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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. The *Journal* has been published (with various titles) since 1935.

Editorial

Regional Communications and the Role of Satellites

Leith H. Campbell
Managing Editor

Abstract: This editorial comes in two parts: some remarks on the role of satellites for regional telecommunications; and a brief introduction to the papers in this issue.

Keywords: Regional communications, Satellites, LEOs, Editorial

Regional Communications and Satellites

Now that Starlink's satellite-based Internet access is available in Australia and New Zealand (Fogg, 2022) and OneWeb has agreements with Field Solutions Holdings, Vocus and Telstra (Pritchard-Kelly & Costa, 2022, p. 22), are we about to see a revolution in Internet access in regional Australia? There is growing demand and some dissatisfaction with other offerings.

The latest triennial review by the Australian Government of regional and rural communications has recently been published (Australian Government, 2021). It recognizes that telecommunications continues to be a significant infrastructure issue for regional Australia in the face of a "step change in demand". It notes that, while Australia's National Broadband Network (NBN) provides a "baseline level of connectivity", mobile coverage remains inconsistent – described as a "'patchwork quilt' of connectivity"; also known as "salt and pepper connectivity" in the Agri-Tech report (Waters & Koch, 2022) from the Australian Broadband Advisory Committee.

One way of providing data communications coverage everywhere is by using earth-orbiting satellites. The NBN, whose role is to provide wholesale broadband connections to business and residential premises, uses geostationary satellites to provide service to about 100,000 premises (out of a potential 400,000 planned connections). This satellite service, called Sky Muster, came in for particular criticism:

http://doi.org/10.18080/jtde.v10n1.565

> Although Sky Muster Plus has improved access to data, Sky Muster users are frustrated by insufficient data allowances, high latency and reliability issues (Australian Government, 2021, Key finding 9, p. 7).

Geostationary satellites have long been used for communications – the first commercial one is now a museum piece (Intelsat, 2022) – but they are not suitable for voice communications because of high signal latency. They have provided – and will continue to provide – global data communications. The stated policy of NBN Co in 2021 was to consider replacing the Sky Muster satellites when they reach the end of their nominal operating lives (Campbell, 2021).

Partly in response to the criticisms in the Regional Telecommunications Review, and in line with general network development, the Australian Government and NBN Co have announced a further extension of the NBN Fixed Wireless Access footprint to provide a terrestrial substitute for some Sky Muster services (Davey & Spears, 2022).

Meanwhile, new constellations of low-earth-orbit satellites (LEOs) are being deployed. As an example, this issue of the *Journal* contains an article on OneWeb's plans (Pritchard-Kelly & Costa, 2022). The Regional Telecommunications Review devotes several pages (notably pp. 61–62) to the subject of LEOs. Its key finding is:

> There are emerging technology options to meet the demand for data but their service performance has not yet been validated (Australian Government, 2021, Finding 11, p. 61).

There are also some potential barriers to the future deployment of LEOs described in another paper (Canning, 2022) in the current issue.

Starlink Internet access in Australia costs AUD 1,039 upfront for equipment and shipping, plus AUD 139 per month (Starlink, 2022). It is available in many parts of Australia, including the east-coast capital cities and Adelaide, but not yet Perth. It is unlikely to be price-competitive within the NBN fixed-line footprint, but it may be attractive in less densely populated areas and for other reasons. Performance is still being assessed.

On the use of satellites for regional communications, the Regional Telecommunications Review concludes:

> Nonetheless, it has been suggested to the Committee a potential future state will involve the complementary and interoperable use of both geosynchronous and LEO satellites based on their respective advantages and the specific usecase. Given the relative lack of maturity in the new satellite technology market, we consider that it is too early to make a definitive call on the role this technology will play in the Australian telecommunications landscape (Australian Government, 2021, p. 62).

It is a stated aim of the 5G/6G standards development path that there will be full integration between terrestrial and non-terrestrial systems for communications services (Soldani, 2021). Whatever the final configuration of telecommunications service delivery, it is clear that data services delivered by LEOs and other satellite systems will be a major driver of global communications services over the next decade. They may first influence regional communications but their effects are also likely to extend into competition with terrestrial networks in more populated areas. Future issues of the *Journal* will no doubt cover the growing influence of space-based systems.

In This Issue

This issue has a focus on public policy related to regional telecommunications. In addition, it includes papers on various topics in telecommunications operations and technology, an obituary, and an historical reprint.

Continuing our series of outputs from TelSoc's Broadband Futures Forums, we publish a Special Interest Paper, *Low Earth Orbit Satellite Systems: Comparisons with Geostationary and Other Satellite Systems, and their Significant Advantages*, from a Forum in August 2021.

In the Public Policy section itself, we publish an account from another Broadband Futures Forum, *The Broadband Futures Forum: The Australian Broadband Advisory Council Agri-Tech Expert Working Group Report*, held in October 2021. We also publish a commentary on the Agri-Tech Expert Working Group's report, *Australian AgTech: A Commentary on the Report of the Agri-Tech Expert Working Group June 2021*.

In the Telecommunications section, we have three papers covering a wide variety of topics. *Collaboration Principles between Telecommunication Operators and Over-The-Top (OTT) Platform Providers in the Context of the Indonesian Job Creation Regulation* considers the relationship between telecoms operators and over-the-top service providers in Indonesia. *Mobile Advertising Modelling for Telecommunications Industry: Focusing on the Boosting of Value Co-Creation* looks at the value of co-creation in mobile advertising. *Enhancements to the Deep Learning Signal Detection Model in Non-Orthogonal Multiple Access Receivers and Noisy Channels* describes improvements in signal detection from enhanced deep learning.

In the Biography and History of Telecommunications sections, we publish an obituary of Gavan Rosman and we reprint a paper from 1991 on the Iridium satellite network.

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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Low Earth Orbit Satellite Systems

Comparisons with Geostationary and Other Satellite Systems, and their Significant Advantages

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John Costa
Member, TelSoc Broadband Futures Group

Abstract: Satellites have been around for many decades, yet the low Earth orbit (LEO) was avoided as the cost exceeded the demand until recently. This paper is based on a live presentation to the Australian Telecommunications Association (TelSoc) by Ruth Pritchard-Kelly, Senior Advisor on Regulatory Affairs for OneWeb, and was chaired by TelSoc Broadband Futures Group member, John Costa. This paper describes the new generation of LEO satellites, how they substantially differ from earlier satellites, and the factors now making them not only viable but increasingly indispensable as part of a global communication ecosystem. The paper then introduces OneWeb's specific LEO plans, including details about deployment in Australia.

Keywords: Geostationary Satellite, Non-Geostationary Satellite, Low Earth Orbit, Medium Earth Orbit, Intersatellite Link

Introduction

This paper is based on a Forum about Low Earth Orbit satellites (LEOs) held in August 2021, the eighth in a series by the TelSoc Broadband Futures Group. LEOs are attracting global attention for provision of high-speed broadband in rural, remote, mobile, aeronautical, and maritime areas, particularly underserved or completely unconnected areas not adequately served by other infrastructures or prior satellite technology.

