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Table of Contents

Editorial Team

The *Journal* is published by The Telecommunications Association (TelSoc), a not-for-profit society registered as an incorporated association. It is the Australian telecommunication industry's oldest learned society.

Editorial

Approaching the Promise of 5G

Leith H. Campbell
Managing Editor

Abstract: This editorial comes in two parts: some remarks on fulfilling the promise of 5G as it rolls out; and a brief introduction to the papers in this issue.

Keywords: 5G, Mobile standard, Editorial

Fulfilling the Promise of 5G

The fifth generation of mobile technology and services, "5G", is being rolled out in many countries, as we know from the many marketing announcements. Thus far, much public attention has been about 5G New Radio, a unified and more capable wireless air interface, which is already delivering enhanced mobile broadband in many locations.

But the 5G standards also include a core network for service delivery based on cloud computing (as described by Bruce Davie and summarized in Campbell (2021)). This provides interfaces, potentially open to third parties, through which they can define and deliver unique and innovative services. It remains to be seen how the telecommunications network providers will respond to this opportunity and what capabilities they will make available to third-party service providers.

The 5G capabilities include network slicing, where aggregations of network and service resources are made available to a restricted group of users. This can provide, for example, highly available and specifically tailored telecommunications services to emergency responders, without the need for a separate mobile network. Other uses for network slices could include "private" industrial or mining networks delivered over the public mobile network.

In addition to enhanced broadband, the 5G standards respond to the use cases for ultra-reliable and low-latency communications and for massive machine-type communications. These use cases have not yet received much marketing attention, but they are likely to be

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transformative in some applications. For example, a widespread deployment of sensors and actuators for smart-city applications could be supported by massive machine-type communications delivered over a 5G network. We are yet to see just how widely these use cases will be supported in the ongoing 5G deployments.

Of course, the standards development process is never complete. As a paper in this issue (Soldani, 2021) points out, new standards are continually in development. The vision of 6G is a long wish list of features building on the foundation of 5G. There will be regular releases of new standards, but what will eventually form "6G" is still a work in progress.

Meanwhile, the broadband performance of mobile networks is approaching or exceeding the performance of many fixed-network accesses. Mobile broadband is becoming a realistic competitor to fixed broadband, at least in terms of download and upload speeds. While fixed networks *can* always provide better performance than mobile networks, the fact that they do not is a reflection of all the innovation, research and development that has been directed at mobile communications over the past two decades. Fixed networks have not received the same attention. Fixed access can be used to accelerate the deployment of 5G mobile services (see, for example, the remarks by Andrew Hamilton reported in Campbell (2021) or Cioffi *et al.* (2020)) – and they should be, to support cost-effective availability of the benefits of 5G.

As Reg Coutts, whose obituary we publish in this issue (Gerrand, 2021), was fond of saying: "5G is much more than mobile". As he understood, fulfilling the promise of 5G is only just beginning.

In This Issue

We publish in this issue two papers related to public policy. *The Broadband Futures Forum: The Rise of 5G and the NBN* continues our series of reports on TelSoc forums concerning the future of broadband access in Australia, this one from May 2021. *Regional Mobile Telecommunications Performance* recommends the monitoring of mobile broadband performance in rural areas to improve the delivery of communications services in these regions.

In our Digital Economy section, we publish two papers. *Appropriate Social Media Platforms Commensurate with the Maturity of Organizations* describes several levels of sophistication in the use of social media by businesses. *The Adoption of E-commerce in SMEs: the Colombian Case* identifies the drivers for small and medium businesses to take up e-commerce.

In our Telecommunications section, we have three papers. The paper *6G Fundamentals: Vision and Enabling Technologies* looks at the ongoing standards process and outlines new

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features that could be included in a "6G" release. *An Analysis of Consumer Trends in the Telecommunications Markets of Russia and Vietnam* presents data from these countries and identifies similar trends in each. *Universal Service and Competition: The Cook Islands and Australia* describes the policy coordination that should apply in the introduction of a universal service levy.

In our Biography and History sections, there is one research paper, *Policy Legacies from Early Australian Telecommunications*, which describes the interaction of public and private sectors in the development of communications in Australia. We also publish an obituary of Reg Coutts, founding President of TelSoc (publisher of this *Journal*), in *Emeritus Professor Reginald Paul (Reg) Coutts (1949-2021)* and reprint one of his papers in *Revisiting the Universal Service Obligation Scheme*.

As always, we encourage you to consider submitting articles to the *Journal* and we welcome comments and suggestions on which topics or special issues would be of interest.

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The Broadband Futures Forum

The Rise of 5G and the NBN

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Abstract: On 25 May 2021, TelSoc hosted the seventh Broadband Futures Forum, held online, to examine the relationship between 5G and Australia's National Broadband Network (NBN). Two speakers discussed opportunities arising from the 5G core architecture for service creation and delivery via the NBN. Several 5G-related services that could be offered by the NBN to be used by its retail service providers were outlined. Discussion following the speeches included questions about potential service characteristics, possibilities for automation, and deployment scenarios.

Keywords: NBN, 5G, cloud computing

Introduction

The Broadband (formerly NBN) Futures Project (Holmes & Campbell, 2019) has been organizing a series of public forums under the title Broadband Futures to encourage debate, and potentially to build consensus, about the future of Australia's National Broadband Network (NBN) and a national broadband strategy (Holmes *et al.*, 2020) for Australia. The seventh in the series, held on 25 May 2021, was entitled "The Rise of 5G" and provided some insight into ways in which 5G and the NBN could be complementary. Specifically, the forum was designed to address two questions:

1) How does 5G represent an opportunity for the NBN to offer new wholesale services in addition to its existing layer-2 offerings?
2) How can the NBN support the deployment of 5G services in Australia?

The forums are hosted by TelSoc (the Telecommunications Association Inc, publisher of this *Journal*). The first forum was held in July 2019 (Campbell & Milner, 2019), the second in October 2019 (Campbell, 2019), the third in February 2020 (Campbell, 2020a), the fourth in August 2020 (Campbell, Smith & Brooks, 2020), the fifth in November 2020 (Campbell, 2020b) and the sixth in March 2021 (Campbell, 2021).

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

The Broadband Futures Forum

The Forum was conducted online via Zoom. There were more than 50 people registered to attend and at least 38 of them were online at one time.

Introduction

Dr Leith Campbell, Secretary of TelSoc and member of the Broadband Futures Group, chaired the Forum. He noted that, while mobile broadband would be a competitor to fixed broadband, the rollout of 5G also provided some opportunities for enhancement of the NBN. This is the approach taken in the Forum.

There were two speakers: Dr Bruce Davie of Systems Approach, LLC (and formerly with VMware and Cisco); and Mr Andrew Hamilton, a member of the Broadband Futures Group and principal author of the annex on 5G in the Group's major report (Holmes *et al.*, 2020).

Bruce Davie: Cloud networks and the NBN

Bruce Davie characterized his presentation as a 'technical tutorial' on the networking transformation through cloud computing that has been taking place over the past dozen years and its reflection in the 5G architecture. This forms an introduction to Andrew Hamilton's following presentation on implications for the NBN.

Bruce Davie described cloud networking as a key component of cloud computing. The introduction of cloud computing has had a profound effect on how computing and networking are done. This is clear in 5G, which introduces an entirely new network architecture, based on cloud computing, from that of earlier generations.

He suggested that growth in cloud computing really accelerated after Amazon Web Services (AWS) was started in 2006. Very quickly (Figure 1), AWS was using more network bandwidth than Amazon's own operations, and 'infrastructure as a service' was born.

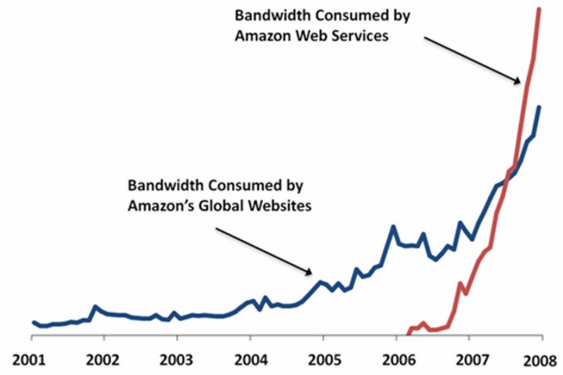

Figure 1: The birth of cloud computing at Amazon (Source: https://aws.amazon.com/blogs/aws/lots-of-bits/)

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With cloud computing, computation and storage has become, he suggested, like a utility. A user only pays for resources needed, without having to pre-provision for the maximum likely capacity; there is no need for in-house computing resources; there is an illusion of infinite capacity, where compute and storage resources can be added or reduced almost instantaneously; and, in most instances, users are heedless of where their computing resources are located.

Cloud computing has enabled a range of service options, from a basic 'infrastructure as a service', through 'platform as a service', which includes higher level functions like messaging, to 'software as a service', which provides a full range of end-user services including, for example, databases.

He noted that a core technology to enable cloud computing has been virtualization. Originally, starting from the early 2000s, this permitted decoupling of applications from the physical systems hosting them: an application or operating system could be implemented in a virtual machine, which could share, completely independently of other applications, a set of physical resources. Many virtual machines can run on a single physical machine, leading to the concept of 'slicing', where an application has a 'slice' of physical resources without being in any way aware of the presence of other applications running on the same resource.

The same ideas apply to network virtualization. This began with large technology companies, like Amazon and Google, but is now common in large enterprise data centres. With network virtualization, network characteristics such as firewalls, switching and routing can be created quickly and in complete isolation from other network instances. This has become central to networking today. There is no longer the need to allocate a physical resource, such as a router, to a single user or application; rather, the physical resource is shared by applications, each of which has the illusion, created in software, of having a dedicated physical resource.

For a new Retail Service Provider, he suggested, network virtualization means that it could create its service on the NBN without the need to install any of its own physical equipment.

Dr Davie then introduced the term 'Software-Defined Networking' (SDN), coined in 2009. SDN refers to a set of software services that enable the creation and management of virtual networks. SDN is in widespread use in cloud networks and large enterprise networks. It has enabled a high level of automation, avoiding manual configuration of networks, and has led to software-defined Wide Area Networks (WANs), which are used in multi-site corporate networks.

Cloud computing, network virtualization and SDN are then applied to mobile networking to create the 5G architecture (Figure 2). It looks much more like a modern cloud data centre, with many commodity servers running software to deliver services in a much more automated and

http://doi.org/10.18080/jtde.v9n3.432

flexible way than was possible in 4G. The architecture consists of a collection of clouds, including a 'telco cloud', in which services and networks are configured, and 'edge clouds', which sit much closer to the radio resources and end users and can run latency-sensitive services. New services, especially third-party over-the-top (OTT) services, can be easily provisioned in edge clouds or other cloud locations. This means that many third parties can potentially be involved in creating new services in the 5G architecture.

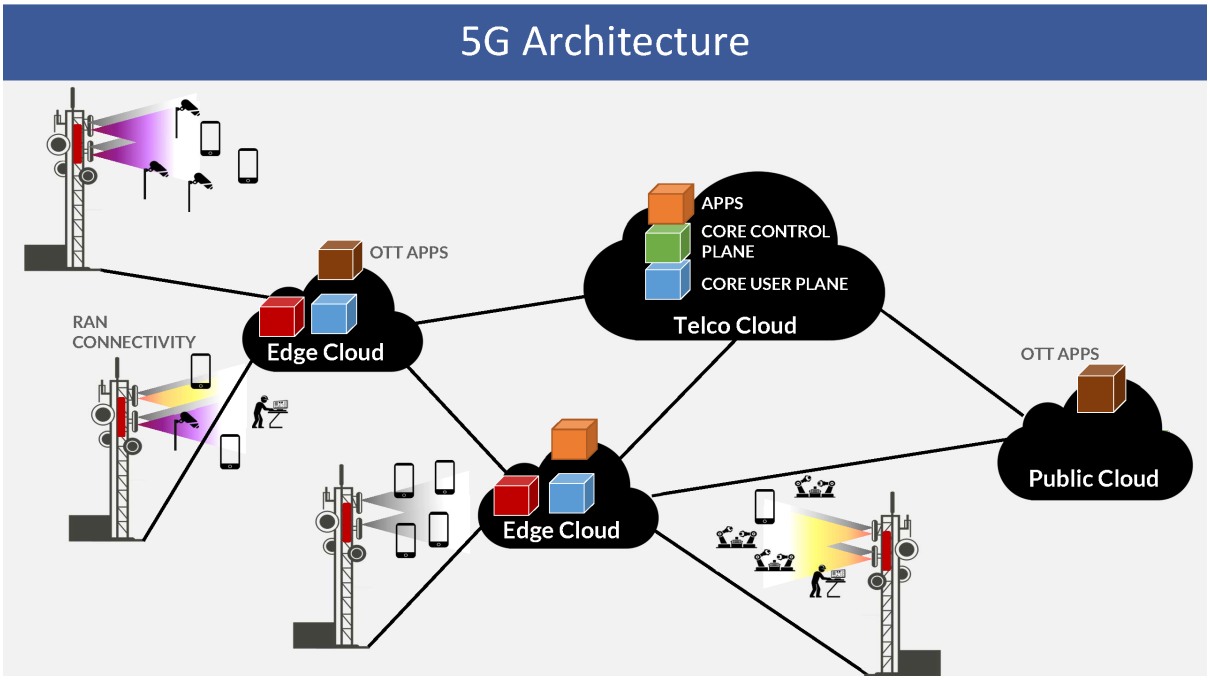

Figure 2: 5G architecture (Source: Bruce Davie)

Figure 3 shows an example of a managed edge cloud in 5G, where a network is delivered to an enterprise but managed by a service provider. In the edge cloud there are many enterprise services that need to run, for example, for the Internet of Things, that are provisioned in the edge cloud but are centrally managed by the service provider. A single service provider could provide these features to many different enterprises.

In summing up, Dr Davie described 5G as the first mobile generation to leverage cloud computing, benefiting from the advances in virtualization of computing and networking over the past 20 years. The 5G architecture will enable a revolution in the provision of new services, enabling them to be implemented much faster with their own isolated 'slice' of networking resources, while sharing the radio resources, computing resources, backhaul and other network capabilities.

In answer to a question posed in the chat about cyber-crime, Dr Davie described some of the security approaches, such as zero-trust, being implemented by cloud service providers and claimed that these implementations were the best available defences against cyber-crime. (For a survey of security aspects in 5G, see Cao *et al.*, 2020.)

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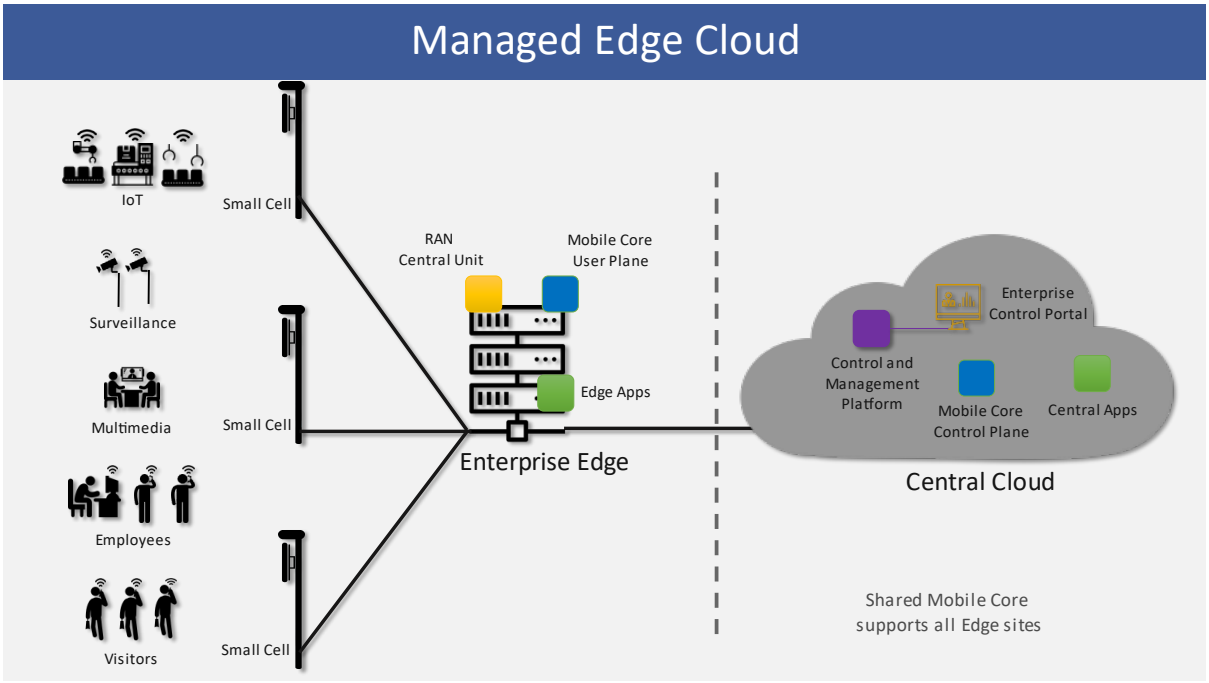

Figure 3: Managed edge cloud (Source: Bruce Davie)

Andrew Hamilton: The implications of 5G for the NBN

When introducing Andrew Hamilton, Dr Campbell noted that he was a published author in the *Telecommunication Journal of Australia* (Kitchen & Hamilton, 1998).

Andrew Hamilton began by quoting Andy Penn, CEO of Telstra, on the importance and significance of 5G mobile. He noted that 5G is already being rolled out by Telstra, Optus and Vodafone (TPG) as fast as possible. He suggested that, while the benefits of 5G may be being oversold, it will provide new broadband benefits and should be taken into account in planning the NBN.

Mr Hamilton was of the view that 5G, and the technologies on which it is based, can enhance the NBN, providing benefits to users, retail service providers, and NBN Co itself. In this context, he suggested two potential new wholesale products that NBN Co could provide:

1) Network as a service, a variation on infrastructure as a service described by Bruce Davie;
2) 5G hotspots, short-range *fixed* 5G interfaces, similar to a Wi-Fi hotspot.

He indicated that these services were not being advocated by the Broadband Futures Group but had been discussed, and were examples of concepts that should be taken into account in planning the broadband future for the NBN and Australia.

The network-as-a-service product would be supported by two technologies: one or more virtual servers ('in the cloud'); and a 'transport slice' to connect them. The virtual servers in the NBN could be located at fibre access nodes (at the metro-network edge of the fibre

http://doi.org/10.18080/jtde.v9n3.432

footprint) and the NBN Points of Interconnect (PoIs) (where retail service providers connect to the NBN). The transport slice is an allocation of network resources dedicated, via software control, for transmission between the virtual servers. (In relation to the earlier discussion of cyber-crime, he noted that the use of a network slice would mean that there is no sharing of traffic as occurs in the general Internet.)

Mr Hamilton wished to emphasize the economics of the network-as-a-service product. By virtualizing the network resources, the user (a retail service provider in the context of the NBN) would only pay for the resources it needs, rather than having to make an initial investment in physical infrastructure, thereby lowering the barriers to entry.

He noted that location of the servers close to end users would be important for low-latency services. There are developing standards for this purpose, including ETSI's multi-service edge computing (MEC) initiatives (Giust, Costa-Perez & Reznik, 2017). MEC integrates virtual servers with the network, particularly at the edge. The MEC standards are separate from the 5G standards but are compatible with them. MEC can thus be used in 5G and non-5G worlds, including the NBN.

NBN Co could implement MEC servers at its fibre access nodes and offer MEC-based services to retail service providers. The retail service providers, or their customers, could then implement low-latency services.

Mr Hamilton suggested, however, that a more intriguing use would be to provide network function virtualization, in which network equipment functions are implemented as software, making them 'cloud native'. The 5G core network, as described by Bruce Davie, is also cloud native and is implemented with network function virtualization and software-defined networking. For an end-user, network function virtualization would lower the cost of entry and convert capital cost for equipment to ongoing operational cost. Transport slices would also be required between virtual servers and to the PoI.

The second potential wholesale service for the NBN is a 5G hotspot, a short-range, fixed radio interface at customers' premises, similar to a Wi-Fi hotspot. The customer premises equipment would be a 5G femtocell, the 5G equivalent of a Wi-Fi access point. The access point could use radio spectrum in the 3.4 GHz band but would better use millimetre wave spectrum, which is currently available in Australia. In December 2020, the ACMA issued a class licence variation (ACMA, 2020) making 850 MHz of mmWave spectrum available to anyone who wished to run a private 5G network, subject to low-interference operation.

To run a 5G service, a user would also need a 5G core network. Mr Hamilton explained that NBN Co will likely upgrade its fixed-wireless accesses from 4G to 5G and will therefore need

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to implement a standalone 5G core network as well. Consequently, NBN Co will also be able to connect 5G femtocells to its 5G core network.

What are the benefits of 5G hotspots for end users? Mr Hamilton suggested an example of the Internet of Things used for connecting premises security cameras. The cameras would be connected to a 5G hotspot and, via a secure network slice, transmit their data to a cloud-based server. A second benefit would come about by roaming from one 5G hotspot to another; a 5G device could connect to a premises 5G hotspot when it comes within range. This would have the added benefit of offloading traffic from 5G mobile macrocells onto the NBN, providing more reliable service for all users.

Pricing for these services would also be an issue. Mr Hamilton believed that the same AVC/CVC pricing structure as used in the current NBN could be adapted for the new wholesale services, with service features being equivalent to AVCs or CVCs. A network slice, for example, would be equivalent to a CVC. Retail service providers would issue their own SIM cards, permitting users to roam onto NBN-provided 5G hotspots. The price of access between a 5G access point and a PoI would depend on the bandwidth subscribed to, as it does with an AVC.

For connectivity into a service provider's network, the 5G standards provide for two options: local breakout, equivalent to the current NBN network-network interface; and home routed, referring to routing a connection back to its home 5G network. The second option would permit a 5G operator to implement a 5G core but not have any 5G access network: the access network would be provided by another operator. Mr Hamilton explained that such an operator could use the NBN, enhanced with 5G hotspots, to be its 5G access network.

He noted that retail service providers could themselves provide 5G hotspots, that is, 5G access devices, connected to the NBN. He foresaw that some retail service providers would do so. There are, however, two advantages stemming from the NBN providing the 5G hotspots. The first is that NBN Co could also provide edge-cloud services from a fibre access node, a location not accessible to retail service providers. The second is that it would avoid the risk of market fragmentation. Mr Hamilton described an example of a security service provider deploying and managing security cameras on customers' premises. If the 5G connections were provided by a retail service provider, the security provider would either need to subscribe to all retail service providers or would restrict its deployments only to premises served by the retail service providers with which it has subscriptions. This could be to the disadvantage of smaller retail service providers. The alternative of the 5G hotspots provided by NBN Co would mean that the security provider would need only one arrangement, that with NBN Co.

In summary, Mr Hamilton noted that there is an overarching need for a national broadband strategy, as described by the Broadband Futures Group, with the NBN as a central facility. One

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can assume that NBN Co evaluates speculative networking opportunities as part of its planning, but this is not made public. The ACMA provides an annual communications report, which identifies advances in network technology but does not consider their implications for the NBN. Mr Hamilton suggested that, at the least, these two government-supported strands should be brought together in a coordinating document, which could inform more detailed policies such as the allocation of radio spectrum.

To be clear, Mr Hamilton also summarized what he was *not* suggesting:

- He was not suggesting that NBN Co should become a mobile network operator.
- He was not suggesting that NBN Co be compelled to offer a virtual network as a service and 5G hotspot services. The offering would depend on a suitable business case.
- He was not suggesting that NBN Co stop providing its current layer-2 Ethernet services.
- He was not suggesting that retail service providers be prohibited from offering their own 5G hotspot services. In fact, he would expect that they would offer such services.
- He was not suggesting that NBN Co should offer any retail services; it should remain a provider of wholesale services.

Questions and Answers

Question: Why had a cloud-based core infrastructure not been introduced with 4G?

There had been some discussion of this issue in the chat during the presentations. It was noted that there were cloud-based services available 'over the top' in current 4G networks but the full integration of networks and cloud services had been restricted by the technical maturity of the various components and had only become possible with 5G.

Dr Campbell added that there is a security boundary around a mobile operator's core network and the opening up of services through this boundary depends on a business case for the operator and the pressure of user demand.

Question: Are you advocating the 5G approach for NBN Co just for its internal operations or are there end-user applications provided by NBN Co?

Andrew Hamilton replied that virtual machines can be used to benefit the network provider but also can be used to provide services to end-users, as in the security camera example.

Bruce Davie added that it was clear that 5G services could be provided to end-users by the NBN. He noted that, in a fully virtualized 5G core network, a service provider could use the 5G mobile network provider's core resources in the same way as it could gain compute or storage resources from Amazon Web Services. This opens up many new service possibilities. It would

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apply to the NBN if it also implemented a 5G core architecture. Just as the NBN uses 4G for some accesses, so 5G could also be used, but the 5G architecture in addition adds many new capabilities independent of the radio access.

Question: Low-latency services have been mentioned, but what about performance in general? Does network slicing, for example, degrade network performance?

Bruce Davie noted that in all virtualizations there are choices about how resources are shared. Amazon Web Services, for example, offers two types of access to compute cycles: either the cycles are allocated to the one customer and cannot be used by others; or, more cheaply, cycles can be shared with other users and may not always be available. The same options can be applied to network slicing: either dedicated bandwidth is allocated and guaranteed; or the bandwidth is shared with other users.

Question: Can we expect that fixed network providers will also implement a 5G core?

Andrew Hamilton outlined the current work by the Broadband Forum on wireless-wireline convergence to ensure that a 5G core can be used both for wireless networks and for fixed networks. This permits a service to be provided on either network. Mr Hamilton suggested that, in this way, the distinction between mobile and fixed networks was disappearing.

Question: Will the 5G hotspots enable retail service providers to do end-to-end management of services, including the in-premises network?

Both speakers agreed that end-to-end management of services will be possible. Bruce Davie added that end-to-end management of services is in the vision of the 5G operators.

Question: Can the speakers comment on the cost and time to deploy 5G access points within 50-100 m of every premises, compared to in-premises deployments via 5G hotspots?

Andrew Hamilton suggested that the best way to get 5G services in premises is to implement a 5G hotspot connected to the NBN. The alternative is that 5G mobile operators will deploy small 5G base stations along streets, which will be much more costly and take a long time. Wireless signals from street deployments may also not penetrate walls and can suffer other degradations.

Dr Campbell reminded the audience that some of this thinking about deploying 5G via the NBN was triggered by a presentation by Professor John Cioffi to TelSoc in August 2020, which described the concept of 'cellular subscriber lines' (Cioffi *et al.*, 2020).

Conclusion

This was the seventh of a planned series of forums related to the future of the NBN and a broadband strategy for Australia. It was the first to concentrate on technical developments, in

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this instance the deployment and architecture of 5G mobile networks. It addressed some questions around how the NBN and 5G could provide complementary broadband services.

As Bruce Davie described in his speech, the 5G core network is designed to be cloud-native and provides the infrastructure for the rapid definition and deployment of new end-user services. This architecture, which will be implemented, at least partially, to support the 5G extensions of the NBN's Fixed Wireless Access, will open up new opportunities for NBN Co.

Andrew Hamilton outlined two of these possibilities. Clearly, NBN Co can introduce cloud-based features into its own access network to enable its retail service providers to support low-latency services. More interestingly, NBN Co could offer 5G wireless access points at the customer ends of its fixed access network. In this architecture, the NBN would be 'transparent' to a 5G service provider, as if its customers were roaming onto another provider's network. This provides a mechanism for rolling out 5G access into customers' premises at low cost and in a timely manner.

To exploit such opportunities efficiently, Australia needs a technical roadmap based on an overarching broadband strategy to support the development of the digital economy. As Andrew Hamilton pointed out, there are some isolated silos of technical planning within government entities, as in the ACMA and NBN Co, but no apparent coordination between them. This can lead to economically inefficient outcomes, such as market fragmentation or an inability to support greater levels of automation. Modern computing technologies, now tightly integrated with telecommunications through the 5G core architecture, provide opportunities for advancing the digital economy that should not be missed.

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Appropriate Social Media Platforms Commensurate with the Maturity of Organizations

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Abstract: As digital technologies advance, the digital world is integrated with the real one through various digital platforms. Digital transformation in organizations is essentially based on emerging technologies and social and digital platforms. The purpose of this study is to help organizations choose the appropriate platforms to interact with customers and participate in the digital world in accordance with the maturity they gain in using these digital technologies. The present research, by synthesizing empirical studies on the use of various social platforms in organizations, provides a conceptual map of the relationship between the platform type and the maturity stage of organizations. According to the findings of this study, general social networks are suitable platforms for organizations with the first-stage maturity characteristics. Various social networks and creativity works sharing sites were recognized as suitable for the second stage; and public blogs and educational materials sharing for the third stage. Microblogs, discussion forums, and business networking sites are also appropriate for organizations with the characteristics of stages four and five. Using the findings of this research, organizations will be able to identify a social platform appropriate to their stage of readiness and maturity and make the most out of its benefits.

Keywords: Social Media Platform, Stage of growth, Maturity Stage, Systematic mapping, Digital platform

Introduction

Social media is generally defined as the tools and platforms that provide users with the possibility of virtually creating and sharing information (Perrin, 2015). Over 3.6 billion people (45% of the world population) are social media users (Kavota, Kamdjoug, & Wamba, 2020). By 2025, this number will reach 4.41 billion people (Tankovska, 2021). The COVID-19 pandemic situation of 2020 forced more people to use social media and find ways to interact

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with each other. Every day, 1.3 million people are added to social platform users. Of these users, 98.8% are active on more than one platform. On average, each user uses 8.4 different social platforms (Michopoulou & Moisa, 2019). Social media is considered a low-cost information exchange platform for organizations (Dwivedi, Kapoor & Chen, 2015). Organizations use this technology for marketing, public relations, training, recruitment, research, product testing, criticism, suggestions, and funding (Orlandi, Zardini & Rossignoli, 2020; Ngai, Tao & Moon, 2015). According to the Global State of Digital 2021 report, 40.4% of Internet users use social platforms for business purposes; 86% of organizations in the Fortune 500 use at least one social platform (Zhang *et al.*, 2019). With the evolution of social media, new social platforms emerge; thus, selecting the right platform has become an integral part of any organization's success (Dwivedi *et al.*, 2020). While small businesses should keep their social media efforts focused due to limited resources, it is critical to ensure that this investment yields results.

The organization must devote resources to content production and activity on various platforms to be present on social media. In fact, 65% of organizations respond to this need by using their existing staff and 9% by recruiting new employees. Statistics show that it takes at least 32 hours a month to be active on any platform (Kavota *et al.*, 2020). Some organizations want to be active on all popular platforms, although they do not possess the necessary resources to participate in all of these platforms. Such organizations do not achieve the desired results from social media because they bite off more than they can chew. On the other hand, some organizations spend resources only on Facebook and Twitter without examining the suitability of the platform features for their purpose, arguing that these platforms have the highest number of members. They ignore the question of whether or not these platforms are appropriate for their needs. These organizations, too, will not achieve the desired success on social media. Although research on social media in organizations has attracted a lot of attention, few studies have been conducted on the appropriate platforms for each organization. Most studies have examined a specific type of social platform and have not examined other platforms by changing the organization's characteristics (Song *et al.*, 2019).

The majority of studies reviewed focus on single social media platforms with a couple of exceptions (e.g., Bakri, 2017; Odoom, Anning-Dorson, & Acheampong, 2017). Most of these studies have highlighted similar limitations, which involved studying their concept on other platforms. He *et al.* (2017) suggest that future research needs to expand the scope of data collection by including relevant data from other social platforms. On the other hand, most previous studies have assumed maximum use of social media capabilities in organizations. In practice, organizations cannot take advantage of all capabilities of technology at once and go through a maturing process in using its capabilities. In addition, choosing the way and the

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level of using social media in any organization is specific to the characteristics of that organization, and the successful approach of an organization cannot necessarily be a good model for other organizations. Therefore, the level of technology utilization should be determined according to the organization's specific characteristics (Aral, Dellarocas & Godes, 2013). If the ground is prepared for using social media and the organization is immature, progress will face difficulties (Chan & Swatman, 2004). Hence, it is necessary to determine the organization's maturity stage for using social media capabilities. To this end, this study strives to address the following question: Which platforms are suitable for the use of social media in the gradual maturity development path of the organization?

To answer this question, the stages of an organization's maturity in the use of social media with social platforms appropriate to that stage of maturity will be explained. This research contributes to the literature of social media platforms through its key findings that are relevant from both theoretical and managerial perspectives. The findings of this study include the identification of appropriate platforms for each maturity stage in social media use in organizations. Using the results of this study, managers will be able to identify platforms appropriate to the characteristics of their organization and plan for future investments in social media. Other audiences for the present study include the research community and experts interested in social media in organizations. In the present study, the platforms with high research density have been identified. At the same time, overlooked cases will be determined. In addition, by identifying the stages of maturity that are less addressed, researchers can plan for future studies and identify platforms appropriate to the characteristics of those stages.

The rest of the article is structured as follows. In the next section, the theoretical background for the conceptual map is presented. In the methodology section, the systematic mapping approach, the components of the literature review protocol, and the data processing method are described. Then, the findings of the study are presented, and appropriate platforms for each maturity stage of the organization are introduced. Finally, the conclusion summarizes our findings and recommendations, together with some comments on limitations of the study and future research directions.

Theoretical Background

This study aims to identify appropriate platforms during the maturity stage of the organization in social media. Given the multiplicity of social platforms, they need to be categorized in terms of function in the organization. In this study, the classification presented in Misirlis & Vlachopoulou (2018) has been used. This classification has also been used in studies such as

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Olanrewaju *et al.* (2020), Ismagilova *et al.* (2020), and Chi *et al.* (2018), and has been accepted by researchers.

To describe the maturity status of an organization in social media use, a reference model is needed in which the characteristics of each maturity stage are described. In this study, the social media stages of growth model (SMSOG) presented by Chung *et al.* (2017) has been employed. In what follows, the types of social platforms used in organizations are categorized, and the bases of the SMSOG model are described.

Types of social media platforms

In the literature, the social platforms of organizations have been categorized from different perspectives. Concerning the type of content published on the platform, they have been divided into five categories: 1. social networks; 2. professional networks; 3. media sharing; 4. content production; and 5. virtual reality and gaming environments (Hagg, Dahinten & Currie, 2018). In terms of audience, Kwahk & Park (2016) divided social platforms into two categories: enterprise social media (ESM) and public social media (PSM). Kaplan & Haenlein (2010) classified platforms into six categories with respect to social presence/media richness and self-presentation/self-disclosure: 1. social networking sites; 2. content communities; 3. blogs; 4. collaborative projects; 5. virtual social worlds; and 6. virtual game worlds.

In the present study, it is required to classify the platforms with respect to their function in organizations, because the goal of the study is to identify platforms suitable for each maturity stage of the organization with a focus on the findings of empirical studies on social media. In this regard, the classification offered by Misirlis & Vlachopoulou (2018) is used. In this classification, platforms are divided into four groups: 1. social networks; 2. Content communities; 3. Blogs; and 4. Online forums. Each category is described in the following section.

1. Social Networking Sites

Social networks are created with the aim of human-to-human interactions (Kapoor *et al.*, 2018). In social networks, users connect with each other and share user-generated content (Boyd & Ellison, 2007). One of the capabilities of a social network is to create a (semi-)public profile. Profiles are unique pages where one can “type oneself into being”. In a profile, in addition to the identity information of each user, a list of other users with whom they are connected is articulated (Liu & Ying, 2010). In these networks, informational messages are sent to create engagement with followers. Social media is often used as a tool for customer relationship management. This capability is a great advantage for entrepreneurs who are looking to expand contact bases. International organizations also use social networks to keep in touch with audiences in different geographical areas. In social networks, one-way

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communications are often established (Manetti & Bellucci, 2016). Thus, the social network is not considered a suitable platform for shaping active two-way interactions with stakeholders (Lovejoy, Waters & Saxton, 2012). The types of social networks are explained below.

1.1. General social network sites

General social networks have changed the way people interact and share experiences (de Reuver, Sørensen & Basole, 2018). These networks are appropriate spaces for sharing visual content and engaging audience, especially visual learners (Davis *et al.*, 2020). Facebook is the most popular general social network site. On Facebook, users comment on various products as self-reporting (Gamboa & Gonçalves, 2014). By analysing these comments, organizations identify ways to improve the product according to customer needs (Roberts & Piller, 2016). In addition to Facebook, similar platforms have been created for users in specific geographic areas (such as Spaces in Russia, Qzone in China, and Band in South Korea). Organizations enhance their relationships with the target audience by monitoring the interactions in these networks and sending advertisements (Ko, 2018).

1.2. Instant messaging

Instant messaging (IM) is a type of online chat for real-time text transmission (Hsieh & Tseng, 2017). These platforms are a good alternative to operator-based text messaging via SMS due to their free or low-cost chat services (Isaacs *et al.*, 2002). IM (such as WhatsApp, QQ, Skype, Zoom) is known as the Jill of all trades. On these platforms, it is possible to group chat, and exchange graphics, files, videos, and stickers (Hagg, Dahinten & Currie, 2018). Organizations use these capabilities to shape communication networks with potential business partners (Ellison & Vitak, 2015). As an all-in-one platform, WeChat offers capabilities such as online shopping, money transfer, making reservations, and booking taxis, in addition to messaging and calling. A similar platform in Japan is Line.

1.3. Business networking sites

These platforms are specifically designed to promote relationships in the business community (Davis *et al.*, 2020). On these sites, users share work-related information. On business networking sites, each user's profile reflects their professional skills. Profile information is business-oriented rather than personal (Papacharissi, 2009). On business networking sites, using statistical techniques, each user is given suggestions to connect or link with potential contacts and relevant groups (Ellison & Vitak, 2015).

The most popular platform in this category is LinkedIn. Fifty-five million companies are active on this site (McCosker, 2017). Organizations use this platform for professional networking and monitoring the labour market (Van Dijck, 2013). Other platforms are also used to exchange business information. In Glassdoor, for example, information about how organizations treat

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their employees is shared. People use this information to understand the values of the organization. By examining the information published on this platform, organizations also become familiar with employees' attitude toward them and plan to improve employees' experience (Karabarbounis & Pinto, 2018).

2. Content communities

The purpose of these platforms is to provide the possibility of sharing content (text, image, video, audio) among users (Kaplan & Haenlein, 2010). Unlike social networks, users in content communities are not required to create a personal profile page after signing up. In content communities, users upload multimedia content and submit a description for it. This content is made available to the public. Visitors can subscribe to individual users and respond to content published by others. Some content community platforms are specifically designed to share educational content and manage relationships in training courses. The rate of using these platforms has increased with the COVID-19 pandemic (Huang *et al.*, 2020).

2.1. Creativity works sharing sites

Popular platforms in this category include YouTube, Instagram, and SlideShare. Image sharing sites (such as Instagram, Imgur, and Flickr) are considered a gift for photogenic businesses. Video hosting platforms are used to train the audience and promote the brand. In addition, Pinterest as a digital pinboard is used for inspiration in B2C fashion, food and beauty. In this platform, "pinning" is used to store image and video content in a virtual board. Almost 93% of users do the pinning to plan future purchases (Sethna, Hazari & Brown, 2021). This platform is a good space for branding in the minds of the audience.

2.2. Educational materials sharing

These platforms are used as tools for sharing educational content and evaluating educational outcomes. They are also employed for raising awareness and educating stakeholders. Spiral, for example, offers collaborative, multimedia assessment tools. The benefits of educational materials sharing include knowledge sharing through open discussion, engaging the audience, and providing opportunities for collaborative and experiential learning (Al-Rahmi *et al.*, 2018). In Parlay, critical-thinking skills are developed through discussion between users. NowComment also allows the audience to give and take feedback, annotate, brainstorm, and make media.

3. Blogs

A blog is the oldest social platform (Kaplan & Haenlein, 2010). Blogs are known as publicly accessible personal journals (Blood, 2002). In blogs, the users are given a space to express their thoughts (Rollins, Nickell & Wei, 2014). One of the differences between a blog and a social network is the public nature of the messages so that all users can read and comment on

http://doi.org/10.18080/jtde.v9n3.421

them (Kaplan & Haenlein, 2010). In general, two types of blogging occur in organizations. The first type is publishing work-related information (such as exchanging work experience and submitting work reports and announcements). The second type is sharing non-work-related information (Luo *et al.*, 2018). Participating in the first type of blogging leads to effective communication and work skills. In the second type, people in the organization expand their communication network by sharing leisure information, documenting life experiences, and exchanging emotional feelings. Blogs are divided into two types: general blogs and microblogs.

3.1. General Blogs

In traditional blogs (such as WordPress and Blogger), long and specialized articles are published. Tumblr and Medium are also general blogs with short posts. By recording business information on these platforms, organizations introduce a new range of readers to their brand (Steyn *et al.*, 2010). Blogging is used as a marketing tool. By talking to people in a conversational manner, a blog puts a human face on a company that is difficult to duplicate in any other way. Perhaps the single most powerful aspect of blogs in the area of public relations is the personalization aspect.

3.2. Microblogs

The difference between a microblog and a traditional blog lies in the content size. In a microblog, users share short content (such as short sentences, individual images, and video links) (Kaplan & Haenlein, 2010). These platforms create new opportunities to shape ongoing conversations with the audience (Henderson & Bowley, 2010). This feature has led to the rapid development and general popularity of microblogs (Mirkovski *et al.*, 2018). These platforms are used for rich discussions. Thus, microblogs are effective in all three stages of the marketing process (i.e., 1. prepurchase and market research; 2. purchase and marketing communications; and 3. post-purchase and customer service) (Alarcón *et al.*, 2018). Twitter, as the most popular microblog, with its hashtag-driven capability and geographic location sharing, has connected a large audience to specific events (Lovejoy *et al.*, 2012). This platform is commonly used for sharing information on politics, sports, and natural disasters (Kapoor *et al.*, 2018). In China, Sina Weibo has a similar function as Twitter (Gruzd, Lannigan & Quigley, 2018).

4. Online discussion forums

Online discussion forums are web-based arenas where content is created and edited jointly and simultaneously (Amidi *et al.*, 2015). In forums, geographically dispersed users debate or discuss various topics. One type of platform that falls into this category is social bookmarking. In social bookmarking, media content is ranked by users in a group-based manner (Kaplan & Haenlein, 2010). Organizations use these platforms to access a wide range of market information. Therefore, this platform is a suitable space for market research and audience

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recognition. In the following section, different types of platforms in the category of online forums are described.

4.1. Collaborative websites

Collaborative websites have been created with the aim of facilitating information sharing and creating a common knowledge base (Seliaman, 2013). In cause & help platforms, questions and answers revolved around a specific issue. For example, Reddit involves a number of sub-communities called subreddits. In each community, a user's question or statement is answered by others. In Quora, users answer registered industry-related questions. By participating in answering the questions, the organization can introduce its business and direct the audience to its site. Other types of these sites include publicly edited encyclopedias. An encyclopedia is a combination of several articles that are thematically categorized. Unlike dictionaries, which contain linguistic information about words, encyclopedias contain factual information about various topics. For example, in Wikipedia, about one million articles have been generated with users' participation (Tausch, 2020). Organizations use these wikis to record and manage ideas related to new product development (Amidi *et al.*, 2015).

4.2. Social review sites

Social review sites, aiming to reduce guesswork, offer suggestions to users based on community members' experiences. These platforms are used to facilitate the decision-making process and overcome information overload. For example, in the area of tourism services, well-known sites are Yelp and TripAdvisor. On these sites, tourists publish their ideas about the services of hotels and tourist places. Receiving positive reviews on these platforms means social proof (Duan *et al.*, 2016). Such platforms, as a decision support system, offer suggestions to users. Collaborative Filtering (CF) recommendation systems are used to offer these suggestions. CF algorithms provide recommendations by collecting users' opinions and identifying similarities (Chaudhari & Thakkar, 2020). By examining these suggestions, an organization recognizes the positive and negative aspects of the customer's perspective and specifies areas for improvement (Tajvidi & Karami, 2017).

4.3. Company-sponsored networks

Enterprise social media is developed to manage relationships in a specific organization or group (Liu & Bakici, 2019). One reason for investing in the development of an organization-specific platform is the limitations of existing platforms (Kane *et al.*, 2014). In other words, when using general platforms, some of the organization's needs remain unmet. On the other hand, given the high rate of social media use by employees, managers are concerned about wasting time on these media. For these two reasons, some organizations develop their own social platform for organizational social interaction. The capabilities of these platforms include: 1. creating a network of relationships with co-workers and organization partners;

http://doi.org/10.18080/jtde.v9n3.421

2. exchanging messages with colleagues and broadcasting them to all members; 3. sending, editing, and arranging organizational text and files; and 4. observing the interactions of other people in the network (Leonardi, Huysman & Steinfield, 2013). The organization owns the data circulating on these platforms. Therefore, it can apply various strategies to manage access levels and retrieve private information (Kuegler, Smolnik & Kane, 2015).

Social media stages of growth

Different models have been proposed to describe an organization's maturity stage in using social media (Duane & O'Reilly, 2016). Stages-of-growth models are widely used for the management of information technology (Solli-Sæther & Gottschalk, 2010). These models describe phenomena observed as IT evolves through different stages of its lifecycle (Jacobs & Nakata, 2010). At each stage, various technologies are used. Each technology requires varying activities on the part of management. Hence, in a growth model, the relevant technologies and managerial activities are specified for each stage (McKay, Prananto & Marshall, 2000).

In the present study, SMSOG has been used to identify the organization's maturity in the use of social media. The five stages of this model with their different properties are explained in Table 1.

Table 1. The suggested stage model for social media implementation (Chung *et al.*,2017)

Stage	Focus	Strategy	Problems
1- Experimentation & learning	Announcing the launch of social media, posting, and providing some information.	It is experimental, with every department doing its own thing.	Lack of understanding of social media; Lack of social media training programs
2- Rapid growth	Consumer-centric focus. Efforts aimed at increasing internal and external awareness.	It is coordinated across all departments by management. Objectives have been established.	Lack of strategic interest from senior management; Lack of social media training programs
3- Formalization	Planning, strategy, governance and alignment with overall business strategy	It is controlled across the company, with a strategy aligned with the business plan.	Employee misuse; Inappropriate social media strategies; Negative feedback from internal and external detractors
4- Consolidation & integration	Optimization of processes. Pursue alignment with external partners/suppliers. Creation/ideation, crowdsourcing.	It is very well integrated with key business processes, driving fundamental change in how business is done.	Lack of social media passion/creativity among stakeholders; Failure to establish metrics for measuring social media ROI
5- Institutional absorption	De-facto application for key business tasks. Enterprise-wide social media for the entire workforce. New/re-engineer existing business models.	It is embedded into the core of what is done and how it is done, from customers to suppliers, from internal partners to external partners.	Failure to enforce formal policies; Lack of funding or resources for social media development; Over-zealous management control of social media tools

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The SMSOG model was developed by Duane & O'Reilly (2016) to measure organizational growth in social media utilization. In this model, the focus, strategies, and dominant problems of each stage are explained. The SMSOG model is theoretically evaluated compared to other growth models in the information systems area, and its performance is reported empirically in Duane & O'Reilly (2016). In Duane & O'Reilly (2017), the maturity stage of 103 organizations was determined using this model as well. The results indicate the appropriate accuracy of the model in the definition and guidelines suggested for each stage. Chung *et al.* (2017) have also introduced it as a desirable model for measuring an organization's maturity stage in social media use. In this study, the stages of growth are considered as representing the organization's maturity stage in using social media. In the next section, the research methodology and data collection are described.

Methodology

In the present study, systematic mapping of the literature was used for the classification and content analysis of the articles according to the model presented in Petersen *et al.* (2008). This type of literature review aims to create deep insight and understanding about a phenomenon by collecting and evaluating evidence in a specific area. Hence, suggestions can be proposed for future studies (Unterkalmsteiner *et al.*, 2012). The review protocol is presented in Table 2.

Table 2. The systematic literature review protocol for this study

Protocol elements	Translation to this study
Research objective	Which platforms are suitable for each maturity stage of the organization in using social media?
Sources searched	Emerald, IEEE Explore, Science Direct, Scopus, Web of Science, Business Source Premier, AIS Electronic Library, Google Scholar
Search terms	("Organization" OR "Workplace") AND ("Social media" OR "Platform" OR "Web 2.0") AND ("Social network" OR "Blog" OR "collaborative sites" OR "forums" OR "virtual world" OR "content communities")
Search strategy	- Peer-reviewed journals; - Published during the intended timeframe (2011-2020); - Theoretical and empirical studies; no sector limit; - Search terms contained in articles' title, abstract and keywords.
Inclusion criteria	Related to the topic of the present study: investigating the outcomes of using social media platforms in organizations. The name of the social media platform should be explicitly mentioned in the text of the article.
Exclusion criteria	- Conference papers, book chapters, theses, reports; - Inaccessibility to the textual body of articles; - Published in languages other than English; - Repetitive articles

Considering the goal of this study, business journals were searched. The searched databases are shown in Table 2. These resources cover social sciences and management literature better than other databases (Ngai *et al.*, 2015). Conference papers, book chapters, theses, and reports were excluded as refereed journal articles represent state-of-the-art research output with high

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impact (Ahmed *et al.*, 2018). This approach is consistent with previous review papers on social media that also have limited their scope to journal articles (e.g., Bhimani *et al.*, 2019; Ngai *et al.*,2015).

After an electronic search of titles, abstracts, and keywords of articles (published in 2011-2020), 478 articles were obtained. Then, based on the approach proposed by Wohlin (2014), for the articles that were well related to the research topic, another 56 articles were identified through the snowball technique. After removing duplicates, a total of 353 articles were selected for analysis. After reviewing the text of the articles, 198 articles were removed due to the incompatibility of their content with the scope of the study. The criterion for determining the scope of the study was their focus on the functions of social media platforms in organizations. Thus, studies examining the impact of social media platforms outside the organization were removed. Additionally, 35 articles that did not explicitly mention the name of the platform under study were omitted from the list of the articles. Finally, 120 articles were selected for analysis. The bibliographic details of the individual articles are listed in Appendix 1.

Our investigation took place in multiple steps, which can be summarized as follows. First, the maturity stage of the organization studied in the articles was identified based on the SMSOG model. The social platforms used by the organizations were then identified and categorized based on what is stated in the theoretical background section. Finally, according to the knowledge obtained about the characteristics of each category of platforms and the definition offered for different maturity stages, a mapping between each maturity stage and the platforms was developed. These steps are described below.

Extracting Data

To determine the maturity stage of the organizations mentioned in the articles, the definitions of stages in the SMSOG model in Chung *et al.* (2017) and the problems identified for each stage in Chung *et al.* (2018) were used. By analysing the text of the articles, the distinguishing features of each stage were identified and marked. Thus, each article was attributed to one of the five stages of the SMSOG. Keywords for each stage are described in the literature review section.

In order to identify the social platform used, the name of the platform was identified by reviewing the text of the article. Each article was placed in one of the four categories introduced in Misirlis & Vlachopoulou (2018). To identify the platform of each article, the name of the platform was searched in the text. Articles addressing more than one platform were removed from the list of reviewed articles. Therefore, only one platform was assigned to each article. Finally, all 120 articles reviewed were assigned a SMSOG model stage and a

http://doi.org/10.18080/jtde.v9n3.421

platform. The distribution of articles by maturity stage and social platform studied is presented in Appendix 2.

Integrating the Evidence

In order to determine the appropriate platforms for each stage, a matrix of platforms and stages was developed as described in Appendix 3. Using this matrix, the researchers sought to identify the features or capabilities of each platform as established in one of the SMSOG stages or the context for the realization of those capabilities provided by the platform. The columns of this matrix represent SMSOG stages, and its rows show the platforms. For each stage, the focus, the strategy, and the prevailing problems of the organization were identified. In the matrix rows, the functions and advantages of each platform were identified. By determining the relationship between the characteristics of each stage and the functions of each platform, each stage was mapped to appropriate platforms.

In the present study, at the stage of reviewing empirical studies, it was assumed that the organisation under study is able to use all capabilities of a digital platform (functions or services). For example, if three distinct capabilities are provided by a digital platform, an organisation has the capacity to use all the capabilities of that digital platform. Hence, a maturity stage is considered for the organization in the mapping stage of the research design which corresponds to taking most advantage of all the digital platform's capabilities.

