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The Digital Economy Lights Up

Editorial

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Abstract: The effect of the COVID-19 crisis on the digital economy has been profound. How and whether the widespread adoption of teleworking, telehealth and remote learning will continue after the crisis subsides is a matter for policy debate. Digital inclusion will, in any case, be important. This issue of the *Journal* publishes four public policy papers, two of which arise from the NBN Futures Forum in February 2020. The other two provide contrasting views on the rising influence of China on the Internet. The issue also contains five more technical papers and a historical reprint. The *Journal* welcomes contributions on telecommunications and the digital economy.

The Digital Economy in a Time of Crisis

The COVID-19 crisis has brought change to the digital economy like never before. What was unusual in February was commonplace by April. Teleworking and telehealth – two of the economically most important broadband services (Süßspeck, 2017) – have seen the barriers to their adoption fall away. Thousands of children – and their parents – have experienced the mixed pleasures of remote learning (tele-education) at home. Will our society ever be the same again?

We in the telecommunications industry tend to think that these changes are long overdue. Telework and telehealth have been discussed for many decades and have attracted significant R&D attention, mostly without much ongoing effect. The economic benefits through greater efficiency are well understood and, in recent years, the reduced carbon footprint (Süßspeck, 2017) has been quantified. Now that millions of people have experienced the new ways of working, many will not want to return fulltime to the previous arrangements.

While we may see only benefits, others are less sure, Naomi Klein, the Canadian writer and activist, for one. She (Klein, 2020) sees a more mixed picture for telehealth and remote learning. Although her main concern is the growing influence on government of large technology companies, she makes a specific point about enhancing education (p. 39):

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> [O]vercrowded classrooms present a health risk, at least until we have a vaccine. So how about hiring double the number of teachers and cutting class size in half?

As she says: "That would create jobs in a depression-level unemployment crisis". It is well worth remembering that the future must create jobs to replace all those lost through the economic restructuring caused by the pandemic crisis. A policy of encouraging new employment in high-value areas while also investing in the newly popular tools of the digital economy will be most beneficial.

Klein is also concerned with digital inclusion. She asks rhetorically (p. 39): "If the internet is essential for so much in our lives, as it clearly is, should it be treated as a nonprofit public utility?" In Australia, we have approached this issue in a slightly different way, through the National Broadband Network, but there is still work to be done to achieve universal adoption of internet access. For more details on the transition from a universal service regime to a universal access regime, see Gregory (2015).

The COVID-19 crisis has made the need for digital inclusion for everyone more urgent, particularly for remote learning but also in telehealth for the less technologically savvy. The NBN Futures Group, which has been organizing public forums hosted by TelSoc,[i] has had a focus on the issues around digital inclusion and will be making recommendations in its final report on a way forward to encourage greater participation.

In This Issue

In this issue of the *Journal*, we publish four papers related to Public Policy. Two papers, by Richard Ferrers (p. 1) and Murray Milner (p. 31), expand on their talks at the NBN Futures Forum on Learning from International Experience, held in February 2020. Two other papers describe contrasting views on the influence of China. One, by David Soldani (p. 146), looks at using 5G and advanced technologies for helping to control pandemics, based largely on experience from China. The other, by Alan Dupont (p. 159), expresses concern about the growing influence of China on the development of the Internet.

The Internet is central to two technical papers. Al-Musawi, Hassan & Alturfi (p. 18) describe a tool for detecting Internet routing disruptions in real time. Le, Nguyen & Tran (p. 56) provide an overview of progress towards the "tactile internet" and haptics.

Other papers are concerned with how telecommunications is used. Kim & Lee (p. 94) analyse survey results from Korea to identify a "digital trust gap". Hidayat & Mahardiko (p. 110) consider the effect of a new law in Indonesia regulating social media content and the dissemination of "fake news". Esquivias *et al.* (p. 123) discern the relationship between financial inclusion and the use of mobile technologies from a survey in Indonesia.

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The historical reprint (p. 167) describes Army communications in 1983.

The *Journal*, Looking Forward

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

Leith H. Campbell

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Endnote

[i] TelSoc, the Telecommunications Association, is the publisher of this *Journal*.

Enhancing NBN's Value

Comparing NBN with Australia's Top 10 Trading Partners and OECD

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Abstract: The NBN, Australia's National Broadband Network, is nearing its 2020 completion. The value of the NBN depends on what you compare it to. While Australia's broadband has significantly improved over the last ten years, it is useful to compare Australia's NBN with similar activity in the OECD and with Australia's Top 10 Trading Partners to gain a richer understanding of NBN's value. Australia's broadband performance compares poorly with other OECD countries on download speed, especially over 100 Mbps download subscriptions and average download speed. However, imminent release in May 2020 of new NBN gigabit pricing could significantly improve Australia's world ranking on this average download speed comparison. Recommendations for improving NBN's value beyond speed are made, including encouraging affordable gigabit NBN services; ongoing NBN upgrades; encouraging NBN use; focussing NBN Corporate Reporting on customer satisfaction and ongoing international comparison.

Keywords: NBN, Broadband, International comparison, Value, Australia.

Introduction

This paper is an expanded version of a presentation at TelSoc's NBN Futures Forum – Learning from International Experience (TelSoc, 2020), 25 February 2020, and a submission to the Joint Standing Committee on the NBN, *Inquiry into the business case for the NBN and the experiences of small businesses* (Parliament of Australia, 2020). The data, presentation and Parliamentary submission are available at Figshare (Ferrers and OECD, 2019). The NBN, Australia's National Broadband Network, is a $51 billion investment "to lift the digital capability of Australia" (NBN Co., 2019a, p.4), to "ensure all Australians have access to high-speed, resilient and secure broadband" (NBN Co., 2019a, p.12) and "to foster productivity and provide a platform for innovation in order to deliver economic and social benefits for all

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Australians" (NBN Co., 2016). The NBN is an important foundation infrastructure on which to build Australia's innovation future.

Value is a way of understanding a complex, dynamic innovation like NBN. But what is value? Value is how we work out what something is worth, individually and socially through valuing practices (Ferrers, 2013; 2018). Value is also the emotional attitude we have toward something, either positive or negative, strong or weak. Value is also a way of understanding the complexity of modern innovation, as a personal emotional response to fast-moving new products and services. NBN triggers emotional reactions from many people, which evidences their assessment of NBN's value. One valuing practice is *comparing*. We assess a thing's value by placing it next to something else. Therefore, I compare NBN with other countries' overseas broadband experience and national broadband plans, and it helps to understand NBN better. I use data from OECD, and then narrow in to examining Australia's Top 10 Trading Partners, based on Australia's exports and imports (OEC, n.d.).

Broadband is often thought about in terms of speed, upload and download. But it also has other important dimensions, such as price and reliability and technical aspects, such as latency. The Broadband Commission, which encourages nations to improve their broadband, sets seven goals for broadband in their 2025 Targets (ITU/UNESCO, n.d.). The major targets include:

- A national broadband plan (or strategy or including broadband in the universal service definition)
- Affordability in terms of a per cent of income
- User penetration, i.e. that the network is used, aiming at 75% worldwide (and lower in developing countries).

Other goals of the 2025 Targets include skills to use broadband, for instance amongst the elderly, the unemployed or other disadvantaged groups; digital financial services; use of broadband by SMEs (small and medium businesses); and lastly "gender equality across all targets".

The Broadband Commission also sees broadband more broadly:

> "The concept of '*meaningful universal connectivity'… encompasses broadband adoption that is not just* ***available***, ***accessible***, ***relevant*** *and* ***affordable***, *but also that is* ***safe***, ***trusted***, ***empowering users*** *and leading to* ***positive*** *impact."* (ITU/UNESCO, 2019, p. ix)

This paper seeks to consider what is NBN's value (more broadly), through comparing Australian consumer experience with other countries' experience. I will look at: (1) Where have we come from?; (2) Where do we stand now?; and (3) Where are we going with the NBN? NBN

Co. also provided a view (AlphaBeta, 2019) of where it stands internationally after public pressure about falling in Speedtest rankings, which I will touch on later.

Where have we come from?

In 2020, the NBN rollout is nearly complete, but where were we ten years ago? In 2009, Australia, according to ABS (2009), had 10% of internet subscriptions still on dial-up services, using 100 MB per month. Faster DSL and cable services were averaging 6 GB per month. NBN Co., the builder of the NBN, reports average usage in late 2019 of 255 GB per month (NBN Co., 2019a, p.24). Thus, over ten years there was substantial progress in data activity. Similarly in speed, ten years ago only around 10% had a service faster than 25 Mbps, and a substantial proportion of users were on less than 2 Mbps (see Figure 1 below; which follows OECD's best-at-leftside-of-graph convention).

OECD collects data from 36 member countries (OECD, 2019), including about broadband in a Broadband Portal (OECD, 2018). Included for each country is the number of broadband subscriptions at various speeds. Australia is a member of OECD, but not all of its major trading partners are. OECD (2018) data reports Australia had only around ¼ of services at over 25 Mbps, with the rest under 25 Mbps. Later versions of this OECD (2018) data, since I downloaded the report (Ferrers and OECD, 2019), interestingly, no longer provide an Australia subscription speed breakdown, reporting only total users.

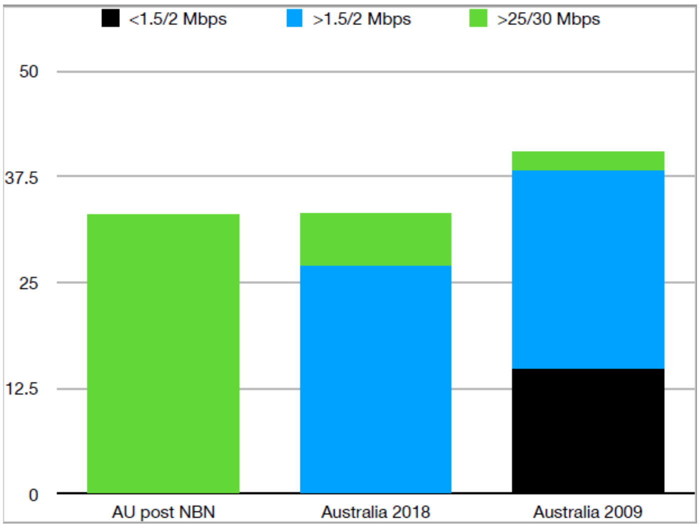

Figure 1. Australia Broadband Download Speeds 2020, 2018, 2009 – Subscriptions per 100pp. ABS (2009) 8153.00, OECD (2018), Author estimate post-NBN usage.

By the end of the initial NBN rollout (June 2020), everyone will have at least 25 Mbps services, per the NBN *Statement of Expectations* (NBN Co., 2016); 90% of fixed line services will have access to 50 Mbps service. Thus, over ten years, broadband has had substantial progress in Australia. Yet, despite the progress, much of the attitude towards the NBN is vocally negative.

Perhaps this is because NBN users compare their current service with what might have been under a full fibre rollout, or what they experience in other countries. I turn to this next.

Where are we now?

The OECD provides broadband usage statistics every two years from 36 countries (OECD, 2019). The latest speed and usage data available were for the end of 2018 (OECD, 2018). The statistics include number of subscriptions and prices, but of interest in this value analysis is how many subscriptions are at various speeds: over 100 Mbps, under 25 Mbps, and 25-100 Mbps. This data provides useful insight into what customers are prepared to pay for. It signals the value to consumers of the various broadband speeds. Another data source on broadband usage is the Ookla Global Speed Index. In this section, we look at Australia's ranking in both datasets.

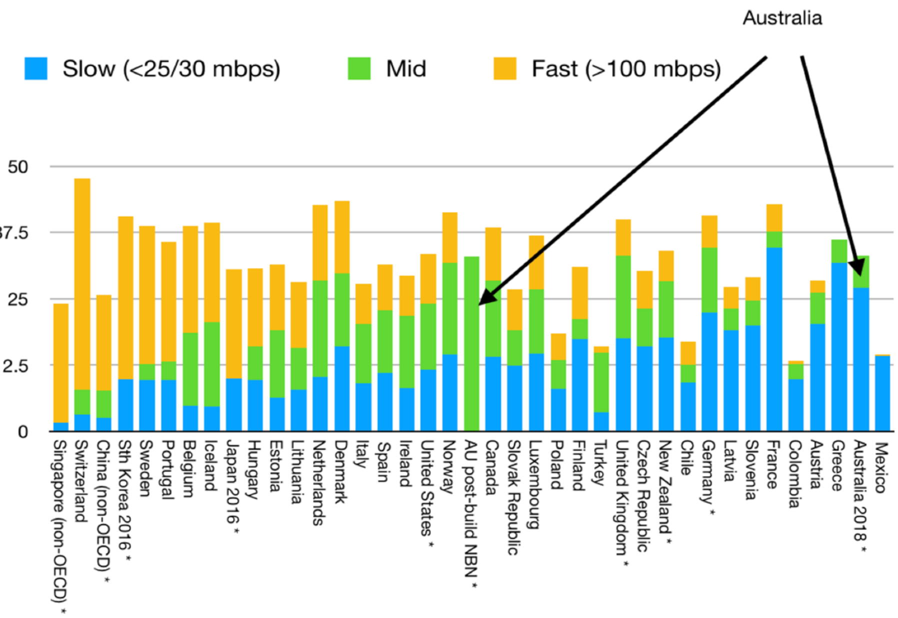

Figure 2. Australia Broadband Download speeds vs OECD (2018), plus China, Singapore (sorted by average speed). NB: * indicates one of Australia's Top 10 Trading Partners. Source: Ferrers and OECD (2019).

Firstly, ranking the OECD countries by average download speed, Australia in 2018 is placed near the bottom (see Figure 2, which again follows OECD's best-at-left-side convention). But with expected speed increases (at least 25 Mbps for all, 90% with 50 Mbps), Australia jumps to mid-range in the average speed rankings. NBN Co. noted this increase in performance, particularly that Australia's average speed would jump ahead of France, Germany and New Zealand, based on their 2018 reported broadband performance levels. However, the Speedtest Global Index, a monthly national broadband speed table (Ookla, 2019), reveals countries' average speeds are increasing, often at 30%, and sometimes 100% in a single year. A graph of this data is provided below (Figure 3). So, comparing Australia's performance in 2020 against other countries' OECD 2018 broadband performance, as a proxy for their 2020 performance, is problematic due to the fast-changing nature of this data.

A few points are obvious from the graph (showing the 36 OECD countries, plus Singapore and China):

- Many countries (except Australia) report very fast services (at over 100 Mbps). Australia reports Nil in this category, but ACCC (n.d.) reports at the end of 2018 show around 400,000 NBN connections at 100 Mbps, similar to Austria. This level of very fast broadband, however, would only lift Australia one place in the ranking. The lack of very fast services puts our national average close to the bottom. Later, I will show that only a few per cent of very fast services can significantly lift Australia's average national broadband speed.
- Even countries with lots of very fast broadband (e.g. Japan, South Korea) still have substantial services on slow speeds (less than 25 Mbps).
- Post NBN build, I assumed all Australians would have minimum 25 Mbps services, so Australia would be the exception with no slow-speed users. However, Australia has one million NBN users on 12 Mbps (ACCC, 2020), which has not reduced as millions of new NBN users switch to or join NBN on 50 Mbps, even though faster services are available.

The OECD graph shows many more countries than can be explored in depth in this paper. Therefore, I choose to narrow the comparison to those countries with which Australia has strongest links, in terms of exports and imports. Looking at the Top 10 Trading Partners would include around 70-80% of Australia's exports and imports. Other possibilities are to compare Australia to similar area countries (e.g. Canada, China), high broadband countries (e.g. Sweden), and our local neighbours (e.g. New Zealand, Indonesia). Trading partners are a sensible choice for comparison, since our trade (both imports and exports) shows who Australia, in the world, is most connected to. I used data from the OEC (n.d.) which identifies Australia's major trading partners as:

- OECD countries: Germany (DE), Japan (JP), New Zealand (NZ), South Korea (SK), United Kingdom (UK), United States (US);
- Non-OECD countries: China (CN), India (IN), Singapore and Thailand (TH).

These ten countries provide an interesting mix of local and distant, small and large area, small and large populations, G20 and other countries.

The Broadband Commission shows national broadband plans for several OECD countries in its State of Broadband Report (ITU/UNESCO, 2018, p. 37). In Table 1, I compare the national broadband plans of Australia's Top 10 Trading Partners, expanding on the State of Broadband

Report (ITU/UNESCO, 2018), looking at their planned national speed and penetration targets. But I have collated plan details for all ten major trading partners (see Appendix 1, Parliamentary Submission, Ferrers and OECD, 2019). I summarise those (see Table 1), then examine in a little more detail, three countries – China, South Korea and Thailand (as representative of the variety of our trading partners' approaches to their national broadband plans). Conveniently, the Broadband Commission provides links to all countries' national broadband plans. Interestingly, there are now over 150 countries with national broadband plans, up significantly from when Australians first nationally considered the NBN in the 2007 Federal election, when there were only 34 such plans (ITU/UNESCO, 2019).

Table 1. National Broadband Plan targets – Australia's Top 10 Trading Partners.
Source: Broadband Commission (2018), Appendix 1, Ferrers and OECD (2019) Parliamentary Submission.

Broadband Penetration Target	Speed		
	Slow	**Medium**	**Fast**
High	AU 100% 25 Mbps UK 95% 25 Mbps TH 95% broadband	DE 100% 50 Mbps IN 100% 50 Mbps NZ 99% 50 Mbps	SK 99% 100 Mbps
Medium		AU 90%* 50 Mbps	
Lower **Missing**: Singapore, Japan **NB**: * Urban		CN 70%* 50 Mbps	US 80% 100 Mbps CN 50%* 100 Mbps plus some gigabit TH cities 100 Mbps (2020) IN gigabit to villages (2020), multi-gigabit (2022)

Source: ITU/UNESCO (2018); China (2013); Thailand (MICT, 2015); India (n.d.).

Australia's national broadband target is similar to Germany, New Zealand, India and China targets in speed (50 Mbps). Australia has similar 100% coverage speed targets (25 Mbps) to the United Kingdom and Thailand. However, Australia's main speed target is slower than several Trading Partners, such as the United States, Thailand and South Korea's faster target (100 Mbps). Thus, Australia's NBN speed target, like our OECD NBN post-build ranking, is middling: not too fast, not too slow. Similarly, if you compare OECD (2018) reported speeds with these countries, we are similarly mid-ranked (but I found no current data for India or Thailand).

A second data source to use to compare Australia to our trading partners is the Speedtest Global Index (Ookla, 2018; 2019) data which is updated monthly with national speed averages. Similar to OECD (2018) data, Australia performs poorly relative to the trading partners, only coming in ahead of India. Using data from Ookla for two years, it is also possible to see the change over one year (from end 2018 to end 2019).

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Table 2. Ookla (2018; 2019) National Average Download Speed: Australia's Top 10 Trading Partners

Country	2018 (Mbps)	2019 (Mbps)	Increase (Mbps)	Increase (%)
Singapore	200	190	-10	-5
South Korea	110	160	50	50*
United States	110	130	20	20
Thailand	55	110	50	100
New Zealand	85	105	0	20
Japan	100	105	5	5
China	85	100	20	20
Germany	65	80	20	20
United Kingdom	55	65	10	20
Australia	33	42	10	30
India	26	38	10	50

NB:* South Korea fell from 130 Mbps (in 2017), so increase is a bounce-back. All figures rounded.

A graphical version of Table 2 is shown in Figure 3.

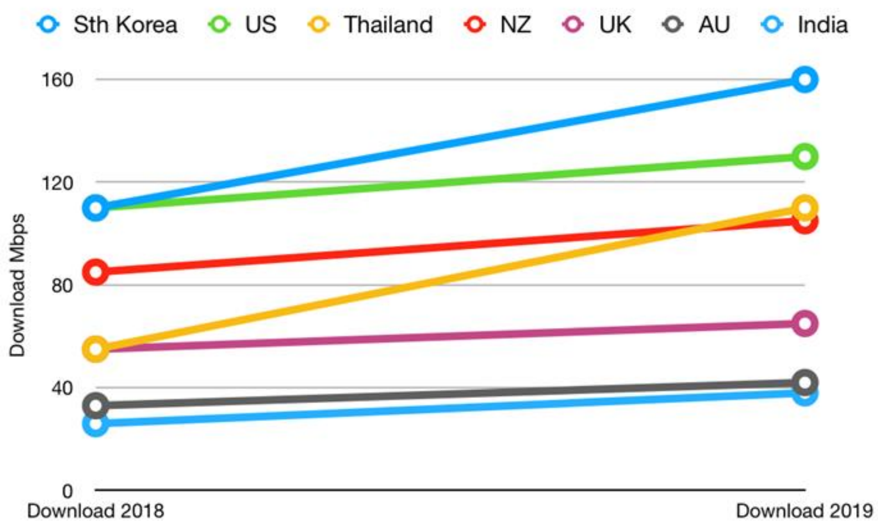

Figure 3. National Average Download Speed, per Ookla Speedtest Global Index (Dec 2018, 2019). NB: Japan, China (removed) similar to New Zealand. Germany (removed) similar to United Kingdom.

A few points from this graph are:

- Every country is following a similar trajectory of around 20-30% growth in speed per year, as shown by parallel increases – India, Australia, United Kingdom, New Zealand, United States; a jump of 10 Mbps in the slower countries and 20 Mbps in the faster countries. Thus, looking at OECD (2018) figures, which are over a year old, is likely to underestimate national average speeds by 20-30% per year. Hence NBN Co.'s suggestion (NBN Co., 2019b), using 2018 OECD data, that a post-build NBN will be faster in 2020 than France, Germany or New Zealand (AlphaBeta, 2019), is unlikely to be realised.
- A couple of countries showed a greater increase than 30%: Thailand jumped 100% from 55 Mbps to 110 Mbps in just one year, and South Korea jumped from

100 Mbps to 160 Mbps. South Korea had fallen from 130 Mbps in the year before (2017), so seems more like a statistical aberration. However, the Thailand download gain seems worthy of further investigation below.

- The Speedtest average for Australia in late 2019 is 42 Mbps, quite similar to my estimate of 50 Mbps average for a post-build Australian average national download speed. What this average doesn't make obvious is that the slowest NBN Co. plan (12 Mbps) continues to retain around one million NBN users, which is unchanged by the large recent increase in faster 50 Mbps services (ACCC, n.d.).

I now examine three countries in more detail – China, South Korea and especially the substantial speed rise in Thailand.

Case 1: South Korea

South Korea is held up as a leader in broadband and has been for several years (Labour, 2019). This can be seen by its new national target that 50% of premises will be able to access 10 Gbps by 2022 (Wang, 2018), an order of magnitude faster than Australia in early 2020. Reports from the United Kingdom (Labour, 2019) compared the United Kingdom broadband capability unfavourably to South Korea and Japan in the lead-up to the United Kingdom late-2019 election, and referenced both Japan and South Korea having 99% of their homes able to access the best broadband – fibre to the home (FTTH). FTTH is regarded as the gold standard for broadband (Gregory, 2019), compared to the multi-technology mix (MTM) of Australia. Looking deeper into broadband in South Korea, however, shows that South Korea has an MTM too (Netmanias, 2018); even though there is widespread (99%) access to FTTP, take-up is less widespread (see Table 3 below).

Over the last ten years, HFC has remained a significant proportion of South Korea's broadband, falling from 5 million connections (2006) to 4 million connections in 2017. Fibre over that time increased significantly from nothing to nearly 8 million connections, while xDSL services fell from 6 million to 1 million premises. A fourth type of broadband, called LAN (UTP), seems to be FTTB, that is, broadband to apartment buildings using copper (unshielded twisted pair; UTP) to deliver broadband into apartments. LAN (UTP) has risen from 3 million connections in 2006 to over 8 million in 2017, even more popular than FTTH. Some observers might combine LAN (UTP) and FTTH as fibre connections, making fibre some 75% of total broadband services. However, South Korea appears to have an MTM like Australia, given its considerable use of HFC, notwithstanding nearly everyone could have FTTH (99% access) if they wanted to use it. FTTH is available, but not used, everywhere.

One lesson from South Korea (see Table 3) is to "improve, improve, improve". Improve your strong technologies and reduce your weaker technologies. Similarly for NBN Co., a priority

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after finishing the build is to start the next phase of improvements, which I **recommend** below as an appropriate approach in Australia.

Table 3. South Korea Multi-Technology Mix. Source: Netmanias (2018)

Technology	2007 (Million Users)	2007 (%)	2017 (Million Users)	2017 (%)
FTTB (LAN-UTP)	3	21	8.5	40
FTTH	0	0	7.5	36
HFC	5	36	4	19
xDSL	6	43	1	5
Total	**14**	**100**	**21**	**100**

Case 2: China

China in contrast has used FTTH for a significant rollout since 2013 (see Table 4 below). Except for regional broadband, fibre is used, so it appears, in nearly all urban areas. China reports annually on their broadband status including fibre. China's plan in speeds is very similar to Australia, aiming for 70% penetration of 50 Mbps broadband, and 50% of homes to have access to 100 Mbps, plus some with access to gigabit (China, 2013). Australia's NBN is similar. It is committed to 50 Mbps for 90% of the fixed-line network, but it has capability for gigabit services for 55% of the NBN urban footprint, using a mix of FTTH, HFC and FTTC technologies (Fletcher, 2019; 2020).

Table 4. China Fibre Broadband User Subscriptions. Source: CNNIC (2018, 2019)

Date	Fibre User Subscriptions (M)	Fibre User Subscriptions (FTTH*) / Total Internet Users (%)	Fibre user Subscriptions at/over 100 Mbps (%)
Dec 2012	20.3	11.6	
Dec 2013	40.8	21.6	
Dec 2014	68.3	34.1	
Dec 2015	119.7	57.1	
Dec 2016	227.7	76.6	
Dec 2017	293.9	84.3	38.9
Dec 2018	368.3	90.4	70.3
Jun 2019	395.8	91.0	77.1

NB: * Includes FTTO – Fibre to the Office.

What is different about China is the level of usage of high speeds across their network (Table 4). China reports how many of their users are on the 100 Mbps speeds, and the numbers are extraordinary for a country of China's size, with some 480 million households (Euromonitor International, 2020). China reports in mid-2019 396 million fibre-using households and offices, which is over 80% of China's total 480 million households. With 77% Chinese households or offices on fast (at or over 100 Mbps) broadband services, this equates to over 300 million fast broadband subscriptions.

An interesting comparison with China is the next biggest broadband country, the United States. Both countries report that 90% of their homes can access 100 Mbps (FCC, 2019; CNNIC, 2019). As a proportion of users, in 2018 China had far greater fast broadband users than the United States (70% vs 28%; OECD, 2018), and a year later China had 77% premises on this speed.

Reflecting on lessons from China's broadband, and looking forward for Australia, and for the use of the NBN, post-build, in Australia, we want to be more in the position of China, with a well-used broadband network with a high proportion of users on the 100 Mbps service, than the United States, with a far smaller proportion of users on the 100 Mbps service. Therefore, I **recommend** *NBN Co. focus post-build on encouraging more high-speed network usage*. It is possible that China puts consumers on high-speed plans without them choosing high-speed plans. NBN Co. did a similar thing in Australia, by making 25 Mbps and 50 Mbps plans the same price. Major telcos like Telstra and Optus upgraded plans to 50 Mbps without asking consumers. China possibly has a similar situation where usage of fast services is not a choice.

One small extra data point is that China's ARPU (average monthly revenue per user) for fixed broadband is around $6 per month (China Mobile, 2019). Gigabit prices are expected to be around $60 per month (China.org.cn, 2019). Both prices are substantially lower than Australia, but the fast China gigabit service is priced at a significant premium (i.e. 10 times ARPU) to the typical broadband service.

Case 3: Thailand

A third country worthwhile to examine is Thailand, and especially its recent sizeable increase in average national broadband speed (per Ookla data, Table 2, Figure 3). Looking at local Thailand telecoms media reveals that Thailand has a recent sizeable population of fibre internet users. By 2018, there were 7 million fibre users, some 39% of 18 million Thai households. Around that time, there were price falls for gigabit services, which fell 70% (Bangkok Post, 2018) from around $500 per month to $140 per month. While average broadband users spend $30 per month (True Corp, 2019), the availability of gigabit services at more affordable prices may possibly explain the sudden 100% rise in national average broadband speed (see Table 2; Figure 3).

I examined some of the YouTube advertising for fast broadband services to see how Thailand was promoting such services. There were very generic business services (TrueInternet, 2014, 1:10), with interesting future-oriented tools (such as see-through iPads). Fibre to the home was promoted as more reliable, for instance during the heavy tropical rain in Thailand (Infographic Thailand, 2016, 0:53). Some suggested services on Thai broadband are very

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familiar in Australia, including E-Shopping, E-Payment, E-Entertainment, E-Education, and perhaps less familiar services such as E-Medical and E-Security (FibreOne, 2016, 2:49).

Similarly in Australia, gigabit services are coming to a wider market as gigabit is enabled for HFC and FTTC services, beyond the current FTTP availability. NBN Co. has announced (NBN Co., 2019c) that a more affordable gigabit price will be available shortly. Current gigabit NBN services (Enterprise Ethernet; NBN Co., 2018) are around $800 per month (Aussie Broadband, n.d.), beyond the reach of most households, but targeted at business users and interestingly available on three-year plans to anyone in the fixed-line network, with free installation of fibre to any fixed-line premises (Aussie Broadband, n.d.). The new prices are expected to allow lower retail pricing in a few months' time, perhaps as low as $150-200 per month, with the possibility of even lower prices if retailers do not guarantee top speeds during congested peak hours. This is a key element of the future path of a post-build NBN.

Looking at these cases, Australia has a similar multi-technology mix as South Korea, but the higher installation of FTTH in South Korea (36%), Thailand (39%) and China (80%) goes a long way to explain Australia's poor comparative average download speed performance. I discuss national broadband averages in the next section. Interestingly, South Korea, which is seen as a world broadband leader, has FTTH available to 99% of homes, but it is only used by 36%, suggesting weak demand to increase speeds from slower-but-popular FTTB technology, used by 40% of Korean households. These cases paint a more complex picture of broadband demand. They do not show that Australia has a weak, slow NBN, requiring immediate upgrade to full fibre, but that Australia needs to, in part, emulate countries that are progressively working to improve their broadband capability. Australia is doing this too, especially with more widespread gigabit services coming available in mid-2020 to 55% of NBN residential premises (FTTP, HFC, FTTC), and available for all Australian fixed line business premises (through Enterprise Ethernet). But affordable gigabit is just one part of what I **recommend** as a broader commitment, through my five recommendations below, to enhancing the value of Australia's NBN. I turn now to what next for the NBN.

Where are we going?

In a few short months, the NBN will be declared built. If there is one thing Australia's political powers can agree on (as Minister of Communications, Paul Fletcher and Shadow Minister of Communications, Michelle Rowland did agree on when they introduced the first TelSoc Futures Forum (TelSoc 2019)), and with the NBN there are regrettably few things they agree on, it is that following the significant NBN investment, Australia needs:

(1) to "get the maximum social and economic impact from the $51 billion [of] taxpayer's money",

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(2) to work out "how best to leverage this extraordinary national investment" (Minister Fletcher) and

(3) how to "maximise the benefit of [NBN] investment now and in the future" (Shadow Minister Rowland).

I have no doubt the next steps are twofold. Firstly, maximise use of the fastest speeds through the release, scheduled in May 2020, of new affordable gigabit plans. From May, FTTH, HFC and FTTC, some 55% of the fixed line network, are likely to be able to provide access for many significantly faster and significantly cheaper gigabit offerings. I foresee that the upcoming NBN "closing ceremony" and Press Release will celebrate the end of the NBN build and the release of affordable gigabit services. This is quite a contrast to earlier statements by NBN Co.'s CEO (Morrow, 2017) that "there is still minimal consumer demand for these ultra-fast speeds". The demand is not for speed at any price, but for speed at reasonable and affordable prices; for speed at a price which consumers see as *good value*. In contrast, New Zealand has 10% of its users on gigabit speeds (Crown Infrastructure Partners, 2019, p.6), though their prices are likely to be far lower (sometimes (Broadband Compare, n.d.; UFB NZ, n.d.) under $100 per month) than Australia's CVC-driven pricing. Therefore, I **recommend,** an important next step is *NBN Co. launch affordable gigabit services*.

One benefit of more widely used gigabit services is a likely significant impact on national average speed, with potential for large improvements in Australia's ranking in Ookla international rankings (Table 2, Figure 3). As a mathematical exercise (see Table 5), if post-build NBN average speed was 50 Mbps, then a 5% uptake of gigabit services would double average national speed to around 100 Mbps. A 10% uptake would triple average national speed to about 150 Mbps, and a 20% uptake would lift average national speed to 240 Mbps. A 5% gigabit uptake would put Australia at the top of the OECD (2018) national averages, but only lift Australia to 7th (equal) of our Top 10 Trading Partners. A 10% uptake would place us 3rd amongst our trading partners, and a 20% uptake would take us to first place. Table 5 summarises the impact of gigabit users on Australia's global speed ranking.

Table 5. Impact of gigabit users on Australia's national average download speed. Source: Author comparison

Scenario	Average Download Speed (Mbps)	Ookla Rank (2019) vs Top 10 Trading Partners	OECD Rank (2018)
Australia 2018 (OECD)	21	10th	35 / 36
Australia post-build NBN	50	10th	18 / 36
5% gigabit	98	Equal 7th	1 / 36
10% gigabit	145	3rd	1 / 36
20% gigabit	240	1st	1 / 36

The second obvious NBN step forward is to commit to ongoing improvements in the NBN. Table 5 shows the ranking leap is what I call a 'tyranny of averages'. Australia could place fastest amongst our Trading Partners (with a 20% gigabit uptake) but 80% of NBN users would have had no change in their broadband performance. And some NBN performance is poor. The NBN Fixed Wireless and Satellite services are guaranteed to deliver a minimum 25 Mbps (NBN Co., 2016), under the *Statement of Expectations*. Similarly, some of the FTTN services have only slow access speeds (less than 50 Mbps) – perhaps around 25% of FTTN connections — yet with 20% gigabit users, Australia would be the fastest amongst our peers, our Top 10 Trading Partners. It is to this 25% of poorest connections that some of the profits from NBN post-build should be directed to enhance the network for the worst-performing services. Therefore, I **recommend**: *Post-build NBN Co. continue to invest in enhancing the network for the worst-performing technologies and services.*

Conclusions/Recommendations

In conclusion, the initial NBN rollout is nearly complete, and we need to think about enhancing the value of the NBN after that. Comparing the Australian NBN to overseas approaches can shed new light on the value of our NBN. I propose several recommendations, which I made to the NBN Joint Standing Committee (Ferrers and OECD, 2019) *Inquiry into the business case for the NBN and the experiences of small business*, from my international comparative analysis above, including:

R1: NBN Co. launch gigabit services at affordable prices. Affordable network services indicate high value. And gigabit services will lift Australia's comparative international broadband download performance. New gigabit pricing is due in May 2020 (NBN Co., 2019c), so we will see if it is affordable.

R2: NBN Co. continue to invest to enhance the NBN post-build, especially for the poorest performing 25% of connections, from NBN generated cashflow, according to a new *Statement of Expectations*, preferably bipartisan. An improving network is enhancing its value.

R3: Focus NBN Co. on encouraging NBN usage, including affordable pricing, such as entry-level pricing of 50 Mbps (rather than 12 Mbps) service, and affordable gigabit pricing. NBN should have a high-performing but also highly used network (like China), rather than a less used network (like the United States). An unused NBN is low value.

For completeness, I include now two further value-enhancing recommendations I made to the Parliamentary Inquiry (Parliament of Australia, 2020), but which did not fit within the story in the paper above. These recommendations address feedback the Inquiry sought about the

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following issues from its terms of reference: “a. the economics of the NBN including key operational and financial performance forecasts in the Corporate Plan 2020-23; c. network coverage issues, including reporting of outages; f. compliance with the NBN Statement of Expectations and the adequacy of that Statement”. In value terms, these recommendations make NBN value more transparent by reporting regularly on customer satisfaction (R4) and international comparisons (R5).

R4: NBN Co. should listen to customers, plan for their satisfaction including targets in Corporate Reporting (such as speed, reliability, affordability and other dimensions as outlined in the Broadband Commission’s 2025 Targets; ITU/UNESCO, n.d.), measure customer satisfaction (by relevant categories, such as technology, urban and rural, business and consumer) and report their satisfaction to the public within regular financial reports. Customer satisfaction is a key indicator of NBN value and enhancing customer satisfaction enhances NBN value.

R5: Given the above international comparison analysis has merit and value, NBN Co. Corporate Plans should include regular target setting based on international comparison with Australia’s Top 10 Trading Partners, along key metrics, to reflect shareholder preference for relative performance against these countries. The NBN’s value becomes more richly visible and understandable by comparing its performance to its international peers, particularly Australia’s top 10 Trading Partners.

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RDTD: A Tool for Detecting Internet Routing Disruptions at AS-Level

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Abstract: Anomalous events such as link failure, misconfiguration, and Denial of Service attacks can affect the Internet inter-domain routing protocol. This effect can range from small to large-scale impact. While large-scale events can be detected using one or multiple global monitoring points, small-scale events need monitoring at the Autonomous System (AS) level. This paper presents a Real-time Detection Tool for Internet routing protocol Disruptions (RDTD) at AS-level. RDTD is a black-box statistical approach that detects disruptions based on observing changes in the underlying behaviour of a series of inter-domain routing updates rather than information contained in inter-domain routing updates. The RDTD can be connected to a designated AS to detect disruptions at that AS or to one of the collectors at public vantage points to detect the Internet routing disruptions from the public vantage-point's view. The evaluation of the detection tool has been made through replaying route traffic related to one of the most well-known events within a controlled testbed. Our evaluation shows the ability of the detection tool to detect route leak in near real-time without requiring a long history of data. RDTD can also detect hidden anomalous behaviour in the underlying traffic that may pass without detection.

Keywords: Inter-domain routing, route leak, emulation, anomaly detection, testbed.

1. Introduction

The Internet is a decentralized global network that consists of tens of thousands of Autonomous Systems (ASes); an Internet Service Provider (ISP) is an example of an AS. ASes use inter-domain routing protocols such as Border Gateway Protocol (BGP) to communicate with other ASes and intra-domain routing protocols such as Open Shortest Path First (OSPF) to communicate between routers within an AS (Al-Musawi, Branch, & Armitage, 2017). ISP operators need to monitor their networks including the exchange of information between routers within their domain (intra-domain) and with other ASes (inter-domain). In this paper, our interest is in the latter. In particular, we are interested in the rapid detection of inter-domain routing disruptions at the AS-level.

BGP is the de-facto Internet routing protocol responsible for exchanging Network Reachability Information (NRI) between ASes. Although many attempts have been made to improve its security, it is still vulnerable to different types of disruptions that threaten its stability. ISPs increasingly suffer from large-scale or small-scale route disruptions in recent years. Recent statistics on the Internet inter-domain routing protocol performance show approximately 20% of the hijackings and misconfigurations lasted less than 10 minutes but were able to pollute 90% of the Internet within 2 minutes (Shi *et al.*, 2012). These statistics demonstrate the need for a new tool that can detect different types of inter-domain routing disruptions in real-time. ISP operators need to react quickly by tuning their configuration to eliminate the propagation of anomalous inter-domain routing traffic or notify other ISPs about serious reachability issues. In this paper, we introduce a Real-time Detection Tool for Internet routing protocol Disruptions (RDTD) at AS-level. RDTD is a black-box statistical approach that does not rely on the information contained in inter-domain routing updates. Alternatively, it detects disruptions based on the key observation that most disruptions correspond to changes in the underlying behaviour of a series of inter-domain routing updates. RDTD is based on using Recurrence Quantification Analysis (RQA), an advanced non-linear statistical analysis technique based on the concept of phase plane trajectory (Trulla *et al.*, 1996; Webber & Zbilut, 2005). Detecting Internet routing disruption at AS-level helps to mitigate the effect of disruptions from propagating to other ASes. In this paper, we do not mainly focus on the concept of RQA: Al-Musawi (2018) provides such a study. Instead, we focus on how to integrate this technique into a tool that can be used by network operators.

Inter-domain routing disruptions can result from different sources, such as hijacking, Denial of Service (DoS) attacks, hardware failure, software bugs, faulty equipment, and misconfiguration by operators. Many types of inter-domain routing disruptions have been noticed, such as TMnet route leak (Toonk, 2015) and Moscow blackout (Roudnev, 2005). Although these events have been noticed as a result of their size and effect on the inter-domain routing traffic and the business relationship among many ASes, other types of events remain unreported or even unnoticed. The RDTD was designed to be applied at AS-level so it can help ISP operators to detect different types of disruptions before their effect spreads to other ASes.

The rest of this paper is organised as follows: Section 2 explores related work in the detection of inter-domain routing disruptions. In section 3, we introduce the structure and design of the RDTD tool. Section 4 shows the operation and configuration setup to run RDTD. Section 5 presents the evaluation of RDTD through replaying one of the most recent well-known BGP events and compares its performance with other techniques. In section 6, we conclude our work and outline future directions.

2. Related Work

One of the earliest efforts of identifying inter-domain routing disruptions was by Labovitz, Malan & Jahanian (1998). To detect Internet routing disruptions, the authors applied the Fast Fourier Transform (FFT) to a series of BGP updates. Although the technique did not provide a way to identify the cause or source of routing disruptions, it demonstrated that rapid changes in the routing traffic are correlated with disruptions. Following the work by Labovitz, other techniques were applied to the problem of inter-domain routing identification. These included using statistical analysis techniques (Deshpande *et al.*, 2009; Huang *et al.*, 2007), validation of Internet routing traffic based on historical routing data sets (Haeberlen *et al.*, 2009; Shi *et al.*, 2012), and tools to detect Internet routing disruptions (Luckie, 2010; Lutu, Bagnulo & Maennel, 2013).

Huang *et al.* (2007) introduced a technique based on using Principal Component Analysis (PCA) and subspace method to detect AS node, link, and peer failure. They used inter-domain routing volume as a single feature extracted every 10 minutes with a window size of 200 minutes. Although the technique can detect and identify the three types of failure, it requires information about router configurations. Their technique cannot work in real-time, detecting the three types of failures in a range of 9-96 minutes.

The Generalized Likelihood Ratio Test (GLRT) is a standard statistical technique used in hypothesis testing. Deshpande *et al.* (2009) adopted it as an instability detection technique. Their approach used statistical pattern recognition, which incorporated the technique. The approach was able to detect different types of inter-domain disruptions such as the Moscow blackout, Nimda, and Panix domain hijack. However, it is slow, typically requiring around one hour to detect instability.

Haeberlen *et al.* (2009) presented a prototype to detect inter-domain routing faults at the AS-level called NetReview. This prototype uses 1 year of routing data to detect inter-domain disruptions, where inter-domain disruptions include node and link failure, misconfiguration, policy violations, and attacks. Although NetReview can detect in near real-time different types of inter-domain disruptions and identify their source cause, it requires each AS to reveal information related to its policy configuration. In addition, it has a scalability problem because of the need to store large log files, a particular issue for ISPs.

