowings to date, expectations about future interest rate prospects and, critically, how these rates compare or are expected to compare with the current Commonwealth rate of 3.96%, are not stated. Clearly, NBN Co may be commercially compromised if it telegraphs detailed rate expectations to the debt markets, but it is important in terms of financial accountability to the public to indicate how its expectations compare to current rates that it incurs.

The additional debt financing is required to complete the initial rollout and to fund the specific fibre business zones, the fibre extensions deeper into the access network, and other initiatives announced on 22 and 23 September 2020. It appears that funding for additional capacity upratings or other new initiatives is not being allowed for in the peak borrowings of $27.5B for the next three years.

Non-performing equity

NBN Co does not pay any dividend on the Commonwealth's equity of $29.5B and there are no public plans to do so. Such an arrangement would not be viable if NBN Co was in private ownership, and, at a long-term infrastructure investment return on equity of 5% to 8%, the current arrangement reduces overall costs by between $1.48B and $2.36B.

Financial expectations and metrics

The financial expectations outlined in the Corporate Plan 2021-24 suggest that NBN Co's revenues will increase from $3.8B in 2020 to $6.2B in 2024, and its EBITDA inclusive of subscriber payments will increase from negative $0.8B in 2020 to $4.5B in 2024. Net profit after tax will improve from a loss of $5.2B in 2020 to a loss of $0.9B in 2024 (p. 54).

These expectations are modest and make no allowance for capacity upratings and upgrades over and above the programs announced on 22 and 23 September 2020. The overall internal rate of return has been recalculated by NBN Co at 3.7%, up from 3.1% prior to the announcements of these programs. The IRR is modest but in line with a major infrastructure business that provides fundamental services across the whole of society and the economy, and which is essential for social wellbeing and economic welfare. However, these outcomes would be inadequate for private investors.

5. Cost structure

From its inception until the conclusion of the initial rollout in 2020, NBN Co has been in large part a construction company and its overriding concern has been to provide broadband access services as well and as early as possible. With the overwhelming bulk of the initial rollout completed, NBN Co becomes progressively more and more of an ongoing network operation, albeit with continuing targeted programs of infrastructure development. In these circumstances, we would expect to see substantial changes in NBN Co's cost structures and some efficiency gains being achieved.

NBN Co announced in May 2020 that it would be reducing its workforce by 800 by the end of 2020 after completing its initial rollout. The Corporate Plan 2021-24 makes no further mention of this reduction and it may have been impacted by the new fibre programs announced on 22 and 23 September. In any case, getting the workforce size and balance right is a matter for NBN Co management, and NBN Co has appropriately concentrated on the impact of its investments on overall employment (estimated at a peak level of 25,000 additional jobs directly created by the new programs – p. 48, based on AlphaBeta modelling) and on the economy (estimated by NBN Co at a GDP increase of $6.4B per annum by 2024 – p. 46).

6. New infrastructure investments and revenue sources

Although the matter is far from clear, it appears that the new fibre programs announced on 22 and 23 September 2020 will be a source of improved net revenue within the period covered by the Corporate Plan. NBN Co and the Minister have attributed the increase of the overall IRR from 3.1% to 3.7% largely to these initiatives.

The program associated with extending fibre deeper into the access network and closer to customer premises is essentially aimed at customers currently served by FTTN. With the exception of the brownfields customers yet to have access to the NBN's fixed network, the fibre extension program seems not to be aimed at improving the overall level of NBN take-up. Those who have yet to connect are presumably not, in general, waiting for the higher speeds that will be available under the new program.