The Broadband Futures Group is currently focusing on broadband inclusion, affordability, and accessibility, particularly in regional, rural, and remote areas. The presentation and this subsequent paper consider factors leading to growing interest in LEOs. Differences between geostationary satellites (GSOs or GEOs) and non-geostationary satellites (NGSOs), specifically LEOs, are discussed, as well as differences among the proposed LEO providers. The paper then

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gives a brief introduction to OneWeb's initial LEO plans with highlights of the deployment in Australia, planned for late 2022. The paper concludes with a wide-ranging selection of questions and answers from the live forum. A postscript completed by the presenter seven months after the Forum, provides a brief update on OneWeb's Australian plans.

New satellite technology is dynamic and evolving and will effect rapid social and economic change in response to growing user demand and governmental inclusion pressures, and will support critical national and global communication and security needs.

Forum Presentation

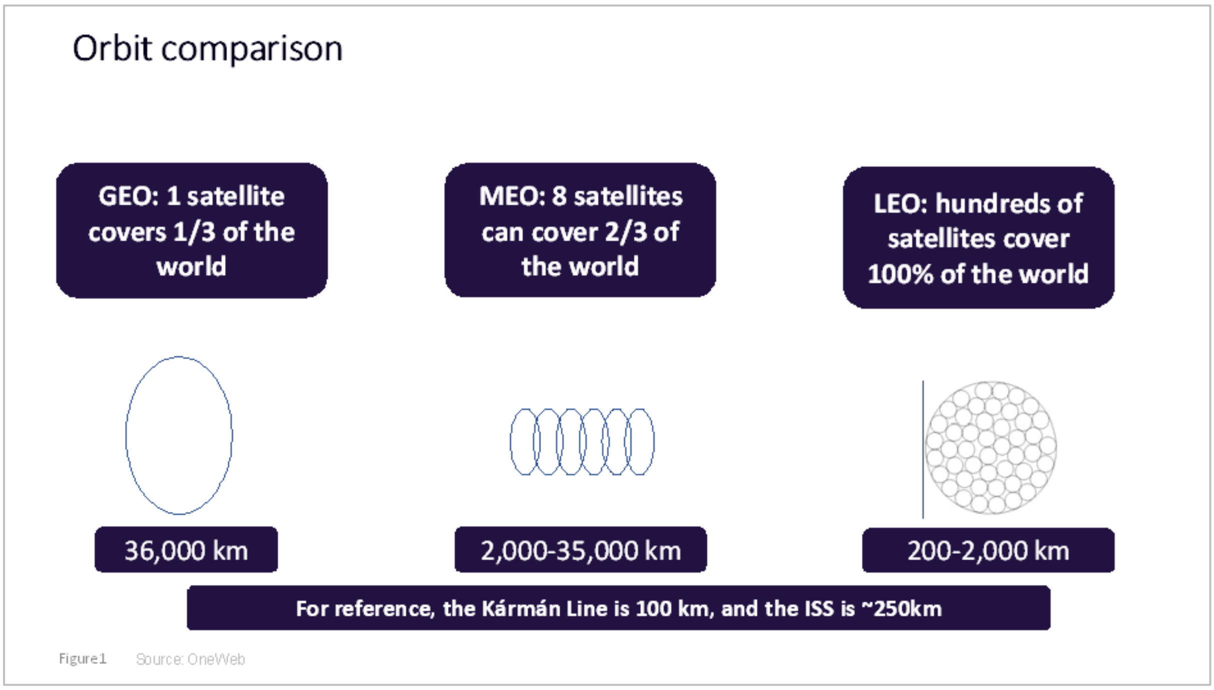

Figure 1. Orbit comparison

Orbital comparisons

Geostationary satellites cover massive areas of the world where a single GEO can cover a third of the world (Figure 1). Sixty years ago, engineers already understood the difference between geostationary satellites and LEOs. They knew that satellites closer to the earth would provide better communications and phone connections, but at that time were very unaffordable. The brilliance of Arthur C. Clarke (1945), the science-fiction writer who first proposed the concept of "radio stations in outer space" in 1945, is that he realized one could put merely three transceivers in a geostationary orbit and that would be all it would take to cover the entire globe. So that is what has been done for decades. Then, about 10 years ago, satellite company O3b (so-named for the "Other 3 Billion" people in the world without an Internet connection) realised that technology and demand had developed to the point where it could develop a cost-effective communication business plan by splitting the difference between GEO and LEO, planning a constellation in a medium Earth orbit (MEO) at roughly 8,100 km, which would only need 8–10 satellites to cover 80% of the world's population. More about the development of modern-day NGSOs is provided below.

Current satellite services and end-user experiences

Earlier satellite technology mostly provided limited end-user experiences that often came at high cost and with high latency, which became problematic for serving the growing demand for two-way, high-speed, low-latency Internet services. O3b's MEO could not quite cover the poles, but, beyond that, achieved the key target of population coverage and, due to the much shorter distance from the Earth, provided very low latency. On the heels of O3b's success, there are now four or five serious LEO competitors, all of whom are in the process of launching truly low Earth orbit satellites with around 50 ms round-trip latency. A couple of factors have contributed to that. In the past, people became frustrated with the performance limits of geostationary services, which were also very expensive. Technically speaking, reliability issues can arise within any part of the link to the user, be it the satellite, fixed wireless connectivity or Wi-Fi. However, the key issue was that, with the rapid growth of the Internet, demand for higher speed two-way connectivity for applications of data became key. Users would often time out mid-session if relying on geostationary satellites.