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Argus (Shi *et al.*, 2012) is a system to detect prefix hijacking and identify the attacker in real-time. Argus uses the control plane to detect bogus routes and the data plane to verify anomalies through checking their reachability. This system uses more than 2 months of historical inter-domain routing data to classify new data as normal or suspicious, then checks the reachability of prefixes to verify the suspicious updates through using tools such as CAIDA's Ark. Although Argus can detect hijacking and identify the source in near real-time, it cannot detect other types of disruptions such as misconfiguration and DoS attacks.

Scamper (Luckie, 2010) is a packet prober designed to support large-scale Internet measurements. It is a tool that implements most of the classical Internet measurement tools such as ping and traceroute that supports IPv4 and IPv6 probing. It was mainly designed to help researchers for scientific experiments rather than building accurate instrumentation. However, Scamper was not designed to detect Internet route disruptions.

BGP Visibility Scanner (Lutu, Bagnulo & Maennel, 2013) is a tool that can help ISP operators to validate the correct implementation of their routing policies through monitoring their routes from multiple observation points. However, this tool is not able to detect different types of disruptions such as Internet route leaks. Furthermore, it requires using multiple monitoring points.

Cyclops (Chi, Oliveira & Zhang, 2008) is a system that displays AS-level connectivity and changes as inferred from Public-View. Cyclops collects data related to AS-level topology from different sources such as looking glasses, inter-domain routing tables and updates of hundreds of ASes across the Internet. It helps the network operators to view their AS connectivity as seen from other ASes, which can provide a comparison between the observed connectivity and the intended connectivity.

Unlike different inter-domain routing disruptions tools, we introduce RDTD, a real-time detection tool to detect Internet inter-domain disruptions at AS-level. RDTD is based on using non-linear statistical analysis calculations that utilise calculations of hidden information occurring in the inter-domain routing traffic to detect disruptions. This information represents recurrence features in a series of Internet routing traffic. Our work differs from others in that we overcome their drawbacks by detecting disruptions in real-time and without requiring a long history of data: our tool requires 1200 seconds of historical data to detect disruptions in a range of 1-200 seconds.

3. Architecture and Design

Real-time Detection Tool for Internet routing Disruptions (RDTD) enables ISP operators to detect different types of Internet routing disruptions in near real-time. Real-time detection enables the operators to mitigate the effect of disruptions to other ASes, which can lead to improving global Internet routing stability. RDTD consists of four stages. These are: collector, calculating the measurements of the non-linear statistical analysis, moving average and detection, as shown in Figure 1.

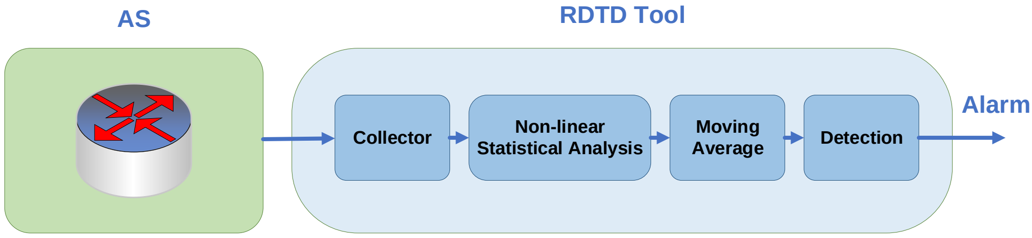

Figure 1. RDTD Structure and Design

3.1 Collector

The purpose of this stage is to provide real-time collection of traffic sent by the monitored AS. Unlike Quagga (Ishiguro, 2018) which is an open-source routing software suite that can be used to establish a connection with the monitored AS and store the inter-domain routing traffic in MRT format (Blunk, Karir & Labovitz, 2011), our collector collects inter-domain routing traffic in a human-readable format. It also calculates several features. These features avoid the need for converting MRT and calculating the features. The outputs of our collector are the total number of announcements and withdrawals (TAW) and the average length of AS-PATH (AVP). These features are calculated every second based on the timestamp of the traffic.

Our collector uses Net::BGP, a module of Perl software, to implement BGP. Net::BGP provides the required functionality to establish AS peering and for exchanging BGP updates. Officially, Net::BGP v0.16 does not support IPv6 BGP updates nor IPv6 BGP peer connection. CAIDA has developed a patch for Net::BGP that allows a BGP router to send IPv6 announcements through Multi-protocol Reachable NLRI, an optional attribute supported as part of Multi-protocol Extensions for BGP (CAIDA, 2016). However, this patch does not support IPv6 prefix withdrawn and requires BGP routers with ADD-PATH capability, an extension to the BGP protocol to allow the advertisement of multiple paths for the same prefix. Therefore, we implemented the IPv6 route withdrawn through the Multi-protocol Unreachable NLRI optional attribute and removed ADD-PATH BGP capability for compatibility purposes (Bates *et al.*, 2007).

3.2 Non-linear Statistical Analysis

Recurrence Quantification Analysis (RQA) is an advanced non-linear statistical analysis technique that uses the concepts of phase plane trajectory, a theoretical space in which every state of a system under study is mapped to a unique spatial location (Trulla *et al.*, 1996). RQA was introduced by Webber and Zbilut (2005) to quantify structures in Recurrence Plots (RPs), an advanced non-linear analysis tool that measures recurrences of a trajectory in the phase plane. RP has been widely used to visualise the time-dependent behaviour of the dynamics of a system as a recurrence matrix R

$$\mathrm{R_{m,n}} = \begin{cases} 1: \overrightarrow{\mathrm{x_m}} \approx \overrightarrow{\mathrm{x_n}}, \\ 0: \overrightarrow{\mathrm{x_m}} \not\approx \overrightarrow{\mathrm{x_n}}, \end{cases} \quad m, n = 1, \dots, J, \tag{1}$$

where $\{\overrightarrow{\mathrm{x_m}}\}_{m=1}^{J}$ is a trajectory of a system in its phase plane, J represents the number of considered states and $\overrightarrow{\mathrm{x_m}} \approx \overrightarrow{\mathrm{x_n}}$ means equality up to a distance ε; ε is essential where systems show approximate recurrence to a formerly visited state. In other words, the recurrence matrix compares system states at time m and n. If the difference between these states is within the threshold distance ε, $\mathrm{R_{m,n}} = 1$; otherwise, $\mathrm{R_{m,n}} = 0$. Consequently, the recurrence matrix tells us when similar states of the underlying system occur (Marwan *et al.*, 2007).

Although RP is a powerful tool for visualizing system behaviour, it requires considerable expertise to interpret and cannot be used for real-time monitoring. Consequently, RQA was introduced to overcome these challenges through quantifying structures in RPs and provide the corresponding values of measurements (Marwan *et al.*, 2007). RQA provides many measurements that are known as RQA measurements. The most well-known RQA measurements are recurrence rate, determinism, and trapping time. Each of these measurements measures individual characteristics in the RP. For example, the recurrence rate refers to the probability that a system recurs after several time states. It represents the number of black dots in the RP excluding the black main diagonal line in the RP.

$$Recurrence\ rate = \frac{1}{J^2} \sum_{m,n=1}^{J} R_{m,n}, \tag{2}$$

where $\mathrm{R_{m,n}}$ is an element in the RP matrix.

RQA has been successfully used in different domains, such as Internet of Things (IoT) (Forkan *et al.*, 2019) and detecting anomalies in intra-domain routing protocols (Al-Musawi *et al.*, 2020). We have shown in Al-Musawi (2018) that RQA can distinguish between recurrent normal behaviour and other behaviours that identify disruptions. RQA can rapidly detect the inter-domain routing disruptions as well as other hidden anomalous periods that may otherwise pass without detection. The strength of RQA applied to this approach is in its ability to rapidly distinguish between the recurrence behaviour that is a part of normal internet-domain traffic behaviour and behaviours that indicate disruptions. Furthermore, RQA can detect behaviour that cannot be detected with other techniques (Al-Musawi, 2018).

Before calculating RQA measurements for the two features, (TAW) and (AVP), we normalise these features by subtracting the mean value to smooth noisy traces. RQA measurements are based on many parameters. These include time delay (τ), embedding dimension (m) and recurrence threshold (ε). The values of (τ) and (m) can be calculated using mutual information and false nearest neighbour, respectively. The first minimum values of mutual information and false nearest neighbour represent the values of (τ) and (m). The value of (ε) can be calculated using the recommendation from Marwan *et al.* (2007) by choosing the threshold value of less than 10% of the maximum phase plane diameter. We use the TISEAN package to calculate the values of (τ) and (m) and a Matlab toolbox available online on (Marwan, 2015) to calculate the value of (ε), which we provide within the RDTD package. In this paper, we do not provide a heuristic analysis for selecting the most effective RQA measurements: Al-Musawi (2018) provides such a heuristic analysis. Instead, we focus on providing a real-time detection tool for detecting Internet routing disruptions.

3.3 Moving Average

This stage aims to smooth the values of the RQA measurements to enable the detection of notable changes. A notable change in values of the RQA measurements in terms of increment or decrement indicates anomalous behaviour in a series of Internet inter-domain routing traffic. To identify RQA measurement changes that indicate an anomaly, we apply the moving average technique based on the following format:

$$RDTD_{alarm} = \bar{M} \pm \sigma(M) * T, \quad (3)$$

where (M) is the length of the window size for the detection, $\bar{M}$ is the mean value of (M), (σ) is the standard deviation of data with length (M) seconds and (T) is the threshold value, expressed as a multiple of the standard deviation. For example, $T = 5$ represents 5 standard deviations of data with length (M) seconds. We did a heuristic analysis to select the optimal values of the window size (M) and the threshold value (X), as well as (W), the window size for calculating RQA measurements: for more details, see Al-Musawi (2018). This included $W = 200 \rightarrow 1200$ and $M = 200 \rightarrow 1200$ with an increment of 50 and $T = 1 \rightarrow 10$ with an increment of 1. Our analysis showed that window sizes $W = 200$ seconds and $M = 1200$ seconds, together with a threshold value in the moving average stage of $T = 9$, are optimal values to be used in our detection scheme.

3.4 Detection

In this stage, the detection decision is made. The input to this stage is multiple RQA alarms calculated by the moving average stage, while the output is an alarm that identifies the detection of the inter-domain routing disruptions. We use all logical ORs based on the need to minimise the False Positives (FPs) rate. FP refers to normal events that are classified as anomalous, while False Negative (FN) refers to anomalous events that are classified as normal.

In this section, we have presented the design of our RDTD tool for detecting the Internet routing disruptions. In the next section, we introduce RDTD and discuss its use.

4. Real-time Detection Tool for Internet routing protocol Disruptions (RDTD)

Real-time Detection Tool for Internet routing protocol Disruptions (RDTD) is a Perl script to detect Internet inter-domain routing disruptions in near real-time. RDTD connects to a peer AS that is intended to be monitored. Although RDTD logs all detected inter-domain disruptions at AS-level with their time stamps and the last 1200 seconds of the traffic features, it offers the facility of sending an e-mail notification and real-time plot. These options can be activated by enabling -email and -plot command line arguments. The optional and mandatory arguments of the RDTD tool are listed in Table 1. A simple example of using RDTD to monitor the peer AS65002 is shown in Figure 2, while the necessary command-line arguments can be as follows:

```
# perl RDTD.pl -colas 65003 -colip 10.0.0.49 -peeras 650002 -peerip 10.0.0.20 -email 1 -plot 1
```

In this example, the user enables the options of sending an e-mail notification when a route leak is detected and enabling a real-time plot of BGP features and alarm detection.

Table 1. RDTD tool command-line arguments

Argument	Value	Optional	Description
-colas	<AS number>	No	RDTD AS number
-colip	<IP address>	No	RDTD IPv4 address
-peeras	<AS number>	No	Peer AS number
-peerip	<IP address>	No	Peer IPv4 address
-email	<0,1>	Yes	1=> send email notification, 0=> don't
-plot	<0,1>	Yes	1 => run real-time plot or 0=> don't
-help		Yes	Display RDTD tool help

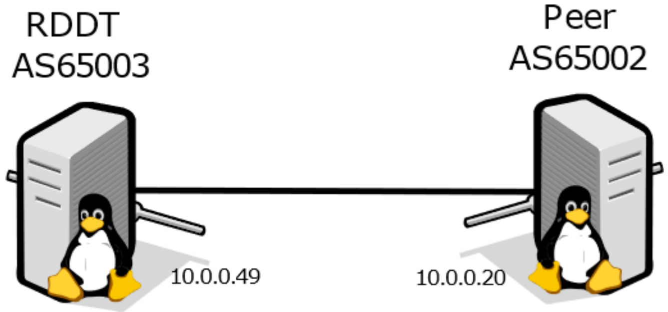

Figure 2. A simple example to monitor an AS using RDTD tool

To run the RDTD tool, RDTD needs some Perl modules and other open-source packages. The Perl modules are listed in Table 2. These modules can be downloaded and installed using cpan shell. For example, to install Net::BGP the following steps are required:

http://doi.org/10.18080/jtde.v8n2.244

```
#perl -MCPAN -e shell
cpan[1]> install Net::BGP
```

Table 2. List of necessary Perl modules

Perl module	Purpose
Net::BGP	Provide the required functionality to establish AS peering and receiving inter-domain routing traffic from AS which intended to monitor
Getopt::Long	Extend processing of command-line options
Statistics::Basic	Provide a collection of statistics calculations such as mean and standard deviation that we need them at moving average stage
Mail::Sender	Sending mails with attachments through an SMTP server

To apply the IPv6 support patch to the Net::BGP module, we provide a patch installation script that simplifies the process. This can be done using the following command:

```
# cd patch
# ./patch.sh
```

In addition to installing the necessary modules, enabling the e-mail option for sending a notification when an anomaly is detected needs extra action. Users need to allow access to less secure apps in their e-mail settings. (For example, allowing less secure apps in a Gmail account can be activated through the following link https://myaccount.google.com/lesssecureapps.) It is important for users to send a test e-mail using the script named test_email.pl in the RDTD package. The RDTD package is available online at https://github.com/Bahaaqm/RDDT.

The RDTD tool also requires the Gnuplot package to be installed. This is necessary if the user enables the optional argument of the real-time plot. Gnuplot is an open-source package for data visualization. It has the advantages of fewer resource requirements and being easy to use. It can be installed in Ubuntu OS as follows:

```
#apt-get install gnuplot-x11
```

5. Evaluation

To evaluate our RDTD detection tool, we replay inter-domain routing traffic related to the TMnet event, one of the well-known Internet inter-domain routing disruption events, using the BGP Replay Tool (BRT) (Al-Musawi *et al.*, 2017), a tool that we built to replay past Internet routing traffic with time stamps. We use the simple topology shown in Figure 2 to monitor inter-domain routing traffic sent by a BRT speaker sending route traffic related to the events.

The TMnet event is an example of an Internet route leak that was observed on 12 June 2015 by TMnet, an ISP owned by Telekom Malaysia. TMnet (AS4788) accidentally advertised 179,000 prefixes with preferable paths to Level 3, which in turn accepted and propagated them, causing significant instability to the global routing system (Al-Musawi, Branch & Armitage, 2015). We use BRT to replay inter-domain routing traffic sent by AS10102, a peer of the route-views4 collector (Routeviews, 2000), during the TMnet event. As a result of the route leak, AS10102 sent a significant amount of inter-domain routing traffic during the event.

In addition to its ability to rapidly detect the Internet routing disruption caused by a high volume of inter-domain routing traffic, RDTD also raises an alarm when AS10102 stops sending inter-domain routing traffic. Figure 3 shows that RDTD raised an alarm 196 seconds after BRT stopped sending any inter-domain routing traffic; this alarm is not as a result of a lost connection. In total, the RDTD tool detected 8 inter-domain routing disruptions during the events, as shown in Figure 4. RDTD detected 8 disruptions during the day of the TMnet event with a time delay ranging between 1 second and 196 seconds. The first two alarms represent an early detection of the TMnet event, before AS10102 was sending a high volume of Internet routing updates.

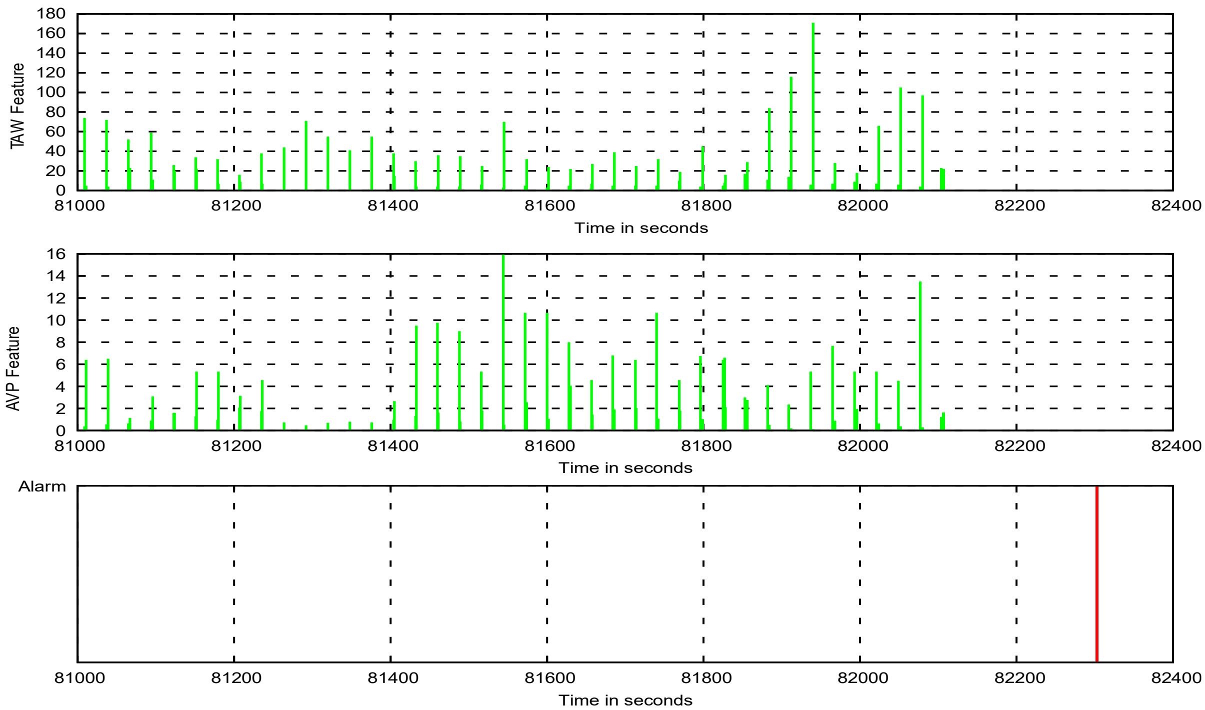

Figure 3. RDTD raised an alarm when the monitored AS stopped sending inter-domain routing traffic

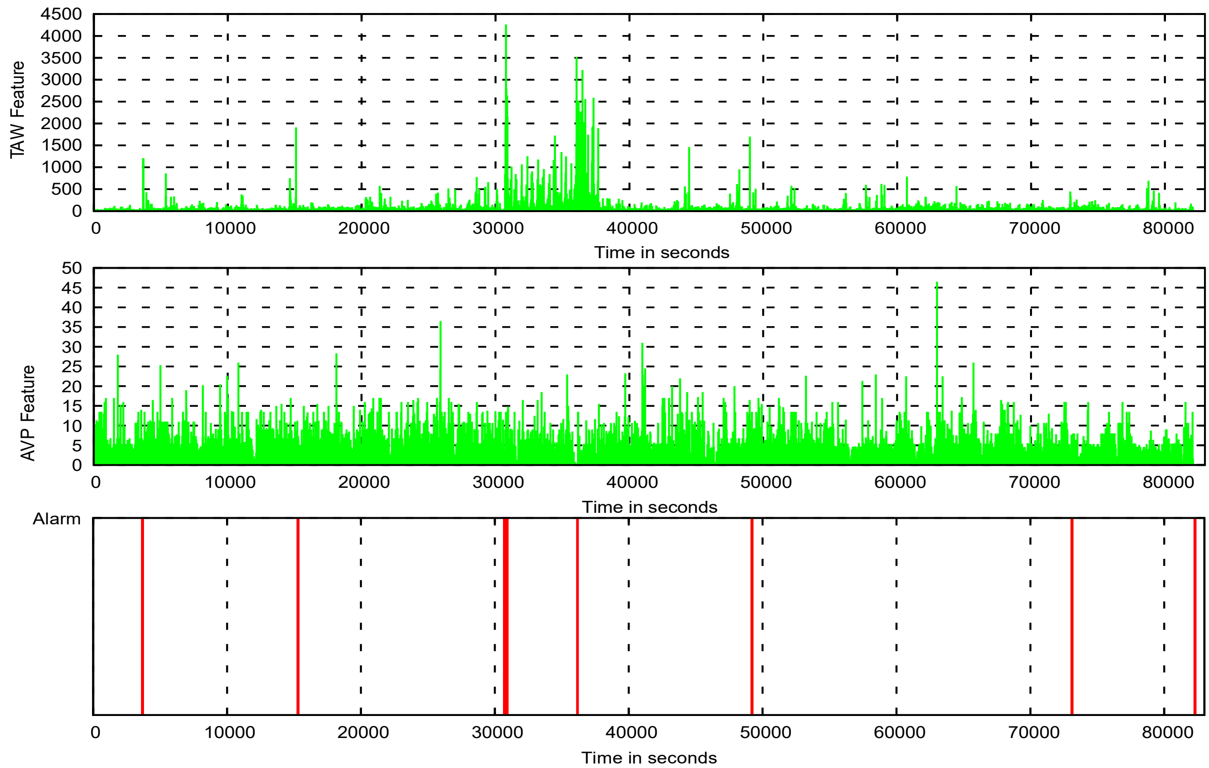

Figure 4. Detected inter-domain routing disruptions using RDTD

Table 3 shows a comparison of techniques described in three papers (Ortiz de Urbina Cazenave, Köşlük & Ganiz, 2011; Deshpande *et al.*, 2009; Haeberlen *et al.*, 2009) as well as our approach used in the RDTD tool. In Deshpande *et al.* (2009), the detection mechanism is based on an adaptive sequential segmentation which uses GLRT to detect the boundary of abnormal behaviours. This mechanism requires 100 minutes of Internet routing history updates and can detect anomalies within an hour. NetReview is a prototype that detects Internet routing disruptions at the AS level (Haeberlen *et al.*, 2009). This prototype requires one year of Internet routing history data to detect BGP disruptions. The framework in Ortiz de Urbina Cazenave, Köşlük & Ganiz (2011) uses machine learning algorithms to detect Internet routing disruptions. It requires data of past events to detect similar types of events. This framework also takes around an hour to detect the disruptions. In contrast, RDTD requires only 20 minutes of BGP history updates and can detect Internet routing disruptions within 200 seconds.

Table 3. Comparison among BGP disruption techniques

Technique	**Time Detection**	**History of Internet routing traffic**
Statistical Analysis (Deshpande *et al.*, 2009)	Around 1 hour	100 minutes
History of BGP Data (Haeberlen *et al.*, 2009)	Near real-time	1 year
Machine Learning (Ortiz de Urbina Cazenave, Köşlük & Ganiz, 2011)	Around 1 hour	720 minutes per training
RDTD	1-200 seconds	20 minutes

6. Conclusion

Inter-domain routing disruptions could produce a local impact on the business relationship between individual ISPs or even a global impact on Internet routing stability. Detecting Internet inter-domain routing disruptions in real-time helps ISP operators to mitigate the impact of disruptions. In this paper, we introduced RDTD, a tool to detect inter-domain routing disruptions in near real-time. RDTD uses an advanced non-linear statistical analysis technique based on the concepts of phase plane trajectory. RDTD has shown its ability to rapidly detect inter-domain routing disruptions without requiring a long history of data. The evaluation of RDTD has been made using a controlled testbed and injecting inter-domain routing traffic related to one of the most well-known Internet route leak events. Our future work will involve connecting RDTD with a real AS.

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Ultra-fast Broadband

The New Zealand Experience

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Abstract: This paper outlines the key learnings from the first decade of the Ultra-fast Broadband (UFB) and its associated Rural Broadband initiatives (RBI) in New Zealand. The UFB initiative provides the opportunity for 87% of New Zealand premises to have access to broadband using Fibre to the Premises (FTTP) technology. The remaining 13% of premises have access to enhanced wireless broadband. These initiatives are due for completion by year end 2023 and are showing promising results as at the end of 2019.

The success of these initiatives has not been achieved without a lot of challenges along the journey. However, as it is shown in the paper, the alignment of policy around broadband development across government and the establishment of a set of policy objectives and principles at the outset has enabled the initiatives to stay on track over time, relative to the original intentions. The establishment of these policy principles and the strict adherence to these principles throughout the execution of the initiatives has been the most significant learning from this substantial programme of telecommunications development in New Zealand.

Keywords: Ultra-fast Broadband, FTTP, Rural Broadband Initiative, NZ public policy

Introduction

At the 2008 elections in New Zealand, the leader of the National Party (Key, 2008) promised to improve the broadband services available to all New Zealanders through the introduction of a government-led Ultra-fast Broadband (UFB) initiative. The initiative was launched in late 2009, through a government-owned company called Crown Fibre Holdings[i] (CFH, www.crownfibre.govt.nz). The initial UFB deployment to 75% of New Zealand urban premises was to be completed by 31 December 2019, with a government funding contribution of NZD 1.5B. Looking back from early 2020, the initiative established in 2009 has achieved its

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goals and has been subsequently expanded to encompass the provision of improved broadband services to over 99% of New Zealand premises by YE2023.

The establishment of the Ultra-fast Broadband (UFB) initiative in New Zealand is discussed in a 2009 paper published in the *Telecommunications Journal of Australia* (Milner, 2009) and early progress is described in a 2013 paper published in the same *Journal* (MacMahon & Milner, 2013). These papers provide an excellent background to the initiative, describe the essential parameters under which the initiative was established, and the progress made in the first few years. This paper will build on the foundation provided in these papers and identify the results that have been achieved through to the end of 2019. In particular, the focus will be on the identification of the key learnings that have evolved through the 10 years of execution of this substantial programme of investment in broadband telecommunications infrastructure for New Zealand.

Policy Alignment

Since the mid-2000s in New Zealand, the governments of the day have been reasonably well aligned regarding their policy objectives with respect to the delivery of broadband into the New Zealand market. This alignment really becomes apparent following the Telecommunications Stocktake undertaken by a Labour government in 2006 (Cabinet Policy Committee, 2006). This stocktake led to the Operational Separation of Telecom New Zealand (Telecom, 2008) and the requirement for the Wholesale arm of the business (called Chorus) to offer broadband services on a non-discriminatory basis to both the Retail arm of Telecom New Zealand and all other Service Providers within the New Zealand market on equitable terms. In addition, there was a requirement for Chorus to rollout Very High-Speed Digital Subscriber Loop (VDSL) technology from street-side cabinets fed by fibre optic technology (referred to as Fibre to the Node (FTTN)). The FTTN was to enable enhanced broadband service for at least 80% of all premises in New Zealand by 31 December 2011. This outcome was achieved but was subsequently overtaken by the Ultra-fast Broadband initiative established by the National Party in 2009. This substantial enhancement to broadband development in New Zealand was largely seen as a positive step by the then opposition parties. It should also be noted, though, that leading up to this decision there were a variety of alternative approaches explored by various commentators (InternetNZ, 2008).

The UFB initiative was managed on behalf of the National government through a Crown-owned company called Crown Fibre Holdings (CFH), which was constituted in late 2009. This company operated under a set of Policies and Principles agreed with government (see below) and executed a commercial tender process to select Partners to deliver the UFB under a Public Private Partnership (PPP) model (MED, 2009). An analysis of this model has been undertaken more recently to determine how the approach applied to the UFB compares with other PPP models (e.g. for roading) applied in the New Zealand environment (Howell & Sadowski, 2018).

One of the key requirements for parties to become Partners was that they must not be majority owned by a Retail Service Provider (RSP) operating in the New Zealand market. Hence, for Telecom New Zealand to participate in the UFB initiative, it elected to Structurally Separate in 2011, with the resulting Wholesale Service Provider (WSP) retaining the Chorus name, and the RSP being renamed as Spark. This Structural Separation was implemented under a National government, with support from the then opposition Labour party.

The UFB initiative was successfully implemented over the next decade, notwithstanding several substantial challenges (identified below). In late 2017, a Labour-led Coalition party became the government of New Zealand following a National Election. Due to the policy alignment on broadband matters, the UFB rollout continued unabated through this political transition. In fact, the extensions to the UFB and the related Rural Broadband (RBI) and Mobile Blackspot Fund (MBSF) initiatives, commenced under the National government in 2016, were encouraged and enhanced during 2018 and 2019 under the Labour-led Coalition. It was also this government that celebrated the completion of the original UFB initiative on 20 November 2019 with a Parliamentary function.

UFB Policy Principles

The key policy principles behind the New Zealand government investment in the UFB initiative were as follows:

- The government would only invest in wholesale-only, open-access, common infrastructure, which under the UFB is best described as common fibre access infrastructure[ii] (CFAI) – this is the investment component which was considered to be highest risk for commercial entities (see UFB Economics below);
- The CFAI within any designated geographic area (defined as a Candidate Area (CA)) would be delivered by a single WSP on a monopoly basis and the designated WSP must pass all premises (public, business and residential) within the designated area;
- The CFAI delivered by a given WSP must be made available on an equitable basis to any RSP who wishes to deliver a fibre-based broadband service to any premises or special entity[iii] passed by the common infrastructure;
- Any RSP participating in the UFB must not have a majority ownership in any WSP, in order to avoid any discriminatory behaviour in the market;

- Any existing access infrastructure within a Candidate Area, whether copper, fibre or wireless, could continue to operate in a manner like that which existed prior to the initiative being implemented (i.e. existing vertically integrated access service providers could compete with the WSP within the Candidate Area for the provision of broadband service to customers within that Candidate Area);
- The CFAI would be terminated at designated Points of Interconnect (POIs) associated with each geographic area covered by any WSP, typically resulting in two POIs per CA, to ensure diversity for robustness;
- The government would fund the WSPs for each premises passed up to a Cost per Premises Passed (CPPP) cap, which was agreed by competitive tender for each CA;
- The government funding was to be contributed either as equity in a PPP of which CFH was the public party and the WSP the private party, or as interest-free debt where the PPP was not an applicable instrument — in either case the government investment was capped by the CPPP figure multiplied by the number of premises located within a designated CA;
- The wholesale price for a reference set of wholesale broadband products was to be established at the commencement of the initiative and committed by contract with the WSPs – these prices would remain in force until a Regulatory Review scheduled for post 2020;
- The WSPs would be committed to comply with a set of contractual obligations to ensure that service levels involving delivery of the CFAI and the connection of customers to the CFAI were achieved in a timely and quality manner, with penalties for poor performance.

All these principles were implemented and enforced through active engagement by CFH throughout the deployment tenure. A robust review of these principles and the outcomes they have driven was undertaken by Webb. Toner & Cox in 2014 (Webb, Toner & Cox, 2014). Their conclusion was that the outcome has been largely successful.

UFB1 Economics

The economics of delivering the UFB across New Zealand has been front and centre of the initiative, even before it was first officially announced in 2008. The Treasury and the Ministry of Economic Development (as it was in 2008) had undertaken extensive economic modelling to determine the most cost-effective approach for the delivery of UFB. It was recognised that implementing Fibre to the Premises (FTTP) technology universally across New Zealand would be an economic disaster. Instead, it was determined that an economic modelling exercise would determine a cap on the government investment in this technology. This would by definition mean that not all New Zealanders would receive broadband via this technology and other means would need to be identified to address the obvious gap that would remain. However, the provision of FTTP to most New Zealand premises was expected to deliver a sound benefit for the New Zealand economy (NZI, 2007).

The Treasury recognised that the commercial risk in the deployment of FTTP only applied to the deployment of the Common Fibre Access Infrastructure (CFAI), which needs to be deployed ahead of any connections to customers. This is the provision of fibre optic infrastructure from a central distribution point past each of the premises within a designated geographic area. It is the uncertainty of the uptake by customers to use the investment in CFAI that makes the commercial risk exceedingly high. As customers are connected to the CFAI, then the cost of each connection becomes much lower risk, as each connection comes with a known revenue stream. Hence the Government was adamant that any government investment in UFB should only apply to the CFAI costs and not to any connection costs.

Furthermore, it was recognised that over time the Service Providers would be able to recoup the investment in both the CFAI and the customer connections, but that the risk around the time to recoup the CFAI investment was highly uncertain and hence commercially risky. Thus, the government was keen for their investment to be more of an interest-free loan rather than a pure grant. This meant that there would be an expectation that, if the initiative was commercially successful over time, then the government would receive its investment back, less the time cost of money.

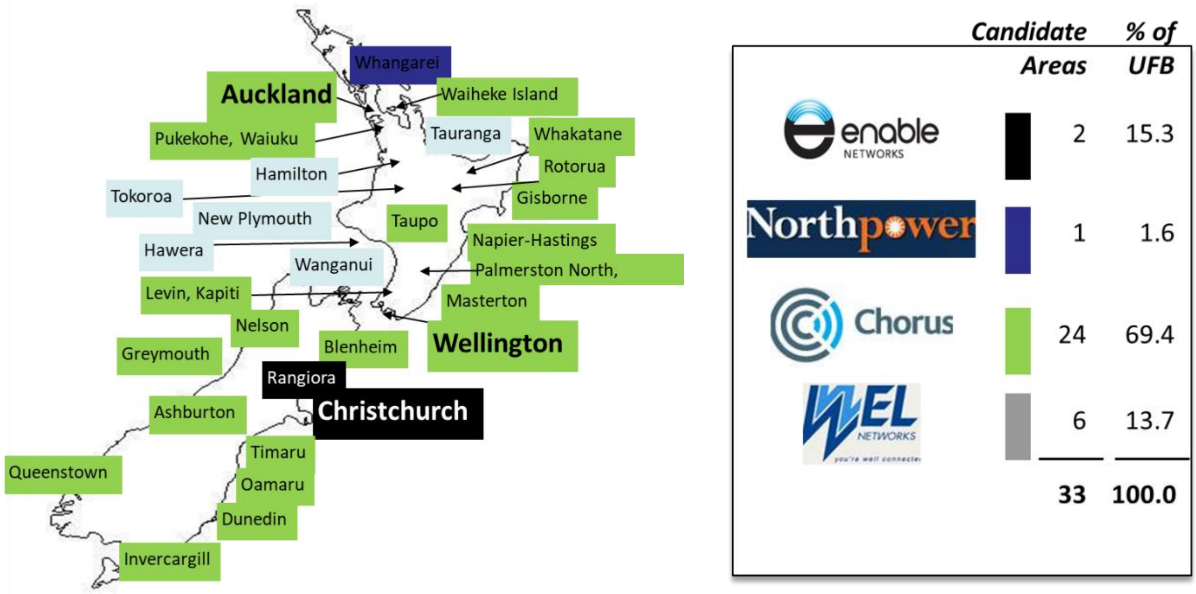

Figure 1. The result of the competitive tender process for the selection of Partners to undertake UFB deployment in 33 Candidate Areas (Source: CFH).

The modelling undertaken before the initiative was officially announced showed that around 75% of premises in New Zealand have an average frontage of around 20 m and that these premises could be passed by fibre optic technology at a reasonable cost. Furthermore, the modelling showed that, with the appropriate use of both aerial and underground fibre technologies, this proportion of premises could be passed at a cost of around NZD 1500 per passing. As 75% of premises in New Zealand represents around 1 million premises, then the initiative was dimensioned at NZD 1.5B of government contribution. The Cost per Premises Passed (CPPP) cap was set at a nominal NZD 1500, with the actual figure to be determined through the tender process related to the designated Candidate Areas which make up the 75% of coverage.

In order to achieve the parameters identified above, the 75% of premises needed to be all within urban boundaries. Through further geographic modelling, this defined a total of 33 urban areas which enabled the 20 m average frontage to be achieved. These 33 urban areas were defined to be the Candidate Areas (CAs) for the initiative. CFH then managed a competitive tender process for the allocation of these CAs to WSP partners. The tender was aimed at getting the partner for each CA that would deliver the lowest CPPP for a given CA. In practice, most bidding entities combined several CAs into bundles and tendered for the groups of CAs. The result of this process is shown in Figure 1, wherein 4 entities won the opportunity to partner with CFH to deploy FTTP across the 33 Candidate Areas. The resulting average CPPP across all CAs was less than NZD 1500 and the maximum for any single CA was less than NZD 1600, so the initiative was deemed to be economically viable.

Priority Premises

The government recognised that the economic benefit to New Zealand would most likely be derived from increased business activity and reduced costs of doing business in the early phases of the rollout. Hence the concept of priority premises was defined. Priority premises are essentially all premises that are not residential, and includes businesses, public facilities, and government buildings, such as schools. The priority was reflected in the contracted requirement for more than 95% of these priority premises, located within the Candidate Areas, to be passed by 31 December 2015, as compared to 100% of all premises by 31 December 2019. This requirement did have some impact on the way in which the deployment of the fibre was undertaken within the Candidate Areas and, in fact, caused some inefficiency in the deployment. However, the requirement to pass these priority premises early was largely achieved and did enable early uptake of services by small business customers and schools. The government saw this type of early uptake as incredibly positive.

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The UFB Initiative

The government funding was administered through a wholly owned government entity called Crown Fibre Holdings Ltd (CFH). This entity was structured as a company under New Zealand law and had its own board reporting directly to two designated Ministers of the Crown. These Ministers set annual expectations for the functioning of CFH and interacted with the board on matters of governance. The board of CFH provided oversight of CFH, which consisted of around 20 permanent staff throughout most of its existence. The board members together with senior company executives also provided governance oversight within each of the WSPs (Partners) who were undertaking the implementation of the UFB within selected Candidate Areas. Mostly, this involved providing governance within a Joint Venture board, which was expressly formed to govern the PPP. This approach applied to three of the partners who were not publicly listed companies (these entities were either privately owned or community trust owned businesses). In one case, namely that involving Chorus as the partner, governance was applied through joint membership of a UFB Oversight Steering Committee reporting to the Chorus board. (The execution of a formal PPP with a publicly listed company proved to be challenging from both legal and disclosure perspectives.) These governance structures were clearly set out within the contractual framework established between CFH and each WSP as part of the competitive bidding process.

The Contractual framework used between CFH and the selected partners for the UFB initiative has been particularly important in the smooth execution of the initiative. Through the competitive tender process to select partners for the build, the CFH management established several contractual obligations on all of the partnerships, including:

- Network build timing with penalties for not meeting milestones;
- Network build quality standards, with penalties for poor performance;
- Wholesale product specifications to ensure national consistency for a reference set of products (WSPs could offer additional products if desired);
- Product price caps for the national reference products;
- Provisioning service levels, with penalties for consistent poor performance;
- Fault repair service levels, with penalties for consistent poor performance;
- Network performance related to a core set of performance parameters related to the common access network assets;

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- Network availability performance requirements, to ensure sound network design and implementation practices.

All these functions are intended to migrate from the current contractual obligations into a revised regulatory regime to be implemented by the Commerce Commission post 2020. The contractual obligations remain in force until this transition formally occurs. Having this set of contractual obligations and the ability for CFH to enforce them has been a primary success factor in the implementation of the regime over the last 10 years. All the obligations have come under scrutiny at some time or other, with most issues being resolved through negotiation, although penalties have been applied from time to time, especially in the first few years of implementation.

In addition to the above, the industry was mandated to establish a Wholesale Services Agreement under the direction and approval of CFH, which defines the obligations that the Wholesale Service Providers have to their Retail Service Provider customers. This document was prepared through an industry forum under the New Zealand Telecommunications Forum (TCF) to ensure that it was "owned" by the parties to whom it applies. This set of obligations includes the following:

- The Governance of the relationship for the provision of UFB services between the Wholesale Service Providers and the Retail Service Providers;
- The obligations for each of the parties involved in any service transaction;
- The detailed specification of the products to be delivered to customers;
- The standards expected for any customer installation;
- The pricing, rebates and penalties associated with any customer installation;
- The general terms and conditions associated with any service transaction.

The initial Agreement is intended to be reviewed in 2020, to reflect the industry experience to date and to reflect any changes that may be required following the planned Regulatory Review. To date the Agreement has generally been considered to be fit for purpose, even if there have been some challenges between the parties. Most challenges have been able to be resolved within the context of the current obligations.

It should be noted that, within the above framework, all 4 partners implemented Gigabit Passive Optical Network (GPON) infrastructure for the CFAI in their respective CAs, all in compliance with the international GPON standard ITU-T Rec. G.984 (ITU-T, 2003). Initially, all partners also configured their GPON networks with a 24:1 passive split ratio, although some have reduced this ratio to 16:1 in more recent years. The maximum passive fibre run within any CA has been kept below the 20 km limit within the standard and most fibre runs are well below this limit to enable some resiliency to be incorporated in the architectures. Within this overall commonality of architecture, there is plenty of scope for the individual WSPs to optimise their fibre counts per duct, fibre counts per cabinet, number of cabinets and splitters per cabinet depending on the geographic distribution and density of premises and the deployment of aerial versus buried deployment practices. Throughout the deployment, all four partners went through one or more architectural optimisation processes to best manage both CPPP and Cost per Premises Connected (CPPC) costs (further detail below).

New Zealand Consumers Retain Choice

One of the primary principles established by the New Zealand government associated with the UFB initiative was that New Zealand consumers should always retain the opportunity to exercise their choice in the selection of broadband services from the market. Under the UFB initiative, within the defined Candidate Areas, the selected WSPs must pass all premises (public, business or residential) defined within the respective CA. This means that the UFB initiative has over-built any existing access infrastructure within the CA, unless some commercial arrangement has been made to use existing access infrastructure that meets all the UFB Contractual Obligations.

At the same time, in New Zealand, no consumer can be forced to migrate to use the UFB-based services. Any use of the UFB access infrastructure by New Zealand consumers is purely through market-based forces. All consumers retain their choice of service provider and technology. Similarly, all forms of Service Provider can offer broadband services to New Zealand consumers in competition with the UFB, if they so desire, and so long as they do not conflict with the discrimination requirements noted in the UFB Principles and as promoted under normal Commercial Law. This means that all existing copper, fibre and wireless access infrastructure owned and operated by a variety of Service Providers can continue to be offered to consumers in competition to that offered under the UFB initiative.

Given this choice retention, it has been surprising to most commentators how quickly the uptake of UFB-based broadband services has occurred (see Figure 2). In fact, early adoption results were variable, as indicated in the results of a survey under the World Internet Project banner in 2015 (Crothers *et al.*, 2015).