Table 3. Part of the relation matrix of stages and platforms

		Stage 4							
		Focus			**Strategy**		**Dominant problems**		
Platform	**Function**	Optimization of processes & creating scale	Alignment with external partners/suppliers	Co creation, ideation	Well integrated with key business processes	Fundamental business change	Negative comments, reviews & feedback	Security policy & control	Lack of SM passion & creativity among stakeholders
Collaborative websites	Industry-related questions		✓	✓				✓	✓
	Build connections								✓
	Customer research		✓			✓			
	Content marketing	✓							
	Co-ideation			✓					
	Participate in lively discussions						✓		✓
	Optimize current marketing campaigns	✓							

To illustrate how the mapping is done, Table 3 shows part of the matrix (related to the relationship of collaborative websites and the fourth stage) as an example. One of the functions

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of collaborative websites is to create discussions and opportunities to answer industry-related questions. At the fourth stage, the organization's focus is to create alignment among stakeholders through social media. The organization will be able to provide a suitable platform for communication among stakeholders using the responsiveness created in collaborative websites. On the other hand, one of the problems reported in the fourth stage is the lack of passion and creativity among stakeholders. The capability to participate in lively discussions can tackle this problem. Also, the fourth stage focuses on facilitating stakeholder ideation through social media. The organization can achieve this goal by using the co-ideation capability in collaborative websites.

Appendix 3 presents the details of the relation matrix of SMSOG stages and platforms. Using this matrix, concept mapping between maturity stages and platforms was developed.

In what follows the components of concept mapping for each SMSOG stage are described separately.

Findings

The present study intends to identify appropriate social platforms for each maturity stage of the organization in the use of social media. To this aim, two theories of organization maturity stages in social media (Chung *et al.*, 2017) and various types of social platforms (Misirlis & Vlachopoulou, 2018) were synthesized as described below. After reviewing the literature, the relation matrix of the characteristic of the levels and capabilities of each platform was created. Using this matrix, a concept map between maturity stages and platforms was developed. The details of this map are presented in Appendix 3, and its graphical result is shown in Figure 1. In this map, the capabilities of each platform that meet the organization's strategy and solve the prevailing problems of each of the five maturity stages were identified. Figure 1 shows each of the SMSOG stages in a circle. Moving from one maturity stage to another (from stage 1 to 2, and the like), larger circles are used: the larger the circle, the higher the level of maturity stage. In other words, as an organization moves from low maturity to high maturity, the circle level of Figure 1 becomes larger than previous maturity levels and, as noted, this reflects the wider ability of the organization to use social platforms. The reason for using the largest circle for the fifth stage is to show the organization's vast use of social platforms at that stage. The platforms appropriate to each stage are written in the circles related to the given stage. The four categories of platform types are also distinguished by dashed lines.

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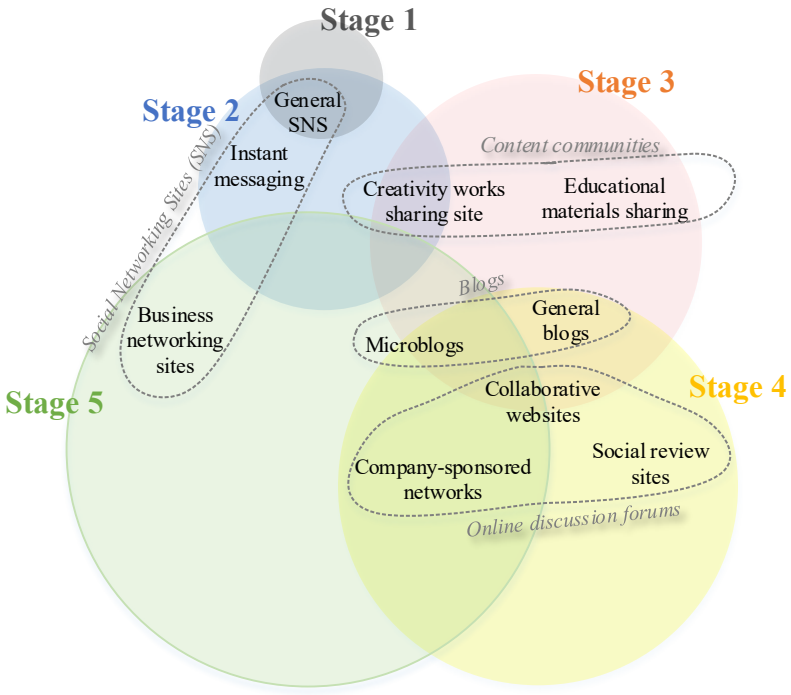

Figure 1. The relationship between platforms and maturity stages in the SMSOG model

The appropriate platform for each stage should have functions or capabilities that meet that stage's needs, goals, and problems. As shown in Figure 1, the most suitable platform for use in organizations at the first stage is general social networking sites (SNS). At the first stage, the organization has just started to use social media. Thus, the goal is to announce the launch of the organization's social media (Duane & O'Reilly, 2017). Social networks connect people at the lowest cost (Leonardi, 2014). Facebook, as one of the most popular social networks, is available to users for free. Therefore, the organization can inform its entry into social media in this network. One of the organization's needs at the first stage is to promote its social presence (Chung *et al.*, 2017). General social networks are one of the channels for communicating with the audience and introducing products (Moro, Rita & Vala, 2016). Therefore, by producing content in various social networks, the organization can attract the attention of potential customers and communicate with them (Parveen, Jaafar & Ainin, 2015).

As the organization's maturity grows to the second stage, as shown in Figure 1, a variety of social networks and creativity works sharing sites have been identified as appropriate platforms. At the second stage, the organization seeks to strengthen its relationship with the customer using social media (Chung *et al.*, 2017). Instant messaging is an effective mechanism for communicating with customers (Khan, Hoffman & Misztur, 2014) In fact, messengers allow one to communicate with different groups of audiences. In addition to messengers, customers publish their opinions about different products on creativity works sharing sites as multimedia materials (Boyd & Ellison, 2007). The organization will be able to identify customer interests by analysing the data published on these sites (Geurin & Burch, 2017). In

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the second stage, the focus of the organization is on increasing internal and external awareness of the organization (Duane & O'Reilly, 2017). As the most advanced video-sharing platform, YouTube allows the organization to build brand awareness and attract an audience (Geurin & Burch, 2017). In addition, 64% of online shoppers use videos published on video-sharing platforms to buy goods (Manika, Papagiannidis & Bourlaki, 2017). Therefore, by producing content on these platforms, the organization can influence customers' purchasing decisions (Benthaus, Risius & Beck, 2016). In other words, creativity works sharing sites are a good tool for implementing low-cost marketing programs (Geurin & Burch, 2017). E-commerce retailers promote their brand and products by advertising on Pinterest. Hence, a product can be introduced to numerous customers at low cost (Odoom, Anning-Dorson, & Acheampong, 2017).

As shown in Figure 1, suitable platforms for use at the third stage of maturity are blogs, content communities, and collaborative websites. The organization's strategy at the third stage is to build communication networks to receive feedback (Duane & O'Reilly, 2016). To implement this strategy, the organization can employ collaborative websites to exchange information with customers. Organizations join forums or create new ones to introduce their brand (Kukulska-Hulme, 2010). On the other hand, if employees are employed in the right setting and the right tasks with the right strategy, the use of collaborative websites will have a positive impact on their performance (Kuegler, Smolnik & Kane, 2015). Another goal of the organization at the third stage is defining and realizing the strategy of social media use (Chung *et al.*, 2017). Discussion forums are appropriate platforms for receiving feedback from the stakeholders on defined strategies. By receiving the stakeholders' opinions, the organization involves them in developing strategies. This leads to their commitment to the developed plans and strategies (Aral, Dellarocas & Godes, 2013). One of the problems the organization faces at the third stage is the employees' misuse of social media in the workplace (Chung *et al.*, 2018). To face such a challenge, a clear boundary should be defined between personal and work activities (Munene & Nyaribo, 2013). By producing content on educational platforms, the policies for using social media in the work environment can be taught to employees. Blogs can also be used to publish the latest version of terms and conditions. Organizations use social blogging to build engagement and introduce people to their business (Michaelidou, Siamagka & Christodoulides, 2011).

Blogs help the knowledge management process by facilitating information exchange in the virtual social and workplace environment. Thus, visibility in the organization increases (Zhang *et al.*, 2020). As shown in Figure 1, platforms suitable for organizations at the fourth stage are various types of blogs and online forums. At this stage, the organization is looking for ideation to create a new product with the help of social media (Duane & O'Reilly, 2017). At the fourth

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stage, social media is something beyond marketing and public relations tools (Duane & O'Reilly, 2016). Therefore, social review sites are used to engage established customers in the co-creation of new products and services (Bizzi & Labban, 2019). Customer reviews reflect the customer experience. Such reviews are published publicly and privately. On social review sites, the customer gives direct feedback about the organization. In addition, the organization can use data from third-party review sites. By analysing this information, the organization is informed of the customer's satisfaction stage and will be able to improve its product or service according to the customer's wishes (Chaudhari & Thakkar, 2020).

At the fourth stage, social platforms, besides leading to interaction with external stakeholders, also affect the cooperation of employees (Kane *et al.*, 2014). An internal intranet is a tool for sharing official information of the organization. Nevertheless, the microblog is a good platform for sharing ideas (Bashir, Papamichail & Malik, 2017). People honestly express their feelings in microblogs and feel more comfortable asking questions and requesting help (Gilbert, 2016). Therefore, microblogs can be used to establish information flow between people and support informal education. Publicly edited encyclopedias are also used to facilitate the knowledge sharing process in an organization (Huang, Baptista & Galliers, 2013). In wikis, open communication is established between managers and employees. Therefore, employees effectively share their experiences and ideas with the team (Al-Rahmi *et al.*, 2018). Of course, one of the problems identified for organizations with Stage 4 characteristics is the stakeholders' reluctance to use social media (Chung *et al.*, 2018). Collaborative websites have been suggested to raise the motivation for information exchange between stakeholders (Cai *et al.*, 2018). In these platforms, two-way communications are formed by creating one-to-one interactions (Nik-Bakht & El-Diraby, 2020). Using collaborative websites, intra-team relationships become productive. This change also leads to improved employee performance, productivity and agility (Holtzblatt *et al.*, 2013). On the other hand, the need to exchange confidential information among all supply chain members leads the fourth-stage organization to invest in creating company-sponsored networks. Through these networks, the organization will be able to provide alignment and integration in the supply chain (Chung *et al.*, 2017). In addition, these technologies have shifted the focus of Internet services from consumption-centred to interactive, two-way or multi-way. This creates new opportunities for active interaction among organizational elements (Henderson & Bowley, 2010).

Given that few organizations are ranked at the fifth stage in terms of maturity, there is not sufficient evidence to identify appropriate platforms and prevailing problems at this stage (Duane & O'Reilly, 2017). However, as indicated in Figure 1, company-sponsored networks, collaborative websites, microblogs, and business networking sites are predicted to help the organization achieve its fifth-stage goals and strategies better than other platforms. At the fifth

http://doi.org/10.18080/jtde.v9n3.421

stage, management has a broader perspective, maintaining what is appropriate in existing social media applications and embracing new applications as appropriate (Chung *et al.*, 2017). At this stage, social platforms are used to integrate the pillars of the organization (Chung *et al.*, 2016). The focus of the organization at the fifth stage is on generating new, or reengineering existing, business models. Therefore, it is recommended to analyse microblogs' content and use social listening tools to receive feedback and better understand the audience. By extracting knowledge from these platforms, the organization will be able to design and implement actionable strategies (Benthaus *et al.*, 2016). Finally, with the optimal allocation of resources, customer service will be provided in line with customer needs, and sales will increase (Moore, Hopkins & Raymond, 2013).

Enterprise blogs can increase the rate of problem-solving, help employees gain access to knowledge experts, and reduce internal communication costs (Huang, Singh & Ghose, 2015). One of the needs of the organization at the fifth stage is to monitor the organizational environment (Duane & O'Reilly, 2017). Business networking sites are suitable platforms for learning about the market and the status of competitors. These sites facilitate communication with external stakeholders. Organizations make decisions about hiring personnel based on information obtained from these platforms. LinkedIn, for example, is used to monitor the labour market of a specialized workforce: 70% of employers use the information on this site to find job candidates (Quinton & Wilson, 2016). In addition to LinkedIn, Glassdoor can provide information on the views of internal stakeholders. Based on this information, the organization will be able to plan to increase the satisfaction of its stakeholders. Increasing employee satisfaction will lead to increased sales and a reduction in the rate of staff resignation from the organization (Pitt *et al.*, 2018). At the fifth stage, staff integration reaches a point where organizations implement enterprise-wide social media for the entire workforce, empowering staff to regularly use social media (Duane & O'Reilly, 2016). A direct relationship has been reported between enterprise social media and agility. In addition, using enterprise social media promotes efficiency, adaptability and flexibility of the staff (Cai *et al.*, 2018).

Conclusion

In the digital economy, the key to the success of organizations is the effective use of information and communication technology (Gruzd *et al.*, 2018); therefore, despite limited resources, social platforms appropriate to the characteristics of the organization need to be identified and invested in. This research seeks to establish a relationship between the types of platforms and the organization's maturity stage. To this aim, after a systematic study, the types of platforms studied in 120 selected articles based on the classification of Misirlis & Vlachopoulou (2018) were identified and placed in one of the five stages of the SMSOG model

http://doi.org/10.18080/jtde.v9n3.421

(Chung *et al.*, 2017). Then, a mapping was developed through the relationship matrix of each platform type with the characteristics of each SMSOG stage, which represents a conjecture of the appropriate platform for each maturity level of organizations.

Based on our study and the relevant literature, we provide the following insights and recommendations for business owners or practitioners interested in adopting social media platforms for their business benefits. General platforms such as Facebook, Twitter, Myspace, and YouTube are available to all Internet users free of charge. For example, the organization can create brand loyalty by creating relationships on Facebook. In the food, arts and clothing industry, Pinterest — and in the retail, beauty and entertainment industry, Instagram — can be used to visually present the organization's products and lead generation. Twitter is a good platform for public relations, and LinkedIn is appropriate for business development and B2B communications. YouTube is useful for brand awareness, especially in the service industry. Blogs and Wikis are also suitable tools for training stakeholders. Wikis are appropriate for knowledge sharing, thanks to their collaborative and conversational bases (Amidi *et al.*, 2015).

In choosing a platform, it is necessary for the organizations to have a good understanding of the variables affecting the participation of members in these platforms and plan to guide these efforts. The organization should not limit itself to popular platforms. Before choosing a platform, it is necessary to determine the organization's purpose of using social media and its maturity stage in using this media, based on the SMSOG model. The questionnaire used by Duane & O'Reilly (2017) can be used to determine the maturity stage of the organization.

If the organization is in the first three maturity stages, the main focus will be on customer interaction and designing a strategy to communicate with external stakeholders through social media. Therefore, it is necessary to determine the target audience and how they can be accessed through social media. To this end, a proper understanding of the demographic conditions of the audience should be obtained. Platforms with higher audience densities are the most appropriate platforms at these stages. If the organization's maturity is at the two final stages of the model (fourth and fifth), all elements of the organization will be integrated through social media and investment will be generally required for company-sponsored networks. Hence, it is necessary to clearly identify the needs of the audience and select appropriate platforms for them.

To summarize, social networks meet the needs of organizations at the initial stages of maturity well. Social networks connect people at the lowest cost. With the growth and maturity of the organization at the second and third stages, content communities and blogs are appropriate. Organizations in these platforms shape organizational relationships by categorizing users and

http://doi.org/10.18080/jtde.v9n3.421

selecting the target group. Forums and collaborative websites can also provide the desired value-creation at the high stages of organizational maturity.

The recommendations presented in this article regarding the relationship between the appropriate platform and the organization's maturity stage are not based on tests with empirical data. Instead, these recommendations are offered based on previous studies reported in the literature. This study treats only information that appeared in the papers and thus the indicators for each organization could be incomplete, depending on the focus of the cited paper. Future studies can conduct experimental tests on the recommendations of this study regarding the relationship between platform type and an organization's maturity stage as independent research. Also, considering the nature and characteristics of an industry may be effective in proposing the relationship between the type of platform and the organization's maturity stage, so it is suggested that directed research in different industries be done on the findings of the present study.

In this study, at the stage of reviewing empirical studies, it was assumed that the organisation under study is able to use all capabilities of a digital platform. However, in reality, some of the capabilities of a social media site may be used at a lower level of maturity and others at the higher levels. Therefore, as a future study, studying the level of maturity of different combinations of capabilities of a digital platform will provide a more realistic insight into building the capacity for organizations to use the capabilities of social platforms. Also, future studies are recommended to investigate the impact of features like the field and the size of the firm, B2B or B2C business type, the geographical regions, etc. In addition, given the increasing growth of using social media in organizations, its impact on performance can also be considered in the growth phase. Therefore, in order to complete the findings of this research, it is necessary for future research to focus on identifying appropriate platforms for organizations at higher stages of the growth model, especially stage 5.

Using the results of the present study, researchers can identify platforms with low frequency of use, and focus their future research on those types of platform. For example, despite the numerous capabilities that virtual worlds provide to users, few studies have addressed the impact of using these platforms in an organization. Among the top features of this platform are the simulation of the real world in cyberspace and the lack of restrictive rules for interactions among the users. Organizations can use these platforms to evaluate their performance in marketing, human resource management and internal processes, and apply the lessons learned in the real world.

There are a number of limitations to this body of research. Firstly, the literature review is not exhaustive, with the exclusion of conference papers and book chapters. This means that some

http://doi.org/10.18080/jtde.v9n3.421

significant literature and findings may have been excluded. Secondly, articles not published in English were also excluded. Although this is common in scoping reviews, we may have missed relevant papers published in other languages.

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Appendix 1: Reviewed papers

#	Author(s) & Year	SMSOG	Platform	
			Type	Subtype
[1]	Agnihotri *et al.*, 2012	1	Social Networking Sites	Facebook
[2]	Alarcón *et al.*, 2018	4	Blogs	Microblogs
[3]	Ali, Wang, & Khan, 2019	4	Social Networking Sites	Instant messaging
[4]	Al-Rahmi *et al.*, 2018	4	Content communities	Creativity works sharing sites
[5]	Amidi *et al.*, 2015	1	Online discussion forums	Social review sites
[6]	Andzulis, Panagopoulos & Rapp, 2012	1	Content communities	Creativity works sharing sites
[7]	Atmaca, Schoors, & Verschelde, 2017	2	Online discussion forums	Company-sponsored Networks
[8]	Barber *et al.*, 2018	3	Social Networking Sites	General social networking sites
[9]	Behringer & Sassenberg, 2015	2	Online discussion forums	Social review sites
[10]	Benetoli *et al.*, 2018	2	Online discussion forums	Collaborative websites
[11]	Benitez *et al.*, 2018	4	Social Networking Sites	Facebook
[12]	Benthaus *et al.*, 2016	3	Blogs	Microblogs
[13]	Bizzi & Labban, 2019	3	Online discussion forums	Social review sites
[14]	Cade, 2018	4	Blogs	Microblogs
[15]	Cai *et al.*, 2018	3	Online discussion forums	Company-sponsored Networks
[16]	Cao *et al.*, 2016	3	Social Networking Sites	Facebook
[17]	Chang, Tu, & Hajiyev, 2019	4	Content communities	Educational materials sharing
[18]	Chen & Lin, 2019	2	Social Networking Sites	General social networking sites
[19]	Cho *et al.*, 2014	4	Social Networking Sites	Facebook
[20]	Choo *et al.*, 2015	3	Blogs	Microblogs
[21]	Chung *et al.*, 2016	3	Social Networking Sites	Instant messaging
[22]	Demircioglu & Chen, 2019	2	Online discussion forums	Company-sponsored Networks
[23]	Dolan, Seo, & Kemper, 2019	4	Social Networking Sites	Facebook
[24]	Drummond *et al.*, 2018	3	Social Networking Sites	Facebook
[25]	Duan *et al.*, 2016	3	Online discussion forums	Social review sites
[26]	Ellison *et al.*, 2011	4	Social Networking Sites	Facebook
[27]	Foltean, Trif, & Tuleu, 2019	4	Online discussion forums	Company-sponsored Networks
[28]	Gamboa & Gonçalves, 2014	2	Social Networking Sites	Facebook
[29]	Gao & Feng, 2016	4	Blogs	Microblogs
[30]	Geurin & Burch, 2017	3	Content communities	Creativity works sharing sites
[31]	Gilbert, 2016	2	Blogs	Microblogs
[32]	Godey *et al.*, 2016	2	Social Networking Sites	Facebook
[33]	Hagg, Dahinten, & Currie, 2018	2	Online discussion forums	Company-sponsored Networks
[34]	Hajli & Sims, 2015	2	Social Networking Sites	Facebook
[35]	Hajli, 2014	3	Social Networking Sites	Facebook
[36]	Hollebeek, 2017	3	Online discussion forums	Company-sponsored Networks
[37]	Huang *et al.*, 2013	4	Online discussion forums	Social review sites
[38]	Hudson *et al.*, 2016	2	Online discussion forums	Company-sponsored Networks
[39]	Kaewkitipong, Chen, & Ractham, 2016	3	Social Networking Sites	Facebook
[40]	Karjaluoto, Mustonen, & Ulkuniemi, 2015	3	Online discussion forums	Company-sponsored Networks
[41]	Kavota, Kamdjoug, & Wamba, 2020	4	Social Networking Sites	General social networking sites
[42]	Kim & Johnson, 2016	2	Social Networking Sites	Facebook
[43]	Kim & Kim, 2018	3	Social Networking Sites	Facebook
[44]	Kim, Bae & Hastak, 2018	1	Blogs	Microblogs
[45]	Kuegler, Smolnik, & Kane, 2015	4	Online discussion forums	Company-sponsored Networks
[46]	Kwahk & Park, 2016	3	Social Networking Sites	Facebook
[47]	Kwahk. & Park, 2018	4	Content communities	Creativity works sharing sites

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#	Author(s) & Year	SMSOG	Platform	
			Type	Subtype
[48]	Lachlan *et al.*, 2016	2	Blogs	Microblogs
[49]	Lacoste, 2016	3	Social Networking Sites	Business networking sites
[50]	Lambić, 2016	1	Social Networking Sites	Facebook
[51]	Langaro, Rita & de Fátima Salgueiro, 2018	2	Social Networking Sites	Facebook
[52]	Laroche *et al.*, 2012	2	Content communities	Creativity works sharing sites
[53]	Lee & Choi, 2017	2	Online discussion forums	Collaborative websites
[54]	Lee, Agrawal & Choudhary, 2015	1	Blogs	Microblogs
[55]	Lee, Shin & Hong, 2018	2	Social Networking Sites	General social networking sites
[56]	Leek, Canning & Houghton, 2016	5	Blogs	Microblogs
[57]	Leonardi, 2014	3	Social Networking Sites	Instant messaging
[58]	Liu & Bakici, 2019	4	Online discussion forums	Company-sponsored Networks
[59]	Loehmer *et al.*, 2018	2	Content communities	Educational materials sharing
[60]	Lovejoy *et al.*, 2012	4	Blogs	Microblogs
[61]	Lund *et al.*, 2018	3	Online discussion forums	Collaborative websites
[62]	Molinillo *et al.*, 2019	4	Content communities	Creativity works sharing sites
[63]	Malthouse *et al.*, 2013	4	Online discussion forums	Company-sponsored Networks
[64]	Manika, Papagiannidis & Bourlakis, 2017	2	Content communities	Creativity works sharing sites
[65]	Mäntymäki & Riemer, 2016	4	Online discussion forums	Company-sponsored Networks
[66]	MContenty. *et al.*, 2014	2	Content communities	Creativity works sharing sites
[67]	McCosker, 2017	4	Social Networking Sites	Business networking sites
[68]	Mehmet & Clarke, 2016	2	Online discussion forums	Collaborative websites
[69]	Men, O'Neil, & Ewing, 2020	2	Online discussion forums	Company-sponsored Networks
[70]	Meng *et al.*, 2020	3	Online discussion forums	Company-sponsored Networks
[71]	Ma & Chan, 2014	3	Blogs	Microblogs
[72]	Moro, Rita & Vala, 2016	2	Social Networking Sites	Facebook
[73]	Narangajavana *et al.*, 2017	3	Online discussion forums	Collaborative websites
[74]	Nguyen *et al.*, 2015	5	Social Networking Sites	Instant messaging
[75]	Odoom, Anning-Dorson, & Acheampong, 2017	2	Blogs	Microblogs
[76]	Oostervink, Agterberg & Huysman, 2016	3	Online discussion forums	Company-sponsored Networks
[77]	Orlandi *et al.*, 2020	4	Social Networking Sites	Facebook
[78]	Paniagua & Sapena, 2014	2	Blogs	Microblogs
[79]	Pitt *et al.*, 2018	4	Online discussion forums	Social review sites
[80]	Price *et al.*, 2018	1	Blogs	MICROBLOGS
[81]	Quinton & Wilson, 2016	4	Social Networking Sites	Business networking sites
[82]	Rialp-Criado & Rialp-Criado, 2018	3	Online discussion forums	Social review sites
[83]	Risius & Beck, 2015	3	Blogs	Microblogs
[84]	Robertson & Kee, 2017	4	Social Networking Sites	Facebook
[85]	Rodrigues *et al.*, 2016	4	Online discussion forums	Company-sponsored Networks
[86]	Rollins, Nickell & Wei, 2014	1	Blogs	General blog
[87]	Roshan, Warren & Carr, 2016	3	Blogs	Microblogs
[88]	Roy *et al.*, 2020	3	Blogs	Microblogs
[89]	Saboo *et al.*, 2016	2	Social Networking Sites	General social networking sites
[90]	Sadovykh, Sundaram & Piramuthu, 2015	4	Social Networking Sites	General social networking sites
[91]	Sahaym, Datta, & Brooks, 2019	4	Online discussion forums	Collaborative websites
[92]	Schniederjans, Cao & Schniederjans, 2013	3	Online discussion forums	Company-sponsored Networks
[93]	Seliaman, 2013	2	Online discussion forums	Collaborative websites
[94]	Seo & Park, 2018	4	Online discussion forums	Company-sponsored Networks
[95]	Shang, Wu & Li, 2017	3	Social Networking Sites	General social networking sites
[96]	Sigala & Chalkiti, 2015	3	Social Networking Sites	Business networking sites

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#	Author(s) & Year	SMSOG	Platform	
			Type	Subtype
[97]	Singaraju *et al.*, 2016	5	Online discussion forums	Company-sponsored Networks
[98]	Song *et al.*, 2019	5	Social Networking Sites	Instant messaging
[99]	Surucu-Balci, Balci, & Yuen, 2020	4	Blogs	Microblogs
[100]	Swani *et al.*, 2014	1	Blogs	Microblogs
[101]	Tajudeen, Jaafar & Ainin, 2018	4	Blogs	Microblogs
[102]	Tajvidi & Karami, 2017	4	Online discussion forums	Social review sites
[103]	Tajvidi *et al.*, 2018	4	Content communities	Creativity works sharing sites
[104]	Trainor *et al.*, 2014	2	Social Networking Sites	Instant messaging
[105]	Trainor, 2013	1	Content communities	Creativity works sharing sites
[106]	Tursunbayeva, Franco & Pagliari, 2017	4	Blogs	Microblogs
[107]	Wang & Kim, 2017	2	Social Networking Sites	Facebook
[108]	Wang *et al.*, 2016	2	Online discussion forums	Collaborative websites
[109]	Whelan, Islam & Brooks, 2020	1	Content communities	Educational materials sharing
[110]	Williams *et al.*, 2018	5	Blogs	Microblogs
[111]	Wu, 2013	3	Social Networking Sites	Instant messaging
[112]	Wu *et al.*, 2018	4	Social Networking Sites	Instant messaging
[113]	Xiong, Chapple & Yin, 2018	3	Blogs	Microblogs
[114]	Yang, 2020	5	Social Networking Sites	Facebook
[115]	Yates & Paquette, 2011	2	Blogs	Microblogs
[116]	Yadav & Rahman, 2017	2	Online discussion forums	Social review sites
[117]	Yoshida *et al.*, 2018	4	Online discussion forums	Company-sponsored Networks
[118]	Zhang, Kang, Jiang, & Pei, 2020	3	Blogs	Microblogs
[119]	Zheng & Zheng, 2014	3	Blogs	Microblogs
[120]	Zu, Diao, & Meng, 2019	2	Blogs	Microblogs

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Appendix 2: Distribution of articles

Platform		Examples	Social media stage of growth				
Type	Subtype		Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Social Networking Sites	General social networking sites	*Facebook*	[1]; [50]	[28]; [32]; [34]; [42]; [51]; [72]; [107];	[16]; [35]; [39]; [24]; [43]; [46]	[19]; [23]; [26]; [77]; [84]; [11]	[114]
		Myspace, Kakao-story, Naver-band, Friendster, Vkontakte, vk, myworld		[18]; [55]; [89]	[8]; [95]	[41]; [90]	
	Instant messaging	*WhatsApp, Line, Telegram, WeChat, QQ, Skype, Zoom*		[104]	[21]; [57]; [111]	[3]; [112]	[74]; [98]
	Business networking sites	*LinkedIn, Viadeo, Glassdoor*			[49]; [96]	[67]; [81]	
Content communities	Creativity works sharing sites	*Video (YouTube, TikTok, Vine), Photo (Instagram, Flickr), Pinterest, Voice/Music (Clubhouse), Slideshare,*	[6]; [105]	[52]; [64]; [66]	[30]; [71]	[4]; [47]; [103]	
	Educational materials sharing	*MIT OpenCourseWare, MERLOT, Koofers, Labroots*	[109]	[59]		[17]	
Blogs	General blogs	*BlogSpot, wordpress, Tumblr, Medium,*	[86]				
	Microblogs	*Twitter, twitxr, tweetpeek, plurk, Sina Weibo*	[44]; [54]; [80]; [100]	[75]; [78]; [115]; [31]; [48]; [120]	[87]; [12]; [20]; [83]; [88]; [113]; [118]; [119]	[2]; [14]; [29]; [60]; [62]; [99]; [106]; [101]	[110]; [56]
Online discussion forums	Collaborative websites	*Wikipedia, StumbleUpon, Digg, Newsvine, Reddit,*		[10]; [53]; [68]; [93]; [108]	[61]; [73]	[91]	
	Social review sites	*TripAdvisor, Yelp, Zomato, Kickstarter*	[5]	[9]; [116]	[13]; [25]; [82]	[37]; [79]; [102]	
	Company-sponsored networks	*social-CRM house, Apple, P&G's Vocalpoint, social-CRM house*		[7]; [22]; [33]; [38]; [69]	[15]; [36]; [40]; [70]; [76]; [92]	[27]; [45]; [58]; [63]; [65]; [85]; [94]; [117]	[97]

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Appendix 3: The relation matrix of stages and platforms

Platforms \ SMSOG			Stage 1				
			Focus	*Strategy*	*Problem*		
Type		*Benefits*	Announcing launch of SM	Experimental with every department doing their own	Understand the skills required	Test the capabilities of the applications	Lack of understanding of SM
Social Networking Sites	General social networking sites	Reach a target audience through ads	✓				
		Connect across geographical borders	✓				
		Understand the customer's perspective			✓		✓
		Form groups based on interests					
		Get visitors to your site	✓	✓		✓	
		Generate new leads					
		Build up loyalty of current customers					
		Provide customer service					
		Find like-minded customers through groups		✓			
	Instant messaging	Human-to-human interaction	✓	✓			
		Customer research					
		Expand brand awareness	✓				
		Shop online and make payment offline	✓				
		Relationship building					
	Business networking sites	B2B connections					
		Share and connect on a professional level					
		Formal professionalism					
		Job searching		✓	✓		
		Developing professional career			✓		
		Establishing thought leadership					
		To see what employees say about your business		✓			
		Improve your employees' experience					
Content communities	Creativity works sharing sites	Create inspiration	✓				
		Engage customer					
		Engage visual learner audience	✓				
		Relationship building					
		Encourage user-generated content					
		Social awareness	✓				
		Brand building					
		Build up loyalty of current customers					
		Lead generation					
		Targeting		✓			
		Educating the audience					✓
		Widen audience base					
		Run well-planned campaign	✓				

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SMSOG / Platforms	Type	Benefits	Stage 1				
			Focus	*Strategy*	*Problem*		
			Announcing launch of SM	Experimental with every department doing their own	Understand the skills required	Test the capabilities of the applications	Lack of understanding of SM
Content community		Customer service					
		Review product					
		Integrate with other app		✓	✓	✓	
		Market research					
	Educational materials sharing	Educating the audience	✓		✓		✓
		Encourage knowledge sharing					✓
		Special offer	✓	✓			
		Share phenomenal content					
		Inspiration					
Blog	General Blogs	Develop voice/ to express thoughts	✓				
		Self-expression	✓				
		Get clear about your vision	✓				
		To build engagement and get people familiar with your business.					
		Content marketing					
		Leverage brand					
		Reaching a broader audience beyond your own readership	✓				
		Syndicate content					
	Microblog	Branding					
		Increase visibility	✓				
		Find potential business partners through	✓				
		Market research					
Online discussion forums	Collaborative websites	Answer industry-related questions					
		Build connections	✓				
		Customer research		✓			
		Content marketing					
		Co-ideation					
		Participate in lively discussions	✓				
		Optimize current marketing campaigns					
	Social review sites	Market research					
		Understand customer's perspective		✓		✓	
		Social Proof	✓				
		Situation awareness					✓
		Discover areas for improvement					✓
		Run location-based social campaigns					
		Network research					
	Company-sponsored networks	Team based collaboration					
		Encourage knowledge sharing					
		Syndicate content					
		Collective intelligence					

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Platforms / SMSOG			Stage 2					
			Focus	*Strategy*	*Problem*			
Type		*Benefits*	Consumer-centric focus	To increase internal & external awareness	Establish metrics for measuring SM ROI	Translating SM data into actionable strategies	Appoint a group to coordinate SM	Lack of strategic interest from senior management
Social Networking Sites	General social networking sites	Reach a target audience through ads	✓					
		Connect across geographical borders	✓					
		Understand the customer's perspective	✓		✓	✓		
		Form groups based on interests					✓	
		Get visitors to your site						
		Generate new leads	✓	✓		✓		
		Build up loyalty of current customers	✓	✓				
		Provide customer service	✓					
		Find like-minded customers through groups	✓					
	Instant messaging	Human-to-human interaction						
		Customer research	✓		✓	✓		
		Expand brand awareness	✓	✓				
		Shop online and make payment offline						
		Relationship building		✓				
	Business networking sites	B2B connections						
		Share and connect on a professional level						
		Formal professionalism						
		Job searching						
		Developing professional career						
		Establishing thought leadership						
		To see what employees say about your business						✓
		Improve your employees' experience					✓	
Content communities	Creativity works sharing sites	Create inspiration	✓					
		Engage customer	✓					
		Engage visual learner audience	✓					
		Relationship building	✓	✓				
		Encourage user-generated content						
		Social awareness		✓				
		Brand building		✓				
		Build up loyalty of current customers	✓					
		Lead generation						✓
		Targeting	✓		✓	✓		
		Educating the audience		✓				
		Widen audience base		✓				
		Run well-planned campaign	✓					
C	**9**	Customer service	✓					

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Platforms / SMSOG			Stage 2					
			Focus	*Strategy*	*Problem*			
Type		*Benefits*	Consumer-centric focus	To increase internal & external awareness	Establish metrics for measuring SM ROI	Translating SM data into actionable	Appoint a group to coordinate SM	Lack of strategic interest from senior management
		Review product						
		Integrate with other app						✓
		Market research	✓					
	Educational materials sharing	Educating the audience	✓	✓				✓
		Encourage knowledge sharing		✓				✓
		Special offer	✓			✓		
		Share phenomenal content		✓				
		Inspiration		✓				
Blog	General Blogs	Develop voice/ to express thoughts						
		Self-expression						
		Get clear about your vision	✓	✓				
		To build engagement and get people familiar with your business.	✓	✓		✓		
		Content marketing		✓				
		Leverage brand		✓				
		Reaching a broader audience beyond your own readership	✓	✓				
		Syndicate content		✓				✓
	Microblog	Branding						
		Increase visibility			✓			✓
		Find potential business partners through					✓	
		Market research	✓					
Online discussion forums	Collaborative websites	Answer industry-related questions		✓				
		Build connections	✓	✓				
		Customer research	✓		✓			
		Content marketing						
		Co-ideation						
		Participate in lively discussions						
		Optimize current marketing campaigns	✓	✓				
	Social review sites	Market research						
		Understand customer's perspective	✓					
		Social Proof		✓				
		Situation awareness		✓				
		Discover areas for improvement						
		Run location-based social campaigns	✓					
		Network research						
	Company-sponsored networks	Team based collaboration						
		Encourage knowledge sharing						
		Syndicate content						
		Collective intelligence						

http://doi.org/10.18080/jtde.v9n3.421

Platforms \ SMSOG			Stage 3						
			Focus	*Strategy*		*Problem*			
			Formalized & control across company	Planning & alignment with overall business strategy	Knowledge acquisition	Establish metrics for measuring SM ROI	Funding for SM development	Employee misuse	Lack of understanding of SM
Type		*Benefits*							
Social Networking Sites	General social networking sites	Reach a target audience through ads				✓			
		Connect across geographical borders							
		Understand the customer's perspective			✓	✓			
		Form groups based on interests	✓						
		Get visitors to your site	✓						
		Generate new leads					✓		
		Build up loyalty of current customers							
		Provide customer service							
		Find like-minded customers through groups							
	Instant messaging	Human-to-human interaction							
		Customer research		✓	✓	✓			
		Expand brand awareness							
		Shop online and make payment offline							
		Relationship building							
	Business networking sites	B2B connections	✓						
		Share and connect on a professional level			✓				
		Formal professionalism	✓						
		Job searching						✓	
		Developing professional career	✓						
		Establishing thought leadership	✓						
		To see what employees say about your business							✓
		Improve your employees' experience						✓	
Content communities	Creativity works sharing sites	Create inspiration							
		Engage customer							
		Engage visual learner audience							
		Relationship building							
		Encourage user-generated content							
		Social awareness							
		Brand building							
		Build up loyalty of current customers							
		Lead generation				✓			
		Targeting							
		Educating the audience							
		Widen audience base		✓					
		Run well-planned campaign	✓				✓		

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Platforms \ SMSOG			Stage 3						
			Focus	*Strategy*		*Problem*			
			Formalized & control across company	Planning & alignment with overall business strategy	Knowledge acquisition	Establish metrics for measuring SM ROI	Funding for SM development	Employee misuse	Lack of understanding of SM
Type		*Benefits*							
		Customer service							
		Review product		✓					
		Integrate with other app					✓		
		Market research		✓					
	Educational materials sharing	Educating the audience		✓	✓			✓	✓
		Encourage knowledge sharing		✓	✓			✓	✓
		Special offer			✓				
		Share phenomenal content			✓				
		Inspiration							
Blog	General Blogs	Develop voice/ to express thoughts			✓				
		Self-expression			✓				
		Get clear about your vision						✓	✓
		To build engagement and get people familiar with your business.							
		Content marketing							
		Leverage brand			✓				
		Reaching a broader audience beyond your own readership							
		Syndicate content						✓	
	Microblog	Branding			✓				
		Increase visibility						✓	✓
		Find potential business partners through			✓			✓	
		Market research		✓	✓				
Online discussion forums	Collaborative websites	Answer industry-related questions						✓	
		Build connections						✓	
		Customer research		✓	✓	✓			
		Content marketing							
		Co-ideation							
		Participate in lively discussions						✓	
		Optimize current marketing campaigns							
	Social review sites	Market research			✓				
		Understand customer's perspective			✓	✓			
		Social Proof	✓		✓				
		Situation awareness			✓				
		Discover areas for improvement			✓	✓			
		Run location-based social campaigns	✓		✓				
		Network research							
	Company-sponsored networks	Team based collaboration	✓						
		Encourage knowledge sharing			✓				
		Syndicate content			✓				
		Collective intelligence							

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Platforms / SMSOG			Stage 4									
			Focus			*Strategy*		*Problems*				
			Optimization of processes and creating scale	Alignment with external partners/suppliers	Co-creation/ideation	Well integrated with key business processes	Fundamental business change	Negative comments, reviews and feedback	Security policy and control	Lack of SM passion & creativity among stakeholders	Monologue occurrence resulting from a failure to listen to/involve
Type		*Benefits*									
Social Networking Sites	General social networking sites	Reach a target audience through ads									
		Connect across geographical borders		✓							
		Understand the customer's perspective			✓						✓
		Form groups based on interests				✓					
		Get visitors to your site									
		Generate new leads									
		Build up loyalty of current customers		✓							
		Provide customer service		✓							
		Find like-minded customers through groups	✓							✓	✓
	Instant messaging	Human-to-human interaction	✓								
		Customer research			✓						✓
		Expand brand awareness									
		Shop online and make payment offline	✓								
		Relationship building									
	Business networking sites	B2B connections	✓								
		Share and connect on a professional level	✓		✓						
		Formal professionalism	✓								
		Job searching									
		Developing professional career									
		Establishing thought leadership	✓								
		To see what employees say about your business	✓								
		Improve your employees' experience									
Content communities	Creativity works sharing sites	Create inspiration									
		Engage customer								✓	✓
		Engage visual learner audience	✓								
		Relationship building									
		Encourage user-generated content									
		Social awareness									
		Brand building									
		Build up loyalty of current customers		✓				✓			
		Lead generation	✓								
		Targeting	✓								
		Educating the audience									
		Widen audience base									
		Run well-planned campaign									

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Platforms / SMSOG			Stage 4									
			Focus			*Strategy*		*Problems*				
			Optimization of processes and creating scale	Alignment with external partners/suppliers	Co-creation/ideation	Well integrated with key business processes	Fundamental business change	Negative comments, reviews and feedback	Security policy and control	Lack of SM passion & creativity among stakeholders	Monologue occurrence resulting from a failure to listen to/involve
Type		*Benefits*									
Blogs		Customer service									
		Review product									
		Integrate with other app	✓								
		Market research									
	Educational materials sharing	Educating the audience					✓				
		Encourage knowledge sharing			✓			✓		✓	
		Special offer	✓								
		Share phenomenal content	✓		✓						
		Inspiration									
	General Blogs	Develop voice/ to express thoughts									
		Self-expression						✓		✓	✓
		Get clear about your vision						✓		✓	✓
		To build engagement and get people familiar with your business.		✓							
		Content marketing	✓								
		Leverage brand									
		Reaching a broader audience beyond your own readership	✓								
		Syndicate content									
	Microblog	Branding									
		Increase visibility	✓								
		Find potential business partners through #	✓	✓						✓	
		Market research			✓						
Online discussion forums	Collaborative websites	Answer industry-related questions		✓		✓	✓		✓		✓
		Build connections									✓
		Customer research		✓			✓				
		Content marketing	✓								
		Co-ideation			✓						
		Participate in lively discussions						✓			✓
		Optimize current marketing campaigns	✓								
	Social review sites	Market research			✓						
		Understand customer's perspective						✓			
		Social Proof									
		Situation awareness	✓								
		Discover areas for improvement	✓			✓					
		Run location-based social campaigns	✓								
		Network research									
	Company-sponsored networks	Team based collaboration		✓					✓	✓	✓
		Encourage knowledge sharing			✓			✓			✓
		Syndicate content	✓								
		Collective intelligence		✓	✓	✓					

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Platforms / SMSOG			Stage 5					
			Focus		*Strategy*		*Problem*	
type		*benefits*	Enterprise-wide SM technologies for entire workforce	De-facto application for key business tasks	Embedded into the core of what we do, & how we do it.	Reengineer existing business models	Monitor external environment	Lack of creativity among stakeholders
Social Networking Sites	General social networking sites	Reach a target audience through ads		✓				
		Connect across geographical borders	✓					
		Understand the customer's perspective					✓	
		Form groups based on interests	✓					
		Get visitors to your site						
		Generate new leads		✓				
		Build up loyalty of current customers				✓		
		Provide customer service						
		Find like-minded customers through groups						
	Instant messaging	Human-to-human interaction						
		Customer research	✓				✓	
		Expand brand awareness						
		Shop online & make payment offline						
		Relationship building	✓					
	Business networking sites	B2B connections	✓	✓				✓
		Share and connect on a professional level	✓	✓		✓		
		Formal professionalism						
		Job searching						
		Developing professional career		✓		✓		
		Establishing thought leadership	✓	✓		✓		
		To see what employees say about your business						
		Improve your employees' experience	✓			✓	✓	
Content communities	Creativity works sharing sites	Create inspiration				✓		✓
		Engage customer						✓
		Engage visual learner audience						
		Relationship building	✓					
		Encourage user-generated content						
		Social awareness						
		Brand building						
		Build up loyalty of current customers						✓
		Lead generation		✓				
		Targeting		✓				
		Educating the audience						✓
		Widen audience base	✓					
		Run well-planned campaign						

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Platforms / SMSOG			Stage 5					
			Focus		*Strategy*		*Problem*	
type		*benefits*	Enterprise-wide SM technologies for entire workforce	De-facto application for key business tasks	Embedded into the core of what we do, & how we do it.	Reengineer existing business models	Monitor external environment	Lack of creativity among stakeholders
		Customer service						
		Review product						
		Integrate with other app	✓		✓			
		Market research						
	Educational materials sharing	Educating the audience			✓			✓
		Encourage knowledge sharing	✓		✓			✓
		Special offer				✓		
		Share phenomenal content				✓		
		Inspiration						✓
Blog	General Blogs	Develop voice/ to express thoughts						
		Self-expression						
		Get clear about your vision						
		To build engagement and get people familiar with your business	✓					
		Content marketing						
		Leverage brand						
		Reaching a broader audience beyond your own readership	✓					
		Syndicate content					✓	
	Microblog	Branding						
		Increase visibility					✓	
		Find potential business partners through	✓					
		Market research					✓	
Online discussion forums	Collaborative websites	Answer industry-related questions	✓				✓	
		Build connections		✓	✓			
		Customer research						
		Content marketing						
		Co-ideation	✓	✓		✓		
		Participate in lively discussions	✓					
		Optimize current marketing campaigns		✓		✓		
	Social review sites	Market research					✓	
		Understand customer's perspective						✓
		Social Proof		✓				
		Situation awareness					✓	
		Discover areas for improvement		✓				
		Run location-based social campaigns						
		Network research						
	Company-sponsored networks	Team based collaboration	✓					
		Encourage knowledge sharing	✓	✓		✓	✓	✓
		Syndicate content	✓				✓	
		Collective intelligence	✓				✓	

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6G Fundamentals: Vision and Enabling Technologies

From 5G to 6G Trustworthy and Resilient Systems

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Abstract: This article reviews the 6G global landscape and the most relevant private and public initiatives, with US$ billions of investments in next generation information and communication (ICT) systems and application services. Then, it presents the 3rd Generation Partnership Project (3GPP) technology roadmap towards 6G and 5G New Radio (NR) releases. This is followed by an introduction to the latest shift in paradigm "from Internet of Things (IoT) to Internet of Intelligence (IoI)", which paves the way towards 6G wireless. The new system is anticipated to provide pervasive connectivity to functions with the ability to represent knowledge, process knowledge, and make decisions, with or without human intervention. Beyond that, the paper discusses the new carrier frequency bands above 110 GHz; and innovative fundamental enabling technologies, such as integrated semantic communication and sensing, low earth orbiting satellites, quantum key distribution, post quantum cryptography, and distributed ledger technology; and portrays a network vision for 6G wireless, looking to 2030 and beyond. Conclusions are drawn on 6G prospects, the needs of security by design for 6G; as well as the potential of 6G for securely connecting pervasive intelligence and preserving privacy; and new research directions to cater for new use categories and requirements.

Keywords: 5G, B5G, 6G, Cyber Security, Privacy Protection

5G is Operational and Accelerating

The fifth generation of mobile communication system, denoted as 5G, is expanding over the world. The global 5G landscape was discussed in GSMA (2021a), in terms of assigned spectrum and live and planned 5G launches. As of Q4 2020, "new" spectrum specifically earmarked for 5G had been assigned in 38 markets. About 130 operators have already received spectrum across low (≤ 1GHz), mid (= 1-6 GHz) and high bands (≥ 6GHz); about 50 operators in low band, 100 operators in mid band (mostly exploited), and 40 operators in high band. More

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than 110 operators have planned to launch 5G, most of them in Asia Pacific and Europe. (For updates see gsmaintelligence.com.)

Today, 5G services are already available across East Asia and North America, and most new launches continue to be in Europe. We therefore expect to see significant connections growth across this region in 2022. China with its massive base and local device availability dominates the global 5G connections (230+ millions, at the time of writing), and China will still account for nearly half of the global consumer 5G connections, which the Global System for Mobile Communications Association (GSMA) forecasts to reach 1.8 billion by 2025 (GSMA, 2021a).

The 5G landscape briefly – in terms of announced 5G devices by form factor, 5G connections and 5G global adoption by 2025 – was captured in GSA (2021). According to the Global Mobile Suppliers Association (GSA), by mid-April 2021 we had more than 700 announced devices: 350+ smartphones, 130+ Fixed Wireless Access (FWA) Customer Premise Equipment (CPE) devices (indoor and outdoor), 90+ modules, 30+ modems, 30+ hotspots, 20+ notebooks and tablets, and 30+ other devices (including drones, TVs, vehicle OBUs, etc.).

The architecture of 5G is constantly evolving and will continue to evolve over the next decade until 6G is developed (Soldani *et al.*, 2018; Nokia, 2020; Ericsson, 2020; 5G Americas, 2021a). Whereas the first 5G release (Release 15) predominantly addressed the immediate needs of enhancing the mobile broadband experience (eMBB), the release of the 16th and 17th versions take 5G toward the full 5G vision, balancing the needs of mobile broadband operators with expansion into new markets, including vertical players. The second phase of 5G has been finalised in 3GPP with the anticipated release of the 16th version (Release 16) of the technical specifications (3GPP, 2020a). The 18th releases and beyond will focus on the definition of new use cases, study items (SI) and work items (WI) towards 6G, which is expected to be specified by 2030 (Soldani, 2021a). The 3GPP 5G to 6G high level roadmap is depicted in Figure 1.

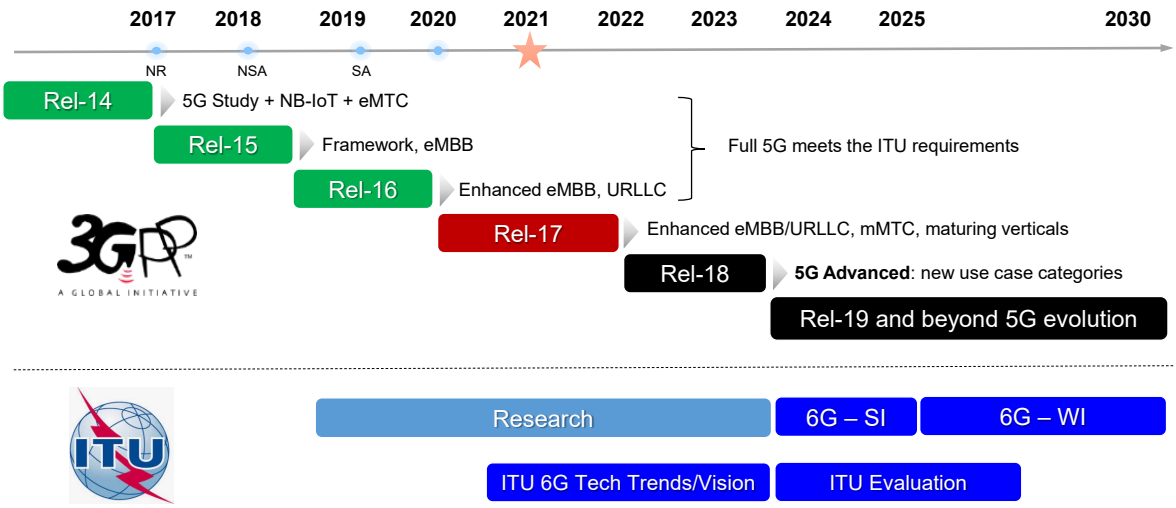

Figure 1. 3GPP 5G to 6G roadmap (Soldani, 2021a).

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

Beyond this, Release 16 supports Full 5G System Resilience with security features for service-based interfaces (SBI), Transport Layer Security (TLS) and Token-based authorization (Auth2.0); Authentication and Key Management for Applications (AKMA), such as IoT over 5G; and Network Slice-Specific Authentication and Authorization (NSSAA). It also supports Wireless-Wireline Convergence (WWC) and Future Railway Mobile Communication System (FRMCS – Phase 2). The support extends to Network Automation Phase 2; Integrated Access & Backhaul (IAB), which adds support for wireless backhauling of base stations using the NR radio interface with larger bandwidths, for network densification without requiring fibre implementation in every base station; Device Power Saving; Mobility Enhancement, and Enhanced Massive MIMO with multiple Transmission and Reception Points (TRPs). Dynamic Spectrum Sharing (DSS) – already supported by Release 15 – will become Wideband New Radio DSS with Carrier Aggregation (CA) to enable a quicker NR deployment on existing LTE bands, with efficient pooling of the resources between LTE and NR, providing a path for NR and LTE to co-exist while also enabling a granular spectrum re-farming (3GPP, 2020a).