Non-geostationary constellations offer lower latency

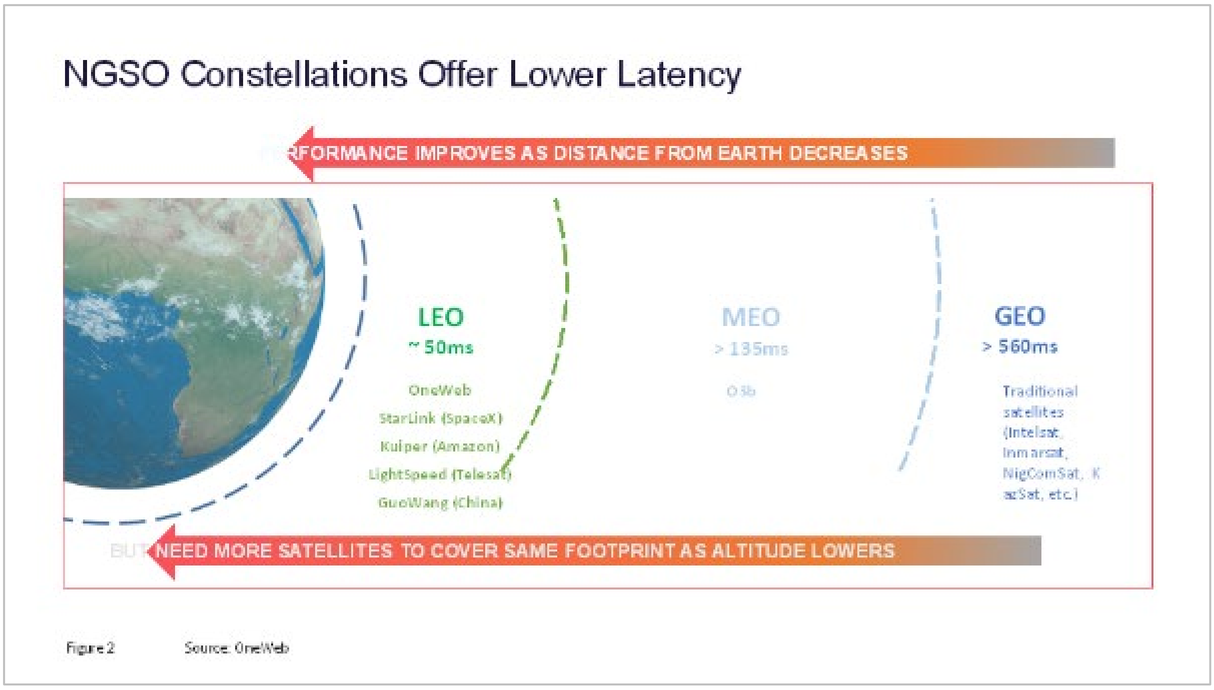

Figure 2. NGSO constellations offer lower latency

Now that the supply is less costly and the demand is higher, lower Earth orbit non-geostationary satellites is where recent constellations are all headed. Of these, OneWeb currently operates at the highest altitude of about 1,200 km, while Starlink, Kuiper and Guo Wang operate at around 500 km (Kulu, 2022). LightSpeed appears to be cutting the difference at about 800 km. O3b operates at roughly 8,100 km. The only drawback of O3b at the slightly higher MEO altitude is that its equatorial orbit does not cover north or south of 45 degrees. At the farthest extreme GEOs have greater individual coverage. That might appear favourable, except that they are designed as point-to-multipoint technology, and achieve that outstandingly. However, two-way, real-time connectivity is not their specialty. Latency (the delay between sending and receiving a signal) on GEO satellites at around 560 ms as a result of the much greater distance involved, compared to around 50 ms for LEOs (Figure 2).

Transformative satellite production

Substantial development has occurred in relation to throughput, launch costs, and therefore time to market. Very quickly a new generation of LEO satellites has drastically reduced costs for launches and assembly-line manufacturing of satellites (Figure 3). Some may recall the clean room of traditional satellite manufacturers, where it used to take a year, sometimes up to two, for hand-made construction. Now there are assembly lines in factories, not just for OneWeb, but also SpaceX and most likely Amazon are also looking to such an approach. This now means a satellite can be very quickly produced in under a day. Apart from cost savings, this translates to an ability to manufacture and start operating a new satellite generation in a matter of weeks, no longer a decade.

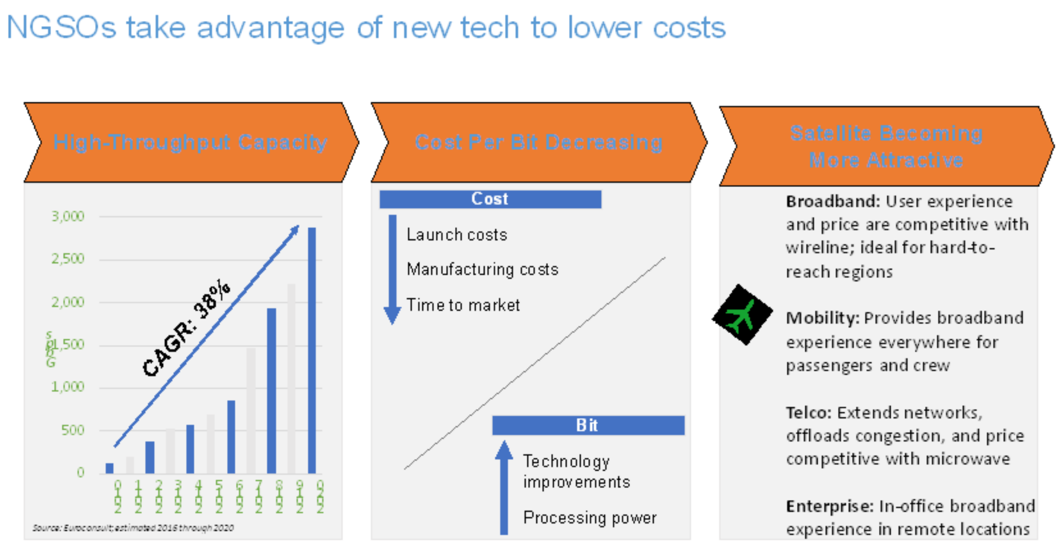

Figure 3 Source: OneWeb

Figure 3. NGSOs take advantage of new technology to lower costs

Consequently, demand has skyrocketed, both because of the increased demand for high-speed Internet and also because of increased use of personal mobility devices. Those two things have changed the world from 20 years ago, when a whole group of LEOs in the 1990s tried to implement this concept but were not successful, resulting in some spectacular bankruptcies. Many in today's satellite industry worked in the 1990s for Iridium and will remember that it went into and out of bankruptcy but survived because of one major customer (the US Department of Defense), which allowed Iridium to survive long enough to benefit from the rise of the Internet and the explosion in demand for connectivity while mobile that followed. As an early starter, Teledesic failed despite being operationally ahead of its time. The concept was exceptional, but the demand simply was not there.

The OneWeb satellite manufacturing plant in Florida, USA, features a streamlined, rapid, and meticulous production process. The plant is a joint venture between OneWeb and Airbus, which was very excited to get into the new form of satellite manufacturing. When fully staffed, this plant can produce three satellites a day.

Development of NGSOs since the 1990s

Figure 4. Development of NGSOs since the 1990s

As shown in Figure 4, Teledesic excited the whole world about changing spectrum allocations at the International Telecommunication Union (ITU), making sure that non-geostationary satellites were a new part of communication thinking, which had not previously been the case; nor previously was the software available for the ITU to assess a non-geostationary satellite spectrum filing. This was previously all done basically by hand, not quite with slide rules, but Teledesic very significantly raised the awareness within the ITU of NGSOs. A very good book on this is *Eccentric Orbits* about Iridium (Bloom, 2016). It is the thrilling story of how Iridium stumbled and fell but then survived.