Initially it was thought that matching price for similar broadband capability would be critical to uptake: hence the introduction of a 30 Mbps down/10 Mbps up reference product into the market, in order to compete directly with the predominant VDSL over copper, fed from a FTTN cabinet. The wholesale price for this product was set to ensure that it could be competitive with that of the equivalent VDSL product. For the first couple of years, this strategy was successful in converting customers to the UFB-based product as the fibre was rolled out. However, even for a similar product, the fibre-based version was perceived by consumers to be preferable in terms of quality relative to any alternative technology.

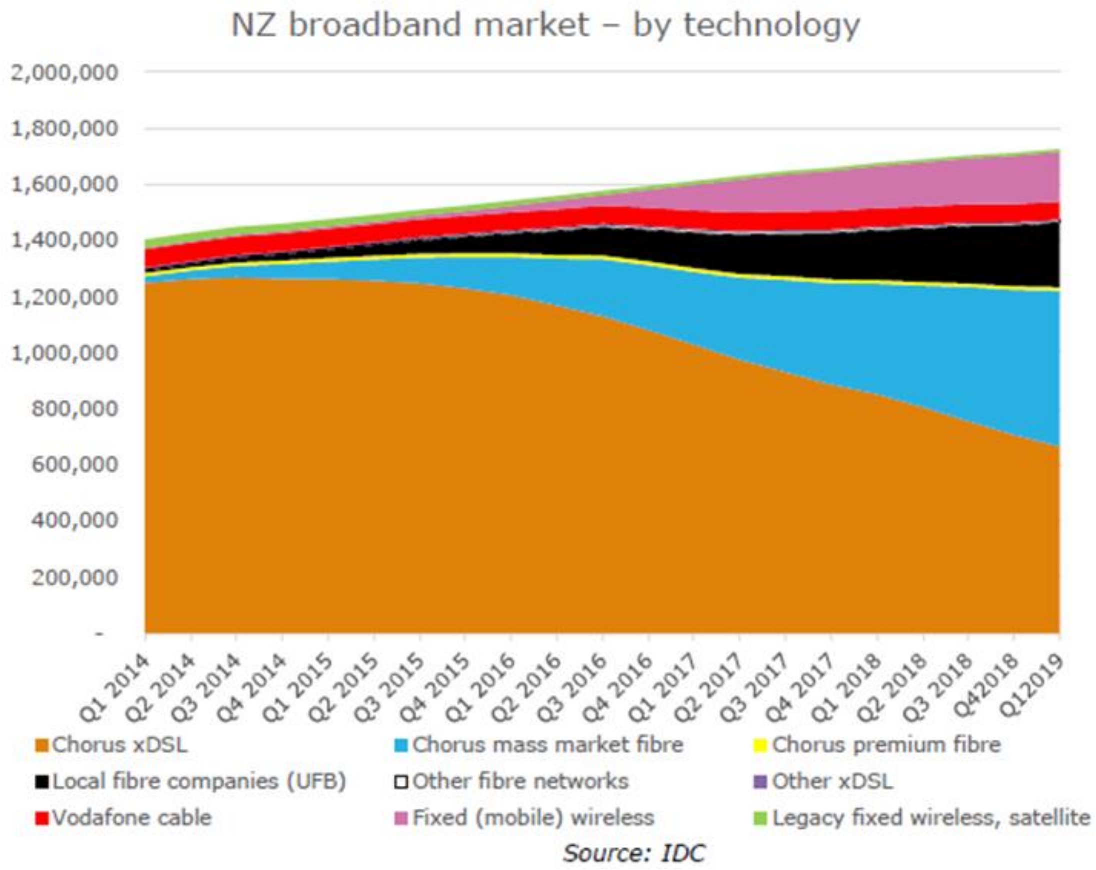

Figure 2. Broadband uptake in New Zealand by technology (Source: IDC).

It also quickly became evident that the market was willing to pay a small premium for enhanced broadband service over fibre. From 2013 to 2015, the 50 Mbps down/20 Mbps up UFB product at a couple of dollars premium became immensely popular. Then, around 2015, Chorus promoted its "Gigatown" competition, encouraging candidate towns and cities to compete to be the first town or city to be fully configured for Gigabit broadband services. Eventually, Dunedin won the title of "Gigatown" and the sale of Gigabit per second (Gbps) services was promoted widely in Dunedin. Of course, under the UFB model, all other CAs were easily upgraded to support Gbps broadband services and so this rapidly became the high-end norm for businesses and many residential customers. At the same time, this focus on higher and higher broadband speeds pulled through most residential customers to focus on 100 Mbps down/50 Mbps up as being preferred and for business customers 200 Mbps down/200 Mbps up became the preferred norm.

The evolution and uptake of broadband services under the New Zealand market driven model has been a surprise for most people in the industry (Mirza & Beltran, 2013). Given that all consumers have choice, it was originally predicted by the best market analysts that by the end of 2017 the uptake of UFB services in the Candidate Areas built out at that time would be 20% at best and that most of the products consumed would be below 100 Mbps downstream.

In reality, by the end of 2017, the actual uptake was 40% overall and some 6% of those connections were at Gbps downstream speeds. By year end 2019, the uptake across all CAs is more than 55%, with around 70% of those at 100 Mbps downstream and 10% at Gbps downstream. Chorus has announced that it will be offering 2, 4 and 8 Gbps down services in 2020 (O'Neil, 2019).

Not All Plain Sailing

The execution of the UFB initiative by the selected WSP partners did not commence smoothly. All had some challenges during the initial period of deployment and for some years thereafter.

NorthPower Fibre (NPF) was the first partner to begin fibre deployment, in the Northland region (see Figure 1). NorthPower is a very experienced electricity lines company with a very capable field force that does work all over New Zealand, as well as in Northland. They had already experimented with the deployment of fibre optic cable on the cross arms of electricity poles prior to the UFB initiative. This approach produces a very low visual impact, high speed deployment approach, with low cost per metre of fibre deployed. This approach, though, does require a highly skilled and qualified workforce and was only used by NPF in Northland. However, it did provide NPF with a rapid, low-cost launch into UFB deployment. On the other hand, it did also provide some constraints in terms of fibre architecture, which needed to be addressed during the build (in the initial deployment, the number of fibres per aerial cable run was insufficient to meet 100% uptake in demand, so higher density aerial fibre cables had to be sourced). Overall, though, NPF encountered the least challenges and completed their relatively small deployment quickly and efficiently with a CPPP well below the cap set by CFH.

Ultrafast Fibre (UFF), located largely in the Waikato and surrounding regions (see Figure 1), also started their build well using electricity lines company experience and a high proportion of aerial deployment — below the cross arms, as compared to NPF. However, they did encounter challenges with underground deployment, where poles were not available, and CPPP costs blossomed out, before being reined in by substantial changes to field practices and fibre architecture (using the optimisation parameters outlined above). The cost increases caused stress within the partner ownership structure and required careful governance through the PPP structure for a couple of years. Eventually though by 2016, the partner owners were beginning to see the potential for the business to grow and prosper and so took the step to buy out the CFH equity early. This was a major step forward in the maturity of the UFB initiative and led to the UFB extension, as described below.

Enable Networks Limited (ENL) is the partner deploying UFB to around 13% of premises passed in the greater Christchurch city area. Enable Networks had been deploying fibre in Christchurch city prior to the commencement of the UFB initiative. Involvement as a UFB partner required substantial restructuring in order to transform the business from a vertically integrated Service Provider into a wholesale only service provider. Given the prior experience with fibre deployment, Enable Networks was keen to ensure that Christchurch would be provided with a highly fibre rich, fully underground infrastructure, which would ensure future-proofing for many decades to come.

Counter to this enthusiasm, though, Christchurch experienced a series of horrendous earthquakes during 2010 and 2011, which meant that the Enable Networks rollout had to contend with and potentially leverage off the rebuild of Christchurch city. The biggest impact of the earthquakes was a shortage of skilled labour to undertake the fibre deployment. This was due to the enormous effort being made to restore all forms of horizontal infrastructure across Christchurch, so creating an extremely competitive market for the skills required.

All the above factors led to an explosion of CPPP for ENL, which pushed up debt levels for the partner (given that the government contribution was capped). By 2014, it was recognised that ENL needed to change its fibre architecture and restructure its contractual relationships with its construction partners to dramatically reduce costs. By year end 2015 these changes were producing improved results and the construction was getting back on track, with CPPP values becoming more reasonable.

Chorus was the partner for around 70% of the UFB initiative across New Zealand (see Figure 1). Chorus was formed following the structural separation of Telecom New Zealand into a Wholesale Service Provider (Chorus) and a Retail Service Provider (Spark). As a result of this separation activity, Chorus was the last of the partners to be awarded with a UFB contract by CFH. In fact, for some time during this process, the largest city in New Zealand, Auckland, could well have been awarded to a separate entity, which would have reduced Chorus's UFB share to less than 50%.

Chorus was also a publicly listed company, which required that the contractual and governance relationship between Chorus and CFH needed to be established in a different manner to that of the other partners. In this case the government contribution was structured along the lines of an interest-free loan mechanism, and the Governance oversight involved a Joint Oversight Committee reporting to the Chorus board.

Chorus had within it considerable experience in deploying fibre infrastructure as part of its legacy from Telecom New Zealand. However, what was not recognised initially was the sheer size of the build undertaking required to deliver on the Premises Passed milestones for the UFB initiative. The field force required was some ten times larger than that deployed for business as usual. Ramping up this skilled field force proved to be highly challenging for Chorus and resulted in penalty payments for missing the first-year deployment milestone. In addition, the existing contractual arrangements with field contractors did not prove to be appropriate for the UFB build and had to be renegotiated.

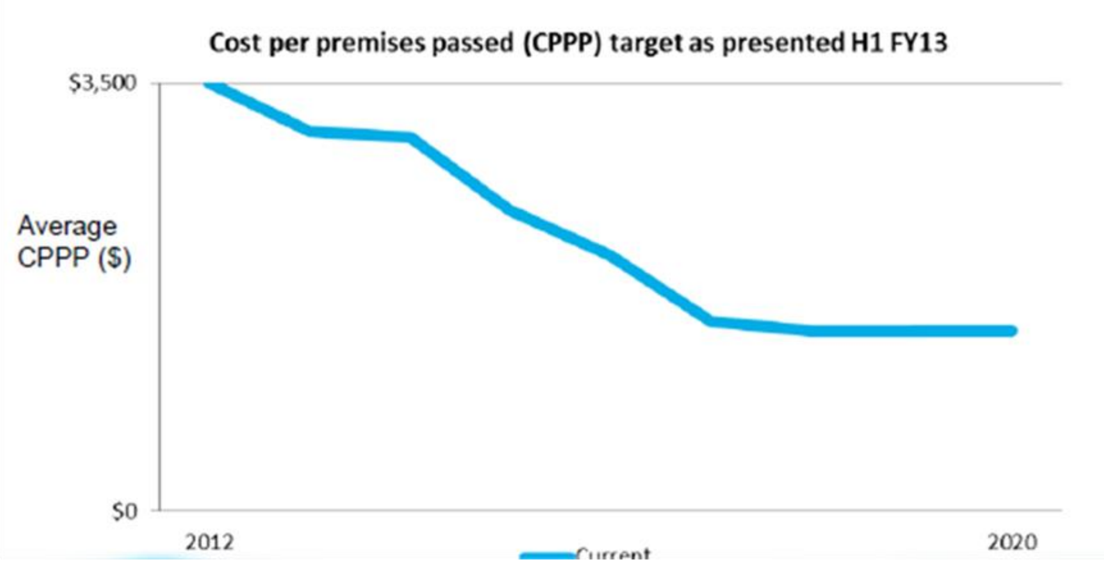

Figure 3. Chorus CPPP trend over the period from 2012 to 2020 (Source: Chorus)

This ramp-up difficulty was not helped by the initial deployment areas chosen by Chorus being high cost in their own right, due to frontages being closer to 30 metres rather than the 20 m average. In addition, these areas were not well suited to the use of aerial deployment. Hence, it was not surprising that the CPPP in 2012 was above NZD 3500. As shown in Figure 3, it was not until around mid-2016 before the high cost for CPPP was brought under control. During this early phase of the deployment, Chorus needed to fund the difference between the actual CPPP and the CPPP cap and so, as the number of premises passed mounted, so did the Chorus debt.

This caused stress within the newly formed Chorus organisation as the Chorus debt structure had not been optimised and so could not easily absorb the additional UFB debt. CFH provided Chorus with some relief within its financial capability in order to enable Chorus to restructure its debt position. After a difficult time during 2014, Chorus took all necessary steps to both restructure its debt and reduce its CPPP. The result of the efforts on managing the CPPP are

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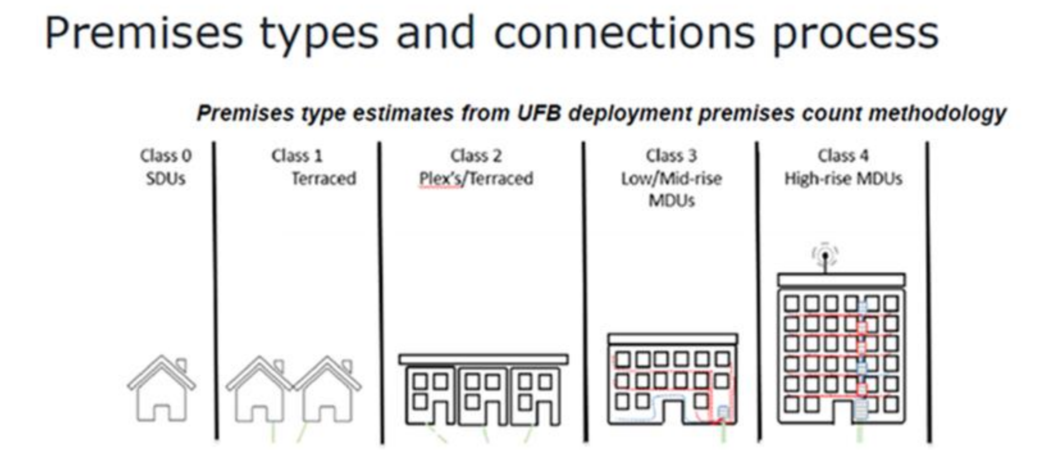
illustrated in Figure 3. Averaged across their CAs, Chorus is now achieving a CPPP roughly in alignment with that originally estimated in the economic modelling.

All four partners experienced significant challenges with Health and Safety throughout their build programmes. The magnitude of the build programme, with both aerial and underground construction in progress across hundreds of locations simultaneously throughout New Zealand, meant that all field practices needed to be exemplary to ensure a good health and safety outcome. This situation was highlighted in 2015 when a new Health and Safety Law was introduced for all workplaces in New Zealand. This highlighted the formality and diligence required to manage health and safety for all parties involved in the UFB build, from the labourer in the trench through to the CFH board. All the partners suffered some difficulties with health and safety practice and especially the reporting of their performance following the introduction of the new legal framework. Each of the partners had different challenges to overcome, from workers failing drug tests through to intense focus on safety in aerial practice.

As the challenges to the common fibre access infrastructure build were being overcome by each of the partners in their own way and through sharing of best practice, it soon became evident that the connection of customers to the common infrastructure was becoming the next big challenge. It should be noted that sharing of best practice was enabled by the UFB policy structure, in which each WSP is a monopoly provider within its CAs, so removing competition as a factor, and the prices for reference wholesale products was established by contract, so that little market collusion was possible.



Premises	649,000	123,000	10,000	4,000	1,000	787,000*
End user connections	649,000	267,000	43,000	34,000	57,000	1,050,000

Figure 4. Premises types and estimates of volumes for each type within the Chorus CAs (Source: Chorus).

The provision of service to single dwelling units (SDUs) (see Figure 4) was relatively straightforward, although each partner had to work very hard on the optimisation of field practice to ensure the lowest cost connection to a quality standard that reflected consumer expectations and contractual obligations. In this case, the cost pressure was applied by the RSPs as they had an essentially fixed wholesale price for the CPPP component and their ability to compete in the retail market depended on the additional CPPC component. Unfortunately, the values for CPPC varied greatly by type of premises being connected (see Figure 4) and the efficiency of the contractors performing the connection work for each of the WSPs. Initially the provision of a connection to an SDU took four-man crews two 8-hour days to execute. Today, this same connection can be typically performed by a two-man crew in half a day, which represents a reduction in CPPC by a factor of 8:1. Under the current scenario, the CPPC is around NZD 1000 for a "good" SDU connection, with the average sitting at around NZD 1500. These numbers are in alignment with the pre UFB economic modelling, which had the average total cost of an FTTP-connected residential SDU customer with a 20 m frontage at NZD 2500-3000.

The provision of connections to premises with shared driveways and multiple dwelling premises proved to be particularly challenging (see Figure 4). In all cases, initially there were major delays caused by coordination between the parties, including the Wholesale Service Provider, the Retail Service Provider, the field contractor and the customer. Getting all of these parties to perform their part in the connection process in a timely and cost effective manner proved to be very challenging, especially when the numbers of connections being requested was exploding, through consumer demand being beyond any expectation. Across the country, Chorus is currently connecting customers at the average rate of one per minute, around the clock. The CPPC for these premises can also vary considerably, from being exceptionally low in some modern pre-wired multi-dwelling buildings to being considerably higher in heritage multi-dwelling buildings.

The provision of connections into shared access and multi-dwelling premises required a change in the Law to address delays due to the need for Consents from all parties affected before installation could commence. This was an essential learning to ensure delivery success.

Rural Broadband Initiative 1

With the UFB initiative underway in 2010, the New Zealand Government was concerned that the broadband needs of the remaining 25% of New Zealand premises were not being addressed. They wanted to see some progress towards addressing the broadband needs of this sector of the population. This desire led to the formation of the first Rural Broadband Initiative (Treloar, 2012), which was implemented from within the Ministry of Economic Development, through a competitive tender process. This process led to the production of contracts with Chorus and Vodafone. This initiative had several objectives as follows:

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- Extend the coverage of Fibre to the Node so that an additional 40,000 premises could access this technology;
- Upgrade the FTTN technology serving some 110,000 homes and businesses to deliver improved broadband performance – up to 40 Mbps down and 10 Mbps up;
- Connect over 1000 schools in rural New Zealand with Fibre to the Premises technology;
- Deliver FTTP to 39 rural hospitals and 183 rural libraries;
- Provide fibre access to more than 150 new Vodafone rural cell sites;
- Build over 150 new Vodafone rural cell sites and upgrade a further 330 Vodafone rural cell sites for 4G capability, so delivering up to 40 Mbps downstream to a potential of around 290,000 rural premises.

Figure 5 illustrates these outcomes.

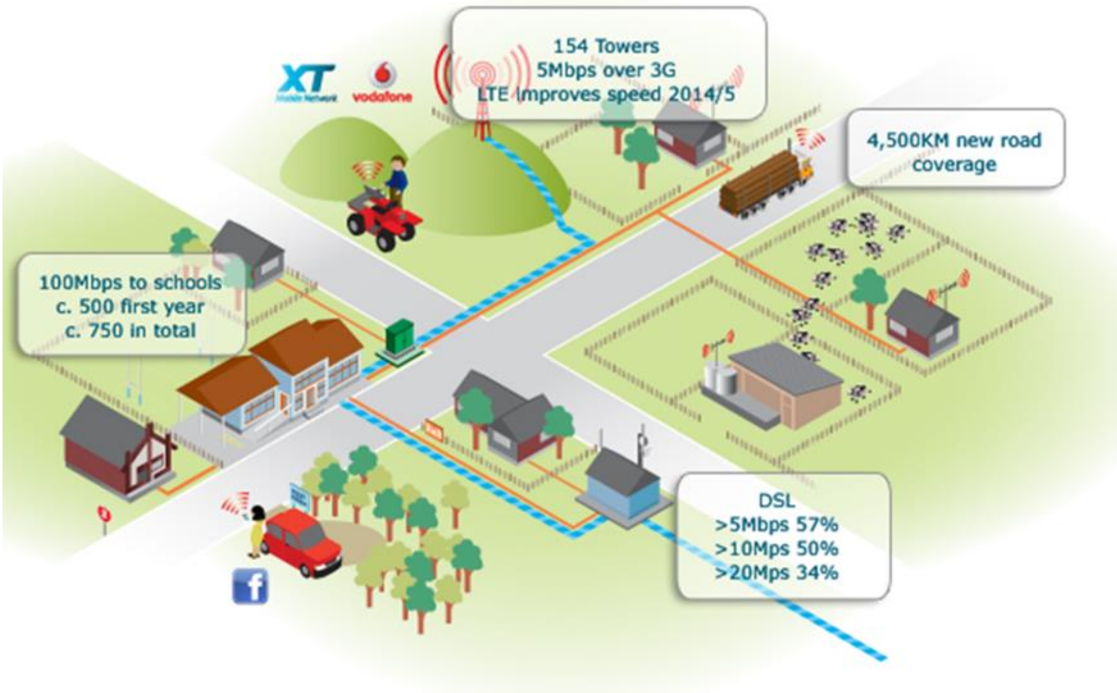

Figure 5. Rural Broadband Initiative 1 outcomes (Source: Chorus).

Although this initiative did achieve many of its objectives, it was found by 2015 to be very costly on a per-user basis and did not achieve the full uptake of broadband service as was expected.

UFB Extension

When it was found in 2016 that the government equity in some of the partnerships was to be returned to the crown early — most notably from UFF — CFH was tasked with determining whether this money could be re-invested to economically increase the fibre coverage. By 2016 it was also clear that all of the partners were getting control of their deployment costs (see Section on "Not All Plain Sailing" above), so that within the defined CAs a CPPP of less than NZD 1500 was being consistently achieved on average. It was also clear by this time that uptake of the UFB was well above initial predictions, making the entire initiative more attractive commercially. All these factors led to the proposition that, with a modest relaxation of the government contribution cap, it was likely that many more towns across New Zealand could be enabled with UFB.

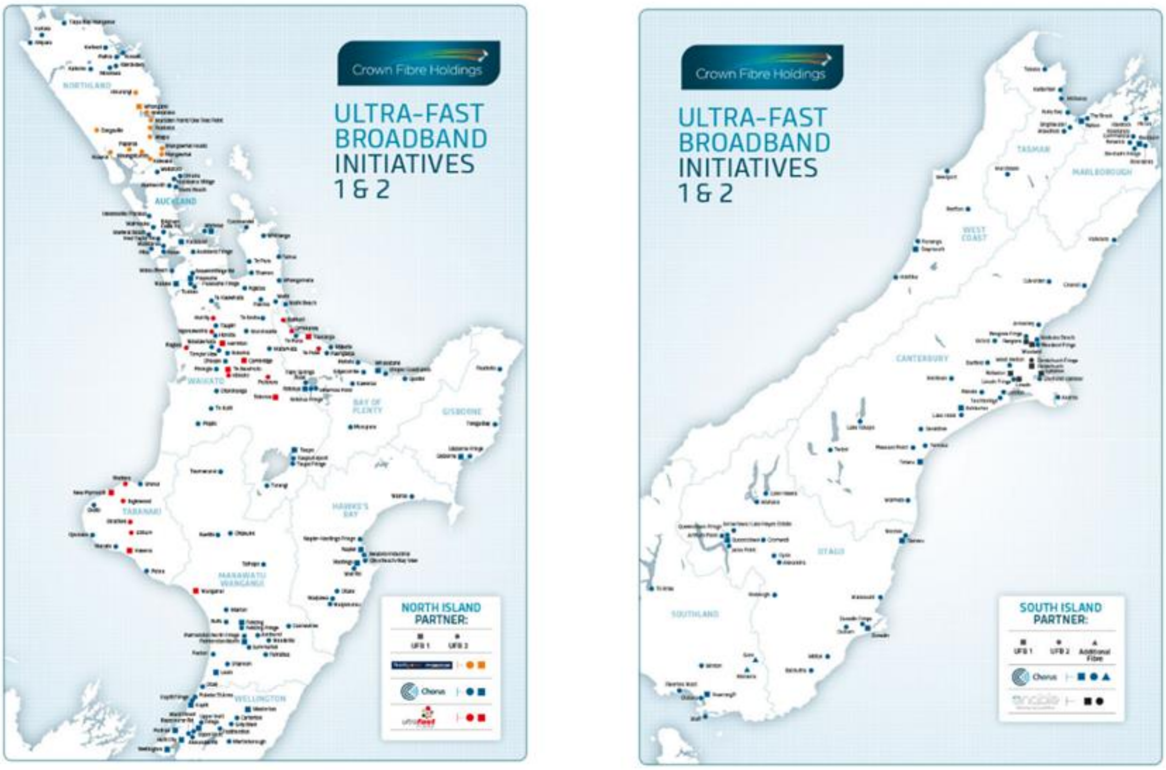

Figure 6. UFB coverage after the extension deployment is completed before YE2022 (Source: CFH).

A new round of competitive tenders was completed, and it was found that some 370 additional towns could be covered with a CPPP cap of NZD 2000 on average. These contracts were established and the UFB rollout was extended to cover more than 400 towns and cities, resulting in an increase in UFB coverage from 75% to 87% of all New Zealand premises (see Figure 6). The funding for this additional coverage was largely paid for by recycling the UFB1 funding, plus a modest additional contribution from the government.

It should be noted that the threshold cap of NZD 2000 for the CPPP was established as a cross-over point for the equivalent provision of service by alternative wireless technologies (allowing for the connection component to be included as well). Hence, beyond the 87% of coverage, it was considered to be more economic to invest in wireless technology to deliver a similar, but more constrained, broadband service to premises in these more remote areas.

Stage 2 Rural Broadband and Mobile Blackspot Initiatives

Having determined conclusively that it would not be economic to serve all New Zealand premises with UFB, the government was keen to ensure that the remaining nearly 13% of premises could be provided with broadband service with 50 Mbps downstream or better. This became the foundation for the second stage Rural Broadband Initiative (RBI2).

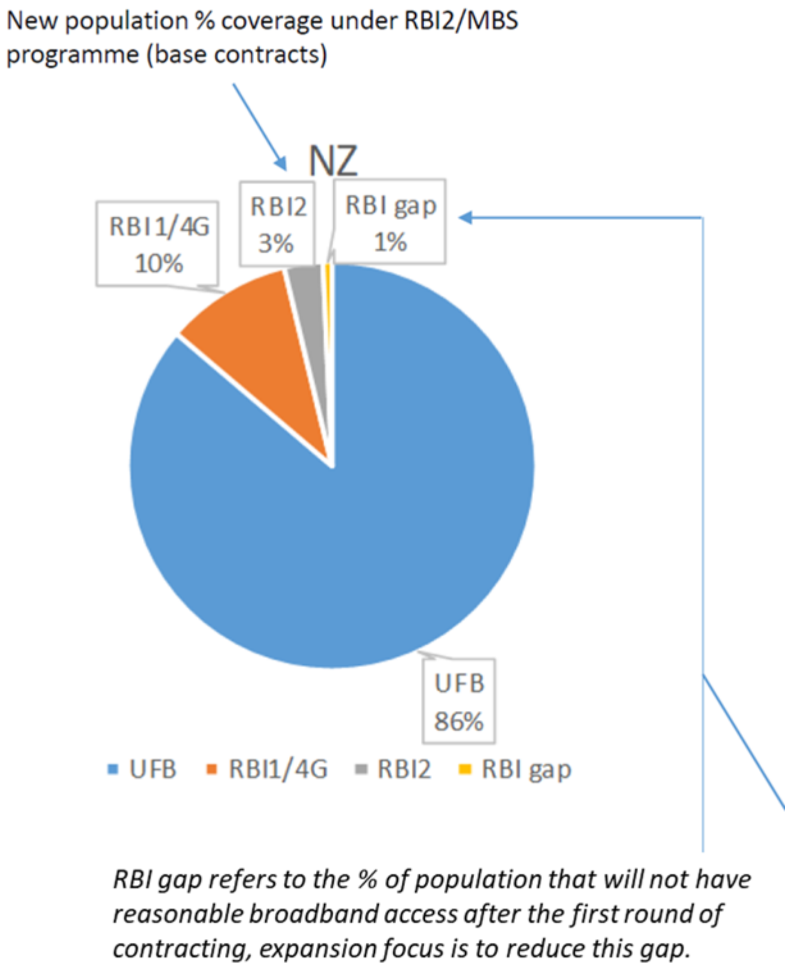

Figure 7. RBI1, RBI2 and MBS filling in the gap in broadband coverage (Source: CFH)

Unlike the UFB initiatives, the RBI2 was funded through a grant process managed by CFH, with funding being derived from the Telecommunication Development Levy. This levy has annual contributions from all telecommunication service providers based on market share and is essentially a Universal Service Fund designed to address issues of Common Good and Equity, such as to address user disabilities and remote access. The levy raises some NZD 50m per annum.

At the same time, the government also wanted to address another coverage issue: that of mobile cellular coverage along main roads throughout New Zealand. Most main roads and highways are provided with commercial cellular coverage from one or more of the three cellular service providers operating in New Zealand. However, many roads of significance, particularly for tourists, have blackspots in coverage which are not economical to fill in on a commercial basis. The Mobile Blackspot Fund initiative is intended to fill in the coverage on most of these roads of significance and include some 168 tourist sites. Again, this initiative was passed to CFH to manage the execution.

The execution of these two initiatives simultaneously by the same oversight entity enabled synergies to be achieved, as much of the enhanced mobile coverage of the main roads also delivered wireless coverage to many rural premises. This enabled around 80% of the 13% of rural premises required to be provided with RBI service to be served by fixed cellular broadband service (see Figure 7).

The remaining RBI coverage (around 3% of the total premises) is also being delivered using broadband wireless, but of a different kind and by different players. Over the last couple of decades, the provision of broadband services in selected rural areas has been provided by Wireless Internet Service Providers (WISPs). These are typically entrepreneurial small businesses who install wireless infrastructure on hilltops around New Zealand. They use typically unlicensed spectrum to deliver 10-20 Mbps down/5-10 Mbps up broadband Internet services to customer premises scattered across the landscape within line of sight of the selected hilltops. As at 2015, there were around 50 such entities operating around New Zealand.

In order to leverage this existing capability, the RBI2 introduced a competitive grant process which enabled these WISPs to upgrade both their services and their coverage to address the broadband needs of most of the remaining rural customers not covered by any other means.

Around 20 WISPs were able to provide proposals to address the bulk of the remaining rural customer premises and deliver the 50 Mbps downstream service required under the RBI. Contracts were awarded over the 2016/17 years and the upgrade is to be completed by Year End 2023, although some WISPs have already completed their build programmes by the end of 2019.

During 2019, a further extension to the programme was made with the addition of Maori Marae (traditional meeting houses) to the coverage requirement. This coverage extension involves some 810 Marae and is funded through the Regional Development Fund and is scheduled to be completed by YE2023.

Overall Broadband Outcomes for New Zealand

By year end 2019, the UFB1 initiative was completed and the government celebrated this success in Parliament on 20 November 2019. The UFB Extension, RBI2 and MBSF initiatives were also progressing well. Some 120 towns and cities around New Zealand have the UFB CFAI completed so that customers can access UFB services. This corresponds to the completion of fibre rollout to around 80% of New Zealand premises, with the remaining 7% expected before year end 2022. When the UFB program is complete, it is expected that New Zealand will sit within the top five countries in the OECD for fibre-based broadband availability.

Furthermore, some 84,000 rural premises, 810 Marae, 168 tourist sites and 1400 km of roads of significance will have much improved broadband coverage by year end 2023. This will mean that approximately 99.8% of New Zealand premises will be assured of access to broadband capability of better than 50 Mbps downstream.

Putting this outcome into financial terms, as at the end of 2019, nearly NZD 2.1B of funding has been committed through CFH. This consists of NZD 1.55B of UFB appropriations directly from government. In addition, NZD 180M has been committed from the Telecommunications Development Levy, which is effectively industry-based funding. The above has been supplemented by NZD 337M of internal CFH funding derived from the recycling of the original government appropriation. Most recently, there has been a further contribution from the Regional Development Fund to support the provision of service to Marae. Of this approximate NZD 2.1B of funding from various sources, there is an expectation that over NZD 1B will be returned to the Crown by 2036, when a couple of the interest-free loans mature. Hence the set of initiatives to greatly enhance the broadband capability for all New Zealanders is forecast to cost the Crown in the order of NZD 1B over 36 years.

The most important outcome of all, though, is the numbers of customers using the capability. Of the approximate 80% of premises passed by the UFB to date, some 55% have been connected to the UFB and are receiving the benefits of excellent broadband service (see below for speeds). This is even though there is no compulsion for adoption.

This represents close to 850,000 businesses and residences using fibre-based broadband. The rate of uptake is roughly twice that which was forecast at the beginning of the initiative by the experts, such as IDC. It should also be noted that the 55% uptake is an average over the entire build. Many towns and suburbs within cities are achieving 65-70% uptake, and it is expected that more than 80% uptake will be likely within a couple more years.

The product mix has also been rapidly changing as the initiative has progressed. This is illustrated in Figure 8. In early 2016 the predominant product consumed was less than 100 Mbps downstream, with Gbps downstream services just starting to emerge. Eighteen months later, the 100 Mbps and above downstream products were sitting at nearly 70% of the sales volume.

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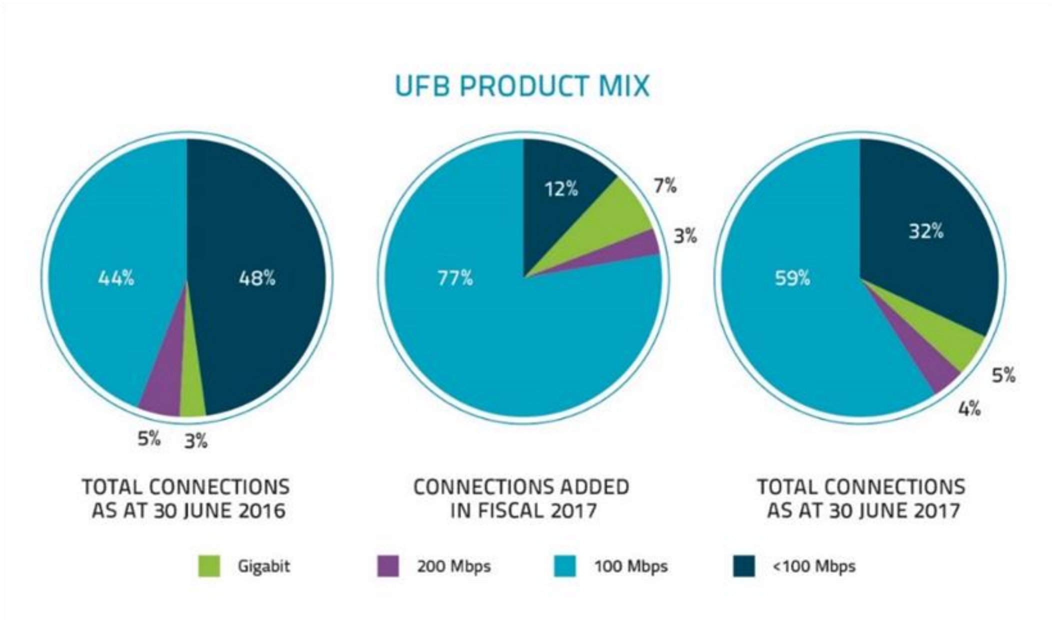

Figure 8. UFB product mix change during 2016 and 2017 (Source CFH).

By mid-2019 (see Figure 9) the largest selling product is 100 Mbps down with 20 or 50 Mbps up for residential customers, while the 200 Mbps symmetrical product is popular with business customers. In the same timeframe, Gbps downstream services were 9% of the sales volume and, by the end of 2019, this volume had increased to over 10%. By mid-2019, the average speed of UFB service was 179 Mbps down and consumers are continuing to migrate to higher speed plans.

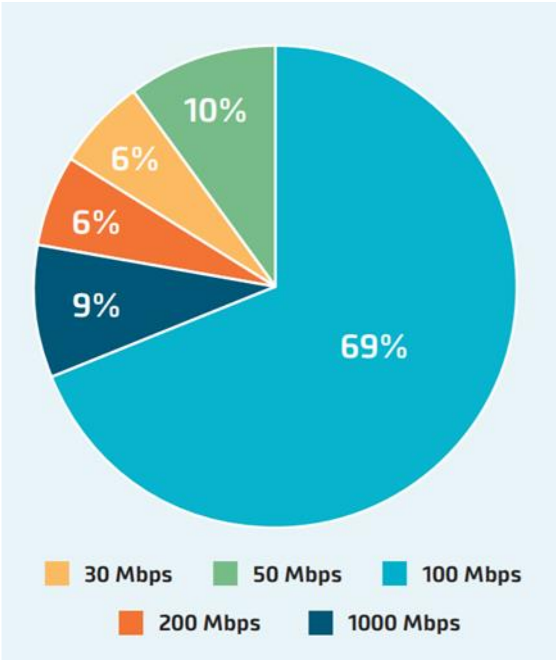

Figure 9. UFB product distribution as at mid-2019.

Currently, one of the largest Retail Service Providers offers the 50 Mbps down/20 Mbps up product as standard, with unlimited data volume and bundled Netflix and other content for

NZD 95 per month. For NZD 3 extra per month, consumers can purchase the same package with 100 Mbps down and 50 Mbps up, which is proving to be popular.

The Gbps services have also been rapidly reducing in price and are now very comparable with the 100 Mbps services. Depending on the packages bundled with the broadband, the Gbps services can now be purchased for below NZD 100 per month and are widely available below NZD 120 per month.

It should also be noted that the UFB performance is very much more consistent than that experienced in many countries. Often the headline speeds are only experienced by end users for short periods of time when usage by the surrounding population is low. When the network is heavily loaded, the actual speed experienced by end users can reduce by as much as 50% relative to the headline value. In comparison, all NZ providers are achieving results within 5% of the 100 Mbps downstream target for better than 95% of the time, where this is the headline speed purchased by the customer. This is a significant positive outcome for providers and for NZ business and society.

As the UFB uptake grows, so too has the uptake of the rural broadband products over wireless. In many rural locations fixed wireless products over cellular are being offered at comparable prices to that for the UFB and with downstream speeds approaching 100 Mbps and upstream speeds exceeding 20 Mbps. Data volumes for fixed wireless users are restricted to around 200-300 GB per month. If these limits are exceeded consistently, at least one RSP retains the right to convert the customer to UFB, if available at the location.

Similarly, there has been substantial uptake of wireless broadband over WISP infrastructure. Again, prices are comparable for 50 Mbps downstream products with data volumes typically capped at around 200 GB per month.

The use cases for the adoption of UFB are also continually evolving. There is no doubt that streaming media to all types of devices, but especially large screen, high definition TVs, is a major driver for residential uptake. However, the expanded learning experience for children in association with their schools is becoming a critical use case, especially for children in lower socio-economic groups (Grimes & Townsend, 2017). Here there are several innovative packages emerging to assist children to connect via UFB and RBI to their schools to access educational content at very reasonable prices (NZD 10 per month).

However, the biggest area for innovation is in association with small and medium businesses (Murray *et al.*, 2016). Many businesses are finding that they can successfully operate their business from any location in New Zealand. This has meant that many small businesses are moving out of the high-cost big cities and are setting up in smaller towns and even rural locations, where the cost of doing business is lower and the lifestyle is greatly enhanced. This opportunity is even encouraging New Zealanders from overseas to relocate back to New Zealand.

Conclusions

The Ultrafast Broadband initiative was formally launched by the New Zealand National Government in late 2009, through a special-purpose government entity called CFH. The UFB in New Zealand was driven by a strict set of policy objectives which promoted commercial principles, including competition, explicit economic outcomes and incentive mechanisms. Key to the outcomes being achieved was the use of a Public Private Partnership (PPP) mechanism, with the government funding into the PPP being capped in the form of what effectively looks like an interest-free loan. Within this structure there were strong incentives for the partnership to perform in terms of delivery in a cost-effective, quality and timely manner. At the same time, New Zealand consumers retained their right to choose the Service Provider and technology which best meet their needs. During the implementation period, political change has occurred but, due to an established policy alignment around broadband, these changes have had no negative impact. These are all essential learnings from the successful experience of UFB deployment within the New Zealand market.

Even with a strong framework of policy objectives, alignment and strong commercial principles, the challenges encountered during execution were massive and required considerable effort and adaptation to overcome. However, continued tight focus on the core principles did eventually enable the required outcomes to be achieved, on time and on budget. By 20 November 2019, the completion of the initial passing of 75% of urban premises by the UFB was celebrated though a function held at Parliament. Furthermore, during execution, the initiative was expanded to deliver UFB to 87% of premises across New Zealand by year end 2022 and, through associated Rural Broadband Initiatives, the provision of greatly enhanced broadband to 99.8% of New Zealand premises will be achieved by year end 2023.

The greatest testament to the success of the initiative, though, is the uptake by broadband users on the UFB and associated rural broadband infrastructures. As at the end of 2019 the uptake in those areas where the UFB build has been completed was over 55%. Some towns and suburbs within cities have uptake in 65-70% range. This is being achieved in an environment where all other technology choices remain in the market and there is no compulsion for the adoption of the UFB products. Furthermore, this uptake is being driven through the development of innovative applications and associated work practices that are beginning to impact positively on all parts of NZ business and society.

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Endnotes

[i] In 2017 Crown Fibre Holdings was restructured with an enhanced mandate and renamed Crown Infrastructure Partners (CIP). For ease of continuity for the reader, the company will be referred to as Crown Fibre Holdings consistently throughout this paper.

[ii] The CFAI includes the fibre access infrastructure from a local point of interconnection to the street boundary of each of the premises within a designated geographic area.

[iii] Special entities include roadside infrastructure such as electronic signboards, mobile radio cell sites and any other facility not directly attributable to the specific premises.

The 1-Millisecond Challenge – Tactile Internet: From Concept to Standardization

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Abstract: In recent years, Tactile Internet (TI) has become a familiar concept to humankind. It is expected to have the potential to create many new opportunities and applications that reshape our life and economy. However, the biggest challenge for recognizing the TI – the "1-millisecond challenge" remains unchanged, and it requires additional research efforts. In this paper, we will dissect what has been done and what needs to be done for the "TI ecosystem". We will also investigate the TI concept from the perspective of the "network latency evolution", as well as analyzing the architecture and the emerging technologies, which are needed to meet the strict requirements of the TI.

Keywords: Tactile Internet, Internet of Skills, Haptic Communication, 1-millisecond challenge, latency.

1. Introduction

Today's world has witnessed the emergence of various Internet generations. As we all know, the first generation is the fixed Internet, which created extensive connections between computers, allowing users to interact with each other regardless of geographical location. The second generation is the mobile Internet, adding flexibility and convenience to users by combining telecommunication infrastructure with the Internet (Salkintzis, 2004). Therefore, people could connect virtually anywhere, any time. As a result, the number of Internet users, as well as mobile devices, increases quickly. With the increasing number of users, it would open a new direction for the next generation of the Internet, where everything and every object can be connected to the Internet to create the Internet of Things (IoT) (Gubbi *et al.*, 2013). An

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important question to be addressed is: "What will the future Internet be after the era of IoT?" (Cao, 2017). Scientists have now begun to discuss an entirely new Internet generation – Tactile Internet (TI) (Fettweis, 2014; Dohler, 2015) or Internet with ultra-low latency for the evolution of the IoT.