As regards Release 17, the features to be included in this version have been agreed to and are scheduled for completion by the end of 2021 (3GPP, 2020b). Release 17 targets an even wider ecosystem expansion, particularly Critical IoT (CIoT). It will support native Time Sensitive Communication (TSC); High-Accuracy Positioning (cm-level); Sidelink enhancement for public safety and pedestrians; Multimedia Broadcast Multicast Services (MBMS); Non-Terrestrial Networks (NTN), such as Geostationary Earth Orbiting (GEO) and Low Earth Orbiting (LEO) satellites; and FRMCS enhancements (FRMCS – Phase 3). Further support will be provided to Radio Access Network (RAN) Slicing; Network Automation enhancements; New Radio in the 52–71 GHz frequency range; Device Power Saving enhancements; Further enhanced MIMO; Multiple USIMs; Unmanned Aircraft Systems (UAS) and Multi-Access Edge

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Computing (MEC), particularly suitable for delay-sensitive applications. This is illustrated in Figure 2 (3GPP, 2020b).

An NTN system is a network where spaceborne (i.e., GEO, MEO, LEO) or airborne (i.e., UAS and HAPS) vehicles behave either as a relay node or as a base station, thus distinguishing transparent (amplify and forward, or decode and forward) and non-transparent (with own radio resource management algorithms) satellite architectures. GEO satellites are at around 35,786 km altitude in synchronicity with the Earth's rotation. GEO beam footprint size ranges from 200 to 3500 km. MEO satellites circulate at an altitude varying from 7000 to 25000 km with a beam footprint size that ranges from 100 to 1000 km. LEO satellites move at an altitude from 300 to 1500 km, with a beam footprint size that ranges from 100 to 1000 km. LEO and MEO are also known as Non-GEO (NGSO) satellites and their motion around Earth varies from 1.5 to 10 hours (Rinaldi *et al.*, 2020; Lin *et al.*, 2021). The airborne category encompasses UAS platforms, which are typically placed at an altitude between 8 and 50 km and includes High Altitude Platform Systems (HAPS) at 20 km altitude. Like the GEO satellite, the UAS position can be kept fixed in the sky with respect to a given point on the ground. UAS beam footprint size ranges from 5 to 200 km. NTN terminal refers to either the 3GPP UE or a specific satellite terminal. Very small aperture terminals operate in the radio frequency of Ka-band (i.e., 30 GHz in the uplink and 20 GHz in the downlink), whereas handheld terminals operate in the S-band (i.e., 2 GHz) (3GPP, 2020b).

Narrow Band IoT (NB-IoT) and LTE-Machine Type Communication (MTC), i.e., broadband IoT, will be further enhanced in parallel and will coexist with the current and NR future 3GPP releases. Currently, the majority of cellular IoT connections still rely on 4G connectivity. This technology is likely to have a large market penetration by 2025, with massive-machine type communications, based on NB-IoT and LTE-MTC devices, predicted to constitute more than 40% of all cellular IoT connections. Broadband IoT will contribute nearly 34 of those percentage points. Critical-IoT with requirements on extremely low latency and ultra-high reliability will contribute only a small fraction to the total cellular IoT connections even in 2025 (5G Americas, 2021a).

The release of versions 16 and 17 will witness an expansion of the ecosystem that can take advantage of 5G. As depicted in Figure 2, it will do so by adding many features to provide the full range of functionality required by new industry segments. It will make 5G networks easier to deploy and operate end to end. As already described, Release 17 is currently anticipated to be finalized in the second quarter of 2022. However, the evolution of mobile communication technology will obviously not end with Release 17.

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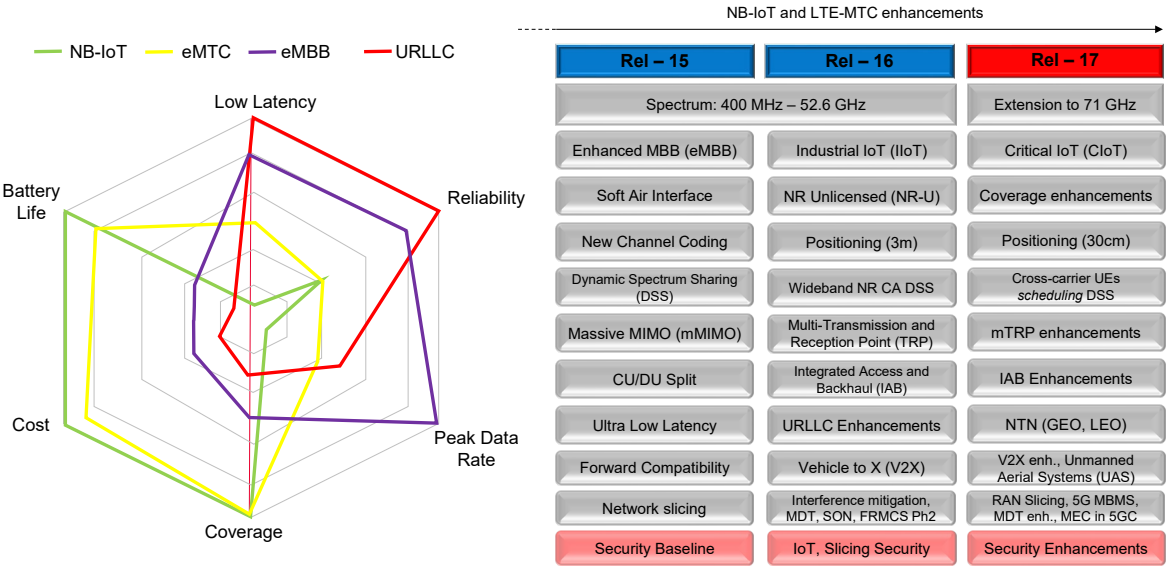

Figure 2. 3GPP R15, 16 and 17 supported spectrum and key features (Soldani, 2021a).

The evolution of 5G will continue in subsequent releases, and Release 18, denoted as *5G-Advanced* by 3GPP, will enhance its capabilities and extend the use cases to which it can be applied. However, as shown in Figure 1, at some stage, the wireless industry is expected to transit from 5G into 6G, that is, the *Sixth-Generation mobile communication system*.

At the time of writing, many use cases and related enabling technologies of 6G wireless are still under discussion, and it remains to be seen whether 6G will come along with a new air-interface or it will simply further enhance the 5G Advanced new radio. At this stage, 6G-related activities are primarily focusing on identifying the new problems and stakeholders' needs that, in turn, will drive the definition of a new set of technical requirements and features, which 6G wireless will need to support from day one. In parallel, as examined in the following sections, many joint research and innovation projects are currently focusing on fundamental technology components to cater for the needs of consumers and vertical sectors (5G Americas, 2021b).

6G Gains Momentum

While the deployment of next generation mobile communication systems still lies ahead on a time frame of ten or more years, many ongoing 6G programs and related investments provide a captivating prospect for significant acceleration of 6G studies. Industry and public organisations have already started investing in research and innovation (R&I) actions, to meet the requirements 6G will probably demand when it goes live around 2030 (Castro, 2021, 5G Americas, 2021b).

These include the usage scenarios promised in 5G networks but not achieved yet, and more advanced use cases that are emerging in the context of 6G systems. Examples of such emerging scenarios include communications at Terahertz, ubiquitous coverage (land, air, space, sea),

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holoportation, tactile/haptic communications, medical/health vertical, government/national security, imaging and sensing, public safety services, cyber-physical systems/manufacturing, and transportation. Examples of relevant use cases and consequent technology requirements are shown in Figure 3 (5G Americas, 2021b). For more information and other usage scenarios, towards 6G, the reader may refer to, for example, 6G Flagship (2021a) or 6GIC Vision (2021).

Specific international efforts by leading nations in the wireless cellular industry and relevant beyond 5G (B5G) and 6G initiatives and associated investments are illustrated in Figure 4.

In **Europe**, within the EU Horizon 2020 R&I framework program, three recent joint projects, focused on 6G development, have been announced, namely: Hexa-X, RISE-6G, and NEW-6G. The European Commission (EC), within the Smart Network and Service framework program, has proposed a €900 million budget to invest in 6G research, with particular attention to standardisation leadership and boosting 5G deployment (Castro, 2021).

Beyond that, several countries have kicked off their own endeavours and allocated budget to conduct their own research. Australia, USA, UK, Europe, Japan, South Korea, and China are in the mix, and there is pressure on other nations to join the club.

In 2021, in **Australia**, the Federal Government has pledged AU$ 1.2 billion, investing in the settings, infrastructure, and incentives to grow Australia's digital economy. (The investment boosts the recently launched Modern Manufacturing Initiative (MMI), AU$ 1.3 billion.) New investments under the Digital Economy Strategy in Australia's cyber security, safety and trust include $31.7 million to secure their future connectivity using 5G and 6G mobile networks.

Use case	Technology requirement	Performance indicator (5G ➲ 6G)
Holographic, tactile/haptic communications, digital twins	Very high bandwidth	Uplink: 10 Gbps ➲ 500 Gbps – 1 Tbps Downlink: 20 Gbps ➲ 1 Tbps Spectrum: 400 MHz – 71 GHz ➲ Up to 10 THz
Ubiquitous services, massive scale IoT networks, transportation, agriculture & livestock	Very wide coverage	10 Mbps / m^2 ➲ 1-10 Gbps / m^3 everywhere, e.g., sky, sea, space, etc.
AR/VR/MR, digital twin, tactile/haptic communications, medical/healthcare, telesurgery, Government/National security, first responder/emergency services, transportation	Enhanced reliability	$1\text{-}10^{-5}$ (99.999%) ➲ $1\text{-}10^{-9}$ (99.9999999%) availability
Massive scale of IoT networks, smart agriculture & livestock	High density endpoints	1 million connections / km^2 ➲ 10 million connections / km^2
AR/VR/MR, holographic communications, digital twin, tactile/haptic communications, tele-healthcare, tele-surgery	Synchronization of multiple flows to multiple devices	Air interface latency: 1 ms ➲ 10 ns – 0.1 ms End to end latency: 5 – 10 ms ➲ < 100 µs Jitter: not specified ➲ < ±0.1 µs
AR/VR/MR, tactile/haptic communications, transportation vertical	Precise position tracking	10 cm on 2D ➲ 1 cm on 3D, with 6 degrees of motion: (x, y, z) plus pitch, yaw, and rotation
Massive scale of IoT networks, smart agriculture & livestock	Extremely low power and resource constrained devices	Energy/bit: Not specified ➲ 1 pJ/bit, extremely low power: sensor battery life 20 years, including devices never to be charged (e.g., absorbing energy from environment)

Figure 3. Examples of use cases and corresponding technology requirements (5G Americas, 2021b).

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Country	B5G/6G Initiative
	- Australian Digital Economy Strategy, AU$ 1.2 billion - Modern Manufacturing Initiative, AU$ 1.3 billion - 5G & 6G Security and Testbed, AU$ 31.7 million / 4 years
	- "Secure 5G & Beyond Act" March 2020 - DoD Testbed programme, US$ 600 million - Next-G initiative, industry federation
	- MIC "Roadmap towards 6G", June 2020 - METI Support - US$ 380 million
	- MSIT 6G programme, September 2020 - US$ 200 million public support
	- MIIT 6G programme, creation of IMT 2030 Promotion committee (2019) - Multi € billion until 2035, including industrialization
	- 6G Flagship launched in February 2019 - € 250 million / 7 years
	- 6G Smart Networks and Services Joint Undertaking proposal - € 900 million / 7 years

Figure 4. Examples of Beyond 5G (B5G) and 6G initiatives ongoing globally (Castro, 2021).

The Australia Government will build a joint 'Secure-G' Connectivity Test Lab with industry, which will enable the involved organisations to verify protocols, compliance with standards, and quality of software towards a transparent and secure 5G connectivity. Beyond that, the Government will invest in 6G security to address the security requirements of 6G and future connectivity technologies. This will make Australia become a global leader in cyber space, ensuring that 6G technologies are secure by design and help shape international security standards in alignment with Australia's national interest (Australian Government, 2021).

In **North America**, Next G activities are primarily centred around academia with additional efforts from agencies of the US government and Standards Developing Organizations (SDOs) (5G Americas, 2021b). In 2020, the industry Alliance for Telecommunications Industry Solutions (ATIS) launched the Next G Alliance (NGA), an initiative aiming to lay out the foundations of 6G in North America, and issued a call-for-action urging the United States to promote 6G leadership. The group currently has 48 founders and contributing members, including some tech. giants like Google, Apple, Microsoft, Facebook, Samsung, Ericsson, Nokia, Qualcomm, and most of the major carriers in the U.S. and Canada. The first initiative outcome – a common roadmap to 6G – is expected to be delivered by the end of 2021 (ATIS, 2021).

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In 2018, in **Finland**, the University of Oulu started leading a national research program on 6G. The 6G Flagship initiative consists of five collaboration partners, including Aalto University, Nokia and VTT (5G Americas, 2021b).

In 2019, **Japan** announced a stimulus pack of $2 billion to support industry research on 6G technologies with a timeline of 2020-2030. In 2020, the Japanese government announced plans to develop a 6G strategy with private sector representatives and university researchers. The Beyond 5G Promotion Consortium includes the University of Tokyo, along with major Japanese telecom players such as Rakuten Mobile, Nippon Telegraph & Telephone, NTT Docomo, KDDI and SoftBank Corp, which aims at commercialising 6G services in the 2030s. During the same year, the Japan communications ministry unveiled ambitious goals under its "Beyond 5G" strategy, seeking to capture a 30% global market share for base stations and other infrastructure, up from just 2% at the time of writing (5G Americas, 2021b).

In 2021, Japan's Beyond 5G Promotion Consortium has signed an agreement with Finnish group 6G Flagship. The initiative follows a $4.5 billion commitment by Japan and the U.S. toward the development of next-generation communications technology (Hirose, 2021).

In 2020, in **South Korea**, the Ministry of Science & ICT (MSIT) announced US$170 million of public support for investments in 6G research and development for five years. The targets are to reach 1 Tbps data rate; achieve 0.1 ms wireless latency (below 5ms wired latency); expand connectivity from ground to 10 km in space; apply artificial intelligence to the entire network; and provide security by design, end to end. The use cases in focus are smart factories, smart cities, and autonomous vehicles. Non-terrestrial networks, such as 6G satellites, will be among the key fundamental enabling technologies that will be investigated (Castro, 2021).

In **China**, the Chinese Government has invested more than $30 billion towards 5G R&D over five years, and 6G is expected to receive comparable investments (5G Americas, 2021b). In 2019, two working groups were set up. The first team are government agencies responsible for promoting 6G research and development. The second group, called the "China 6G Wireless Technology Task Force", consists of vendors, operators, China Research Agencies and Chinese universities, tasked with laying out the development of 6G and proving its scientific feasibility. Beyond that, in 2020, China launched a satellite containing experimental 6G technologies. The Tianyan-5 Satellite, sent up with 13 other satellites, will test Terahertz (THz) communications in what the BBC described as a "world first" test of 6G technology in space (Tonkin, 2020).

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6G Network Architecture Vision

Based on the following evidence, the author's vision is that, by 2030, *all intelligence will be connected following a defence-in-depth strategy – augmented by a zero-trust model – through digital twinning, using B5G/6G wireless, and machine reasoning will meet machine learning at the edge.*

The following societal challenges and necessities are the main source of inspiration for the formulation of this vision (Soldani, 2021b):

1. The power cost per operation is from 1000 to 5000 higher in machines than in humans. Hence, *the intelligence must be centralized*, which also reduces the cost of the device of any form factor (GSA, 2021). As illustrated in Figure 5, our brain corresponds to a lamp of 40 W and can perform 10^{16} operations per second, while one of the most advanced humanoid platforms, produced and named *iCub* by the Italian Institute of Technology (iit), requires 200 W to perform 10^{8} operations. This means that a boy after eating a chocolate would keep moving for 1 week and iCub, with an equivalent amount of energy in kWh, would run out of power in 2 hours.
2. The two-way, end-to-end latency must be below 5-10 ms for dependable *remote control* of a connected device, or to exchange *haptic feedback* with no cyber sickness, between two peer entities (Soldani & Innocenti, 2019). Hence, *all intelligent functions must be placed at the Edge*: i.e., close to the device or end user.
3. Machine Learning, i.e., pattern recognition algorithms, have many flaws, limitations and biases. Hence, *machine learning (ML) must meet machine reasoning (MR)*, and a possible reference architecture to achieve this goal is shown in Figure 6.
4. It is an imperative to improve efficiency and productivity to reduce Green House Gas (GHG) emission (CO_2). Hence, digitization and digital transformation is a must, and currently one of the most valuable approaches is *digital twinning*. (A digital twin is a virtual representation that serves as the real-time digital counterpart of a physical object or process.)
5. We are currently witnessing a paradigm shift from "all things connected" to "connected intelligence" and that is only feasible if we make technology safe, secure, and protective of privacy. Hence, a *new mobile communication system (B5G/6G) is required that supports security by design, based on a Zero Trust model.*

In May 2021, similar views were presented at the recent 6G Symposium on "Shaping Industry & Society Beyond 5G", where use cases; emerging digital, virtual, and physical worlds, bringing new business opportunities; and the *wireless* technology evolution towards 6G were discussed (6G Symposium, 2021).

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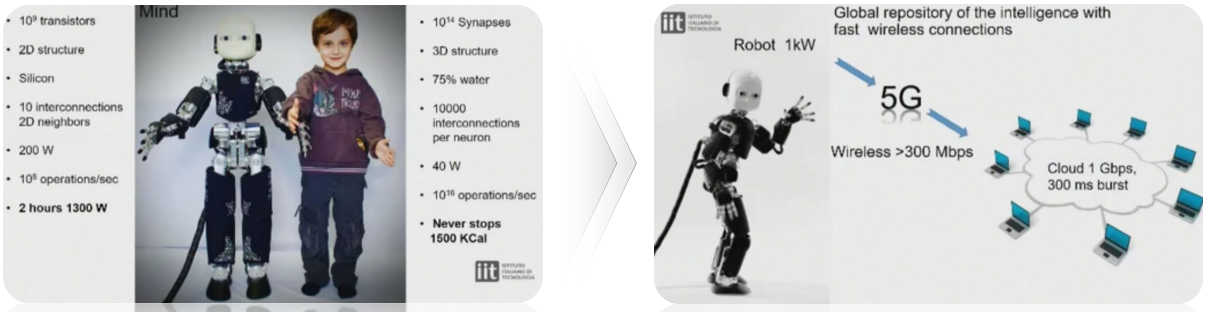

1. Centralized intelligence	2. Intelligence at the Edge	3. ML needs machine reasoning	4. Digitisation, digitalisation and digital transformation	5. From 5G to B5G/6G with Zero Trust model
Power cost per operation: **1000-5000** higher in machines	End to end **latency** below e.g. **10ms** is a must	Pattern recognition techniques have many **limitations** and **bias**	It is a must to improve **efficiency** and **productivity** to reduce $C0_2$ (GHG) emission	From all things connected to **connected intelligence** with **dependability** and **trust**

Figure 5. Examples of societal challenges and necessary corrective actions (Soldani, 2021b).

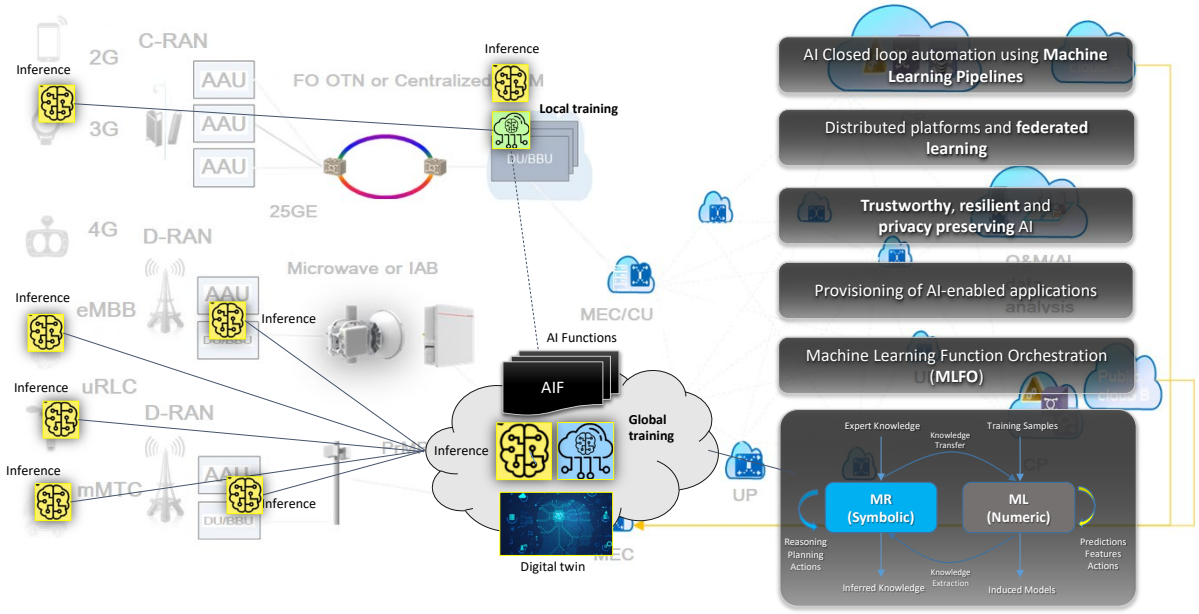

Figure 6. Examples of how Machine Learning (ML) may meet Machine Reasoning (MR) (Soldani, 2021b).

In short, 6G wireless aims at bridging the "physical world" and the "cyber world"; it is about a new paradigm shift: from *connected people and things* (information world) to *connected intelligence* (intelligent world). 6G wireless is the technology to deliver artificial intelligence to everyone, anywhere and at any time (Tong & Zhu, 2021, Soldani, 2021e).

This is precisely what was already envisioned in Soldani & Manzalini (2015), where the authors presented a blueprint of an AI native operating system for the first time and, particularly, the services on top expected in the horizon 2020 and 2030. Figure 7 is identically inspired by the architecture the authors published at that time, looking at 5G and beyond. It also included the possibility of integrating sensing and communication capabilities of access nodes together with intelligent functions pervasively distributed at the edge of the network, as well as with centralised computing platforms. The latter is responsible for the control of all connected functions, as well as the orchestration, not only of virtual network functions or virtual slice

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instances, but also the placement of nodes of different machine learning pipelines, which will unquestionably characterize the 6G system (5GPPP Technology Board, 2021).

The 6G wireless architecture will be shaped by five key constituents (Tong & Zhu, 2021), as illustrated in Figure 7: *virtual-X*, *tactile*, *inferencing*, *sensing*, and *learning*. AI will be the dominant service and application (5GPPP Technology Board, 2021). The primary spectrum will be millimetre and terahertz waves, which lie at the far end of the infrared band, just before the start of the microwave band (6G Flagship, 2021b). This will allow us to apply wireless sensing capabilities and 6G wireless will operate as a sensor network (6G Flagship, 2020a). The network and devices can perform real-time (RT) sensing, which will be the fabric to link the physical world and the cyber world (6GIC Vision, 2021).

The primary service will be virtual reality (VR) for everything. The virtual-X channel will allow access to digital content in the cyber world; the augmented tactile channel will carry haptic feedback, as the augmented neural system for the physical world (Soldani & Innocenti, 2019); and the inference channel will exchange services between the AI engine and the end user.

From the physical world to the digital world, the primary applications are sensing and collecting big data for machine learning (ML). New compression technologies and novel approaches will be required to train the neural networks (Soldani & Illingworth, 2020). The integration of sensing with communication capabilities in the mmWave/THz multiband radio heads, operating above 110 GHz, as well as in other connected devices, of any form factor (such as cameras and sensors), is expected to lead to significant advances in 6G wireless technology. Higher frequency bands allow the system to sense objects with very fine resolutions, in all physical dimensions: range, angle, and Doppler shift (6GIC Vision, 2021).

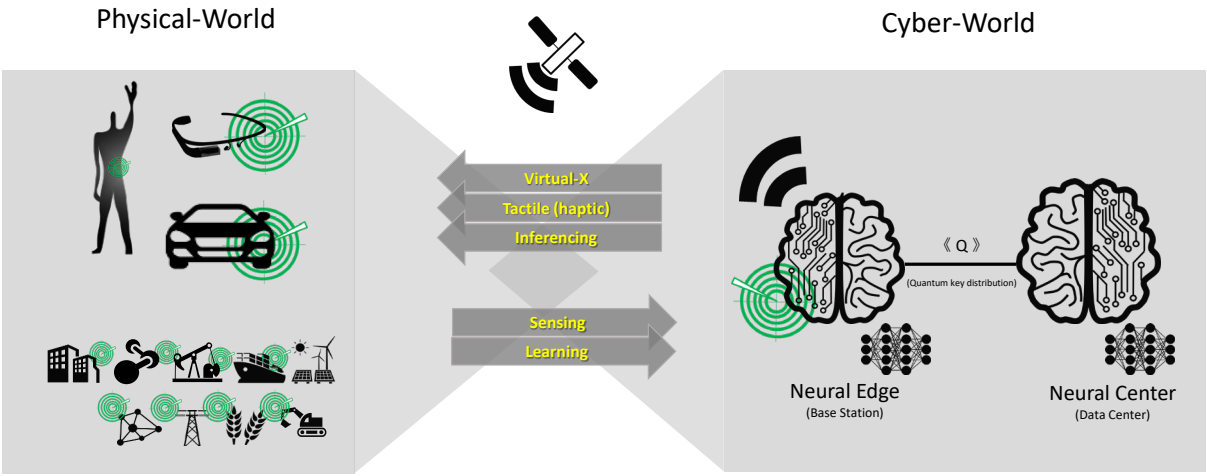

Figure 7. 6G Wireless network architecture vision (Tong & Zhu, 2021, Soldani, 2021e).

On the network side, we have the 6G Base Station (BS) node, at the Deep Edge, and 6G Neural Edge, at the Edge. Edge Nodes will have capabilities for AI resource runtime scheduling and

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orchestration (IaaS) and AI workflow/data runtime scheduling and orchestration (PaaS). The Edge Node will be mostly used for local ML, so the classical Point of Presence (PoP) at the edge will become the Neural Edge, and the BS will become the Deep Neural Node. Neural Centres (Cloud with Global AI capabilities) provide AI services to external customers (AIaaS). Examples of such services could include AI-enabled high precision localisation and end user mobility trends, etc. Quantum Key Distribution (QKD) can be deployed for the fibre-optic link between the Neural Centre and the Neural Edge (GSMA, 2021b). IaaS, PaaS and AIaaS, borrowed from cloud services, could very well coexist as they would cover diversified AI service requirements from very different sectors. AI services that run on this advanced infrastructure will bring many advantages: from global AI to local AI, form offline AI to real-time AI (Soldani & Manzalini, 2015; Tong & Zhu, 2021).

Non-terrestrial networks are an integral part of the 6G wireless system, and a massive LEO satellite constellation will bridge traditional and non-traditional networks aiming at full planet coverage, eventually, by combining different fronthaul, backhaul, and midhaul techniques. For instance, satellite or fibre may form the backhaul, whereas the multi-hop could be part of the fronthaul, in conjunction with the 6G terrestrial nodes, used for direct access, as depicted in Figure 8, which is an improved version of what the authors presented in Yaacoub & Alouini (2020).

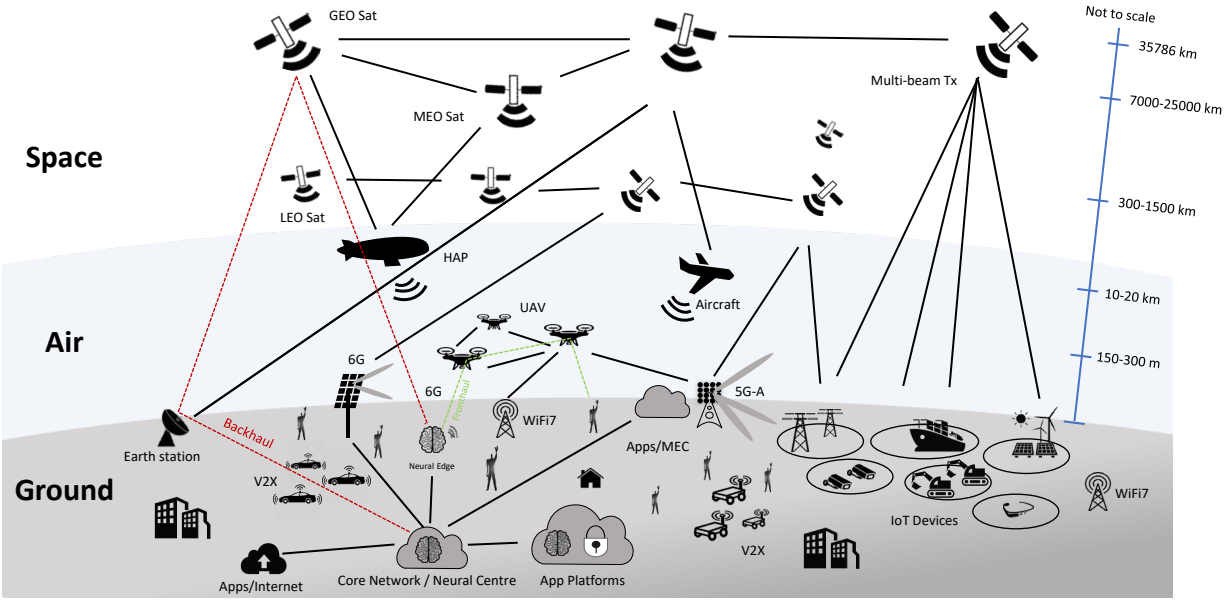

Figure 8. Examples of fronthaul (in red) and backhaul (in green) approaches towards ubiquitous connectivity.

6G Fundamental Enabling Technologies

This section provides examples of concrete technical approaches or solutions to cater for the usage scenarios and use cases introduced in the previous sections while satisfying the related technology requirements collected in Figure 3.

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This paper anticipates five essential technology enablers that will be necessary to fulfill the needs of the next generation system to realise the fundamental shift in paradigm *from the internet of things to the internet of intelligence*, the latter being defined as functions with the ability to represent knowledge, process knowledge and make decisions (Soldani, 2021b).

Artificial Intelligence at the network edge

The first shift in paradigm is about going *from an artificial intelligence enhanced network*, which is the 5G system today and its future releases, to an *AI native communication platform*, as shown in Figure 9.

A unified, logical architecture for ML for future networks, including 5G, has been already defined by the ITU-T Focus Group (FG) -ML5G (Soldani & Illingworth, 2020). The FG-ML5G proposes a logical *ML pipeline*, i.e., a set of logical entities (each with specific functionalities) that can be combined to form an *analytics function*. Each functionality in the ML pipeline is defined as a *ML Pipeline node*, e.g., source, collector, pre-processor, model, policy, distributor, or sink. In particular:

- A ***source*** (src) is a node that *generates data* that can be used as input for the ML function; it could be a UE, session management function (SMF), access and mobility management function (AMF) or any other entity in the network, including an application function (AF).
- A ***collector*** (C) is a node responsible for *collecting data* from the src: e.g., it may use the radio resource control (RRC) protocol to configure UE, acting as a src; or vendor specific operations, administration and maintenance (OAM) protocols to configure an AMF or AF acting as a src.
- A ***pre-processor*** (PP) is a node responsible for c*leaning data, aggregating data or performing any other pre-processing* needed for the data so that it is in a suitable form for the ML model to consume it.
- A ***model*** (M) is an *ML model*, e.g., a prediction function. (Model training is required to be done in a *sandbox* – a domain internal to the network operator in which ML models can be trained, verified and their effects on the network studied – using training data.)
- A ***policy*** (P) is a node that provides a *control* for an operator to put a *mechanism* into place to minimise impacts on a live network, so that the operation is not impacted, e.g., to safeguard the sanity of the network.
- A ***distributor*** (D) is a node responsible for identifying the sinks and *distributing the ML output to the corresponding sinks*; it may use RRC protocol to configure a UE acting as a sink.
- A ***sink*** (S) is the *target node* of the ML output, on which it takes action (*inference*), e.g., a UE adjusting its measurement periodicity based on ML output.

Chaining is the process of connecting ML functions or nodes together to form a complete ML pipeline. The chain itself is declared by the network operator (NOP) in the use case specification, i.e., in the *intent* – a declarative mechanism used for specifying the ML use case

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– and its technology-specific implementation in the network is done by the *ML function orchestrator* (MLFO).

The MLFO utilises the constraints (e.g., timing constraints for prediction) defined in the intent to determine the *placement and chaining of ML functions*. Also, the MLFO monitors and manages the ML pipeline nodes in the system and the model, and performs all necessary tasks, including *model reselection*, when the performance falls below a predefined threshold.

An *ML application* can be realised by instantiating logical entities of the ML pipeline with specific roles (e.g., src, collector, sink) and distributing these entities among network functions (NFs) specific to the technology, e.g., virtual network functions (VNFs), based on the related requirements of the logical entities (e.g., a traffic classifier that needs to be fed with data summaries every *X* ms) and capabilities of the node (e.g., computing power at the edge).

In addition to supporting the concept of ML pipeline by design, 6G Wireless is expected to incorporate *outer semantic channels* (Tong & Zhu, 2021), starting precisely from the initial Shannon and Weaver's categorization, which was inspired by Nikola Tesla — who stated, in 1926: "When wireless is perfectly applied, the whole Earth will be converted into a huge brain" (Tesla Universe, n.d.).

The communication through the *inner Shannon channel*, studied and optimised for more than 60 years, could be augmented by an outer channel that models how the human brain processes signals, sensed from the environment, and takes actions. Our brain acquires knowledge from experience, and, in *real time* (RT), i.e., instantaneously, takes complex decisions, without thinking or hesitating, and performs extremely complicated tasks with a sustainable energy consumption (Soldani, 2021b).

Mimicking how our brain works, an AI native 6G wireless system could support semantic communication capabilities by design. A goal-oriented and semantic communication may be enabled by the broad adoption of deep neural networks (DNN), which allow the derivation of exploitable and explainable meanings from an unlimited amount of sanitised information (data) (Calvanese Strinati & Barbarossa, 2021).

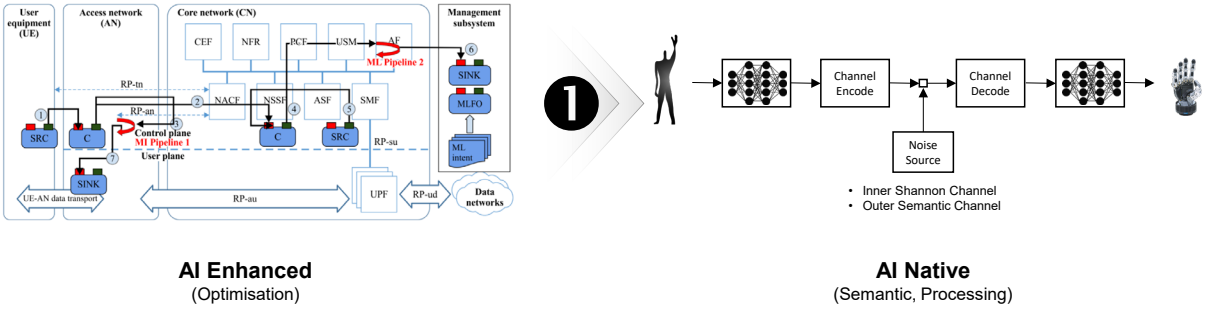

Figure 9. From AI enhanced networks to AI native communication systems (Soldani, 2021b).

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The design and effective control and management of new generation wireless networks may be achieved with a massive exploitation of generative pre-trained transformer platforms (GTP) (Tong & Zhu, 2021, Soldani, 2021e).

Combined sensing and communication

The second shift in paradigm is about going *from an information centric approach of bits and bytes to uplink and downlink sensing*, with sensing capabilities embedded in devices and access points (radio heads), denoted as *Neural Edges* in Figure 7 and Figure 8, operating at very high frequencies (millimetre waves and THz communications) and using very large contiguous and/or non-contiguous (detached) bandwidths (of several GHz).

Several definitions of the THz band may be found in the literature, although the ITU definition of the *tremendously high frequency* (THF) region states that the *THz band* is from 0.3 THz to 3 THz (6G Flagship, 2021b).

In 6G Flagship (2021b), the authors call the higher end of the extremely high frequency (EHF) band the *upper mmW band* or *region*. The band covers frequencies of 100–300 GHz, and that will likely be among the most interesting bands in coming years for the design of new-found radio communication systems. This region provides a much larger slice of spectrum than the *lower mmW region* (30–100 GHz). As discussed earlier, the latter has already been adopted extensively by many standardisation organisations, e.g., 3GPP 5G NR, IEEE 802.11, and other wireless technologies, which, at these frequencies, are unable to provide Tbps radio speeds.

The capability of 6G wireless link transmission is expected to improve by at least 10–100 fold, above that of 5G, to achieve the very high band target and to support the throughput demands of data-rate-intensive services, such as those reported in Figure 3. In addition to improving *spectral efficiency*, 6G wireless is anticipated to widen the supported frequency bandwidths, operate at a variety of carrier frequencies, and transmit at minimal transmission power. Going to the upper mmW band (100–300 GHz), and, in the future, also to the THz band (>300 GHz), network throughput and resource sharing among users could be pushed far beyond that of the current 5G systems, especially in densely populated areas. 6G wireless communication at Terahertz can be used to create powerful links that act as if optical fibres were installed, while connecting satellites or connecting the ground and satellites (6G Flagship, 2021b).

The upper mmW or THz band, with wavelength (λ) around 10 μm, has both the potential for *extremely high-rate communications* and *sensing networks*, in which network infrastructures and devices, of any form factor, are equipped with sensing capabilities (6G Flagship, 2020a).

Sensing is the fundamental enabling technology for *connected intelligence*, which is perhaps the most important application of 6G. Integrating sensing functions with the base stations on

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already installed networks is a viable way of constructing a 6G sensing network, as shown in Figure 8. The 6G sensing capabilities can be deployed on any critical infrastructure, such as transport, water, gas, ports, electricity, datacentres, close to important points to determine the status and dynamics of traffic, fluids, gas, etc. and then process these data to realise a system able to make decisions, with little or no human intervention (6G Flagship, 2021b).

From the terminal's perspective, the sensing capability could be exploited using methods that make use of various sensor types, such as touch panels, camera, infrared, or gyroscope to smart devices, which allow them to sense the situation and context of the surrounding environment. The results can then be transferred to other parts of the network via a wireless connection (6G Flagship, 2021b).

In short, sensing is a basic means of intelligence and an important part of future 6G networks and devices. We will have full capability of sensing the environment, context, like the radar or lidar systems today, and therefore can extract extensive information, in addition to the classical channel quality indicator (CQI) and other radio measurements, and integrate this information with other sources of data, images, or anything that can be captured by other devices, and thus make it possible to offer Sensing as a Service (Soldani, 2021b).

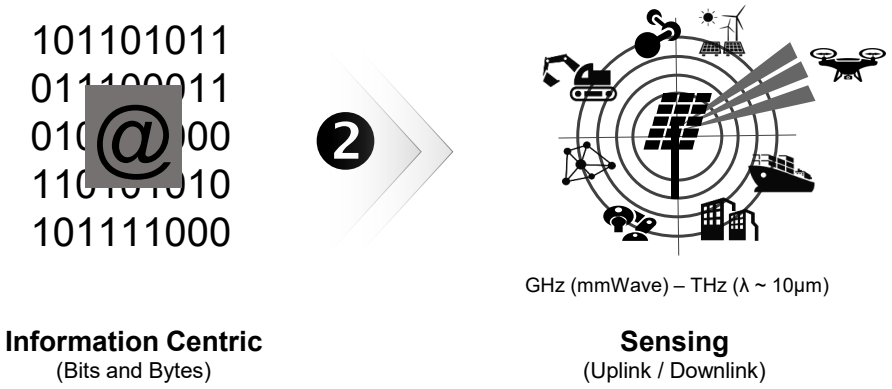

Figure 10. From information centric to integrated sensing and communication (Soldani, 2021b).

Space, air and extreme ground connectivity

The next generation of communication systems is expected to provide *ubiquitous services* in new remote areas not previously served at all (e.g., remote areas, outer space and across entire oceans). Such communication services will create a seamless unified connectivity framework consisting of *terrestrial* (ground-based and marine), *airborne* (satellites, balloons, drones, etc.) and *space based* (LEO/MEO/GEO satellite constellations) networks (see Figure 8).

NTN systems are likely to be an integral part of the *access* network to 6G services and *backhaul* of next generation information and communication systems. The uniqueness of NTNs is in their capability to offer wide area coverage by providing connectivity over regions (e.g., rural

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areas, vessels, aeroplanes) that are expensive or difficult to reach with terrestrial networks. Therefore, the NTN represents a coverage extension for the terrestrial network in a world market where the demand for different services is growing steadily, due to the ever-increasing number of devices connected to the Internet (Rinaldi *et al.*, 2020; Lin *et al.*, 2021).

Moreover, LEO satellite constellations may be deployed to provide *ultra-low latency services*, optimally down to 1 to 3 ms, between two or more devices in communication. This is because the length of the satellite radio link, end to end, would be shorter than the orthodromic surface distance that would be required to connect the two peer entities by deploying fibre on ground. As illustrated in Figure 11, for example, from London to Shanghai the orthodromic distance is ~10,000 km and that would be reduced to about 1,500 km if the two entities were connected via LEO satellites (Tong & Zhu, 2021, Soldani, 2021e).

When THz communication is used on LEO communications, *beam steering* is required, even for a fixed station to facilitate installation, and its development will be important in the future.

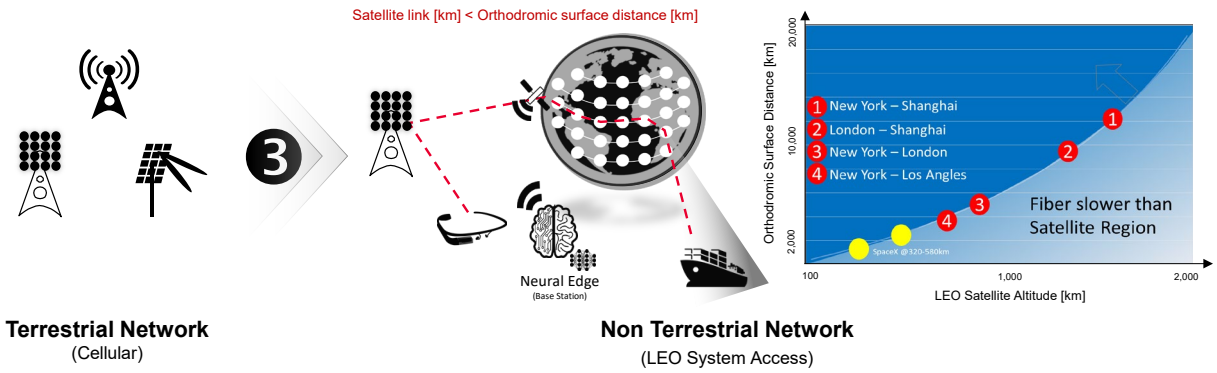


Figure 11. From cellular networks to integrated terrestrial and non-terrestrial infrastructures (Soldani, 2021b).

Privacy preservation, security controls and assurance

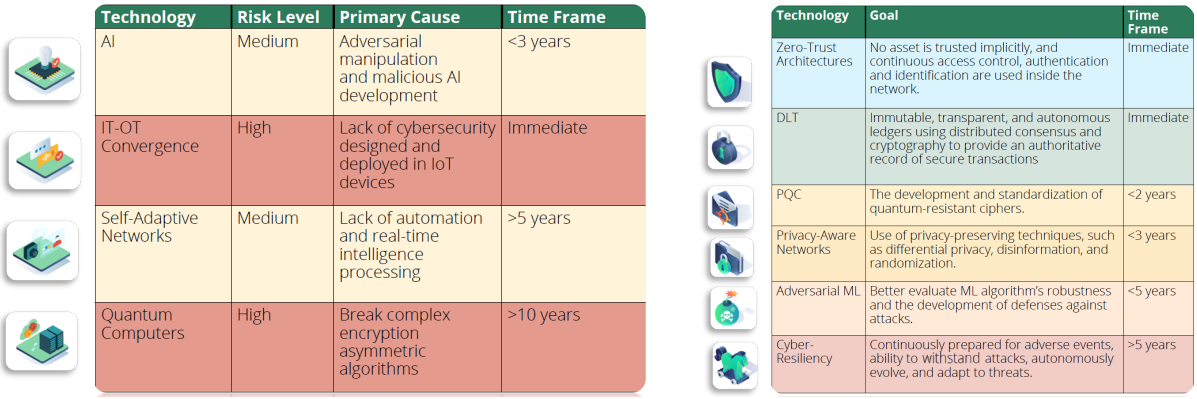
The fourth shift in paradigm is about cyber security and privacy protection, in general: *6G wireless is projected to be secure by design*, which is more than a security enhanced system, as is the case today for 5G with respect to 4G (Soldani *et al.*, 2018; 5G Americas, 2020).

Although it is currently difficult to envision pre-emptive security controls – as 6G wireless has not been agreed and specified by any standardisation development organization(SDO) yet – it is important to recognise the fact that a preliminary analysis of the potential threats can be done by simply examining the *risk exposure of the proposed 6G technologies*, as, with any new technology, new threats will emerge that need to be mitigated, in addition to any existing threats that will be carried over from past generation networks (Menting, 2021).

A comprehensive list of potential risks and new threats inherent in the design, development and implementation of 6G wireless communications was discussed in Menting (2021), along

http://doi.org/10.18080/jtde.v9n3.418

with possible security controls, measures and necessary efforts to remediate for the potential weaknesses. A summary of the potential threats, vulnerabilities and corresponding security mechanisms is depicted in Figure 12 (see also ENISA, 2020).



Technology	Risk Level	Primary Cause	Time Frame
AI	Medium	Adversarial manipulation and malicious AI development	<3 years
IT-OT Convergence	High	Lack of cybersecurity designed and deployed in IoT devices	Immediate
Self-Adaptive Networks	Medium	Lack of automation and real-time intelligence processing	>5 years
Quantum Computers	High	Break complex encryption asymmetric algorithms	>10 years

Technology	Goal	Time Frame
Zero-Trust Architectures	No asset is trusted implicitly, and continuous access control, authentication and identification are used inside the network.	Immediate
DLT	Immutable, transparent, and autonomous ledgers using distributed consensus and cryptography to provide an authoritative record of secure transactions	Immediate
PQC	The development and standardization of quantum-resistant ciphers.	<2 years
Privacy-Aware Networks	Use of privacy-preserving techniques, such as differential privacy, disinformation, and randomization.	<3 years
Adversarial ML	Better evaluate ML algorithm's robustness and the development of defenses against attacks.	<5 years
Cyber-Resiliency	Continuously prepared for adverse events, ability to withstand attacks, autonomously evolve, and adapt to threats.	>5 years

Figure 12. Potential threats and novel events, and corresponding security measures (Menting, 2021).

To shift from a *security enhanced network to a security by design system*, 6G needs to integrate security at the heart of the infrastructure and instil the whole network end-to-end with a defence-in-depth strategy, augmented by a Zero Trust model (Soldani, 2020), with the ability to cope with different situations and unexpected events in extreme conditions. Also, the standardization process for 6G must provide new mechanisms for security control, security assurance and privacy preservation (Soldani, 2021d), as shown in Figure 13.

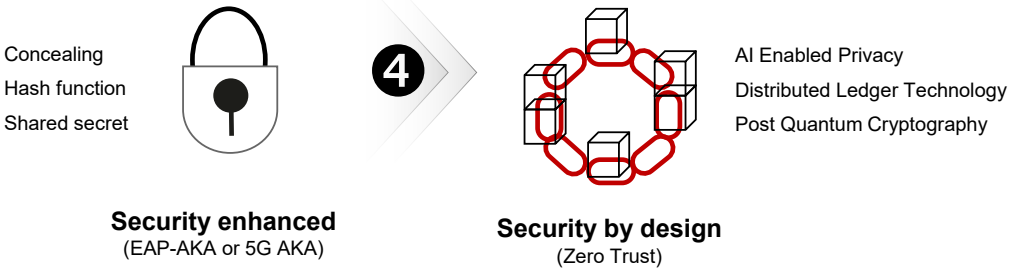


Figure 13. From security enhanced networks to security by design systems (Soldani, 2021b).

Privacy preservation

In 5G, the Extensible Authentication Protocol—Authentication and Key Agreement (EAP-AKA), and 5G Authentication and Key Agreement (5G AKA) – used for Non-3GPP and 3GPP authorized access, respectively – procedures support the *mutual authentication* between the UE and the network, based on a secret (shared) master key (***K***) in the Universal Integrated Circuit Card (UICC), better known as Universal Subscriber Identity Module (USIM), and the Authentication Credential Repository and Processing Function (ARPF). The user's privacy is preserved by concealing the globally unique 5G Subscription Permanent Identifier (SUPI), which can be either in the format of International Mobile Subscriber Identity (IMSI) or presented as a Network Access Identifier (NAI) (3GPP, 2021).

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The EAP supports both *primary authentication* (implemented during initial registration, for example, when a terminal is turned on for the first time during a call or session) and *secondary authentication* (executed for authorisation during the set-up of user plane connections, for example, to surf the web or to establish a voice over IP call). The secondary authentication allows the operator to delegate the authorisation to a third party; it is meant for authentication between UE and external data networks (EDN), residing outside the operator's domain. (A similar service was also possible in 4G, but it is now integrated in the 5G architecture.) This mechanism allows an independent authentication and authorization, e.g., using 5G *network slicing*, before the UE may connect to that external network using EAP to request secondary authentication by, e.g., a private network, such as a campus network, in the case of MEC deployment (3GPP, 2021).

As summarised in Figure 14, on the side of the 5G Core Network (5GC), the key element that effectively performs authentication with the UE is Authentication Server Function (AUSF). The AUSF utilises services of Unified Data Management (UDM) and ARPF, which are responsible for hosting the functions related to subscribers' data management and for selecting authentication methods and computing data and keying material that AUSF needs to do its job.

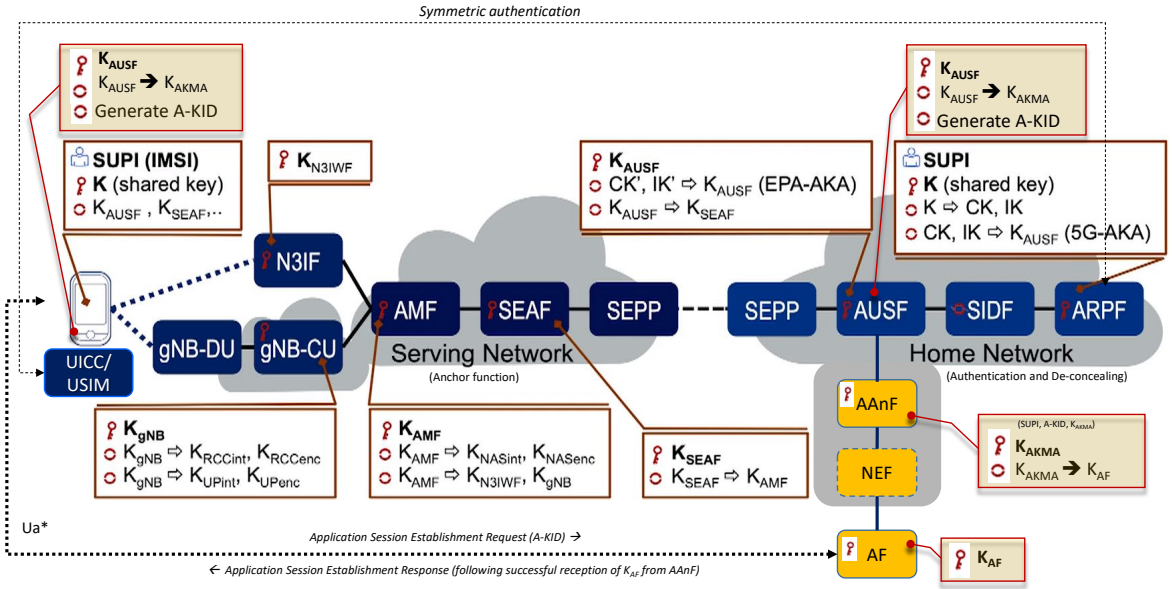

Figure 14. Key generation hierarchy in 5G, improved version of what was shown in Stuhlfauth (2020).

Concurrently, Subscriber Identifier De-concealing Function (SIDF) derives the Subscription Permanent Identifier (SUPI) from the Subscription Concealed Identifier (SUCI). In 5G, this all happens in the Home Network (HN) core, which was not the case on earlier core network platforms (3GPP, 2021).

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In the 5G system, SUCI is a *privacy preserving identifier* containing the hidden SUPI. The UE generates a SUCI using a protection scheme with the public key of the HN that was securely provisioned to the USIM during the subscriber registration.