It is almost unbelievable how close Iridium came to de-orbiting a fully-functioning asset in outer space, but thankfully that did not happen. No fully-functioning asset in outer space has ever been deorbited, even ICO, Inmarsat's original attempt at a non-geostationary constellation. They only got one satellite up, although they needed 20 for the full constellation. The company went bankrupt; and after a year or so, the United Kingdom cancelled the associated filing with the ITU, but another operator bought that single satellite and made a new filing at the ITU and used that same satellite for a different purpose for many more years. So, simply getting an asset into outer space can be a very useful thing.

Then, just a little more than 10 years ago, an engineer named Greg Wyler was struggling to set up a mobile phone network in Rwanda and he was irritated that he could not receive signals outside the city. Wyler went to a group of engineers he knew in Boulder, Colorado (USA) and asked them how he could address this challenge. Their response was to create a space-based solution, realizing that satellite is the only economical way to get geographic coverage across the world. SES, the Luxembourg-based satellite behemoth, quickly recognized that non-GEO satellite technology was the future and invested further by fully purchasing O3b. It is now reportedly considering inclined orbits for O3b, knowing the drawback of having only an equatorial orbit. OneWeb, along with three or four other very likely competitors, are now committed to lower Earth orbits. These LEOs want to provide 5G where possible and are already looking ahead to 6G, which is currently being explored.

Today's NGSOs build on past experience

Today's NGSOs build on that experience

Now, with the internet and personal mobility, the demand has skyrocketed at the same time the technology has developed and lowered in cost

	OneWeb	SES O3b mPOWER	SpaceX Starlink	Telesat LIGHTSPEED	amazon project kuiper	Guo Wang 国网
Constellation Size	588 (Gen1) (254 launched)	11	4,409 (Gen1) (1,740 launched)	298	3,236	6080 Gen1 12,992 Gen2
Frequency Bands	Ka gateways Ku users	Ka	Ka gateways Ku users	Ka	Ka	Ka (maybe also V, Q)
Orbit	1,200 km	8,062 km	550 km	1000 km	600 km	590-600 km 1145 km
Capacity	~5 Tbps (~7.5 Gbps/sat)	~2.7 Tbps (~200-315 Gbps/sat)	~75 Tbps (~17 Gbps/sat)	~12 Tbps (20-50 Gbps/sat)	~30-32 Tbps	Unk.
Target Markets	Wholesale, B2B, backhaul, enterprise, government, mobility	Backhaul, trunking, energy, cruise, aero, government	Residential broadband, government	Backhaul, mobility, enterprise, government	Residential broadband, enterprise, backhaul, mobility	Belt & Road diplomacy

Figure 5 Source: OneWeb

Figure 5. Today's NGSOs build on past experience

Figure 5 highlights differences between the current six main LEO competitors. None of them is fully operational yet but close to becoming so. It is effectively a race. What is particularly interesting is that each one of these constellations has a different architecture and each employs the most outstanding systems engineers. There are various ways to be *not* geostationary, and these can all work differently. Some of the competitive factors at play here include who gets financing and who gets built, because each one of these constellations costs $5 billion to $10 billion to put up, as you cannot simply put up just a single LEO, or even just one plane of LEOs. A full constellation is required and that is a lot of satellites and a great deal of money. Overall, it is effectively a matter of who attracts the funding.

The next key issue is who is going to get the customers? Many will remember fights between hardware and software, where the winner was not necessarily the one which engineers considered the best. Rather, it could be a matter of who has better marketing, or who has best bundled its software and hardware. As an example, Microsoft bundled the “Word” word-processing software with its computers for free, so most of the world starting using that software, as opposed to WordPerfect, which was arguably a better software. Similarly, others may remember Beta versus VHS back in the video cassette day. Most engineers considered Beta a better product but, for various market-driven reasons, VHS became the success story. So, unfortunately, the best engineering does not always win the day. There are other factors. All these LEO constellations include excellent engineering, but all are based on different architectures.

Importantly, it is to be pointed out that the one thing all these satellite systems do have in common is the Ka spectrum band. Every single one of these LEOs is dependent on the Ka band. For at least four of these systems, it is both the gateway’s main band as well as the band for user links. Some of these satellite systems use other bands for user links, but the Ka band being used, the 28 GHz band, is vital. And so, the incursion by terrestrial use into this band is a unifying enemy for the LEO world. It is a real threat, and the satellite industry strongly prefers that the terrestrial industry moves into the 26 GHz band, where there are not as many satellite users.

Note, too, that the competing LEOs use different orbits, and they are all claiming to offer different capacity. In reality, capacity is scalable, depending on how many satellites are put up. And then, with second and third generation constellations (often shortened as “Gen2” and “Gen3”), everyone will design more powerful satellites. So even though you will have still only 200 satellites, they will have 10 times the capacity because each one will be larger or more powerful. Finally, these constellations are basically all going for the same target markets. Anything terrestrial in such situations does not do so well.

These LEOs work exceptionally well in particular situations. Some LEO providers are starting out more in the wholesale direction. For example, OneWeb will not be selling directly to consumers. The likes of Telstra and Optus and local mobile phone companies will be OneWeb's customers. They will use the OneWeb infrastructure as their backbone to provide their universal service and/or their coverage to all of mainland, islands, waters, and skies of Australia. SpaceX currently is using a different business model. While obviously they can offer wholesale to a mobile network operator, they are aiming to go direct to consumers right away as in their current beta trials. They are starting with residential broadband as their main focus. It should also be pointed out that Guo Wang, the Chinese satellite company, actually has three or four systems under contemplation and may now be known as ChinaSatNet. It can be anticipated that one of these might get built more for political and diplomatic than for commercial reasons.

However, there are always challenging issues; for example, the USA and China have had disagreements over Huawei. It would likely be very hard for political reasons for the Chinese government to allow its people to use Amazon or SpaceX. And so, use of a satellite constellation may relate to what its home country is, and who are that country's allies. The Russians have talked about a system, but perhaps the Russians will join with a Chinese or other system. Then, there are further political issues. You might want to use a Chinese launch vehicle, but might not be allowed by your government to do so. And so, such complex issues get thrown into the mix as well.

The early days of OneWeb

Some will remember that, at the same time the world effectively went into lockdown for a pandemic, OneWeb went into bankruptcy, and these events are not unrelated. SoftBank, OneWeb's main investor at that time, lost $40 billion in a week. When they pulled their financing, OneWeb was not yet fully funded and it was a real shock. OneWeb fired 95% of its staff, retained only core employees and fleet engineers to keep the satellites safely flying, and — through the United States Court bankruptcy process — started to find new ownership.

What emerged was that Bharti Airtel, a multi-national mobile network operator based in India and offering service in many nations in Africa as well, and who had been an early investor in OneWeb, effectively stepped back in and was able to convince the UK government that — since these satellites were authorized by the UK and listed in the UN as UK objects and the ITU spectrum filing was also through the UK — this constellation was a national asset, and that the UK had every reason to keep it going, and to make it better. It turned out to be a successful argument, and Bharti and the UK jointly put in a billion dollars and brought OneWeb out of bankruptcy. That was in the summer of 2020. This is broadly outlined in Figure 6.