In this paper, we aim to investigate the concept of the TI from a perspective of technologies and applications while highlighting some challenges in this respect. Although some researchers provided general descriptions of the TI, they only focused on some aspects of the TI. This paper reviews all the aspects of the TI: concept, requirements, architecture, technologies towards the TI, the relation with new concepts (such as Internet of Skills (IoS) and Haptic Communication (HC)), applications, and standardization. The main contributions of this paper are as follows:

- The paper investigates the TI based on the evolution of the latency in the network: NGN network – Medical network – TI network;
- The paper summarizes all different definitions of TI concept;
- All emerging technologies towards TI from the point of "1-millisecond challenge" are described.

The standardization process and contributions from various companies and alliance groups are summarized at the end of the paper to help readers get a general overview of the TI ecosystem.

1.1. The evolution of latency in network and telecommunication systems

The cornerstone of the TI concept is the evolution of latency in network and telecommunication systems under the increasingly stringent requirements of new applications and services. The latency problem has been noticed since the stage of the packet switching network Next Generation Network (NGN) (Hany, Hossain & Saha, 2010). The latency should not exceed 100 ms (ITU-T Y.1541, 2015) to ensure the quality of audio and video communications for the users in the same quality as in the Public Switched Telephone Network (PSTN). This problem has been resolved. However, in recent years, some new applications and services have emerged, especially in the medical industry. These real-time applications require much lower latency in the network (≤10 ms) than the audio transmission latency. Such networks are termed low-latency networks and need higher access speeds (Koucheryavy, Paramonov & Al-Naggar, 2013). This fact led to a change in the structure and the way of building the network.

The next step in the evolution of network latency involves the concept of tactile information. In simple words, human senses will be transmitted over the Internet. In this case, the latency of transmitting information within the network must be ≤1 ms because this time is sufficient

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for a "true sensation" since the human body response time under tactile stimulation is measured at 0.15-0.8 s (Fettweis *et al.*, 2014; Jastrebova, Vybornova & Kirichek, 2016). Then, why do the senses need to be transferred? The following example will emphasize the importance of why senses need to be transferred. For example, you want to buy a coat from an online store. If we could feel the material and, possibly, try on the coat with the assistance of virtual reality technology combined with the Internet transmitting tactile information, we could avoid dissatisfaction. This example is one of the countless examples to emphasize the benefits of the new Internet generation – TI or Internet with ultra-low latency (Citrin *et al.*, 2003; Grohmann, Spangenberg & Sprott, 2007; Dohler *et al.*, 2017; Zhang, Liu & Zhao, 2018). Table 1 below shows the requirements for latency and access speed of different network generations (Koucheryavy & Vybornova, 2016).

Table 1. The value of latency and access speed required for different types of networks

Network	Required latency	Required access speed
NGN	100 ms	in the order of tens or hundreds Mbps
Low-latency network (Medical Network)	10 ms	in the order of several hundred Gbps
Ultra-low latency network (Tactile Internet)	1 ms	in the order of Tbps

1.2. The Tactile Internet concept

According to ITU (Fettweis *et al.*, 2014), the TI is an ultra-low latency Internet, with short data transmission time, high availability, reliability, and security. It would create a significant impact on the economy and society by bringing new opportunities for the emerging technology market and providing essential services, especially in the Industrial Revolution era 4.0 (Wollschlaeger, Sauter & Jasperneite, 2017). According to IEEE P1918.1 (Aijaz *et al.*, 2018), the TI is a network or a network of networks for remotely accessing, perceiving, manipulating or controlling real and virtual objects or processes perceived in real time. The TI allows us to interact with objects in the environment at tactile latency, for example, the response speed of the senses. Nowadays, communication technologies are widely used to move content(s) from one device to another. Content can be multimedia or data. Unlike the conventional Internet, the TI allows us to transmit the tactile (touch, contact) as well as the stimulation and the control via the Internet in real time. Not only the content needs to be transported, but the tactile information is now also transmitted. The senses allow people to perceive their surroundings and decide whether or not to adapt themselves or adjust the environment accordingly. This cognitive process limits the speed of our interaction with the situation. Therefore, to interact with a technical system naturally and intuitively, the feedback of the system must be adapted to the human responding time. For this reason, the TI requires an end-to-end delay of ≤1 ms. However, with the existing network infrastructure and technologies, it is challenging to meet this requirement or "1-millisecond challenge" (Bachhuber & Steinbach, 2017). In conclusion, some of the TI features could be summarized as follows:

- Latency: less than 1 ms;
- Reliability: to perform critical tasks (for example, remote operation), network losses, equipment failure, etc. are unacceptable;
- High data transfer rate: more than 10 Gbps;
- High network density: to support the connection of more than 100 devices per 1 square metre.

The rest of this paper is organized as follows: Section 2 reviews the "1-millisecond challenge" and the importance of technical requirements. Section 3 introduces the reference architecture of the TI. Section 4 will focus on a discussion of the emerging technologies towards the TI. Section 5 considers the relationship between the TI and the Internet of Skills, as well as Haptic Communication. TI applications will be discussed in detail in Section 6. In Section 7, TI standards are presented. Finally, Section 8 provides a conclusion for this paper.

2. The "1-millisecond challenge" and Technical Requirements

There are many challenges and technical requirements in making the TI into reality, such as ultra-low latency, ultra-reliable connectivity, safety, appropriate codecs, etc. This section will investigate these challenges.

2.1. The "1-millisecond challenge"

The most critical requirement of the TI, which will shape the design of future networks, is 1 ms latency (Jiang *et al.*, 2019). It helps to experience real-time interaction with the environment (Varsha & Shashikala, 2017). Otherwise, poor coordination of the digital responses of the senses will cause misconceptions. For example, if the eyes perceive a movement, which is slightly delayed compared to what is perceived by the vestibular system while the rest of our body remains static, this delay leads to "cybersickness" (Burdea & Coiffet, 2003; LaViola, 2000). This fact is vital for machine-type communication that enables real-time automation and control of dynamic processes in industry, manufacturing, traffic management, etc. (Simsek *et al.*, 2016a).

Currently, the latency in wireless network standards has been significantly improved. For instance, in LTE technology, end-to-end latency could reach to 10-25 ms (Ericsson, 2013) and fully meet the requirements of real-time games. However, it is still far away from the 1-millisecond requirement of the TI. The leading cause of latency in the wireless environment is fading; but generally, in a network of the TI context, end-to-end latency consists of the following factors:

- The time to transmit the information from the sensor (or from the person in the case of tactile interactions) through the communication infrastructure to a control server;
- The time for the information to be processed and generate a response;
- The time to pass the response back to the original subject (e.g., human) through the network infrastructure.

If this latency exceeds the response time of the human body, the user experience is less realistic due to the considerable distance between the stimulus and the response received. Figure 1 shows the assumed latency for components in the TI network (Cakuli, 2016).

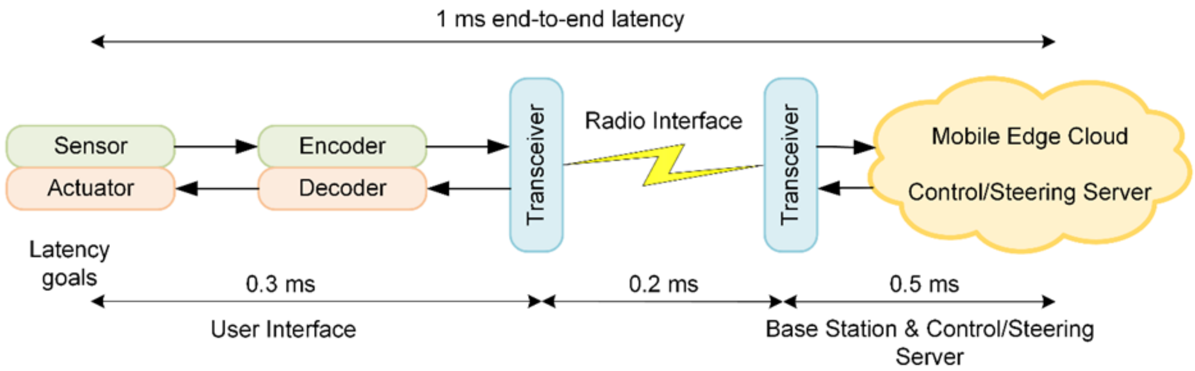

Figure 1. The assumed latency for components in the TI

Notwithstanding, the 1 ms latency requirement is an enormous challenge. The physical transmission must have tiny packets to enable one-way physical layer transmission of 100 µs. To achieve that value, the packet duration must not exceed 33 µs (Fettweis, 2014) so that the processes of encoding/detecting/decoding of the packet at the transmitter/receiver would not result in additional latencies. This fact limits the packet size to less than one-third of the target latency. The modulation used in current LTE systems is not the right choice for the TI; since the duration of one OFDM (Orthogonal Frequency Division Multiplexing) symbol alone is close to 70 µs long (Fettweis, 2014). Current systems and mobile network technologies cannot meet this requirement because their protocols demand too much overhead for connectivity management, synchronization, channel resource allocation, as well as mobility. Thus, a new wireless technology standard (5G) far beyond 4G LTE technology is needed (Li *et al.*, 2019; Durisi, Koch & Popovski, 2016).

2.2. The ultra-reliable connectivity requirement

Another essential specification of the TI is reliability or ultra-reliable connectivity (Aijaz, 2016; Bennis, Debbah & Poor, 2018). It means reliability is quantified as seven nines reliability: i.e., an outage probability of 10^{-7} (milliseconds of outage per day) (Fettweis, 2014; Yilmaz *et al.*, 2015). It is fundamental to keep the packet loss to a minimum, especially in wireless environments that are prone to errors. Again, the next 5G generation wireless technology, which is designed for ultra-reliable connectivity, will be a significant foundation, all credit to the TI that establishes connectivity.

2.3. The safety requirement

The next difficulty is to provide security as well as to improve the safety of the TI and its applications. This fact is noticeable because the uses of the TI will spread from large-scale industrial systems to daily infrastructure or services. Therefore, it could be harmful if it does not operate properly. With the stringent latency requirement, security must be embedded in the physical transmission and ideally be of low computational overhead (Simsek *et al.*, 2016a). New techniques and secure ways need to be developed to ensure that only legitimate receivers can process the information, and it requires new, reliable, and low-delay methods. Advanced trust models, security for new service delivery models, and a broad range of infrastructure are dependent on new technologies, and increased privacy concerns are expected. It can be said that security is a complex issue. It depends on many factors, which should be carefully controlled during communication over the TI (Li *et al.*, 2019; Szymanski, 2017).

2.4. The codec's requirement

Besides, tactile information also should be handled similarly to audio and video information. An essential technological aspect in this context is the acquisition, compression, transmission, and display of haptic information with minimum latency (Steinbach *et al.*, 2019). That means a need for separating the codecs for tactile applications to handle the compression of haptic information and to provide transmission of tactile data. These codecs will be the decisive factor for TI's scalability (Chaudhari *et al.*, 2015); however, it has received comparatively little attention so far.

3. Architecture

Architectural design for the TI requires compliance with many stringent requirements. The architecture needs to have some essential features:

- It can be mapped to various TI applications;
- It can support a diverse range of connectivity from local to broad areas via wireless (5G network) or hybrid networks;
- It should have a modular design, which is suitable and flexible for implementing other network technologies, which help to separate the control and data planes or to take advantage of computing resources from clouds;
- It must have the ability to integrate and interact with third-party products and services;
- It should have efficient resource management.

In addition, because the TI allows transmitting actuation and touching in real-time as well as transmitting haptic and non-haptic control via the Internet, there is a difference compared to auditory and visual senses. Touch should be sensed by imposing a motion on an environment and feeling the environment by a distortion or reaction force (Steinbach *et al.*, 2012). Therefore, the sense of touch occurs bilaterally. It means that haptic feedback needs to close a global control loop (Figure 2), while, in the case of non-haptic feedback, there is no need for the control loop.

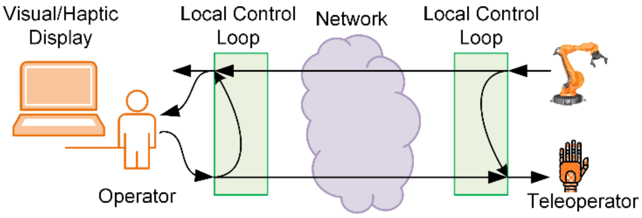

Figure 2. A closed control loop in case of haptic feedback

According to the IEEE P1918.1 standard working group (IEEE 1918.1), the reference architecture of the TI includes three domains: a controller/master domain, a network domain, and a controlled/slave domain. Figure 3 below presents the reference architecture of the TI that includes these three domains.

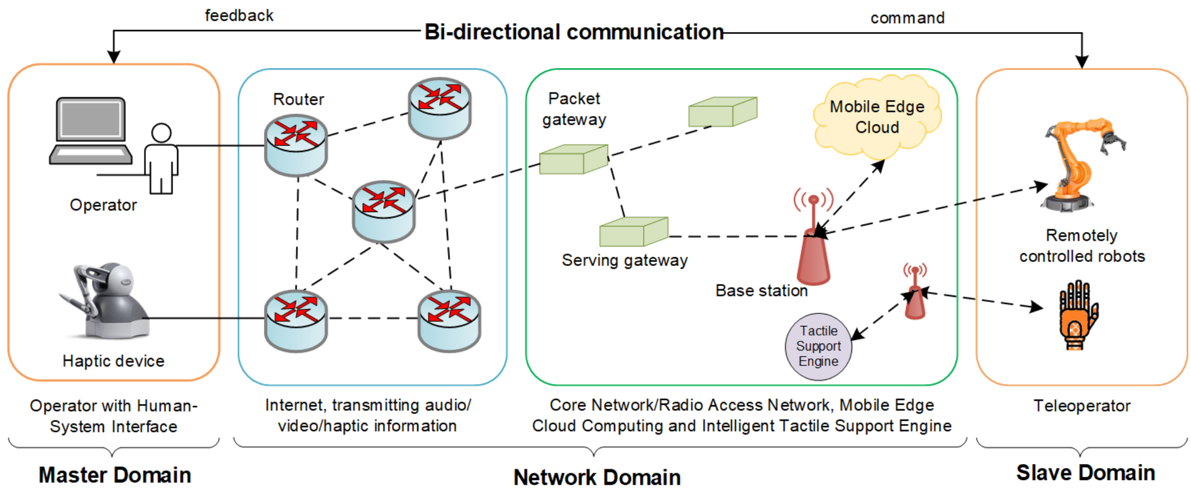

Figure 3. End-to-end reference architecture of TI (Dohler *et al.*, 2017; IEEE 1918.1)

3.1. Master Domain

In the case of remote operation and HC, the master domain includes an operator (human) with tactile Human System Interface (HSI). This system (usually a haptic device, robotic arm, etc.) will convert human input into tactile input via different coding techniques. The user can touch, manipulate, and feel objects in real and virtual environments. The master domain primarily controls the operation of the slave domain, which will be discussed later, through command signals. The master domain also supports audio and video feedback, which not only enables remote operation and non-haptic control but also enhances perception. The networked control systems provide commands to the sensor and actuator system (Aijaz, 2016).

3.2. Slave Domain

As for HC, the slave domain includes a controlled robot (teleoperator) controlled by the master domain through command signals. The teleoperator interacts with the environment and sends haptic feedback using the reverse path. Energy exchanges between the slave and master domains to create a closed control loop through feedback and command signals. The networked control systems also contain sensor and actuator systems in the slave domain. The actuators manipulate the system, whereas the sensors monitor the system and environment.

3.3. Network Domain

The network domain acts as the medium for bilateral communication between the master and slave domains. It consists of network devices such as routers and gateways. The router directs the haptic input (in the form of small packets) to the gateways (e.g., packet gateways, serving gateways). Then the data will be sent to the base stations and communicate with the tactile supported infrastructure and pass to the destination robot in the slave domain. Due to the strict requirements of reliable and responsive connectivity, which determines latencies for real-time control and remote operation, the infrastructure, as well as network technologies in the domain, needs special attention. Besides the 5G communication, new emerging network technologies such as Software Defined Networking (SDN), Network Function Virtualization (NFV), and Mobile Edge Cloud (MEC) should be developed and applied to the TI infrastructure (Antonakoglou *et al*., 2018; Van Den Berg *et al*., 2017).

4. Emerging Technologies towards Tactile Internet

The analysis above indicated the redesign of network infrastructure and the implementation of new technologies to serve the TI are necessary. Although some studies (Ateya *et al*., 2018b) focus on the development of intelligent core networks, capable passive optical LAN (Wong, Dias & Ruan, 2016) or wireless body area networks (WBANs) (Ruan, Dias & Wong, 2017) for the TI, it could be stated that the fifth generation of mobile communications systems will underpin this next Internet generation (Simsek *et al*., 2016b). This section will dissect parts of the emerging technologies, and their combination will be the lever for the establishment and the development of the TI soon (Bojkovic, Bakmaz & Bakmaz, 2017).

4.1. 5G, Network Slicing, and physical layer technologies

Now the 4G mobile communication systems cannot meet the technical requirements of the TI. Therefore, the next 5G mobile communications systems are expected to fulfill the wireless communication requirements (Marcus, 2015) and act as the foundation for the TI at the wireless edge due to the overlapping features of ultra-low latency, high reliability, and security in communication between 5G and TI (Maier *et al.*, 2016; Jiang & Liu, 2016; Sachs *et al.*, 2019; Mountaser, Mahmoodi & Simeone, 2018; Liu *et al.*, 2018b). In general, the introduction of 5G supports the evolution of traditional mobile communication services. It also addresses different uses such as machine-type communication, sensor networking, healthcare, industrial automation, education, smart grids, smart energy networks, and vehicular communication in intelligent transport systems, etc.

According to the prediction of the Cisco Visual Networking Index (VNI) (Cisco VNI, 2016-2021), by 2021, 5G will be 0.2 percent of connections (25 million), but 1.5 percent of total traffic.

Besides, to meet the tremendous growth in connectivity, the density of devices, and a massive increase in traffic in the future, additional spectrum must be allocated to the 5G wireless access. Moreover, to enable high data rates (≥10 Gbps) and high capacity in the 5G network, the millimetre-wave range is consequently relevant (Rappaport *et al.*, 2013; Niu *et al.*, 2015). With massive bandwidth in the band from 30 GHz to 300 GHz, mmWave communications have been proposed to be an essential part of the 5G mobile network to provide multi-gigabit communication services, such as high definition television (HDTV) and ultra-high-definition video (UHDV). Since 5G needs to satisfy the stringent requirements for latency, reliability, connectivity, mobility, and security in the TI (Andrews *et al.*, 2014), the architecture of 5G needs to be flexible and optimized to take advantage of network resources. In particular, it should use modular network functions, which can be deployed and scaled on demand. In other words, 5G should be designed so that different vertical applications can efficiently share a common physical infrastructure. It can be done through the abstraction of 5G networks (e.g., network slicing). The network slice can be considered as a group of network functions that work together with a specific radio access technology to achieve the purpose of the network (Simsek *et al.*, 2017).

In this case, network slices would be designated to differentiate vertical application sectors (Foukas *et al.*, 2017; Zhang *et al.*, 2017a; Rost *et al.*, 2017; Ordonez-Lucena *et al.*, 2017; Shafigh, Glisic & Lorenzo, 2017; D'Ursol *et al.*, 2018; NGMN Alliance, 2015). The 5G slice intends to provide the traffic treatment necessary for its function. A new service can be deployed and tested in a slice without affecting the running services of other slices. The flexibility behind the slice concept expands the existing businesses and creates new businesses. Such envisioned network slicing can be achieved through SDN and NFV (Zhang *et al.*, 2017b), which will be presented in the next sections.

Many communication techniques for the TI services have been developed (Kim *et al.*, 2019), and a lot of companies in the ICT field are engaged in this field to implement the concept of the TI. Specifically, Huawei has recently developed many technologies, such as SCMA, F-OFDM, and polar code, to achieve high speeds and low network delays; each of them will be further considered separately (Huawei, 2015).

Filtered-OFDM (F-OFDM) is a modernized OFDM technology. It is partitioning into sub-carrier spacing and organizing in such a way that a particular set of parameters will be used for each task. It makes the signal processing more accurate, faster, and less energy-intensive. F-OFDM will support various waveforms and multiple access schemes for different application/service scenarios. The first results of the planned testing showed that F-OFDM increases the overall system throughput by 10% due to the use of free protected bands in the LTE system. F-OFDM also sustains the asynchronous transfer of data from various users; thereby throughput of the system increases to 100% in comparison with the LTE system in the transmission of several types of traffic (Jastrebova, Vybornova & Kirichek, 2016).

Sparse Code Multiple Access (SCMA) technology is a multi-station access technology based on sparse codes. It allows the combination of OFDMA technology with CDMA code to provide broader access for devices. This non-orthogonal technology was explicitly developed for possible usage in the fifth-generation networks (Lu *et al.*, 2015; Nikopour & Baligh, 2013). The idea is to improve the spectral efficiency of wireless radio access. SCMA encodes binary data streams directly to multi-dimensional codewords. Each codeword represents one of the distributed transmission layers. The codeword is selected from the SCMA codebooks for any level. Similarly, coded bits in SCMA are directly mapped to multi-dimensional sparse codewords selected from layer-specific SCMA codebooks. It allows several data streams to share the same time-frequency resources of the OFDMA signal. The technology provides a more flexible and efficient adaptive mechanism, increases throughput, reduces transmission delays, and saves electricity. The test results indicated that this technology increases the throughput for the downstream channel by 80%, and it increases the number of connected devices by 300% (Jastrebova, Vybornova & Kirichek, 2016).

Polar Code is proven to reach the Shannon channel capacity by using encoders and sequential cancellation decoders (Huawei, 2015). It is one of the best technologies for encoding with direct error correction. Their test outcomes revealed that the polar code outperforms the turbo code used in the LTE system, especially for short code length. Furthermore, under certain conditions, a peak speed of 27 Gbps was achieved in the descending mode.

Multi-User Shared Access (MUSA) (Yuan, Yu & Li, 2015) is a multiple access solution offered by ZTE (Yuan *et al.*, 2016) based on discharged codes. It allows multiple access in networks with a high load without the need for network planning. It significantly increases the number of connected devices to the system, as well as improves the overall coverage. As a consequence,

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it demonstrated an increase in capacity by 200% compared to the networks of the previous generation (Jastrebova, Vybornova & Kirichek, 2016).

Also, the Massive-MIMO technology, which can simultaneously accommodate many co-channel users (Swindlehurst *et al.*, 2014), as well as the Full-Duplex technique (Zhang *et al.*, 2015), which can transmit and receive at the same time on the same frequency, are becoming the most promising ingredients of the emerging 5G technology.

4.2. SDN – Software Defined Networking

SDN technology provides a powerful solution for the challenges in the 5G network and the TI system, especially the "1-millisecond challenge". SDN is an architectural framework formed by decoupling the control plane and the data plane. SDN (Kreutz *et al.*, 2015; Farhady, Lee & Nakao, 2015) enables direct programmability of network control through software-based centralized controllers.

The control and data planes communicate with each other through an open standard interface protocol such as OpenFlow protocol (Athmiya, Shobba & Sarimela, 2016). Due to its centralized nature, the controller can get a global view of the network. It helps the network administrators to adjust the network traffic flow dynamically, facilitate low-latency forwarding path discovery, reliable multipath routing (path optimization based on the application requirements), and network virtualization (Mahmoodi & Seetharaman, 2014; Morales, Aijaz & Mahmoodi, 2015; Kim & Feamster, 2013; Farhoudi *et al.*, 2017; Girish & Rao, 2016). Nonetheless, additional TI research is needed because the most crucial goal is to find the path with the lowest delay while considering the rapid change of network conditions (Van Den Berg *et al.*, 2017). Besides, SDN enables the dynamic provisioning of network resources and functionalities. Hence, the network slicing can be flexibly configured (in terms of security mechanisms, network topology, management policy, etc.) with guaranteed Quality of Service (QoS). In another study (Szabo *et al.*, 2015), the authors show that packet retransmission and latency can be significantly reduced by combining SDN and network coding. As a result, SDN is one of the most critical components of the fifth-generation network.

4.3. NFV – Network Function Virtualization

Today, network services such as caching and load balancing are typically dedicated hardware (middleboxes). Their deployment and maintenance are usually complicated and inefficient. Network Function Virtualization (NFV) shifts middlebox processing from hardware to software, which can be quickly deployed in the network. In other words, NFV provides virtualization and softwarization for network functions. Therefore, it significantly decreases the dependency on hardware and results in increases in the reliability and scalability of the network (Joshi & Benson, 2016; Han *et al.*, 2015; Mijumbi *et al.*, 2016; Li & Chen, 2015). The

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resources can be easily shared among different network functions and by NFV. The numerous network functions are managed as software modules, which can be deployed in different locations of the network such as network nodes, end-node of the network edge, and data centres (Li & Chen, 2015). NFV can transfer those functions across the network to optimize the performance of the service, especially in terms of latency (Giannoulakis *et al.*, 2014). At present, the market of NFV includes switching elements (Broadband Network Gateway and Router), network appliances, network services, and applications. NFV also supports the coexistence of multi-tenancy of network and service functions by allowing the practice of a physical platform for different applications, tenants, and services. Therefore, NFV has many advantages, such as high flexibility, scalability, low cost, security, and location independence.

Particularly, NFV will adequately control the network functions, and SDN will manage the physical communication infrastructure (e.g., switches, network links, and even path management). The combination of NFV and SDN offers a method to actualize the fundamental concept of network slicing. It guarantees the closing of the loop in the TI applications, assures low latency, dynamically handles the traffic taking account of the network conditions, and accommodates a wide range of heterogeneous services with stringent QoS.

In a recent study (Ateya *et al.*, 2018b), the authors combined SDN, NFV, and Mobile Edge Cloud (MEC) into multi-levels for the core of the cellular network. The obtained result shows that this combination may support one another to solve the 1-ms problem. MEC will be further discussed in the next section.

4.4. MEC – Mobile Edge Cloud

Given the speed of light (approximately 300,000 km/s), the distance for transmission within 1 ms can be no greater than 300 km. In the case of the TI, that is the maximum distance over which the loop of tactile application can be accomplished with the assumption that there are no latencies in the communication path. This fact also means the distance between the steering and control server from the point of tactile interaction by the users should be less than 150 km (Varsha & Shashikala, 2017). Yet, considering the signal processing, switching latency, protocol handling, and impact from the air environment, the TI servers need to be placed closer to the base stations, if not integrated into the same equipment. This requirement leads to the concept of MEC, which is being standardized by ETSI Industry Specification Group (ISG) (Hu *et al.*, 2015). MEC has a robust computing capability (cloud-computing capabilities), and it is often used to handle critical requests at the edge of the mobile network and thereby dramatically reduces the latency of the process. Likewise, it provides a higher system bandwidth and reduces network congestion by providing a way for offloading data (Liu *et al.*, 2018a).

By adding some decision-making services, MEC manages traffic at the mobile edge instead of forwarding it to the remote data centres. When packets do not go through the core network to the remote data centres, the real-time services can be provided with low end-to-end latency (Ateya *et al.*, 2018a). In like manner, the TI applications can be supported if MEC architecture eliminates the considerable delay in processing. It leads to a requirement for the decentralization of services, which in turn should change the network architecture.

The architecture of a network with ultra-low delays is suggested for the implementation of the TI services (Maier *et al.*, 2016). This architecture assumes the decentralization of cloud computing in the TI networks. Figure 4 shows the traditional architecture of the IoT networks, in which several fields of IoT devices are associated with a cloud system (in this case, individual for each field).

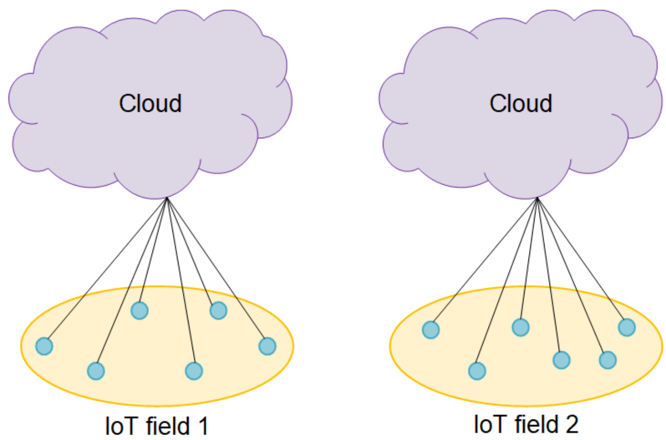

Figure 4. The traditional architecture of the IoT network

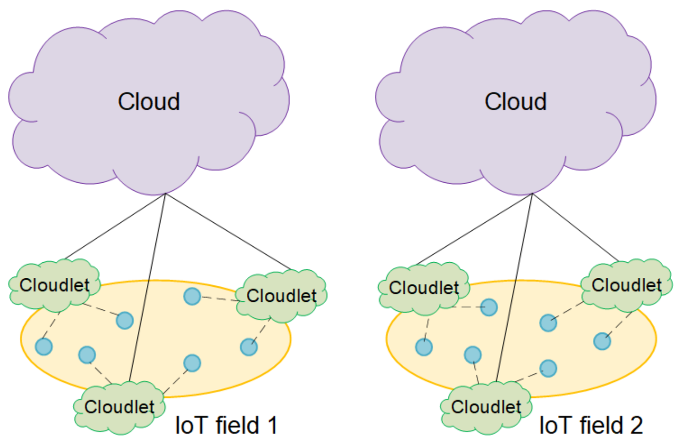

Figure 5. The decentralized architecture for realizing the TI services

When traditional architecture is used to implement TI services, delays in transmission of information between the IoT and the cloud will frequently be too large to provide the necessary quality for TI services. In a decentralized architecture, the practice of resources distributed (cloudlets) over the field of IoT devices will avoid unnecessary delays in the provision of TI services (Koucheryavy & Vybornova, 2016; Verbelen *et al.*, 2012). From a technical

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perspective, users take advantage of reduced communication latency and data centres take advantage of reduced overall traffic (Neaime, 2018; Oteafy & Hassanein, 2019). Figure 5 shows the assumed decentralized architecture for realizing the TI services.

4.5. Network coding

The combination of SDN and NFV provides virtualization and softwarization for networks. It also significantly reduces latency. However, to meet the 1 ms requirement in the TI, there is a need to incorporate other technologies. One of those technologies is network coding, also known as new coding strategies. It is necessary because, in the application of existing coding strategies, such as Reed-Solomon and Raptor (Fragouli & Soljanin, 2008; Wicker & Bhargava, 1994) (which are only end-to-end based), the network nodes cannot self-evaluate or change based on the network situation. By contrast, network coding permits the network node dynamically and adaptively to change the coding strategies depending on the current condition of the network (Szabo *et al.*, 2015). The most prominent network coding now is Random Linear Network Coding (RLNC) (Ho *et al.*, 2006) that supports a sliding window approach and does not work on blocks of packets. Therefore, it would decrease the delay of any communication.

Nevertheless, when using network coding, nodes will not only store but also compute and then forward the packets. Thus, the current situation for next-hop communication would be considered. The node will select the appropriate coding strategy. It does not deal with the losses over the whole path (end-to-end, E2E), but it just takes care of the losses between two nodes (hop-by-hop, HbH). It reduces retransmissions dramatically, so latency is also reduced (Cabrera *et al.*, 2019). The encoders, recoders, and decoders need to be allocated flexibly so that the network coding could work properly. With the appearance of SDN and NFV (encoders, recoders, and decoders are implemented as NFV), network coding promises to be a crucial technique in the 5G network. The authors in Szabo *et al.* (2015) pointed out that the combination of network coding with SDN can improve reliability and reduce the latency in the 5G system by recoding and sliding window features of network coding.

4.6. Compression methods

One of many methods to comply with the latency requirement of the TI is to use a suitable data compression method. In the ideal case, the distortion must not go beyond human perceptual thresholds. The essence of data compression is to remove irrelevant information, which either is not perceivable by the human or cannot be displayed due to hardware limitations. If the perceptual quality and system performance are not affected by the compression methods, then these methods are known as transparent (Elhajj *et al.*, 2001). It means that the correct parameters (max-level value, window-session size, etc.) are needed to compress the data and achieve the required reliability. Although there are many data reduction standards for digital audio and video (Storer, 1987; Sikora, 1997; Kimura & Latifi, 2005), these algorithms cannot be applied to tactile data, especially haptic data, because it requires a low execution time and stability (Chaudhari *et al.*, 2015; Steinbach *et al.*, 2011; Shahabi, Ortega & Kolahdouzan, 2002). Therefore, to achieve a reliable data reduction for each combination of data samples, further research is necessary.

4.7. Multiplexing different modalities

In addition to transmitting haptic data in the TI, there is still a need to transmit both audio and video to provide synchronization of all media forms. Combining multiple data types or multiplexing will increase perceptual performance; thus, it would meet TI requirements. Because each data type has different requirements, such as frequency, priority, latency, or transmission rates, an adaptive multiplexing model is needed to encode data from different streams (Al Jaafreh *et al.*, 2018). Moreover, large video packets can affect or block haptic packets. This fact leads to latency and jitter violation. A few approaches give the haptic data the highest priority (Cizmeci *et al.*, 2014), but, in reality, this is not efficient due to protocol header overhead when transmitting small packets with a high rate (Cizmeci *et al.*, 2017). Besides, different error control schemes and congestion controls need to be considered when applying the multiplexing system.

In Eid, Cha & El Saddik (2011), the authors proposed to use ADMUX multiplexer with compression and control methods to improve the service quality of communication. In Yuan, Ghinea & Muntean (2015), Adaptive Mulsemedia Delivery Solution (ADAMS) multiplexer was proposed based on a client-server architecture. It permits adaptively controlling the transmission rate of different streams regarding the human perception limits. Then again, it does not cooperate with the security mechanisms. Overall, the current works in the field of multiplexing the haptic data with audio and video modalities are limited, making it an open challenge.

4.8. Cloud robotics

With recent advancements in robotic development environments, robots become more prevalent in everyday human activities, especially in the health care field (assisting the elderly, people with disabilities, remote surgery, etc.). For the TI, robots provide three main functions: sensation, actuation, and control (Kamei *et al.*, 2012). However, standalone robotic services are not enough to support countless daily tasks and medical-related activities, which require multi-robot systems with many functionalities. In fact, stand-alone robots, sensors, and humans should collaborate and communicate with each other via a network to create networked robots (Sanfeliu, Hagita & Saffiotti, 2008). Similarly, some technological issues should be considered when providing robotic services: multi-robot management (e.g., classify abilities and allocate appropriate robots depending on the services); service coordination management (e.g., the state of each location must be monitored to execute the service in proper situations); multi-area management (e.g., dynamic location information of users, robots, and target objects should be shared); user attribute management (e.g., appropriate robots should be chosen by referring to the user information). Cloud robotic solution provides robotic services continuously and seamlessly through distributed task coordination at various locations and will become a critical element in the TI (Huaimin *et al.*, 2018). Cloud robotics will abstract robotic devices and provide the means for utilizing multi-robot systems as a cloud of robots to support task offloading and share computation resources, information, and data in robot applications (Kamei *et al.*, 2012; Hu, Tay & Wen, 2012; Kehoe *et al.*, 2015). Likewise, it offers access to new skills and knowledge, which are not learned by robots through IoS (Dohler *et al.*, 2017). Cloud robotics takes advantage of machine-to-machine (M2M) for the communication between robots, and machine-to-cloud (M2C) for the communication between robots and remote cloud (Hu, Tay & Wen, 2012). Yet, cloud robotics introduces new challenges in privacy and security because robotic services are related to both the real physical world and cyberspace. If a robot is being attacked, then it could lead to significant problems due to disrupting functionality or loss of user data.

4.9. Artificial Intelligence

Artificial Intelligence (AI) (Russell & Norvig, 2009) is necessary to break the limitations and to improve safety, accuracy, and security in the TI. It also reduces congestion in the core network, thereby reducing the latency. Using intelligent algorithms, AI speeds up the action at the robot side and the reaction at the operating side. In other words, AI predicts haptic and tactile experience (Simsek *et al.*, 2016a) (the most basic prediction algorithm is a linear predictor (Hinterseer *et al.*, 2008)). The collected tactile data will improve these algorithms. To demonstrate, after the initialization and training process, the algorithms will decide whether to update training values from current real data or not. These algorithms must be able to recognize patterns, learn from false predictions, and improve over time (Van Den Berg *et al.*, 2017). For example, in the field of telesurgery, after AI engines are monitoring, learning data, and foreseeing the risks of a manipulation error due to the delayed display of video stream, these AI engines can immediately postpone the surgical operations while sending out warnings to the surgeon (Zhang, Liu & Zhao, 2018). Not to mention, if AI techniques are applied to edge cloud architectures, then it will accelerate the computing process so that the physical limitation that arises due to the finite speed of light could be overcome.

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5. Tactile Internet in Relation to Haptic Communication and Internet of Skills

As mentioned above, the TI transmits touch sensation and actuation via the Internet in real time by enabling HC (Steinbach *et al.*, 2012) and supporting the IoS (Dohler *et al.*, 2017). Their combination creates multiple beneficial applications in many life aspects. The HC and IoS, in relation to the TI, will be reviewed in this section.

5.1. Tactile Internet and Haptic Communication

Firstly, it is essential to distinguish the relationship between TI and HC. Similarly to the data communications that run over the conventional internet, HC is primary applications (touch, actuation, control in real time) that run over the TI. It does not mean that the TI only transmits haptic information, which requires strict latency due to the characteristics of haptic feedback. But the TI also transmits non-haptic information such as networked control signals, in which the dynamic processes for connecting sensors and actuators are involved. It should be noted that, unlike in conventional audio/video transmission, haptic information and feedback signals close a global control loop. The sense of touch occurs bilaterally, i.e., it is sensed by imposing a motion on an environment and feeling the environment by a distortion or reaction force (Aijaz *et al.*, 2016).

There are two types of feedback in haptic information: kinesthetic/force perception and tactile/cutaneous perception. Kinesthetic provides information on forces, position, torque, and velocity, which are sensed by the joints, muscles, and tendons of the body. Tactile perception provides information on surface texture and friction, which are sensed by the human skin. The term “tactile” suggests the perception of touch and leads to the requirement of an ultra-low delay constraint in the TI (Fettweis & Alamouti, 2014). In HC, the sensors convert tactile parameters, like contact, location, pressure, shear, slip, vibration, and temperature, and kinesthetic perceptions, like position, orientation, and force, into electrical signals that are transmitted when the commands are executed. However, haptic signals need to be digitized and standardized to create compatible products for vendors.

Currently, the applications of HC, such as telesurgery and education (see Section 6), are synchronized with video and audio data. Anyhow, if the time interval between tactile movement and visual is greater than 1 ms, then it can cause motion sickness or other uncomfortable influences. In a virtual environment, multi-modal sensory information (e.g., combination of different types of data) plays a crucial role in enabling the participants to interact and communicate (Basdogan *et al.*, 2000); especially haptic modality will enhance the experience for the users. This combination is comparable to billions of nerve cells arranged in patterns to coordinate multiple functions. The brain synthesizes information about colour

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and sound. Then it combines this information with shape data, which can be perceived through touch to create a complete representation of the object. The integration of haptic feedback into conventional communication will develop countless new uses in various fields. The TI creates a "paradigm shift" to deliver the content with ultra-low latency and high throughput. The most common function is haptic telepresence, which is the haptic interaction between remote objects, such as in teleoperation or telesurgery, or in hazardous environments (Steinbach *et al.*, 2019). Alternatively, a virtual reality system (see Section 6) is useful in education and remote training (Basdogan *et al.*, 2000). Haptic devices are required to facilitate these applications and support the HC. Some examples are the ultrasound panel (Hoshi *et al.*, 2010), vibro-tactile glove (Martinez *et al.*, 2011), finger (Weber *et al.*, 2016), force feedback glove, force feedback gripper, and force feedback mechanical arm (Shima & Sato, 2017). Adding to the haptic devices are the kinematic devices to capture the motion of the operator (kinematic sensors) and mimic that motion at the slave domain (see Section 3) (kinematic actuators) (Dipietro, Sabatini & Dario, 2008; Ma & Ben-Tzvi, 2015; Baldi *et al.*, 2017; Ma *et al.*, 2011; Bainbridge & Paradiso, 2011). However, the effect of delay on HC is considerable because minor latency may destabilize the haptic system. That is why HC needs TI with ultra-low latency and high-reliable connections.

5.2. Tactile Internet and Internet of Skills

The IoS concept (Dohler *et al.*, 2017) assumes the transfer of "experience" virtually, as a result of the "digitization" of physical skills. In other words, the IoS will deliver the physical experiences remotely. This concept will push the learning process to a new level and revolutionize servicing capabilities for industries. IoS, unlike the IoT and the TI, does not impose new demands on networks with ultra-high density and ultra-low latencies. But this kind of network would be fully suited for the characteristics of the TI. IoS implements new classes of services (see Section 6) to apply a "skilful" network for acquiring new skills by people and robotic devices, which eventually lead to better educational activities in general.

The two concepts, TI and IoS, were designed to complement each other. They work together as a single cyclical system, where "human skills" are primarily recorded in the master domain. Then the information is transferred to the slave domain, where the feedback (tactile response) is returned as a new set of information back to the master domain. Human skills in the master domain can be captured using the human-system interface. For example, a tactile glove translates human input data into a specific set of instructions for movements and pressing so that the robotic arm in the slave domain can follow these instructions to perform the same movements and press with a precise pressure (Kim, Dohler & Dasgupta, 2018). As soon as the hand signals are received, they are transmitted through the network infrastructure to the slave domain, in which the robotic device reproduces the received signals. The communication

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between the two remote domains should be fast and stable so that the master domain can accurately control and "sense" the remote environment based on the feedback signals generated by the robot in the slave domain.

The introduction of new services transforms the network into a network of intelligence, then provides the new skills training to people and robots. Ultimately, this would lead to higher labour productivity and better product quality. For these reasons, IoS, as well as IoT and TI, are essential components of the digital economy (Goldfarb & Tucker, 2017).

6. Applications

It has been about six years since Professor Gerhard P. Fettweis introduced the TI concept (Fettweis, 2014). Various technologies have been improved over the years. Besides, new technologies also appear more and more. TI implementation is increasing (Pilz *et al.*, 2016) with inventive applications that have not been discovered before. Along with TI's existence are the appearances of HC and IoS. These three factors create a new dimension for human-machine interaction in real time.

Potential TI applications based on ultra-low, end-to-end latency are expected to extend throughout many aspects of life with positive impacts on economic, social, educational, and medical device developments. It is difficult to list all the TI applications because it is beyond a human's imagination capabilities. This section will elaborate on some of the prominent applications that the TI brings.