As at 2020 the gap between premises ready to connect and those connected to the NBN is planned to have been reduced, as shown below (p. 53):

	2020	**2024**
Premises ready to connect (millions)	11.7	12.5
Premises connected (millions)	7.3	9.0
Gap – unconnected to NBN (millions)	4.4	3.5

Closing the gap further represents a major source of additional revenue at low incremental cost. The announced fibre extension initiatives are directed mainly at existing NBN customers and will not have a major impact on those that are unconnected. The forecasts in the Corporate Plan indicate that NBN Co expects the gap to decrease from 4.4 million premises to 3.5 million premises over the period to 2024. However, all of the gap reduction is expected to occur in the next 18 months or so, suggesting that it will be the result of the existing 18-month transition period expiring for customers to move from legacy network services.

NBN Co should be developing effective programs, with retail service providers, to address the gap of 4 million premises that remain unconnected.

Revenue estimates will be affected by the extent of connection of the 4.4 million premises that are passed by the NBN and are ready to connect as at June 2020, but are not yet connected. Some of these will be connected during the 18-month transition period that NBN Co provides, some may remain or become all-mobile data services, others will be affected by affordability and other digital inclusion issues, and there may be some residual who do not take up any broadband service option. NBN Co estimates take-up of around 73% to 2024. We consider that NBN Co should make clear the programs it will undertake in conjunction with retail service providers to achieve and potentially exceed this take-up, provide estimates of revenue impacts for different levels of take-up, and regularly report results to date.

The Corporate Plan contains no details of whatever plans NBN Co may have to uprate the capacity of FWA and satellite services.

7. Risk management

The risk management discussion in the Corporate Plan is inadequate, especially in relation to responding to infrastructure competition and wireless substitution (including 5G) with competitive products (p. 57). The risk management challenge for NBN Co is also a potential business opportunity, especially in relation to the provision of 5G wholesale services. To say that “NBN Co must actively manage the impact of infrastructure competition and mass market offerings for business and residential segments through competitive products and pricing constructs that generate positive brand awareness in the market” says nothing about the risk management work in any detail that must be undertaken and the assessment through sensitivity analysis of the potential impact of harms, if realised, to the financial underpinnings of the Corporate Plan.

8. Conclusion

Available information from NBN Co is at a high level of aggregation, including in the Corporate Plan 2021-24. However, we can conclude that NBN Co has the capacity to extend borrowings to allow debt funding at least to the extent of the programs included in the Corporate Plan. It may be able to extend debt funding further to encompass some of the capital programs needed to upgrade the capacity of the various access technologies that are included in the current Multi-Technology Mix. Little is known about how NBN Co intends to upgrade Fixed Wireless Access connection, but there are a number of ways in which these services might be improved. We have no detail on plans for improving satellite service performance.

The Commonwealth is not receiving any financial return on its capital investment of $29.5B in NBN Co and there are no provisions in the Corporate Plan 2021-24 for this to change. This is an important reminder that the financial underpinnings of NBN Co are not commercial, and would need to change if it ceased to be Government-owned.

Endnotes

[1] The Corporate Plan 2021-24 (CP21), at page 54, increases these amounts significantly, to $3.4B in FY21, $3.8B in FY22, $2.4B in F23 and $2.2B in FY24, at least partly to reflect the additional capital program associated with the Fibre Zone and Fibre Extension programs announced in September 2020. However, the question about the make-up of the capital works program and the extent to which other technology uprating is to be pursued, remains. The issue goes also to transparency and accountability.

Annex G: NBN Co Ownership Considerations

Introduction

Australia's economy is a mixed economy comprising both public and private enterprises. The specific mix that provides the best results in terms of incentives and benefits at any given time is always a matter for policy discourse, and is often influenced by ideological preferences.

In this Annex we aim to stay clear of ideological preferences and to discuss the ownership options for the NBN in terms of the circumstances that might render some outcomes desirable and some undesirable at given stages in its development, for the provision of optimum social as well as economic benefits.

The current policy of the Government is to consider the sale of NBN Co following the completion of the initial broadband access network rollout, subject to a number of legislated pre-conditions being met. These factors and pre-conditions are discussed further below. The Government has reiterated this policy on a number of occasions.