Only the Mobile Subscriber Identification Number (MSIN), part of the SUPI, gets concealed by the protection scheme, while the home network identifier MCC/MNC – the first three digits represent the Mobile Country Code (MCC) and the next two to three bits form the Mobile Network Code (MNC), identifying the network operator – gets transmitted in plaintext (3GPP, 2021).

The subscriber identification mechanism allows the identification of a UE on the radio path by means of the SUCI. This mechanism is usually invoked by the Serving Network (SN) by sending an Identifier (ID) Request to the UE, when the UE is not identifiable by means of a temporary identity. The UE then responds with the Identifier Response, containing the SUCI. Additionally, if the UE sends a Registration Request message of type "initial registration" to a mobile network for which it does not already have a 5G Globally Unique Temporary User Equipment Identity (5G-GUTI), then the UE includes a SUCI with the Registration Request.

On the side of the serving network, the key function is 5G Security Anchor Function (SEAF) that stores the anchor key (K_{SEAF}) provided by the AUSF of the home network. Keys for more than one security context can then be derived from the K_{SEAF}, without the need of a new authentication run, *regardless of the access network technology used by the UE*. In 5G, the home network always oversees the authentication, instead of the visiting/roaming network, as done in 4G or earlier system generations (3GPP, 2021).

Moreover, in 5G mobile systems, another authentication framework is the Authentication and Key Management for Applications (AKMA), where subscriber credentials can be used for authentication and key management of 3rd party applications and IoT traffic (ENISA, 2021).

As 5G networks evolve, it is expected that there will be increased reliance on AI enabled smart applications requiring situational, context-aware, and customized privacy solutions. Hence, the 5G privacy preserving approach may not be well suited for future wireless applications, due to a diverse and complex set of novel privacy challenges (6G Flagship, 2020c).

One potential solution is the use of *pairs of deep neural networks,* which can be trained with differential privacy, a formal privacy framework that limits the likelihood that queries of *personal identifiable information* (PII) – sensitive data that can include, e.g., the full name of a person, his or her social security number, driver's license, financial information, medical records, etc. – could identify a real data subject (Beaulieu-Jones *et al.*, 2019).

Also, *Distributed Ledger Technologies* (DTL), such as *blockchain*, may be an enabler for data integrity – beyond Hash Functions, used in 5G and other traditional communication systems

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– and the use of trustless computing between stakeholders, as well as presenting a privacy protection ability across the network (WBGTIL, 2021). For example, blockchain offers privacy-protection data sharing mechanisms, can optimize access control, provide key characteristics, such as data integrity, traceability and monitoring, and ensure an efficient accountability mechanism, among other aspects, for Machine Type Communications in 6G (6G Flagship, 2020c).

The concepts related to *Federated Learning* (FL), as exemplified in Figure 6, are also active topics in the research community for ensuring privacy protection. FL is a distributed machine learning technique that allows model training for large amounts of data generated locally and the required modelling is done by each individual learner in the federation. Instead of sending a raw training dataset, each individual learner transmits their local model to an "aggregator" to build a global model. This method can provide solutions to vital challenges of data privacy, data ownership and data locality as it follows the approach of "bringing the code to the data, instead of the data to the code" (6G Flagship, 2020c).

Furthermore, 6G wireless is expected to be *privacy-aware*, supporting privacy-preserving techniques, such as, for instance, *differential privacy, disinformation and randomization* (Menting, 2021).

Protection of network interfaces

In 5G, the implementation of the radio access network may be split or disaggregated, where the RAN is separated into Distributed Units (DU) and Central Units (CU). The CU performs security functions (cryptography), it terminates the Access Stratum (AS) security protocols and is typically deployed in sites with restricted access to maintenance personnel. Together, DU and CU form the gNB (Soldani, 2021c), as shown in Figure 15.

In 5G, at the radio interface, the signalling and user plane traffic is encrypted using a 128-bits cypher key (256-bits after 3GPP Release 17) and information integrity is provided using a Hash Function. (The user plane integrity at the radio interface is only supported by the NR.) However, in 5G, only the Non-Access Stratum (NAS) protocol – end-to-end direct transfer signalling, i.e., control plane traffic between the UE and Access and Mobility Function (AMF) – is encrypted with integrity protection, using K_{NASint}, K_{NASenc} (see Figure 14 and Figure 15).

Since the traffic transmitted through F1 and E1 interfaces (Figure 15) may carry sensitive data, the 3GPP security assurance specifications (3GPP, 2021) require compulsory confidentiality, integrity and replay protection for signalling messages at F1 (F1-C) and E1 interface (E1-C and E1-U), while making it optional for user plane traffic at F1 interface (F1-U). For both F1 and E1 interfaces, the support of IPSec ESP protocol (IETF RFC 4303) and IKEv2 certificate-based

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authentication (TS 33.310) is mandatory. The user plane traffic at F1 interface (F1-U) may be safeguarded differently, including setting integrity and/or encryption off/on (ENISA, 2021).

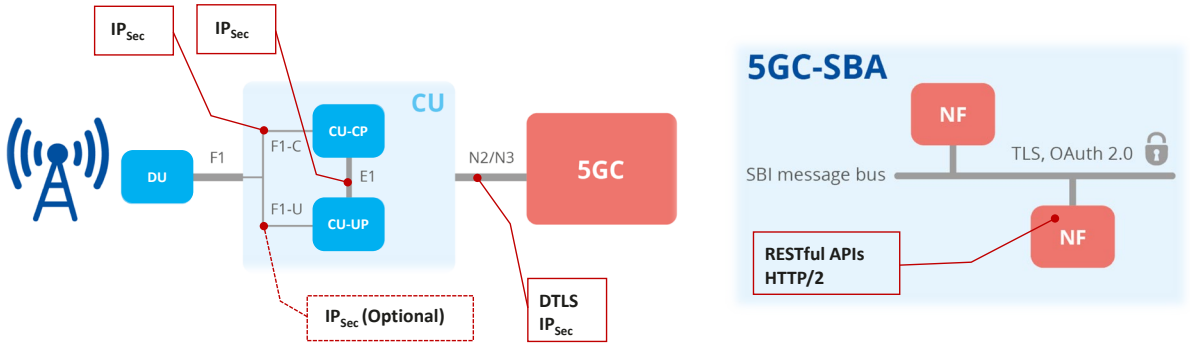

Figure 15. Protection of interfaces/virtual functions in 5G, improved version of what shown in ENISA **(2021).**

Interfaces N2 and N3 (also shown in Figure 15) are interfaces that connect 5G-RAN with AMF and User Plane Function (UPF), respectively. The support of IPsec ESP and IKEv2 certificate-based authentication is required for both interfaces. In addition, 3GPP (2021) demands the support of DTLS (RFC 6083) together with IPSec, which hides network topology. Particularly, the IPSec tunnel, between the gNB and 5GC, may be implemented using a Security Gateway (SEG) at both sides, to terminate the connection between the two elements (ENISA, 2021).

The 5GC Service Based Architecture (SBA) is based on virtual network functions (VNF) that support several micro-services, which can be exposed to other network entities. These VNFs offer their micro-services through Service Based Interfaces (SBIs), using HTTP/2 and RESTful APIs (3GPP, 2021).

From the security perspective, the network functions (NFs) must support client and server *certificates* and TLS, which needs to be implemented for transport protection, whilst NDS/IP may be integrated in the protocol stack for safeguarding the network layer (ENISA, 2021). Overall, the Network Repository Function (NRF) plays the role of an *authorization server* that provides access tokens to other network functions in communication, which need to exchange messages safely between them. Mutual authentication between these network functions is compulsory. For example, the mutual authentication of NF-NRF takes place during the discovery, registration and access token request procedures. (The authentication function depends on the supported protocol. If that is TLS, then the authentication provided by TLS would be used.) The authorization is based on the OAuth 2.0 framework (RFC 6749).

The *5G security architecture, features and protocols simply enhance the mechanisms that constitute the 4G security posture, and 6G is expected to go well beyond that* (Soldani, 2021f).

For example, as shown in Figure 12, 6G wireless is expected to support, but not be limited to, the following security controls and assurance mechanisms (Menting, 2021; Soldani, 2020):

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- **Zero-Trust architecture (ZTA)**: not a single asset is trusted implicitly, and continuous access control, authentication and identification are used inside the network.
- **Distributed Ledger Technology (DLT)**: immutable, transparent, and autonomous ledgers using distributed consensus and cryptography to provide an authoritative record of secure transactions.
- **Post Quantum Cryptography (PQC)**: creating quantum-resistant ciphers that future quantum computers cannot crack.
- **Adversarial ML**: better evaluate ML algorithm's robustness and the development of defences against attacks.
- **Cyber-Resiliency**: continuous detection and appropriate response to adverse events, ability to withstand attacks, autonomously evolve, and adapt to threats.

Security assurance

The GSMA network element security assurance scheme (NESAS), jointly defined by 3GPP and GSMA, provides an industry-wide security assurance framework to facilitate improvements in security levels across the mobile industry (GSMA, 2020).

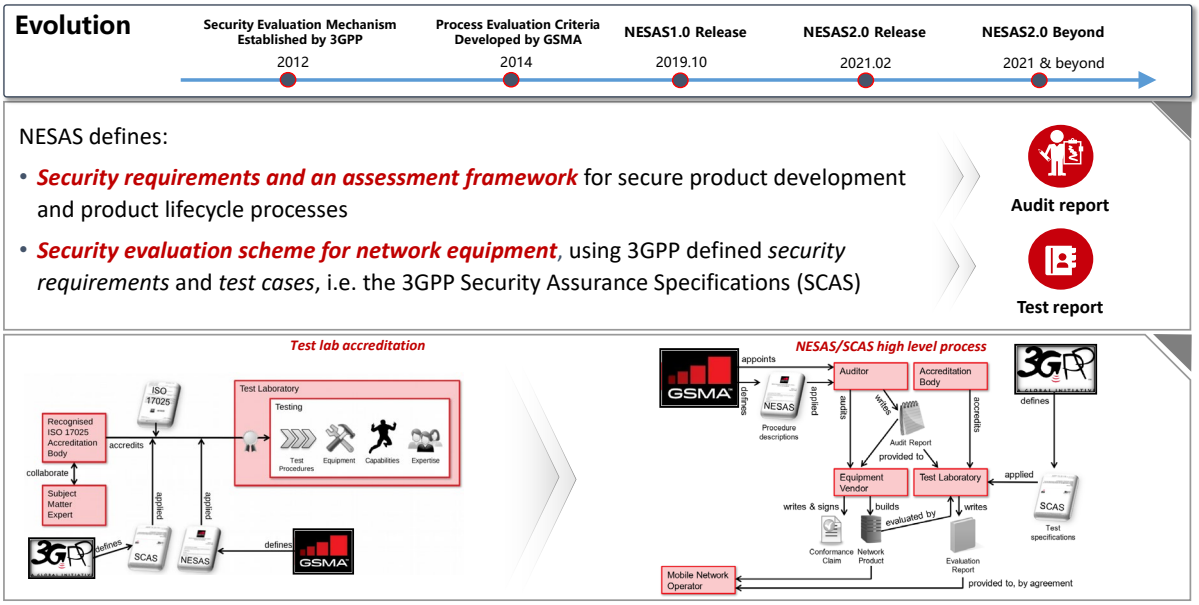

Figure 16. GSMA NESAS and 3GPP SCAS methodologies and milestones (Soldani, 2021d).

The NESAS defines security requirements based on 3GPP technical specifications and an assessment framework for secure product development and product lifecycle processes; and a security evaluation scheme for network equipment using the 3GPP-defined security specifications and test cases, i.e., 3GPP security assurance specifications (SCAS).

- **NESAS Development and Lifecycle Assessment Methodology** — defines audit and assessment process for vendor development and product lifecycle process under the GSMA NESAS.

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- **NESAS Development and Lifecycle Security Requirements** — defines security requirements for vendor development and product lifecycle process under the GSMA NESAS.

The NESAS is focused on the vendor aspects of the supply chain, and thus provides a security assurance framework to improve security levels across all mobile industry, because it has been developed and will progress, as the ICT will evolve, following well established practices and schemes that provide trustworthy security assurance (Soldani, 2021d).

Industry players, governments, security agencies and regulators are recommended to adopt the GSMA NESAS for testing and evaluating telecoms equipment of current and future generations. The NESAS is a customized, authoritative, unified, efficient and constantly evolving security assurance scheme for the mobile industry and could be a part of *certification & accreditation processes* against a fixed set of security standards and policies for current 5G and future 6G network security authorization in any country (Soldani, 2021d).

Ultimately, to realise the above vision of 6G information and network security will require collaboration among all key stakeholders. All parties in the industry chain need to take their own security responsibilities, to mitigate the related cyber security risks (Soldani, 2021d):

- **Suppliers** must prioritize cyber security sufficiently (e.g., respect laws, regulations, standards, certify their products, and ensure quality in their supply chains).
- **Telco operators** are responsible for assessing risks and taking appropriate measures to ensure compliance, security and resilience of their networks.
- **Service providers and customers** are responsible for the implementation, deployment, support and activation of all appropriate security mechanisms of service applications and information (data).
- **Regulators** are responsible for guaranteeing that telco providers take appropriate measures to safeguard the general security and resilience of their networks and services.
- **Governments** have the responsibility of taking the necessary measures to ensure the protection of the national security interests and the enforcement of conformance programs and independent product testing and certification.
- **Standardization development organizations** must ensure that there are proper specifications and standards for security assurance and best practices in place, such as the GSMA NESAS.

Prosumer centric systems

The last, but not the least, critical shift in paradigm is that we are moving *from an operator centric system*, which is essentially a generic pipe of bits, *to something truly centred on the end user*.

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The end user is expected to become a true *prosumer*, meaning that subscribers will be able not only to consume content and information, but also create content and substance and share that, making it available to communities of people and cyber entities, connecting to and exploiting 6G services (Soldani, 2021b).

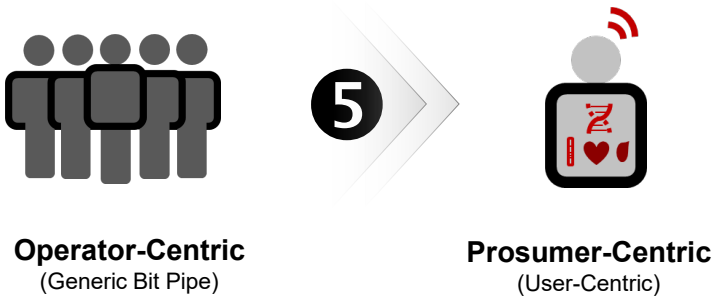

Figure 17. From generic bit-pipe networks to prosumer-centric systems (Soldani, 2021b).

Conclusions

The next generation of information and communication systems, denoted as 6G wireless, will enable the shift *from the Internet of Things to the Internet of Intelligence*, the latter defined as functions with the capability of representing knowledge and an ability to process knowledge and take decisions: *6G wireless will be the nervous system of the global digital economy*.

6G wireless is expected to be *secure by design*; connect intelligence, being AI native and prosumer centric; support a variety of new usage scenarios; and, consequently, cater for more stringent technology requirements than earlier mobile communication systems; by enhancing the performance of 5G wireless by a factor of tenfold or more, in terms of, but not be limited to, the following metrics: supported spectrum and bandwidth; coverage; reliability; latency; density of endpoints; synchronization of multiple flows to and from multiple *collaborative* devices; location and position tracking; and energy and resources consumption; amid other performance indicators. Also, new security control measures, security assurance schemes and privacy preservation approaches will form a core part of the 6G wireless posture.

Many 6G development initiatives are ongoing globally and the investments in R&I provide a fascinating prospect for our future. In Australia, EU, the UK, China, the US, South Korea and Japan, public and private sectors have already started investing US$ billions in R&I actions to tackle the technology requirements that 6G will demand, when it matures around 2030.

To realise the compelling vision of 6G wireless presented in this work requires *close cooperation and collaboration within all stakeholders and regions, globally*, even more than usual; as well as the *integration of satellite associations, alliances of vertical sectors, with the standardization development organizations*, such as the 3GPP, responsible for the technical specification of 6G wireless.

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It also requires an ecosystem of public and private players and a multi-disciplinary approach to ensure that: a) all assets that form part of 6G systems are *interoperable* and *compliant* with *standardised security evaluation criteria*, such as the GSMA/3GPP NESAS (GSMA, 2020), for security authorisation in the country, where the system is deployed; and b) even the smallest and most insignificant asset within the end-to-end supply chain must support a *minimal set of approved security, safety and privacy requirements*.

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An Analysis of Consumer Trends in the Telecommunications Markets of Russia and Vietnam

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Abstract: By way of descriptive and comparative analysis, the subscriber bases and revenues of television, fixed and mobile telephony, and fixed and mobile broadband segments of the Russian and Vietnamese telecommunications markets for the period of 2015-2019 were analysed. The results of the study revealed similar global trends in the telecommunications markets of Russia and Vietnam. Fixed and mobile telephony revenues are declining, since customers prefer new communication technologies to the old ones. The television subscriber base is growing in both countries; TV revenues are increasing in the Russian market and somewhat declining in the Vietnamese telecommunications market. With further penetration of broadband, more customers are upgrading their television from Free TV to Pay TV (IPTV and OTT services). The results of the study confirmed the global consumer trends in telecommunications markets and the applicability of approaches used herein for other countries.

Keywords: telecommunications, subscriber base, revenue, ARPU, broadband

Introduction

The development of communication as a linking element of the digital economy has led to a variety of different communication modes. Today the consumer has a wide choice. When landline telephony is gradually losing its popularity and traditional mobile telecommunication services are receding into the background with the appearance of services such as WhatsApp, Viber, and the like, the market is gradually shifting to the Internet space with a significant range of services (Lugovskaya & Simakina, 2019). The ease of transition between not only individual mobile operators and the tariffs they offer, but also between types of communication (Internet and/or mobile), has led to the emergence of a new consumer

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characterised by market awareness, insistence on high standards, individualism, mobility of consumer decisions, and critical evaluation of market offers. In view of this, the development of a scientific and practical approach to analysing the process of making consumer choice and the formation of consumer reactions in the modern digital economy is relevant. The telecommunications market is a very representative example in this field as it reflects all the trends of the world economy – coronavirus pandemic, growing unemployment, reduction in the number of active business projects, general decline in economic activity – and remains the basis of the modern digital economy. At the same time, individual consumer demands will maintain their steady growth, if not multiply.

A modern consumer of telecommunication services values time most and prefers those market operators who are able to provide them with high-speed access to the service and convenience of its use (Litvinenko & Tarasova, 2020). These user attitudes set the tone for industry development.

The purpose of the study is to define trends in telecommunications customer behaviour using global industry-specific indicators. The following objectives have been set:

- to analyse the dynamics of the development of the telecommunications industry on a national scale (based on the examples of Russia and Vietnam) over the past five years;
- to search for the relationship between the changes in the structure of consumer preferences in the analysed markets;
- to compare results of the study for Russian and Vietnamese markets and define whether the approach and methodology used herein can be universal for any telecommunication market.

Materials and Methods

Domestic Russian and Vietnamese telecommunications markets were chosen as the basis of the study as a reflection of overall global dynamics. According to the World Bank's country income classifications for the 2020 fiscal year, the Russian Federation belongs to the upper middle-income group of countries, while Vietnam is a lower middle-income country (World Bank, 2020). Despite both countries belonging to the developing category, the structures of the economies, the telecom market scales and the levels of development of the two countries differ significantly. Therefore, the comparison of the results for each market will allow us to determine whether the approach used herein is universal for any market and the trends in each telecommunications market are comparable.

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There are three main indicators for the telecommunications industry: number of subscribers, revenue, and average revenue per user (ARPU) (Yadav, Sushil & Bititci, 2018). The latter indicator is the total recurring (service) revenue generated per connection per month in the period and is specific for each telecommunications company (Faccio & Zingales, 2017). ARPU should be treated with caution. Despite growing figures of number of subscribers and revenues, ARPU tends to decline and cannot be used to track customers' preferences and behaviour (Hendrawan & Nugroho, 2018; Pfeifer & Conroy, 2017; Son *et al.*, 2019; Stork, Esselaar & Chair, 2017).

For the purposes of the study, the following telecommunication market indicators were collected and systemised (each indicator separately for the Russian and Vietnamese markets) for the period of 2015-2019:

1. Total number of mobile telephony subscribers;
2. Total number of fixed telephony subscribers;
3. Total number of fixed broadband subscribers;
4. Total number of mobile broadband subscribers;
5. Total number of TV subscribers;
6. Average revenue per user;
7. Annual mobile broadband revenue;
8. Annual mobile telephony revenue;
9. Annual fixed broadband revenue;
10. Annual fixed telephony revenue;
11. Annual TV revenue;
12. Total annual industry revenue.

The number of subscribers and revenues of the television segment include Pay TV services like cable television, Pay TV Direct-To-Home and Over-The-Top services and do not include free TV like analogue and digital terrestrial television, free TV Direct-To-Home, etc.

Average revenue per user (ARPU) was determined according to generalised data for the entire market provided by the Ministry of Digital Development, Communications and Mass Media of the Russian Federation (https://digital.gov.ru/ru/activity/statistic/rating/telekommunikacii/) and individual companies – MTS PJSC (MTS, 2021), AC&M (AC&M, 2021), VimpelCom PJSC (VimpelCom, 2021), and MegaFon PJSC (MegaFon, 2021).

Apart from this, the following data sources were used.

For Russian telecommunication market:

1. RosTelecom Strategic Report (RosTelecom, 2019a): Industry Overview and Competitive Analysis;
2. RosTelecom Annual Report (RosTelecom, 2019b);
3. Digital industry statistics (Ministry of Digital Development, 2020).

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For Vietnamese telecommunication market:

1. Vietnam Telecommunication Market Report (2020-2025) (Global Monitor, n.d.);
2. Vietnam Number of Subscriber Mobile (CEIC, n.d.)
3. STATISTICAL SUMMARY BOOK OF VIET NAM 2020 (General Statistics Office, 2020)

Analysis of the behaviour of telecommunications industry users in Russia and Vietnam based on open data was performed under the sequence of steps shown in Figure 1.

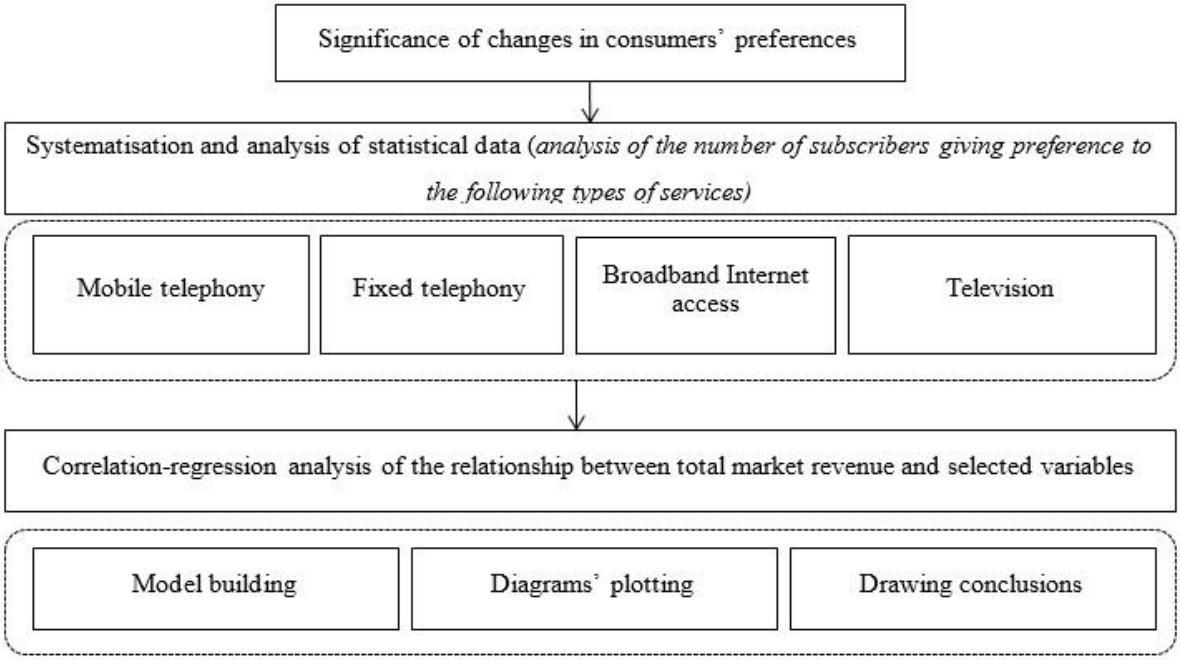

Figure 1. Research plan

The influence of variation of the independent variable (X) on the dependent one (Y) was analysed with the help of the following linear equation:

$$Y=a+bX \quad (1)$$

where X is the independent variable (number of subscribers);
Y - dependent variable (revenue);
a - regression coefficient, showing the value of Y at X = 0;
b - regression coefficient, showing the average value of changes in Y from X to X+1.

Descriptive and comparative analysis methods of quantitative data were used for the purposes of the study. Based on the above indicators, the following parameters were calculated and analysed:

1. Total amount of subscribers in telecommunications industry in each country in question.

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2. Dynamics of total number of subscribers and dynamics of number of subscribers of each industry segment within the time period in question.
3. Dynamics of annual revenues, both total and per industry segment, within the time period in question.
4. Share of each segment indicator in total number of subscribers in the industry and dynamics thereof within the time period in question.
5. Share of each segment indicator in total annual industry revenue and dynamics thereof within the time period in question.

Results

Russian telecommunications market

In the period 2015 to 2019, the total number of subscribers in the Russian telecom industry grew from 385 to 432 million subscribers, and the total revenue grew from 1,492 to 1,687 billion Russian roubles (RUB). As of 2019, the Russian telecommunications market had the largest number of subscribers in the mobile telephony segment (261 million subs) and the lowest in the fixed telephony segment (24 million subs). In terms of annual revenues, the mobile broadband segment was the leader among the segments of the industry (822 billion RUB), while television had the lowest revenues per year: 55 billion RUB (Table 1).

Table 1. Dynamics of performance and financial indicators of telecommunications industry in Russia, 2015-2019

Indicator	2015	2016	2017	2018	2019
Number of subscribers, million					
Mobile telephony subscribers	248	256	255	256	261
Mobile broadband subscribers	50	56	66	73	85
Fixed telephony subscribers	33	30	28	26	24
Fixed broadband subscribers	30	31	33	33	34
TV subscribers	24	25	26	27	28
Industry subscribers	385	398	408	415	432
Financial indicators, billion RUB					
Mobile broadband revenue	660	710	750	798	822
Mobile telephony revenue	487	466	409	347	299
Fixed broadband revenue	222	234	303	376	455
Fixed telephony revenue	88	77	72	64	56
TV revenue	36	35	46	51	55
Total industry revenue	1492	1522	1579	1636	1687

Source: Authors based on data from Rosstat (2019) and AC&M (2021).

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As can be seen from Table 1, mobile communication is the most popular among the studied communication means, occupying 74% of the whole range of services. This can be explained by the fact that it grants open access to information, lack of attachment to the place of residence, compactness of the device, and the availability of favourable tariff plans from the leading operators. Fixed telephony, on the other hand, cannot be enhanced by such conveniences, so consumers are gradually abandoning it altogether. As a result, the provision of services of this kind is becoming unprofitable. Confirmation of this can be found in the results of the correlation analysis (Table 2).

Table 2. Correlation analysis results

	Revenue (Y)	**Mobile telephony (X1)**	**Fixed telephony (X2)**	**Broadband Internet access (X3)**	**Television (X4)**
Revenue (Y)	1				
Mobile telephony (X1)	0.906496	1			
Fixed telephony (X2)	-0.98495	-0.94804	1		
Broadband Internet access (X3)	0.957742	0.98034	-0.96557	1	
Television (X4)	0.995286	0.925696	-0.99639	0.959373	1

The obtained correlation coefficients are almost equal to 1, which indicates the presence of a high correlation between the analysed indicators. This means that subscriber's preferences are one of the decisive factors in the described situation. No less fascinating is the inverse relationship between revenues and the number of fixed telephony users. Although the profitability of this communication means is falling, this does not affect the overall situation in the industry. On the contrary, consumers are not leaving the market but choose another communication method (mobile), which contributes to its rapid growth and development.

The results of the multifactor regression analysis outlined that the coefficient of determination is equal to 1 (R=1), which implies a functional relationship between the studied factors. From this it follows that any change in at least one of the values of X will lead to a change in the dependent variable, and the model can be deemed highly reliable.

The obtained regression equation has the following form:

$$Y = 60 + 20X1 - 18X2 + 38X3 + 3X4$$

Hence, each new mobile telephony subscriber brings, on average, 20 RUB of income, while the installation of a fixed-line phone, on the contrary, leads to losses in the future.

The analysis of dynamics shows that the number of subscribers of the telecommunications industry, as well as subscribers of mobile telephony, mobile broadband, fixed broadband and

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television, were growing, while the number of subscribers of fixed telephony was declining (Figure 2).

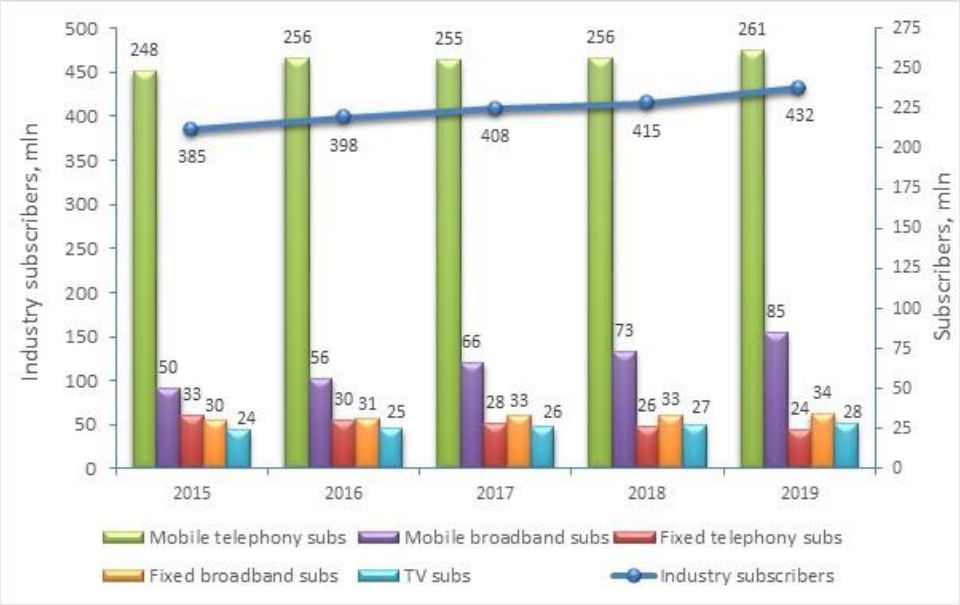

Figure 2. Comparative dynamics of Russian telecommunications market indicators: numbers of subscribers in each market segment and total industry subscribers in 2015-2019. Source: Table 1.

In terms of revenues, the industry in total, mobile broadband, fixed broadband, and television showed positive dynamics, while mobile telephony and fixed telephony revenues were declining within the period in question (Figure 3). Comparative dynamics of television revenues and subscribers show a positive trend for both indicators (Figure 4).

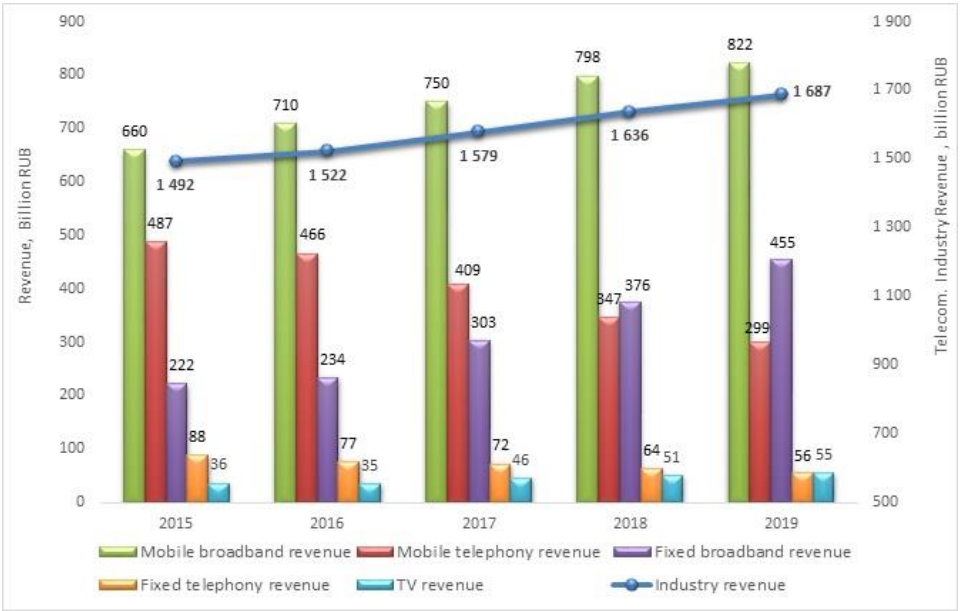

Figure 3. Comparative dynamics of Russian telecommunications market indicators: annual revenues in each market segment and total industry revenues in 2015-2019. Source: Table 1.

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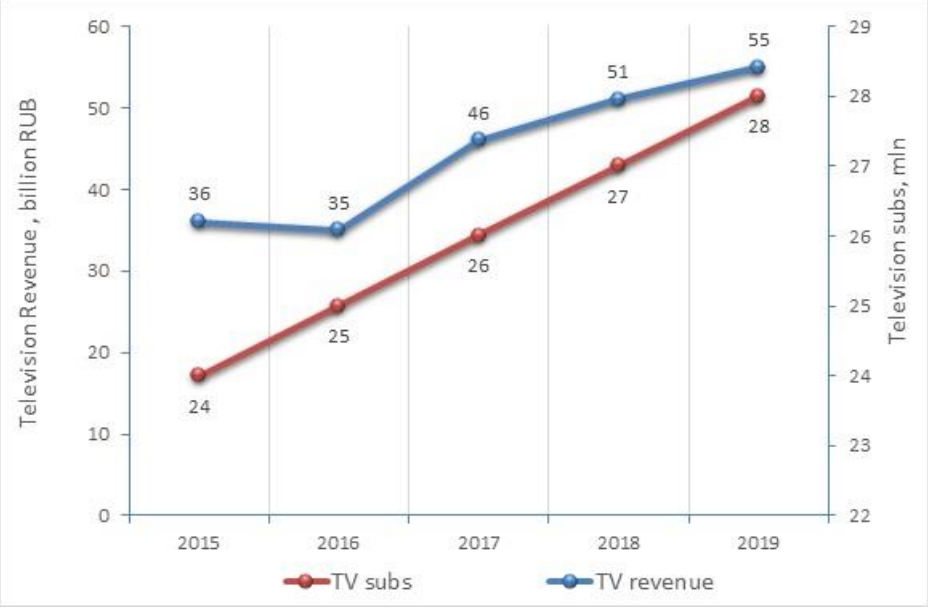

Figure 4. Comparative dynamics of television subscribers and revenues in Russian Federation in 2015-2019. Source: Table 1.

The comparative dynamics of mobile telephony subscribers and revenues reveal two opposing trends: growing number of subscribers (248 to 261 million subscribers) and declining revenues (487 to 299 billion RUB) (Figure 5). This can be explained by market saturation, high competition and more focus by subscribers on using mobile Internet and message services, and less usage of voice telephony services.

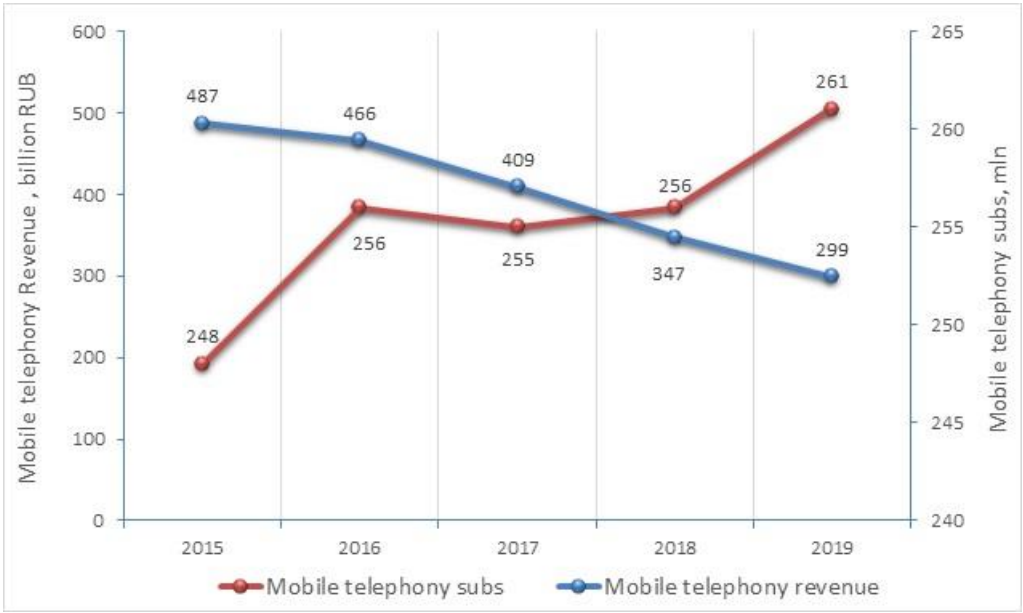

Figure 5. Comparative dynamics of mobile telephony subscribers and revenues in Russian Federation in 2015-2019. Source: Table 1.

The positive dynamics of mobile broadband subscribers and revenues confirm customers switching from voice mobile telephony to usage of mobile Internet: subscribers grew from 50 to 85 million, revenues from 660 to 822 billion RUB (Figure 6).

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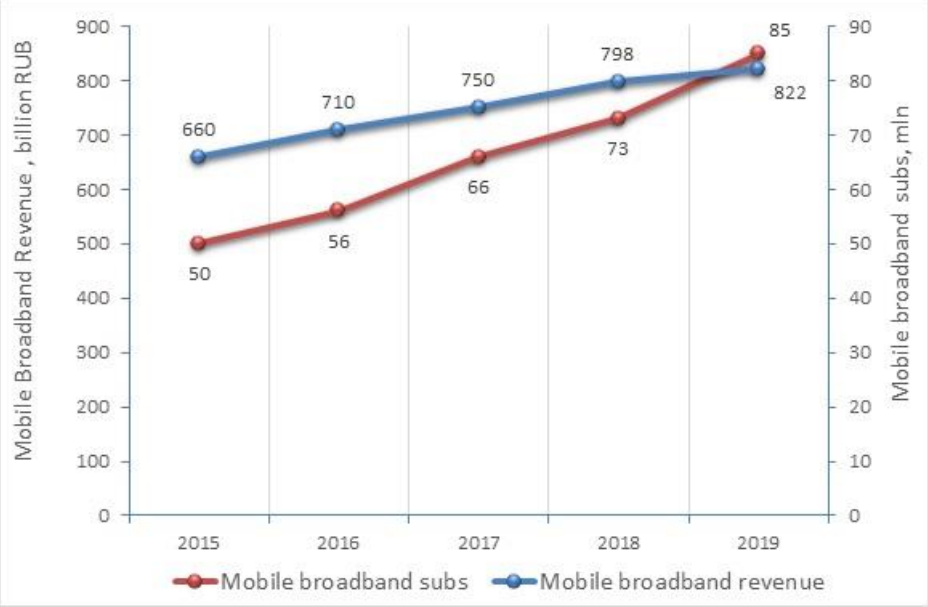

Figure 6. Comparative dynamics of mobile broadband subscribers and revenues in Russian Federation in 2015-2019. Source: Table 1.

As a result of development of new communication technologies, traditional fixed telephony in the Russian Federation is decreasing, both in terms of subscribers (from 33 to 24 million) and revenues (from 88 to 56 billion RUB) (Figure 7).

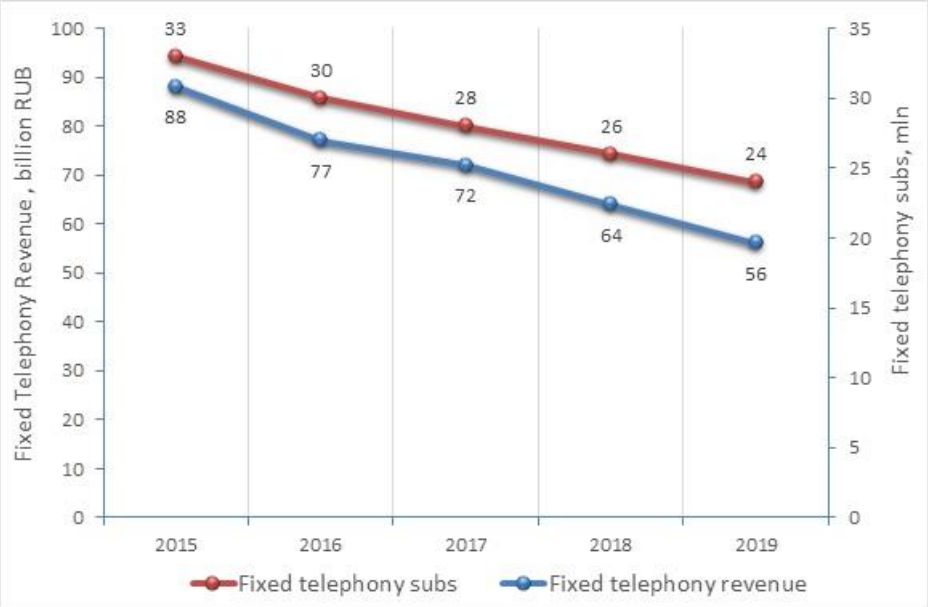

Figure 7. Comparative dynamics of fixed telephony subscribers and revenues in Russian Federation in 2015-2019. Source: Table 1.

Fixed broadband subscribers and revenues have been rapidly increasing during the time period in question: from 30 to 34 million subscribers and from 222 to 455 billion RUB (Figure 8).

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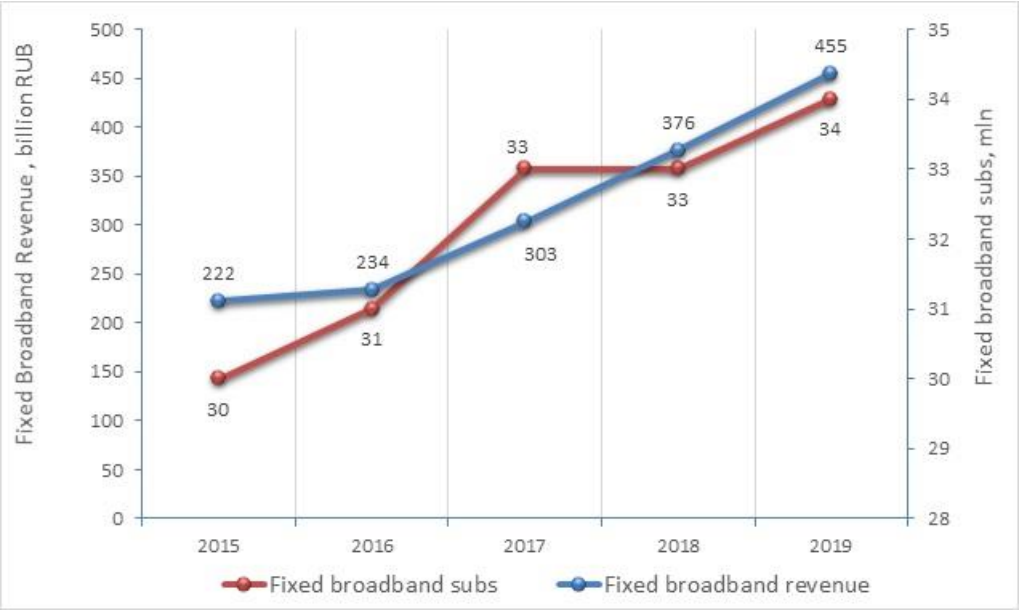

Figure 8. Comparative dynamics of fixed broadband subscribers and revenues in Russian Federation in 2015-2019. Source: Table 1.

In terms of telecommunication sector revenues as a share of the total revenue of the industry, the most rapid growth was found in fixed broadband revenues (from 15% to 27%), and the most rapid decline in mobile telephony revenues (from 33% to 18%). The share of mobile broadband revenues in total industry revenues grew insignificantly, from 44% to 49%; in absolute terms, the growth was 35 billion RUB. There was a fall in fixed telephony share from 6% to 3% and television share remained almost constant: a slight increase from 2% to 3% was detected. (Figure 9)

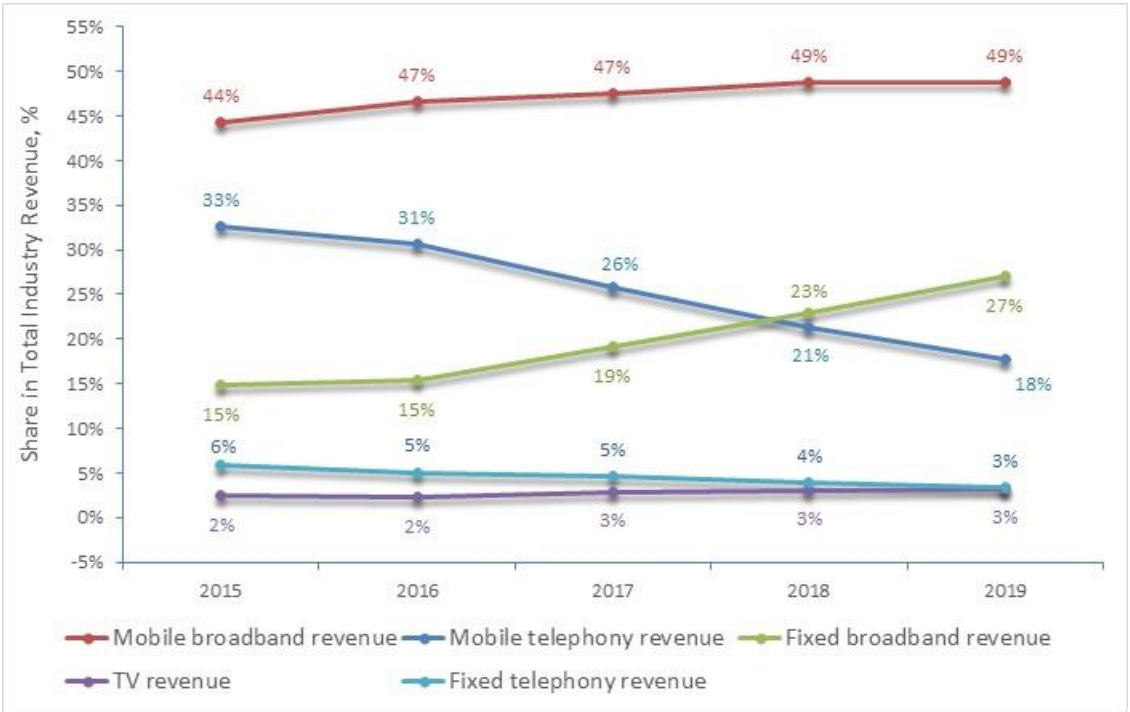

Figure 9. Comparative dynamics of share of annual industry sectors' revenues in total annual industry revenues in Russian Federation in 2015-2019. Source: Table 1.

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A comparative analysis of such parameters as subscriber base, revenues, and share of each segment revenues within total industry revenues clearly demonstrates the redistribution of consumer focus: people pay less for traditional means of communication like fixed telephony and mobile (voice) telephony and are ready to pay more for new means of communications like mobile and fixed broadband.

ARPU in the telecom industry in Russia is quite low (Statista, n.d.): in 2019, it was valued at 5.17 USD, while in developing countries, ARPU was 10.2 USD and in the world 13.6 USD on average (Figure 10).

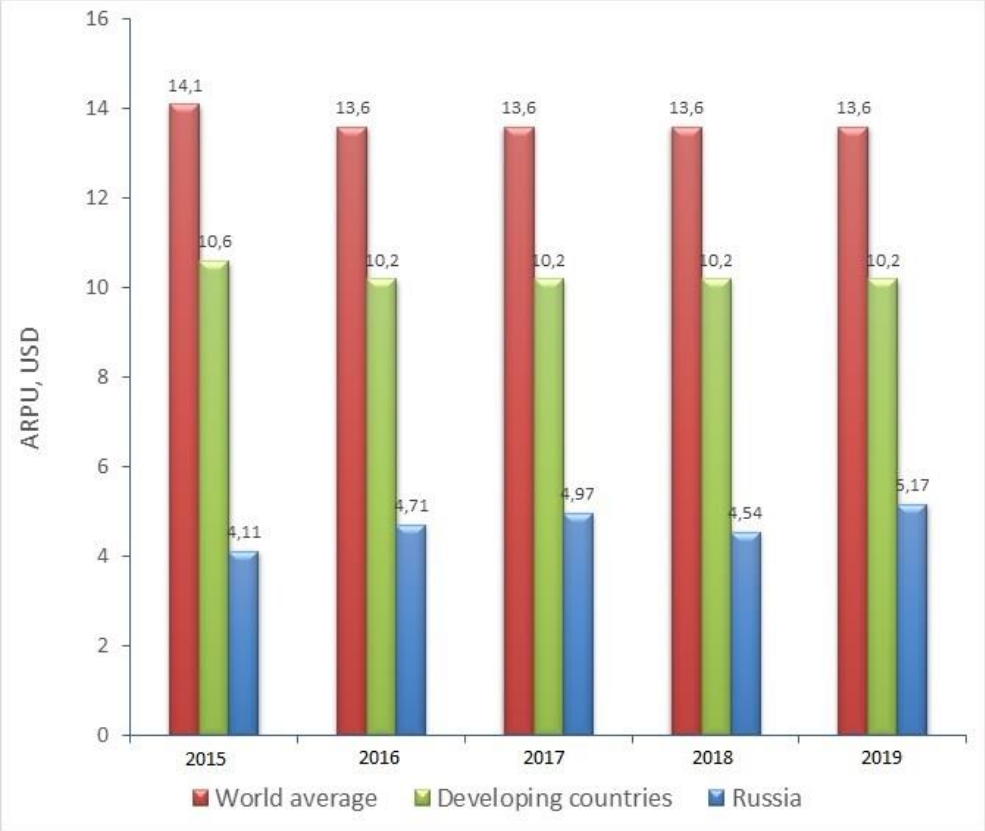

Figure 10. Comparative dynamics of ARPU in Russian Federation, developing countries and in the world (Average revenue per user (ARPU) of federal mobile operators in Russia from 3rd quarter 2017 to 3rd quarter 2019(in RUB)). Source: Statista (n.d.)

According to Figure 10, the ARPUs in Russia, developing countries and the world were approximately stable in 2015-2019.

Vietnamese telecommunications market

Telecom industry subscribers in Vietnam grew from 181.5 to 219.5 million in 2015 to 2019, while total industry revenues declined from 6491.2 to 6111.8 million USD. The leading industry sector in terms of subscribers was mobile telephony, with 126.2 million subscribers as of 2019, while the fixed telephony sector had the least number of subscribers, 3.7 million. The highest

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revenue of 3208.8 million USD was detected in mobile telephony in 2019, the lowest in fixed telephony: 270.5 million USD (Table 3).

Table 3. Dynamics of the performance and financial indicators of telecommunications industry in Vietnam, 2015-2019

Indicator	2015	2016	2017	2018	2019
Number of subscribers, million					
Mobile telephony subscribers	126.5	129.0	120.0	136.1	126.2
Mobile broadband subscribers	32.0	36.0	45.0	53.0	61.0
Fixed broadband subscribers	7.7	9.1	11.3	13.0	14.8
Fixed telephony subscribers	5.4	5.6	4.4	4.3	3.7
TV subscribers	9.9	12.5	13.2	14.5	13.8
Total Industry subscribers	181.5	192.2	193.9	220.9	219.5
Financial indicators, million USD					
1. Mobile revenue	4885.4	5015.6	4541.8	4198.7	4257.9
1.1 Mobile telephony revenue	4330.9	4352.5	3793.8	3393.8	3208.8
1.2 Mobile broadband revenue	554.5	663.1	748.0	804.9	1049.1
2. Fixed land telecommunications service revenue	1176.8	1142.5	1337.6	1474.9	1482.9
2.1 Fixed broadband revenue	254.0	375.1	866.5	1047.0	1212.4
2.2 Fixed telephony revenue	922.8	767.4	471.1	427.9	270.5
3. TV revenue	429	528	323	357	371
Total industry revenue	6491.2	6686.1	6202.4	6030.6	6111.8

Sources: Authors using data from the General Statistics Office (2020), IctNews (2019), Hanoimoi (2020), and Ministry of Information and Communications of the Socialist Republic of Vietnam (2019).

A correlation and regression analysis with the corresponding indicators was also performed for Vietnam. Its results show the same trends as for the Russian Federation, with correlation coefficients ranging between 0.89 and 0.95. Besides, as in the case of Russia, mobile communication services were revealed to be the most popular.