6.1. Healthcare

Healthcare (E-health) is considered as the most promising application of the TI. In the past, when the Internet was first created, information and knowledge were delivered worldwide. When the TI is available now, geographical location, as well as travel expenses, will no longer be a limitation to medical services such as surgery, diagnosis, and rehabilitation. It also means that a patient in Africa can thoroughly be examined and treated by doctors in Singapore without leaving Africa. This technology will benefit patients and assist physicians along with medical providers by incorporating TI and IoS. To have a better picture, the coronavirus disease 2019 (COVID-19) is an excellent illustration. There are many cases where medical professionals are infected with the virus while taking care of sick patients. If healthcare providers could render routine medical care remotely through gestures, pictures, or animations by using tactile robots via the IoS, then medical care providers could work in a safer environment without risking their own lives (Dohler *et al.*, 2017; Lema *et al.*, 2017; Majid *et al.*, 2020).

Another scenario for the application of the IoS is remote surgery (Arata *et al.*, 2007; Miao *et al.*, 2018). The doctor (in the master domain) will control a robotic arm (in the slave domain) to send commands and receive feedback displayed on a screen (Figure 6). To ensure a successful operation, the latency in control and the feedback must be very low, and the reliability of the connection must be very high, because unreliable communication, which leads to delayed imaging or poor image resolution, will affect the efficacy of the operator's remote handling.

Similarly, telediagnosis is the next prominent TI application, especially for people from rural areas, pregnant women, or people with disabilities. Telediagnosis is defined as a diagnosis performed remotely by a healthcare provider. Then, the evaluation data collected from the machine that monitors the patients is transmitted to a linked diagnostic centre. This kind of practice will reduce the waiting time for providing specialized medical care and reduce unnecessary costs. Although telediagnostic services have been implemented previously (even in the agricultural field (Li *et al.*, 2006)), they have used only voice and video functions without any touch sensation. However, with the TI, by using tactile gloves, physicians will have a complete picture (not only audio and video information, but also haptic information is provided) to examine the condition of patients accurately.

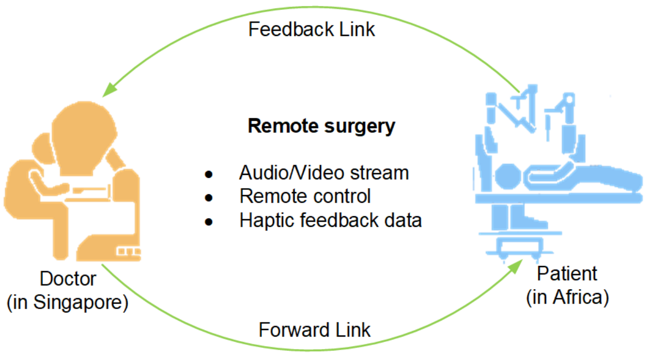

Figure 6. Remote surgery scenario

Another potential TI application in healthcare is telerehabilitation. This service will help patients who need constant care from medical workers and improve the efficiency of personalized treatment to ensure a faster recovery process. It introduces new equipment – exoskeletons (Lo & Xie, 2012) — which are attached to the limbs of the patient and controlled remotely. It reinforces the limbs to move with more force than a patient's muscles. Therefore, a patient who uses a wheelchair can walk with an exoskeleton's support. The time spent on calculating the exoskeleton reaction should be short enough so that these movements would be within the tactile delay.

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6.2. Industry and robotics

Unlike the Industrial Revolution 1 (the revolution of steam power), the Industrial Revolution 2 (the revolution of the division of labour) and the Industrial Revolution 3 (the revolution of electronic and information technology systems), the upcoming Industrial Revolution 4.0 (Wollschlaeger, Sauter & Jasperneite, 2017) will improve the production process to meet market changes quickly. This real-time revolution enables cyber-physical systems and moves toward digital transformation that includes storage, smart machines, smart factories, and exchanging information systems. It connects humans and machines and improves resource handling and coordination of processes in the manufacturing chain (Haddadin, Johannsmeir & Diaz Ledezma, 2019). Therefore, it sets out many new requirements from reliability to security in real time. The production systems and the robots in the high-tech factories are remotely controlled (industrial teleoperation) through the monitoring and control system (e.g., in construction sites or mines) (Li *et al.*, 2019). These high-tech factories (e.g., the automobile or electronic components factories) and processes (e.g., precisely controlling moving devices) have stringent requirements in latency, reliability, safety, or energy consumption, which can only be realized in the TI (Weiner *et al.*, 2014; Varghese & Tandur, 2014; Aijaz & Sooriyabandara, 2019).

6.3. Road traffic and self-driving vehicles

The transport system is a vital factor in the economy, especially in the context of smart city development. However, accidents, traffic congestion, fuel efficiency, and even air pollution problems in traffic systems cause significant losses in life and economics. New TI communication standards between vehicles, in particular the use of integrated network/control design and cloud computing (Whaiduzzaman *et al.*, 2014; Chen *et al.*, 2019), as well as the use of orthogonal heterogeneous communication technologies, will deal with the issues mentioned above (Dressler *et al.*, 2019).

In Vehicular Ad Hoc Network (VANET) (Cunha *et al.*, 2016), the vehicles and drivers need the full picture of the traffic flow and the road conditions to prevent collisions and emergencies on the road (Duc *et al.*, 2018). To meet this requirement, wireless connections should be used, because they have high reliability, the ability to support multiple connections at the same time, and especially ultra-low latency (in the order of 1 ms). Again, these requirements can only be met in TI based on 5G connections.

Some cases benefit from the network generation with super-low latency as follows:

- Emergency vehicles (e.g., ambulance, police cars, firefighting vehicles, etc.);
- Avoiding hidden objects and obstacles (She & Yang, 2016);
- Self-driving vehicles (Amadeo, Campolo & Molinaro, 2012; Lee *et al.*, 2002).

6.4. Virtual Reality, Augmented Reality and gaming

Virtual Reality (VR) and Augmented Reality (AR) are drawing more and more attention from researchers as well as industry. VR is defined as a completely virtual environment, where the users interact with the virtual objects. In other words, VR immerses users into the virtual environment. VR applications are useful in future education and gaming applications. By combining with HC, VR creates a haptic virtual world and allows multiple users to interact with each other physically via a simulation tool. For example, users can feel the impact of being attacked when playing a video game through haptic feedback. That makes the experience lifelike.

On the other hand, augmented reality combines virtual and real objects in a physical environment. An AR application visualizes the dynamic content and displays an augmented view of a real object in real time. These applications are more useful in assistance systems such as driver-assistance systems, medicine, maintenance, or education. The content is no longer static but becomes more dynamic. The combination of VR, AR, and haptic devices promises to produce many application scenarios in the film, gaming, and mobile industries (Repperger & Phillips, 2006).

Yet, some technical challenges must be solved to facilitate the implementation of these applications. Specifically, a high level of precision or high-fidelity interaction in VR requires low-latency, high-throughput and reliable communication (Elbamby *et al.*, 2018) to transmit the movements of the users to the VR server for processing. Then, the results are returned to the users in the form of haptic feedback. The players' experience in real-time gaming also requires low end-to-end latency because the delay impacts the synchronization between multiple players (so-called lag) and the perceived realism of the game directly. The TI can solve all problems encountered in VR, AR, and gaming with virtualization and computing technologies (Braun *et al.*, 2017; Sukhmani *et al.*, 2019).

6.5. Education and sports

The TI would establish multiple beneficial applications in the educational field based on haptic interaction in combination with virtual and augmented reality. Distance learning becomes more popular and effective through virtual environments with multimedia and haptic feedback. Not only knowledge but also skills will be conveyed to the learners with the support of the IoS. Through the TI, students experience real-time activities anywhere, any time with all kinds of senses by performing a manual operation on a virtual object, and the instructors guide or correct their students if necessary. The instructor's physical presence is not needed any more (Yorita *et al.*, 2009). Such activity requires multi-modal human-to-machine

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communication, which is only possible if the latency is extremely low, and the network throughput is high.

Another useful application for individuals with speech disabilities is tactile gloves that convert the hand's movements (sign language) into speech (sound) by using fast streaming encoded data (Cakuli, 2016).

Many coaches for swimming, skiing, and figure skating found it difficult to capture athletes' performances comprehensively through visual contact or typical communication methods. The athletes use a tactile wearable training suit or bracelet to provide feedback about speed, position, posture, and endurance to their coaches. Then, the coaches can give commands or train the athletes in a real-time manner (Spelmezan, 2012; Shull & Damian, 2015; Umek, Tomažič & Kos, 2015; Bermejo & Hui, 2017). This real-time interaction is impossible without ultra-low latency. Besides, the information feedback collected can be stored and handled by other smart systems to get the individual top-level performance.

6.6. Energy and smart grids

In recent years, due to high electricity demand, the electricity industry tends to shift from a centralized system to a decentralized system. In that context, smart grids (Fang *et al.*, 2012) emerged as a potential solution to control power production, distribution, and transport based on advanced communication technologies (Gao *et al.*, 2012; Tuballa & Abundo, 2016). The TI and 5G provide more reliable, high-speed communications through human-to-machine interaction (Maier, Ebrahimzadeh & Chowdhury, 2018), then they can be applied in smart grids to meet the strict requirements (Faheem *et al.*, 2018). Smart meters (the consumer side) and intelligent monitors (the company side) (Siano, 2014) can be used to automate energy distribution and optimize power consumption based on two-way communication using wireless connections with low latency and high throughput over the TI.

Another benefit of the low latency of communications between local suppliers is the synchronization of co-phases of power suppliers. It is necessary because the system needs to minimize reactive power and dynamically control status (on/off) of suppliers within a small angle of phase (Fettweis, 2014).

6.7. Online shopping and E-commerce

As was illustrated in Section 1, the TI brings a new experience to the users (touch and feel objects) for the online shopping experience. It invents countless business opportunities for consumers, application developers, businesses, and telecommunication companies, and also leads to a big jump in the product sales industry.

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7. Standardization and Contributions

The TI has been studied in the last six years and its deployment is still limited. The involvement of different organizations in the development of the TI is also limited. The reason for that limitation is the lack of common standards to ensure that the products and services are used securely, reliably, and interactively. In other words, standardization is critical to end-users. Thanks to standardization, new technologies will attract a lot of attention from technology companies and quickly be introduced to the market.

Currently, various standardization bodies focus on the TI based on the technology watch report by ITU in 2014 (Fettweis, 2014) and work item on IPv6-based TI by ETSI IP6 ISG (ETSI, 2017). Among them, the emerging IEEE P1918.1 standard working group (created in March 2016) (IEEE P1918.1) defines a framework for the TI. This framework includes definitions, terminology, architecture, reference models, and application scenarios. It mainly focuses on three main areas: reference architecture (see Section 3), haptic codecs, and use cases. In addition, the standards for 5G (e.g., 5G New Radio (NR) specification by 3GPP) are also necessary for the standardization process of the TI.

This standardization process requires a coordination of the alliance groups and the collaboration of different companies to have a joint agreement on product specifications. Up to the present time, the researchers can expect positive contributions from:

- 3GPP: for 5G standardization, which is the foundation for the development of the TI. Some important documents released by 3GPP (Cakuli, 2016) are: TR 22.862 (requirements for communications in the context of 5G); TR 22.864 (network functionality, network slicing, and services); TR 23.714 (architectural design for Core Network); TR 32.842 (management of virtualized networks); TR 38.913 (requirements for next-generation access technologies).
- ETSI: for SDN and NFV to separate hardware and software or softwarization of network functionalities. In addition, ETSI also focuses on researching the Mobile Edge Cloud and routing techniques to minimize latency.
- ITU: focusing on supporting flexible networks, which meet the end-to-end QoS requirements; studies mobile front haul and backhaul to handle the bandwidth; and network softwarization.
- IEEE: focusing on standardizing building blocks of 5G, creating working groups for the TI, such as IEEE P1918.1.1 for codecs, IEEE P1918.1.2 for AI in TI, and IEEE P1918.1.3 for MAC & PHY.

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8. Conclusion

The development of new telecommunication technologies has led to the emergence of communication networks with low, and then ultra-low, latencies. The networks with ultra-low latency allow the transmission of tactile data via the Internet. Therefore, the new concept of the next generation of the Internet is called TI. Nevertheless, the introduction of the TI produced a significant challenge – "1-millisecond challenge". The study of this challenge and the technical aspects related to this issue are the concern of this paper.

We have reviewed the reference architecture, which is believed to be compatible with the TI. This architecture consists of three domains: the master domain, the slave domain, and the network domain. This piece of work also pointed out that, in order to provide TI services to users, the network should be decentralized.

In this article, emerging technologies, which support the TI to solve the "1-millisecond challenge", were reviewed. The combination of network slicing in 5G networks with SDN and NFV promises a high degree of flexibility, reliability, and a significant reduction in latency, which forms the basis of TI's growth. Other technologies, such as artificial intelligence, cloud computing, or AR and VR technologies, will also be used to increase the efficiency and diversity of TI applications. The TI, with the coexistence of human senses in the real/virtual worlds, will be widely used in various aspects of life, ranging from healthcare and education to energy and e-commerce.

Equally importantly, this paper also considered and clarified the relationship between TI with HC and IoS. Their relationship is emerging and prominent in the near future. Finally, this article reviewed the active contributions of organizations and companies in the development of TI, which is the foundation for creating standards for the "TI ecosystem".

There are many future research directions for the TI. We can list some directions as follows:

- Applying machine learning and artificial intelligence algorithms to make communication intelligent for the future tactile internet (Mondal, Ruan & Wong, 2020);
- Using cognitive radio technologies to achieve quality of service without compromising delay (Farhang & Bizaki, 2020);
- Blockchain techniques may be one of the many other solutions for supporting security and privacy in the future tactile internet (Yu, Wang & Zhu, 2019);
- Redesigning protocols on different layers to guarantee 1-ms latency (Yu *et al.*, 2020).

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Digital Trust Gap

The differences in perceptions of trust between experienced and inexperienced users

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Abstract: This study examines the relationship between an information and communication technology (ICT) environment developed by strong national policy and the level of user trust in cyberspace in South Korea, using a secondary data analysis of a national survey dataset. We categorised a subsample into the following types of online activities: 'content creation', 'transaction' and 'communication'. Each category was analysed by the types of information and the users' experience while using the internet. The results revealed that the more internet experience a user had, the less they trusted information in cyberspace. In contrast, less experienced users perceived information in cyberspace to be more trustworthy. This was especially evident during transaction and content creation activities. These results differ from existing studies, which showed that developments to the ICT environment with increased internet usage were strongly correlated with increased trust. We present some suggestions drawn from the results of this study that focus on online trust in relation to the ICT environment.

Keywords: Information communication technologies (ICTs); digital trust; online activity; South Korea; secondary data analysis

Introduction

The term 'digital society' has become a commonly used expression to define our current technology-driven lifestyle. In common with other developed economies, South Korea (hereafter Korea) has experienced remarkable changes in its society over the last few decades due to its visibly changing and accelerating digital economy. South Korea tops global rankings in terms of number of households with access to the internet (99.5%), as recorded by the Information and Communication Technology (ICT) Development Index from the International Telecommunication Union (ITU) in 2019. The latest Index notes that 96% of the population had used the internet at some point in 2018 (ITU,2019). South Korea has developed a strong digital culture, with digital technology becoming one of the most frequently used sources for obtaining information. According to the Korean Press Foundation (2019), TV (53.2%) is the most trusted form of media in terms of information gathering amongst South Koreans, followed by the internet (39.1%). This result suggests that a universal digital culture has been cultivated; a paradigm shift which has transformed Korea into a highly knowledge-based society and reduced the inequality of information access found previously. In fact, the Korean Government has implemented digital inclusion policies for several decades. As a result, the internet access gap has narrowed significantly, and the Korean Government's policy is considered by many countries to be an exemplary case of a strong government drive in this field (Park & Kim, 2014).

Currently, the Korean Government defines its country as a highly advanced information society. Their national information and communications technology strategy has aimed to create a balanced knowledge information society in which information literacy plays a key role in users being able to select reliable knowledge-based resources. In this regard, there is an emerging ability to not only access social resources through digital technology, but also to create information value. In order to establish a society with a balanced digital culture, it is essential to ensure that every person can make effective use of the internet in their daily lives and can generate digital opportunities to engage fully in the consumption and production of digital content.

Paradoxically, criticism of the current ICT environment and cyberspace outcomes have been gradually increasing in Korea. While the ICT environment has developed exponentially, concerns over its negative aspects are also being raised. In particular, there is growing concern about personal information security and increasing distrust of online transactions. This may be due to expanding knowledge of cybercrimes, such as scams and identity theft, which have been increasingly reported on the news. Consequently, despite increasing dependency on the internet, its reliability is still perceived as being relatively low when compared to other forms of media, such as TV and newspapers. For instance, in the 2013 Korean Information Culture Index[i], the digital trust index was assigned a score of 66.3 out of 100, a figure which is relatively lower than other indices such as online digital tolerance (80.1). This result may imply that a highly developed ICT environment may not be enough to guarantee strong user trust in cyberspace. That is, there may not be a strong correlation between ICT outcomes driven by policy and trust in the ICT environment. If so, previous studies that propose a correlation between development levels and trust may be inaccurate. Moreover, the negative aspects of online technology and resulting distrust can lead to wider distrust within society, including of social organisations and individuals. As society has increasingly moved forward online and the boundaries between the online and offline world become blurred, the accumulated distrust of online activities can have a critical effect on social trust, which is an integral element of social capital (Coleman, 1988).

This study therefore attempts to examine the relationship between an internet environment developed by strong national policy and the level of user trust in Korean cyberspace by approaching the issue from the perspective of its users. We begin with an overview of the concept of trust and its relationship with the internet environment.

Trust Online

Trust is a long-standing concept which has been extensively studied across a variety of disciplines, including sociology, psychology, management and marketing (Das & Teng, 2004; McKnight & Chervany, 2002). Although there have been different ways of conceptualising and identifying the elements that make up trust, it is largely agreed that trust is relied upon when people encounter uncertain settings. Trust would seem to play a key role in diminishing uncertainty (Corritore, Kracher & Wiedenbeck, 2003).

The concept of trust has been paid considerable scholarly attention in recent years in social capital literature. Bourdieu (1986) defines social capital as "the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalised relationships of mutual acquaintance and recognition—or in other words, to membership in a group" (p. 248). Social resources accumulated from social networks can enhance an individual's social capital (Coleman, 1988), and social trust has been recognised as an integral element of social capital, with the two possessing a mutual relationship (Adler & Kwon, 2000). The social capital built and accumulated from social trust plays a crucial role in reducing potential risks and uncertainties in terms of social interactions and transactions (Coleman, 1990; Ellison, Steinfield & Lampe, 2007; Williams, 2006). Therefore, social trust is one of the key components of social capital, and functions in a number of ways to allow societies and individuals to avoid potential risks and uncertainties.

In an online setting, the importance of trust has received considerable attention (Beldad, de Jong & Steehouder, 2010; Corritore, Kracher & Wiedenbeck, 2003). As the online context has become an integral part of social activities and systems, including in the case of commercial and government services, increasing dependency on the internet has been noted in commercial transactions, management of social relationships and researching information. Researchers have begun to review the concept of social capital and trust as a result of

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increasing computer-mediated social exchanges in online contexts (Mandarano, Meenar & Steins, 2010; Williams, 2006). The risks and uncertainties might be perceived by individuals to be greater in online than in offline settings (Cheshire, 2011), due to the anonymity and invisibility of some online activities. Given the many risks and sources of uncertainty that exist during online interactions, online trust is critical for sustaining online interactions and furthering a reliable and secure digital society.

Differences in Online Trust among Users

It has been shown that there are a variety of determining factors which significantly influence online trust. In their review study, Shankar, Urban & Sultan (2002) summarise the main factors: past performance, long-term orientation, perceived information availability, perceived size and reputation, references, navigation, presentation and technology (p. 334). These can then be classified into website-related factors and user-related factors. Of the two, there has been greater focus on the former, which is concerned with provider-centric strategies to cultivate and improve customer trust. In general, the major factors that contribute to online trust include: ease of use, effective and efficient navigation, a search engine on the site, a sitemap and accurate descriptions of products (Bart *et al.*, 2005; Chau *et al.*, 2007; Flavian, Guinaliu & Gurrea, 2006; Grabner-Kraeuter, 2002; Lohse & Spiller, 1998). Many researchers also highlight the importance of the provision of quality information online, which includes accuracy, credibility, diversity and depth (Kim *et al.*, 2005; Koehn, 2003; Liao, Palvia & Lin, 2006; Sillence *et al.*, 2004; Sillence *et al.*, 2007). In addition, recent literature emphasizes the increasing importance of policies involving privacy and security, including on-site privacy statements and third-party evaluations (Aiken & Bousch, 2006; Koufaris & Hampton-Sosa, 2004; Lauer & Deng, 2007; Yoon, 2002).

In comparison to website-related factors, there has been relatively less attention paid to the user-related factors that may lead to different levels of trust among online users. A number of studies conducted with a focus on users have shown that different user features can have direct and mediated effects on trust in websites. For example, Shankar, Urban & Sultan (2002) summarise significant individual features influencing website trust, such as ease of use, familiarity, past performance, long-term orientation to the internet, predisposition to technology and other experiences of online use for entertainment and communication. Similarly, Corritore, Kracher & Wiedenbeck (2003) have found that the more online experience users have had, the higher the level of trust. Metzger (2006) supports this finding, identifying the positive relationship between proficiency of online usage and perceived risk online with the improvement in user trust during online transactions. However, several studies have also found that there is a negative relationship between perceived trust in online

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environments and an individual's ability to use the internet, which is defined by their knowledge of online environments and confidence in using the internet (Hankowski, Kantowitz & Kantowitz, 1994; Kantowitz, Hankowski & Kantowitz, 1997). In this regard, Aiken & Bousch (2006) explain that, in the initial stage, experiences of use can have positive effects on online trust; however, accumulated experience over time can turn to distrust due to a perceived lack of trustworthiness of online information and issues related to privacy.

Friedman, Khan & Howe (2000) view trust as the user's capability to be able to control perceived risk and uncertainty in situations where the user may be vulnerable. When it comes to the online context, trust refers to users' understanding of how to safely practise online functions. In other words, it can be supposed that online-use literacy can enable users to evaluate the credibility of the online platforms and, by doing so, users' trust in the websites can be affected. Relevant literature reveals that individuals' differences in terms of their familiarity and ability to use the internet can have direct and mediated effects on trust in websites, in parallel with system-related factors (Beldad, de Jong & Steehouder, 2010; Yoon, 2002). The online environment has become increasingly diverse and complex with the advancement of innovative technologies; the ability of users to evaluate the credibility of the system has become crucial, because it can explain differences in users' ability to harness the system.

It is evident that the experience of users can have a positive effect on user familiarity online, depending on the medium and frequency of use, and thus improve user confidence (Phythian *et al.*, 2014). The experience of users can influence trust in information and resources online. On the other hand, accumulated knowledge of online information and resources resulting from experience can enhance users' capability to evaluate, as well as increase their awareness of, online issues such as security and ethics, which can negatively affect users' perception of trust. It is worth noting that either reasoning is based on the premise that an individual's level of experience online is a factor influencing increases in his/her capabilities and knowledge.

South Korea's ICT Strategy and Digital Culture

The Korean Government's information and communications technology (ICT) policy is an exemplary case of strong government drive, which led to a rapid and high penetration of broadband networks (Kongaut & Bohlin, 2015; Park & Kim, 2014). Since the early 1990s, the Korean Government has established progressive master plans for the development of an information society including: the First National Informatisation Promotion Plan (1996–2000), Cyber Korea 21(1999–2002), e-Korea Vision 2006 (2002–2006), Broadband IT Korea Vision 2007 (2003–2007), and the U-Korea Master Plan (2006–2015). Since rolling out broadband infrastructure, the Korean Government has recognised digital inclusion as an integral component of the digital economy which reduces the digital divide within its population. This has led to a series of additional policy practices including extensive computer training in rural areas, localised ICT promotion projects, and the construction of public database access systems (NIA, 2013).

As Korea becomes a fully-fledged information society, there have been increasing calls for a shift from equality of access to more effective use of the available technology throughout the entire population (Nansen *et al.*, 2013; Shin & Jung, 2012). While early ICT policies encouraged the diffusion of an information culture throughout society in order to build the foundation for a knowledge-based society, this paradigm has shifted. There has been a move away from increasing access and reducing digital inequality towards enhancing the reliability of information resources (Kim, Shin & Lee, 2015). The aim is to increase opportunities for reliable utilisation of online information resources and ultimately to produce a more mature digital society. Trust online has been deemed to be an important social recourse that facilitates a more transparent social system and enables coordinated social interaction online in the national ICT-driven vision.

In this study, we conducted a secondary data analysis of a national survey on Korean internet use and digital culture. The survey is part of the Korean Government's ongoing efforts to enhance digital culture and promote awareness of its value by continually measuring Koreans' digital life and perception of the internet, including trust in online information.

This study focuses on identifying the differences in users' perception of online trust and further examines whether there is a difference in the relationship depending on the different types of online experience, such as content creation, communication and online transactions.

Methodology

Research questions

The research questions of this study are:

RQ 1: What is the relationship between the user's experience of the internet and perceived trust of the information online?

RQ 2: What is the relationship between the types of online activities users engage in and the perceived trust of the information online?

National survey on Korean internet use and digital culture

As mentioned above, this study conducted a secondary analysis of a national survey dataset in order to answer the research questions. The original dataset was collected using face-to-face structured interviews with those who had used the internet via a personal computer (laptop/desktop) and mobile devices, such as a smartphone or tablet, during the last month. The participants were selected in 2013 in South Korea using a multi-stage, stratified random sampling method. Gallop Korea (http://www.gallup.co.kr/), who were commissioned by the National Information Society Agency (NIA), conducted the survey. Overall, 4,650 Koreans aged six years old or over were surveyed in 17 major provinces. Of these, we selected 3,641 subjects aged over 20 years for this study, thereby confining our analysis to adults. Of the 3,641 participants, 53.2% were male and 46.8% were female. The age distribution of participants was as follows: 20-29 (22.8%), 30-39 (27.0%), 40-49 (27.0%), 50-59 (16.2%), and 60 or over (7.5%). A breakdown by education level showed that 44.9% were educated at the high school level or lower, 44.6% at the undergraduate level, and 1.5% at the postgraduate level.

The original questionnaire consisted of 40 items in three parts, including six sub-parts: internet use (digital life and participation), cognition (digital trust and tolerance), and norms (ethical awareness, and ethical attitude and behaviour). For this study, we selected the online activities and trust in online information variables. The measurements of the variables used are outlined below.

Online activities. Engagement levels in content creation, transactions and communication activities with ten items were measured on a 5-point Likert-type scale (Tullis & Albert, 2013) of (1) 'more than once a day', (2) 'more than once a week', (3) 'more than once a month', (4) 'less than once a month', and (5) 'never'. These frequency variables were reverse-coded and used as a continuous variable. Content creation activities included 'post or reply to something online', 'upload photos or videos', and 'share posts/photos/videos of others.' Transaction activities included 'online banking', 'online purchasing or booking', and 'requesting public documents online'. Communication activities included 'email', 'online communities', 'social networking sites (SNS)', and 'instant messaging (IM)'. The mean score for the items in each activity (content creation, transactions and communication) was calculated and respondents who scored 'less than 1' were categorised into the non-user group, whilst those scoring '2 or more' were placed into the user group. We divided the user group in two — infrequent users (less than 3) and frequent users (3 or more). The non-users were excluded from the analysis.

Trust online. Participants were asked how much they trusted online information published or presented on (1) e-commerce websites (online shopping sites or companies' websites), (2) government and public service websites, (3) news media, and (4) SNS. All items were answered on a 5-point Likert type scale (1= not at all, 5= very much).

Results

Differences in perceived trust between different demographics

We compared the perceived trust levels between different demographics, including gender, age and level of education. Interestingly, there was no significant difference between those with a high school level of education or below and degree holders. Also, no significant generational gaps in trust of online information (except news) were observed. In terms of online news, younger respondents were less likely to trust this domain than older respondents. There were some gender differences in perceived trust. A higher level of trust was observed among female respondents in e-commerce (M=3.19) and online information from SNS (M=3.20) than in male respondents (Table 1). There was no significant difference when it came to sources from government and news organisations.

Table 1. Gender difference in perceived trust of online information

Gender	N	E-commerce		Government source		News		SNS	
		M	SD	M	SD	M	SD	M	SD
Male	1,937	3.09***	0.790	3.54	0.809	3.50	0.812	3.14**	0.796
Female	1,704	3.19***	0.735	3.54	0.798	3.55	0.781	3.20**	0.733

$^{*}p < 0.05$ $^{**}p < 0.01$ $^{***}p < 0.001$

Differences in perceived trust between internet non-users and users

T-tests[ii] were conducted to examine the relationship between the experience of online activities and the perception of trust in online information. We divided respondents into two groups, those engaged in creating content, transactions or communications online (users), and those who had not engaged (non-users). As shown in Table 2, higher trust of online information was observed among the user group. However, the pattern of trust differences between the two groups differed by the type of online activity the group was engaged in. For content creation, there were significant differences in perceived trust between the two groups: those who had engaged in content creation activities online (M=3.57) were more likely to trust in government sources, news and in information from SNS (M=3.21) than non-users. However, trust of e-commerce showed no significant difference. In terms of transactions, there was a significantly higher trust of e-commerce (M=3.16), government sources (M=3.58) and news (M=3.54) among those engaged in transactions online, while no significant difference of trust in information on SNS was observed. For communication, there were significant differences of trust in e-commerce (M=3.14) and online information from SNS (M=3.17) when we compared the two user groups.

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Table 2. Users' and non-users' perceived trust of online information

Online activities	Type of user	N	E-commerce		Government source		News		SNS	
			M	SD	M	SD	M	SD	M	SD
Content creation	Non-user	1,007	3.10	.788	3.47***	.793	3.45**	.796	3.06***	.799
	User	2,634	3.15	.757	3.57***	.806	3.55**	.797	3.21***	.752
Transaction	Non-user	621	3.04***	.841	3.38***	.808	3.41***	.774	3.15	.785
	User	3,020	3.16***	.748	3.58***	.799	3.54***	.801	3.17	.765
Communic-ation	Non-user	147	2.98*	.762	3.47	.850	3.46	.864	3.01*	.893
	User	3,494	3.14*	.766	3.55	.802	3.52	.795	3.17*	.762

*p < 0.05 **p < 0.01 ***p < 0.001

The *t*-test results suggest that trust in online information may vary depending on the types of online activities in which users are engaged. In the next section, in order to further understand the perception of trust in online information among users, we examined trust levels for each type of online information as classified by its source and for each kind of online activity among users.

Does perceived trust depend on the type of online activities that users engage in?

In order to examine the trust differences between different levels of engagement in online activities involving content creation, transaction and communication, we first divided the users into two groups — frequent and infrequent users — and then conducted a *t*-test.

As shown in Table 3, there was a higher trust of online information among infrequent users. For content creation, there were significant differences in perceived trust in e-commerce (M=3.18), government sources (M=3.60) and news (M=3.61), indicating that frequent users are less likely to trust in e-commerce, government sources and news than infrequent users. However, there was no significant difference of trust in information observed for SNS. When it came to transactions, regardless of the type of information, infrequent users' perception of trust online was significantly higher than that of frequent users. On the other hand, those who were more frequently engaged with communication activities online (M=3.21) were more likely to trust in the information from SNS.

Table 3. Perceived trust by frequent and infrequent users

Online activity	Type of user	N	E-commerce		Government source		News		SNS	
			M	SD	M	SD	M	SD	M	SD
Content creation	infrequent	1,751	3.18**	.770	3.60*	.775	3.61***	.774	3.22	.749
	frequent	883	3.09**	.729	3.51*	.861	3.44***	.829	3.18	.758
Transaction	infrequent	2,607	3.18**	.754	3.61***	.787	3.58***	.787	3.19**	.760
	frequent	413	3.05**	.702	3.38***	.846	3.30***	.844	3.05**	.781
Communic-ation	infrequent	1,644	3.12	.791	3.54	.811	3.53	.797	3.13**	.748
	frequent	1,851	3.16	.742	3.55	.794	3.52	.793	3.21**	.772

*$p < 0.05$ **$p < 0.01$ ***$p < 0.001$

Discussion

With the increasing integrity of the online environment, the internet has become one of the most trusted sources of information among users along with traditional media such as newspapers and television. In particular, most developed countries such as South Korea have fully embraced the online environment in their everyday lives. The Korean government has intensively focused on ICT development across all sectors of the society by implementing a series of strong, government-driven ICT policies. However, there has been an increasing social need for the building of a mature information society, which can lead to a range of initiatives aimed at building trust and confidence in the internet. The National Information Culture Survey (NICS) is one such effort by the government to increase awareness of digital culture and reliable online information among users.

This study attempted to better understand online trust among internet users by examining the relationship between the perception of trust and online user engagement. This engagement involved different activities such as online communication and transactions.

The first finding in this study was that those who engage in online activities, including creating content, undertaking transactions and/or communication, are more likely to trust in online information, such as e-commerce, government sources and news and information on SNS, than those who do not. In the literature on e-commerce, user familiarity has been deemed to be one of the significant contributors to increasing users' trust online (Bart *et al.*, 2005; Corbitt, Thanasankit & Yi, 2003; Gefen, 2000; Yoon, 2002). While the concept of familiarity has been mainly studied on online platforms, such as websites, it seems that our results showing higher levels of trust online amongst users versus non-users is in line with these studies. However, the perceived trust among users varied depending on the types of online activities in which users were engaged and the types of information being accessed. It is notable that those who engage in transactions online are more likely to trust e-commerce, e-government and news online, whereas those who engage in online communication via email, online communities and SNS are more likely to trust information found on SNS. This result may imply that trust in these ICT-based applications and content is, to a degree, established among users in Korea.

In order to further understand the perception of trust in online information among users, we attempted to examine trust differences between different levels of engagement in online activities. The second finding reveals that, surprisingly, those who engage more frequently in online activities are less likely to trust online information than those who use it sporadically. This is especially the case for online transaction users who, amongst the frequent users, show significantly lower trust in all online information. However, this is not the case for online communication users: those who engage in communication activities online are more likely to trust the information found on SNS. Johnson and Kaye (2014) conclude from their studies on SNS and user credibility that the credibility of SNS is linked to the degree of reliance on SNS. This shows that frequent and loyal users find SNS more credible than less frequent users. They explain that it may be due to frequent users being more experienced and thus more adept at filtering untrustworthy information and sources. Our results above partially support such an assertion.

Although different patterns in terms of trust online were found among users, our results explicitly show that there is a 'trust gap' among some internet users, which needs to be further understood in order to continue enhancing the quality of ICT development. In many countries, including Korea, ICT policies have largely focused on the development of hardware such as networks and devices in order to improve their competitiveness in the field. It was believed that increasing the development of ICT environments in terms of hardware would lead to improvements in quality, such as narrowing social inequality between social groups and promoting openness and transparency in a society (Shim & Eom, 2008). However, the demand-side of ICT policies has been relatively neglected in the research as most studies have been focused on external growth factors in the field of ICT (Roy, Dewit & Aubert, 2001; Grabner-Kräuter & Kaluscha, 2003). Within this context, it is true that discussions relating to improvements in aspects of quality control, such as trust online, have been intermittently covered when analysing the issue of the digital divide (Nieminen, 2016; Kim & Park, 2015; Warschauer, 2004). However, the findings show that environment-centred policies and improvements in quality in the field of ICT can be another focus. In other words, the supply-side outcomes driven by ICT policy may not automatically result in mature digital cultures. Indeed, for the last decade, we have witnessed increasing online risks in parallel with the increasingly evolving adoption of innovation technology, including the distribution of misinformation and security risks. Digital trust has become the primary focus for policy makers to develop ICT environments that balance quantity and quality in a society.

The findings in this study suggest that it is diverse factors, such as individual attributions beyond environmental factors, that influence trust in online information. Such user-focused factors should be taken into account in the furthering of research into trust online from the digital literacy perspective. For example, one possible interpretation from the findings in this study is that the digital literacy gap could lead to a trust gap, not only between users and non-users but also among users. As social interactions and exchanges are predominantly carried out online, trust online has become a crucial component in building a reliable digital society. Buell (2016) highlights that confidence in the internet is a key factor in enhancing users' trust online. In order for users to continue to trust the internet and to ensure a mature digital society, users need to be informed about online risks and ways to protect their privacy and security from the negative and harmful aspects associated with the internet. There is a critical role for industry and governments in continuing to improve user awareness to increase trust online. This will include ensuring that internet users are more aware of the online risks and dangers they face and are able to identify appropriate sources of information.

Conclusion

This study used robust national survey data on Korean internet use and digital culture to examine the relationship in South Korea between an internet environment developed by strong national policy and the level of user trust in cyberspace. It found that there is a significant gap in online trust between non-users and users as well as among users, showing the degree of scepticism about online information and content amongst frequent users of the internet. Contemporary society has witnessed a persistent growing mistrust in many areas; for example, trust in the news has continually declined in many countries, including Australia and Korea, over the last few years (Fisher *et al.*, 2019). The findings of this study may be indicative of the mistrust which has become pervasive over the last few years.

This paper is not without limitations. As previously noted, we carried out the analysis with secondary data from the NIA. While the data used in the analysis is representative of the population, having been gathered nationally and systematically, there were limitations in operationalising the concepts of trust and online engagement with the data collected originally. Secondly, the data used for this study may be somewhat dated, given that digital technology has been rapidly evolving over the last few years and society has also changed accordingly. Nevertheless, the findings of this study are well worth discussing, considering the

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current circumstances surrounding digital trust, and provide insights into the pressing issue of mistrust and the digital divide.

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Endnotes

[i] The Korean Information Culture Index was first developed in 2008 to measure Korean informatisation capability, and the Government integrated the Index with other existing national surveys on Koreans' internet use and digital culture in 2015.

[ii] A *t*-test is a type of inferential statistic used to determine if there is a significant difference between the means of two groups.

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The Effect of Social Media Regulatory Content Law in Indonesia

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Abstract: Nowadays, information technology (IT) has been used widely in the world. People use IT in their jobs and get the latest information about everything that happens in the world. Therefore, IT has a big impact on peoples' lives. Information can be found easily in a news portal, social media, and a search engine. This study used social media WhatsApp, Telegram, Facebook, and Instagram as the primary sources. In using social media, people can share positive (news, current research) or negative (hoax) information. Unfortunately, messages can be shared without verifying their truthfulness. Many people have used social media to share fake news and bullying. Hong Kong, France, Indonesia and Venezuela are examples of countries where a hoax has become the part of peoples' lives. In Indonesia, the government created a Constitutional Law (CL), *Undang-Undang Informasi dan Transaksi Elektronik* (CL of Information and Electronic Transactions), to regulate responses to negative information and filter this kind of information. This paper analyses the effect of social media regulatory law and hoax news on social life. The results of this study show that the Indonesian CL could be useful to regulate the use of social media in other countries.

Keywords: Social Media, Social Media Regulation, Constitutional Law, Hoax News Effect

Introduction

The influence of social media on society's life has a very big impact (Idota, Bunno, & Tsuji, 2016; Bryan *et al.*, 2019). Social media can be used by people to store videos and photos of every moment with family and friends (Cheung & She, 2016; Suzor, 2018). Many people use social media to make money because it can advertise products or services (Dyson *et al.*, 2016;

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Chu *et al.*, 2019). Social media not only makes it easy to share videos, photos, and information (Bolton *et al.*, 2013), but also can be registered easily by an individual with only an e-mail (Suzor, 2018). Because of its ease of use, people may try to do irresponsible activities by creating a fake account to share negative information (a hoax) (Fang, 2017) or ethnic or religious hate speech (Valaskivi, 2007; Qin, Strömberg, & Wu, 2017; Bryan *et al.*, 2019), instead of giving positive information (news, current research).

Some government issues have been the target of fake news and shared throughout the country without being filtered. The use of social media dealing with national issues could be seen when protesters in Hong Kong urged the government to keep their country free from mainland China (Purbrick, 2019). During the highly tense situation in Hong Kong, the primary protest movement is sometimes started by the use of the messaging app Telegram, Facebook, WhatsApp, Google Maps, or Twitch (IHS Markit, 2019). Outside the primary protest movement itself, hoax news about the Hong Kong situation can also be found in social media (China Daily, 2019). Protests have occurred not only in Hong Kong, but also in France, where the Yellow Vest Movement was sparked by a fuel tax increase (Sikharulidze, 2019). The same problem of hoax news was also found in France during the Yellow Vest Movement that reached around 105 million views on Facebook alone, with 35 million Facebook monthly active users (Avaaz, 2019).

We also have collected other surprising facts. There is at least one political party or government agency using social media to spread hoax news throughout a country for shaping public attitudes (Bradshaw & Howard, 2019). During the last 3 years, there is a significant increment of social media manipulation campaigns, which have taken place in 70 countries in 2019, up from 28 countries in 2017 (Bradshaw & Howard, 2019). From this point of view, we believe that hoax news cannot be reduced or eliminated. Table 1 is a summary of the number of hoaxes in each event in the world.

Table 1. List of countries where hoaxes are found

Country	Year	The number of hoaxes	Event situation	Fact-check on hoax (processed or not)	Punishment to disseminator (processed or not)	Source
Hong Kong	2019	Around 451 hoaxes were found	To free Hong Kong from China	Processed (fact-check)	Not	China Daily, 2019; IHS Markit, 2019; Purbrick, 2019
France	2019	100 top hoax news	French Yellow Vest Movement	Processed (fact-check)	Not	Avaaz, 2019; Sikharulidze, 2019

Country	Year	The number of hoaxes	Event situation	Fact-check on hoax (processed or not)	Punishment to disseminator (processed or not)	Source
Indonesia	2019	620 hoax news items during election event	Presidential election	Processed (fact-check)	6 hoaxes have been processed (jailed and fined as punishment)	Kemkominfo, 2019
Venezuela	2017	Nearly 300 hoax news items were detected	Fight President Nicolas Maduro regime	Processed (fact-check)	Not	Ellis, 2017

To reduce negative information (hoaxes) in social media, the Indonesian government is trying to minimize the dissemination of negative information by punishing every disseminator (Qin, Strömberg, & Wu, 2017). Unfortunately, Constitutional Law (CL) (Kemenkumham, 2008) is still weak in its application (Luxton, June & Fairall, 2012; Raudsepp, 2019).

The CL *Undang-Undang Informasi dan Transaksi Elektronik* (CL of Information and Electronic Transactions) (UU ITE) No. 11/2008 is the first law in Indonesia regulating IT criminal offenses. The Draft of UU ITE was issued in March 2003 by the State Ministry of Communication and Information. In September 2005, the draft of UU ITE was delivered to the People's Representative Council (DPR) of Indonesia. In April 2008, UU ITE was passed. The process took 5 years from 2003 to 2008. Therefore, UU ITE is a relatively new law in terms of time and material aspects. The law itself has 13 Chapters and 54 Articles.