1. Ownership options

The ownership options that we have been concerned with were initially discussed in the first Forum conducted by the NBN Futures Group on 31 July 2019 and reported on in the *Journal* (Campbell & Milner, 2019). The options that we are now considering are:

a) Privatisation through a sale of the business;
b) Retention in public ownership; and
c) Variations on a) and b) based on timing.

At the time of the Forum in July 2019 two further options were being considered. One was the breakup of NBN Co into a number of entities based on the prevailing technologies being deployed, thereby creating a basis for potential modal competition between the entities. This approach would have enabled sale of some of the newly created entities on a progressive basis, and the possible retention of some in public ownership. This option was promoted by the Vertigan Committee Inquiry in 2014 (Vertigan, 2014), and more recently by Gary McLaren (McLaren, 2018). However, there are several practical objections to a structural separation of NBN Co based upon access technologies:

- Its likely accentuation of the digital divide in the lower speed NBN access footprints available to rural and remote areas and certain lower density metro suburbs, versus the higher speed FTTP/FTTB accesses available elsewhere.

- The economic costs in quintuplicating management teams, staff and support systems for the five new companies based upon different technology platforms (satellite, fixed radio, FTTN, HFC and FTTP/K/B), each suffering a loss of the scope and scale of the original NBN Co. These additional costs would inevitably be passed on to the end users, and/or require additional government subsidies.
- The more recent complication of NBN Co's 2020 policy to provide FTTP accesses to individual businesses or residents based within 130 designated 'fibre upgrade' regional cities or metropolitan suburbs, currently within lower speed FTTN or HFC footprints.
- The further complication of NBN Co's future business incentives to support the Radio Access Networks of 5G companies, which will inevitably motivate the company to provide new fibre links to radio base stations well outside existing FTTP footprints.

In short, what might begin as five 'Baby NBNs' largely differentiated by their technology platforms would soon become network companies largely distinguished by their geographical presence, but with each forced to support the highest speed access technologies in order to meet user demand. This scenario would simply lead to the wealthier companies buying up the smaller ones – as happened with the 'Baby Bells' in the USA – with the financial benefits of the mergers rapidly accruing to the shareholders rather than to the end users.

A second approach which needs to be considered is that NBN Co should be merged with Telstra's fixed wholesale network business unit, InfraCo, after the latter is spun off from Telstra as a standalone entity, and the combined entity (which might be conveniently called "NetCo") would then become a viable wholesale transmission network operator providing internodal, backhaul and access services. For NBN Co and InfraCo to merge, either NBN Co would need to buy InfraCo, thereby potentially retaining NetCo in public ownership, or NBN Co could be sold to InfraCo (once Telstra's shareholding in InfraCo was reduced to a level satisfying competition policy), thereby privatising NBN Co. Therefore, if this merger were to proceed, it would become a variant of either option a) or option b) above. The pros and cons of the merger of NBN Co with a Telstra-liberated InfraCo have been discussed in detail by Peter Gerrand (Gerrand, 2019).

2. Factors affecting ownership

The legislated process and pre-conditions for the sale of NBN Co are set out in the *National Broadband Network Companies Act 2011*, Part 3 (Ownership and Control of NBN Co). Part 3 sets out the matters that must occur before a sale, namely:

- Declaration by the Communications Minister that the national broadband network should be treated as built and fully operational (section 48). The Act requires this declaration to be given by 31 December 2020. As an alternative to such a declaration the Act enables the

Minister to make a pre-termination period declaration (section 48: The pre-termination period relates to the period before termination of the Commonwealth's ownership in NBN Co.) under the Act, and to define the finishing time of that period. Effectively, this enables the Minister to either make or defer the declaration that the NBN is built and fully operational, if that is needed, and to determine the period for any sale process (or pre-termination period), subject to it being no longer than 12 months (section 48(4)). In any case, these declarations should not be a major hurdle for a sale.