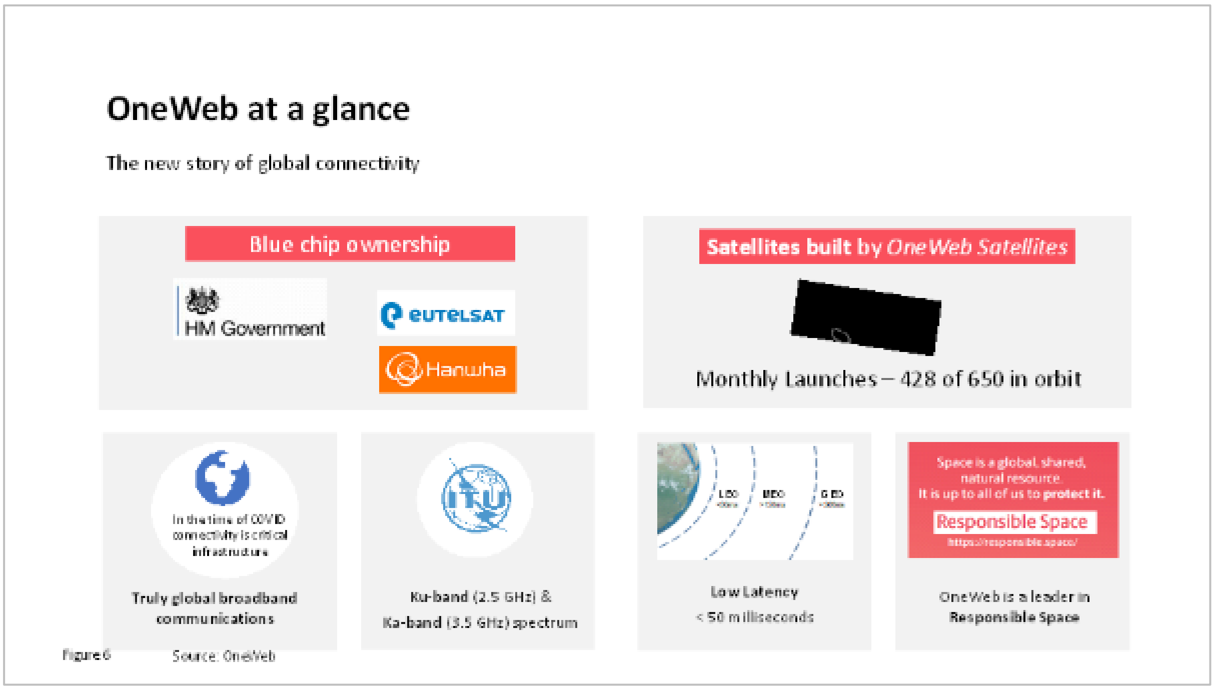

Figure 6. OneWeb at a glance

By the end of 2020, Eutelsat had come in with a significant investment and Bharti put in a further half billion as a way to confirm its commitment and prevent dilution of its share. In 2022, Eutelsat increased its investment, and Hanwha of South Korea also invested. OneWeb are now fully funded for their first-generation satellites and well into the design of the second generation. At the time of writing, OneWeb has over two-thirds of its constellation in orbit. Already OneWeb can provide service above 50 degrees north. As it is a polar orbiting satellite system, one can picture lines of longitude around the globe to sense the layout of the architecture.

Although OneWeb could theoretically also provide service below 50 degrees south, as that area is also already fully covered by satellites, the gateways and service providers are not in place for that part of the globe as yet. The whole rest of the globe should be covered by satellites by the end of 2022, and services will start as soon as gateways and service providers are set up in regions. By the end of 2022, OneWeb expects to have all of the first generation of satellites in orbit and able to provide coverage anywhere in the world, including the oceans and the skies. As shown at the lower left of Figure 6, and as is now widely recognised, the pandemic strongly reaffirmed the need for remote connectivity.

Of particular interest are the events that made OneWeb's business plan make sense to the financial world. The first was when Amazon entered the field a couple of years ago, which was after SpaceX and OneWeb and several other companies had applied to the US Federal Communications Commission (FCC) and obtained their licenses, and crucially after these companies had already filed for spectrum at the ITU. Amazon came in after all the others, which said to the world that Amazon thought they could compete and win, despite those hurdles. Suddenly that made financial analysts look at OneWeb differently. Then, intriguingly, the pandemic led to demand for universal remote wireless connections, and staff in Wall Street itself and the City of London also needed remote connectivity, which led them to truly understand the global need for remote connectivity.

Then, the last thing on Figure 6 is to point out that sustainability of outer space has become *the* discussion. All users of outer space, not just the satellite operators, now recognise that space objects are coming under great scrutiny as people begin to recognise and understand that space includes garbage, left intentionally or unintentionally, that could cause collisions, disrupting communications for people on earth. So work is underway on that important discussion.

OneWeb is acutely aware of and engaged in work avoiding physical traces of unneeded space objects. They are also now discussing with the astronomers the unexpected issue of light pollution, and the great concern to the astronomers of the world that all of these constellations are creating. It is a problem for them, so OneWeb are strongly focused on responsible space use and appropriate measures.