From Table 1, we can see that the CL can punish a disseminator in Indonesia. The table also shows that Hong Kong, France and Venezuela have no CL to punish a disseminator. Even though the application of the CL is still weak, we, the authors, believe that the CL can be used wisely in other countries if the other countries want to adopt it. In this paper, we describe the relationship between hoaxes in social media and the CL. The next section indicates different types of hoaxes. The following section outlines our research method and results.

Literature Review

Social media

Social media provides digitalization, interactivity and development of networks to create and send messages (Dekker, van den Brink & Meijer, 2020). Social media offers an interactive way for users to choose any readable information and control their output (Zhu, Chan & Chou, 2019). Social media is communicated through an application, such as Telegram, WhatsApp, or Twitter.

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The growth of social media allows users to share information (He *et al.*, 2020). Communication changes from using social media can include belief, attitude, a view of the world, social organization, human character, activity orientation, and the perception of others (Fogel & Adnan, 2019).

Hoaxes in social media

Today, while the development of social media can be appreciated in many ways, social media sometimes is used to spread hoaxes (Park & Rim, 2019). The use of social media in disasters can be analysed to identify rumours but cannot detect and control spreading rumours, especially hoaxes (Zhang *et al.*, 2019). Lots of receivers will believe hoax news and send it to their friends, colleagues, and families. It is worse if the disseminators do not have sufficient knowledge in using the internet to validate hoax news (Ozbay & Alatas, 2020).

There are some categories of hoax news:

1. Fake news can be purposed to change the original news. A writer of fake news usually adds their own fake information. If the readers accept misleading news, they will confirm it as real news.
2. Clickbait is a link that is strategically located in a site for transferring people's attention to enter other links. There is often an interesting picture to get the reader's attention (Shang *et al.*, 2019).
3. Confirmation is a where the receiver accepts the newest event as a fact (van Brussel *et al.*, 2020).
4. Misinformation is false information intended to fool the victim (Wang *et al.*, 2019).
5. Satire can be explained as a comment on today's news that is being exaggerated (Salas-Zárate *et al.*, 2017; Khan *et al.*, 2019).
6. Post-truth is an emotion control using facts to create public opinion (Cheng & Lee, 2019).
7. Propaganda is an activity to spread information, argument, fact, and even lies to create public opinion (Loeb *et al.*, 2019).

Constitutional Law

UU ITE No. 11/2008 can be said to be a CL published by the Indonesia government to control every national development impacted by IT (Kemenkumham, 2008). Also, this law has broader jurisdiction not only to impact legal actions in Indonesia, but also legal actions outside Indonesia. Examples of legal actions outside Indonesia could be legal action conducted by foreigners, corporations, or a legal entity (Brown & Dent, 2018; Gintova, 2019).

UU ITE actions in Indonesia may have broader territorial or even universal implications (Thornthwaite, 2016; Zhang *et al.*, 2019). To reduce any negative effects, the government may choose to deploy cyber police for digital law enforcement.

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There are some benefits of UU ITE No. 11/2008 being applied, such as (Kemenkumham, 2008):

1. To ensure legal certainty for society transacting electronically/digitally;
2. To push Indonesian economic growth;
3. To prevent IT-based crime;
4. To protect society members utilizing IT.

With the presence of UU ITE, there are some other benefits (Kemenkumham, 2008):

1. Every electronic transaction and its derivatives have legal protection. Society should optimize every opportunity of the digital economy and have the chance to become an electronic certification provider.
2. E-tourism gets legal protection. Society should maximize the value to the Indonesia tourism industry by utilizing IT services.
3. Indonesia's internet bandwidth should be used very well to advance the nation. Society should use internet access to promote healthy content in accordance with Indonesian culture.
4. Indonesian Internet transactions can be received on time by subscribers in the destination country. Society should use the opportunity to maximize national creativity to compete in global challenges.

Research Method

Doctrinal research

The research uses doctrinal-based research or library research (Ali, Yusoff & Ayub, 2017). It is a common style of research in law areas. There are some questions raised regarding the law, such as: what kind of law should be applied in a certain case? (Hutchinson & Duncan, 2012). This research studies associated doctrinal analysis of law in social media cases.

Theoretical research can be said to be research aiming to find a certain legal position or use logical analysis to find out something more complex (Hutchinson & Duncan, 2012). In short, library research tries to find the "right answer" for a certain legal statement. Therefore, this kind of research tends to create a specific question to identify related pieces of information (Ali, Yusoff & Ayub, 2017). Every specific question seeks answers to be verified. This is the purpose of doctrinal research (Stefan-Duicu & Stefan-Duicu, 2015): see Figure 1.

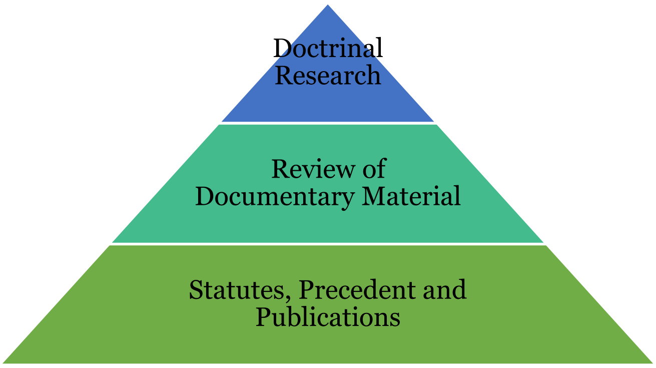

Figure 1. Doctrinal research

Data analysis by doctrinal method

Data with hoax news are collected, then processed by using the doctrinal method. After that, each hoax case should be classified into an article in CL.

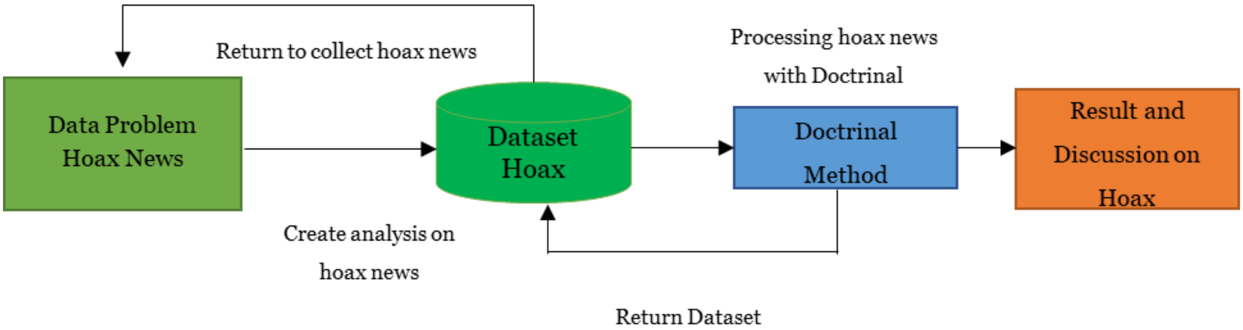

Figure 2. Dataset processing hoax news

The IT Cyber Crime in Indonesia

IT crime review

The Internet drastically changes relationships between distance and time, so that there is a sense where no borders can be found in the Internet world. Every person with Internet access can talk and conduct business with other people on other continents by just using a keyboard and mouse (Bolton *et al.*, 2013; Luxton, June & Fairall, 2012).

In the early days, cyber-crime was defined as computer crime. The use of the term computer crime is diverse, and experts use the computer-crime term because it is broader and used internationally (Thornthwaite, 2018).

IT development, especially the Internet, may challenge law development in Indonesia. Indonesian law is required to adjust to every social change that has occurred. Changes in society and the law are not always together (Brown & Dent, 2018; Eaton, 2014). It means that Indonesian law may be left behind by the development of culture and other elements of society (Fang, 2017).

A platform of received hoax distribution

Dissemination of hoax news can be easily found in social media (Zhu, Chan & Chou, 2019; Talwar *et al.*, 2019). Figure 3 exhibits every application that disseminates hoax news.

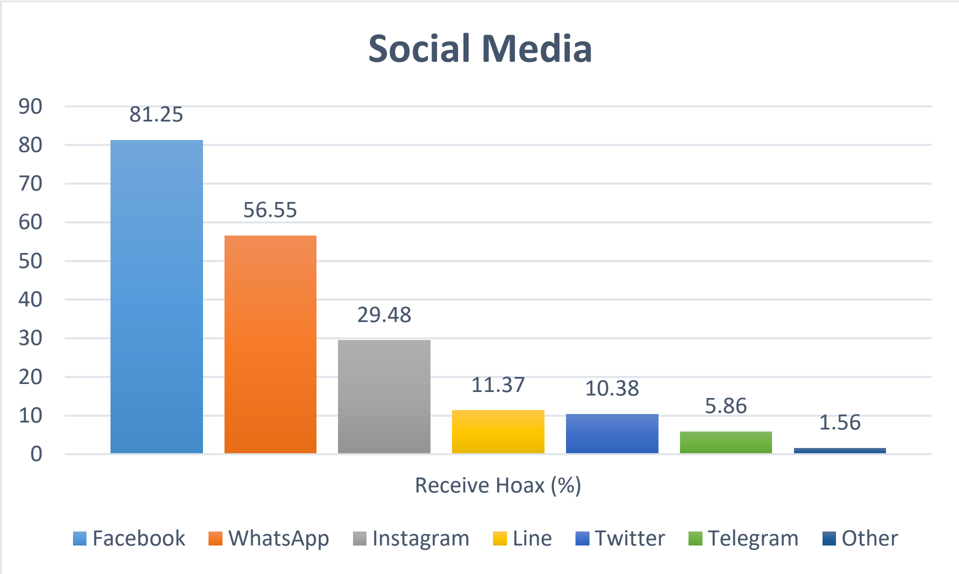

Figure 3. A platform of Application for Hoax Distribution (Randi Eka, 2018)

Social media applications, such as Facebook, WhatsApp, and Instagram, are very popular in Indonesia. Children, teenagers, and adults are users of these applications (Rasmussen *et al.*, 2020). The Dailysocial.id research team used mobile survey platform Jackpot to ask 2,032 smartphone users regarding hoax news dissemination. In Indonesia, Facebook is the first ranked on hoax dissemination by 81.25%. The second ranked is WhatsApp by 56.55%. The third ranked is Instagram by 29.48%.

Hoax news on politics

The Ministry of Communication and Information Technology (Kemkominfo) noted 486 hoax news postings during April 2019, with 209 with hoax news on politics. Hoax news is focussed on General Election Commissions (KPU), political party participants, and the Board of Election Watchdog (Bawaslu). Kemkominfo collected hoax news from August 2018 to April 2019. A total of 1,713 hoax news postings were gathered. Figure 4 depicts a hoax news classification.

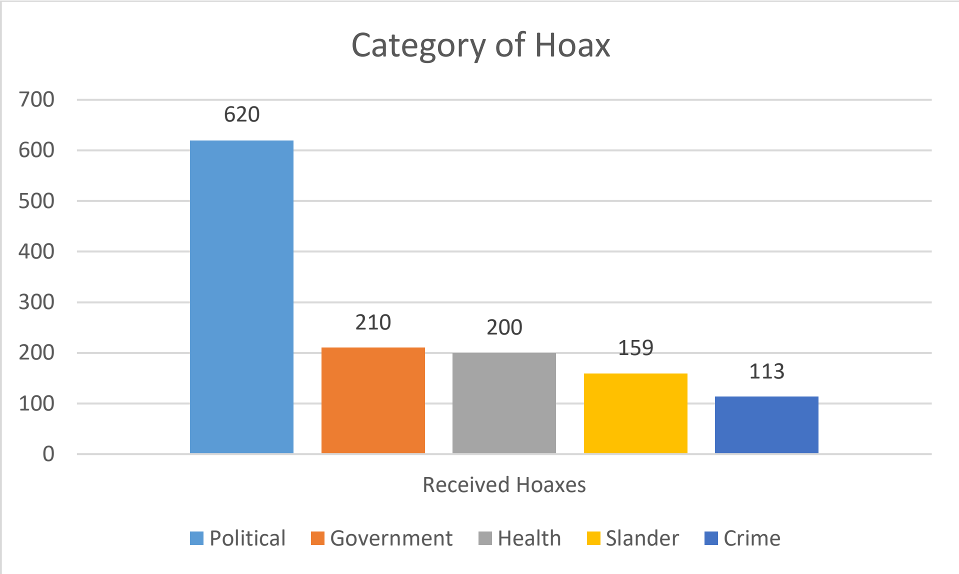

Figure 4. Hoax classification (Kemkominfo, 2019)

Result and Discussion

Analysis result of Constitutional Law for reducing hoax cases

This paper highlights the use of information on social media as evidence in defamation cases based on UU ITE No. 11/2008. Further discussion regarding the crime of defamation in UU ITE No. 11/2008 is emphasized in article 27, paragraph 3, which regulates criminal acts of defamation.

In application, article 27, paragraph 3, expresses concerns for the community. Some blogger activists, Legal Aid, the Human Rights Association (PBHI), Alliance of Independent Journalists (AJI), and the Legal Institution of the Press can apply to the constitutional court (MK) for a material test of article 27, paragraph 3. MK itself has already declared the regulation is valid, as stated in MK decisions No. 50/PUU-VI/2008 and No. 2/PUU-VIII/2009.

The essence of humiliation for the real and virtual worlds is similar. This applies to attacks on people through publicity. So, to be called out publicly is the essence of article 310 of the Criminal Code (KUHP), together with article 27, paragraph 3, of UU ITE.

Table 2. Classification analysis of hoax news into CL

Article in CL (UU ITE)	Hoax News Cases	As of date
Article 28	1	4 Oct 2018
Article 14, paragraph 1	1	6 Apr 2019
Article 27, paragraph 4	1	6 Apr 2019
Article 27, paragraph 3	2	11 Jun 2019, 3 Jul 2019
Article 28, paragraph 2	1	23 Apr 2019

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Article in CL (UU ITE)	Hoax News Cases	As of date
Article 45, paragraph 4	1	6 Apr 2019
Article 45, paragraph 3	1	3 Jul 2019
Article 46, paragraph 3	1	11 Jun 2019
Article 28, paragraph 2	1	6 Apr 2019
Article 45, paragraph 2	3	6 Apr 2019, 15 Aug 2019, 23 Apr 2019

In Table 2, we classify the number of hoax news cases during the Presidential election in 2019; there were 6 hoax news cases that had been processed. All 10 cases are categorized into 5 articles. Hence, the disseminator can be punished by CL.

Conclusion

This research has shown the effect of social media regulatory law and hoax news on social life. Ideally, very negative items of information (hoaxes, hate speech, slander) disseminated through social media could be snared by UU ITE. Social media should be intended to offer positive information and used to minimise negative information.

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Mobile Technologies, Financial Inclusion and Inclusive Growth in East Indonesia

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Abstract: This paper examines the influence of mobile technologies on financial inclusion, and the matter of whether mobile technologies and financial inclusion have an impact on the income of individuals in East Indonesia, considering the data from the Survey on Financial Inclusion and Access (SOFIA) in 2017. A seemingly unrelated probit model and an ordinary least-squares model are used to compare both determinants of formal and informal financial services, as well as simple and smart mobile technologies. The study finds that mobile technologies and access to finance significantly increase the likelihood of higher incomes. Smart technologies and formal finance have higher effects on incomes compared to the effects of simple devices or semi-formal and informal finance. Significant gaps in financial access exist between individuals in accordance with gender, income, education, and location. Technologies account for a small difference in the broader access to financial services.

Keywords: Financial Inclusion; Mobile Technologies; Inclusive Growth; Financial institutions; Indonesia

Introduction

Financial inclusion is defined as having access to formal financial services either for saving, borrowing, or conducting financial transactions (Wang & Guan, 2017) at competitive cost (Mehrotra & Yetman, 2015). Several countries (including Indonesia) have increased their

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numbers of 'bankable' people since a decade ago (Demirguc-Kunt *et al.*, 2018). Nevertheless, Indonesia still has 17% of its total population financially excluded (that is, they have no bank accounts), nearly 40% excluded from savings, and almost 60% excluded from credit. Above and beyond this, critical gaps exist among individuals in Indonesia with respect to financial inclusion. Those in urban areas who are male, older and with higher education, along with those who work in non-agricultural activities and earn high incomes, are more likely than those without these advantages to be financially included.

Although financial entities in Indonesia are liquid and profitable, still a large portion of the population remains unbanked (Rosengard & Prasetyantoko, 2011). Banks face greater adverse borrower selection with implications of lower efficiency and the threat of non-performing loans (Hanh, Daly & Akhter, 2016) if they allow 'bankability' among the whole adult population, which possibly explains why lower-income people have remained unbaked (Wang & Guan, 2017). For instance, a focus on financial performance, market competition, or financial infrastructure alone may not lead to higher financial inclusion.

On the other hand, the link between bankability and mobile technology use suggests that mobile technologies support broad access to finance (Asongu & Nwachukwu, 2016) and have a positive impact on inclusive growth, while mobile users also generally have higher incomes (Asongu, 2015; Asongu, 2013). In 2017, there were nearly 174 mobile devices per 100 persons in Indonesia, although only 40% of individuals were connected to the Internet (ITU, 2018). While smartphones have gained rapid usage (Das *et al.*, 2016), still only 32% of the phones were connected to the Internet in 2017, according to the Financial Inclusion Insight Survey (2018), and only 5% of transactions were financial according to the same survey.

This study questions whether access to mobile technologies influences the likelihood of individuals in East Indonesia enjoying improved financial access, and whether technologies play a role in removing obstacles to banking, while driving banking services. This study focusses on individuals' characteristics, such as income, education, age, gender, and rural-urban location, which are likely to influence their participation in finance (Corrado & Corrado, 2015; Fungáčová & Weill, 2015). The study also investigates whether people in East Java, Indonesia (Jatim hereafter), display different attitudes towards financial services compared to people from three other provinces outside Java. East Java is the second largest province in Indonesia (with 40 million people of the total 270 million nationwide). East Java is also the gateway to East Indonesia. A further contribution to the literature arises as we investigate whether broader access to technology and better access to financial services play a role in improving the welfare of individuals in Indonesia (higher income). The effect of mobile technology on finance and the combined effects of technology and finance on income remain as empirical questions.

This study uses the Survey on Financial Inclusion and Access (SOFIA) in 2017, which includes East Java, West Nusa Tenggara (NTB), East Nusa Tenggara (NTT) and South Sulawesi, and has a total sample size of 20,000. A probit method is employed to analyse how individual characteristics – gender, age, income level, education, and location (rural/urban) – contribute to the determinants. Additionally, the model developed introduces binary data on low-tech (basic mobile phones) and high-tech devices (smartphones/Internet/PCs) to analyse the impact they have on financial inclusion. To evaluate the impact of digital technologies and finance on income level, the paper applies ordinary least-squares (OLS) regression, differentiating impacts based on the type of finance (formal, semi-formal, informal, and family), the level of technology (low or high), and income level (low, medium, and high). A seemingly unrelated regression equation (SURE) probit model is employed for robustness.

In Indonesia, financial inclusion plays a central role in the government's financial development agenda (OECD, 2018), as there is evidence that finance plays a vital role in reducing poverty and income inequality (Park & Mercado, 2015; Swamy, 2014) and that it supports inclusive growth (Sanjaya & Nursechafia, 2016). Financial inclusion is expected to allow larger expenditures, to multiply sources for borrowing, to increase the prospect of being employed (Bruhn & Love, 2014), to allow larger savings or credit for education or entrepreneurial investment (Demirgüç-Kunt & Klapper, 2012), to support the empowerment of women, to cushion against financial shocks (Han & Melecky, 2013), and to manage risk amid hard-hitting times (Dienillah & Anggraeni, 2018). This paper contributes to the literature of financial inclusion as it offers evidence of the determinants of financial inclusion based on an individual's characteristics, and analyses financial products according to formality. Additionally, this paper considers the effect of mobile technologies and financial inclusion combined, whereas earlier research has considered the effects of each only individually.

Literature Review

In this section, there are two main points addressed: first, the relevance of financial inclusion for welfare; and, second, links between mobile technology and finance. Addressing financial inclusion is relevant as there are welfare benefits for recipients by their having broader access to financial services. A more inclusive financial system could help decrease poverty beyond urban areas (e.g., the Indian case (Burgess & Pande, 2005)), reduce unemployment (Bruhn & Love, 2014), allow individuals higher expenditures (Dupas & Robinson, 2013), raise the national saving levels (e.g., the Malawi case in Brune *et al.* (2016)), support government policies (e.g., poverty reduction programs in Beck & Demirgüç-Kunt (2008)), and help in aid transfers. Financial inclusion plays a decisive role in firm performance, through either informal financial services (Allen, Qian & Xie, 2018) or through formal finance arrangements

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(Chauvet & Jacolin, 2017), where it supports a competitive landscape for firms. In Indonesia, although a general deepening in financial services is on-going (Riwayati, 2017; Tambunan, 2018), significant social gaps in financial access remain, where access to savings and credit is low for younger people, the less-educated, lower-income individuals, and those out of the labour force (Demirguc-Kunt *et al.*, 2018). Besides the challenges to close social gaps, financial literacy and skills in ASEAN remain low (OECD, 2018).

Efforts to advance financial inclusion are in place (Llanto, 2015; Tambunan, 2018; Yoshino & Morgan, 2016), which will promote financial literacy, regulation, and the facility to expand services. Nevertheless, Indonesia ranks as an average country in financial inclusion, as demand for finance is limited to basic services (e.g., payments, as in Kostov, Arun & Annim (2015)), which offer only weak incentives for banks to expand. Besides, the high cost of finance, barriers, market failures, and self-exclusion remain (Cole, Sampson & Zia, 2011). Substantial evidence suggests that low financial literacy and a poor level of financial knowledge are critical to low financial inclusion (Allen *et al.*, 2012; Grohmann, Klühs & Menkhoff, 2018). Cole, Sampson & Zia (2011) provide evidence for how financial literacy and knowledge influences financial behaviour that is associated with better decision-making, broader demand for banking services, and wiser use of accounts. Technology provides a potential link to address financial literacy and knowledge, as mobile technologies contribute to more in-depth financial inclusion (Ouma, Odongo & Were, 2017), by providing information (Abor, Amidu & Issahaku, 2018), broader access to services, facilitating account management and securing transactions. Additionally, technology creates a more conducive environment for banking associated with broader access, lower cost, proximity, and less documentation, by removing barriers (Allen *et al.*, 2016).

Nevertheless, in developing countries, socio-economic gaps among individuals are wide, with technological improvements making uneven differences in the broader access to financial services, as other barriers may hinder individuals from accessing services. Gaps among individuals are observed in gender (Demirguc-Kunt & Klapper, 2012; Ghosh & Vinod, 2017; Swamy, 2014), culture, education (Zins & Weill, 2016), job status, economics (Aterido, Beck & Iacovone, 2013), or with legal-social structures (Demirguc-Kunt *et al.*, 2013). As those socio-economic gaps prevail, critical breaches remain among individuals with respect to financial inclusion. Informal financial services, as opposed to formal finance, including interpersonal borrowing, trade credit, private money houses, pawnshops, and cooperatives, are widespread in developing countries (Fungáčová & Weill, 2015; Grohmann, Klühs & Menkhoff, 2018). Allen, Qian & Xie (2018) noted that the existence of informal finance arises as informal investors have superior information and stronger networks than formal institutions that help in reducing hazards and adverse selection. Mobile technology could assist in intermediation –

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moral hazard and adverse selection – and deliver finance at a lower cost than conventional finance (Beck, Demirguc-Kunt & Martinez Peria, 2007), while closing the gap of low financial knowledge and bridging exclusion.

Methodology

Data

This study uses the most recent survey (that of 2017) from Indonesia's Survey on Financial Inclusion and Access (SOFIA), which covers the provinces of East Java, West Nusa Tenggara (NTB), East Nusa Tenggara (NTT) and South Sulawesi, with a total sample size of 20,000 individuals within 93 districts and 1,250 villages. The database provides indicators on access to an array of financial services, main barriers to inclusion, motivations for saving and seeking credit, sources of credit, mobile finance, and informal finance. The micro-level data allows for individual differences in gender, age, income, education, location, and employment, and differentiates financial services by formality: account, savings or credit.

While considering the structure of the SOFIA Database (answers under a dummy structure – yes or no, one or zero), this study uses a probit regression, with a dependent variable (y_i) taking values of one or zero. The model assumes that y^* is determined by a set of exogenous variables introduced as controls in a z' vector (e.g., gender, age, income, education), so that:

$$y_i^* = z_i^{'}\beta + u_i \tag{1}$$

$$y_i = 1 \text{ if } y_i^* > 0;\ y_i = 0 \text{ otherwise,} \tag{2}$$

where the subscript i represents individuals, the vector β contains the parameters of the model, and u is the normal distribution error term, assumed to have an average of 0 and variance of 1. The model assumes a critical threshold in y_i when y_i^* is over y_i, indicating that the individual is financially included (in either of the services tested), as noted in Martínez, Hidalgo & Tuesta (2013).

The probit model is estimated using the standard maximum likelihood approach as:

$$y_i^* = \alpha + Male_i + Age_i + Age^2{}_i + Edu_i + Inc\_low_i + Inc\_med_i + Rural_i + JATIM_i + Tech\_low_i + Tech\_high_i + u_i \tag{3}$$

where y represents the variable for financial inclusion, the sampled individual is i, and the additional independent variables are the explanatory components. As z′ parameters (β'), a set of variables are proposed in Table 1.

The impact of the different technologies (low or high) and the effects of each sort of financial service is regressed against the income level groups employing an OLS regression model.

$$y_i = \beta_0 + \beta_1 Z_i + \beta_2 \gamma_i + \beta_3 \tau_i + X_i^{'}\delta + \varepsilon_i \tag{4}$$

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where y_i represents the income of the individual (low, medium, or high), Z_i is the proxy for access to a simple mobile phone, γ_i measures access to smartphone/Internet/computer, τ_i represents access to financial services (formal, semi-formal, formal non-bank, family, informal, and credit from suppliers or business). To address the endogeneity, the Woolridge test is performed (available upon request).

Table 1 Descriptions of the Variables

Variable	Definition	Measurement
Male	Gender of the respondent	1 = male; 0 = female
Age	Age	Years
Age2	Age squared	Years Squared
Edu	Education of respondent	1= Elementary (SD/ MI/ Paket A) 2= Junior high school (SMP/ MTS/ Paket B) 3= Senior high school (SMA/ MA/ Paket C/SMK) 4= Diploma (D1, D2, D3) 5= Bachelor 6= Master/Doctoral
Inc_low	Respondent who has low income (< US$ 2 a day)	1 = if yes; 0 = otherwise
Inc_med	Respondent who has medium income (US$ 2-20 a day),	1 = if yes; 0 = otherwise
Rural	Respondent lives in rural area	1 = if yes; 0 = otherwise
Jatim	Respondent's residence in East Java	1 = if yes; 0 = otherwise
Tech_low	Respondent only uses simple mobile phone	1 = if yes; 0 = otherwise
Tech_high	Respondent uses Internet/ Smartphone/Personal Computer	1 = if yes; 0 = otherwise

Source: Author's compilation from SOFIA Dataset

Finally, a latent simultaneous model (seemingly unrelated SURE probit) is applied as a robustness test to address the endogeneity issue arising in cases where having a phone or access to finance could be attributed to higher income levels rather than the other way around. SURE addresses unobserved heterogeneity, endogeneity and correlation (Abor, Amidu & Issahaku, 2018). Intuitively, it is expected that belonging to a higher income group increases the likelihood of access to high-tech and to financial services. It may be that having a middle income makes for mobile phone ownership and high-tech device ownership. That is the natural endogeneity question that often appears in studies of this class. Due to this reason, a model simultaneously estimating the ownership of mobile phones and the income status is proposed by employing a SURE model. Mobile technologies are proxied by two different dichotomous variables proxying the two different technologies employed in this study: simple mobile phones or smart technologies. Inclusive income categorizes individuals based on low-, medium- or high-income level. Considering that both are dichotomous variables (taking values of 1 or 0), a latent simultaneous model is proposed (Greene, 2003):

$$y_{i1}^{*} = \acute{\pi}_1 x_{i1} + \varphi_1 y_{i2}^{*} + \varepsilon_{i1},\ \ y_{i1} = 1; 0 \text{ otherwise} \quad (5)$$

$$y_{i2}^{*} = \acute{\pi}_2 x_{i2} + \acute{\varphi}_2 y_{i1}^{*} + \varepsilon_{i2},\ y_{i2} = 1 \text{ if} ; 0 \text{ otherwise} \quad (6)$$

$$\text{where} \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} \sim N \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix} \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix} \right]$$

That is, the two error terms ($\varepsilon_1, \varepsilon_2$) are simultaneously estimated with zero mean, constant variance and correlation (ρ). A ρ equal to 0 will suggest that the equations are unrelated, meaning that the equations do not need to be estimated simultaneously. The variable y_1^* represents the unobservable latent variable related to mobile phones, while y_2^* is the measured income level of the individual: y_1 will take the value of 1 if the individual owns a mobile device; y_2 will take the value of 1 if the individual belongs to the low income level; and zero otherwise. The method models the different technologies (simple and smart) and income levels (low, middle, and high) proposed in the study. The variables x_S are vectors of exogenous variables measuring socio-economic characteristics of the individuals (gender, age, education, and location); $\acute{\pi}_S$ and $\acute{\varphi}_S$ are vectors of parameters.

Results

Descriptive Indicators of Financial Inclusion

The SOFIA dataset captures the fact that nearly 41% of the population have access to formal accounts, 42% have access to semi-formal or/and informal services, while 17% are financially excluded (Table 2). While nearly 57% of the population in East Indonesia have access to savings, only 24% employ formal savings. Access to credit is 41%: nevertheless, only 13% do formally access credit; 4% from non-bank sources; and 25% from semi-formal and informal sources.

Table 2 Descriptive Statistics Sample Data

Variable	Percentage (yes)	Variable	Percentage (yes)
Male	42.73%	Save Money Formal	41.93%
Income_low	50.11%	Save Money informal	76.96%
Income_med	43.05%	Banked	15.85%
Jatim	35.00%	Paid_bill	62.67%
Rural	65.41%	Mobile_money	2.36%
Tech_low	72.45%		
Tech_high	31.40%		

Source: Author's calculation from SOFIA Dataset.

In Indonesia, more males (43%) have access to formal financial services (accounts, saving, and credit) than females (39%). Nevertheless, females have greater access to informal services (10% as opposed to 6% among males) than males. Financial inclusion is predominant amongst non-farm labouring people, with higher education and higher income; and among those in urban areas (49% formal in urban areas vs 35% in rural). While the gap in financial inclusion has narrowed in terms of gender, the gap between less and more educated (80 percentage points) and the gap between lowest income and highest income (68 percentage points) is large.

Determinants of Financial Inclusion (Savings and Credit)

The study first looks at the main determinants of financial inclusion in East Indonesia and identifies how individual characteristics, the use of technology, and location affect the likelihood of people to be financially excluded. Table 3 displays the results. Regarding individual characteristics, males have 6.4% higher likelihood of saving within formal institutions than females; nevertheless, males have 15.5% higher likelihood of being excluded from savings (Table 3, column 1). Females have 13.4% greater likelihood of being engaged in informal savings than males (additional results on saving and credit motivations in Appendix Table 10).

Higher levels of education are associated with greater access to formal savings and credit, and to a lower share of informal finance. By contrast, lower levels of education are associated with higher use of informal savings and credit, and with higher dependence on family loans. Foreign remittances are more likely among people with lower education (common among Indonesian overseas workers).

Together with education, income accounts for the most significant determinant of financial inclusion. Individuals with low income are 23.1% significantly less likely to save; they are 27% less likely to save in a formal institution; and 5.4% more likely to save informally. High income also lowers dependency on family as a source of loans. Formal and semi-formal services overlap among high-income earners, but leave the lower-income people to the informal services. This is similar to findings for Africa (Zins & Weill, 2016) and China (Fungáčová & Weill, 2015). Individuals in rural areas have a 5.11% lower probability of saving and of being bankable for credit (4.5%) versus those in urban areas. People in rural areas save and borrow more from informal sources, borrow more from family members, and send/receive more international remittances (3.5%) than urban people.

Technology and Financial Inclusion

The use of both simple phones and higher-end mobile technologies is associated with broader access to savings and credit. Individuals with simple mobile phones are 5.5% more likely to save money than those without a device, but those with higher-tech devices are 10% more likely (twice as likely as those with simple mobile phones) to save than non-device users. High-tech devices also turn individuals 18.6% more likely to save formally, while lowering informal savings by -7.8%, informal credit (-8.6%) and family loans; but they increase formal and semi-formal savings and credit.

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Different arguments support the claim that higher access to mobile technologies increases access to formal finance. First, mobile devices support more efficient communication, associated with efficient use of time, lower cost, and complete information. Mobile phones may be associated with professional activities by enhancing work performance and making users more "bankable". The perception of high cost or no money in savings and use of bank accounts falls by 5% for simple phone users and nearly 10% for users of smart technologies (see Appendix Table 8).

Lack of knowledge as a barrier to insurance services decreases by 4% for users of mobile phones and by 8.7% when it comes to a lack of knowledge for mobile payments. Users of mobiles and smart phones employ more bank services for transactions and use less cash; they are more likely to use internet banking and mobile banking, and to use ATMs to pay bills (results on Remittances, Transfers, Bill Payments, Appendix Table 7).

Nevertheless, the most substantial barrier to broader finance is voluntary self-exclusion, meaning that users prefer to use cash, and find no need to use financial services; nor do they want to save, use accounts, or borrow money. Lack of trust in saving, borrowing and getting insurance remains a barrier even for individuals with mobile phones, meaning that more information and connection does not guarantee trust. The perception of high cost remains a barrier to finance (results on barriers to finance available, Appendix Table 8).

Technology shapes saving motivations of individuals with smart devices, as they are less directed towards consumption (-6.0%), have 2.4% higher awareness of the need to save for emergencies, and higher intention to save for business expansion. Use of credit among high-tech users decreases for consumption (-10.5%), decreases for emergencies (-1.4%, perhaps as a result of higher savings for emergencies), but increases when it comes to buying a house (2%), and starting/expanding a business (4.2%) (Appendix Table 10).

Nevertheless, this study finds a rather low use of financial services for remittances, sending/receiving money, bill payments, mobile banking, ATMs, and other banking services empowered by technology. The potential of digital services remains untapped, with barriers to finance placed in non-technology aspects.

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Table 3 Determinants of Finance (Savings, Credit, Remittances)

	Saving (1-3)				Credit (4-8)				Services (9-12)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Save ALL	**Save Formal**	**Save Informal**	**Banked**	**Semi-Formal**	**Formal non-Bank**	**Family**	**Informal**	**Paid Bill**	**Mobile Money**	**Insurance**	**Remittance Abroad**
Male	-0.155***	0.064***	-0.134***	0.045***	-0.012	0.015**	-0.028**	-0.019**	-0.017*	0.000	-0.018*	-0.029***
Age	0.009***	0.028***	-0.012***	0.023***	0.016***	0.008***	-0.024***	0.004***	0.039***	0.001***	0.007***	-0.003***
age2	-0.001***	-0.000***	0.000***	-0.00***	-0.00***	-0.00***	0.000***	-0.000**	-0.000***	-0.00***	-0.000*	0.000**
edu	0.056***	0.126***	-0.051***	0.051***	0.009**	-0.001	-0.053***	-0.012***	0.009*	0.006***	0.033***	-0.016***
inc_low	-0.231***	-0.270***	0.054***	-0.117***	-0.002	-0.017	0.115***	-0.011	-0.085***	-0.017***	-0.001	-0.014
inc_med	-0.113***	-0.106***	-0.0148	-0.056***	0.027*	0.000	0.041*	-0.003	-0.037*	-0.009***	0.069***	0.008
Jatim	-0.030***	-0.115***	0.078***	-0.000	0.024***	-0.008	0.009	0.060***	0.067***	0.009***	-0.144***	-0.003
Rural	-0.051***	-0.062***	0.048***	-0.040***	-0.010	-0.026***	0.087***	-0.026***	0.001	-0.004***	-0.035***	0.035***
tech_low	0.055***	0.082***	-0.032**	0.065***	0.023*	0.014*	-0.05***	-0.005	0.071***	0.000	-0.027**	-0.002
tech_high	0.101***	0.186***	-0.078***	0.082***	0.026**	0.023***	-0.086***	-0.025***	0.008	0.018***	0.004	0.014*
N	14160	9841	9841	9497	9497	9497	9497	9497	14159	14159	14161	7494
Log likelihood	-7872.23	-5462.99	-5007.82	-3840.73	-3634.47	-2496.53	-5165.27	-2960.50	-8536.92	-1572.37	-9263.64	-1573.01
Pseudo R2	0.0961	0.1974	0.1081	0.1671	0.0378	0.0235	0.1112	0.0406	0.0521	0.2090	0.0320	0.0682

Note. Standard errors not presented (space limitation). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Prob>Chi 0.
Source: Author's Calculation

Table 4 SURE Probit Estimations for Mobile Phones (low tech) and Smartphones, the Internet, and Computers (high tech). Selected indicators displayed

	Low Income		Med Income		Low Tech		High tech		Banked		Family	
	Coef	dy/dx	Coef	dy/dx	Coef	dy/dx	Coef	dy/dx	Coef	dy/dx	Coef	dy/dx
Inc_low					-0.11***	0.13	-0.49***	-0.02	-0.45	-0.10	0.30	0.10
Inc_med					-0.04	0.06	-0.20***	-0.01	-0.25	-0.06	0.13	0.04
Tech_low	-0.11***	-0.04	0.08***	0.03					0.26	0.06	-0.15	-0.05
Tech_high	-0.29***	-0.11	0.22***	0.09					0.34	0.09	-0.25	-0.09
Banked	-0.26***	-0.09	0.07***	0.03	0.23***	-0.06	0.26***	-0.01				
Semi_formal	-0.13***	-0.05	0.17***	0.07	0.12***	-0.02	0.11***	-0.01				
Formal_nbank	-0.14***	-0.05	0.11***	0.04	0.13***	-0.04	0.17***	-0.01				
Family	0.06	0.02	(-0.03)	-0.01	0.02	0.05	-0.14***	-0.01				
Informal	-0.03	-0.01	0.04***	0.02	0.06	0.06	-0.16***	-0.02				
Supplies & business	-0.42***	-0.14	0.39***	0.15	-0.17	0.01	-0.10	0.01				
Male	-0.17***	-0.06	0.07***	0.03	0.04	-0.05	0.17***	0.01	(0.21)	0.05	(-0.11)	-0.04
Young_adult	0.15***	0.06	-0.20***	-0.08	-0.08	-0.09	0.25***	0.03	(-0.29)	-0.06	(0.29)	0.10
Age	-0.05***	-0.02	0.02***	0.01	0.03***	0.02	-0.06***	-0.01	(0.08)	0.02	(-0.05)	-0.02
Edu	-0.14	-0.05	0.09***	0.04	0.07***	-0.13	0.45***	0.02	(0.22)	0.05	(-0.16)	-0.05
Jatim	0.18***	0.07	-0.12***	-0.05	-0.06***	-0.06	0.17***	0.02	(0.00)	-0.01	(0.03)	0.01
Rural	-0.16***	-0.06	0.03***	0.01	0.00	0.15	-0.47***	-0.03	(-0.19)	-0.04	(0.28)	0.11
Obs	8216				8216				8216			
Rho (ρ)	-0.99				-0.25				-0.285			
	(0.00047)				(0.02373)							
Wald	949.84				2509.2***				1316.13			
Log-Likelihood	-6988.6				-7783.56				-6042.801			
Likel. ratio test of ρ $X^2(1)$	6753.77***				105.762***				82.2522***			

Note. T-values in parentheses. ***, **, * indicates 1%, 5%, 10% significance level. Rho tests for correlation between errors, Validity model (Wald tests), and log-likelihood ratio test for correlation. dy/dx (marginal effects ~ non-linear). Marginal effects under linear estimation equal the coefficient value in percentage terms.

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Effects of Mobile Technologies and Financial Inclusion on Income

Table 5 displays the results of the OLS estimates for the effects of mobile technologies on income. Table 6 applies the same model relating different financial services to income. Low tech (mobile phones) and high tech (smartphones/Internet/PCs) are positively associated with higher per capita income level, significant at a 1% level. People owning a mobile phone (tech low) have a 13% probability [(exp(0.119)-1)*100] of escaping low-income status, 8.8% higher likelihood of belonging to the medium income group, and 3.36% likelihood of being among the high-income earners. Access to high-tech increases likelihood to belong to a higher income group beyond that associated with the simple mobile phone, by 5% to 7%.

Table 5 Estimates for Basic Mobile Phones and Smart Phones and Inclusive Growth (Income)

	East Indonesia			East Java (JATIM)		
	Income Low	**Income Medium**	**Income High**	**Income Low**	**Income Medium**	**Income High**
Tech_Low	-0.119***	0.0882***	0.0336***	-0.107***	0.0848***	0.0234***
Tech_High	-0.176***	0.135***	0.0340***	-0.223***	0.186***	0.0295***
N Obs	19202	19202	19202	6675	6675	6675
Log Likelihood	-12927.17	-12894.53	-4706.85	-3439.78	-3514.29	-1236.94
Pseudo R2	0.0287	0.0175	0.0167	0.0290	0.0187	0.0113

Note. Standard errors not displayed due to space limitation. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: Author's calculation

The effects of technology on individuals in East Java are higher than for individuals outside Java, as using high-tech increases the likelihood of individuals escaping the low-income level (22.3%) and raises the likelihood of being a middle-income earner by 18.6%. This finding suggests superior technology within Java Island, versus out-of-Java areas, where access to technology results in higher empowerment. These results are in similar line with Bulman, Eden & Nguyen (2014).

Mobile technologies can influence the welfare of people who may in fact save because of more effective communication, lower transaction costs, more available information (Potnis, 2015), offering a wider variety of services, and facilitated information sharing. Mobile technology relates to gains in productivity through digitalization, allowing a broader base of users.

At the same time, those who are banked have nearly 25% higher likelihood of escaping the low-income level group, more than 14% probability of belonging to the medium-income class, or to climb towards a higher income (6.4%). Formal financial services have a higher impact on income than access to semi-formal and formal non-bank services and larger significant effects when compared to informal finance (e.g., family). While borrowing from family increases likeliness to exit the low-income level by 7%, an individual borrowing from family has a negative likelihood of making it to medium-high income level. Access to credit from suppliers or business increases the likelihood of having higher income levels, which may be in line with the findings of Chauvet & Jacolin (2017), who argue that financial inclusion and access to credit supports firm growth.