The resulting regression equation is as follows:

$$Y = 68 + 23X1 - 17X2 + 35X3 + 4X4$$

That is, each new mobile subscriber brings, on average, 28 units of income, while the installation of a landline incurs losses.

In general, the subscriber bases of mobile and fixed broadband and television grew; fixed telephony subscribes declined; and the mobile telephony subscriber base remained the same within the period in question (Figure 11).

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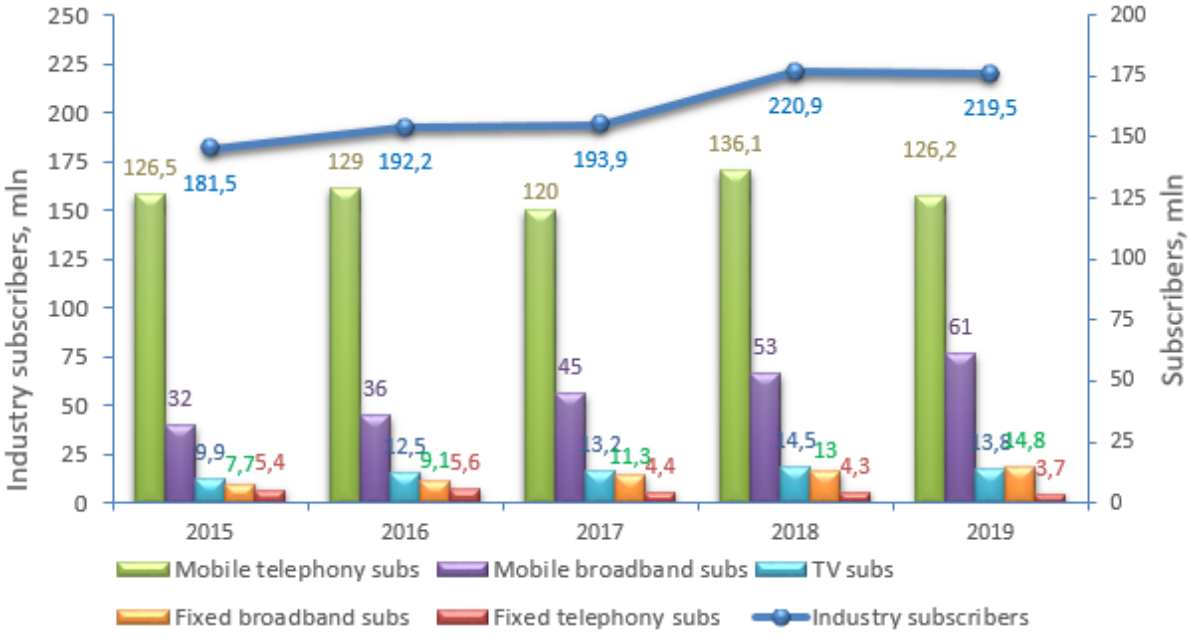

Figure 11. Comparative dynamics of Vietnamese telecommunications market indicators: numbers of subscribers in each market segment and total industry subscribers in 2015-2019. Source: Table 3.

From 2015 to 2019, mobile broadband and fixed broadband revenues grew, while mobile telephony, fixed telephony and television revenues decreased (Figure 12).

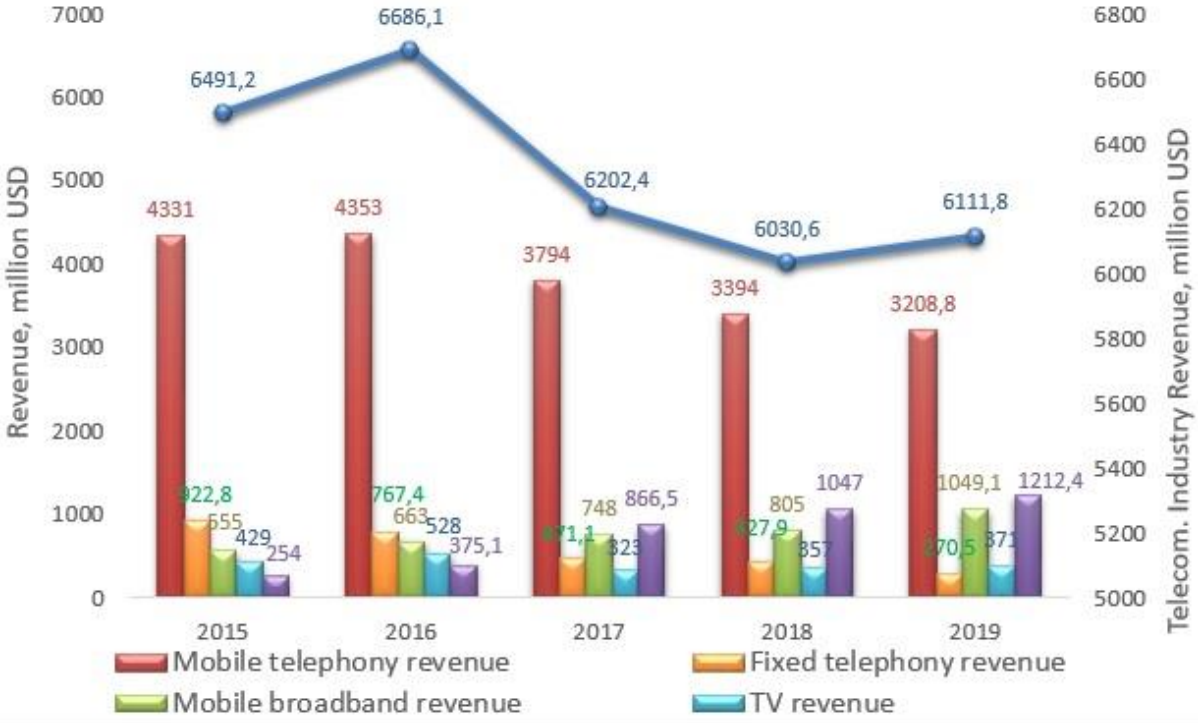

Figure 12. Comparative dynamics of Vietnamese telecommunications market indicators: annual revenues in each market segment and total industry revenues in 2015-2019. Source: Table 3.

While television subscribers increased from 9.9 to 13.8 million, revenues generated by this sector of the market decreased from 429 to 371 million USD (Figure 13). Such opposing trends

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can be explained by high competition in the Pay TV market in Vietnam and people spending more money on Internet than on TV.

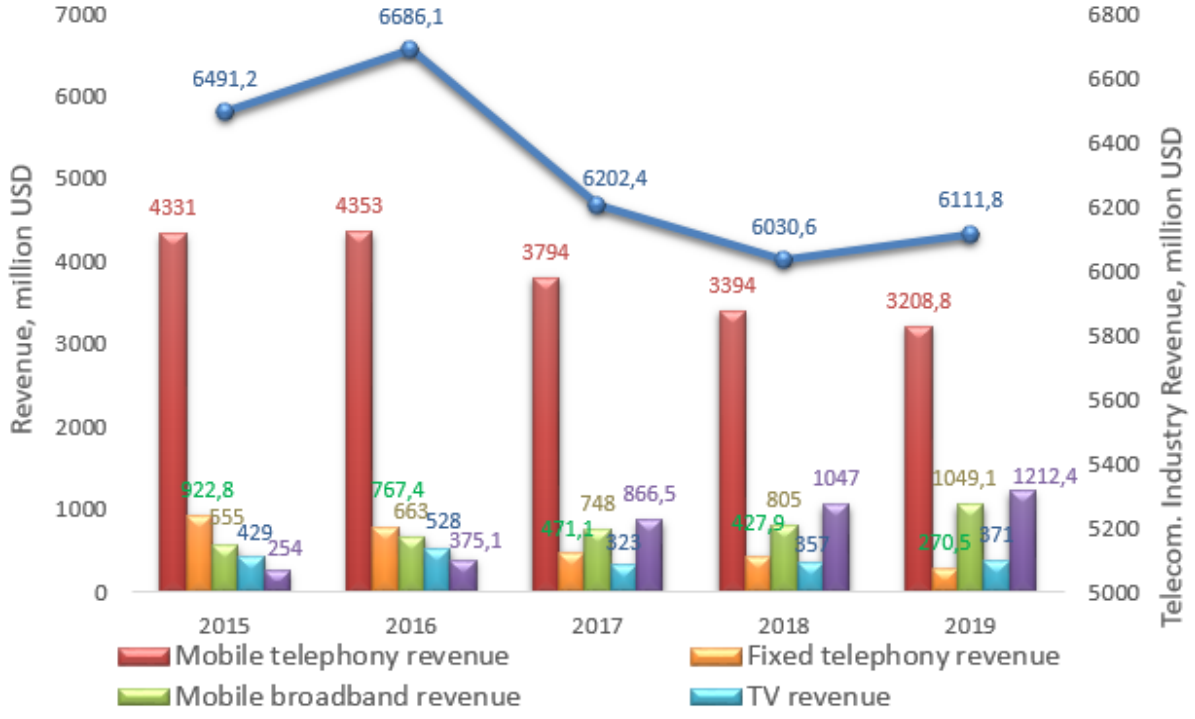

Figure 13. Comparative dynamics of television subscribers and revenues in Vietnam in 2015-2019. Source: Table 3.

Despite approximately the same number in the subscriber base in 2015 and 2019 (126.5 million and 126.2 million, respectively), mobile telephony revenues declined from 4331 to 3208.8 million USD (Figure 14). Such a picture is similar to that detected in the Russian communication market, where a rising number of mobile (voice) communication subscribers pay less for the service.

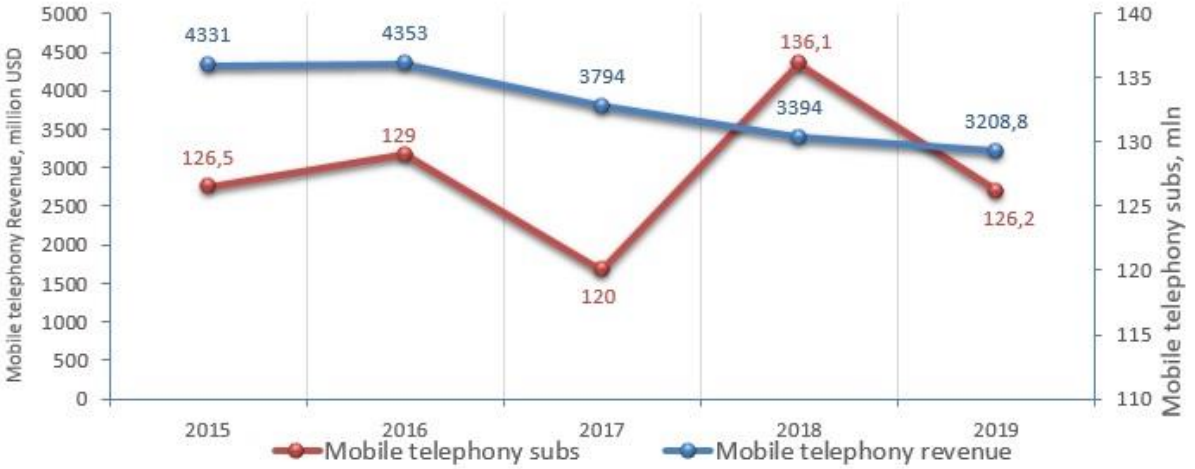

Figure 14. Comparative dynamics of mobile telephony subscribers and revenues in Vietnam in 2015-2019. Source: Table 3.

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Mobile broadband, both subscribers and revenues, grew rapidly during the period in question: from 32 to 61 million subscribers and from 555 to 1049.1 million USD, respectively (Figure 15).

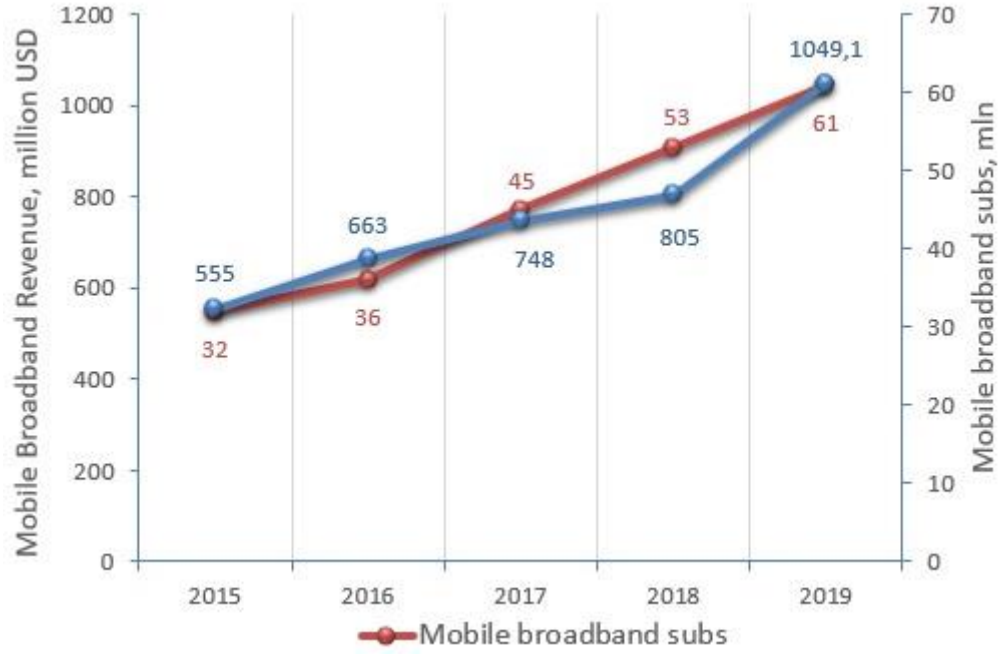

Figure 15. Comparative dynamics of mobile broadband subscribers and revenues in Vietnam in 2015-2019. Source: Table 3.

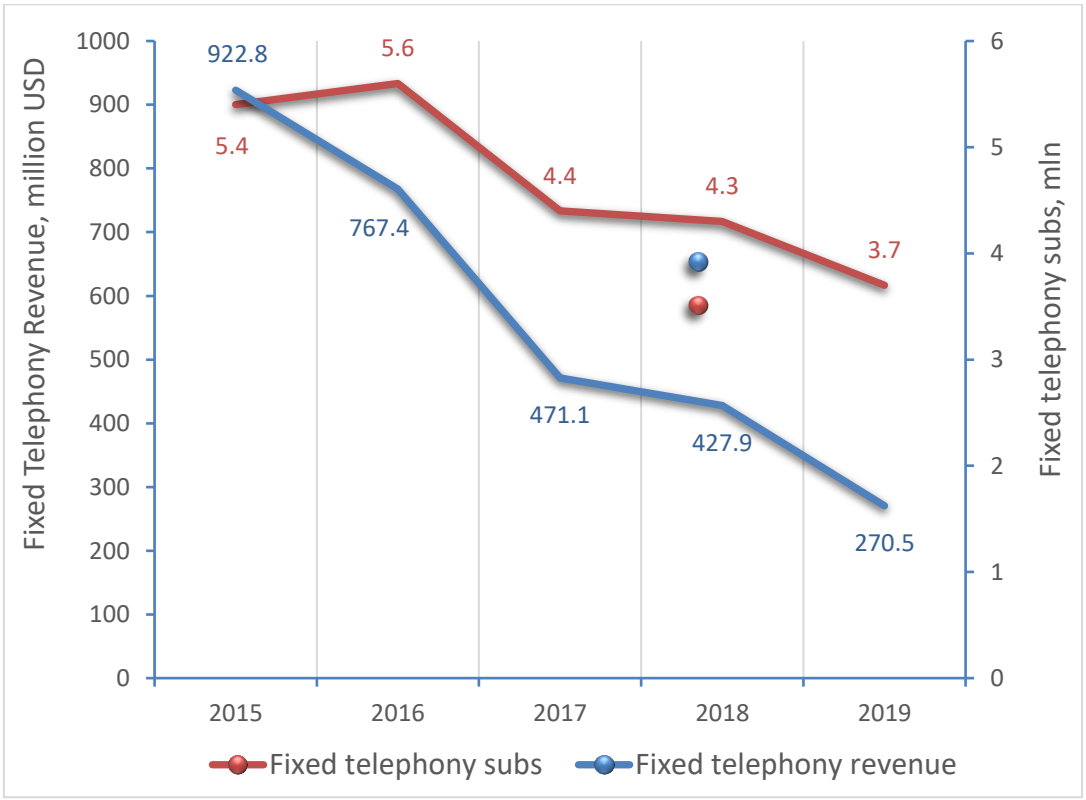

Figure 16. Comparative dynamics of fixed telephony subscribers and revenues in Vietnam in 2015-2019. Source: Table 3.

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Together with a decline in the subscriber base (from 5.4 to 3.7 million subscribers), the fall in revenues in fixed telephony was 3.4 times: from 922.8 million USD in 2015 to 270.5 million USD in 2019 (Figure 16).

Fixed broadband subscribers almost doubled (from 7.7 to 14.8 million) and revenues from this sector of the telecommunications market increased by nearly five times: from 254 to 1212.4 million USD (Figure 17).

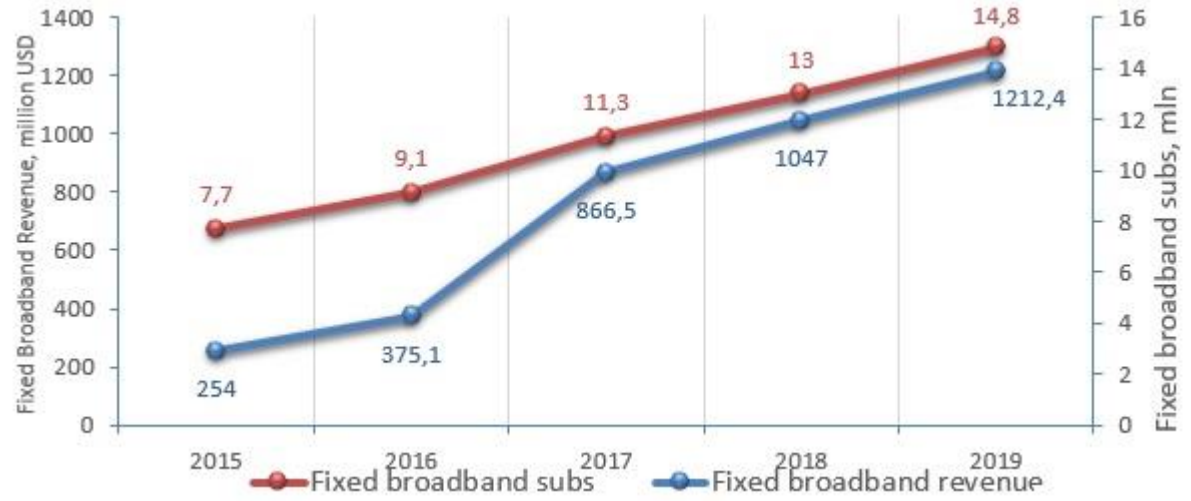

Figure 17. Comparative dynamics of fixed broadband subscribers and revenues in Vietnam in 2015-2019. Source: Table 3.

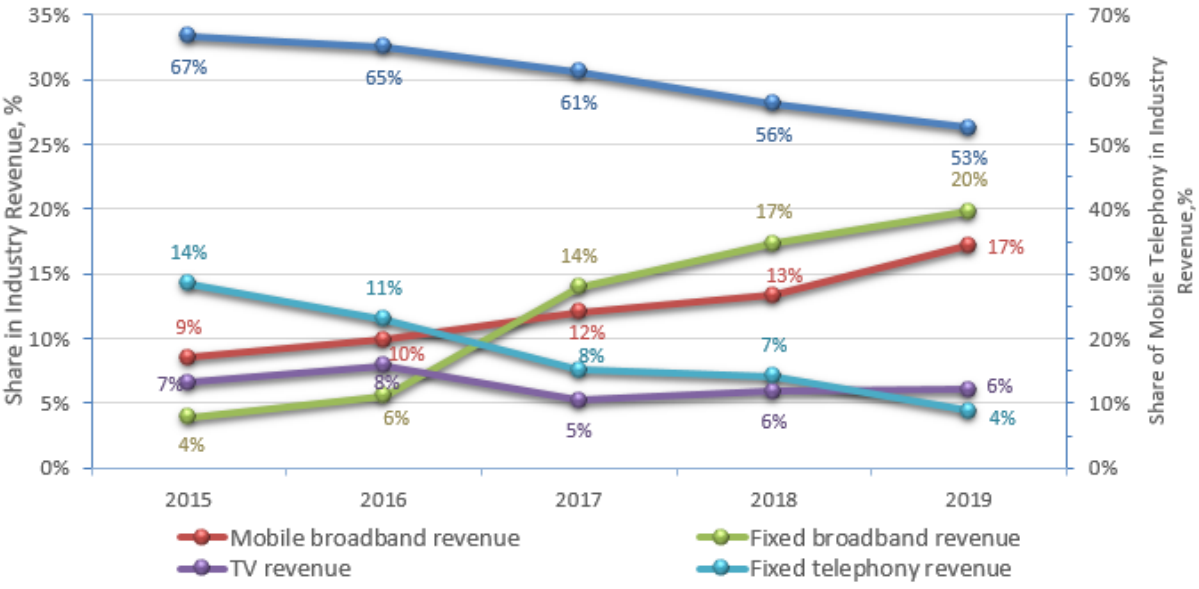

Figure 18. Comparative dynamics of share of annual industry sectors' revenues in total annual industry revenues in Vietnam in 2015-2019. Source: Table 3.

The comparative analysis of the dynamics of share of annual industry sectors' revenues in total annual industry revenues in Vietnam in 2015-2019 showed the redistribution of shares among sectors. While the share of mobile telephony decreased from 67% to 53%, the shares of mobile broadband and fixed broadband increased from 9% to 17% and 4% to 20%, respectively

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(Figure 18). There was a slight decline in the share of TV revenue (from 7% to 6%) and a significant fall in fixed telephony (from 14% to 4%).

As shown in Figure 19, the ARPU in the telecom industry in Vietnam in 2019 (2.82 USD) (Statista, n.d.) was almost three times less than that in developing countries (10.2 USD), and almost five times less than the average ARPU in the world (13.60 USD).

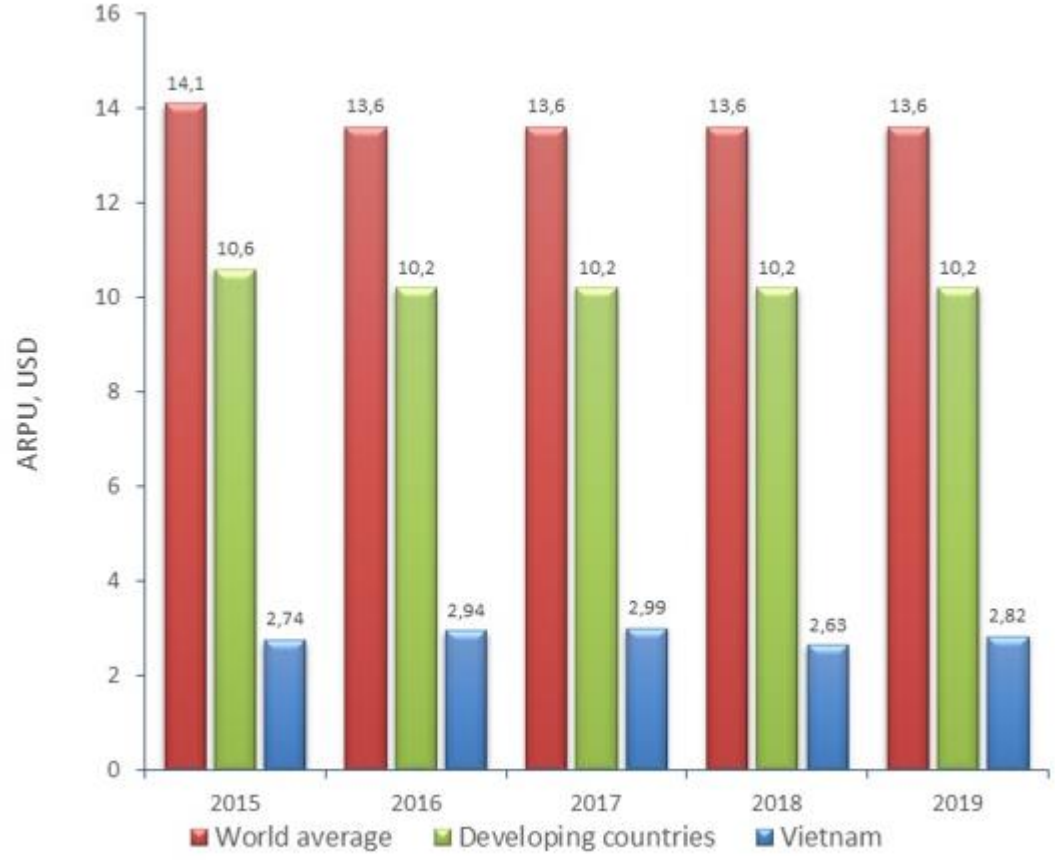

Figure 19. Comparative dynamics of ARPU in Vietnam, developing countries and in the world. Source: Statista (n.d.)

According to Figure 18, ARPU in Vietnam was almost stable and grew from 2.74 USD to 2.82 USD from 2015 to 2019.

Comparing trends in the telecommunications markets of the Russian Federation and Vietnam

The results of the study revealed the same global trends in the Russian and Vietnamese telecommunication markets. Despite growth of mobile telephony subscriptions, revenues of this sector of the industry are decreasing and the shares of the sector revenues within the total telecom market revenues are redistributed in favour of fixed and mobile broadband, the subscriber bases and revenues of which have been rapidly increasing for the previous five

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years. Fixed and mobile telephony revenues are declining, since customers prefer new communication technologies to the old ones.

The television subscriber base is growing in both countries. TV revenues are increasing in the Russian market and somewhat declining in the Vietnamese telecommunications market. This shows that (Pay) TV is still in demand as a means of communication and leisure.

To summarise, the results of the study confirmed the global trends in consumer behaviour in these telecommunications markets and suggest the applicability of approaches used herein for other countries.

Discussion

Forecasting and modelling the development of the telecommunications market is also complicated by the fact that the structure of market agents changes depending on the stage of development of communication technology in the country. An interesting feature of the telecommunications market is the distribution of new technologies and their perception by the population. As evidenced in some recent studies, the problem of telecommunications market development is caused not only by the emergence of new technologies but also by the human factor, which actually determines the speed of new technologies' perception, acceptance, and/or rejection.

Telecommunication businesses are challenged by a need to retain existing customers coupled with the high cost associated with acquiring new ones (Amin *et al.*, 2017). In the global telecommunications industry, there has been a rather high level of customer churn recently (from 10 to 60%) (Statista, n.d.). Attracting or retaining a long-term customer is 5–10 times more valuable than acquiring a new short-term one (Sharma *et al.*, 2020). Thus, customer attraction and retention is one of the key tasks in the telecommunications industry. It is very important to identify the most important factors that influence customer behaviour in order to channel efforts to retain customers and attract new ones (Al-Mashraie, Chung & Jeon, 2020).

In this day and age, the Russian and Vietnamese telecommunications markets have reached a high level of saturation, which dramatically enhances the importance and role of the competitive tools used by their mobile operators. In general, the markets of these countries display the same trends as are in force in the developed states. During the period under consideration, the telecommunication resources of networks using CDMA EV-DO technology increased considerably. The interest in the development of CDMA EV-DO on the part of enterprises is a sign of its further accelerated development following global trends. At the same

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time, there is no tendency to abandon mobile communications and increase the use of the Internet, just as in the case of fixed telephony.

To attract and retain customers, it is vitally important for a telecom company to understand the global trends in customer behaviour. This is usually done by analysing such specific telecommunications KPIs as subscriber base, revenue, and ARPU for each kind of service (Yadav, Sushil & Bititci, 2018). Still, as soon as customers use bundles of services, ARPU is usually calculated as a company financial performance indicator. The tendency of ARPUs to decline makes this KPI a somewhat unreliable indicator (Hendrawan & Nugroho, 2018; Pfeifer & Conroy, 2017; Son *et al.*, 2019; Stork, Esselaar & Chair, 2017).

Subscriber base and revenues are not sufficient indicators by themselves. As shown by the results of this study, the subscriber base may be rising but revenues may decline. Or revenues for a segment may increase, but its share in total revenues may be redistributed in favour of other services. All this is caused by changes in consumer behaviour (Confraria, Ribeiro & Vasconcelos, 2017).

With the opportunities provided by new technologies, including fixed and mobile broadband, more and more customers are reducing voice telephony usage and increasing spending on broadband-related services; and such a redirection of cash flows causes a large increase in fixed and mobile broadband subscriptions and revenues (Whalley & Curwen, 2018). While numbers of mobile telephony subscriptions grow, the revenues from voice telephony are declining (Ogidiaka & Ogwueleka, 2019).

The increase in subscriber base and revenues in the television sector reveals another trend in consumer behaviour. With further penetration of broadband, more and more customers upgrade their television from free TV to Pay TV, mainly using IPTV and OTT services (Kim, Nam & Ryu, 2019).

Consumer behaviour is influenced by numerous factors, like brand, price, usefulness, compatibility, product or service attachments, social influence, global changes and breakthroughs in technology and communications, smartphones and broadband penetration (Ting *et al.*, 2019). The companies that take into account all the factors influencing consumer behaviour in their activities are more likely to be competitive in this market. Overall, the modern telecommunications services user is not likely to be distinguished by loyalty; this concerns both the Russian Federation and Vietnam.

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Conclusions

Subscriber bases and revenues of television, fixed and mobile telephony, and fixed and mobile broadband segments of the Russian and Vietnamese telecommunications markets for the period of 2015-2019 were analysed by way of descriptive and comparative analysis methods.

The results of the study revealed similar global trends in Russian and Vietnamese telecommunications markets. Despite growth of mobile telephony subscriptions, revenues of this sector of the industry are decreasing and the shares of sector revenues in total telecom market revenues are redistributed in favour of fixed and mobile broadband, the subscriber bases and revenues of which have been rapidly increasing for the previous five years.

Fixed and mobile telephony revenues are declining since customers prefer new communication technologies to the old ones. The television subscriber base is growing in both countries. TV revenues are increasing in the Russian market and somewhat declining in the Vietnamese telecommunications market. With further penetration of broadband, more and more customers upgrade their television from free TV to Pay TV (IPTV and OTT services).

The results of the study confirmed the global trends in consumer behaviour in these telecommunications markets and the applicability of approaches used herein for other countries.

This study is limited to the countries of this research (Russian Federation and Vietnam), investigated indicators (subscriber base, revenue and ARPU) and methodology. There is room for further research with a wider set of countries, other or additional indicators, and other methodologies like correlation and regression analysis.

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The Adoption of E-commerce in SMEs: the Colombian Case

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Abstract: The few studies in South American developing countries that refer to the adoption of e-commerce in SMEs require knowledge of how this context is presented. The objective of this study addresses this need and seeks to determine the variables that influence the adoption of e-commerce in SMEs in Colombia. The measurement tool (IMAES) was applied using a digital questionnaire; 263 surveys were collected in SMEs and the data were analysed using the partial least squares methodology, validating tool and model. The results found that Colombian SMEs adopt e-commerce because of pressure from senior management, performance expectations, the competitive advantage it offers, and pressure from their customers. This is one of the first studies in the region that empirically analyses the adoption of e-commerce, as well as describing the theoretical framework for this line of research.

Keywords: e-Commerce, Adoption, SMEs, Information and Communication Technologies

Introduction

Information and Communication Technologies (ICT) are a key element of the revolution in the way in which business is carried out, especially as a result of the Internet as a medium coupled with its applications (Stathis, 2015). In addition to facilitating communication with customers, these technologies work as a channel for delivering value proposals to the stakeholders of an enterprises (Belvedere & Grando, 2017). Thus, it is relevant to indicate that the term e-commerce has been coined to account for the digital channels or media that facilitate the marketing exercise, as well as the personalised (or direct) communication before, during and after the sale. In addition, it is a channel that is not only accepted but required by

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customers, given its immediacy and time savings, as well as the inherent advantages of virtuality (He & Bakht, 2018; Yadav & Mahara, 2018).

In this context, the literature on e-commerce demonstrates that its mediation role offers differential competitive advantages to the enterprises that adopt it (Cecere, 2016), and especially to small and medium-sized enterprises (SMEs) (Abou-Shouk, Megicks & Lim, 2013; Abou-Shouk & Eraqi, 2015; Alrousan & Jones, 2016; Chong *et al.*, 2011; Pickernell *et al.*, 2013) since it is a mechanism that extends borders. In addition, it allows personalisation of the service and attention to users and customers.

The literature that accounts for e-commerce in SMEs began with simple suggestions, such as minimising costs with the use of HTML language formats (Charlton *et al.*, 2000), and then moved on to thinking about more complex issues, such as the evolution of the diffusion and adoption of this technology for the field (Al-Bakri & Katsioloudes, 2015; Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011; MacHaria, 2009; Sparling, Toleman & Cater-Steel, 2007; Wilson, Daniel & Davies, 2008). In addition, previous research also reports on the evaluation of the effectiveness and critical success factors of the strategies (Hamad, Elbeltagi & El-Gohary, 2018; He & Zhang, 2010; Li, Feng & Lin, 2008; Molapo, 2014; Sanayei & Rajabion, 2009; Shah Azam & Quaddus, 2009; Wu *et al.*, 2011). The strategic value and perceived barriers or obstacles have also been investigated (Abou-Shouk & Eraqi, 2015; Mbatha & Ngwenya, 2018; Saffu, Walker & Mazurek, 2012).

Scientific research on the adoption of e-commerce in Colombia, however, is scarce, and the models that have explained this context in other countries have not been tested. Likewise, there is a lack of studies related to South American realities: 80% of the productions found are distributed in Asian, European and African countries (Kwan-Chung & Ortiz-Jiménez, 2021).

In this scenario, it should be noted that, in Colombia, about 99% of companies are SMEs and they have been making efforts to present their websites in languages other than Spanish since 2011, perceiving the advantages of export technologies. They have also implemented e-commerce solutions in their export activities (Rojas-Berrio & Vega-Rodríguez, 2011).

Similarly, in the study by Osorio-Gallego, Londoño-Metaute & López-Zapata (2016), it was found that this type of enterprise showed an electronic commerce adoption of 60.6% by 2014 for uses such as supply purchases and financial and commercial transactions. However, while there are negative perceptions towards information security, implementation and management costs, there are also previous references indicating that entrepreneurs of this type of company are not unaware of the potential benefits (dos Reis & Machado, 2020; Hussein *et al.*, 2019; Lim, Lim & Trakulmaykee, 2018; Mbatha & Ngwenya, 2018; Rojas-Berrio & Vega-Rodríguez, 2011).

http://doi.org/10.18080/jtde.v9n3.403

Meanwhile, the Observatory of Digital Economy in Colombia (OECD, 2019) shows data on the relevance of SMEs to Latin America as comprising 60% of total companies, representing 70% of formal employment and contributing 50% of the Internal Gross Domestic Product (GDP). Similarly, for 2017, the Colombian ICT Ministry presents 98% Internet usage figures for these types of companies, of which 82% use the Internet as a channel to provide services and 30% to deliver them.

However, although it is true that the advance in Internet adoption and broadband use in Colombian companies is almost 99%, its use is mostly limited to basic actions such as intranet and the use of emails, denoting limited adoption of e-commerce (Parra *et al.*, 2019). This is reinforced by Suárez (2020) which, from a compilation of technical reports of unions and institutions, identified the following weaknesses that SME managers find in e-commerce: low presence of SMEs in the digital ecosystem; low organisational culture around technological development and digital innovation; slow adaptation and development of technological skills; management of e-commerce technology platforms; lack of investment in digital technology; deficiency in training in the management of technological and digital tools; distrust of e-commerce (electronic fraud); cost overruns in electronic transactions; and normative and legal knowledge of e-commerce. Finally, the study by Sánchez-Torres (2019) showed that the high digital divide in this country negatively moderates the adoption of e-commerce.

Given the above considerations, it is necessary to more precisely examine the factors that generate the adoption of e-commerce in Colombian SMEs in order to guide actions that promote its adoption by all public and private agents.

The objective of this study is to determine the relationships between the factors that affect the adoption of e-commerce in SMEs in the case of Colombia since, although these companies use these channels, the level of penetration is not sufficient for the marketing challenges and the advantages that this method implies, and because there are few studies in the area. This approach will allow us to review opportunities for improvement and possible solutions in this sector. Thus, this study, through the empirical test of a model proposed by Sánchez-Torres & Juarez-Acosta (2019), will identify the relevant variables that affect the adoption of e-commerce in Colombian SMEs.

This paper is first composed of a summarised theoretical approach to this line of research. Then, the methodology and field work of the empirical study are presented. Finally, the results and conclusions are presented.

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Theoretical Framework

Studies on the adoption of e-commerce in SMEs have used the theoretical models of several schools of organisational thinking that analyse technological adoption (Abou-Shouk, Megicks & Lim, 2013; Alrousan & Jones, 2016; Awa, Ojiabo & Emecheta, 2015; Feng *et al.*, 2018; Grandon & Pearson, 2004; Ibrahim & Moertini, 2015; Kumar & Kaur, 2021; Molla, Heeks &Tjia, 2006; Newby, Nguyen & Waring, 2014; Pickernell *et al.*, 2013; Solaymani, Sohaili & Yazdinejad, 2012; Sparling, Toleman & Cater-Steel, 2007; Wymer & Regan, 2005). These results show empirically that there are several variables that influence the adoption of electronic commerce in SMEs based on the theory "Technology – organisation – environment" (Tornatzky & Fleischer, 1990), which identifies and categorises the internal, environmental and technological factors that intervene in the adoption of this technology (Ghobakhloo & Ching, 2019; Nair, Chellasamy & Singh, 2019; Sánchez-Torres & Juarez-Acosta, 2019).

Internal factors

Based on the Strategic Resource Theory (Barney, 1991), many studies have shown that the adoption of e-commerce is supported by its resources, processes and knowledge. SMEs are oriented strategically around their own resources and take advantage of the surrounding conditions (Hadi Putra & Santoso, 2020). According to Rivard, Raymond & Verreault (2006), SMEs will work when driven by competitive forces and use their resources to formulate and implement strategies that allow them to generate an advantage in the market (Xuhua *et al.*, 2019).

Internally, several variables that influence the adoption of e-commerce in SMEs stand out (Anim-Yeboah *et al.*, 2020). One of these is the extent of the disposition of managers towards innovation and the use of technologies to improve the company's processes (Deng, Duan & Luo, 2019; Rogers, 1995; Wang, 2020). It has also been shown that some internal characteristics of SMEs, such as investing in research and development, having employees with favourable levels of training and decentralised decision-making and long-term planning, increase the likelihood of adopting new technologies (Deng, Duan & Luo, 2019; Giotopoulos *et al.*, 2017; Wang, 2020). In this sense, the investment capacity to adopt e-commerce or the costs incurred stands out as another internal variable of high influence (Harris, Marett & Harris, 2017; Wang, 2020). This is due to the investment in hardware and software that is necessary for the implementation of e-commerce and what it can represent for an SME compared to a large company (MacGregor & Vrazalic, 2005).

Another variable corresponds to the size of the company. Some studies have shown that the size of SMEs is positively related to the adoption of e-commerce (Van-Huy *et al.*, 2012; Wang,

http://doi.org/10.18080/jtde.v9n3.403

2020). However, in general, when the levels of technological adoption are low, the size of SMEs is not significant (Rahayu & Day, 2015).

Finally, some authors propose that the characteristics of the product/service, the type of customer and the characteristics of commercial channels affect the adoption of e-commerce in SMEs (Cassetta *et al.*, 2020; Darsono *et al.*, 2019; MacGregor & Kartiwi, 2010; MacGregor & Vrazalic, 2005; Wymer *et al.*, 2008; Wymer & Regan, 2005; Xuhua *et al.*, 2019).

Environmental factors

From the Contingency Theory External (Stewart & Luthans, 1977), environment agents can put pressure on SMEs to adopt e-commerce. One external agent is the government, which, through government policies that promote transparency and competitiveness, establishes policies to motivate companies to adopt technology (Ahluwalia & Merhi, 2020; Al-Bakri & Katsioloudes, 2015; Alrousan & Jones, 2016; Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011; Grandon & Pearson, 2004; Scupola, 2009; Van-Huy *et al.*, 2012; Wymer & Regan, 2005). In accordance with the government variable, the degree of complexity of the adoption of e-commerce in a country is a factor that also generates effects on adoption. With a greater degree of e-commerce development in a country, there will be greater investment in information and communication technologies, and therefore its adoption by SMEs will be easier (Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011; MacGregor & Vrazalic, 2005; Van-Huy *et al.*, 2012).

Another variable is the pressure exerted by suppliers, competitors and other market forces on SMEs in relation to the use of e-commerce (Dethine, Enjolras &Monticolo, 2020). This is a pressure that is created within the obligation to sustain long-term relationships, although it does not always influence technological adoption (Cassetta *et al.*, 2020; Rahayu & Day, 2015).

Technological factors

The variables associated with technological factors are the most important in studies on SMEs worldwide (Chen & Holsapple, 2013; Sombultawee, 2020) when assessing the technological disposition. Several authors rely on the theory of diffusion of innovations (Rogers, 1995), the theory of technological adoption (TAM) (Davis, 1989) and the unified theory of technological adoption (UTAUT; Venkatesh *et al.*, 2003; Venkatesh, Thong & Xu, 2012) to explain the technological factors that influence technological adoption. These studies have identified that the main variables are perceived risk, perceived utility (compatibility and observability) and perceived facility of use and intention to use (verifiability; Sombultawee, 2020).

The risk perception variable of the system negatively influences the adoption of e-commerce (Al-Tit, 2020; Van-Huy *et al.*, 2012). The risk of adopting e-commerce is associated with the

http://doi.org/10.18080/jtde.v9n3.403

risks of using the Internet. In particular, it is presumed that the levels of confidentiality of companies can be affected by the exposure of information in an open manner and by the levels of insecurity of the Internet (Alam, Ali & Jani, 2011; Wei *et al.*, 2019).

On the other hand, the perceived utility is related to internal factors and refers to the link that people make between the adoption of new technology and the scope for a strategic advantage. In this sense, the adoption of e-commerce and its degree of technological compatibility (e-commerce is in line with existing needs) and observability (the degree of visibility of new innovation outcomes) are factors validated to a large extent in many countries (Abou-Shouk, Megicks & Lim, 2013; Al-Tit, 2020; Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011; Sombultawee, 2020; Van-Huy *et al.*, 2012).

Finally, the intention to use refers to the degree to which a person believes that using a system can be free of effortless since it is flexible and understandable (Alam, Ali & Jani, 2011; Al-Tit, 2020). This is a favourable condition for the adoption of e-commerce by companies (Abou-Shouk, Megicks & Lim, 2013; Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011).

Theoretical Model

To better understand the nature of Colombian SMEs, this study examined the e-commerce adoption model for SMEs (IMAES) proposed by Sánchez-Torres & Juarez-Acosta (2019), which integrates all the variables that have been empirically validated in previous studies in other countries (Figure 1) and has the following hypotheses:

H1: The ease of use regarding e-commerce influences its adoption in Colombian SMEs
H2: Government support regarding e-commerce influences its adoption in Colombian SMEs
H3: Management guidelines regarding e-commerce influence its adoption in Colombian SMEs
H4: The degree of observability regarding e-commerce influences its adoption in Colombian SMEs
H5: Organisational readiness regarding e-commerce influences its adoption in Colombian SMEs
H6: The relative advantage of e-commerce influences its adoption in Colombian SMEs
H7: Perceived risk regarding e-commerce influences its adoption in Colombian SMEs
H8: Customer pressure regarding e-commerce influences its adoption in Colombian SMEs
H9: Compatibility with respect to e-commerce influences its adoption in Colombian SMEs
H10: Direct competitors' attitudes to e-commerce influence its adoption in Colombian SMEs
H11: The complexity of the country with respect to e-commerce influences its adoption in Colombian SMEs
H12: The cost with respect to e-commerce influences its adoption in Colombian SMEs

http://doi.org/10.18080/jtde.v9n3.403

H13: Managers' innovative personality regarding e-commerce influences its adoption in Colombian SMEs

H14: Organisational factors ICT regarding e-commerce influence its adoption in Colombian SMEs

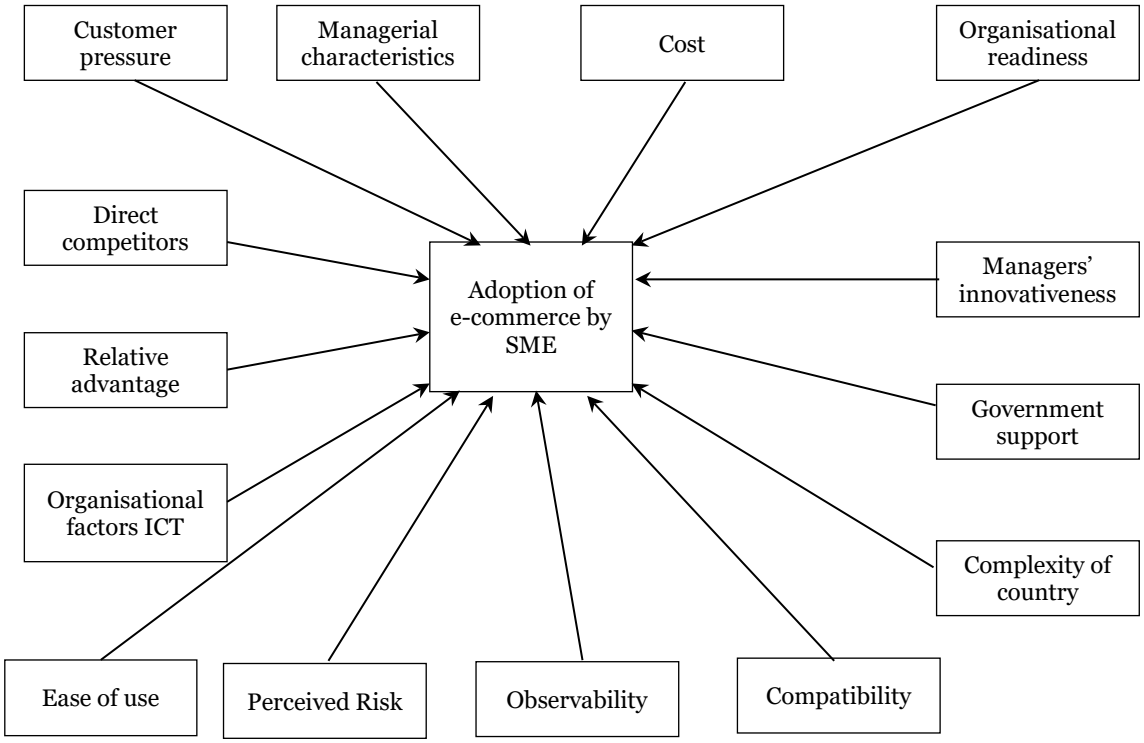

Figure 1. Integrated model for the adoption of electronic commerce SMEs (IMAES). (Source: Authors' elaboration)

Methodology

Measurement tool

The questionnaire was adapted from the one proposed by Sánchez Torres & Juarez-Acosta (2019) since it had already been validated for the country of application. At least three items per variable were chosen so that the measurement met the minimum validity standards. A pilot test was carried out with 15 managers to check the understanding of the questions without finding any discrepancies or doubts (Annex 1).

Sample and field work

The sample was collected using a non-probabilistic random method (Churchill & Iacobucci, 2005) with a minimum quota of 100 SMEs. The survey was developed digitally using an online platform. The contact data were obtained through Chambers of Commerce and other means, whereas databases of SMEs were obtained nationwide. The data collection was developed in the period from January 1, 2019 to December 30, 2019, and a total sample of 263 SMEs was obtained.

http://doi.org/10.18080/jtde.v9n3.403

Of the total, 193 SMEs belonged to the service sector and 70 to manufacturing. In terms of operating time, 100 SMEs have been operating for between 1 and 2 years and 163 for more than 2 years. As for their geographical location, 171 SMEs are located in the Colombian capital (Bogotá), 37 SMEs in the department of Antioquia (Medellín) and the rest are distributed between "Cauca" valley, the Eastern sector and the Caribbean coast.

Analysis of data

The model was analysed using the partial least squares (PLS) technique via the Smart PLS 3.0 program. This technique was chosen due to the fact that the model has many variables and has not been tested empirically and is thus suitable for obtaining exploratory results (Ketchen, 2013). Taking into account the PLS analysis methodology, first, the measurement tool was validated, and, second, the structural model was validated.

Results

It should be noted that the characteristics of the sample did not show any moderating or control effects on the relationships and are therefore completely ignored in the analysis and are not considered in the results.

The individual reliability of each item was measured by the correlation loads of each item compared to each variable, and the loads for each indicator were found to be significant in their entirety (Ketchen, 2013) (Table 1). (For the meaning of variables, see Annex 1).

Table 1. Indicator loads

Variable	Original Sample (O)	T Statistics (|O/STDEV|)	P Values*
BS1 - Customer pressure	0.916	49.055	0.000
BS2 - Customer pressure	0.924	69.109	0.000
BS3 - Customer pressure	0.855	27.722	0.000
CEC1 - Complexity country	0.972	4.830	0.000
CEC2 - Complexity country	0.978	4.933	0.000
CEC3 - Complexity country	0.891	5.002	0.000
CEC4 - Complexity country	0.777	3.364	0.001
CP1 – Direct competitors	0.943	10.383	0.000
CP2 - Direct competitors	0.894	8.372	0.000
CP3 - Direct competitors	0.825	7.457	0.000
CT1 - Cost	0.872	3.959	0.000
CT2 - Cost	0.909	3.472	0.001
CT3 - Cost	0.676	2.471	0.014
CU1 - Compatibility	0.739	2.697	0.007
CU2 - Compatibility	0.808	3.187	0.001
CU3 - Compatibility	0.846	3.325	0.001

http://doi.org/10.18080/jtde.v9n3.403

Variable	Original Sample (O)	T Statistics (|O/STDEV|)	P Values*
CU4 - Compatibility	0.906	3.715	0.000
EU1 - Ease of use	0.914	4.327	0.000
EU2 - Ease of use	0.872	4.541	0.000
EU3 - Ease of use	0.923	4.722	0.000
EU4 - Ease of use	0.814	4.031	0.000
GS1 - Government support	0.938	4.439	0.000
GS2 - Government support	0.909	4.436	0.000
GS3 - Government support	0.915	4.410	0.000
INN1 - Managers' innovativeness	0.854	21.907	0.000
INN2 - Managers' innovativeness	0.907	41.773	0.000
INN3 - Managers' innovativeness	0.892	33.393	0.000
OR1 - Organisational Readiness	0.924	56.239	0.000
OR2 - Organisational Readiness	0.950	99.772	0.000
OR3 - Organisational Readiness	0.838	15.751	0.000
MC1 - Managerial characteristics	0.937	4.981	0.000
MC2 - Managerial characteristics	0.924	5.364	0.000
MC3 - Managerial characteristics	0.834	4.230	0.000
PU1 - Observability	0.943	85.915	0.000
PU2 - Observability	0.927	44.057	0.000
PU3 - Observability	0.952	97.278	0.000
PU4 - Observability	0.933	88.511	0.000
RA1- Relative Advantage	0.917	62.098	0.000
RA2 - Relative Advantage	0.945	99.962	0.000
RA3 - Relative Advantage	0.980	37.763	0.000
SEC1 - Perceived Risk	0.991	3.681	0.000
SEC2 - Perceived Risk	0.665	2.350	0.019
SEC3 - Perceived Risk	0.857	17.521	0.000

Source: Authors. (Significant at: *p<0.05 - t-value 1.960)

To measure the internal measurement coherence of all indicators in relation to their corresponding variables, Dillon-Goldstein's ρ, also known as the composite reliability index, was determined; all resulting values were higher than the minimum acceptable value of 0.70 (Gefen, Straub & Boudreau, 2000). Cronbach's alpha value was also determined (Table 2), obtaining values greater than 0.7 (Churchill & Iacobucci, 2005). Finally, the convergent validity was analysed again in consideration of the variance; in other words, it was determined whether the variance that exists between the indicators and their construct is similar, which means that it must be greater than 0.50 of the variability explained by the indicators (Fornell & Larcker, 1981).

http://doi.org/10.18080/jtde.v9n3.403

Table 2. Construct Reliability and Validity

Variable	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Ease of use	0.911	1.047	0.933	0.777
Government support	0.917	1.015	0.943	0.847
Managerial characteristics	0.923	0.925	0.951	0.867
Observability	0.956	0.978	0.967	0.882
Organisational readiness	0.891	0.943	0.931	0.819
Relative advantage	0.909	0.913	0.943	0.847
Perceived Risk	0.715	2.609	0.826	0.712
Customer pressure	0.883	0.915	0.927	0.808
Compatibility	0.864	0.885	0.896	0.684
Direct competitors	0.820	0.873	0.916	0.845
Complexity country	0.943	0.946	0.949	0.825
Cost	0.820	0.735	0.863	0.681
Managers' innovativeness	0.861	0.873	0.915	0.783
Organisational factors ICT	0.920	1.017	0.938	0.792

Source: Authors.