OneWeb's constellation

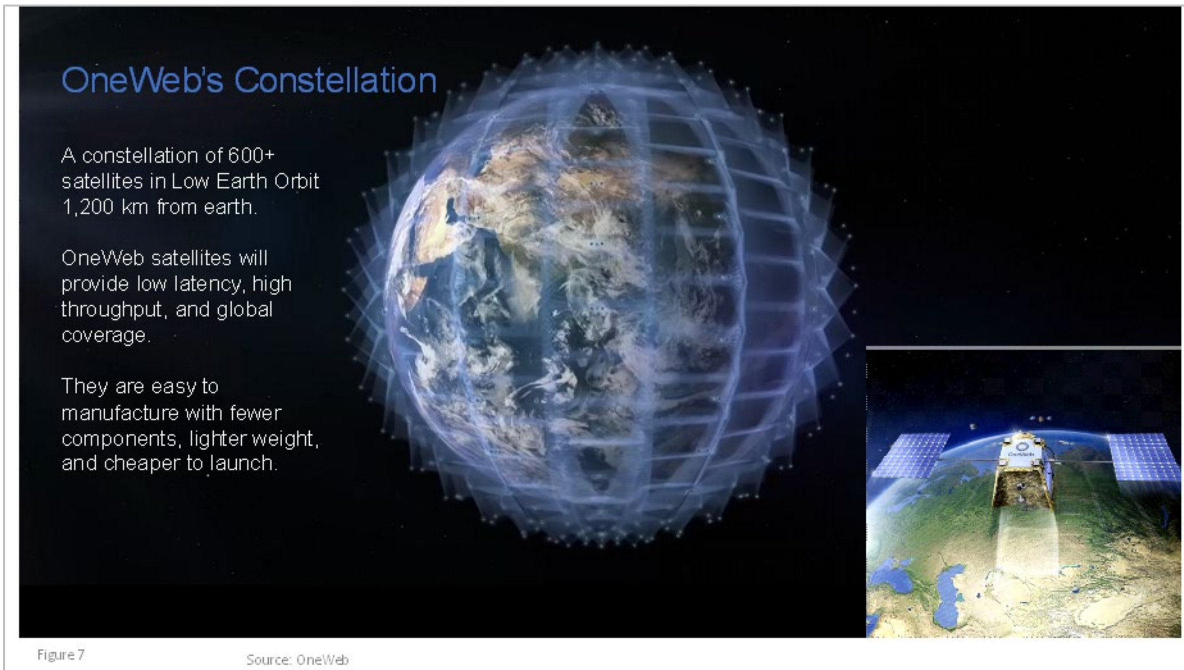

Figure 7. OneWeb's constellation

OneWeb's architecture will have 12 planes in polar orbit (Figure 7). As already indicated, the first generation will comprise about 650 satellites. Some of those will be spares, so it is anticipated there will be 588 active satellites with approximately 50 satellites in each plane.

Depending on how the demand grows, the design is flexible and does not require overbuild. OneWeb has already begun discussions on what the Gen2 satellite system might look like, and its capacity. Some customers are interested in 'hosted payloads' taking advantage of having a constellation up there that could also support other services, such as positioning, timing or remote sensing.

A visual overview of the OneWeb solution is shown in Figure 8. The Ka band is used with OneWeb's large gateway earth stations that are called "satellite network portals" or SNPs, each of which is a group of antennas.

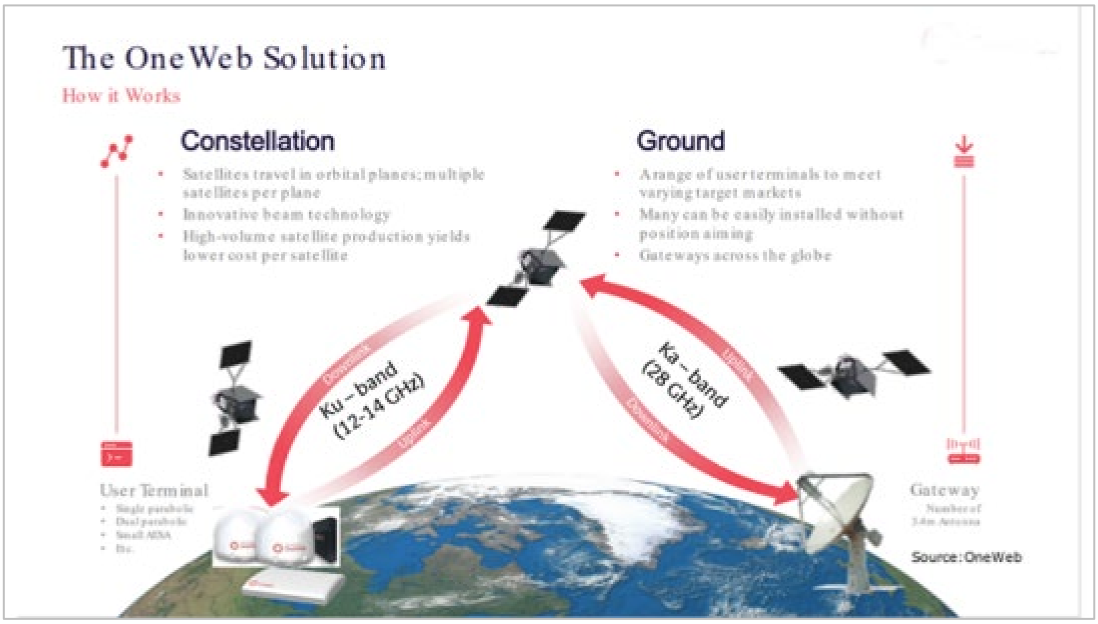

Figure 8. The OneWeb solution

Sometimes, a satellite operator will collocate its network control and its data protection at the gateway, but for OneWeb's operations the connection to the Internet (and therefore data security) happens at Points of Presence (PoPs). The PoP could be many miles away, even in another country. OneWeb does not need an antenna farm in every country of the world, hence it has changed the terminology somewhat to "SNPs". On the left of Figure 8, the downlink to the users is in the Ku band, very typical classic, fixed satellite service allocations, so nothing is new there. It is just the size of the satellites and the size of the antennas on the ground that are somewhat novel.

A simple operational sequence can be visualised as one SNP hands off a user connection to another SNP. The user beams on the satellites are slender rectangular beams, what OneWeb calls a 'Venetian blind pattern'. As any one satellite begins to distance itself from an SNP, a second gateway picks up the signal; and there is a very brief moment when the two SNPs both control the user signal before the first SNP hands off to the second. The LEOs all use some sort of handoff, so there are no dropped communications.

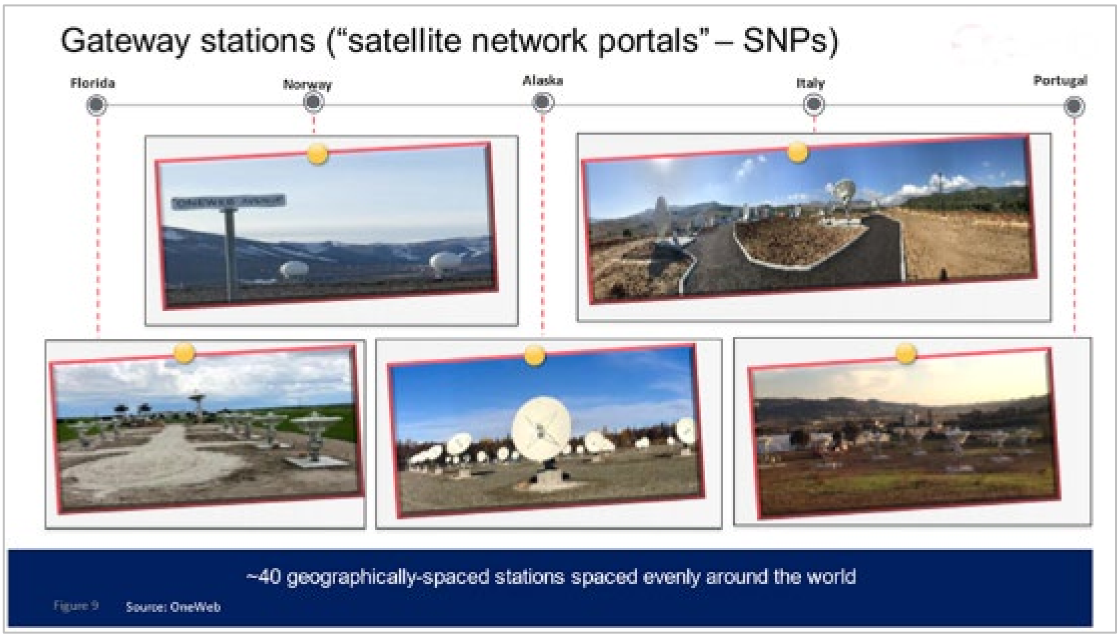

Figure 9. Gateway stations (Satellite Network Portals – SNPs)