Table 6 Estimates for Financial Inclusion and Inclusive Growth (Income Groups)

	East Indonesia			East Java (JATIM)		
	Income Low	Income Medium	Income High	Income Low	Income Medium	Income High
Banked	-0.245***	0.141***	0.0640***	-0.282***	0.198***	0.0491***
Semi-Formal	-0.0937***	0.0888***	0.00498	-0.134***	0.129***	0.0022
Formal_Non-Bank	-0.111***	0.0973***	0.0111	-0.138***	0.135***	-0.0011
Family	0.0719***	-0.0441**	-0.0212***	0.0559**	-0.0386	-0.0134
Informal	0.00714	0.00443	-0.00800	-0.00247	0.0149	-0.0112
Suppliers & Business	-0.201***	0.140**	0.0416	-0.261***	0.206**	0.0337
N	12239	12239	12239	4365	4365	4365
Log Likelihood	-8150.84	-8280.53	-3035.00	-2262.76	-2332.70	-754.26
Pseudo R^2	0.0379	0.0169	0.0369	0.0386	0.0205	0.0357

Note. Standard errors not displayed due to space limitation. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: Author's calculation

A combination of access to technology and access to finance offers positive effects for more inclusive growth, and brings about larger effects within East Java as opposed to out-of-Java. Access to formal services offers 60% higher effects in income inclusion versus access to semi-formal service and formal non-bank services.

The marginal effects of mobile financial services are rather small, suggesting that the potential of inclusion through technologies is still unrealized. Payments offer the largest possibility of engaging with mobile banking.

Robustness Test

A seemingly unrelated probit model (SURE) is applied for robustness to test whether technology and income, as well as finance and income, are simultaneously dependent. A latent simultaneous model (SURE) is applied to address the endogeneity issue arising in cases where having a phone or access to finance could be attributed to higher income levels rather than the other way around. The log-likelihood of the SURE model suggests that the variables are significant (1% level), meaning that both sets of variables should be jointly estimated (mobile devices and income level) as there is multi-directional causality. The estimates for rho (ρ) suggest that the unobserved factors that affect mobile-phone technology and income growth are correctly specified and have the expected negative sign (negatively correlated).

The results in the SURE model in Table 4 are similar to those of the OLS (magnitudes) suggesting that both results properly observed the endogeneity issue, and suggesting that mobile-phone technologies and income are bi-causal, further advising simultaneous estimation. A low-income individual is 11% less likely to have a simple mobile phone, and 49% less likely to have a high-tech device than a medium-income earner. By contrast, middle-income people are only 4% unlikely not to have a phone and 20% unlikely not to own high-tech devices.

The use of technology reduces the likelihood of people belonging to a certain income level. For example, individuals employing simple mobile phones were 11% less likely to be low income. A similar individual employing high-tech devices is 30% less likely to be low income. A mobile phone is associated with 8% higher likelihood of individuals belonging to the middle-income class, and a higher-tech device is associated with 22% higher likeliness to be middle-income earners. The findings are in line with Abor, Amidu & Issahaku (2018), who estimate that ownership and use of mobile technologies in Ghana increases the probability of households to exit poverty, arguing that mobile technologies support inclusive growth. A similar relation is also presented in the case of Kenya (Suri & Jack, 2016) with mobile money having an impact in poverty reduction. Our results also support the findings of Rowntree (2018), who argues that closing the gaps (e.g., gender) in mobile-phone technologies is related to increased incomes in the emerging world, and represents a potential growth in GDP of nearly 0.7 per cent for developing countries.

A bankable individual also has lower likelihood of being low income (26%) as opposed to those who are not banked. Access to semiformal services also lowers the likelihood of individuals being low income; nevertheless, the marginal effect is nearly half of that for formal banking. Informal services play only 3% in favour of individuals to be excluded from the low-income level. Males are 17% less likely to be low income than females, and they are more likely to have simple mobile devices or higher-tech ones. Young adults are more likely to have high-tech devices (25%) than older adults; however, young adults are more likely to be low-income earners. Higher education raises likeliness to have higher income levels and to own higher-tech devices. People in rural areas are less likely to have access to high-tech devices, making it hard to introduce high-tech financial services in rural areas where tech penetration is low.

It is noticeable that young adults are left behind in most fields of financial inclusion in comparison with older adults (proxied by the variable of age), either as they have fewer opportunities (income) or because they have different priorities (e.g., less concerned about health, housing, or being elderly). Table 8 and Table 9 shows results on barriers and preferences to finance, and Table 10 displays results in saving and credit motivation.

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Nevertheless, the youth, similar to females, are more likely to employ higher technology and may have substantial potential for housing credit and entrepreneurship than older adults, in line to the findings reported in Aayog (2015).

Empowering micro financiers, rural banks, and cooperatives with more technology could help to broaden the reach of financial inclusion, so the most vulnerable ones are included (Arun & Kamath, 2015). Mobile technologies could help to lower the cost of finance and support financial education. The massive penetration of mobile phones in Indonesia could benefit the expansion of financial services (cashless transactions). Barriers to finance related to high cost, distance, and documentation, could be addressed by lower-cost products empowered by technology.

Conclusions

This study uses the data from the Survey on Financial Inclusion and Access (SOFIA) in 2017, covering four provinces in East Indonesia: East Java, West Nusa Tenggara (NTB), East Nusa Tenggara (NTT) and South Sulawesi, with a total sample size of 20,000 individuals within 93 districts and 1,250 villages. The study analyses how individual characteristics – gender, age, income level, education, and location (rural/urban) – determine the access to financial services, both based on formality and service provided (accounts, savings, credit, payments, among others). The main focus of the paper is to analyse the impact of digital technologies on financial inclusion and to analyse whether digital technologies and financial inclusion lead to higher income levels among individuals. An OLS regression tested for endogeneity is employed to differentiate impacts based on the type of services (formal, semi-formal, informal, and family), level of technology (low or high), and income levels (low, medium, high).

The results suggest that digital technologies have a positive impact on financial inclusion and on incomes in Indonesia, with higher technology driving higher demand for formal finance (saving and credit), lowering access to informal services, and raising the likelihood of employing other financial services. Use of payments, transfers, mobile banking, insurance, and other non-saving and credit services remain low, rising only slightly even when employing digital devices. Nevertheless, income level and education remain as the most significant determinants of financial inclusion; while perception of high cost, lack of money, and some self-excluding arguments (no-need, do not want) explain a large share of exclusion. Significant gaps in sources of demand, barriers, motivations, and drivers of services are identified across different genders, age, income levels, education, and locations. The province of East Java displays its own particularities in being different from other provinces. In East Java, a combination of access to technology and access to finance offers larger positive effects towards more inclusive growth than out of Java, suggesting that areas out of Java have lower gains in financial deepening through higher use of technology. Finally, financial access and mobile technologies are positively associated with higher incomes, allowing people in lower-income levels to climb the income ladder when employing higher technology (mobile devices, Internet, and computers) and formal financial services.

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Appendix

Table 7 Channels of Remittances, Transfers, Bill Payments (Probit Estimations)

	How People receive Remittances (1-2)		Most Frequent way to send money (3-4)		How people pay Bills (6-10)				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(10)
	Bank	Cash	Bank	Cash	Cash	Internet Banking	Mobile Banking	ATM	Voucher
Male	-0.112***	0.110***	0.0119**	0.0106	-0.0104	0.000476	0.000136	0.00102	0.0152
Age	-0.00930***	0.00978***	0.00689***	0.0150***	0.000132	0.0000	0.000	0.000	-0.000
Age2	0.00011***	-0.0001***	-0.00006***	-0.0001***	0.0000	-0.000	-0.000	-0.000005*	-0.0000
Edu	0.0381***	-0.0178***	0.0311***	0.00236	-0.0106**	0.0003	0.0013***	0.001***	0.002
Inc_low	-0.0924***	0.0373*	-0.096***	-0.154***	-0.036*	-0.000	-0.002	-0.004**	0.042*
Inc_med	0.0119	-0.043**	-0.042***	-0.052***	-0.014	-0.000	-0.0017	-0.002*	0.029
Jatim	-0.0431***	0.0454***	-0.055***	0.138***	-0.024**	0.0005	0.001	-0.0009	-0.0070
Rural	0.0064	-0.019	-0.028***	-0.009	-0.028**	-0.0004	0.0002	-0.004***	0.020*
Tech_low	0.0434**	-0.0298*	0.0162**	0.0431***	0.0277**	-0.0003	-0.000	0.0011	-0.010
Tech_high	0.104***	-0.075***	0.058***	0.010	0.028**	0.0013*	0.003***	0.006***	-0.036***
N	7494	7494	14161	14161	9448	9448	9448	9448	9448
Log likelihood	-4139.8716	-3913.3619	-4081.9116	-8561.0633	-4486.4974	-207.26256	-283.65077	-558.97621	-4927.853
Pseudo R^2	0.0606	0.0428	0.1693	0.0355	0.0177	0.2306	0.1605	0.2328	0.0135

Note. Standard errors not displayed due to space limitation. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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Table 8 Selected Indicators on Barriers to Finance (Probit Estimations)

	M21 Saving Barriers (1-3)			Barriers to Use of Bank Accounts (4-11)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	No Money	No Need	Other	No Money	Don't Know	Lack of Doc	Prefer Cash	Cost	Far	No Trust	Other
Male	0.141***	0.0118***	0.00833**	-0.00771	-0.00660	0.000822	0.00311	0.00145	0.00351	0.00244	0.00124
Age	-0.00911***	-0.000789*	0.00144*	0.00197	-0.00273***	-0.00065**	-0.00257	0.00200***	0.00134	0.000628	0.00139*
age2	0.0001***	0.00001**	-0.00001*	-0.0000	0.00002***	0.0000	0.00003**	-0.00002***	-0.00001*	-0.0000	-0.00001*
Edu	-0.0559***	-0.00000254	0.00478***	-0.0221***	-0.0167***	0.0000357	0.0198***	0.00402***	0.00356	-0.000372	0.00350*
inc_low	0.248***	-0.0155***	-0.0172**	0.220***	-0.0338***	-0.00415	-0.0893***	-0.00998*	-0.0244**	-0.00779*	-0.0205**
inc_med	0.130***	-0.0133**	-0.0100*	0.117***	-0.0222*	-0.00109	-0.0444**	-0.00323	-0.00667	-0.00666*	-0.0127*
Jatim	0.0289***	0.000106	-0.00196	-0.0265*	-0.00736	-0.00319*	0.0567***	-0.000961	-0.00699	0.00408*	-0.0168***
Rural	0.0520***	-0.00307	-0.00458	0.0301**	-0.00792	-0.0048***	-0.00640	-0.00380	0.00970*	-0.00262	-0.00820*
tech_low	-0.0528***	0.00593	-0.00401	-0.0150	-0.00366	0.000597	0.0186*	0.00499	-0.00663	0.00210	0.000800
tech_high	-0.106***	0.0101***	0.00893**	-0.103***	0.00783	0.00346*	0.0442***	0.00724**	0.00693	0.00484*	0.0144***
N	14157	4242	4315	6997	6997	6997	6997	6997	6997	6997	6997
Log likelihood	-7744.081	-281.00	-328.989	-3669.978	-1187.635	-263.897	-2359.440	-477.236	-922.268	-286.089	-710.931
Pseudo R^2	0.0974	0.1200	0.1113	0.0377	0.0237	0.0960	0.0387	0.0667	0.0292	0.0521	0.0538

Note. Standard errors not displayed due to space limitation. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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Table 9 Why people do not borrow, do not use mobile payments and do not get insurance (Selected Indicators, Probit Estimations)

	Why People do not Borrow (1-3)			Why people do not use mobile payments services (4-9)						Why people do not have Insurance (10-15)				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	No Need	Not Want	Have Debt	No Phone	Don't Know	Don't Need	Not Easy	No Docs	No Trust	NO Need	High Price	No Money	Don't Know	No Trust
Male	-0.0475***	-0.030*	0.038***	-0.034***	-0.0001	0.00811	-0.0028	-0.0015	0.0067*	-0.0143	0.0103*	0.0178*	-0.0079	0.0082*
Age	-0.0175***	-0.0059*	0.0202***	-0.0012	0.0007	0.0016	0.008***	-0.0008	0.0009	-0.007***	0.006***	0.006***	-0.007***	0.0054***
age2	0.0001***	0.0000**	-0.000***	0.000***	0.0000	-0.000**	-0.000***	0.0000	-0.000	0.00***	-0.000**	-0.000***	0.000**	-0.000***
Edu	-0.0180***	-0.0496***	0.020***	-0.033***	-0.05***	0.046***	-0.017***	-0.002**	0.009***	0.029***	0.014***	-0.008*	-0.08***	0.0145***
Inc_low	0.0196	0.229***	-0.041**	0.057***	0.110***	-0.043**	-0.08***	-0.013**	-0.012*	-0.11***	0.0215*	0.148***	0.0314	-0.0311***
Inc_med	-0.0125	0.126***	0.0205	0.0260*	0.070***	-0.0202	-0.052**	-0.0038	-0.0058	-0.06***	0.0195	0.098***	0.0085	-0.0167**
Jatim	0.0559***	-0.0973***	-0.04***	-0.06***	-0.03***	0.072***	0.066***	-0.029***	0.017***	0.068***	0.024***	0.037***	-0.13***	0.0155***
Rural	0.0001	-0.0072	-0.0015	0.0077	0.053***	-0.04***	-0.0238*	-0.0039	-0.01***	-0.04***	-0.02***	-0.04***	0.111***	-0.015***
Tech_low	-0.0330**	-0.0291	0.0314**	-0.25***	0.054***	0.073***	0.166***	0.022***	0.012**	-0.0127	0.020**	0.034**	-0.04***	0.0105*
Tech_high	-0.0204	-0.0700***	0.0224*	-0.15***	-0.08***	0.056***	0.077***	0.0058*	0.019***	0.0226*	0.0109	-0.03***	-0.04***	0.0292***
N	5501	5501	5501	13711	13711	13711	13711	13711	13711	12817	12817	12817	12817	12817
Log likelihood	-2118.90	-3515.50	-1850.7	-4480.8	-7082.1	-7704.0	-9296.5	-1635.2	-2172.6	-7889.5	-3752.4	-8473.8	-7844.8	-2502.7
Pseudo R^2	0.0587	0.0549	0.1057	0.2900	0.0660	0.0475	0.0218	0.0529	0.0611	0.0199	0.0244	0.0119	0.0718	0.1108

Note. Standard errors not displayed due to space limitation. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10 Saving and Credit Motivations (Selected Indicators, Probit Estimations)

	Saving Motivation (1-3)			Credit Motivation (4-8)				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Consumption	Emergency	Expand Business	Consumption	Emergency	Access	Buy House	Business
Male	-0.0165	0.00267	0.0254***	-0.0663***	-0.00779	0.0182***	0.0141**	0.0405***
Age	-0.0151***	-0.00806***	0.00499***	-0.0218***	-0.000913	0.00300*	0.00646***	0.0170***
age2	0.000168***	0.000113***	-0.000054***	0.000185***	0.0000131	-0.0000365**	-0.0000610***	-0.000169***
Edu	-0.0202***	0.0164***	-0.000705	-0.0384***	-0.00297	0.00578**	0.0180***	-0.00728*
inc_low	0.121***	0.0212	-0.0308***	0.196***	0.0450***	-0.0178*	-0.0400***	-0.126***
inc_med	0.0806***	0.0408**	-0.0343***	0.139***	0.0450***	0.00396	-0.00444	-0.113***
Jatim	-0.0448***	0.0296***	-0.00336	0.0257*	0.0379***	0.0196***	-0.00618	0.00924
Rural	0.0410***	-0.0277**	-0.00323	0.0239*	0.00253	-0.0172***	-0.00414	-0.0173*
Tech_low	-0.0249*	0.0252*	0.00108	-0.0355**	-0.00223	0.0299***	0.00567	0.0487***
Tech_high	-0.0696***	0.0241*	0.0113*	-0.105***	-0.0139*	0.0328***	0.0206***	0.0420***
N	9737	9737	9737	9497	9497	9497	9497	9497
Log likelihood	-5341.2079	-4890.0717	-1859.144	-6026.3526	-2766.4766	-2133.3543	-2442.2028	-4303.8389
Pseudo R^2	0.0348	0.0164	0.0310	0.0590	0.0142	0.0489	0.0647	0.0382

Note. Standard errors not displayed due to space limitation. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Fighting Pandemics By Exploiting 5G, AI and Bigdata Enabled Technologies

How 5G can help contain the spread of COVID-19

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Abstract: In context, this paper starts by referencing best practices adopted globally to counteract COVID-19, through such means as *testing, tracing, diagnosing and treating* infections. It then presents relevant examples demonstrating where 5G, AI and Bigdata technologies have been successfully deployed via policy measures and resulting processes to keep people safe, through physical distancing and various other arrangements to slow and contain the spread of COVID-19. Beyond this, examples of unique 5G characteristics, such as improved throughput, latency and reliability, and 5G resilient network configurations (including all layers and domains supporting standard security and related enhancements) are described in detail. This is followed by illustrating particular opportunities achievable on secure and resilient 5G systems incorporating digital spill-over capability. Beyond this consideration and responding to some unfounded concerns, the paper reaffirms that 5G will not have the negative effect on people's health about which a few individuals have speculated. Picturing all this together, conclusions are drawn on a possible way forward in which policy makers' focus can now advance from current Smart City concepts towards a more extensive Smart Society approach.

Keywords: 5G, AI, Bigdata, Pandemic, COVID-19.

Introduction

Currently, COVID-19 is being counteracted by a regime including *testing, tracking, diagnosis* and *therapeutic treatment of the infection*. Countries dealing with COVID-19 have concluded that early identification of positive subjects is crucial for the purposes of treatment and containment of infection.

The COVID-19 test is effective when associated with a clear path of contacts, and the tracking is effective as long as it is combined with an appropriate communication system for collecting

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and disseminating information about the movements of potentially infected people and other necessary information.

To this end, 5G, AI and Bigdata technologies can help increase diagnostic abilities in areas at risk by locating infected subjects as early as possible and promptly tracing their contacts and identifying the origin of the infection, thus minimising future propagation of the virus through subsequent interactions.

Through high-speed and low-latency 5G technology – not supported by earlier generation networks – the exchange of high resolution images, videos and other information in digital form, sometimes in almost real time, related to successful and unsuccessful cases, could take place in just fractions of a second, across an entire country or around the world.

5G technology could also help us monitor in real time patients with mild symptoms, particularly those who remain undiagnosed in their home, as well as health workers, who are the most exposed staff and therefore at greater risk. These people represent a strong risk for the transmission of the infection in their families and in the community, especially in the post-emergency phase or "phase two", i.e. when the social distancing will be relaxed because the curve of new deaths will have turned the corner: see e.g. Financial Times (2020) and Johns Hopkins University (2020).

Such near seamless transfer of information would enable knowledge and experience sharing between hospitals, laboratories and research organisations scattered widely throughout the area or world, and therefore further facilitate accurate and timely diagnoses of COVID-19.

In turn, such a shift towards using 5G technology would allow a shift *from patient-centred care models to a community-based approach*, offering solutions for the whole population (Pisano, Sadun & Zanini, 2020).

For example, in Italy, the evidence shows that different policies followed in different regions towards dealing with COVID-19 produced very different results despite the regions sharing many similarities. Had these different regions been able to take advantage of the benefits offered by 5G technology as outlined in this paper, it would have been possible to implement these across the whole of Italy and subsequently achieve a better outcome.

For many years now the healthcare sector has considered the usage of robotics to deliver more efficient care for patients – COVID-19 saw robots deployed to actually achieve this. Following this real-world, experience we now have evidence to show that the use of service robots, remotely controlled or with a high degree of autonomy and associated with 5G networks, can amplify the diagnostic capabilities of existing laboratories, limiting the number of human resources currently necessary to reach conclusions, such as for ensuring appropriate social distancing from potentially infected people.

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In addition, artificial intelligence can be used "on top" of 5G for analysis of images and data aimed at capturing the temperature of people at risk, clarifying the severity of the infection, and could even be adopted as a general purpose technology to produce data aimed at clarifying, for example, the correlations between antibody levels in the blood and the presence of an infectious virus in respiratory secretions as well as in other areas of the human body. For example, the latter application would help us clarify the idea of using antibody positivity (Australian Government, 2020; Blackman, 2020) as the only useful indicator for the decision about the resumption of an individual's work activity without risks.

The advantages offered by the use of cutting-edge technologies in the fight against the epidemic are manifold, and some pertinent examples are from China, as illustrated in Figure 1 – but the same could be achieved in any country with 5G network availability.

As fever is one of the main symptoms of COVID-19 in China, they are using artificial-intelligence-based systems in transport junctions, office buildings and communities to identify high body temperatures from a flow of people on the move. Based on body shape and other facial information, the intelligent system can help staff identify and monitor people with abnormal body temperature quickly. In addition, in compliance with relevant regulations and standards, Chinese cities are using big data analytics platforms to track close contacts of patients or suspect cases.

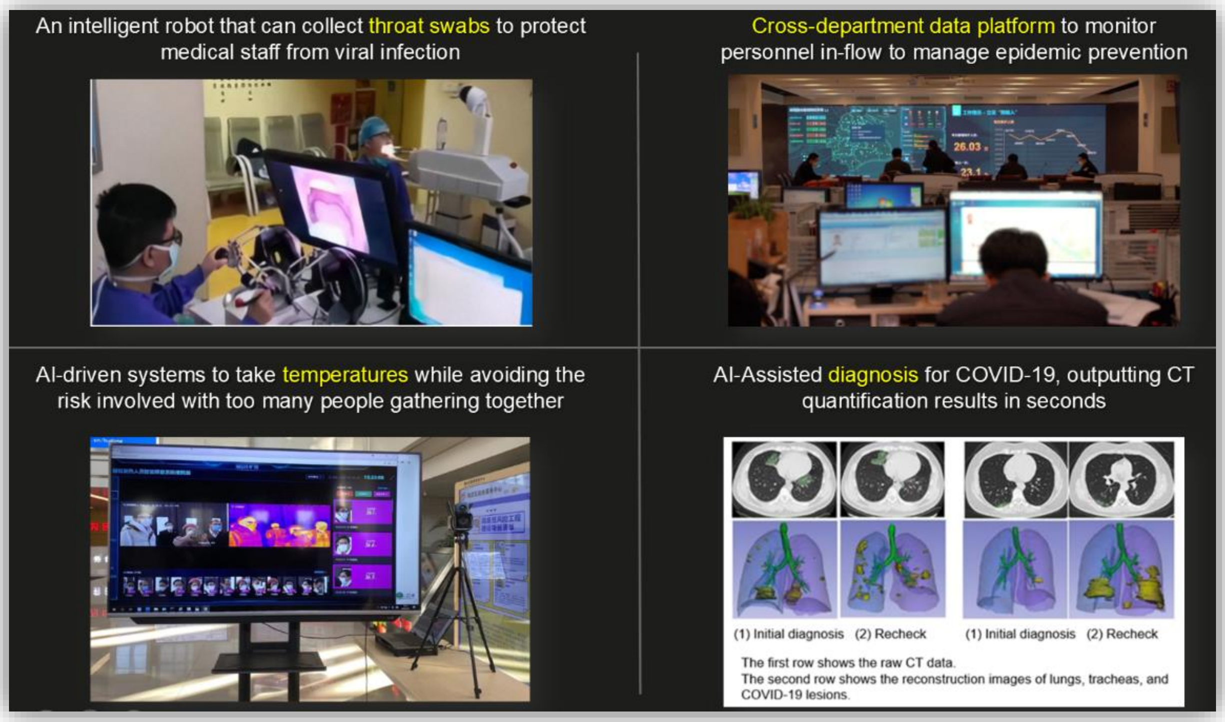

Figure 1. Examples of cutting-edge 5G, Big Data and AI technologies for fighting COVID-19 (CGTN, 2020a)

Intelligent robotic platforms with different functions have been developed to relieve pressure on doctors and nurses. A smart robot, controlled at a safe distance by medical personnel, is able to collect a patient's swabs, without injuring the subject's throat, and with a success rate of over 95% (CGTN, 2020a). In some hospitals, most of the activities normally carried out by medical personnel are currently converted into tasks performed by robots, which go around the departments to deliver drugs, measure the temperature of patients, serve meals, and inform the patients of important medical precautions to be taken.

Also in China, 5G has been widely applied in the tele-medicine sector, playing a crucial role in the treatment of severe cases of COVID-19 and in the sharing of information and experiences at national and world level. For example, the 5G network has made remote computed tomography (CT) scanning more viable, allowing specialized personnel to control CT scanners in hospitals from a distance in real time (National Telemedicine Centre of China, 2020): see Figure 2.

(It should be noted that CT scans give the best diagnosis for COVID-19 and scan results can be shared in real time with doctors across the country – they do not have to be at the hospital.)

The massive deployment of 5G will allow governments to set up a *systemic decision-making approach*, which gives priority to learning and is able to quickly scale successful experiments and identify and close ineffective ones.

Figure 2. Examples of 5G healthcare services on air with digital indoor system (DIS) in China (Soldani, 2020a)

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In What Situations Can 5G Network Technologies Be Readily Exploited?

A 5G system is necessary for all those communications that require high-speed data transmission, especially from the user equipment (UE) to the network (uplink), very low latency between peer entities end-to-end, and very high reliability (Soldani & Innocenti, 2019). With a much faster and more reliable connection on offer, 5G will support many more use cases than Wi-Fi, likely co-exist with WiFi6 in our urban environments, but it will largely complement the need for that. Moreover, 5G supports network slicing, supplementary uplink, super massive MIMO (mMIMO), multi-access edge computing (MEC), more devices and seamless mobility; offers higher bandwidths – using licensed and licence-exempt spectrum in low-bands (e.g. sub-3 GHz), mid-bands (e.g. C-band) and high-bands (e.g. mmWave spectrum); provides widespread indoor and outdoor coverage in all areas; and, especially, lower latency for end users (Soldani, 2017; Soldani *et al.*, 2018; Soldani, 2019; Soldani & Innocenti, 2019).

The use of *self-driving or remote-controlled vehicles* (*unmanned cars*) can reduce contact between individuals. Specifically, these cars can be used to deliver supplies, critical medical equipment and disinfect contaminated places or areas at risk. For safe remote control, the images, captured by the many cameras installed on vehicles on the road, must be transferred to the control station in real time. In practice, this requires at least 50 Mb/s in the uplink direction and end-to-end delay – including the time required to capture images, process and render them, and exchange commands between the two communicating parties (application platform and onboard unit) – of less than 150 ms, so that vehicles can avoid obstacles and stop immediately when required from a remote control distance (Soldani *et al.*, 2018).

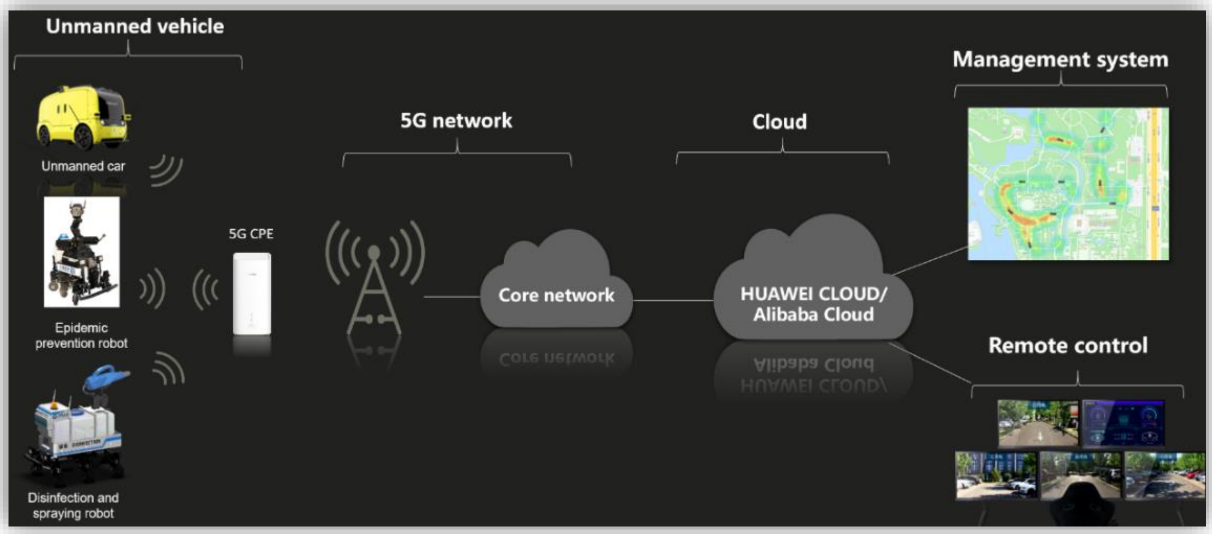

Figure 3. Example of 5G solution for unmanned vehicles: car and service robots (Soldani, 2020a)

In addition to these autonomous or semi-autonomous transport systems*, epidemic prevention robots* and *disinfection and spraying robots* have been introduced for:

- *Prevention* of COVID-19 epidemic, as means for measuring body temperature, disinfection, sterilization and spraying, and communication via a remote intercom;
- *Security* patrol, with facial recognition and license plate recognition.

The network requirements, to support applications and machines of this kind, are more or less the same as those required for the management and control of automated guided cars, especially in terms of throughput and latency (Soldani *et al.*, 2018).

An example of a 5G solution for connecting unmanned vehicles (car and service robots) is shown in Figure 3. Figure 4 reports examples of service applications for verticals and related network performance requirements.

The solution – meeting optimal end-user experience and public safety requirements – for the use, control and management of unmanned vehicles consists of a 5G network that connects the automaton to the cloud by means of a CPE (customer premises equipment, similar to a fixed broadband modem) and a management and control system for the operator.

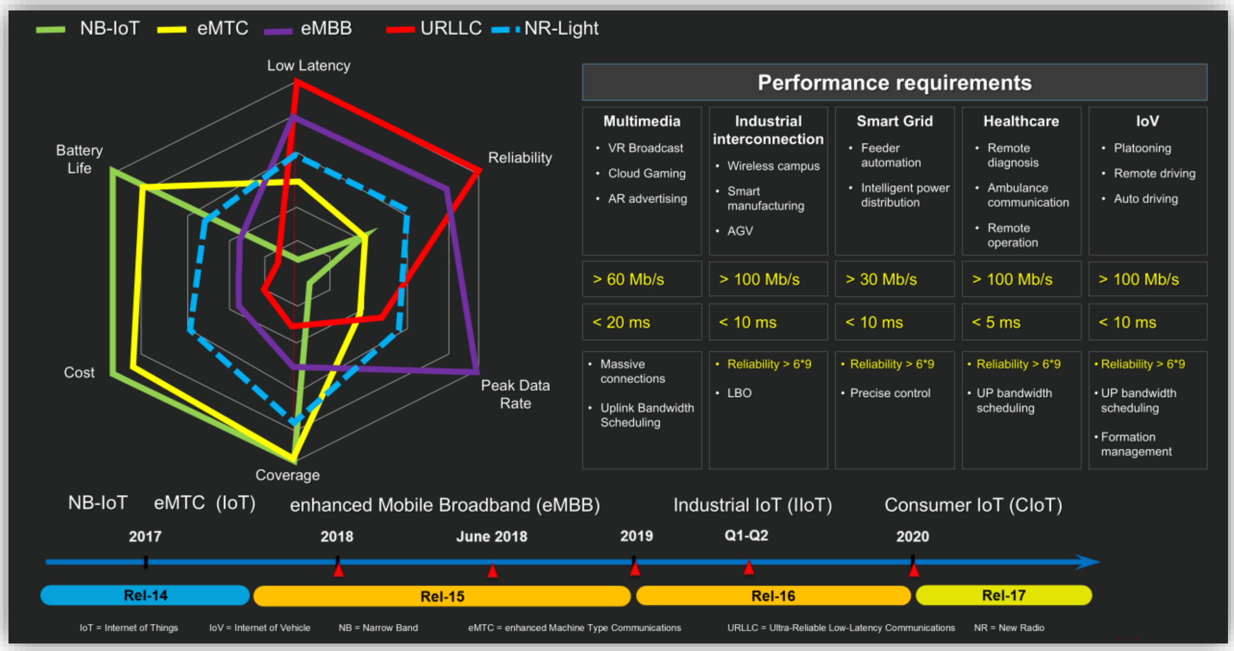

Figure 4. Example of performance requirements for vertical applications (Soldani, 2020a)

What Other Potential Opportunities Exist for Now and in Future Using New 5G Network Technologies?

The drama of the COVID-19 pandemic cannot be overlooked. In the world, there have been millions of infected people, loss of lives, loss of jobs, and economic consequences whose vastness is impossible to evaluate at present. However, the COVID-19 crisis actually presents itself as an interesting challenge for the information and communication technology (ICT) and industry. China, having been the first nation hit hard by the virus and the first one on its way out, has already defined its post-COVID-19 plans to foster economic recovery.

To this end, investments will be placed on the following seven sectors (CGTN, 2020b):

- "First of all", the distribution of the 5G network; and consequently:
- The development of artificial intelligence;
- Construction of data centres;
- Industrial Internet;
- Inter- and intra-city railway systems;
- New energy charging stations for electric vehicles; and
- High voltage electric grids.

Most of these investment areas will adopt 5G and its related technologies. In focusing on those fields and related infrastructures, China aims at stimulating itself towards new economic and social development, especially in areas currently less developed, where trade and industry growth would be needed.

Figure 5. Example of 5G solution to enable mobile UHD (4K) live broadcast (Soldani, 2020a)

The same opportunity now presents itself in any country adversely affected by the COVID-19 pandemic, which should take advantage of the current crisis to build next generation infrastructures, to be used in the imminent future and, above all, to be left to future generations – also in order to be further modernized. Countries should not find themselves still unprepared to face a probable future "war" with the same "weapons" used in this very moment.

What Is the Way Forward?

Leaving aside the problem of the COVID-19 pandemic for a moment, I would like to add that the 5G infrastructure allows other revolutionary applications based on virtual reality (VR) and augmented reality (AR) and also using artificial intelligence (AI).

AR and VR can be used in a wide range of entertainment, industrial and educational applications. All these services are currently constrained and limited, because bandwidth (50 Mb/s for 4K/Basic 3D AR/VR; and 100 Mb/s for 8K/Immersive 3D AR/VR) and latency (below 20 ms) are not available on 4G (LTE) networks. (A 4G network would support up to 1080P (~2K) VR/AR with limited applications.)

The 5G network will allow the instant transmission of 4K UHD live from a mobile location (or camera operator, as shown in Figure 5), intelligent public transport (see Figure 6 for an example of a smart bus), and will ensure greater public safety.

Figure 6. Example of 5G for smart buses, making travellers safer (Soldani, 2020a)

For example, as depicted in Figure 7, a police officer wearing wireless AR glasses could easily identify a suspect in the crowd. The glasses worn by the agent upload 4K videos to the network, the cloud renders the objects and compares them with other images stored in a facial database and returns alarms information to the glasses. The latter displays the alarm information on the virtual screen in real time, so that the policeman may take all necessary actions.

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If 5G allows applications of this type after a year of its introduction, let us imagine what it can do in three, five or ten years. The faster countries are able to build and use 5G infrastructures, the sooner they will be able to get the benefits that this technology already offers. In our opinion, nations that do not invest heavily in this direction will lag behind and be the last to benefit from revolutionary applications (Soldani, 2019).

Conclusions

I would like to highlight that, once the COVID-19 emergency has been addressed, with the involvement of other policies and decision makers, our political leaders will enable the deployment and exploitation of new 5G technologies offering substantial benefits.

It would be desirable that our political leaders – once this current crisis has been dealt with – focused on helping to knit-together our homes, schools, hospitals, universities, government services and so much more into more than just a *Smart City* (Soldani, 2018): we should be aiming to use this horrible pandemic to bring about the *Smart Society* (Soldani & Manzalini, 2015).

Figure 7. Example of 5G services for public safety using UHD video and AR wireless glasses (Soldani, 2020a)

It is, of course, recognized that new developments in all cloud, AI, industrial (IIoT) and consumer (CIoT) applications, and software-defined everything are posing an unprecedented challenge to the *cybersecurity* of ICT infrastructures. There are growing security risks that are significant threats to a future *Digital Society* and cannot be ignored.

To address and ultimately solve those rising challenges requires a *strong collaboration between industry and governments, security agencies, regulators and other relevant*

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organizations to embed trust in all telecoms business processes and supply chains, and to enhance cybersecurity through research and innovation at global scale (Batas, Men & Smitham, 2020). Trustworthy equipment, resilient networks and verification shall be all based on standards and further enhanced, for instance, as depicted in Figure 8. This must be a collaborative effort between *private* (industry, SME, and research organizations) and *public* (policy makers, regulators) *parties*, as no single government, vendor, or carrier can do it alone (Soldani, 2019; 2020c).

In Soldani (2020d), it is recommended to work closely with the European Commission (EC) and other Member States, their partner cybersecurity 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 establish 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, 2020) and *network equipment security assurance scheme* (GSMA, 2020b).

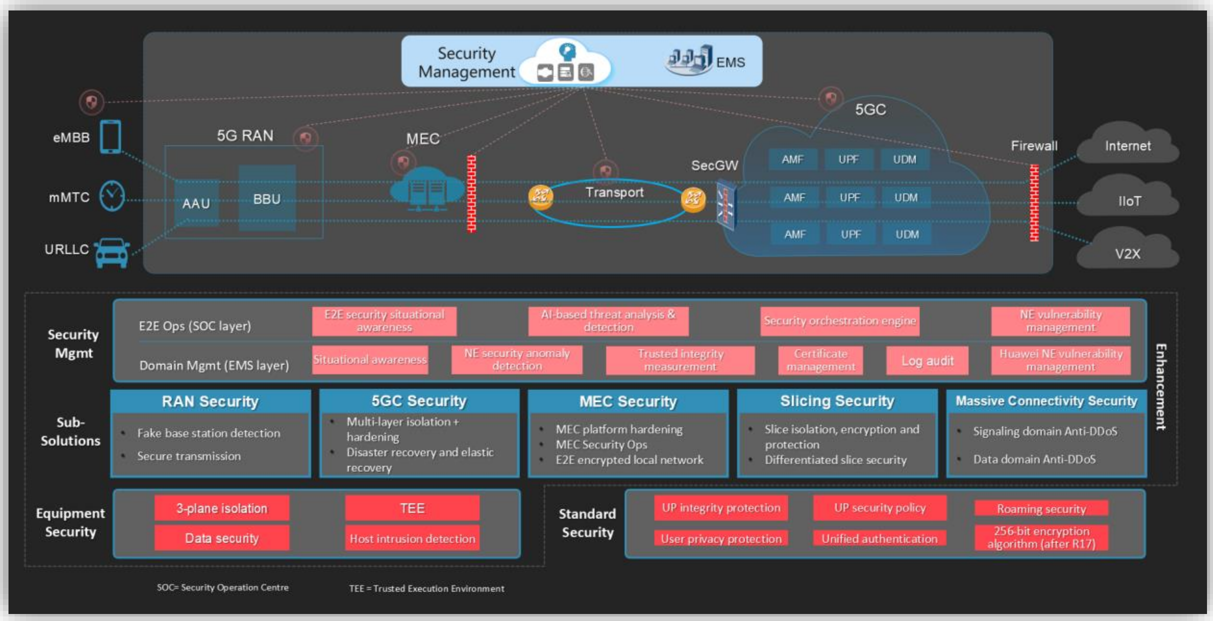

Figure 8. Example of 5G trustworthy products and resilient networks (Soldani, 2020b)

An example of a flagship project aimed at demonstrating how commercial and open-source products can leverage cybersecurity standards and recommended practices for each of the 5G use case scenarios, as well as showcase how 5G security features can be utilized, can be found in Bartock, Cichonski & Souppaya (2020). This iterative approach will provide the flexibility to take advantage of newly introduced 5G security capabilities. This project will result in a freely available cybersecurity practice guide.

The 5G (and future 6G) networks will use much smaller antennas and thus generally lower exposure levels to *electromagnetic fields* (EMF) compared to the current 2G, 3G and 4G networks, but altogether achieve much better quality of service and higher connection speeds (European Commission, 2020). Many of these smaller antennas could, to a certain extent, be compared to Wi-Fi installations. All new specificities of 5G technology have been taken into account in the definition of the revised ICNIRP guidelines (ICNIRP, 2020).

Therefore, following all the existing recommendations, the deployment of *5G will not have a negative effect on people's health* (European Commission, 2020). Conspiracy theories around 5G and health have been circulating globally for the past 18 months or so, but have recently morphed into claims that COVID-19 is being caused by 5G. This *fake news* has resulted in physical attacks on base stations and engineers working on installations, particularly in the UK (GSMA, 2020a).

From a cybersecurity perspective, a quick search reveals that organised campaigns and actions around fake news and other disinformation are taking place across social media, which are fanning the flames, resulting in increased action in the physical world (GSMA, 2020a).

However, while social media companies are taking action, there are still many groups and individuals promoting 5G conspiracy theories, including theories that "*you cannot mitigate the risk of untrusted vendors in 5G networks by placing them in the 'edge' because there is no distinction between the edge and the core*", which has been proved to be incorrect (Soldani *et al.*, 2018; Soldani, 2019). The NG-RAN functions run on proprietary hardware and software and cannot "blur" with a 5G core made by another vendor (Soldani *et al.*, 2018; Soldani, 2019).

Instead of watering our thoughts with lies or fake news to inspire fright, gain power or attain any sort of commercial advantage, we should fuel our views with win-win solutions to cultivate success, and turn the current challenging situation into an opportunity for emerging from COVID-19 much more resilient and prosperous (Soldani, 2020a; 2020b).

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An Analysis of China's Proposal to Control and Centrally Manage the Internet

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Abstract: Governments and telecommunications companies have invested heavily in measures designed to protect overall system security. But these measures may not be enough if China is successful in setting the rules and designing the architecture of a new internet, because the one-party state's internet vision reflects authoritarian values that are diametrically opposed to ours. China has suggested a radical change to the way the internet functions to the International Telecommunications Union. This would bake authoritarianism into the architecture underpinning the web, giving state-run internet service providers granular control over citizens' use. The authoritarian state's ability to monitor and control undersea fibre optic cables is emerging as a major national security issue for Australia and other democracies. The world could split into two separate information worlds, one led by the US and the other by China. A Balkanised internet is not in Australia's interest. We must engage with friends and allies to come up with a fit-for-purpose world wide web that is more efficient, secure, user friendly and compatible with democracy.

Keywords: Internet, security, China, 'Balkanisation', democratic alternative.

Our Wired World

Imagine trying to manage the impact of the coronavirus without the internet and a robust telecommunications sector. If we could not communicate and transact in real time, economic activity would grind to a halt and social contact would be even more difficult. And there would be no COVID-safe App, an important tool in the government's recovery strategy.

Already more wired than most nations, Australia's digital world is expanding rapidly as the coronavirus has forced business, schools, universities and government services online. Video conferencing platforms like Zoom are booming and the much-maligned National Broadband Network is finally starting to realise its potential. But if these networks were to become untrustworthy or disrupted for any length of time it would be hard for the country to function effectively.