- Once declarations are in place that the NBN has been built and is fully operational, the Productivity Minister may require the Productivity Commission to undertake an inquiry (section 49) to consider and report on a number of issues, including the regulatory framework for the NBN; impact on future Commonwealth budgets of a sale of the Commonwealth's equity; the supply of affordable broadband and other carriage services; equity and social inclusion including in different areas; impact on competition in telecommunications markets and whether NBN Co has a substantial degree of market power in any telecommunications market; market factors including retail broadband prices; technologies used; operational considerations; and other factors set out by the Productivity Minister and considered relevant by the Productivity Commission.
- The Parliamentary Joint Committee on the Ownership of NBN Co then examines the Productivity Commission's Report and reports to both Houses of Parliament (section 49, Note 3).
- The Finance Minister is required to make a declaration on whether conditions are suitable for an NBN Co sale scheme (section 50). In deciding to make such a declaration the Finance Minister must have regard to NBN Co's governance arrangements, NBN Co's business record, market conditions, and other matters he or she considers to be relevant. The Finance Minister's declaration is a disallowable instrument.

If the Finance Minister declares under Section 50(2) of the Act that conditions are suitable for a sale of NBN Co, then, once the declaration takes effect under Section 50(6) of the Act, the Commonwealth ownership provisions cease to have effect and a sale scheme may be implemented according to the rules in Sections 52 and following. A range of sale scheme possibilities are envisaged in the Act. The details of these possibilities are beyond the scope of this Annex. Suffice it to say, sale of NBN Co by sale of shares, issue of hybrid securities and other means are all available to the Commonwealth, as are sales in tranches or of parts of the NBN business.

We consider the legislation to be detailed and comprehensive in setting out the process for termination of Commonwealth ownership. The criteria that should apply, although substantial, do not place appropriate emphasis on the NBN as infrastructure of fundamental national importance or on the essential service nature of the services that infrastructure supports – that is, as National Critical Infrastructure. The criteria do not adequately encompass the ongoing and evolving requirements for a national infrastructure to fully deliver possible social and economic benefits. These matters will need to be reviewed and addressed closer to the time if and when privatisation is considered.

3. Analysis of the options – in 2020

As at 2020 there are various arguments that have or might be advanced in favour or against the privatisation of NBN Co – or to terminate Commonwealth ownership, as it is termed in the Act. Some of these have an ideological basis. The arguments (including comments on each) include:

In favour of private ownership:

	Line of argument	**Comment**
1	Efficiency: NBN Co would be more efficiently run as a private enterprise subject to the disciplines of private ownership.	This is an ideological argument, and many examples of more or less efficient commercial enterprises can be found in both private and public ownership.
2	Competitive market: There is some competition in the provision of broadband infrastructure now and this will grow over time. The Government should exit businesses in competitive markets, because its presence skews industry development.	The market for wholesale broadband services is not effectively competitive at present and is unlikely to become so for at least 5 years and possibly for at least 10 years. Note however that this argument may have greater relevance in future.
3	Financial capacity: NBN Co needs to secure further funding for future stages of infrastructure development, and the Commonwealth Government has indicated its reluctance to provide further funding.	In May 2020 NBN Co demonstrated that it could secure low interest loan funds from private sources when it established a facility for $6.1B. This source is the basis of the $4B plus in funding required for the fibre expansion plan announced by the Minister on 23 September 2020. Clearly NBN Co need not rely on additional Government equity or debt funding even while publicly owned. There is of course an issue about the desired gearing of an enterprise of this kind in both the shorter and longer term.
4	The impact of 5G networks: 5G's ability to provide ultra-fast speeds beyond 100 Mbps makes it a "killer" application in NBN Co's FTTN footprints in particular. NBN Co will need access to much larger sources of funds in order to "fibre up" its weaker access networks to meet 5G competition.	5G represents a substantial business opportunity in the wholesale market to NBN Co a well as a competitive threat. Now that NBN Co has largely met its charter in connecting most premises with broadband accesses, it can extend its fibre connectivity business by supporting 5G radio access networks.