Figure 9 show some OneWeb gateways. There are likely to be around 40 of these gateways geographically spaced around the globe. They use traditional parabolic 7.2 m satellite dishes. OneWeb's SNPs need about 20 antennas to link to the full constellation. At the far north and far south of the globe, the SNPs use more antennas because of the convergence of the planes over the poles, where our stations are looking at hundreds of satellites at the same time. The antennas in the far north are covered by a dome, mostly for wind protection but partly also against the cold. SNPs at the equator are not linking to as many satellites at the same time, as the planes are more spaced out at the equator, so there OneWeb only needs about 15 antennas.

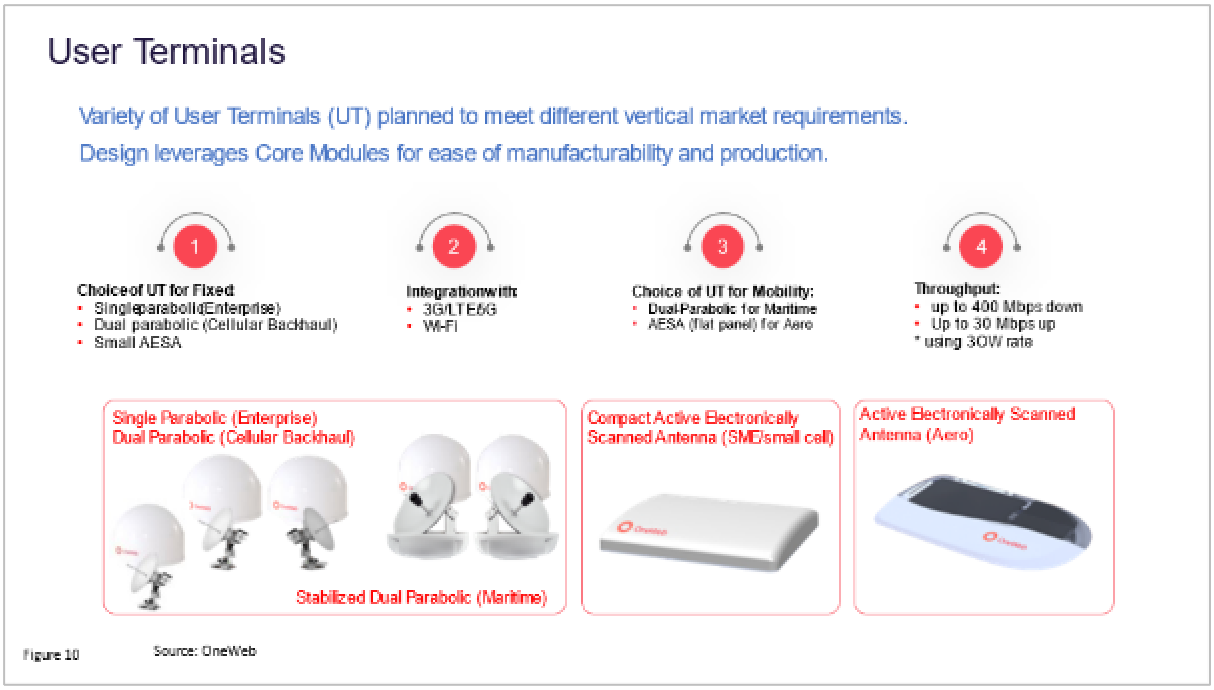

Figure 10. User terminals

Now to describe the generic User Terminal types. On the left of Figure 10, the traditional state-of-the-art is two small parabolic antennas, which track the satellites. The satellites do not appear geostationary: they appear to rise and set just like the sun. So, the antenna must track them as they rise and set. The second antenna receives a hand-off from the first, before the first antenna hops back to the start position to track the next satellite rising on the horizon. They are about a metre in diameter and, while that is too large for mobile applications, for a population in the middle of nowhere, they probably have a field where they would be perfectly happy to place two antennas.

That is the type of user terminals the very first demonstrations and trials will involve and will subsequently always exist as an offering. However, what OneWeb and the other LEOs are designing now are the devices on the right, which are flat panel, electronically steered, phased array antennas, where mechanical tracking is no longer required. They are small and are referred to as being the size of a pizza box. They are also lightweight, which is especially important for aeroplanes, but also in a car. This is where the most inventive work is happening. Antenna manufacturers are actively striving to invent this next generation of user terminals.

Once these LEO constellations prove themselves, they will be in demand in the middle of 'nowhere'. This is not going to catch on in downtown Sydney but, if you need to drive from Sydney to Perth, or you live somewhere between, or you are in a boat or aeroplane, there is a need for reliable and consistent connectivity. And so, space-based wireless will be the solution, and the best antennas are required.

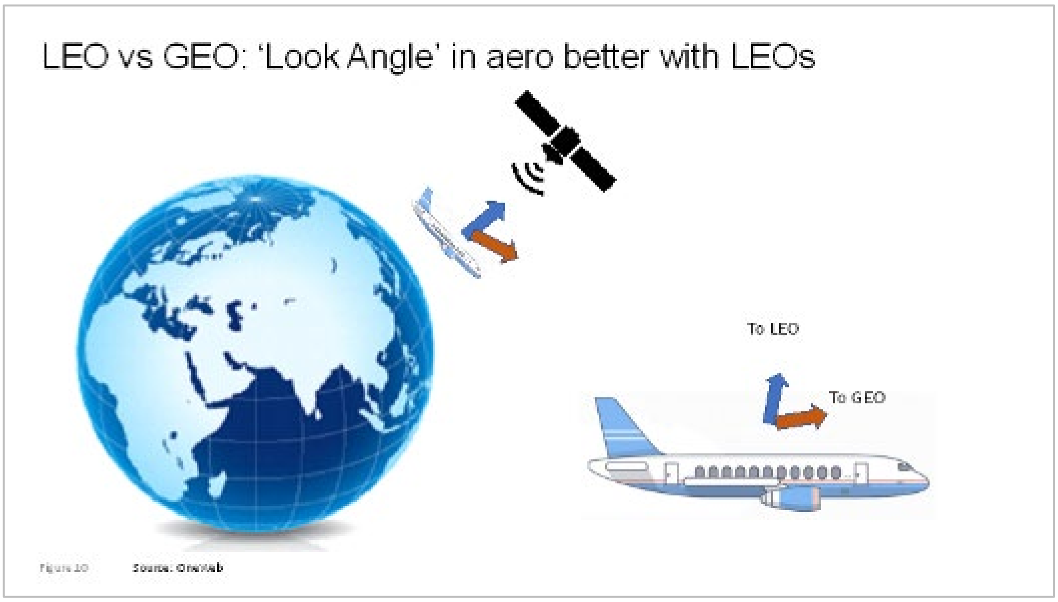

Figure 11. LEOs vs GEOs: 'Look angle' in aero services better with LEOs

Figure 11 illustrates satellite connections to airlines around the world. Until now, they have mostly been using an OCB (One Connect Box) to serve airlines or cruise lines. Their antennas are pointed towards the equator because that is where the geostationary satellites are which

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are the ones currently providing aero services, but that pointing direction is not great for many routes.