Discriminant validity of the measuring instrument was defined correctly (Fornell & Larcker 1981). Similarly, a test used by Henseler, Ringle & Sarstedt (2014) was conducted, finding that all values are below 0.90, therefore confirming that the variables exhibit an acceptable level of discriminant validity (Henseler, Ringle & Sarstedt, 2014). (Tables 3 and 4).

Table 3. Convergent validity of the indicators (Fornell-Larcker Criterion)

Part 1:

Ease of use	0.882						
Government support	0.000	0.920					
Managerial characteristics	0.074	0.138	0.931				
Observability	0.070	0.172	0.510	0.939			
Organisational readiness	0.141	0.156	0.406	0.343	0.905		
Relative advantage	0.007	0.118	0.489	0.756	0.259	0.920	
Perceived Risk	0.034	0.108	0.282	0.226	0.326	0.240	0.844
Customer pressure	-0.010	0.100	0.443	0.349	0.210	0.279	0.194
Compatibility	0.508	0.059	0.112	0.114	0.164	0.034	0.049
Direct competitors	-0.100	-0.077	0.250	0.226	0.110	0.219	0.215
Complexity country	0.071	0.354	0.212	0.138	0.135	0.176	0.186
Cost	0.044	-0.045	0.260	0.232	0.076	0.236	0.218
Managers' Innovativeness	-0.039	0.067	0.442	0.360	0.245	0.361	0.259
Organisational factors ICT	0.218	0.254	0.254	0.283	0.432	0.189	0.202

Part 2:

Ease of use
Government support
Managerial characteristics
Observability

http://doi.org/10.18080/jtde.v9n3.403

Organisational readiness							
Relative advantage							
Perceived Risk							
Customer pressure	0.899						
Compatibility	0.017	0.827					
Direct competitors	0.360	-0.073	0.919				
Complexity country	0.079	0.006	0.020	0.908			
Cost	0.334	0.040	0.299	0.101	0.825		
Managers' Innovativeness	0.385	0.026	0.376	0.122	0.300	0.885	
Organisational factors ICT	0.308	0.114	0.111	0.189	0.009	0.279	0.890

Source: Authors.

Table 4. Convergent validity of the indicators (Heterotrait-Monotrait Ratio - HTMT)

Part 1:

Ease of use						
Government support	0.057					
Managerial characteristics	0.087	0.147				
Observability	0.069	0.186	0.537			
Organisational readiness	0.174	0.178	0.444	0.372		
Relative advantage	0.037	0.126	0.533	0.806	0.286	
Perceived Risk	0.081	0.132	0.324	0.233	0.399	0.240
Customer pressure	0.035	0.115	0.479	0.367	0.230	0.300
Compatibility	0.581	0.098	0.113	0.119	0.191	0.040
Direct competitors	0.129	0.085	0.285	0.259	0.138	0.256
Complexity country	0.088	0.406	0.210	0.120	0.174	0.175
Cost	0.064	0.077	0.224	0.195	0.081	0.213
Managers' Innovativeness	0.082	0.078	0.497	0.392	0.278	0.408
Organisational factors ICT	0.240	0.290	0.262	0.317	0.505	0.213

Part 2:

Ease of use							
Government support							
Managerial characteristics							
Observability							
Organisational readiness							
Relative advantage							
Perceived Risk							
Customer pressure	0.059						
Compatibility	0.050	0.026					
Direct competitors	0.128	0.428	0.095				
Complexity country	0.021	0.081	0.037	0.032			
Cost	0.051	0.382	0.089	0.369	0.065		
Managers' Innovativeness	0.030	0.444	0.041	0.460	0.110	0.348	
Organisational factors ICT	0.034	0.357	0.163	0.153	0.236	0.027	0.082

Source: Authors.

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Regarding the predictability of the model of the adoption of electronic commerce in SMEs, a re-sampling was carried out using the bootstrapping technique with 5,000 sub-samples (Henseler & Chin, 2010). This study obtained an R^2 of 0.318, which is an acceptable value that allows us to conclude that the model may enable a high level of prediction with a great degree of statistical validation of the variables (Table 5).

Regarding validation of the hypotheses, hypothesis H1 (β: -0.074) did not support ease of use as a factor for the adoption of e-commerce in SMEs. This result showed what other studies in the sector noted about the lack of experience in the use of these technologies (Parra *et al.*, 2019; Suarez, 2020).

Hypothesis H2 (β: -0.063) was also not supported. The government was not a positive factor in the adoption of e-commerce in SMEs, verifying that, although this country has improved in connectivity policies, support for SMEs to adopt this technology is poor (Sánchez-Torres, 2019).

Hypothesis H3 (β: 0.264*) was supported, confirming that the characteristics of management are influential in the adoption of e-commerce in Colombian SMEs. This illustrates a core characteristic of Colombian SMEs, since decision-making is generally centralised to the manager or owner of the company (Marin-Idárraga & González, 2021).

Hypothesis H4 (β: 0.120*) was also supported, demonstrating that the degree of observability regarding e-commerce influences its adoption in Colombian SMEs. This is in line with previous studies in other countries, where it is highlighted that perceiving subsequent benefits from the use of e-commerce leads to its adoption (Sombultawee, 2020).

Hypothesis H5 on the organisational readiness of SMEs in Colombia was not supported (β: 0.081). As in other countries (Deng, Duan & Luo, 2019), this result denotes the lack of preparation and training in Colombian SMEs for the implementation of e-commerce (Suarez, 2020).

Hypothesis H6 (β: 0.186*), which states that the relative advantage that e-commerce generates is another determining factor in its adoption, was supported. For example, e-commerce in SMEs generates reduced marketing costs and added value such as personalised customer service (Xuhua *et al.*, 2019).

Hypothesis H7 (β: -0.048) regarding perceived risk was not supported. This is perhaps due to the fact that the Colombian culture does not have a high perception of risk in relation to e-commerce, as concluded in a recent study on e-commerce marketplaces (Sánchez-Torres *et al.*, 2021).

http://doi.org/10.18080/jtde.v9n3.403

Hypothesis H8 (β: 0.210*) was supported, showing that pressure from customers has a positive effect on SMEs' adoption of e-commerce, consistent with other studies worldwide, due to the social and economic trend of e-commerce.

Hypothesis H9 (β: 0.051) on compatibility was not supported. This result can be associated with the high cost of investing in implementing this technology in Colombian SMEs (Suarez, 2020). Hypothesis H10 (β: -0.058) on direct competitors was also not supported. Possibly, characteristics of the market, especially internal to Colombian SMEs, do not present an implementation in process in direct competitors. Hypothesis H11 (β: 0.010) regarding complexity of country was not supported: a country with a wide digital gap and other types of economic gap still lacks support in infrastructure and communications. Hypothesis H12 (β: -0.070) in relation to cost was not supported either. This is another factor closely linked to the problems that this country has, for example in the high cost of Internet connection (Sánchez-Torres, 2019). Hypothesis H13 (β: 0.009) regarding managers´ innovativeness was also not supported, perhaps due to the character of directors of Colombian SMEs, who, also being investors, prefer to be more conservative than innovative (Marin-Idárraga & González, 2021). Finally, Hypothesis H14 (β: 0.013) in relation to organisational factors affecting ICT was not supported, reinforcing the great problems and deficiencies that SMEs present in terms of the adoption of information and communication technologies (see Table 5 and Figure 2).

Table 5. Model results

Hypothesis	Test	β	T-statistics	P-values
H1: Ease of use -> Adoption e-commerce	Not supported	-0.074	1.022	0.307
H2: Govern -> Adoption e-commerce	Not supported	-0.063	0.828	0.408
H3: Managerial Characteristics -> Adoption e-commerce	Supported	0.264*	3.742	0.000
H4: Observability -> Adoption e-commerce	Supported	0.120*	1.999	0.030
H5: Organisational Readiness -> Adoption e-commerce	Not supported	0.081	1.022	0.307
H6: Relative Advantage -> Adoption e-commerce	Supported	0.186*	2.270	0.023
H7: Perceived Risk -> Adoption e-commerce	Not supported	-0.048	1.201	0.230
H8: Customer pressure-> Adoption e-commerce	Supported	0.210*	3.427	0.001
H9: Compatibility -> Adoption e-commerce	Not supported	0.051	0.755	0.450
H10: Direct competitors -> Adoption e-commerce	Not supported	-0.058	0.917	0.359
H11: Complexity country-> Adoption e-commerce	Not supported	0.010	0.206	0.837
H12: Cost -> Adoption e-commerce	Not supported	-0.070	0.950	0.342
H13: Managers´ innovativeness -> Adoption e-commerce	Not supported	0.009	0.135	0.892
H14: Organisational factors ICT -> Adoption e-commerce	Not supported	0.013	0.206	0.835

Source: Authors. (Significant at: *p<0.05 - t-value 1.960)

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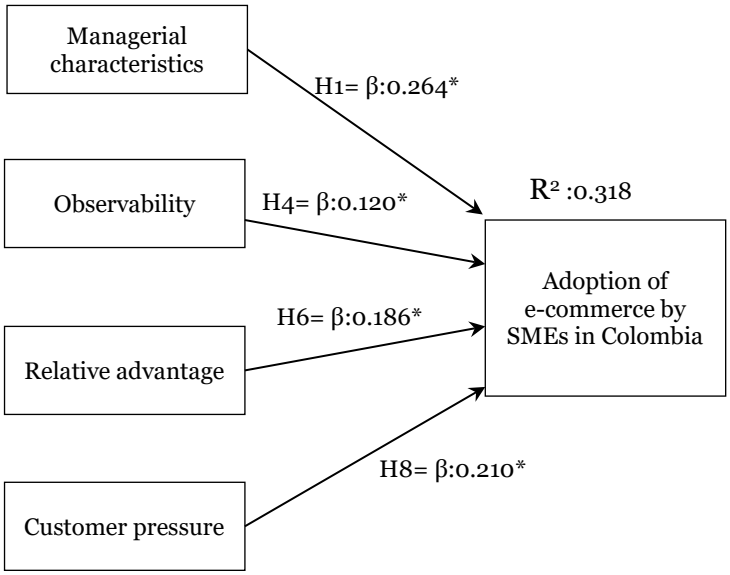

(Significant at: *p<0.05 - t-value 1.960)

Figure 2. Adoption of electronic commerce SMEs In Colombia (Source: Authors).

Discussion

The objective of this study was to determine the factors that generate the adoption of electronic commerce in SMEs in Colombia. For this, the IMAES model (Sánchez-Torres & Juarez-Acosta, 2019) was used in order to examine this phenomenon given the characteristics of this analysis tool. However, the results were not significant for almost all the variables. This behaviour of the model can be explained by the fact that this phenomenon is complex and depends on the context of each country.

The results did not support all the proposed effects, which was expected given that the results vary between countries and also within each country, and because some SMEs may value some factors over others (Dahbi & Benmoussa, 2019). Likewise, the few studies carried out on Colombian SMEs showed great deficiencies in many of the variables (Parra *et al.*, 2019; Suárez, 2020); therefore, one of the first conclusions of this study is the finding that the theoretical models omit the heterogeneous nature of SMEs in developing countries (Abdulhakeem, Edwards & McDonald, 2017).

This is in line with the only similar study carried out on the adoption of information and communication technologies in SMEs in Colombia, in which variables, such as the age of the SME, perceived costs, security, and government incentives, among others, were not supported. This may be due to the fact that, for Colombian SMEs, these factors are not motivating or influential for the adoption of this commercial channel given the characteristics of the Colombian economy and politics. Digital divide levels in this country are high and can even exert a negative moderating effect on e-commerce (Sánchez-Torres, 2019; Sánchez-Torres, Arroyo-Cañada & Gil-lafuente, 2016). In addition, e-commerce is not a strategic issue

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for SMEs due to their short-term vision in decision making. Furthermore, the sales that are generated through e-commerce can be less than traditional channels in this country (Corrales-Liévano, 2019).

The observability variable has been statistically supported as a variable that Colombian SMEs take into account to adopt e-commerce. In this case, as in previous studies, it is of great importance that the technologies that an SME adopts in its operations can generate economic value in the future. In this regard, it can be considered that e-commerce offers great benefits as a distribution channel that allows companies to increase levels of efficiency in distribution channels, in market internationalisation processes, and in customer marketing relationships, among others.

The next statistically validated variable is the relative advantage. This variable was also recently validated in a study on the adoption of information and communication technologies in SMEs in Colombia (Osorio-Gallego, Londoño-Metaute & López-Zapata, 2016). However, that study did not separate e-commerce from the use of the Internet and computer equipment. This variable is important because, if the SMEs consider digital marketing as a mechanism that supports its strategic advantage, it can then carry out actions toward the internationalisation of markets, given the low costs of implementation with respect to other methods of internationalisation. Likewise, it has been proven in other developing countries that SMEs adopt e-commerce when similar ones have been successful in their market, therefore valuing the relative advantage of e-commerce (Reardon *et al.*, 2021).

Finally, with a supported statistical significance, the customer pressure factor is a determining factor for Colombian SMEs in adopting e-commerce. The data reflect the fact that the SMEs that adopt this commercial channel in Colombia have a clear focus on meeting the needs of their customers regarding the use of Internet technologies and are aware of the benefits e-commerce presents for online purchasing and customer service. However, some studies on the use of this commercial channel by buyers have found that Colombian electronic buyers make up only 7% of the population that uses the Internet (Sánchez-Torres *et al.*, 2017). On the other hand, there is a wide digital divide where only those who have a high socioeconomic status have access to e-commerce (Sánchez-Torres, 2019; Sánchez-Torres, Arroyo-Cañada & Gil-lafuente, 2016). This context should be evaluated by companies, given that e-commerce will only be effective for certain products and services and for special segments of the population.

Conclusions

The theoretical contributions of this work are that it empirically tested the IMAES model (Sánchez-Torres & Juarez-Acosta, 2019) for the first time, validating its diagnostic nature and therefore yielding unique results for each social and economic context of a region or country

http://doi.org/10.18080/jtde.v9n3.403

by integrating multiple factors that can explain the adoption of e-commerce in SMEs. The empirical results may occur because the context of SMEs in each country is different: it cannot be expected that the same characteristics will be verified worldwide, since results in previous studies from other developing countries do not support the expected hypotheses in the adoption of information technologies in SMEs (Nair, Chellasamy & Singh,2019).

However, this study has managed to validate some factors that are considered important by Colombian SMEs. It was found that the variables that influence the adoption of e-commerce for Colombian SMEs are the managerial characteristics and the degree of interest of senior management in which digital commercial channel is adopted. The latter is one of the factors that managers consider when implementing e-commerce.

Regarding the contributions to companies, this study has made it possible to diagnose why SMEs in Colombia adopt electronic commerce from an empirical perspective, which offers a precise diagnosis of the real perceptions of SME managers regarding current reasons behind e-commerce use. In this regard, it is especially true that e-commerce is considered a necessary tool for Colombian SMEs for their commercial relationships and for their differential strategy. Likewise, it is evident that SMEs that adopt this technology are aware of its importance from the beginning and the positive results that it can generate in its objectives. Also, the non-validation of many internal, external and technological factors shows that there are still many weaknesses and negative perceptions regarding e-commerce in Colombian SMEs. There is a great need to further support SMEs in the adoption of e-commerce from associations, clusters and public and private agencies to take measures related to programs and policies to promote the use of this technology, not only as a marketing channel between companies and consumers (B2C) but also between companies (B2B). For public policies, the results should motivate the government to act, providing SMEs with programs, policies and support for the development of this commercial channel.

The main limitation of this study is that the sample is low and may not reflect the aggregate of e-commerce adoption behaviour in SMEs. However, the R^2 value shows that the prediction level of the model is acceptable (R^2: 0.318) and achieves a level of prediction of reality. Another aspect is that the model did not validate many of the initial variables that were expected to be statistically accepted because they had only been previously tested in other SMEs and in other countries. However, our study can show that the heterogeneity in the characteristics of the SMEs in this country may be the ones that generate these results.

This allows us to propose, as a future line of research, the application of this e-commerce adoption model in other countries of the region to compare the results in a cross-referenced manner and verify the other relationships of the variables.

http://doi.org/10.18080/jtde.v9n3.403

Finally, the effects on companies derived from the COVID-19 pandemic have led to various commercial decisions in SMEs. Among them, the implementation of e-commerce stands out as a fundamental alternative to achieve sales results and become more familiar with the consumer. This contingency will promote the use of the Internet in different contexts and will boost e-commerce, which will lead to new research. Nevertheless, the damage to the economies as a result of this pandemic could also have delayed and weakened this technological adoption in these types of countries.

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Annex 1. Questionnaire

Construct	**Items**	
Relative advantage (Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011; MacGregor & Vrazalic, 2005; Saffu, Walker, & Hinson, 2008; Sánchez-Torres & Juarez-Acosta, 2019)	RA1	Will increase the competitive advantage for our company
	RA2	Support effective reintermediation
	RA3	Customizing services to customer needs

Construct	Items	
Observability (Abou-Shouk, Megicks & Lim, 2013; Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011; Sánchez-Torres & Juarez-Acosta, 2019; Wilson, Daniel & Davies, 2008; Wymer *et al.*, 2008)	PU1	Using e-commerce would enable my company to accomplish specific tasks more quickly
	PU2	Using e-commerce would improve my job performance
	PU3	Using e-commerce in my job would increase my productivity
	PU4	Using e-commerce would enhance my effectiveness on the job
Compatibility (Alam, Ali & Jani, 2011; Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011; Grandon & Pearson, 2004; Van-Huy *et al.*, 2012; Saffu, Walker & Hinson, 2008; Sánchez-Torres & Juarez-Acosta, 2019)	CU1	Company's traditional operating procedures
	CU2	Company's current operations/procedures
	CU3	Existing values
	CU4	Suppliers' and customers' ways of doing business
Ease of Use (Alam, Ali & Jani, 2011; MacGregor & Vrazalic, 2005; Sánchez-Torres & Juarez-Acosta, 2019)	EU1	e-Commerce to be flexible to interact with
	EU2	e-Commerce would be clear and understandable
	EU3	Ease for me to become skilful at using e-commerce
	EU4	e-Commerce easy to use
Organisational readiness (Alam, Ali & Jani, 2011; Grandon & Pearson, 2004; Sánchez-Torres & Juarez-Acosta, 2019)	OR1	Financial resources to adopt e-commerce
	OR2	Technological resources to adopt e-commerce
	OR3	Skill and knowledge
	OR4	External support
Perceived Risk (Alam, Ali & Jani, 2011; Van-Huy *et al.*, 2012; MacGregor & Vrazalic, 2005; Sánchez-Torres & Juarez-Acosta, 2019)	SEC1	Current laws and regulations are sufficient to protect e-commerce user's interest
	SEC2	My company does not have confidence in the payment system of e-commerce
	SEC3	My company is concerned that information involved in a transaction over the Internet is not private
Managerial characteristics (Alam, Ali & Jani, 2011; Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011; Van-Huy *et al.*, 2012; Rahayu & Day, 2015; Sánchez-Torres & Juarez-Acosta, 2019; Wymer *et al.*, 2008)	MC1	Interest to the top management
	MC2	Feeling on importance of e-commerce adoption
	MC3	Encouraging role of top management
Cost (Alam, Ali & Jani, 2011; Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011)	CT1	High set-up cost
	CT2	Additional staff required
	CT3	Difficult to justify cost and benefits

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Construct	Items	
Competition (Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011; Grandon & Pearson, 2004; Sánchez-Torres & Juarez-Acosta, 2019)	CP1	It is easy for our customers to switch to another company for similar services/products without much difficulty
	CP2	Social factors are important in our decision to adopt e-commerce
	CP3	Competition is a factor in our decision to adopt e-commerce
Customer pressure (Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011; Sánchez-Torres & Juarez-Acosta, 2019)	BS1	Our industry is pressuring us to adopt e-commerce
	BS2	Our customers and buyers are pressuring us to adopt e-commerce
	BS3	Our suppliers are pressuring us to adopt e-commerce
Innovativeness (Ghobakhloo, Arias-Aranda & Benitez-Amado, 2011; Sánchez-Torres & Juarez-Acosta, 2019; Thong & Yap, 1995)	INN1	I have original ideas
	INN2	I would sooner create something new than improve something existing
	INN3	I often risk doing things differently
Organisational factors ICT (Van-Huy *et al.*, 2012; Sánchez-Torres & Juarez-Acosta, 2019)	ORG1	Employees and staff who are knowledgeable about e-commerce
	ORG2	Employees and staff who are competent about new technology
	OGR3	Financial resources to invest in e-commerce business plan
	ORG4	Human resources to invest in e-commerce business plan
Government support (Van-Huy *et al.*, 2012; Sánchez-Torres & Juarez-Acosta, 2019)	GS1	To receive financial support for e-commerce from the government
	GS2	Government support (orientation, direction, information, etc.) encouraging e-commerce development
	GS3	Positive policies related to the information security or information protection of the enterprise
Complexity e-commerce country (Van-Huy *et al.*, 2012; Sánchez-Torres & Juarez-Acosta, 2019)	CEC1	To be located in a country where inhabitants are used to credit cards
	CEC2	To be located in a country with good national IT infrastructure
	CEC3	To be located in a country with a high speed of development of IT infrastructure
	CEC4	To be located in a country with sufficient capability to control networks risks

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Policy Legacies from Early Australian Telecommunications

A Private Sector Perspective

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Abstract: The purpose of this article on the policy legacies from Australia's early telecommunications history is not to present a counterfactual to Australia's choice of public monopoly provision of early telecommunications services, but rather to indicate the extent that politics limited the private sector's role in deploying early telegraph and telephone infrastructure in Australia. The article begins by outlining a theoretical framework for analysing government's role in deploying new telecommunications technologies, before investigating some of the less familiar literature on the historical impact of government intervention on the private sector in the early Australian telegraph and telephone industries. It then discusses some of the political issues relating to the subsequent liberalisation of the telecommunications industry in Australia and concludes with a discussion of the historical legacies of government intervention on the private sector in the Australian telecommunications industry.

Keywords: Australia, Telegraph, Telephone, History, Telecommunications Policy.

Introduction

In the earliest days of the telegraph and the telephone in Australia, these new inventions were first deployed by the private sector. It was the Canadian, Samuel McGowan, a student of Morse, who first brought the telegraph to Australia in 1853 with the hope of recreating the entrepreneurial successes he had witnessed in North America (Moyal, 1984, p. 16). However, Australia presented a remarkably different environment that favoured public provision of essential infrastructure. While McGowan went on to be the general superintendent for the telegraph in Victoria, the promise of official privilege and status ensured he and other would-be telecommunications entrepreneurs in Colonial Australia did not achieve the wealth of their North American commercial counterparts. Later, entrepreneurs of Australian telephone

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systems, including original inventions such as patented telephone and exchange equipment, were ignored by Australian governments in favour of imported overseas equipment.

The purpose of this article on Australia's early telecommunications history is not to present a counterfactual to Australia's choice of public monopoly provision of early telecommunications services, but rather to indicate the extent to which politics limited the private sector's role in deploying early telegraph and telephone infrastructure in Australia. First, the article begins by outlining a theoretical framework for analysing government's role in deploying new telecommunications technologies. Second, it investigates some of the less familiar literature on the historical impact of government intervention on the private sector in the early Australian telegraph and telephone industries. Third, it discusses some of the political issues relating to the liberalisation of the telecommunications market in Australia; and concludes with a discussion of the historical legacies of government intervention on the private sector in the Australian telecommunications industry.

Theorising the Historical Deployment of Infrastructure

Government intervention in the deployment and use of telecommunications technologies operates in three main ways. First, government *enables* the deployment of new telecommunications technology inventions by effectively giving permission or providing resources for telecommunications networks to be established. Second, government *coordinates* the deployment and use of communications networks by establishing institutions which attempt to bring order to the construction of the physical infrastructure and to determine who can access the infrastructure and associated services. Third, government *regulates* telecommunications networks to ensure that the behaviour of network actors and users conforms to laws or principles designed to operate in the public interest. The ways in which a particular government *enables*, *coordinates*, and *regulates* telecommunications networks, then, may be referred to as the jurisdiction's telecommunications policy.

While new inventions often occur independently of government institutions, governments can determine which technologies are enabled. For example, government may decide not to allow a particular technology to be deployed, or to delay its deployment. Government may also create barriers to entry to restrict or limit the industry players involved in a particular market. Indeed, government may decide to monopolise a particular technology in the interests of nation-building or other reasons in the national interest, such as national security. The ability of government to use its coercive powers to create such barriers to entry can have a major influence over the deployment, use, and pricing of communications services.

Once a decision to adopt a particular telecommunications technology is made, government typically takes on the role of coordinating the deployment of the technology, particularly the

http://doi.org/10.18080/jtde.v9n3.431

associated infrastructure, to ensure that rights of way and other property-related rights are protected. Government may also determine the way technologies are used, by either encouraging or discouraging particular uses through legislation. Typically, these rules are accompanied by a government agency which monitors and enforces the rules. In telecommunications industries, government may regulate, or monitor and enforce the rules, which have been established by law or other mechanisms such as 'self-regulation'. Nonetheless, once a new technology is adopted and deployed, government plays a major role in regulating the way the technology is owned or operated. This may include restrictions on ownership, mergers and acquisitions, consumer pricing, or rules enforcing competitive behaviour and consumer protection.

The concepts of enabling, coordinating, and regulating telecommunications technologies as key elements of telecommunications policy in Australia will now be examined in historical perspective.

Deploying the Telegraph in Australia

The arrival of telegraphic technology in Australia occurred in 1853[i] when Samuel McGowan,[ii] an experienced entrepreneur who had witnessed the burgeoning private telegraph companies in North America, had plans for his own telegraph company in Victoria (Moyal, 1984, pp. 16–17). When McGowan arrived in Victoria with several sets of telegraph equipment and a copy of the *Canadian Telegraph Act*, he set about demonstrating the new technology to find interested backers for his company. Despite an initial lack of interest, the Victorian Government soon called for tenders to establish an experimental telegraph line between Melbourne and Williamstown but insisted that ownership would remain with the government. McGowan had been warned that 'any independent approach [to deploying the telegraph] would meet "the utmost resistance."' Technology transfer occurred, but not policy transfer (Legrand, 2012).

McGowan was awarded the construction contract with the understanding that he would become the 'general superintendent of the new [public] electric telegraph of Victoria' (Moyal, 1984, pp. 17–18; Demant, 2009). Private businesses operated as construction contractors, but owning and operating telegraph lines was the sole domain of government (Hunter & Australia Post, 2000, pp. 44–50).

The other Australian colonies, with the exception of Western Australia, opted for Victoria's public ownership model: they, too, resisted private attempts to own and operate telegraph lines. For instance, Charles Todd, who would later lead the construction of the Overland Telegraph Line (OTL), was recommended by the London Colonial Office as the superintendent for South Australia's telegraph system. On the same day that Todd arrived in Adelaide in 1855,

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a private telegraph line funded and constructed by James McGeorge (Moyal, 1984; ABS, 1900) commenced operations. McGeorge had been refused assistance by both the South Australian government and the local chamber of commerce but went ahead with his network anyway. This created problems for Todd as McGeorge's line had captured the market, causing 'the immediate revenue' from the government's duplicate line to be 'infinitesimal' (ABS, 1900, p. 101). McGeorge's line was subsequently purchased by the South Australian Government and dismantled in 1856 to prevent further competition (ABS, 1900, p. 101; Moyal, 1984, p. 20), effectively bringing to an end private sector ownership and operation of telegraph lines in South Australia.

Public ownership of telegraphic infrastructure was adopted by New South Wales, Queensland and Tasmania, with construction being undertaken by Canadian[iii] or local private companies under government contracts. Coupled with colonial hopes 'of mutual goodwill and of rapidly increasing prosperity,' a variety of American and British telegraphic devices were adopted to interlink the colonies in a relatively standardised fashion, with demand driven by the commercial benefits of faster communications encouraging continued government expenditure on the deployment of more telegraph lines (Moyal, 1984, pp. 23–24). As with railways, only in Western Australia did the private sector play an early part in building, owning and operating the infrastructure until such time as the Western Australian government, under pressure from residents, saw the value in the new medium and the commercial operators were bought out. Like McGowan in Victoria, the entrepreneur who enabled the establishment of the privately-owned network in Western Australia became the first superintendent of telegraph in the colony (Moyal, 1984, p. 28). In effect, colonial governments captured the expertise of the original telegraphic entrepreneurs who, possibly reluctantly, substituted the status of a government position for the potential profits of private enterprise (Moyal, 1984, p. 28).

Colonial unanimity on the public ownership of telegraph networks had its advantages. In contrast with the development of the colonies' railway and electricity networks, colonial governments had, although with some rivalry, cooperated to enable interconnectivity of the separate colonial telegraph networks, and by 1857 postal and telegraph matters featured regularly in intercolonial consultations and appeared as news items in newspapers (Livingston, 1996, pp. 27–29). As competing shipping technologies and faster international shipping routes were adopted, the hubs for mail arriving in Australia shifted among the major cities and New Zealand, affecting the speed and priority of the transmission of news arriving from overseas to the regions (Livingston, 1996, pp. 31–33). As telegraph networks developed, so too did regional newspapers (Morrison, 2005, p. 141). The delivery of mail and news across colonial borders required greater cooperation, leading to increasing calls to establish a customs union, in the form of a federation, in the second half of the nineteenth century.[iv]

http://doi.org/10.18080/jtde.v9n3.431

Cooperation was necessary, as newspapers and businesses called for 'major reforms' in the intercolonial telegraph service: problems of delays, particularly at intercolonial connection points, led to the development of additional and more direct telegraph wires between major population centres (Livingston, 1996, p. 55).

The capabilities of early telegraph technologies restricted the extent that interconnectivity could be achieved, especially across large expanses of ocean. With the successful deployment of the transatlantic cable in 1866, however, it was recognised that it would only be a matter of years before Australia would be connected with Britain. By 1869, Tasmania was connected to the mainland telegraph network via the first successful submarine cable in Australia, and in 1872 the construction of the OTL enabled communication between Adelaide and Darwin. Subsequently, the OTL linked to the Singapore-Java submarine cable,[v] connecting Australia to the existing international telegraph network (ASTHC, 2000, p. 529). Government (despite some intercolonial rivalry[vi]) had achieved what is considered to be one of the greatest engineering feats in Australian history, if not the nineteenth century, leaving little room for a commercial telecommunications industry to develop.

Government ownership of telegraph networks was the norm throughout Britain and Europe. In 1869, the government-owned British Post Office took ownership of the formerly private telegraph networks and amalgamated the telegraph and post offices in Britain, and, over time, the Australian colonies followed the British example. To a large extent, the co-location of telegraph offices with post offices facilitated greater intercolonial cooperation (Livingston, 1996, p. 5). In Australia, government ownership of both the telegraph and postal systems, and the move by the colonies to administer posts and telegraphs under individual departments of posts and telegraphs, made the transition of posts and telegraphs to the jurisdiction of the new federal government relatively easy. At the time of Federation, the new Commonwealth Government readily[vii] assumed the constitutional power to legislate in relation to telecommunications (Putnis, 2002). The inclusion of '[p]ostal, telegraphic, telephonic, and other like services' in section 51 (v) of the *Australian Constitution* was significant for the future development of national policy and the assumption of legislative and regulatory functions relating to telecommunications and, later, broadcasting services.

The significance of the term 'other like services' in the Constitution would become apparent when Marconi's invention of the wireless telegraph simultaneously enabled the development of radio broadcasting – an early indicator of the technological convergence which has continued into the present. Yet wireless telegraphy was not regarded with the same urgency as wired telegraphy, and the federal government wavered in its response to the new medium, before responsibility for wireless telegraph was transferred to the Department of the Navy in 1915.[viii] Nonetheless, there was little incentive for the private sector[ix] to compete with the

http://doi.org/10.18080/jtde.v9n3.431

government-owned monopoly on both the fixed-line and wireless telegraphic technologies. Indeed, these technologies would be treated very differently (in terms of their prescribed functions) until the advent of radio and hence the broadcasting industry. For the most part, federal telecommunications policy focused on setting rates and moving, gradually, towards standard fees and charges across the States. With very little private sector involvement in the industry (beyond construction contractors), federal telecommunications policy focused almost exclusively on delivering services to citizens while attempting to keep costs under control – the Postmaster-General's Department would continue to operate in this manner until 1975.

One feature of government ownership was that telecommunications was a persistent political issue. Before Federation, it was accepted 'by colonial Governments, [and] acknowledged at the Intercolonial Conference of 1873, that in a vast country, telecommunications was operating, and should, if necessary, be maintained in the Colonies "at some pecuniary loss"' (Moyal, 1984, pp. 33–34). Rather than being determined by market forces of supply and demand, telecommunications outcomes were most often determined by political, rather than economic, factors. Indeed, as Colonial Governments had monopolised the telegraph network, there was an expectation that these government-funded services would meet the demand, even if it meant running the services at a loss. After Federation, this trend continued. For example, in the lead-up to the 1910 Royal Commission into Postal, Telegraph and Telephone Services (AT&T, 1913, p. 64), the Member for Maranoa (in Queensland), James Page, commented:

> *[N]ot a mile of new telegraph line, except in connexion with new rail ways, has been erected in that State since Federation was inaugurated… Notwithstanding the public complaints, and my efforts, I cannot get the Department to move, and so desperate are my constituents becoming that some of them talk of voting against me because nothing is done for them. I ask the Postmaster-General to give us fair treatment* (Hansard, 1909).

After two years of investigation, the Royal Commission found that sufficient funding to maintain the telecommunications network was often curtailed by the Treasurer to achieve other political aims in federal-state relations. According to the Royal Commission, 'the system of management [was] faulty, in that it permitted the Treasurer to assume financial control of services for whose efficiency he was not responsible' (AT&T, 1913, pp. 44–45). Federation added another layer of control by bringing together the Colonial telegraph networks under the control of the Postmaster General's Department. This, in turn, brought together the various interests at play in telecommunications, leading to a large number of complaints about

http://doi.org/10.18080/jtde.v9n3.431

telecommunications services. The Royal Commission (Cook *et al.*, 1910, p. 187, para 1071) reported:

> *[T]hat the number and magnitude of the complaints received indicate the existence of strong dissatisfaction among the public with the Postal, Telephone and Telegraph services. Your Commissioners are of the opinion that the bulk of complaints were entirely justifiable, and are convinced that to obtain an efficient service it is essential that improved methods of Management, Finance, and Organization be promptly adopted.*

Meanwhile, 'official jealousy' concerning appointments, political pressure undermining the authority of the Deputy Postmasters General, the unwillingness of the Permanent Head of the Department to leave the central headquarters, and a culture of reporting rather than taking action created a 'distinct weakness in the system of control'. Given that the Minister 'permit[ted] political pressure to influence him in reviewing actions' taken by his deputies, the apparent attempt at avoiding 'over-centralization' was thwarted by politics (ABS, 1910: Vol. IV, p. 17). A decade earlier, the NSW Statistician (Coghlan, 1900, p. 713) had claimed enthusiastically:

> *In no country in the world has the development of telegraphic communication been so rapid as in Australasia, and in none has it been taken advantage of by the public to anything like the same extent.*

Yet, at the height of the telegraph era, Australia's enthusiastic response to telecommunications technologies was not reflected in the outcomes achieved by the centrally-controlled monolith.

Telephonic Innovation versus 'Picking Winners'

The first telephone system in Australia commenced operations in 1878,[x] just two years after the telephone was patented by Alexander Graham Bell. However, the first system was restricted to point-to-point communication until the first telephone exchange commenced operations in Melbourne in 1880. American businessmen Masters and Draper (Moyal, 1984, p. 75) established the exchange as a private firm, the Melbourne Telephone Exchange Company Limited, and patented their own design. At first, the Victorian Government seems to have displayed very little interest in the new technology, even though the Melbourne exchange began operations some two years before London opened its own exchange (Mellor, 1974). Indeed, a culture of opposition to private-sector interests in telecommunications is apparent at the time, especially from the Chamber of Commerce in Melbourne, which led to the Victorian Government forcibly taking over the Masters and Draper exchange. Davison (1978, p. 26) claims that the government takeover was largely a result of pressure from the

http://doi.org/10.18080/jtde.v9n3.431

Chamber of Commerce due to subscriber complaints about the exchange's efficiency. While the number of subscribers almost doubled following the takeover (Hunter & Australia Post, 2000, p. 8), consumer charges for telephone services were cheaper under government ownership (Davison, 1978, p. 26). Regardless, at that time in the colonies, government policy was clearly focused on protecting existing domestic primary industries (Sala, 1885, p. 10; Davison, 1978, p. 24), not enabling new tertiary industries.

Moyal (1984, pp. 71–78) points out that, unlike earlier problems associated with the lack of local manufacturing capabilities for telegraphic equipment, local invention and innovation was 'most fertile' in the early days of the telephone in Australia. Effectively, the new technology energised various Australians who were interested in experimenting with the new communications devices (Telecom Australia, 1980). Henry Sutton (McCallum, 1976), for example, invented 20 different telephones but failed to take out patents on his designs, and some 16 of his designs were later patented overseas. Moyal (1984, p. 78) suggests that a 'contemporary tendency to ignore indigenous inventiveness' existed during this period. The proprietors of the Melbourne Telephone Exchange, Masters and Draper, used their own patented design to establish their business in Melbourne. Despite Master's and Draper's success, other Australian inventors, such as J. E. Edwards (see Moyal, 1984, pp. 72–73, for example), had patented several designs and later operated a 'flourishing' Melbourne telephone business until 1885. Edwards was mentioned by the Victorian Postmaster-General during the proposed government takeover of the Melbourne Telephone Exchange Company as:

> *…the first; but he seems to have been more of a practical electrician than a commercial man. He was not so active as the company have been in pressing this – as it was then – new invention on the public notice, and he did not increase the business to any large extent, while they have gone ahead. I have no doubt beyond their expectations* (*The Argus*, 1887, p. 9).

It is interesting that the Masters and Draper design, the first telephone exchange in the country, was not adopted elsewhere. Similarly, Edwards' achievements as the original pioneer of telephone exchanges did not go unnoticed by Derham, then Postmaster-General of Victoria. However, when it came to establishing exchanges in Brisbane and later Sydney (Telstra, 2021), overseas equipment was adopted with no consideration for what had been established locally. Further, E. C. Cracknell (Rutledge & Affleck, 1969), superintendent of telegraphs in NSW, prevented a telephone line being connected between the General Post Office in Sydney with the Royal Exchange. Businessmen at the Royal Exchange decided to build their own telephone exchange to connect to Sydney's docks and this proved to be successful until the exchange burnt down. By this time, Cracknell had decided to open an exchange at the Sydney Post Office,

http://doi.org/10.18080/jtde.v9n3.431

so the private venture, along with Australia's local telephone manufacturing industry, ended abruptly.

According to McLean (1984, pp. 1–2), by 1901 'there were fewer than 33,000 telephone instruments in use among a population of 3.8 million – less than one for each 100 people'. At Federation, the *Post and Telegraph Act* of 1901 gave the Postmaster General the power to regulate the cost of telephone calls, and there were various attempts to standardise fees across the country. Annual fees or 'flat rates' soon gave way to a 'toll' or 'measured rate' system to remove discrimination 'against subscribers who made little use of the phone' and, allegedly, to discourage 'the practice of subscribers granting non-subscribers use of their telephones without payment' (McLean, 1984, p. 4). According to McLean (1984, p. 18), to change post and telegraph charges required a change in legislation, whereas telephone charges could be changed by the department. This meant that 'telephone charges rarely featured in parliamentary discussion'.

The convergence of posts, telegraphs and telephones in the colonies established a precedent that was readily incorporated into the Australian constitution at Federation in 1901. Moreover, almost fifty years of colonial cooperation in posts and telegraphs enabled the telecommunications industry to be assumed by the federal government under its constitutional responsibilities for 'postal, telegraphic, telephonic, and other like services' (Livingston, 1996, p. 4–5). Further, both world wars served to increase the preponderance of government monopoly provision as defence powers and telecommunications powers reinforced each other. As such, it would be unreasonable to expect that the amalgamation of the various services would be a seamless process. Nevertheless, the government monolith continued to have problems well into the 1920s, where periods 'of unsatisfied demand for telephones' existed. McLean (1984, p. 2) suggests that this was either because of 'shortages of materials, or government directives' or simply because 'the spread of telephones [w]as a process of diffusion towards some level of market saturation'. Regardless, persistent issues such as the Postmaster-General's pricing policies and conditions 'clearly reflect[ed] government policy and were intended to favour particular groups – and not just farmers' (McLean, 1984, p. 42). By this time, telecommunications was firmly entrenched as a political tool – or a 'policy lever' – to be 'pulled' whenever government needed to secure votes.

Liberalising the Telecommunications Market

The global economic crises of the 1970s triggered significant social policy changes under the Whitlam Government.[xi] Responsibility for postal and telecommunications services, which had been amalgamated under the control of the PMG from 1901 until 1975, was separated into two statutory monopolies: the Australian Postal Commission (trading as Australia Post) and the

http://doi.org/10.18080/jtde.v9n3.431

Australian Telecommunications Commission (trading as Telecom Australia).[xii] Domestic telecommunications remained under the regulation of Telecom Australia, which retained responsibility for equipment, infrastructure and administration of telecommunications services. Telecommunications policy focused on the concept of the 'universal service obligation' which was a key component of the Australian telecommunications framework for many years (DCITA, 1997). Nonetheless, the new governance arrangements for telecommunications provided a more 'business-like' approach to service delivery and somewhat shielded Telecom from the political concerns that often plagued the PMG (Moyal, 1984, pp. 299, 312). By 1980, Telecom had a teledensity in Australia at a level of almost one telephone for every two Australians (McLean, 1984, pp. 1–2). However, Telecom was plagued by 'a distinctly unfavourable image compounded by extravagance, inefficiency and high cost to the consumer coupled with large profits for itself' (Moyal, 1984, p. 309).

During the 1980s, global trends precipitated a move away from public ownership of telecommunications infrastructure in most of the highly industrialised countries toward market-based solutions designed to reduce the cost of providing government services (Martyn, 2003, p. 327).[xiii] Up until this time, monopoly provision of telecommunications services had been supported by assumptions pertaining to 'natural monopolies'. In 1981, a Committee of Inquiry into Telecommunications Services in Australia was appointed to investigate, among other things, 'the extent to which the private sector could be more widely involved … in the provision of telecommunications services' and the relevant issues surrounding a move to a competitive market system (Commonwealth of Australia, 1982, p. 1). Early moves towards a market-based telecommunications sector began with Telecom's successful $200 million 'keeping you in touch with tomorrow' borrowing campaign in 1976 with both the public and financial institutions as a way to fund capital expenditure (Moyal, 1984, pp. 309–311). Politics, however, was never far away and a dispute with trade unions in 1978, initially over new equipment[xiv] that resulted in job losses, caused political problems for the government.

Bob Hawke (cited in Moyal (1984), p. 323), then President of the Australian Council of Trade Unions (ACTU), claimed that the government, in refusing to let Telecom management negotiate with the unions, 'was facing a Luddite position, that if it went ahead and introduced the new equipment in disregard of the wishes of its employees the danger of sabotage was real'. According to Moyal (1984, pp. 315–335), much of the debate over the introduction of new telecommunications technologies was linked to issues about the responsibility for public entities to provide employment. With rising unemployment coinciding with Telecom's increasing profits, social justice issues affected by technological change outweighed consumer demands for the provision of improved telecommunications technologies. Disputes with

http://doi.org/10.18080/jtde.v9n3.431

unions about wages and the introduction of new technologies did not go away, and the politics of telecommunications soon became more intense as Telecom attempted to capture new technologies such as cable television and videotex (Moyal, 1984, p. 379). As the capabilities of telecommunications technologies extended beyond the telephone, Telecom increasingly encroached on the private sector, in particular Kerry Packer's Publishing and Broadcasting Ltd, and political pressure to move to a market-based telecommunications sector increased (Barry, 2008).

The Davidson report[xv] recommended the introduction of a competitive telecommunications market, with Telecom Australia reconfigured as a government-owned incorporated company, with responsibility for equipment regulation and manufacture transferred to separate entities. In effect, Davidson was introducing a 'user-pays' principle into the provision of telecommunications services that did not fit comfortably with the ideas of universal service established years before. While the Fraser Government set about implementing Davidson's recommendation, but in 'measured stages', the embeddedness of telecommunications in the Australian political psyche enabled the Hawke Government to go to the polls in 1983 with a commitment to retain the ATC (Telecom) as the national carrier (Moyal, 1984, p. 383). This decision was short-lived, however, and the Hawke Government enacted the *Telecommunications Act 1989* and corporatised the ATC as part of a series of Australian telecommunications reforms. Competition in value-added services was introduced, and the Australian Telecommunications Authority (AUSTEL) was established as a regulatory agency designed to 'protect consumers and ensure fair competition' (Martyn, 2003, p. 325).

The next two stages of telecommunications reform occurred with the introduction of the *Telecommunications Act 1991* by the Hawke Government, followed by the Howard Government's *Telecommunications Act 1997*. The first act saw the introduction of Optus and Vodaphone[xvi] as major competitors to the newly formed, 100% government-owned Telstra Corporation Limited. Under the supervision of AUSTEL, Telstra was to provide access rights to retail competitors who resold basic carriage services provided by Telstra (Martyn, 2003, p. 325). Coinciding with the introduction of competition was the establishment of the Telecommunications Industry Ombudsman as a self-regulatory body designed to resolve consumer complaints (Stuhmcke, 1998, p. 808). The second act amended the *Trade Practices Act 1974* to reduce the barriers for new industry entrants and, by 2003, 'more than 60 holders of carrier licences in Australia and around 130 providers of telephony carriage services' were competing with Telstra. Further, the Australian Government had commenced a phased privatisation of Telstra by selling its shares via the Australian Stock Exchange (Taylor, 2003, p. 325; O'Leary, 2003).

http://doi.org/10.18080/jtde.v9n3.431

In 2006, the Howard Government completed the privatisation of Telstra, thus ending over 150 years of government control of telecommunications services. Nonetheless, the government's refusal to reduce Telstra's market dominance before the sale had numerous implications (Koutsoukis, 2005). The telecommunications market was far from mature and, even then, it was considered unlikely that competition would thrive while Telstra remained unchanged. However, some semblance of competition existed in the mobile telephony sector, as the new technology was initially seen as complementary and therefore largely ignored by government. Yet Telstra still controlled the backhaul infrastructure and the landline market, even though the ageing copper network was fast approaching the end of its useful life. In attempting to extend its return on investment, Telstra was regularly accused of engaging in anti-competitive behaviour (Bustos, 1999). Legislation crafted in 2005 to prevent Telstra from engaging in anti-competitive behaviour did not produce the desired effect, and by 2008 the chairman of the ACCC admitted that the legislation had proven to be ineffective (Hendry, 2008). The politics of the Australian telecommunications industry did not end with privatisation, and consumers continued to expect government to influence the price and quality of telecommunications services. While the structure and the major players had changed, federal politics, empowered by section 51(v) of the *Australian Constitution*, projected the industry along the same trajectory it had been launched upon more than 150 years beforehand.

The implementation of the National Broadband Network (NBN) in 2009 signalled the apparent end of Australia's experiment with a competitive telecommunications market. However, the NBN became embroiled in further politics as costs mounted, delays ensued, and governments changed, resulting in controversial changes to the infrastructural design of the NBN. Since 2019, private sector investment in fixed-line infrastructure has been overshadowed by advances in 4G (LTE) and 5G mobile broadband technologies that appear to be outperforming the download speeds envisaged by the Coalition Government's Fibre-to-the-Node NBN introduced in 2013. But that story is beyond the scope of this article.

Conclusion

In examining the early history of Australia's telecommunications industry, the private sector's role has been relatively minor, with a clear policy preference for government ownership of its dominant infrastructure from the beginnings of the telegraph to the present day. However, the long history of public sector ownership overshadows the innovative capacity of Australia's private sector involvement in the industry. To be sure, it is unlikely that Australia's private sector could have achieved what public ownership did for connecting Australians to each other and the rest of the world, but old habits appear hard to break. The tyranny of distance, a small population, the established primary industries, what Kelly (2004) famously referred to as 'the

http://doi.org/10.18080/jtde.v9n3.431

Australian Settlement' argument, and a lack of private sector investment funds all necessitated government action to deploy an effective telecommunications network.

Nevertheless, the failure of the market to adequately address Australia's communications technology needs (the Howard government's failure to structurally separate Telstra notwithstanding) and the subsequent return to a government-dominated telecommunications network via NBN Co. demonstrates the powerful hold historical legacies have over policymaking in the present. Again, the point of this article is not to suggest that the private sector could have produced a better outcome over time. But the historical record has privileged stories of public sector success over the private sector in the Australian telecommunications industry, despite some early innovations by Australian inventors and entrepreneurs. This article has not attempted to set the record straight, as it were, but to point out an important yet otherwise forgotten history of Australia's pioneering telecommunications industry.

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Endnotes

[i] Coghlan (1900, p. 711) claimed that the first telegraph in Australia appeared in NSW in 1851. This is disputed and there is no historical evidence other than this claim.

[ii] McGowan was born in Ireland and was educated in Kingston, Ontario. He studied under Morse but also worked with the earliest telegraph companies in Canada, including the Toronto and Buffalo Electro-Magnetic Telegraph Company, the Montreal Telegraph Company, and the New York, Albany and Buffalo Telegraph Company (Gittens, 1974; Demant, 2009). McGowan was a competent telegrapher and had worked on the construction and operation of telegraph lines in North America.

http://doi.org/10.18080/jtde.v9n3.431

[iii] W. H. Butcher, one of the Canadian contractors, would later accept the position of superintendent of telegraph with the Tasmanian Government.

[iv] See Livingston (1996) for further details. Although cooperation was an important feature of intercolonial telegraphic communications, intercolonial competition ensured that 'cooperation' was achieved only through vigorous debate and politicking.

[v] The Singapore-Java cable was established by the British Australian Telegraph Company, an early predecessor to the British Cable & Wireless Group. The Cable & Wireless Group was predominantly owned and controlled by Sir John Pender and the Pender family until the Group was nationalised by the British Government in 1947, despite Cable & Wireless' petitions. The assets of the Company were subsequently integrated with those of the British Post Office (Livingston, 1996, pp. 27-29).

[vi] For example, the Overland Telegraph Line (OTL) was not the only attempt to connect to Darwin in preparation for the international link. The Queensland Government had attempted to secure the connection to the overseas link with their own telegraph line around the Gulf of Carpentaria, but this venture failed when the South Australian Government agreed to cover some of the costs of construction for the British Australian Telegraph Company (Livingston, 1996, pp. 27-29).

[vii] Although Moyal (1984, p. 88–89) outlines the reluctance of some of the Colonial Postmasters General to lose their positions of power, and some of the political difficulties associated with filling the position of Federal Postmaster General, there was no significant challenge to the federal government's power to manage the national telecommunications network.

[viii] See the *Year Book* series by the Australian Bureau of Statistics from 1907 up until 1917, when the section on wireless telegraphy was discontinued due to the First World War. For many years, wireless telegraphy was regarded as primarily a matter for shipping, in particular the Navy, and not as an alternative means for general communication. The *Wireless Telegraphy Act* came into effect in 1905 but the significance of wireless technology beyond telegraphy would not be fully realised until radio launched the broadcasting industry in the 1920s.

[ix] That is, beyond the monopoly position in wireless technology that was eventually negotiated with Amalgamated Wireless (Australasia) Ltd.

[x] There is some disagreement over which telephone line was first: on 2 January 1878, McLean Bros & Rigg (Demant, 2009) in Elizabeth St in Melbourne connecting with their Spencer Street Depot; or the system established by Robison Brothers, connecting their Flinders Street Office to their South Melbourne works in 1879 (Moyal, 1984, p. 73).

[xi] The Whitlam Government was the first federal Labor government since 1949.

[xii] International telecommunications services were provided by the Overseas Telecommunications Commission (OTC), which was also a statutory monopoly (Martyn, 2003, p. 328).

[xiii] See Raiche (1997): 'The Uruguay Round of the General Agreement on Trade and Tariffs (GATT) negotiations, which included trade in services, meant liberalisation of telecommunications regimes was truly on the international agenda'.

http://doi.org/10.18080/jtde.v9n3.431

[xiv] In particular, the Ericsson ARE 11 local switching system (Moyal, 1984, p. 323).

[xv] Formally the Report of the Committee of Inquiry into Telecommunications Services in Australia (Commonwealth of Australia, 1982).

[xvi] Vodaphone competed in the provision of mobile telephone services only (O'Leary, 2003).