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In favour of public ownership:

	Line of argument	Comment
1	The important pre-conditions required by the National Broadband Companies Act 2011 have not been met and formally certified as required.	These requirements are significant but are only matters of time. The Government's position is that sale will not incur in the current term of Parliament (which could run well into 2022) and the inquiries and other process elements could be met within 1-2 years starting before or after completion of the term.
2	The national benefits resulting from the NBN are not all capable of being realised within the limits of a single enterprise, and therefore the short-term profit perspectives of a private sector owner will necessarily limit investment to lower cost locations with inevitable consequences for equity and service ubiquity.	This is a powerful argument, but may be addressed through public funding of infrastructure or support for service delivery in high-cost rural and regional areas.
3	National Critical Infrastructure that sustains essential services should remain in public ownership.	This is an ideological argument. Other essential services are provided by private firms or a mix of public and private entities. However, the argument strongly indicates that a robust sectoral strategy and regulatory framework (as well as strong regulatory agencies) are needed if the controls associated with public ownership are relinquished. The experience of privatisations in the energy, transport and other sectors is contentious, and certainly has lessons for telecommunications.
4	The NBN needs to be established as a sustainable business capable of delivering on its charter after the initial rollout.	This is an argument for deferring the privatisation issue until some future time, rather than retaining NBN Co in public ownership forever. The criteria for sustainability need to be specified and possibly included in the terms of reference for the Productivity Commission inquiry required by current legislation. There is arguably also a need to update NBN Co's charter once a 2020s update of the 1996 conception of 'universal service' is agreed.
5	The challenge associated with any form of sale based on the Corporate Plan 2021-24 needs to be highlighted. For example, the cost of private equity would hit NBN Co very hard from a cash flow perspective. The ratio of debt to the total of debt plus equity would also be a big hurdle for any sale. It would be hard to see NBN Co being viable for sale even if it addresses its debt issues in the near future without substantial adverse impacts on its operating performance.	Ultimately this may turn out to be a timing argument.

	Line of argument	Comment
6	Sophisticated broadband networks will evolve over time with new technologies and capabilities, as will user needs and social and economic benefits. This necessary adaptation cannot be adequately built into sale contracts at a point in time.	There are limitations to the ability of sales contracts to include longer term regulatory settings and still attract eligible buyers. In particular, the need for the potential buyer to keep investing and to ensure that the infrastructure meets changing needs cannot be secured by contract.
7	The valuation for sale is likely to be considerably lower than the $29.5B of government equity, resulting in a substantial loss on the Commonwealth's investment.	This is especially likely given the need for future significant investment and uncertain regulatory and policy settings in future. On the other hand, loss of the value of equity may be expected and not be considered as a sale deterrent.

The arguments for and against sale are not determinative and some are not compelling at all. Many of the arguments are highly conditional on circumstances in the broadband market at the time of potential sale, and therefore may be reduced to arguments over timing.

4. Conclusions

Our view is that, for the foreseeable future, the NBN should not be considered as a standard commercial entity which exists to maximise profits in the short to medium term for its owners. The exogenous benefits for society and the economy at large are critical and cannot be captured in terms of firm economics alone, particularly during the next 5-10 years when the NBN will be the major broadband services platform and NBN Co will have substantial market power, especially in the fixed broadband wholesale market. During that period of at least 5 years and possibly 10 years, we see retention of the NBN in public ownership as critical for the realisation of the social and economic benefits of broadband.

The issue should be subject to review as circumstances change. We do not envisage an ongoing discussion that would undermine the efficacy of firm policy settings for investment certainty, but, rather, planning for a further review to start in 2026 or later – that is, after the first 5 years of the coverage of the initial National Broadband Strategy.

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