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Fortunately, we are now much better informed and protected from many cyber threats. Passwords, anti-virus software and cyber security are firmly entrenched in our personal lives and business culture. Governments and telecommunications companies have invested heavily in measures designed to protect overall system security. But these measures may not be enough if China is successful in setting the rules and designing the architecture of a new internet, because the one-party state's internet vision reflects authoritarian values that are diametrically opposed to ours.

China's New Internet Protocol

China has suggested a radical change to the way the internet functions to the International Telecommunications Union, a United Nation's body established to standardise global telecommunications technologies, services and operations. The Chinese proposal envisages a different standard for core network technology called New IP (Internet Protocol) that it claims would make the internet more efficient and better structured for the digital age (Joseph, 2020).

Experts agree that the internet should be upgraded to deal with a world in which machines, as well as humans, are connected. And most countries accept that today's model of internet governance is broken and needs reform. But they do not agree on how a new internet should function. This has given China an opening to argue for an alternative internet that would replace the open, unified world wide web with a more fragmented, patchwork of national internets which China calls "cyber sovereignty".

Critics contend that New IP would bake authoritarianism into the architecture underpinning the web and give state-run internet service providers granular control over citizens' use. An investigation by the *Financial Times* found that the new protocol would require the network to have tracking features and a "shut-up command", which could enable governments to arbitrarily deny users access, a major departure from the current internet system which acts as an agnostic postman that simply moves data around (Gross & Murgia, 2020).

Acceptance of the proposal by the governing ITU at its November meeting in India would allow countries to choose the existing Western-designed internet or move to China's version. Many developing states in Asia, Africa and Latin America could choose the latter, which would help realise a long-term Chinese digital foreign policy goal — to entrench Chinese standards and technology as the foundation stones of the future internet, since the new global network would be designed and built by Chinese engineers, led by Huawei, the controversial telecommunications giant.

"What differentiates us from China now is that in the west the public can still mobilise and have a say", says Harvard social scientist, Shoshana Zuboff, as quoted in Gross & Murgia (2020). "What China wants is a technological infrastructure that gives them the absolute control which they have achieved politically, a design that matches the totalitarian impulse. So that is frightening to me and should be frightening to every single person."

The US is highly unlikely to accept this outcome because internet power is mostly held by four large American corporations: Apple, Google, Amazon and Facebook. New IP would end this virtual oligopoly, accelerate China's march to technology leadership and facilitate the export of its authoritarian model globally. If no consensus emerges, which seems probable, the world could split into two separate information worlds, one led by the US and the other by China.

A Balkanised internet is not in Australia's interest. A fractured digital world would vastly complicate e-commerce and trade, restrict the free flow of information, reduce international collaboration and human interaction and leave us vulnerable to the exploitation of our relatively open system by authoritarian states secure behind their digital firewalls.

To prevent these outcomes, the government will need to engage with friends and allies to come up with a fit-for-purpose world wide web that is more efficient, secure, user friendly and compatible with democracy. In the meantime, it needs to have a strategy in place to ensure that China's proposal does not win the day at the critical ITU meeting in November.

Capturing Tech Ecosystems

New IP is only one of several China-associated tech security challenges that the government will have to confront. Techno-economist, Julian Snelder, as quoted in Dupont (2020), says that the technology divide is becoming more evident in other areas of the global economy too, with Beijing relentlessly focused on developing and promoting a "Chinese tech stack" comprising integrated layers of linked software and hardware that could allow it to capture entire market ecosystems in user countries.

International organisations are also targets for China's rules-setting agenda. In March, the UN announced that it would partner with Chinese tech giant Tencent, which owns the highly popular app WeChat, to celebrate its 75th anniversary via videoconference and to discuss, among other topics, solving global pandemics. However, all conversations would be visible to Tencent in unencrypted form and accessible to Beijing which shows scant respect for privacy. Hong Kong academic, Lokman Sui, as quoted in Wong (2020), sees this as "the UN normalising and validating Chinese state surveillance" and says that Tencent censored information about the coronavirus and contributed to its spread.

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Beijing's expanding web includes Zoom, which relies on software developed by Chinese companies legally obliged to provide their government with user data. The videoconferencing platform has been banned by our Department of Defence as well as NASA, entrepreneur Elon Musk's SpaceX, and the New York public school system (Vigliarolo, 2020), highlighting security and human rights concerns about the exposure of sensitive data to Chinese Communist Party surveillance.

The Cable Wars

Trust in the internet could be further eroded by the cable wars, a developing new battleground at sea.

Four hundred internet enabling undersea cables carry around 98 percent of the world's digital traffic, including emails, texts and more than US $10 trillion of financial transactions (Riechmann, 2018). Cheaper and more efficient than satellites, these fibre optic pipes are the communications backbone of the world economy and Western militaries. This makes them priority targets for intelligence collection by submarines and oceanographic vessels equipped with sophisticated hacking technology designed for deep-sea tracking and tapping top-secret communication cables.

Undersea cables have long been intelligence targets. During the Cold War, the US navy sent divers into the Sea of Okhotsk to install listening devices, hoping to garner vital clues about the Soviet Union's nuclear submarines (Blitz, 2017). But the biggest concern today is that these cables could be deliberately severed or jammed with special equipment to interrupt vital communications and military links in times of conflict (Bennett, 2019).

China and Russia pay close attention to where these cables run to identify chokepoints and vulnerabilities. The Chinese navy has a modern oceanographic and submarine fleet able to access the dense network of undersea cables that crisscross the Pacific, linking Australia with Asia and the world (Lew, 2019). Russia has been aggressively probing global networks with spy ships and converted nuclear submarines that deploy deep-sea submersibles like the highly secretive Losharik, capable of cutting cables at depths that would be difficult to repair (O'Neill, 2019).

An emerging strategic problem for Australia, the US and other democracies is how to protect these cables from intelligence exploitation and attack.

The US has already taken defensive measures to tighten control over its critical telecommunications infrastructure. The US Justice Department recently blocked a partially constructed US-Hong Kong undersea cable, the first time the US has denied an undersea cable

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licence on security grounds because of the Chinese partner's close links to Beijing and concerns about Hong Kong's declining autonomy (Harris, 2020).

Ensuring that undersea cables are laid by trusted companies along routes less easily disrupted is an essential element of an effective counter strategy. For Australia, this means lessening dependence on cables that run through the disputed South China Sea and avoiding those built and controlled by Huawei, now a viable option as the world's longest fibre-optic undersea cable linking the US with Southeast Asia nears completion.

Telecommunications Infrastructure and National Security

Built by Nevada-based Trans Pacific Networks, this intercontinental cable project is supported by the US International Development Finance Corporation, established last year by the Trump administration to compete with China's digital Silk Road initiative (McBeth, 2020). The 15,200-kilometre cable will run from the northern Californian port town of Eureka to Guam and then follow a route to the south of the Philippines before entering the Makassar Strait en route to Singapore. There will be a branch to Tanjung Pakis, 50 kilometres north of Jakarta. When completed in 2022, the cable will form a critical element of the region's digital infrastructure, increasing internet speed while reducing costs.

A Darwin branch would open up substantial commercial and strategic opportunities for Australia. National access to a trusted, high capacity subsea fibre-optic cable would deepen our engagement with Southeast Asia's 480 million internet users and Indonesia and Singapore in particular. Indonesia is on track to become one of the largest e-commerce markets in the world and Singapore is the third most important financial centre, having recently surpassed Hong Kong.

Australian Defence Force (ADF) activities in northern Australia are constrained by the Top End's thin telecommunications infrastructure and inadequate high-speed data links. If the North is to become a critical national security hub and forward operating base for the ADF, it will need a lot more bandwidth to support the sophisticated operations, training and exercises necessary to achieve these ambitions. Fast, secure, high bandwidth data is a prerequisite for virtually all modern defence and intelligence platforms, ships, aircraft and drones, including our F-35 joint strike fighters, P-8 Poseidon maritime patrol aircraft and the state-of-the-art Triton surveillance drones we are acquiring from the US.

Connecting to the TPN subsea cable would provide a major data boost that could make northern Australia an attractive training destination for regional friends and allies by enabling the integration of Queensland and the Northern Territory's world class, but siloed, training ranges. It would also turbocharge our data-dependent, fledgling space industry and enhance our capacity to launch Australian owned and built satellites for commercial and national security purposes from the developing space port on the Gove Peninsula (We have lift off, 2019).

Strengthening our telecommunications architecture

A core lesson from the coronavirus pandemic is that improved national resilience and sovereign capabilities are essential to future-proof Australia from external shocks. Strengthening our telecommunication infrastructure should be a strategic priority because the risks are mounting.

A decade ago Karl Rauscher, an advisor to the US government on cyber security, drew attention to the vulnerability of undersea cables and the possibility of catastrophic failure to the global economy should they be disrupted by human action or natural disasters like earthquakes (Liebowitz, 2011). The problem is now much more serious because the demand for bandwidth has increased sharply to meet the insatiable appetite for internet-based services. This has resulted in many new submarine cable systems being laid on established routes, adding to congestion and forming undersea choke points (Sunak, 2017).

To make matters worse, there is little redundancy in the undersea cable system, particularly for intercontinental communications. Satellites cannot come close to making up the difference should key cables fail (Heilprin, 2020). Several choke points have already been adversely affected by natural disasters and illegal anchoring, resulting in multiple faults to cables and serious disruption to global communications. In 2006, an earthquake off southern Taiwan caused significant cable damage, slowing internet and telephone traffic across parts of Asia (Choe & Arnold, 2006).

Worries about terrorists and hostile states attacking major choke points were heightened in April 2013, when operators had to deal with disruptions to multiple undersea communications cables linking Europe to the Middle East and Asia. Alarm bells sounded when the Egyptian coastguard caught three divers trying to cut one of the main cables on the seabed a few hundred yards offshore from the port city of Alexandria (Kazaz, 2020).

Of greatest concern to Australia is the Luzon Strait to the north of the Philippines which is the world's largest undersea cable choke point, followed closely by the Malacca Strait (Sunak, 2017). The Luzon Strait and adjacent South China Sea are now effectively controlled by the Chinese navy, so Defence and the intelligence community should be thinking hard about the implications for the security of sensitive communication links critical to military capability and intelligence collection. Diversifying our cable traffic away from the South China Sea is the key to maintaining the integrity of our telecommunication system.

But it would be a mistake to regard protecting undersea cables and the openness of the internet as exclusively national security projects. The COVID-19 pandemic has brought home to all Australians the importance of the internet for everyday life. It is the indispensable communications highway that underlays virtually everything we do. A closed, untrustworthy system would negatively impact on business, trade, research and industry as well as our privacy and democratic freedoms.

Recommendations

The government would be well advised to take a more holistic approach to telecommunications policy that transcends narrow commercial considerations and places a premium on risk reduction rather than cost reduction, a lesson driven home by the pandemic. Narrow, market-based calculations should be replaced by a more strategic approach that takes better account of the need for sovereign capabilities to improve national resilience, and factors in the cost of relying on systems that don't pass the democratic values test.

Although it might be more efficient, a controlled, politicised internet with built-in shut-up commands would be detrimental to privacy, personal access and security. It is not a system we should support, even if it means inflaming relations with China already under strain from past disputes and the worsening trade conflict. Australia's national interests cannot be left in the hands of other countries to determine if we value our independence.

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Army Communications Looking Ahead

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Abstract: A historic paper from 1983 which describes the need for communications for command and control of the Army.

Keywords: Telecommunications, History, Army Communications

Introduction

The Telecommunication Journal of Australia has hosted many papers from mainstream industry and academia. Occasionally papers are received from unexpected sources, which shine a light into unfamiliar corners of telecommunications. This the case with the historic paper (Skelton, 1983), which describes the need for communications for command and control of the Australian Army.

The paper provides a summary of communications in the Army at the time (1983) and the technical variety that was expected as they advanced towards the year 2000. The paper needs to be viewed from the prospective of the communications that were available at the time, not the significant advances which we take for granted over the last nearly forty years, since the paper was published.

The author, Colonel P. G. Skelton, graduated from the Royal Military College Duntroon in 1960 and served in Vietnam from April to November 1967 (DVA, 2020), where he was responsible for communications support to the HQ AFV [Headquarters, Australian Force Vietnam], including in-country radio relay and High Frequency (HF) radio back to Australia.

The Army has a number of issues to consider when communications are required beyond the unit or local level. Communications need to be secure and they must withstand electronic counter measures; often, relay stations are required for VHF and UHF, given their propagation limitations. Equipment needs to be ruggedized, have excellent energy efficiency to conserve power, and operate properly in direct sunlight and in environments from wet tropical to dry dusty desert heat.

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In 1983, microprocessors were appearing in Army equipment for enciphering and terminal applications. Traditional manual message switching was being replaced with automatic exchanges, and the use of satellite communications was being introduced. Traditional HF was still heavily utilised for long-range communications via teleprinters and transportable 1 kW ISB [independent sideband] transmitters at remote headquarters.

At that time, there was a preference for the Army sourcing design and manufacturing from Australian companies. There was also a focus on developing people to perform the signals and communications functions, which remain critical to winning a war.

This paper was one of several in the *Journal* in 1983 covering defence communications and I can thoroughly recommend a companion paper from Captain Richard Arundel of the Royal Australian Navy, which appeared in the previous edition of the *Journal* (Arundel, 1983).

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The Historic Paper

Army Communications Looking Ahead

Colonel P.G. Skelton, AM, FRMIT, FIREE

This article describes the need for communications for command control of the Army. It summarises the various levels and types of communications provided and describes the elements which exist to provide these communications. The article looks forward indicating the type of communications and equipment which can be expected in the future.

INTRODUCTION

Communications are essential to enable the exercise of ***command*** and ***control.*** One of the responsibilities of a military commander at any level is to provide communications down to those he commands. To execute this responsibility the commander at each level in the Army is provided with a communications staff on his headquarters for planning and co-ordination, and a signal unit to provide the required communications.

There are many variations in the detailed implementation of this theme. There is also variety in the complexity, organisation and transportability of the signal units, depending on the level of the commander and the nature of his command. This summary of communications in the Australian Army today and towards Year 2000 illustrates that variety. The Army is a people, rather than equipment, oriented organization and the variety of interesting careers available in Army communications (both Regular and Army Reserve) can be inferred by the reader.

UNIT COMMUNICATIONS

Within units (that is within Infantry Battalions, Armoured Regiments, Artillery Regiments and so on) communications are provided by Regimental Signallers. These are members of those units who are primarily Infantrymen, Troopers, Gunners etc. and who have been given additional training to enable them to provide communications within their units. They provide VHF simplex voice radio networks (nets), HF simplex voice or CW (morse code) nets, and telephone systems based on small unit switchboards, magneto telephones and field cable. The key characteristics of equipment at this level are light weight, small size, reliability, and ability to withstand for long periods the full range of physical environmental conditions found anywhere in the geographical area of "Australia and its interests". Our emphasis in environmental performance is based on operations in hot wet and hot dry dusty (with high direct solar radiation) conditions, compared with our Northern hemisphere allies who are concerned with cold temperature performance. Electrical characteristics of importance are high frequency stability, clean emission and narrow channel spacing, to permit the required many hundreds of nets to operate in close physical proximity, plus compatibility with encryption devices and electronic counter counter-measures (ECCM) such as frequency hopping.

The Army has in service to-day, a variety of manpack and vehicle (both wheeled and tracked) mounted HF SSB and VHF FM radios, some of which were designed, and almost all manufactured, in Australia. These will all be replaced this decade by the family of radios being developed in Project RAVEN. The RAVEN family comprises a manpack HF transceiver, a manpack VHF transceiver, RF power amplifiers, and a common set of headsets, handsets, message entry device, power cables and so on **(Fig 1)**. RAVEN radios will be manufactured in Australia, with the HF radio entering service in 1987 and the VHF radio in 1989. They will not be much smaller or lighter than their predecessors, but are microprocessor controlled, have far better performance, will be more reliable despite the added complexity, and be easier to maintain.

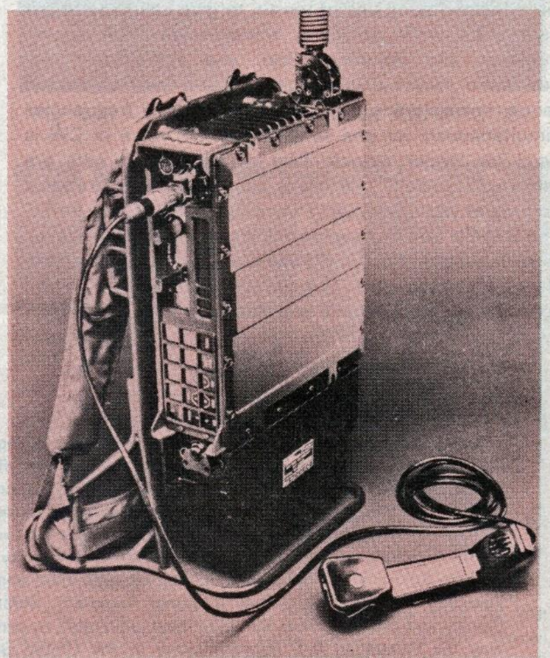

Fig. 1 — The HF manpack transceiver from the RAVEN family of radios. Note the lack of switches and dials. The keypad and screen indicate the greater flexibility of this new range of microprocessor controlled radios.

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COMMUNICATIONS ABOVE UNIT LEVEL

Above unit level, communications are provided by the Royal Australian Corps of Signals (RA Sigs). To scope the variety of tasks undertaken by RA Sigs it is simplest to consider six general categories, namely:

- conventional field communications;
- Special Action Force field communications;
- fixed (strategic) communications;
- technical support;
- training;
- electronic warfare.

RA Sigs has approximately 2600 officers and other ranks (of which about 12.5% are females) engaged in these activities. In addition, about 30% of the officers at any one time are filling "non-Corps" appointments such as in operations, personnel management, logistic support, or material development and acquisition, as part of their career advancement and broader contribution to the Army.

Field Communications — Brigade

A Brigade is a grouping of two to four Infantry Battalions, an Artillery Regiment, a Signal Squadron, and other units, all under a Brigade Headquarters.

A Brigade Signal Squadron provides communications for the Brigade Commander to all units under his command, to the Brigade Headquarters on his right (when deployed in the field with other Brigades), and for various special purposes such as reconnaissance groups and commanders rover groups. The main means of communication is secure VHF FM voice radio with handsets remoted into command posts and with radios sited making good use of terrain to give coverage to our own units while shielding transmission from enemy intercept and jamming. One, and sometimes two, automatic retransmission stations are used to extend range, necessitating the use of up to three frequencies simultaneously for one simplex net. HF voice or CW is used for longer ranges. Two or more radio nets are provided. Typically one net is kept clear for operational command while another is used for more routine traffic. The RAVEN family of radios will also be used at this level. A switchboard of about 30 line capacity **Fig 2** serves the Brigade Headquarters. The current manual board will be replaced by an automatic one this year. Line is laid from Brigade to Battalion Headquarters when possible, such as in a defence position, to avoid use of radio which is susceptable to intercept and jamming. A communication centre containing teleprinters at Brigade Headquarters enables receipt of formal messages from Division Headquarters. Training has commenced on the new microprocessor based teleprinter **Fig 3** now replacing the aged electromechanical one. A Signal Dispatch Service (SDS) based on Dispatch Riders using vehicles or motor bikes supplements electronic communications and provides a means of delivering items such as maps. There are currently three Regular Army and six (soon seven) Army Reserve Brigade Signal Squadrons.

Field Communications — Division

When a Division is formed from several Brigades, a Divisional Signal Regiment provides communications for the Divisional Commander to all Brigades and other headquarters and units directly under his command. The general outline already described is repeated with secure VHF FM voice and HF voice/CW nets, in future using the RAVEN radios, and use of SDS. However at this level the main means is a multichannel trunk communications system **Fig 4(a and b).** It is based on a 12/24 voice channel UHF radio relay sub-system using pulse code modulation (PCM) at 19.6 kbps. This carries common user and sole user voice circuits as well as teleprinter

Fig. 2(a) — Switchboard SB-3614. This ruggedized 30 line microprocessor controlled switchboard is subscriber facility programmable and can be stacked to form a 90 line board. It is also approved for connection to the Telecom system.

Colonel Skelton graduated from the Royal Military College Duntroon in 1960 into the Royal Australian Corps of Signals. He attended RMIT gaining FRMIT (Comm Engr) in 1962. He then commanded a troop responsible for installation of HF transmitting and receiving stations. Following a period as Instructor at the School of Signals he went to Vietnam where he was responsible for communications support to HQ AFV, including in-country radio relay and HF back to Australia. He has had a number of regimental and staff appointments including Commanding Officer 2 Signal Regiment, Commander Field Force Signals and Project Officer for digital field radio relay equipment. In 1978-80 he was the Australian C-E Representative in the United States Joint Tactical Communications Project Office. He has attended the Australian Staff College, the Royal Military College of Science (UK), and US Armed Forces Staff College. He is now Director of Communications — Army.

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circuits. The switchboard is a 150 line automatic board produced in Australia. It is a commercial PABX shock mounted in a "shelter" **Fig. 4 and 5** and modified physically and electronically to the minimum extent necessary to survive the environmental conditions and to interface with the radio relay and other equipments. A "shelter" **Fig. 6,** used widely at Divisional level and above, is a transportable room about 2.0 m x 2.0 m x 3.8 m carried on a truck or slung under a helicopter.

Message switching is still accomplished by manual torn tape relay but this will be replaced in 1986 by a small automatic, shelter mounted, store - and - forward message switch. Single channel secure HF teletype links provide an alternative connection when the radio relay is being moved. A medium power multichannel HF transportable terminal (MEDPORT) **Fig 7** now under production in Australia will replace the present equipment in 1984, as well as provide new capabilities.

The present array of terminal, switching, systems control, and transmission equipments, together with various short term expedient equipments about to be purchased, will all be replaced in the early 1990s with the all digital secure multimode (voice, data, facsimile, telegraph) system being developed under Project PARAKEET. A significant facet of PARAKEET which differentiates it from its overseas counterparts is the depth of investigation into integration of HF bearers into an otherwise wideband (16/32 kbps delta modulation)

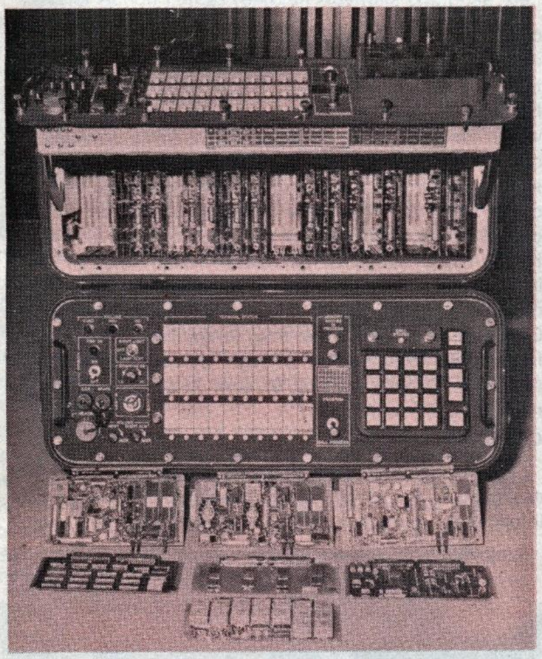

Fig. 2(b) — Another view of the SB-3614 showing: a. in the centre a complete SB-3614; b. on top another SB-3614 partly opened to show internal layout, and; c. at the bottom some of the cords removed from the top board.

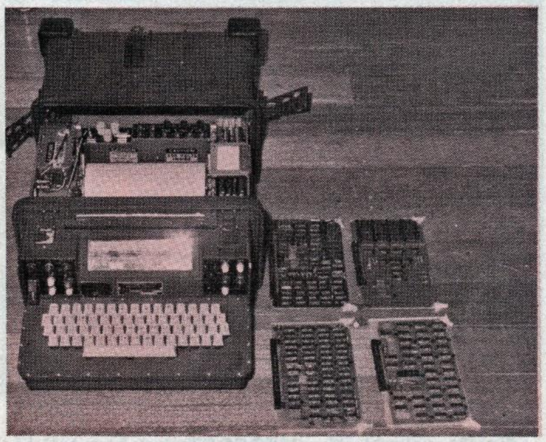

Fig. 3 — Field Teletypewriter AN/UGC-74 shown opened. The four PCBs visible in the right rear are also shown removed alongside.

Fig. 4(a) — Radio Relay Terminal AN/MRC-127.

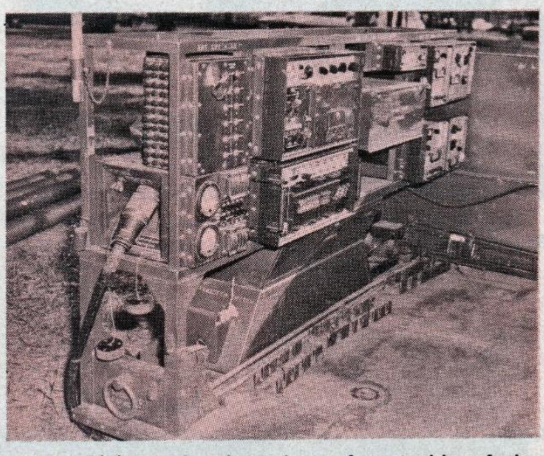

Fig. 4(b) — Another view of one side of the AN/MRC-127F1 radio relay pallet. Top left: signal cable connexion by binding post or (partly obscured) 26 pair cable lock. Bottom left: power cable and power panel. Top centre: 12 voice channel PCM time division multiplexer. Bottom centre: 12 channel telephone signal converter. Top and bottom right: UHF radio.

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system. Although satellite links will doubtless be a part of PARAKEET, there are circumstances in our situation when HF will be indispensible.

Reverting momentarily to the present day, the reader can readily appreciate the difficulty in frequency management generated by a dynamic system in which users are mobile and require of the order of 300 nets for each Division of which many VHF nets need retransmission stations, with some HF applications ground wave and other skywave, plus a frequently reconfigured radio relay system. On top of this many stations are in close physical proximity, alternative frequencies are needed to allow immediate relief from enemy jamming, and the entire assignment must be changed at least daily for other electronic warfare reasons. To overcome the daunting effort in calculation of all the interference possibilities, making compatible assignments, and printing the results in a user useful form, the program FASTNET is used. It was developed and written within Army and is run on a desk top computer in 1st Signal Regiment. In addition to frequencies, FASTNET is used to assign radio call signs and code words which also change at least daily.

Field Communications Behind the Battle

Behind the Combat Zone is the Communication Zone in which are found the less frequently moving and larger logistic support elements of the Army. Provision of communications in this zone follows the same general pattern, with due allowance for high capacity, long range, and less frequent moves, but non-the-less responsiveness to electronic warfare and air attack. One such Signal Regiment currently exists and there are plans to shortly reopen membership of it to the Army Reserve. This unit will also be equipped with both RAVEN and PARAKEET, and already has a shelter mounted automatic store - and - forward message switch based on a commercial minicomputer **(Fig 8)**.

Field Communications — Joint Operations

It is difficult to imagine an operation these days conducted by the Army in isolation. No matter how small or large the Army contingent deployed, it will almost certainly be as part of a Joint Force which would include Naval, Army and Air components. For such a Joint Force which included an Army component, Army provides the communications for the Joint Force Headquarters, with supplementation by communications personnel from the other services. The same building blocks as already described are used, and are practiced on the well known KANGAROO series of exercises, which also embrace interoperation with our allies. Multichannel long range communications to link such a headquarters with Canberra, or provide other long range links within such a force, are provided by a high power (10 kW) HF transportable terminal **(Fig 9)**, soon to be replaced by the new HIPORT terminals.

Computer Assistance

At all headquarters there is scope for computer assistance for both staff procedures involved in information management (such as own force and enemy

Fig. 5 — Inside the Field Automatic Telephone Switch shelter. It is an only slightly modified 150 line Australian made PABX.

Fig. 6 — Typical shelter.

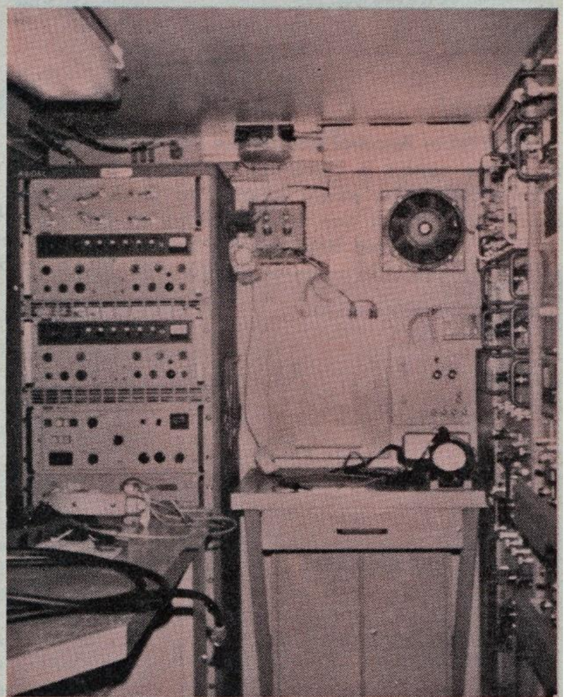

Fig. 7 — Inside the MEDPORT shelter, which is smaller than the other shelters. MEDPORT is based on a 1kW HF ISB transmitter carrying one voice and four teletype circuits.

organizations and locations) logistics and other calculations, as well as communication of key information between headquarters. The AUSTACCS 86 project is developing such a computer assisted system for use at Division and Brigade level. Data channels will be provided by both RAVEN and PARAKEET.

Conventional field communications as outlined above serve the bulk of the Army operations. There are however some interesting special requirements such as described below.

Special Action Force Communications

Special Action Forces (SAF) in Australia comprise the Special Air Service (SAS) Regiment, and a Commando Regiment. Regional surveillance units such as NORFORCE, (based in Darwin) have some similar communications requirements. The nature of SAF operations calls for specialist trained RA Sigs officers and soldiers, a contingent of whom form an integral part of all SAF units.

Some SAF communications, such as those deployed on the familiar commando raids, use similar single channel radio equipments and techniques for command and control as those used by conventional Army units in the Combat Zone. A different challenge for the SAF communicator is the maintenance of the vital links between a patrol base and its small patrols operating for protracted periods under adverse conditions up to several thousand km from their base. For the patrols, conventional communications are not always appropriate, differences are brought about by limitations on equipment size, weight and power output caused by their deployment techniques (from parachute to submarine and many in between) for long periods remote from support. The distances involved currently limit the patrol to HF radio. The need for security and speed, in dangerous operations, necessitates inconspicuous expedient antennas, burst code transmission techniques and minimal set up and tear down times.

The patrol base compensates for the limited resources of the patrol. A wide array of antennas, sensitive receivers and recording and cipher equipment collect the information, which is passed to the staff on the supported Headquarters. This information adds to the Commander's intelligence on the ground ahead and/or the enemy forces that occupy it.

Fixed (Strategic) Communications

Army provides manpower and operates major elements of the Defence Communications Network (DEFCOMMNET) and will continue to do so in DISCON (Ref 2). (Defence strategic communications are discussed in Ref 1 & 2). These elements include message switches, HF radio transmitting and receiving stations, commcens, radio relay and system control facilities.

Major Army units involved in the DEFCOMMNET are located in Sydney, Melbourne, Brisbane, Canberra and smaller facilities are operated in Townsville, Hobart, Adelaide and Perth.

Signal Corps trade structures and training are such that personnel can be employed in both fixed units and the field units already discussed.

DEFCOMMNET is mainly a common user message switched telegraph network which uses both Defence-owned and Telecom bearers but a facsimile service is also provided. In addition, Teleconference links can be established for military staffs, using telegraph facilities, between a number of headquarters.

Army is presently replacing aging electromechanical telegraph equipments with microprocessor based message terminal equipments at all of its commcens.

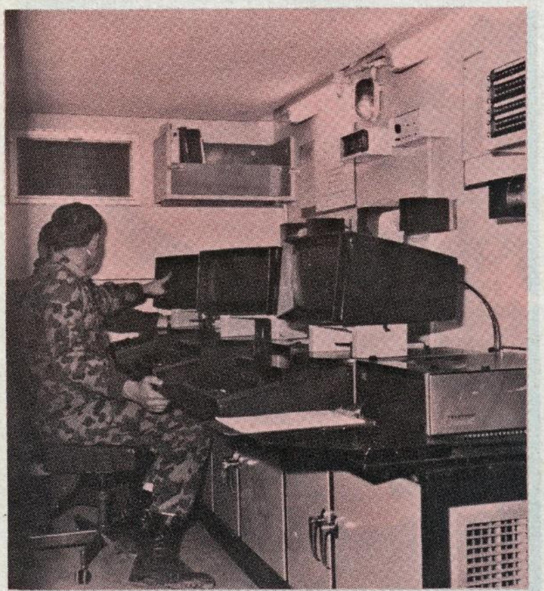

Fig. 8 — Field Automatic Message Switch. Store and forward switch handling 20 duplex teletype circuits. Photo shows interior of the control shelter with its supervisory positions. The fully duplicated minicomputer is in an adjacent shelter.

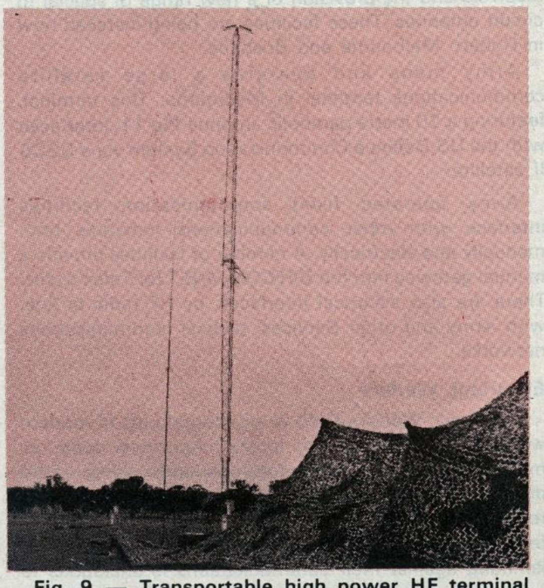

Fig. 9 — Transportable high power HF terminal AN/TSC-38A. Shelter containing one 10kW and one 1kW transmitters, dual diversity receivers, multiplexers and control equipment is under the camouflage net. The system includes two ship antennas and three sloping log periodic antennas.

These software based terminals provide assistance to the operator in formating, editing, routing, and traffic statistics. The terminals have a variety of memory capacities and numbers of keyboard/VDUs to enable tailoring to particular commcen traffic loads **(Fig. 10)**.

Fig. 10 — Fixed services tributory terminal (FIXSTT). The smallest terminal is shown with its single keyboard/VDU, single 3-disc 10 Mbyte memory unit and single high speed printer. The largest size has eight keyboard/VDUs, three memory units for a total 100Mbyte and four printers.

The HF radio facilities operated by Army are currently being upgraded. This has involved the procurement of new generation remotely controlled transmitters and receivers and the provision of a new range of special to circuit antennas. These facilities are being installed now in Hobart, Melbourne and Brisbane.

Army mans and operates a large satellite communications terminal in Melbourne. This terminal, featuring a 20 metre parabolic antenna **Fig 11**, interfaces with the US Defence Communication System via a DSCS II satellite.

Army operated fixed communication facilities interface with other communications networks both manually and electrically. A number of facilities provide a manual gateway into the DEFCOMMNET for Telex traffic. There are also electrical interfaces, by HF radio or line, with Army and other Services' tactical communications networks.

Electronic Warfare

Electronic Warfare (EW) is an integral part of modern warfare and has many facets. Activities such as monitoring enemy transmissions and using radio direction finding techniques to locate their emitters, are really quite akin to other more conventional forms of reconnaissance. Having located the enemy, using jamming against their communications is analogous to using any other kind of weapon. An EW squadron is allocated to support a Division by using all these techniques and Army currently has a major procurement programme to re-equip this squadron.

There are numerous other actions taken to limit the effect enemy EW activities will have on our own communications. These range from disciplined use of radio to minimise time on the air use of minimum power, directional antennas, and antenna siting — all to minimise accessibility of our communications to an enemy — use of codes and automatic encryption, and use of spread spectrum emissions.

Technical Facilities For Support of Army Communications

Army has two units which provide specialist technical support to other units in both the strategic and tactical communications networks.

The first of these units is a project squadron which is responsible for detailed engineering planning and installation of fixed communication facilities as well as some shelter mounted facilities for tactical units. In the strategic network such facilities include commcens, system control stations, message switch centres, HF radio stations, microwave radio terminals and antennas. This unit is also responsible for maintenance of antennas and masts in many parts of Australia. Its role should soon include a software development responsibility to enable the Army to maintain and develop its new computer based communications equipments.

The other unit operates a depot for receipt, storage and issue of a range of communications equipments and stores used by the first unit.

Training and Trade Structure

Army communications training is conducted mainly at the School of Signals located at Watsonia Barracks, outside Melbourne. It trains approximately 950 students per year. The School is organised into two trade training wings and support elements in line with the RA Sigs two

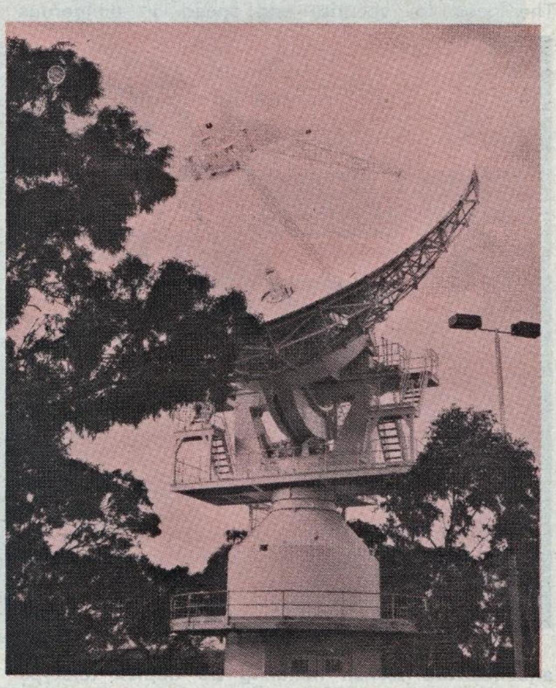

Fig. 11 — Satellite terminal. 20m antenna located at Watsonia Barracks Melbourne.

major career employment groups namely operators and technicians. In addition there is a third wing which is responsible for special signals training for officers and non-commissioned officers.

The operator trade wing conducts initial employment training and continuation training in keyboard, radio, communications security, procedural and management skills needed by the operator trade stream.

The technician trade wing also conducts initial employment and continuation training. The initial employment courses are for technicians electronic, technicians telegraph, riggers and linesmen. Advanced theory courses cover HF radio, radio relay, automatic switch and communications security equipments. The emphasis is to teach tradesmen the full theory of operation whilst also conducting specific equipment maintenance courses on the more complex equipments. Technical Supervisor training includes passing a 12 months certificate course at the Royal Melbourne Institute of Technology.

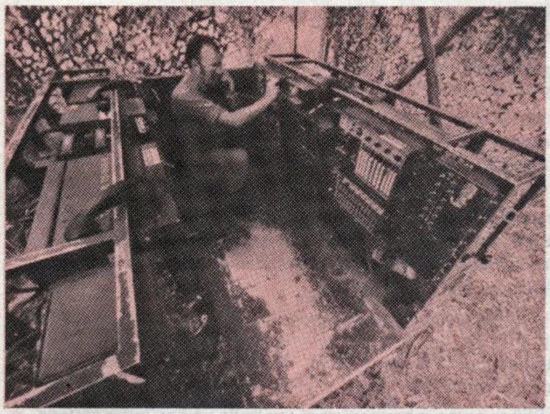

Fig. 12 — Fish eye lens view of 12 channel VHF radio relay terminal.

About 25% of young officers joining RA Sigs should do so with an engineering degree in electrical, electronics, computing, or communications. The remainder will, from 1983, attend early in their career a 12 month Telecommunication Systems Management Course at Swinburne Institute of Technology. All also attend courses at the School of Signals.

CONCLUSION

Although the variety of communications activities is clear there are several unifying features. These include deliberate adoption of complete systems design and management; our use of microprocessor based equipments using LSI chips arranged in a way amenable to rapid fault location and restoration of service; our preference for Australian design and manufacture; and our focus on developing people as the war winning factor.

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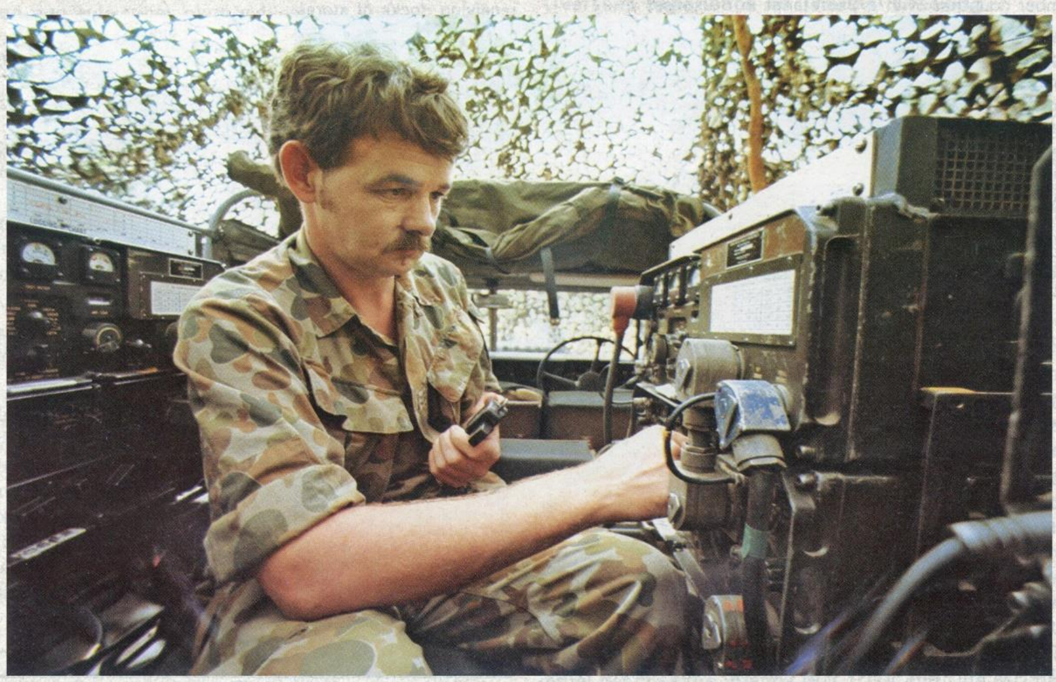

The photo above is from the front cover of the issue and is labelled "Operating an Army portable radio set in back of 3/4 tonne vehicle".