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Universal Service and Competition

The Cook Islands and Australia

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Abstract: The author is advising the Cook Islands on how to introduce mobile competition, drawing on the experience of Australia. In both countries the impact of infrastructure competition on mandated geographically uniform pricing is being (or proposed to be) addressed with a levy. The different approaches to measuring costs and setting the levy are contrasted.

The paper proposes that a universal service levy has to be coupled with consistent access pricing to have efficient competition consistent with universal service policy. Interconnection between networks is free but the pricing of resold wholesale services should be consistent with the aims of the levy; to ensure universal service and efficient competition.

Keywords: universal service, wholesale, ECPR, levy, access pricing

Introduction

Under a monopoly it is possible to have geographically uniform pricing even though the cost to serve will vary geographically. With competition, a new entrant will first address the most profitable segments of the market. The incumbent operator cannot be expected to continue serving loss-making locations voluntarily if it faces competition in the locations (and for the customers) that have funded loss-making activities.

Currently, Vodafone Cook Islands (VCI) has a monopoly of the fixed and mobile markets. The government intends to licence a mobile competitor. The Cook Islands Regulatory Authority (CRA) is required to produce a universal access plan (UAP) that will support geographically uniform pricing and maintain the existing levels of service to the unprofitable locations in the presence of competition.

Cook Islands comprises 15 small islands, spread over 2.2 million square kilometres, between American Samoa and French Polynesia, south of Hawaii. The islands have small and declining populations. About 75% of the population of 17,500 is on Rarotonga and another 11% on

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Aitutaki. The remaining islands are known as the Pa Enua. Only the two main islands plus Pukapuka and Nassau have more than 50 people per square kilometre. The two main islands would clearly be targeted by a new entrant.

The Cook Islands context has similarities to the introduction of a broadband levy in Australia where the last 7% of end customers can be served only by costly fixed wireless or satellite connections.

This paper looks at how both countries deal with this issue.

The Bypass Issue

In Australia, the Government feared that the National Broadband Network's (NBN) internal cross-subsidy of its fixed wireless and satellite connections would be eroded by infrastructure competition in low-cost metro areas. It tasked the Bureau of Communications Research (BCR, now the Bureau of Communications, Arts and Regional Research, BCARR) with estimating this cross-subsidy and how it might be addressed in the presence of infrastructure competition.

Ideally, for economic efficiency prices should be cost-based to ensure efficient bypass decisions. However, the geographically uniform prices set by the NBN conceptually contain two elements: cost and a contribution to the deficit incurred in serving non-commercial customers.

There is an economically inefficient incentive to bypass the NBN when the new entrant's cost is less than the uniform NBN price. But, if a contribution from the new entrant is obtained through an 'excise tax' or levy, this can reconcile the objectives of universal access and the recovery of costs by the NBN in the presence of infrastructure competition (i.e., bypass of NBN's access network).

Laffont & Tirole (2002, p. 119) say that in some countries "*such a tax is politically unlikely and is almost never mentioned in the regulatory debate, even though it could in principle be repackaged as a tax on the whole industry (as will be the case for the funding of universal service) in order not to make it look discriminatory*". This is the approach adopted in Australia and is recommended by the author for the Cook Islands.

The figure below is drawn from data in the BCR's report (BCR, 2016) to the Australian Government, which implemented the BCR's recommendations. The horizontal axis shows users ranked by cost to serve, which is correlated with geography.

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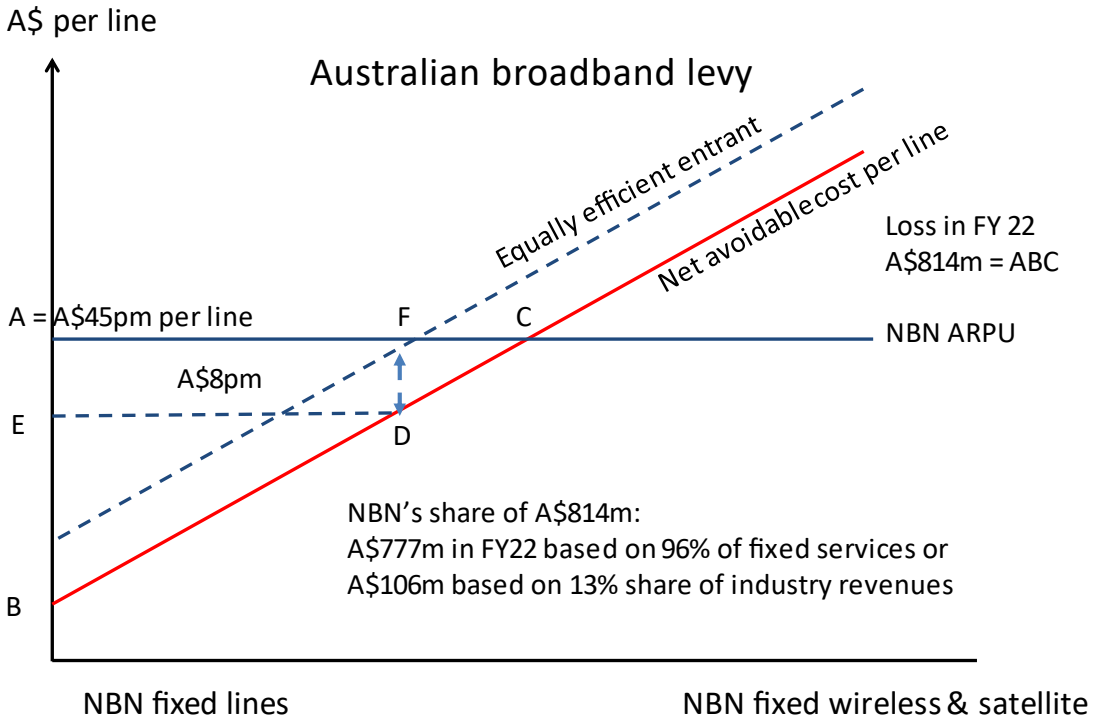

Figure 1. Australia's broadband levy, forecast for 2022

In Figure 1, the levy is A$8 per month per broadband line (the difference between F and D). Neither NBN Co.'s costs nor its prices need to change to accommodate the Bureau's proposed solution and end users between A and F can still be targeted profitably by the new entrant. Note also that, with a uniform levy, the proceeds (AEDF) are still smaller than the actual internal cross-subsidy (ABC).

The net avoidable cost for FY2022 (when the roll-out was expected to be complete) was forecast to be A$814m. The BCR's A$8 pm[i] levy is applied to every fixed broadband line capable of at least 25Mbps. Since the NBN was expected to account for 96% of such services, it would bear A$777m of the forecast FY2022 cost, with the remaining A$37m provided by other providers of fixed broadband infrastructure.

The BCR considered an alternative levy based on industry revenues, including from mobile services. This would have reduced the NBN's share to $110m (13%) and the levy would have been about 2.5% of revenue for every operator.[ii]

Cost Concepts

How should one measure the cross-subsidies that will be eroded with bypass? That depends on how the results are to be used. A classic example is the difference in opinion between the

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Bureau of Transport and Communications Economics (BTCE, now the BCARR) and Telecom (now Telstra) in the costing of Telecom's Community Service Obligation (CSO). The BTCE (BTCE, 1989, p. 6) acknowledged that:

> "*Two possible purposes were apparent from the Ministerial Statements of 25 May 1988:*
>
> *A. to determine the magnitude of the level of national resources being devoted to meeting its CSOs;* and
>
> B. *to take account of the cost of CSOs adequately in setting Telecom's financial target in the corporate plan (and in measuring the achieved rate of return ex post)".*

This led the BTCE to costing CSOs on both an avoidable cost and fully distributed cost basis to address A and B, respectively.

Two other possible public policy purposes concern whether the amount of CSOs is so large:

C. that introducing competition would undermine internal cross-subsidies; and

D. that the enterprise should be kept in the public sector.

The BCR (now the BCARR) was directed by the Australian Government (DOC, 2014) to focus on C above.[iii] This is also the focus for the Cook Islands. The notional question is: what losses would be avoided if VCI was not obliged to provide loss-making services in the Pa Enua? It is a hypothetical question.

The BCR (BCR, 2015, p. 28) struggled with the definition of avoidable costs. In its final consultation paper, it shied away from its "*proposed costing on a 'commercially focused' basis, with full distribution of common or indirect cost*" (also known as fully allocated cost, FAC). It settled on directly attributable costs including a share of common costs used in providing fixed wireless and satellite services.

Like the NBN, VCI's financial records do not identify incremental or direct costs. But we can identify both the difference between revenue and variable costs and the difference between revenues and fully allocated cost (FAC).

Using variable costs is correct only "*under conditions of market stability*" (Rodriguez & Storer, 2000, p. 289) – without market liberalisation. With prospective liberalisation, Rodriguez & Storer suggest looking at the impact on internal cross-subsidies under a range of alternative liberalisation and regulatory scenarios. This is clearly demanding and speculative in terms of the assumptions that would be needed to do that.

Using FAC assumes that the Pa Enua is making a contribution to all fixed costs, which may seem odd if the Pa Enua is not covering its own variable costs. But, echoing Rodriguez & Storer, the NBN (NBN, 2015) argued that the broadband service levy on entrants must include the contribution to the incumbent's fixed and common costs when such entry displaces the

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incumbent, citing Armstrong (2008) and also the support by the ACCC (2015) in the same consultation on the use of FAC for measuring net losses on non-commercial services in other industries including Australia Post.

In the Cook Islands depreciation and staff costs are not included in variable costs but account for over 60% of fixed costs. Beyond that, it is difficult to say what share of common costs should be included. For the BCR "*Avoidable costs are measured as directly attributable costs and a share of common costs that would be avoided if the fixed wireless and satellite networks were not rolled out"* (BCR, 2015, p. 27). The BCR does not report what difference this share of common costs makes to avoidable costs. The ACCC's update of the BCR report used a "*proportional mark-up*" (ACCC, 2020, p. 8) on direct costs without saying how much it was.

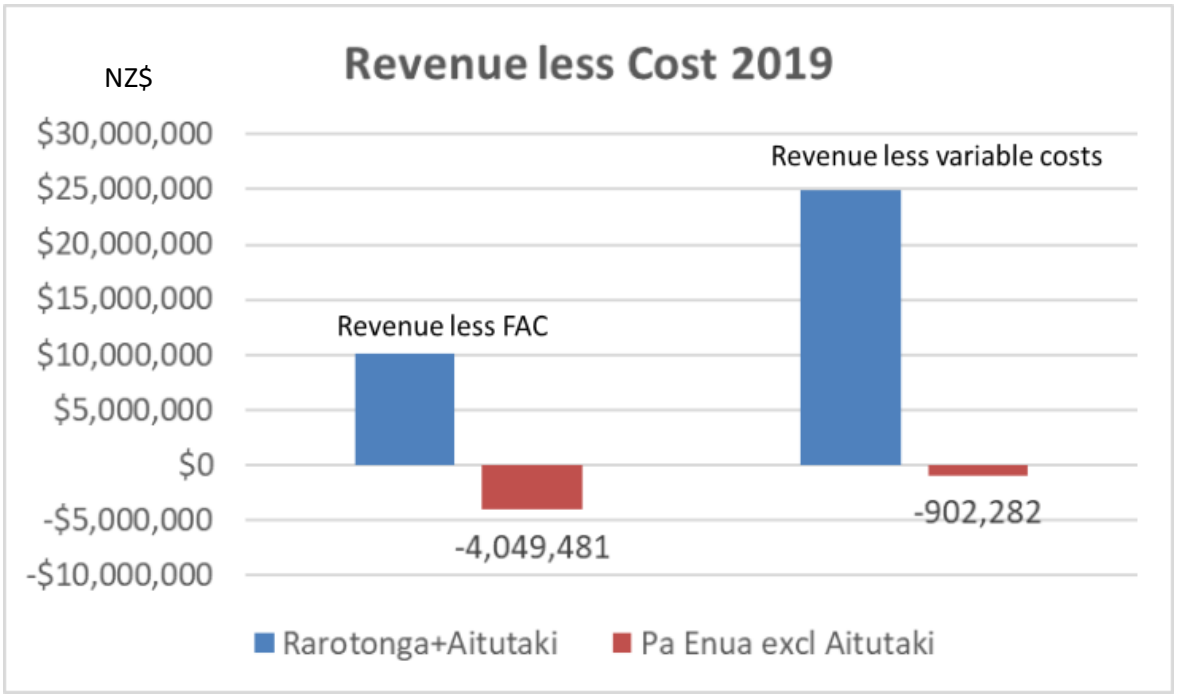

Figure 2. The range of net costs in the Cook Islands, 2019

The difference between the minimum and maximum for the Cook Islands is illustrated in Figure 2. The NZ$4.05m and NZ$0.9m net cost figures are based on FAC and variable cost, respectively. The ratio is about the same as found in the original costing of Telecom's CSO.[iv]

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Costing Losses in the Pa Enua

Cost modelling can be bottom-up or top-down. The former is a complex exercise which is beyond the resources of the Cook Islands.[v] A big advantage of top-down cost modelling is that all costs can be reconciled to audited costs and revenues.

Both the Cook Islands and Australia use a top-down modelling approach. When the BCR did its cost calculations, the NBN was only half-way through its broadband roll-out, so the BCR used the NBN corporate plan and extrapolations to 2040 to estimate the net present value of cash flows associated with the provision of fixed wireless and satellite services.

The infrastructure in the Pa Enua is established, so actual costs and revenues from 2019 were used to get a pre-COVID assessment of the internal cross-subsidy in VCI. A retail product costing model had been developed for VCI for 2019. In this model, all GL (General Ledger) revenues and costs are split in the product dimension, essentially creating one P&L (Profit and Loss) for each product. This product cost model was repurposed to estimate the internal cross-subsidy within VCI for the UAP. The main adjustments were:

1. Disaggregating the existing model by each of the inhabited islands in the Pa Enua using a geographic code for each of the 12 inhabited islands that is used when booking costs or revenues to the GL;
2. Excluding services that are not part of the UAP by excluding products that are not included in the broad definition of universal access which includes not only commercial fixed, mobile and Internet services but also emergency, operator and postal services;
3. Developing a replacement cost asset base so that a return on capital can be estimated;
4. Adding the return to capital as a mark-up on revenue.

Asset valuation

The correct asset valuation for the maintenance of operating capital is depreciated replacement cost. This can be estimated from a bottom-up (long-run incremental cost, LRIC) cost model or obtained from top-down current cost accounts (CCA).

The British telecommunications regulator (Ofcom) uses fully allocated cost (FAC) and current cost accounting (CCA; assets valued at replacement cost) as "*we consider that the use of BT's CCA FAC (or a similar approach such as LRIC+) provides efficient build and buy signals as it reflects the current replacement costs of BT's assets*" (Ofcom, 2018, Clause 2.50).

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VCI and the NBN use standard historical cost accounting (HCA; assets valued at depreciated actual costs) rather than CCA. As a short-cut, the Cook Islands looked to British Telecom, which reports on both CCA and HCA. It reports the ratio of CCA capital employed to HCA capital employed at the same date as 1.058 (Ofcom, 2019).

Using a single ratio is a shortcut and there is a complication. Over time, VCI has invested over NZ$54m. With depreciation and disposals, the depreciated actual cost (DAC or written down value) in the HCA books is $16.64m. However, NZ$18.67m of investment that has been written-off is still in service. It is not 'free' where it will need to be replaced. For these assets which will need to be replaced, the replacement cost is simply the historical cost multiplied by the same BT revaluation ratio. It is not 'double-dipping' to charge depreciation against existing assets that have been fully depreciated because it is needed to ensure productive capacity is maintained to continue service; which is why a bottom-up cost model would also value these fully depreciated assets at replacement cost.

On this basis, the depreciated replacement cost of VCI's assets is NZ$37.4m. This can be rolled forward into future years by adding investment and subtracting depreciation and disposals (the 'building block model') in order to calculate the return to capital.

WACC

The weighted average cost of capital (WACC) is a measure of what the regulated entity needs to earn in a competitive market to service its debts and satisfy its owners. Even if costs exceed revenue for any island, the owner of assets providing services is entitled to an imputed return, which would have the effect of increasing losses on that island.

Choosing a WACC is complex and contentious. Developing countries are less integrated in global markets, so asset returns are not well correlated to world returns, and there is country risk associated with developing countries (Jacobs & van Vuuren, 2015).

Assuming a 13% WACC, the return to capital generates NZ$4.8m. In 2019, VCI paid no interest and dividends (the return to equity) do not appear in its GL, as they are taken out of net profits. Note that VCI can pay whatever dividend it chooses but the CRA must form its own estimate of the return to capital for regulatory purposes.

Rather than changing the GL, the return can be applied as a mark-up on costs. The 13% WACC (NZ$4.8m) translates into a 15% mark-up.

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Cost Results

The net cost per head of providing services in each of the inhabited islands of the Pa Enua is shown in Figure 3. Only Aitutaki (and, of course, Rarotonga) covers its variable costs – see the red line in Figure 3.

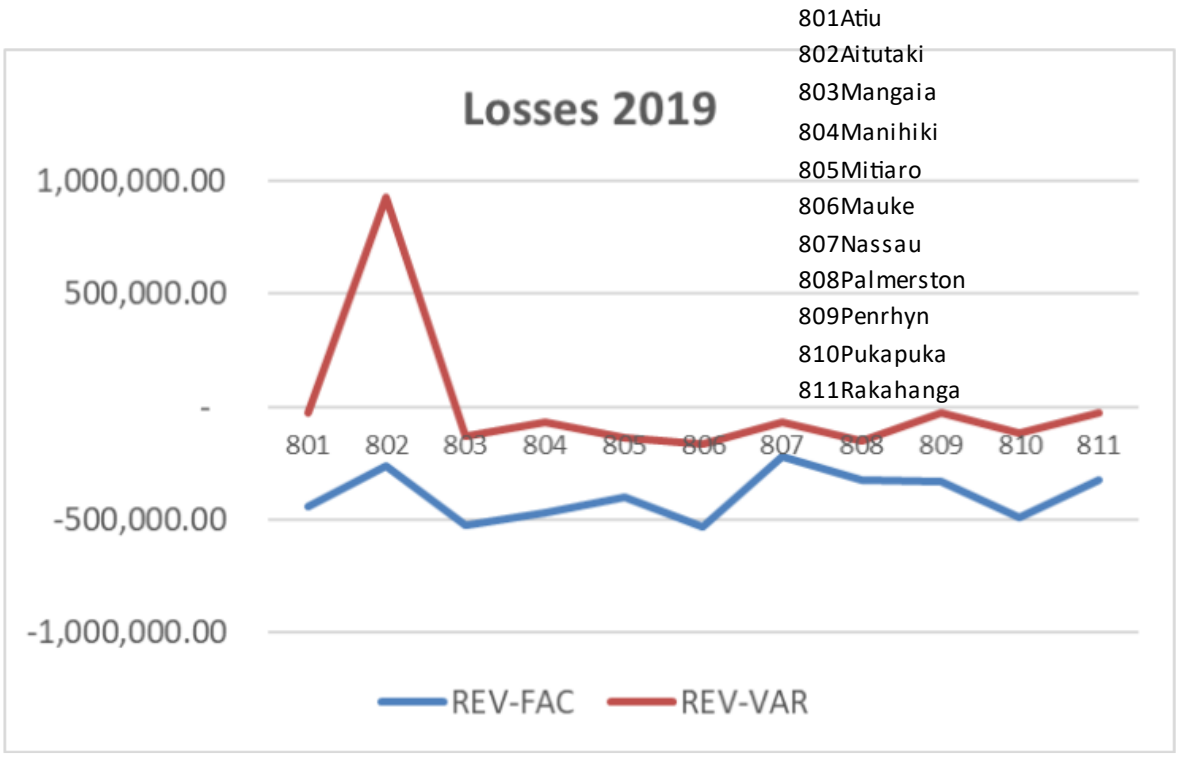

Figure 3. Net losses in each of the Outer Islands, 2019

The corollary of these results is that the islands of the Pa Enua are not attractive markets for new entrants because the markets are small and prices are below cost. Ideally, prices would rise to cover costs, but this could make services in the Pa Enua unaffordable and that is politically unacceptable. The UAP will try to reconcile commercial and political needs.

Funding Options

The current internal cross-subsidy that funds UAP services for the Pa Enua needs to be replaced with a different, sustainable regime.

Cross-subsidy

UAP services in the Pa Enua have been funded by an internal VCI cross-subsidy, which we now know to be worth up to NZ$4m in 2019. This worked well until COVID knocked a hole in tourism and VCI's revenues and reduced its ability to cross-subsidise the Pa Enua. The internal

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cross-subsidy cannot be expected to work in a competitive environment where its competitor(s) target VCI's most lucrative market segments.

Government

The Cook Islands Government requires VCI to maintain universal access services in the Pa Enua with uniform pricing while liberalising the market, making the current internal cross-subsidy unsustainable. It could pay VCI directly out of taxes. That would be appropriate in the situation where the cross-subsidy mechanism broke down with COVID. More generally, for developing countries the tax system is not ideal for transfers and is subject to political vagaries.[vi]

Foreign aid

The New Zealand Government has generously provided a once-off NZ$3m contribution towards a UAP fund. This will be needed to cover the administration of the UAP scheme over time and could also be used to fund new projects proposed by groups of end users which could also be made contestable in supply.

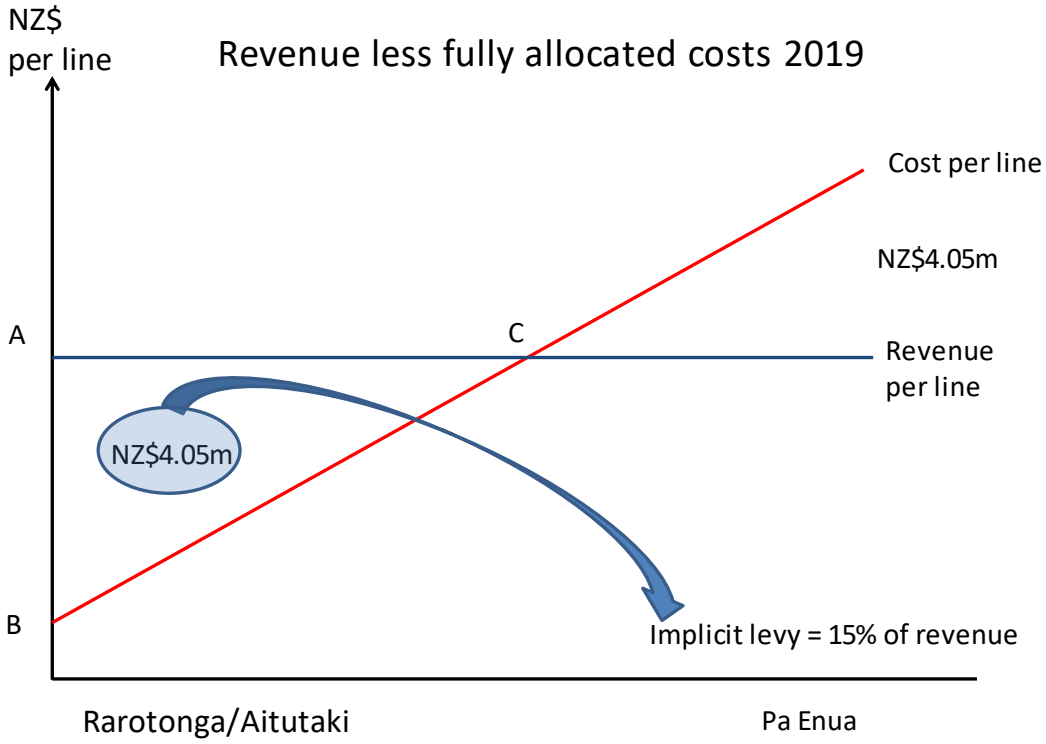

Figure 4. The Cook Islands levy, 2019

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Industry levy

As noted above, the current internal cross-subsidy can be seen as a component of retail prices. The BCR expressed the NBN's cross-subsidy as a levy on all broadband lines. Expressing a levy in terms of revenue was considered and is the same as the approach used in Australia for the standard telephony USO, which is recovered as almost 1% of eligible revenues from each industry operator.[vii] For the Cook Islands in 2019 (Figure 4), VCI is the industry and the NZ$4.05m net cost of service for the Pa Enua is offset by the internal cross-subsidy (ABC in Figure 4). This amount is effectively 15%[viii] of the revenues of Rarotonga plus Aitutaki.

VCI and its competitor(s) could contribute 15 cents in every dollar of revenue in profitable areas to meeting the net costs of providing universal access services in the Pa Enua.

Universal Service and Access Pricing

Receiving 15 cents in every dollar of revenue that VCI loses is not going to guarantee universal service is sustainable.

Universal service and competition have to be approached holistically, looking at both the UAP and access pricing. The universal service levy makes the internal cross-subsidy explicit while competition erodes the cross-subsidy. While imposing the levy on new entrants helps, regulated access pricing complements this to support efficient competition. Below, we look at how wholesale pricing of domestic roaming and interconnection could be treated in the Cook Islands.

Opportunity cost underpins the approach to costing the UAP and it also underpins the 'retail minus' approach for resale to be used in the Cook Islands.

This is unlike Australia where the approaches to costing the USO and costing of access prices are completely different. The former is managed by the Australian Communications Authority (ACA, now ACMA), which uses the net avoidable cost approach taking account of foregone revenues. Access pricing is managed by the Australian Competition and Consumer Commission (ACCC), which looks only at long-run incremental costs (TSLRIC); unless the outcome is too high, when retail-minus was used for local calls.

Even though the cost of the USO was less than Telstra thought it should be,[ix] others thought it was too high and clamoured for contestability in the provision of the services and areas covered by the USO scheme. The ACCC told the 2004 inquiry into the future funding and contestability of the USO (DCITA, 2004) that there was an arbitrage opportunity because the access prices that a contestant paid Telstra to provide services were lower than the USO

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subsidy. In fact, when competitive tenders were issued for two large pilot areas in 2001, nobody applied. Either USO subsidies were too high or access prices too low – take your pick.

Domestic roaming

Domestic roaming is an example of access pricing important to a new mobile entrant. It would allow a new entrant's end users to make or receive calls anywhere in the Cook Islands using VCI's network.

The islands of the Pa Enua are too small to justify requiring any new entrant to roll out network there, so domestic roaming will be necessary to provide coverage and VCI will have to be the designated Universal Access Provider.

The CRA can specify how resale prices such as roaming charges are set (Government of the Cook Islands, 2019). One method is a discount on retail prices, which is closely related to the efficient component pricing rule (Baumol, Ordover & Willig, 1997). The key element of the rule is that the cost of access includes not only the marginal costs (i.e., as measured by, say, TSLRIC) but also the 'opportunity cost'.

ECPR Pricing

The efficient price of access is the marginal cost plus the opportunity cost,

$$Aec = Ca + (Pr - Cr - Ca) \quad (1)$$

where Aec is the ECPR access price, Pr is the retail price, Ca is the marginal cost of providing access and Cr is the marginal cost of providing retail service. (Pr - Cr - Ca) is the opportunity cost.

This rule ensures that the access provider cannot 'price squeeze' its wholesale customers if the access provider's retail price satisfies:

$$Pr > Cr + Aec \quad (2)$$

Retail-Minus

The retail-minus access price is the same as (2):

$$Arm = Pr - Cr \quad (3)$$

The access fee is the efficient component price (Aec) or the retail-minus price (Arm).

Ca is the marginal cost per minute of terminating a voice call on VCI's mobile or fixed networks. This does not apply for interconnection, as the Cook Islands has legislated 'sender keeps all' (SKA). But Ca is needed for ECPR and for some call cases discussed below. The retail product cost model shows the FAC per call minute, including the 15% mark-up for WACC, as

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30 cents for termination on the fixed network and 22 to 25 cents for fixed and mobile calls terminating on the mobile network.

Cr is the retail cost avoided by VCI when it is not providing the retail service. One study found *"Retail costs are generally considered to lie in the range of 20-25% of retail revenues"* (WIK Consult, 2012, p. 78).[x] For demonstration, it is assumed to be 8 cents per minute for both fixed and mobile service.

Pr is VCI's retail price of the voice service replaced by domestic roaming. For the purpose of demonstration, it is assumed to be 38 cents per minute for both fixed and mobile calls.

Table 1. Example parameters and calculation of Efficient Access Price

Voice Call	Pr	Cr	Ca	Aec
Mobile to Mobile (M2M)	0.38	0.08	0.25	0.30
Mobile to Fixed (M2F)	0.38	0.08	0.30	0.30
Fixed to Mobile (F2M)	0.38	0.08	0.22	0.30

The efficient access price (Aec) is always higher than the marginal cost of access (Ca). The difference is the opportunity cost defined as retail price less retail costs less marginal cost of access (Pr-Cr-Ca). If either Cr and/or Ca is high, the opportunity cost is low. The level of Ca does not affect Aec because variations in Ca are offset by corresponding changes in the opportunity cost.

The ECPR has a negative press because it includes VCI's foregone profits (opportunity cost) of providing access. But that aspect of ECPR should make VCI indifferent to providing the retail service itself or providing access so the new entrant can provide the service. The idea is that, if the retail cost per minute for the new entrant is lower than for VCI, it should be able to make a profit. While that might be difficult, ECPR provides strong incentives for the new entrant to build out its own network with 'sender keeps all'.

Network interconnection

Clause 44 of the Cook Islands Telecommunications Act (Government of the Cook Islands, 2019) specifies 'bill-and-keep' (BAK or SKA) as "*the primary principle for interconnection*", subject to traffic balance with no threshold yet specified.[xi] It is proposed that it should not apply to all call cases.

The general case where SKA applies is where the new entrant has built a network in, say, Rarotonga and one of its customers calls another person who is on VCI's network in

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Rarotonga. SKA means that VCI terminates the call from the new entrant at no charge; and vice versa.

It should be left to VCI and the new entrant to commercially agree what the threshold for a traffic imbalance should be, over what period it is measured and what the settlement process should be.

The second case concerns the interconnection principle that terminating traffic is delivered at the point of interconnect (POI) nearest to the called party. If the new entrant's customer on its network in Rarotonga calls someone on an outer island but hands over the call to VCI in Rarotonga because it does not have a local POI in the Pa Enua, this is domestic transit. It is proposed that the Aec fee for M2M or M2F should apply. The entrant is unlikely to make any money on this call, but at least it will have national coverage.

The third case is domestic roaming where the new entrant's customer is in the Pa Enua and makes a call back to Rarotonga. Again, it is proposed that the Aec fee for M2M or M2F should apply.

The fourth case is the termination of inbound international calls. The new entrant will have an international gateway and will be able to negotiate settlement rates with international carriers, as VCI does now. VCI should be charged for termination of calls received from the new entrant's international gateway; and vice versa. The charge could be Ca or commercially negotiated. Since overseas carriers can easily and quickly switch all their traffic towards either VCI or the new entrant, this would force VCI and the new entrant to compete towards Ca.

If, say, the new entrant is handling all inbound international calls, the charge by VCI for calls terminated in the Outer Islands should still be Ca.

There are no guarantees that the reduced inbound termination rates caused by VCI and the new entrant competing for this business will flow through to the retail rates faced by overseas users calling the Cook Islands. But that would be desirable.

Conclusions

The purpose of this paper was to compare how the Cook Islands and Australia have approached supporting cross-subsidies in the presence of infrastructure competition.

Both countries decided that the cross-subsidy implicit in uniform pricing can be made explicit as a levy. While the broadband levy in Australia is expressed as a levy on every fixed broadband line, Australia recovers the cost of the standard telephony universal service obligation as a share of each operator's eligible revenues. The Cook Islands will probably express the levy as a share of revenues.

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Both countries use cost models to estimate the size of the cross-subsidy that needs to be recovered from industry operators. Both used a top-down modelling approach. The BCR used the NBN corporate plan and extrapolations to 2040 to estimate the net present value of cash flows associated with the provision of fixed wireless and satellite services. The Cook Islands repurposed VCI's financial accounts to estimate net losses by island.

There are differences in deciding how much of the common costs to include. In the context of market liberalization in the Cook Islands, it is recommended that all costs are allocated (FAC).

In Australia, the approaches to costing universal service and setting access prices are different. The former respects opportunity cost, while access pricing recognizes only marginal (TSLRIC) costs.

In the Cook Islands, the access price for interconnection is zero (SKA, subject to balanced traffic) but it is proposed that other wholesale prices are set by 'retail-minus', which includes opportunity cost. This aligns the approaches to costing universal service and setting access prices.

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Endnotes

[i] The original $7.10pm indexed at an expected CPI increase of 2.5% pa was due to begin in 2017 but with legislative delays did not start until January 2021 at a rate recalibrated by the ACCC in 2020 (ACCC, 2020).

[ii] Estimated from NBN revenue as 8m SIOs x $45 x 12 = $4,320m pa. So, $106m/$4.320m = 2.5%.

[iii] *"The Bureau of Communications Research (the policy research arm of the Department of Communications) will undertake an assessment of the costs of NBN Co's fixed wireless and satellite services, which serve many non-commercial parts of Australia, and provide options to Government for replacing the current opaque NBN Co cross-subsidy embedded in its wholesale access prices with more transparent funding arrangements. … The cross-subsidies which are currently embedded in NBN Co's wholesale prices will be replaced by transparent funding provided via contributions sourced from owners of high-speed broadband access networks that target residential and small business customers – i.e. the NBN and networks in commercially viable areas that are comparable to the NBN. There will be no additional costs to consumers relative to current NBN pricing – an opaque part of the cost of the NBN will be made explicit".* (DOC, 2014, p.6)

[iv] The BTCE (1989) CSO estimates were: $230m for avoidable cost and $800m for fully allocated cost (discounting at 13.6% for both); excluding payphones.

[v] It would raise the issue of modern equivalent assets (MEA or what the replacement technology should be). The uncertainty that came with repeated bottom-up costing of assets is what led the industry to support the ACCC's shift to the once-only asset valuation in its building block model (ACCC, 2011).

[vi] "*when fiscal efficiency is very limited … (as) is likely to be met in many (developing countries), cross-subsidies should be encouraged as the most efficient way to bring consumers onto the network*" (Estace & Wren-Lewis, 2009, pp. 749–750).

[vii] Divide assessed standard telephony USO levies at ACMA November 2020 (ACMA, 2020b) by eligible revenues reported at ACMA July 2020 (ACMA, 2020a). The total net USO cost for 2019-20 recovered by these levies was $244m.

[viii] It is only a coincidence that the levy is 15% while the mark-up for the WACC is 15%. The former comes from the net cost and revenue on the two main islands, while the latter comes from the WACC times asset base as a share of total revenues.

[ix] The original $230m was indexed to the CPI in 1995 while Telstra developed a detailed cost model. Then Telstra lodged a USO claim of $1,828m for 1997-98. The Australian Communications Authority spent two years building its own model, yielding an estimate of $548m, less than a third of Telstra's claim but more than twice the original estimate. The Communications Minister pre-empted the result with legislation to cap the 1997-98 claim at $280. See Parliamentary Library E-Brief (Jackson, 2000) for details.

[x] An earlier 2007 study (Kim & Seol, 2007) quotes estimates for S. Korea ranging from 20% to 27%.

[xi] For voice calls, there is a reasonable prospect that traffic will be balanced. Suppose that there are two networks with 10 and 90 customers. If the probability of any customer calling any other is the same, then the traffic each way will be equal. There is a 90% chance that customers of the smaller network will make off-net calls and a 10% chance that customers of the larger network will make off-net calls. However, probabilities will be altered by various plans (e.g., get your friends on the same network to exploit the free-hour) or customer type (some make more calls than they receive).

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Regional Mobile Telecommunications Performance

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Abstract: Mobile Telecommunications is an essential service that fundamentally affects quality of life by improving communication, the ability of business and industry to improve productivity and for the nation to compete successfully in the global digital economy. There are three fundamental and measurable parameters that, when combined, provide the basis upon which judgements about mobile telecommunications can be made. The parameters are cost, access and performance. Information is readily available about the first two parameters. Quantifiable information is not available about performance. Regional mobile telecommunications is further complicated by factors including population density, the cost of transit or backhaul and infrastructure subsidies. This paper provides a discussion on regional mobile telecommunications performance and focuses on throughput (capacity). The paper recommends that regional mobile telecommunications performance data be collected and that minimum performance standards for regional mobile telecommunications be legislated.

Keywords: Telecommunications, Mobile, Broadband, Access, Regulation

Introduction

Mobile telecommunications is an essential service that fundamentally affects quality of life by improving communication, the ability of business and industry to improve productivity and for the nation to compete successfully in the global digital economy.

There are three fundamental and measurable parameters that, when combined, provide the basis upon which judgements about mobile telecommunications can be made. The parameters are cost, access and performance. This paper focuses on performance and, in particular, throughput (capacity).

Cost includes the capital cost of infrastructure and devices used to connect to the mobile network and the ongoing operational costs including the monthly plan charges. For consumers, the cost of the mobile network plans is readily available on the mobile network operator websites.

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Access is being able to connect to the mobile telecommunications network at home and at work and with the requisite knowledge to utilise the applications and services (especially government services) provided over the mobile telecommunications network (Infrastructure Australia, 2020). Access also includes service reliability and other impacts that might reduce access. Mobile network operators provide coverage maps on their websites.

Performance is being able to reasonably utilise mobile telecommunications for voice and video calls and to utilise applications and services over the Internet utilising mobile telecommunications broadband data. Measures which can be used to assess performance in mobile telecommunications networks include upload and download speeds, ping time, latency, jitter and packet loss, application processing time, transit link delay, amongst others. Mobile telecommunications performance will vary due to a variety of technical and non-technical factors, such as access network and backhaul capacity, distance from towers, carrier frequency, technology employed, content delivery networks, terrain, weather, and network congestion.

In Australia every three years, the Government appoints the Regional Telecommunications Independent Review Committee (RTIRC) to conduct a review into regional telecommunications in regional, rural and remote parts of Australia (RTR, 2021a).

Complaints about mobile telecommunications in regional, rural and remote areas of Australia gain media coverage, but achieving outcomes based on the complaints can be difficult, particularly related to performance (Richards, 2020; Smith, 2021; Herrmann, 2021; Mills, 2021; Ward & Schremmer, 2021).

In 2018, the RTIRC Report titled *2018 Regional Telecommunications Review – Getting it right out there* (Edwards *et al.*, 2018) made the following recommendations related to cost, access and performance:

1. Cost. Recommendations 3, 8, 9.
2. Access. Recommendations 1, 2, 4, 7, 8, 10.
3. Performance. Recommendation 6.

On 2 June 2021, the Government announced (Coulton, 2021) the RTIRC to undertake the 2021 RTR and provided the Terms of Reference (ToR) (RTR, 2021b).

A review of the eight ToR sections related to cost, access and performance indicates:

1. Cost. Sections 1, 4, 5.
2. Access. Sections 1, 2, 4, 5.
3. Performance. Sections 1, 4.

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Sections 1 and 4 contain generic references to performance that do not identify requirements for data, nor tangible performance outcomes. Sections 1, 6, 7 and 8 relate to the requirement for the committee to carry out public consultations and consultations with people in regional, rural and remote parts of Australia (Section 3), the requirement for a report (Section 6) containing recommendations to the Australian Government, a requirement for the committee to assess the costs and benefits when formulating recommendations (Section 7), and the report submission deadline of 31 December 2021 (Section 8.)

Performance Measures

In this section several factors affecting regional mobile telecommunications performance are discussed. For the consumer, cost, coverage and connection speeds are the three factors that are most visible either through the mobile network operator websites or through media advertising (Ward, 2021; Bushell-Embling, 2020; Fletcher, 2021; Waring, 2021). Advertising related to the performance of mobile networks has, on occasion, been found to make representations that have ended up in court (Reichert, 2018; Arboleda, 2018; Wilkinson, 2020).

Coverage and connection speeds

To gain an understanding of "real-world" coverage and connection speeds it is necessary to read the legal risk mitigation disclaimers provided by the mobile network operators. Often, the disclaimers cover more than one of the mobile network technologies, affording the opportunity to do a comparison. In an online statement about Telstra 4GX, the carrier states (Telstra, 2021a):

> "The Telstra Mobile Network offers 4GX in all capital CBDs and selected suburban and regional areas and is progressively rolling out to more places. In other coverage areas around Australia you'll automatically switch to our fastest available 4G or 3G. Check coverage at telstra.com/coverage.
>
> In 4GX areas, typical download speeds are 2-75Mbps for 4GX category 4 devices, 2-100Mbps for 4GX category 6 devices and 5-150Mbps for 4GX category 9 devices.
>
> With a Telstra 4G device in 4G areas, typical download speeds are 2 – 50Mbps.
>
> Speeds vary for reasons like location, distance from base stations, terrain, user numbers, hardware/software configuration, download source and upload destination. To check the coverage and available speeds in your area, see our coverage."

There are two points of interest made in this statement. The first is that Telstra identifies download connection speed ranges for phone categories. Secondly, the low end of the

http://doi.org/10.18080/jtde.v9n3.444

connection speed range starts at 2 Mbps irrespective of the mobile technology and phone category. The statement does not provide connection speeds for typical scenarios, e.g., standing outside on a clear or cloudy day 500 m from and with clear sight of a mobile base station.

It is important to note that the statement found on the Telstra website is being used as a guide in this paper for two reasons. First, Telstra states that "we cover more than 2.5 million square kilometres – that's 1 million square kilometres more than any other network" (Telstra, 2021b). Secondly, Telstra is the largest carrier and currently it is the Universal Service Obligation (USO) (USO, 2021) provider. Telstra's statement is indicative of the language provided by carriers regarding mobile telecommunications access and typical download speeds.

Location and processing times

It should be noted that application processing time, which is the time taken by an application to process a message after receiving it and to send a response, is a factor under the control of the carriers and the third-party companies that provide the applications and services, but that, for clarity of this paper, this discussion is beyond the scope of this paper.

Another factor that should be considered affecting regional mobile telecommunications performance is the location of the data centres that host most of the applications and services (including content) accessed by end users. A survey of the literature, including online, journals and conference papers, government sources and company documents, did not find any studies that identify the number, distribution or location of the applications and services accessed by mobile telecommunications users.

Streaming media providers have been quick to utilise content distribution network providers and have provided carriers with proxy servers. This has helped with reducing the complaints sent to the Telecommunications Industry Ombudsman (TIO) about buffering and poor performance.

The number of applications and services hosted in data centres in Sydney, Melbourne and overseas is unknown; however, it is reasonable to assume that most of the content is hosted there.

Application performance related to number, distribution, location and processing times is measurable, and, if this was done, the information gathered would have substantial value, when it is combined with other measures, to customers because it would provide more information that they can use when they choose their mobile plan.

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Detrimental performance can occur due to distance to the data centres (latency), the available network capacity provisioned onto the transit (backhaul) links, and the capacity provisioned to each of the mobile base stations.

A mechanism to alleviate performance degradation due to latency and packet loss is to ensure that there is sufficient network capacity. A secondary, but also important, mechanism to improve mobile telecommunications performance is to distribute the applications and services closer to end users, e.g., at edge data centres.

Discussion

Performance studies

A survey of the literature including online, journals and conference papers, government sources and industry sources did not uncover any rigorous studies into the performance of mobile telecommunications in regional, rural and remote areas of Australia. Discussion related to regional mobile telecommunications performance has occurred in the RTR reports, but only in the context of more needs to be done to improve performance (RTR, 2021a).

Infrastructure Australia (2020) has also identified that more needs to be done about mobile telecommunications coverage and performance in regional and remote areas. In an early-stage proposal (stage 1) on *Mobile telecommunications coverage in regional and remote areas*, Infrastructure Australia states that the proposal is to "improve the availability and quality of mobile services in certain regional and remote areas". The proposal does not appear to have moved forward with the next step identified as "Proponent(s) to be identified".

Telecommunications performance is often measured and compared using connection speed tests conducted by users on third-party testing sites (Ookla, 2021). The carriers themselves often also provide access to the third-party connection speed test tools (Telstra, 2021c). However, since most of the applications, services and content required by users is not hosted on the carrier networks but in data centres located in Sydney, Melbourne and overseas, third-party organisations that connect to or operate content delivery networks can provide a more representative result. The third-party organisations, such as Ookla and the crowd-sourced OpenSignal, provide a generic insight into one aspect of mobile telecommunications performance, which is the latency and upload and download speeds between the end-user device and the server hosting the speed test application.

Whilst the generic connections speed tests do not provide a comprehensive measure for mobile telecommunications performance, they do provide a valuable but limited insight.

http://doi.org/10.18080/jtde.v9n3.444

For example, the Telstra mobile network connection speed tests in Western Australia are carried out between end-user devices and the application servers located in Perth. If the vast majority of applications and services are located in data centres in Melbourne, Sydney and overseas, what effect does the transit link from Perth to the data centre have?

The mobile network connection speed test servers appear to be located in the capital cities in each state and territory. This provides an opportunity for the following equity related questions to be answered:

1. Are the mobile network connection speeds and latency consistent between states and territories?
2. Are the mobile telecommunications connection speeds and latency experienced in regional, rural and remote areas of Australia similar to that in urban areas of Australia?
3. What is the latency for each of the interstate and territory transmission links?

Access

In 2015, I argued for a universal access regime in the paper titled *The Rationale for Universal Access to Digital Services* (Gregory, 2015) that enshrines the principal of "ensuring that federal, state and local egovernment and other specified digital services are reasonably accessible to all, on an equitable basis, wherever they work or live".

The principal of universal service upon which the proposed universal access regime is based is a long-standing consumer protection that ensures everyone has access to landline telephones and payphones regardless of where they live or work (USO, 2021). There is an understanding that the performance of the landline telephones and payphones covered under the USO would meet industry standards and guidelines and be similar, irrespective of where the infrastructure is located. The performance criteria to be met by the current USO provider, Telstra, for fixed-line and payphone standards and benchmarks are contained in the Telecommunications (Consumer Protection and Service Standards) Act 1999 (TCPSS Act) (TCPSS, 2020).

Section 115 of the TCPSS Act provides for the required performance standards and subsection 115(1) states that the Australian Communications and Media Authority (ACMA):

> "may, by written instrument, make standards to be complied with by carriage service providers in relation to:
>
> > (a) the making of arrangements with customers about the period taken to comply with requests to connect customers to specified kinds of carriage services; and

http://doi.org/10.18080/jtde.v9n3.444

(b) the periods that carriage service providers may offer to customers when making those arrangements; and

(c) the compliance by carriage service providers with the terms of those arrangements; and

(d) the period taken to comply with requests to rectify faults or service difficulties relating to specified kinds of carriage services, where the rectification follows the making of a customer report about a fault or service difficulty; and

(e) the keeping of appointments to meet customers, or representatives of customers, where the appointment relates to:

(i) a connection of a kind covered by paragraph (a); or

(ii) a rectification of a kind covered by paragraph (d); and

(f) any other matter concerning the supply, or proposed supply, of a carriage service to a customer."

Section 117B of the TCPSS Act provides for performance benchmarks and subsection 117B(1) states that "the Minister may, by legislative instrument, set minimum benchmarks in relation to compliance by carriage service providers with a standard in force under section 115."

Following deregulation of the Australian telecommunications market in the 1990s, the focus has been on access to telecommunications and the government has facilitated 'Black Spot' programs (Australian Government, 2021) to provide government funding to mobile telecommunications carriers to build infrastructure in areas of need that might not otherwise be covered.

It is arguable that access and the cost of providing access has been somewhat quantified and government, government agencies and the carriers have the information necessary to make justifiable decisions related to the provision of access, sometimes at taxpayer expense.

Utility

It is possible for cost to be reasonable and access to be available but for the utility of mobile telecommunications to be poor.

For example, in 2018, I proposed four options for the future ownership of NBN Co beyond 2022, when the National Broadband Network (NBN) is expected to be built and fully operational (Gregory, 2018). What that paper did not address was what performance users of the NBN should expect before or after the NBN completion date, and this question highlights

http://doi.org/10.18080/jtde.v9n3.444

the similarity between the NBN and mobile telecommunications, particularly when it comes to the question of utility.

The Australian Competition and Consumer Commission (ACCC) commenced a Measuring Broadband Australia (MBA) program to monitor the NBN connection speeds and latency in 2018, eight years after the NBN rollout commenced (ACCC, 2021). In the years prior, a rising number of complaints about NBN connection performance from advocates and consumers convinced government to fund the ACCC program, and this program has now been extended for a second term until 2025.

In a review of the program, the ACCC reported (ACCC, 2021) that the program is the "only independent source of reliable broadband performance information" and that:

> "The Measuring Broadband Australia program is an important component in furthering the Government's priority to facilitate consumer access to affordable and reliable communications services, irrespective of where consumers live or work. It is also a key element of the ACCC's integrated strategy for improving competition and consumer outcomes in broadband markets, along with our Broadband Speed Claims guidance and enforcement actions. This approach has successfully assisted in the delivery of improved market outcomes for consumers of high speed broadband services."

The ACCC states that "the MBA program is a light touch, market based measure that increases competitive pressure on RSPs to deliver the performance they represent to the market". The ACCC argues that this light-touch approach has led to a decrease in the number of underperforming services and an increase in download speeds of monitored services.

The ACCC draws upon the support of regional, rural and remote consumer advocate groups that expressed in 2018 strong support for the program and for it to be extended to cover NBN fixed wireless and satellite services (Edwards *et al.*, 2018).

Whilst the MBA program has only been partially successful in achieving improved connection speed and latency for NBN fixed access customers, the alternative, no MBA program, would be unimaginable to consumer advocates. In other words, the data that the MBA program has provided has been vital in the effort to improve NBN performance and consumer outcomes.

The outcomes have been promising but limited by the "light-touch" approach adopted by the ACCC and the failure of government (1) to acknowledge the mistake to shift from FTTP; and (2) to mandate a rapid rollout of FTTP to 93 per cent of premises.

http://doi.org/10.18080/jtde.v9n3.444

The question remains, what will the minimum performance be for NBN consumer connections when the MBA program ends in 2025, or will government be forced to continue to fund this program indefinitely?

The cost of mobile telecommunications for users in regional, rural and remote areas of Australia is equitable with the cost for users in urban areas. The tier one Australian mobile network operators offer mobile plans consistently to all consumers, irrespective of where they live or work.

From a consumer perspective, mobile telecommunications performance is about the utility of mobile telecommunications to successfully carry out voice and video telephone calls and to be able to fully utilise applications and services over the Internet utilising mobile telecommunications broadband data.

Preliminary Study

There is an identifiable lack of data related to regional mobile telecommunications performance. Without quantifiable data, government is not able to formulate reasonable policy and regulations.

Consumers can, of course, complain to the TIO about the performance of their mobile telecommunications service; however, without an objective measure of what constitutes acceptable 'performance', it is challenging for the TIO to act. Further, the number of complaints about regional mobile services is low when compared to the number of overall complaints about the NBN. This is to be expected when the number of people living and working in regional, rural and remote areas is significantly smaller than the number of NBN subscribers.

Due to deficiencies in the data available from the TIO, it is difficult to identify TIO complaint figures related to regional mobile telecommunications and it is therefore problematic to refer to TIO data outputs (TIO, 2020) when discussing the state of regional mobile telecommunications.

To investigate the issue, a preliminary study of regional mobile telecommunications performance was carried out during July and August 2021 in South Australia, Northern Territory and Western Australia. The Telstra mobile network was used for the connection speed and latency tests for two reasons: (1) availability of a 3G/4G/5G phone connected to the Telstra network; and (2) in many areas traversed, the only provider is Telstra.

It is important to identify that this was an exploratory study and the results are not rigorous and therefore not suitable for publication. The purpose of the exploratory study was: (1) to

http://doi.org/10.18080/jtde.v9n3.444

follow up on a number of requests that were received for regional mobile telecommunications performance to be investigated; and (2) to identify if a rigorous study should be carried out.

Connection speed and latency tests were not carried out in every location traversed due to the time available.

There were three high-level outcomes identified from the exploratory study:

1. Across all regional areas studied, the average connection speeds were between 0-10 Mbps download and 0-2 Mbps upload.
2. Most small cells near mining sites had download and upload connection speeds above 20 Mbps.
3. Connection speeds in more than five major regional centres in Western Australia were between 0-10 Mbps download and 0-2 Mbps upload.
4. Connection speeds greater than 50 Mbps download and 20 Mbps upload were only achieved in Perth and Kalgoorlie.

In all cases, the measurements were taken with clear line of sight to the mobile base stations, on a clear or cloudy day and with the distance to the mobile base stations of between 500 m to 750 m. Other measurements were made and are not referred to here, such as measurements made whilst in transit; however, none of these measurements were inconsistent with the performance observed.

Discussion

It is my view that, based on the outcomes of the preliminary study, there is an urgent need for a rigorous study of regional mobile telecommunications performance. This study should include connection speed and latency tests, transit latency and capacity, and number, distribution, location and processing times of applications and services utilised by regional mobile telecommunications users (particularly government digital services).

As with the NBN, there is an urgent need for the ACCC to develop minimum mobile telecommunication service expectations that go beyond the flawed "light-touch" approach that is currently in favour at the ACCC for NBN services.

When the MBA program ends, there could be a reversion of NBN connection performance to a previous state that is detrimental to consumers. Also, the ACCC does not have a full and clear understanding of factors affecting performance, as it does not appear to be considering the parts of the networks beyond the access network.

The Australian mobile telecommunications industry is self-regulated. To improve customer outcomes the government should direct the Australian Communications and Media Authority (ACMA) to work with the industry peak body, Communications Alliance, to develop an

http://doi.org/10.18080/jtde.v9n3.444

industry standard covering mobile telecommunications performance that includes standard scenarios, connection speeds and capacity.

Domestic Mobile Roaming Declaration

An ACCC domestic mobile roaming declaration inquiry was completed on 23 October 2017 (ACCC, 2017). The inquiry outcome was a decision by the ACCC to not declare domestic mobile roaming. The ACCC stated that it was "not satisfied that declaration would promote the long-term interests of end-users". The ACCC released a paper titled *Measures to address regional mobile issues* that contained proposals for "a number of measures to improve mobile services in regional areas".

The rationale for the ACCC decision was fundamentally flawed. The proposals related to performance identified in the ACCC paper do not appear to have been achieved, and a review has not identified an ACCC work program that will lead, in a reasonable time, to the proposals being achieved.

In the years since this decision, the disparity between the Telstra regional mobile telecommunications network and the competitor networks appears to have increased (Telstra, 2021b), Telstra continues to attract the majority of Black Spot funding from the Federal and State governments (Telstra, 2021d) and there does not appear to have been a substantive change in the amount of regional Australia that is covered by more than one mobile network operator.

The ACCC paper states that "there is a need for better transparency about network coverage, quality, expansions and improvements", yet this does not appear to have occurred. The ACCC paper also states that "network coverage and quality information is inaccurate and lacks transparency".

The ACCC paper provides strong and justifiable arguments for a declaration of domestic mobile roaming to be made, yet the "light-touch" ideology that appears to be in favour at the ACCC means that the declaration was not made in 2017.

On 22 February 2018, the ACCC hosted a forum (ACCC, 2018) with stakeholders to discuss the issues raised in the *Measures to address regional mobile issues* paper. The summary of findings from session 1 includes the statement that "improvements are needed in the provision of accurate, comparable and reliable information on the quality and extent of mobile coverage".

The mobile network operators provide coverage maps on their websites and, whilst the coverage maps cannot be replicated with the information available, it is possible to gain an insight into the "extent of mobile coverage".

http://doi.org/10.18080/jtde.v9n3.444

"Accurate, comparable and reliable information on the quality" of mobile coverage does not appear to be available in any form. It does not appear to be available on the mobile network operator websites, nor does it appear to be available from the ACCC or any other government agency.

The only information available on the mobile network operator websites appears to exist in disclaimer form, as if to ensure that performance, whether poor, reasonable or good, is covered by a legal risk mitigation statement.

For example, Telstra's website (Telstra, 2021a) contains the statement "with a Telstra 4G device in 4G areas, typical download speeds are 2 – 50Mbps" and "[i]n 4GX areas, typical download speeds are 2-75Mbps for 4GX category 4 devices, 2-100Mbps for 4GX category 6 devices and 5-150Mbps for 4GX category 9 devices."

If urban mobile telecommunications users were experiencing mobile telecommunications download speeds sub-10 Mbps for long periods of time, as it appears to be the case in regional, rural and remote areas as identified in the exploratory study mentioned earlier, it would be assumed that there would be a significant rise in complaints via the TIO and the problem would become a prime-time media topic.

It is also remarkable that the ACCC permits the mobile network operators to boast of "amazing" download speeds, up to 1 Gbps for 5G, yet the ACCC does not require the mobile network operators to temper this marketing hype with information on typical speeds achieved for a range of standard scenarios, e.g., (1) time of day, (2) location, and (3) standing or walking within clear sight and 500 m of a tower on a clear or cloudy day.

This begs the question: when will action be taken to secure the data needed to generate "accurate, comparable and reliable information on the quality" of regional mobile telecommunications?

One positive outcome that a declaration of domestic roaming in regional, rural and remote areas would have is an improvement in performance, because it is assumed that (1) the other carriers would want minimum performance standards to be set to reduce the likelihood of complaints, and (2) an increase in the number of mobile telecommunications users in regional, rural and remote areas, thereby increasing the number of complaints when poor performance occurs.

Recommendations

The following recommendations are made:

http://doi.org/10.18080/jtde.v9n3.444

1. Federal government funding should be made available for an academic study of regional mobile telecommunications performance to be carried out or for funding to be provided to the ACCC for the MBA program to be extended to regional mobile telecommunications.
2. The Federal government should legislate minimum performance standards for regional mobile telecommunications.
3. The Federal government should require the ACMA to work with Communications Alliance to prepare an industry standard on mobile telecommunications performance.
4. Regional mobile telecommunications performance should be the same as urban mobile telecommunications performance for government applications and services.
5. The ACCC should declare domestic mobile roaming for regional mobile telecommunications for a period of three years.

Conclusion

This paper discusses regional mobile telecommunications performance and identifies the urgent need for data to be collected that will permit the current state of regional mobile telecommunications to be ascertained. The imbalance in the provision of mobile telecommunications in regional, rural and remote areas, and the lack of follow through on data collection, provide strong justification for the ACCC to declare domestic mobile roaming for a period of three years. The lack of legislated minimum performance standards for all telecommunications in Australia means that consumers can experience sub-standard performance, and this is especially evident for regional, rural and remote mobile telecommunications users. This situation must be rectified by the Federal government and minimum performance standards for telecommunications should be legislated. Regional mobile telecommunications users need relief, and there must be a realisation that minimum performance standards and expectations for urban and regional, rural and remote users should not differ.

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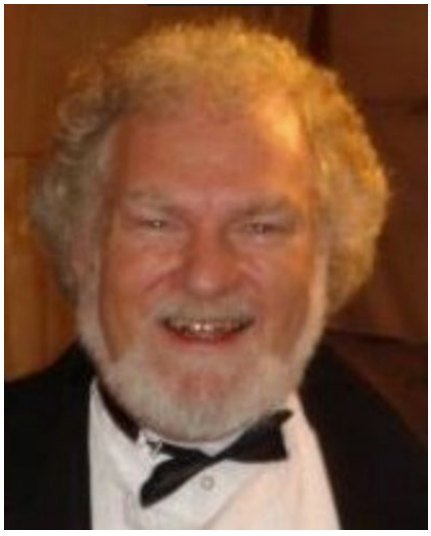
Emeritus Professor
Reginald Paul (Reg) Coutts (1949–2021)

Peter Gerrand
Life Member, TelSoc

Abstract: This obituary celebrates the many contributions of Emeritus Professor Reg Coutts (1949–2021) to telecommunications, to ICT innovation and to the Australian industry associations in which he had key leadership roles. The article quotes comments from many of Reg's co-workers at different stages of his multi-faceted career.

Keywords: Obituary, Reg Coutts, History of Australian telecommunications.

Introduction



Reg Coutts

Reg Coutts, one of Australia's most distinguished telecommunications engineers, died on 29 August 2021 at St Andrew's Hospital in Adelaide, in the company of his wife Pam and daughter Louise. This article celebrates Reg's contributions to telecommunications and ICT innovation, and to the industry associations in which he had key leadership roles.

Born on 13 July 1949 in Woodville, S.A., Reg Coutts was the second son of Hubert and Gertrude May Coutts. As a boy he grew up in Findon, S.A., and attended St Michael's College, where he matriculated in 1967. While a child, he contracted polio, leading to a permanent withering of his right arm. Reg ensured throughout his life that this physical disability would never bar him from achieving anything he wanted to do.

From 1968 to 1972, Reg studied electrical engineering, computer science and applied mathematics at the University of Adelaide, graduating with a B.Sc. in 1971 and a B.Eng. (Honours) degree in electrical engineering in 1973.

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With the assistance of a Commonwealth Postgraduate Award, he carried out research from 1973 to 1977 for a PhD degree in electrical engineering, awarded in 1978, on the topic of "Channel state feedback, for digital communications in a fading environment" (Coutts, 1976).

Reg's Career at the PMG/Telecom Australia/Telstra

While a university student, Reg was supported by a PMG[i] Engineering Cadetship from 1971 to 1976. In 1976, he moved to Melbourne to join Telecom Australia's Research Laboratories (TRL). He was able to combine writing up his Ph.D. thesis there with carrying out research in TRL's Radio and Satellite Networks Division, studying the potential of new radio technologies for application in Telecom's national network.

Reg's career in telecommunications was very important to him, as it was to us, his numerous friends and colleagues across the industry and in academia.

I first met Reg when we both worked at TRL in Clayton, Victoria, in the late 1970s, at a time in which TRL's expertise had great influence within Telecom. While we worked in different areas of TRL and on different network technologies, we shared an active interest in our union (the Professional Officers Association) and in progressive politics. Besides which, Reg's gregariousness and outgoing nature meant that he created friendships easily across the Laboratories and beyond. Meanwhile, the effectiveness of his research work was such that he rose through several promotions to become Section Head of the Radio and Satellite Networks Division in 1985.

In 1989, he had an unexpected career change when he was recruited by Ian Campbell to join Telecom's Mobile Communications Services Division as National Manager, Strategy and Business Development. The immediate challenge was the imminent introduction of competition in mobile services, legislated for 1991. Reg's first job was to advise on which new digital radio technology Telecom, soon to become Telstra, should recommend to the regulator for implementation. The new job gave Reg scope to use his 'big picture' knowledge and skills. In 1992, the expected competition from Optus and Vodafone in mobile networks began.

Kevin Phillips, then head of Mobiles Engineering, has written:[ii]

> "I worked closely with Reg early on in mobiles and briefly more recently.
>
> "There were a large number of operational issues which had to be addressed urgently. Reg's lateral thinking strategies and persuasive ways were very helpful in planning and implementing these changes and managing the relationship with the rest of Telstra.

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> "In mobile communications, new billing, marketing and customer service systems had to be defined, acquired and operated. Reg worked comfortably in strategy across all these domains.
>
> "On the network side we had a head start but due to the ever-rising demand, continually underestimated, we struggled with capacity. I recall Reg's famous broom chart which spelt out the issue and helped in later years to get more realistic predictions and match resources for the business."

Simon Moorhead and Brian Louey-Gung worked for Reg during his time at Mobiles. Simon remembered Reg's extraordinary energy and enthusiasm, working long hours every week at the job. Brian attests to Reg's talents as a manager:[iii]

> "He threw highly complex tasks at me that I didn't realise that I was capable of completing, that forced me to network strongly both inside and outside Telstra in order to just understand the challenges, let alone successful[ly] complete them, and supported me throughout."

In parallel with his work on business strategy for Mobile, Reg continued his participation in the standards work of the Telecommunications Union's CCIR (International Consultative Committee on Radio), which he had begun while at TRL. His priority was on providing inputs to third generation cellular mobile network standards. The Working Group meetings were held in varied locations, such as Vancouver, Costa Rica, Japan and Washington, and Reg became a seasoned traveller.

Professor Coutts

In 1993, Reg left Telstra to take up a newly created Chair in Telecommunications at the University of Adelaide, a position requiring a strong focus on commercialisation. His colleague, Professor Derek Abbott (2021), has written:

> "He swiftly started up the Centre for Telecommunications Information Networking (CTIN). … The establishment of CTIN was a joint venture between Vodafone, the South Australian State Government and the University of Adelaide. … Reg's Centre typically bought in $1M in funds per annum, which for the time was significant funding into the University. Major clients included AAPT, Optus, and Vodafone.
>
> The CTIN's funded studies included: high density wireless LAN (Wi-Fi) performance modelling analysis; 3G terrestrial links network planning; GPRS network signalling traffic modelling; TCP/IP performance measurement of the public Internet; and radio spectrum auction analysis and training.

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> "Reg's CTIN worked in Australia and internationally with individual start-ups, the major telecommunications companies, manufacturers, universities, and government (including a report for a working group for the Prime Minister's Science and Engineering Council). It was at the right place, at the right time, with the right multidisciplinary approach, as the telecommunications industry in Australia was deregulated" (Abbott, 2021).

Reg was also active in enabling the University of Adelaide's participation in the Smart Internet Cooperative Research Centre, a seven-year Commonwealth-funded CRC set up in 2001. This CRC linked eight universities across four states with several private sector organizations, notably Telstra, Motorola and Westpac.

Trevor Barr has written:[iv]

> "Reg's most valuable role, together with Pam, was advocacy for projects concerning how end users could benefit more as the Internet technology platform evolved. Reg called for research into the complexities of *who* has Internet access *on whose terms*, together with issues related to affordability, with a strong call for projects about neglected groups, especially the disabled.
>
> "Reg thrived at the CRC dinners over a glass or two of red wine. I incurred his wrath on several occasions, and learnt the hard way to never criticise his beloved Adelaide Crows!"

In the 1990s and 2000s, Reg and Pam, a social science researcher, were regular contributors at the Network Insight Institute's multidisciplinary annual conferences in Sydney, delivering papers on their research. These were very stimulating conferences at which telecommunications engineers, economists, lawyers, media researchers, social scientists, marketers and user advocates got together to debate research findings and ideas on the future of Australian media and telecommunications. Reg flourished in that environment.

One of Reg's enduring interests over the past twenty years has been the replacement of the traditional Universal Service Obligation, which provides universal access to telephony services (only) across rural and regional Australia, by a more modern means of providing universal access to broadband Internet-based services. His ideas are developed in his 2015 paper 'Better Telecommunications Services for all Australians' (Coutts, 2015).[v]

Expert Consultant and Advisor

While at Adelaide, Reg set up his company Coutts Communications, to provide a vehicle for his private consulting work, particularly as an expert witness and technical advisor in court cases dealing with mobile telecommunications.

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Here's Kevin Phillips again:[ii]

> "In more recent times I had some connection with Reg in the field of law enforcement's use of network based mobile location. This had become a subject of strong personal interest to Reg, and he pursued it with his characteristic enthusiasm and scientific approach. He had doctoral students working on the subject and published papers in an attempt to wind back what he saw as over reliance, and some travesties of justice, based on the use of these techniques."

In 2004, Reg formally retired from the University of Adelaide, who bestowed upon him the title of Emeritus Professor. According to his colleagues, Reg cheerfully explained his new title as "It means you get to keep your desk and still work as a professor, but they don't pay you anymore". At Reg's funeral, Derek Abbott (2021) told us:

> "Now, many retired Professors go into hiding and we never see them again. … Not Reg. … He religiously came into work, was active in the University community, and was a staunch drinking member of the University Staff Club.
>
> "In these retirement years Reg kept himself busy and performed expert witness work for courts that needed an expert opinion on mobile phone records to decide whether a phone was near the scene of a crime or not. In as little as a week before Reg passed away, I remember him looking forward to a forthcoming case where he believed he would easily take down the case of the Prosecution" (Abbott, 2021).

In fact, after formally retiring from the University in 2004, Reg became busier than ever. In 2007, he was appointed to the Rudd Government's Panel of Experts to advise on bids from the industry on the best way to implement a national broadband network adequate to serve Australia in the future. Another distinguished member of that Panel, Emeritus Professor Rod Tucker, has written:[vi]

> "I worked closely with Reg on the NBN Panel of Experts and came to appreciate his wisdom on telecommunications matters. Interactions with Reg were always lively, and he kept all members of the committee on their toes with his questions, comments, and insights. It was a pleasure working with Reg."

In further recognition by government of his expertise, Reg was appointed as a part-time Member of ACMA (the Australian Communications and Media Authority) from October 2010 to May 2014.

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Leadership of the Telecommunications Society

Participation in the NBN Panel of Experts was far from the only major issue requiring Reg's attention in 2007. In the previous year, he had been elected as Chair of the Telecommunications Society of Australia (TSA), whose role in disseminating knowledge to the industry of new developments in telecommunications has a history going back to 1874.

In 2007, Reg had the challenge of keeping the TSA's activities alive and well in an era of shrinking membership and vanishing sponsorship revenues. As a radical solution, the TSA Board decided to transfer its functions and assets to the Australian Computer Society (ACS), after being assured it would be supported there. For six years, Reg and his colleagues were able to keep the activities and morale of the TSA alive, through the Computer Society's Telecommunications Committee, which Reg chaired. During those years the "TSA" remained as active as ever, producing regular issues of its online journal, the *Telecommunications Journal of Australia*, as well as holding lunchtime lectures in Melbourne, Sydney and Adelaide, and the annual Charles Todd Oration in Sydney.

However, in 2013, the new CEO of ACS announced he would ban the use of the Telecommunications Society's name, in his desire to use a single brand name, the Australian Computer Society. This threat to the prestige and importance of telecommunications was of course incendiary to our members. After a period of unproductive negotiations, Reg and the Telecommunications Committee decided to take the telecommunications group out of the ACS and recreate the TSA.

Thus was born the Telecommunications Association Inc. (TelSoc for short), and its new Journal, the *Australian Journal of Telecommunications and the Digital Economy*. Seven former TSA members acted as founding directors of TelSoc, and Reg was unanimously elected its founding Chairman in July 2013. He remained Chairman for seven years, stepping down last year to become Vice Chairman to assist his successor, Jim Holmes, and the new members of the Board.

In this way Reg and his colleagues ensured the continuation of the almost 150-year traditions of this very active society. The rescue of the Telecommunications Society is one of the many achievements of Reg's career, and it attests to the multi-faceted nature of his many contributions to Australian telecommunications.

In 2018, Reg was admitted by the Pearcey Foundation to its Hall of Fame for "distinguished lifetime achievement and contribution to the development and growth of the Australian Information and Communication Technology industry".

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Final Years

In his last two years, Reg was capable of further surprises. In the lead-up to the 2019 federal election, the seat of Mayo, held by the Centre Alliance (cross bench member) Rebekha Sharkey, was under threat from Georgina Downer, a conservative candidate from a Liberal Party dynasty. Reg's offer to stand as a candidate was gratefully accepted by the ALP, and Jim Holmes flew over to Adelaide to support Reg in his campaign. According to Jim, Pam was slightly worried her talented husband might just win, destroying any chance of a happy retirement together. Reg assured her that, realistically, he had no chance of winning the seat. Fortunately, from Pam's point of view, his prediction was accurate and, just as he intended, his flow of preferences helped ensure that the more progressive Ms Sharkey won the seat.

Reg's death from cancer in August, 2021 came as a shock to his many friends across the industry. However, to the end, he remained cheerful and upbeat. In tribute to his sunny character and sense of humour, the final video shown at his funeral was the Monty Python masterpiece, "Always look on the bright side of life".

Farewell, Reg – comrade, colleague and friend.

Acknowledgements

The author thanks Pam and Louise Coutts, Derek Abbott, Trevor Barr, Ian Campbell, Jim Holmes, Brian Louey-Gung, Simon Moorhead, Kevin Phillips and Rod Tucker for their contributions to this obituary.

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Moorhead, S. (2021). Revisiting the Universal Service Obligation Scheme, *Journal of Telecommunications and the Digital Economy*, *9*(3), 194—215. https://doi.org/10.18080/jtde.v9n3.451

Endnotes

[i] The telecommunications functions of the Commonwealth of Australia's Postmaster General's Department (known as the PMG) were transferred to the newly created government-owned business enterprise Telecom Australia on 1 July 1975.

[ii] Kevin Phillips. 'Articles on Reg', email to Tim Herring, 3 September 2021.

[iii] Brian Louey-Gung. 'Reg Coutts', email to Peter Gerrand, 13 September 2021.

[iv] Trevor Barr. 'Reg Coutts', email to Peter Gerrand, 8 September 2021.

[v] The paper is also reprinted in this issue of the *Journal* (Moorhead, 2021).

[vi] Rod Tucker. 'Reg Coutts', email to Peter Gerrand, 8 September 2021.

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Revisiting the Universal Service Obligation Scheme

Simon Moorhead
Ericsson Australia and New Zealand

Abstract: In this *Journal's* tradition of revisiting past papers which have relevance to today's events, this article reminds us of the value of the paper "Better telecommunications services for all Australians." (2015) by Reg Coutts. This paper makes five interrelated recommendations to replace the current Universal Service Obligation (USO) policy in Australia, given the NBN rollout and customer preference for mobile services anywhere anytime. Some of its recommendations were arguably taken up by the Productivity Commission's Public Inquiry into the USO in 2016-17, and implemented by the Australian Government in the form of a new Universal Service Guarantee.

Keywords: history, telecommunications, NBN, Universal Service Obligations, USO

Introduction

This historic paper (Coutts, 2015) was written by the late Emeritus Professor Reg Coutts who was chairman of the Telecommunications Society of Australia and its successor, TelSoc, for many years, and whose obituary appears elsewhere in this issue of the *Journal* (Gerrand, 2021). Those of us who were lucky enough to know Reg would acknowledge his life's focus on making the world a better place. So, it is not surprising that he chose to write about the Universal Service Obligations (USOs), which were sixteen years old at the time and originally legislated in 1999 "to ensure that standard telephone services and payphones were reasonably accessible to all people in Australia wherever they resided".

The Australian telecommunications market had changed fundamentally between 1999 and 2015. The old copper network has been made largely redundant by the NBN; and the USO, which focussed on subsidising fixed-line services over the copper network, was largely out-of-date.

The paper suggested:

> "that now is the ideal time to again lead public USO policy for the communications needs of today and the future. Australia has the opportunity to create a new universal

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service scheme that delivers reliable voice and internet services for all Australians using a range of technologies through the NBN, including wholesale mobile service."

The paper explored the provision of USOs in a number of countries and suggested that "reform of the current USOs in Australia presents an opportunity for targeted subsidies to protect regional consumer interests and promote competition and innovation". The paper explored the increasing importance of mobile, Internet and the need for choice. It also pointed to the opportunities provided by the NBN and the need to bring payphones into the modern era.[1]

The paper makes five interrelated recommendations to replace the current USO policy with a *Universal Service Fund* which uses the NBN network as a springboard for further service improvement and recognises the importance of mobile services to regional Australians.

Reg's paper was based on a report he had written earlier in 2015, commissioned by Vodafone Hutchison, prior to the Australian Productivity Commission commencing a twelve-month public inquiry into the USO in 2016. The Commission's report (Productivity Commission, 2017) in turn led to the Australian Government (Prime Minister Malcolm Turnbull) in 2017 declaring that it would take action to improve regional telecommunications via a new Universal Service Guarantee (USG). The USG would augment the continuing USO with the new requirements that (Fifield, 2017):

a. broadband services are available to 100% of Australian premises, on request, at the completion of the NBN rollout in 2020;

b. voice services are available to 100% of Australian premises on request;

c. any proposed new service delivery arrangements are more cost effective than the existing USO contract (including any transitional costs);

d. a new consumer safeguards framework is in place following a review and associated public consultation process.

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Endnote

[1] On 3 August 2021, Telstra announced that all national calls from its 15,000 payphones will in future be free.

The Historic Paper

Journal of Telecommunications and the Digital Economy

Better telecommunications services for all Australians

Further Thoughts on the Universal Service Obligation

Reg Coutts
Coutts Communications

Abstract: The Universal Service Obligation (USO) scheme we have in place in Australia in 2015 was put in place over 25 years ago when the world was very different than what it is today. The paper documents how the current USO entrenches an annual subsidy of some $300 million to Telstra to provide a standard telephone service over an aging copper infrastructure to regional and remote premises across Australia. The current expensive USO scheme is inadequate for people in remote and regional Australia and in the light of the NBN roll out and the demand for mobile services is in urgent need of review. The paper reviews the approach taken to providing high cost telecommunications services in rural areas both developed and developing economies across the world and draws lessons for devising a basis for a way forward. Given the now bipartisan acceptance of the rural and remote component of the NBN roll out and drawing on these lessons, now is the opportunity to scrap the current USO scheme and establish a Universal Service Fund (USF) where the NBN is the Universal Infrastructure wholesale provider with alternative retailers. The paper supports five practical interrelated recommendations that diverts current USO funding to ensure broadband and mobile services extension in rural and remote Australia as well as reimagining future payphones around public WiFi and rural community innovation.

Introduction

Three decades ago, prior to the internet, most Australians – especially people living outside major cities –used a fixed line telephone. Mobile phones were in their infancy, and public payphones were a vital communications service outside the home.

The main role of the Universal Service Obligation (USO) was to provide funding to Telecom Australia (in 1995 becoming "Telstra"), to maintain its copper access network in regional areas where it was deemed uneconomic. This infrastructure subsidy has been funded largely via a levy on telecommunications companies.

In 2015, the Australian society and economy have been forever and fundamentally altered by the internet and new telecommunications technologies. Smart devices and mobile

telecommunications have increased connectivity, grown the economy and jobs, enabled new industries and boosted productivity.

Consumers are demanding improved mobile coverage, devices are becoming more data-hungry and businesses want access to next-generation networks to improve productivity. Consumers now expect a choice of providers so that they can examine who is best able to meet their needs and give them the best deal.

Unfortunately, public policy on delivering access to the benefits of modern technology outside our major cities is stuck in the past.

The NBN gives Australia a unique opportunity to close the digital divide between city and country by massively improving access for voice and broadband data services using new technologies. With the profound changes the NBN will deliver, government funding and policy arrangements need to change.

As it stands, the USO is a costly and ineffective scheme that is holding Australia back and treating people living in regional Australia as second-class citizens. Through the NBN, taxpayers are spending billions of dollars funding the replacement of copper lines in regional areas, with fixed-wireless and satellite, for the delivery of internet services. Yet in the same areas, taxpayers also help fund Telstra to maintain its copper wire network for fixed-line home phones despite the intrinsic capability of fixed-wireless and satellite technologies to provide a high quality telephone service.

A new, smarter approach is needed. Overcoming the roadblocks to competitive investment in regional Australia will ensure consumers and businesses receive greater coverage, better value, better service and greater innovation.

Vodafone commissioned the author to analyse the current USO and propose recommendations to reshape the USO for the 21st century to deliver reliable communications services for all Australians. The report (Coutts 2015) was released in July 2015 and was included as an attachment to the Vodafone submission to the Shiff Regional Telecommunications Review.

This paper is based on this report (Coutts 2015) and references the final report of the Shiff Regional Telecommunications Review released in November 20115 and also references the ACCAN-commissioned Occasional Paper on the USO by John De Ridder.

Background

When it was created almost 30 years ago, the Universal Service Obligation (USO) scheme was leading-edge public policy. When the Australian telecommunications market was deregulated, the USO was created to ensure that standard telephone services and payphones were

reasonably accessible to all people in Australia wherever they resided[i]. This was when the dominant form of communications for Australians was the fixed line home phone and payphones were considered a necessity.

Almost three decades later, the telecommunications market is vastly different. Internet and mobile services are now considered by consumers to be essential and access to fast and reliable broadband is seen as very important. The deployment of fast 4G services has resulted in Australians becoming some of the fastest adopters of internet-enabled smart phones in the world.

The rollout of the NBN will see further changes in the telecommunications market as over time the old copper access network will be made redundant by a mixture of fibre optic cable, fixed wireless and satellite technologies. The NBN can also be used to deliver improved mobile services, particularly in regional Australia.

Despite these enormous changes and the increasing use of data, the USO remains in its original outmoded form as a costly subsidy scheme for fixed-line phone services delivered over the copper wire network[ii]. Each year, the telecommunications industry and Australian taxpayers spend approximately $300 million maintaining ageing copper wire and payphone networks under the complex and opaque USO arrangement (TUSMA 2014).

The NBN rollout and the increasing consumer preference for mobile services anywhere, anytime means now is the ideal time to have a discussion about how best to reshape the USO for the communications needs of today and the future.

The Federal Government has acknowledged the need to modernise the USO. For example, the Agricultural Competitiveness White Paper released in July 2015 (Australian Government 2015) states that "traditional policy responses need to be updated so that internet connectivity can be funded as an essential service."

Australia has the opportunity to create a new universal service scheme that delivers reliable voice and internet services for all Australians using a range of technologies through the NBN.

In addition, some of the current USO funding could be used to improve mobile coverage and choice in regional Australia by co-funding much-needed infrastructure in remote areas and by creating incentives for the industry to innovate, further invest in and share mobile networks.

The report made five interrelated recommendations to replace the current USO scheme with a more transparent and efficient scheme that uses the NBN as a springboard for change. The report did not address other similarly challenging communications services to extend to rural and remote Australia, including the Triple Zero emergency service and Public Safety Mobile Broadband. These could however be incorporated in the proposed scheme.

This paper has provided me the opportunity for further thoughts on the USO particularly given the publication of the Regional Telecommunications Review (Shiff 2015) and the ACCAN Occasional Paper by John De Ridder in late 2015 (De Ridder 2015).

What is the USO?

The USO is an industry and taxpayer-funded scheme designed to ensure that all Australians have access to a 'Standard Telephone Service'[iii] and that payphones are reasonably accessible.

The USO was created to ensure that a voice telephony service could be provided, even in remote uneconomic areas. The *Telecommunications Act 1991* provided that Telstra would bear the USO and all telecommunications carriers would be required to contribute to the cost of it.

Prior to 2012 the Minister, based on advice from the Australian Communications and Media Authority, set the annual level of USO funding. In July 2012 Telstra entered into a contractual obligation to deliver the standard telephone service for a term of 20 years. At this time, the government increased the annual USO levy provided to Telstra and included an annual Budget contribution of $100 million from 2014-15.

Currently, $253 million per annum is allocated to the provision of a standard telephone service, with $44 million per annum allocated to the provision of payphones (TUSMA 2014). It is important to note that funding is provided to deliver uneconomic infrastructure. In effect the current framework brings together the 'infrastructure-provider-of-last-resort' and the 'service-provider-of-last-resort' obligations. With the delivery of the NBN this intertwining of obligations requires a rethink.

Once the NBN is rolled out, Telstra will deliver the standard telephone service over NBN technology within the NBN fibre footprint. Outside the NBN fibre footprint, which includes much of regional Australia, Telstra is required to provide a standard telephone service, largely via its ageing copper network. This appears to be a conflated and redundant requirement given the NBN has in effect become the 'Universal Infrastructure Provider' using modern technology platforms. 'Service provider of last resort' obligations could now be provided by a wider range of providers in more flexible and innovative ways.

Evolution of the USO

When the USO was introduced, Telstra as the incumbent national carrier was chosen to deliver the standard telephone service to high cost/low revenue regional and remote areas. As part of industry liberalisation, all telecommunications service providers contribute to the USO fund in proportion to their industry revenue.[iv]

Over the period of the next 10 years from the mid-1990s, governments conducted a number of reviews to enable the USO to be more technology-relevant and sustainable, with minimal change to the USO as a result.

After much public discussion, the USO service definition was modified to include data[v] and services to enable better access for people with disabilities. Despite attempts to introduce provider contestability and to review ways to improve transparency to the cost of the subsidy provided to Telstra, few changes were made.

Further, the definition of the USO solely around the fixed telephone began to be questioned (Coutts 2004). Despite the significant increase in the reliance on mobile services, including in regional and remote Australia, there has been a reluctance for any policy intervention to deliver greater mobile coverage as part of the NBN.

Mobile services are now considered by many Australians to be their primary avenue of access to broadband and telephony services. Since the launch of 3G HSPA, HSPA+ and 4G LTE data services, mobile has become a reliable and fast mechanism to deliver broadband for many people in regional Australia.

Despite the changes to consumer behaviour (and priorities) and the developments in mobile services, the policy debate about broadband delivery remains focused on fixed services. The more recent policy conversation has been focused on the political debate about the NBN, preventing a fresh analysis of the role of a universal service scheme or consideration of how best to reshape the policy framework.

To put the USO in perspective, the evolution of USO policy can be described in four distinct successive phases.

Phase 1: Coverage

In the early development of telecommunications it was recognised that the value of a telephone increased with its interoperability with more people who were connected. This is the 'externality value' that still applies in many developing markets. The argument is then made for an internal cross-subsidy by the monopoly incumbent to deliver a broad geographic service. A monopoly solution was seen as an acceptable model, largely because this was how telecommunications services were provided up until the 1980's and 1990's.

Phase 2: Affordability

In a developed economy, competition is progressively introduced in high margin segments such as long distance calls. The need for a USO-type scheme is argued to ensure affordable access to all citizens. This is usually funded by the industry rather than by government. Relative to the US that entered this phase in the early 1970s, Australia started this phase in the

early 1990s. Competition was the main driver for reducing prices but if there were monopoly areas then the infrastructure subsidy of the USO tacitly expected that these areas would not pay higher prices.

Phase 3: The Internet

The third phase accelerates from the mid-1990s with the transformative impacts of the internet and mobile services. In this phase the standard telephone service is no longer the universal service, broadband has become the norm and smart phones have become an essential tool for both internet access and telephony.

The convergence of telecommunications with information technology and broadcasting and the growth of Over the Top (OTT) services results in reduced viability of levying only telecommunications companies as part of a USO scheme. At the same time, the USO payments to one telecommunications entity, which is usually the original incumbent, distorts competition in higher cost areas, particularly rural and regional areas.

Phase 4: Digital Convergence

Given the convergence of fixed and mobile technologies, the need for integrated fixed and mobile broadband must now be recognised. In Australia this requires a modification of the original strategic decisions behind the NBN, and an examination of the role that the NBN can play in delivering better mobile services in addition to fixed broadband services. It also requires changing the current USO to a more transparent and efficient scheme that uses the NBN network to bring improved services to more Australians.

While there are some programs that facilitate the provision of mobile services, there are no examples overseas of the Phase 4 of the USO policy evolution where governments have committed to an intervention in universal broadband, although the United States is in the process of attempting change. In my view, Australia has the opportunity to be again at the forefront of this policy approach with a forward-looking *Universal Service Fund* (USF)[vi] to replace the USO funding mechanism.

Overseas experience with universal service schemes

Both developing and developed countries continue to grapple with how to intervene effectively in telecommunications markets for the national good. A key observation from experiences overseas of the last 10 years of a universal service scheme, particularly in developed countries, is that these schemes have not been developed to take into account the rapid adoption of new technology.[vii] Indeed, some of the major innovations in universal service policy are in fact coming from developing economies (ITU 2007).

A theoretical framework for universal service schemes has been developed by the International Telecommunications Union (ITU). This defines the two components of the Universal Access and the Service (UAS). The ITU has reviewed the approach taken to policy and implementation of UAS around the world (Intelecon 2009).

European Union

There have been moves to broaden the USO service definition in the European Union to incorporate broadband policy objectives in universal service and access strategies, but there has been a reluctance to include mobile services. There is currently a variety of USO arrangements across Member States.

The European Commission's response is illustrative of the glacial pace of progress. The EU Universal Service Directive introduced a requirement that the scope of universal service obligations be reviewed every three years. To be included in the scope of a universal service policy in the EU, a service has to satisfy two tests:

(a) In the light of social, economic and technological developments, has the ability to use the service become essential for social inclusion?

(b) Are normal commercial forces unable to make the service available for all to use?

This is a somewhat backward-looking perspective, and continues to neglect the need for subsidies to enhance not hinder competition.

United States

In the United States, the $4.5 billion Universal Service Fund (USF) covers a myriad of services. Since 2011, the USF has included broadband and mobile. While it is highly complex, it does take a broad funding approach as I recommend rather than being service-specific like Australia or Europe (KPMG 2012).

Latin America

Latin American countries have been successful in using reverse auctions as a way to achieve competitive tension and allow for the provision of services in areas which have previously not been serviced.

For example, Chile implemented an innovative USO policy that has both achieved spectacular results and confirmed the value of a transparent process. The Chilean approach is based on government funding for specific projects via a competitive tender process. This has resulted in minimising the need for state funding and achieving greater leveraging of private investment with subsidies determined by market forces rather than administrative determinations (World Bank 2002). I note that the Australian Government's Mobile Black Spot Programme has incorporated a similar approach and has garnered significant community support.

In developing countries, mobile broadband offers the most attractive platform for introducing integrated broadband, making no distinction between fixed and mobile. In Mexico, for example, the Government proposes a single mobile wholesale operator initially owned by government but to be then sold.

Africa

The African continent in particular has achieved seen tremendous growth (ITU 2007) in tele-density as a result of the adoption of mobile communications effectively 'leap-frogging' the need for a fixed telecommunications infrastructure as we have known it. A number of countries in Africa are considering mobile broadband and USF schemes to provide affordable access to all.

The potential of a single LTE broadband mobile wholesale has recently received a lot of interest to extend mobile coverage into regional areas (Frontier Economics 2015).

Broader international activity

The ITU World Regulatory Database helps in detecting trends in regulatory practice. Summarising the data supplied on universal service policies over the last 14 years (Hernandez 2014) indicates that:

- Universal Access and Service Funds are rising in popularity, and in 2007 were used in 60 per cent of countries that responded to the ITU survey;
- Obligatory investment in unprofitable areas has correspondingly been declining in popularity; and
- The use of state-imposed tariff controls to benefit all customers or just to benefit specific eligible groups has declined steadily since 2003 and dipped below 20 per cent of respondent countries in 2007.

The OECD has examined reforming the USO for what are called 'next generation' networks where service evolution is considered in a broad service architecture (Xavier 2006). To create an updated USO, it states that the challenge has moved from simply ensuring equitable access to voice services to including broadband, content and applications (Dymond 2010).

In summary, some of the good practices from overseas are:

- The definition of 'essential services' is updated in policy;
- The move towards a Universal Service Fund model to fund required infrastructure and services in regional communities;
- The use of reverse auctions as a way to achieve competitive tension instead of using an administrative approach to costing subsidies;

- The move away from relying on telecommunications industry taxation towards alternative models to fund subsidies; and
- The use of 'smart subsidies' to leverage public investment from telecommunications providers and communities.

It has been argued that there is no economic argument for a universal service scheme in developed economies and that it is just another tax on industry (Cato 1998). If this approach were followed in light of the current Federal Government's deregulation agenda, the USO could be seen as an easy target for removal. In its current guise, the argument for abolition of the USO is compelling. It is essentially an anti-competition tax on industry to benefit of the already dominant telecommunications provider.

In the author's view however, reform of the current USO presents an opportunity for targeted subsidies to protect regional consumer interests and promote competition and innovation.

Rethinking the USO

The current out-dated 'one size fits all' USO scheme has resulted in unintended consequences – taxing some companies and their customers, distorting competition, blocking innovation and subsidising one industry participant at the expense of others.

Over more than a decade, four successive Regional Telecommunications Reviews have all commented on the increasing failure of the USO to achieve its perceived purpose. Unfortunately, successive governments have failed to act to address the crucial role affordable access by all Australians to modern telecommunications plays in our economy and society.

The 2002 Esten Review (Estens 2002) said: "In particular, we found that the current Universal Service Obligation (USO) arrangements are not working well. Nearly all stakeholders are dissatisfied with them and they are neither practical nor functional for modern telecommunications."

The 2008 Glasson Review (Glasson 2008) identified that a new regulatory framework was needed to replace the existing USO legislation and noted that the transition to the NBN provided a clear opportunity to reform the USO.

The 2012 Sinclair Review (Sinclair 2012) made a clear recommendation for greater mobile coverage including the consideration of regional roaming. The current Government has recently announced the first round of implementation of the Mobile Black Spot Programme under a policy approach that incentivises co-investment as discussed later in this report.

The 2015 Shiff Review (Shiff 2015) has agreeable synergy with the author's earlier report and reinforces the need to consider mobile service. However, the report stops short of making

recommendations on how to expand mobile coverage, presumably under some belief that policy intervention in the mobile sector is either not warranted or too risky.

The objective of any universal service scheme is to provide an economic incentive to invest in infrastructure to enable affordable access to basic telecommunications services where it is uneconomic to do so without the incentive.

Under the current USO scheme, the most profitable market participant receives 100 per cent of the benefit of the scheme, which results in significant market distortion. With the significant changes in the telecommunications market, including the construction of the NBN fixed wireless and satellite networks in regional Australia, the current USO funding of the copper access network in particular is increasingly redundant.

Consequently, the current USO scheme needs to be urgently updated to address inadequacies in regional telecommunications infrastructure for voice and internet services that cannot be addressed by market forces alone.

The roll out of the NBN to regional and remote premises provides the opportunity and basis for updating the current USO and moving to a *Universal Service Fund* approach. The worldwide trend to a *Universal Service Fund* approach provides for better targeting of the incentive and avoids the narrow legislative prescription of the basic telecommunications service. The 2015 Shiff Regional Telecommunications Review (Shiff 2015) has recommended the establishment of a Consumer Communications Fund which is in line with my recommendation for a USF.

In short, a modern telecommunications infrastructure underpins the digital economy, particularly in regional and remote Australia where its contribution, for example, to the Agricultural sector is recognised. A Universal Service scheme via a *Universal Service Fund* makes sense in Australia because it can improve access to telecommunications services in regional areas where population densities are low and it is often uneconomic for the private sector to provide such infrastructure.

The increasing importance of mobile and the need for choice

For many regional Australians, mobiles are increasingly more important than fixed telephone services (Empirica 2014). Despite this, competitive mobile services are not available to many regional and remote areas of Australia.

The initial starting premise for my report and this paper was that mobile services should be part of a reformed universal service scheme. Today's mobile services support voice and data and have been progressively recognised (Coutts 2004) as an essential element of a modern universal service scheme.

Even though mobile phones are now widely accepted as a way of providing voice and data and are also used to provide public access, developed countries have to date not used USO-style interventions to provide better mobile coverage in rural areas. Policy makers have been wary not to distort the competitive rivalry in addition to coverage licence conditions[viii]. Meanwhile, in developing countries mobile services are often recognised as the only way to provide an accessible and affordable broadband communications service. Developing countries have been less wary.

While there has been an assumption by successive governments in Australia that mobile carriers would continue to expand coverage, the investment required to improve networks is prohibitive where there are large distances and small markets. However in Australia in particular the coverage disparity between Telstra and its two rivals has been increased by actions by State Governments and other factors further deterring regional investment. The build economics in many places in regional Australia mean that even one infrastructure network is not viable without subsidies.

There is, however, a smarter way to approach the issue of mobile coverage expansion beyond the existing coverage footprint by using government funds to encourage private sector investment and boost industry collaboration.

The Federal Government's Mobile Black Spot Programme was borne out of the need to provide coverage to places where it was uneconomical for the mobile carriers to build the infrastructure needed to deliver a mobile service. Unfortunately, State Government intervention[ix] again distorted the potential of this program.

Under the Programme the Government is offering subsidies to improve the business case for coverage expansion, thereby accepting that there needs to be an intervention in the market to deliver coverage to many places outside of the existing coverage footprints of the mobile carriers. By requiring the winning bidder of a site to explore opportunities to share or co-fund with other mobile network operators, the Programme is also helping to create a more competitive market in regional areas.

The Mobile Black Spot Programme process has identified more than 6,000 black spots in need of coverage expansion. The $100 million in Government funding for the first phase of the Programme and $60 million in funding for phase two is a good start in tandem with state government and carrier funding.

The Programme is not enough by itself, however, to deliver improved coverage to every inhabited area that requires it. In my view, a modern policy framework that addresses the need for mobile coverage expansion and competition must include a rural wholesale mobile infrastructure option.

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To further improve mobile coverage and choice in regional Australia, this paper therefore recommends that a portion of the current Government USO funding of $100 million per annum be diverted to an expanded Mobile Black Spot Programme. This will provide a sizable fund to improve and expand mobile services and competition in regional Australia. An ongoing[x], as opposed to ad hoc, programme would have the additional benefit of providing greater opportunities for industry collaboration for infrastructure sharing and more strategic long term planning by regional communities about what are the long term objectives of their telecommunications requirements.

The opportunity provided by the NBN

In 2009, based on recommendations of an expert group, the Federal Government announced that it would fund the construction of a wholesale-only fixed National Broadband Network (NBN) to provide broadband services to all premises in Australia, including the remotest seven per cent.

This remote portion was estimated to account for some 25 per cent[xi] of the total capital cost of the NBN. The NBN will deliver broadband services via a mix of fibre optic cable, fixed wireless and satellite to urban, regional and remote consumers.

The NBN will not provide a standard telephone service to the remotest seven per cent of Australia (nbn 2015). It is proposed that these premises will receive NBN fixed wireless or satellite internet services, but will continue to rely on the ageing copper wire network, or equivalent, for their telephone service. As will be discussed below, by proscribing the technology solution, government policy has established dangerous rigidities in objectives and outcomes.

In the recent Vertigan report, the net cost of delivering the NBN's fixed wireless and satellite services has been estimated at $6.1 billion (Vertigan 2014). This represents a huge investment in broadband for regional and remote Australia, and shapes the context for any discussion of a reformed USO scheme.

The case for reform of the USO in Australia has been building for more than ten years as a result of rapid technological change and convergence and a more competitive market. The rollout of the NBN presents an opportunity to manage the progressive retirement of the redundant copper wire network that underpins the current USO scheme, providing an ideal case for urgent reform.

We need to recognise that the entire copper wire network will be retired over time, not just in the metro fibre rollout. The NBN fixed wireless and LTSS satellite services can both provide a high quality telephone service. USO funding can accelerate this opportunity and enable a

wider range of better solutions where the standard NBN project cannot deliver the requirements.

It is therefore difficult to justify taxpayer funding to Telstra for the upkeep of a redundant copper wire network while also funding the delivery of superior fixed wireless and satellite services to the very same premises.

The fixed wireless network the NBN is deploying is using point to point LTE technology that is capable of delivering a high quality Voice over LTE (VoLTE) service. The NBN satellite delivery of broadband is also capable of delivering a telephony service called Traffic Class 1 (TC-1) which will benefit remote and indigenous communities in particular. In the long term future satellite deployments (or partnerships) could deliver even better low latency solutions.

The scope of NBN's fixed wireless mandate should be extended to provide an open-access wholesale 4G mobile network that would significantly improve the depth of coverage to residences over the more targeted individual coverage of the three mobile network operators.

Further, the NBN could also provide access to its infrastructure on reasonable terms, including facilities and backhaul, to facilitate the supply of better mobile services in rural and regional areas. A modernisation of the current USO scheme could help fund these important extensions to the NBN network and may go some way to addressing competition distortions caused by current policies in these areas and to reducing the overall funding burden associated with the current cross-subsidy arrangements.

This paper recommends that the Government formally designate NBN as the *Universal Infrastructure Provider* to connect all premises in Australia. This is already part of its roll out remit and would mean that all Retail Service Providers on the NBN would be able to provide voice and broadband services to all premises in Australia.

In parallel, this paper recommends that the Government direct NBN to develop a project plan to assist the industry to expand competitive mobile services in regional Australia by providing access to NBN backhaul and by upgrading its fixed wireless towers to deliver a wholesale 4G regional mobile network. NBN's objective should be to deliver improvements in both fixed and mobile voice and broadband services.

The Government should also plan the phased diversion of USO funding from Telstra to NBN to help fund its Universal Infrastructure Provider obligations via a new *Universal Service Fund*. This fund could help deliver infrastructure to premises and mobile base stations. Consideration should also be given to provide funds for NBN to upgrade its fixed wireless network to enable a wholesale regional 4G mobile network.

Bringing payphones into the modern era

The USO includes the provision of public payphones, the need for which has been challenged by the routine availability of mobile phones. Over five years Telstra has decommissioned half of its payphones in recognition of reduced demand[xii]. Despite the decreasing number of payphones, a set amount of $44 million per annum is allocated under the USO for the provision of payphones (TUSMA 2014).

The question is whether there is an ongoing need for access to some form of public payphone as part of the USO reform. More recently there has also been a growing argument that public open access should be through WiFi, because broadband access now rivals telephony as an essential service. In considering this, we would need to assess demand trends coupled with coverage gaps and competition issues. In November 2014, New York embarked on a new-age payphone infrastructure based on free WiFi that addresses demand from the disadvantaged (Flegenheimer 2014). Closer to home, Telecom NZ (Telecom Asia 2014) and Telstra (Ramli 2014) both have programs which will convert payphones into WiFi hotspots.

Yet unlike New York, these WiFi zones will be available free only to customers of Telecom NZ and Telstra, with customers of other providers able to access these services at a cost. The Government is also expanding the provision of free WiFi, with the indigenous payphone program opening up the concept of public access.

A payphone that provides affordable open access to basic telecommunications (e.g. internet, voice and social networking) is still relevant but needs to be recast around free public WiFi. The risk of competitive distortion of the potential public good needs to be addressed.

As an alternative to traditional payphone subsidies, it is recommended that a review be undertaken into the costs and benefits of the provision of public open access WiFi services in regional centres and other areas. Consideration should also be given to provide funds for small scale community-led telecommunication projects utilising WiFi and other technologies.

In areas of remote Australia where, even with micro-base station technology and incentives, 'continuous' mobile is not realistic, islands of WiFi coverage fed from satellite hubs can provide a much improved mobile experience.

There is therefore an important opportunity to allocate funds towards community led local solutions. The immediate opportunity is WiFi services but it could expand into other services. For example *Universal Service Fund* funds could be allocated to facilitate the development of important end user requirements.

Examples that come to mind include:

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- **Farming productivity:** Development of mobile coverage expansion technology that farmers could deploy on their properties using the NBN. Individual farmers could use this technology to deliver improved mobile coverage where they need it, resulting in significant improvements in farm productivity.
- **Disability services:** The key challenge in disability services is to source funds to deliver improvements and changes to disability telecommunications equipment and services. USF funds could be used to deliver telecommunications products for end users that have specific needs.
- **Indigenous communities:** Indigenous communities often have distinct telecommunications requirements that require tailored solutions. Funds could be made available to meet these specific needs.

Recommendations

The basic challenge for universal service policy reform is to deliver a scheme that leverages the NBN, progressively encourages the involvement of the private sector and drives greater competition.

This paper makes five interrelated recommendations to replace the current USO policy with a more transparent and efficient approach by establishing a *Universal Service Fund* which uses the NBN network as a springboard for further service improvement and recognises the importance of mobile services to regional Australians.

Recommendation 1: Universal Service Fund

Establish a *Universal Service Fund* (USF)[xiii], to help fund non-commercial but socially important telecommunications infrastructure. The USF would be funded from contributions via an improved levy scheme that would look to reduce the distortionary impositions of the current arrangements.

Recommendation 2: NBN as the Universal Infrastructure Provider

Consistent with NBN's current remit, formally designate NBN as the *Universal Infrastructure Provider* to connect all premises in Australia. This would mean that all Retail Service Providers on the NBN would be able to provide voice and broadband services to all premises in Australia.

Recommendation 3: NBN as the Standard Communications Service Provider

Plan the phase-out of Telstra's current USO obligation, to maintain its copper network to provide a Standard Telephone Service, and provide funds to NBN to deliver a modern *Standard Communications Service*[xiv] delivering voice and broadband capability to all premises.

Recommendation 4: Mobile coverage and choice

The *Universal Service Fund* should also consider the provision of funding for other essential services such as improving mobile coverage and choice in regional Australia via an expanded Mobile Black Spot Programme. The NBN should also develop a project plan to assist the industry expand competitive mobile services in regional Australia by providing access to NBN backhaul and by upgrading its fixed wireless towers to deliver a wholesale 4G regional mobile network

Recommendation 5: Broader range of telecommunications solutions

As an alternate to traditional payphone subsidies, consider broadening the remit of the *Universal Service Fund* to deliver a broader range of telecommunications solutions for regional communities and other consumers, such as public open access WiFi. Consideration should also be given to providing funds for small-scale community-led innovative communication projects to enable broadband services to all Australians.

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Notes

[i] John De Ridder makes the pertinent point that a USO service should encompass people rather than premises in future.

[ii] An obvious historical relic of the current USO is the need for 'pre-selection' allowing customer selection of long distance carrier

[iii] The Standard Telephone Service (STS) is a service prescribed by regulation. Essentially it is a voice-grade service which enables the user to establish a telephony connection to another user. There is also a set of service performance requirements such as reliability and service quality. Broadband capability is not a remit of the current USO scheme.

[iv] Eligible revenue as assessed by the ACMA for the USO levy termed the *Telecommunications Industry Levy* (TIL).

[v] The requirement is to allow 'reasonable access' to a data service.

[vi] Recommendation 9 of the Shiff Regional Telecommunications Review terms this the Consumer Communication Fund.

[vii] In Australia this is compounded by the scale of the incumbent's geographic dominance.

[viii] Coverage licence conditions for mobile operators were rightly removed in the late 90s review of competition unlike in many other countries.

[ix] It is understood the Victorian State Government would only commit funds to contracts awarded to Telstra.

[x] The Government has allowed $60million for a further round.

[xi] The author assessed this figure based on the NBN 2008 Implementation Study.

[xii] According to the ACMA Communications report 2008-09, there were around 39,328 payphones. According to the ACMA Communications report 2013-14, there were around 17,805 payphones.

[xiii] The Shiff Regional Telecommunication Review recommends a Consumer Communications Fund.

[xiv] The Shiff Regional Telecommunication Review recommends a Consumer Communication Standard.