If, for example, you are flying the North Atlantic route from Paris or London to New York or Los Angeles using the old technology, there is quite a low ‘look angle’ to link to your satellite and that is a problem. However, if you use a LEO, given that these constellations cover the entire globe, there is always a satellite directly above you. Connection via LEO for aeroplanes will substantially improve communication service and quality, just as for shipping of any kind. The only problem area, true for all of the LEOs, will be a small patch of the South Pacific that is quite far from any landmass, and thus hard to land the link at a gateway or SNP.

Constellations are challenged by where best to locate gateways, as some parts of the oceans are too far from any land and so mobility customers in the sea or air would not be able to connect currently. The obvious solution is Intersatellite Links (ISLs), which can then deliver communication from anywhere to anywhere. ISLs allow satellites to talk directly to each other, without landing the signal on Earth. Although some countries have been nervous about intersatellite links, because of a fear this could be a way for one home ITU administration to control another country's communications, in fact ISLs are the very way that a nation can ensure that its air and maritime communications do not need to land in an unintended foreign territory.

The industry will likely have ISLs on most of the second-generation LEOs. And again, ISL — like the flat-panel antenna technology — is just not yet fully available for mass production but is expected to be in the next year or so.

Anywhere in the world in the middle of nowhere, a pole or tower can be erected, whether for a village or a mining community — or along the path of a highway, an antenna can simply be used that might also be a user terminal — and these can be connected to a community with Wi-Fi, fibre or whatever else might be required on the ground for wider local distribution. You can also be on any kind of moving vehicle or ship, large or small. The new LEOs hope that, with a smaller antenna, they can also compete with the existing maritime satellite operator for superior experience, lower latency, and higher broadband speeds.

The military and the UN have been using O3b from 2015 for various peacekeeping missions in areas such as central Africa. These have mobile requirements with wide locational needs. Again, space-based infrastructure is clearly the solution for many military theatres.

Finally, cities can be covered too; however, satellites are not likely to be used where terrestrially-based wired and wireless services already exist and are plentiful and affordable. Space-based solutions can also offer a kind of insurance in case of natural disasters. It is possible to drop in a new terminal via helicopter and have replacement communications within a few hours. Space-based communication is the only technology that literally covers the whole world at any time.

Given OneWeb's horizontal organisation structure, its overall market sectors broadly comprise Cellular backhaul, Government, Satellite Broadband and Mobility, visually summarised in Figure 12.

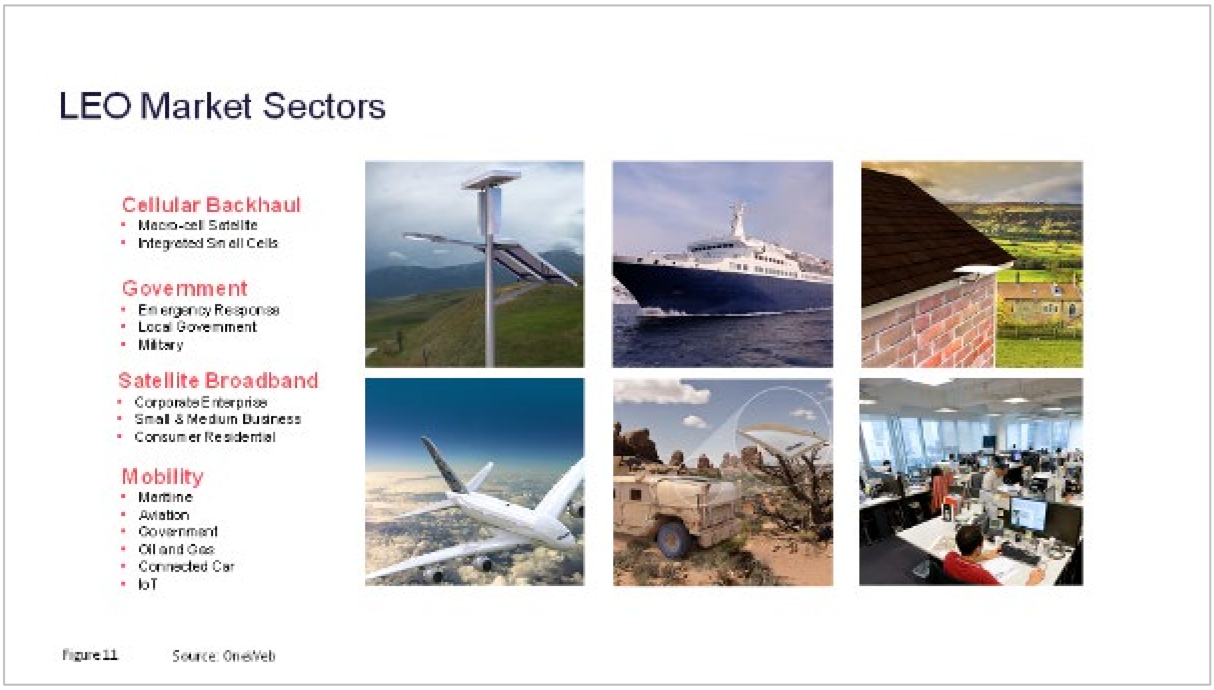

Figure 12. OneWeb's market sectors

In Australia, OneWeb has already started building three SNPs. Coverage of Australia should be complete by the end of 2022 and service can begin when local partners are ready. OneWeb has two POPs, near Sydney and Perth. There will be a customer demonstration site in Sydney. There will be both Ka- and Ku-band antennas on the roof of that demonstration site, and a package showing what user experience would be like. OneWeb will also support large customers ready to trial or demonstrate at their own premises.

OneWeb's Australian presence at this stage comprises 3 SNPs in Perth (*West:* Gnangara, Perth, WA), Darwin (*North:* Tivendale, Darwin, NT), and Toowoomba (*East:* Charlton, Toowoomba, QLD); 2 PoPs in Sydney and Perth; and a planned Sales and Service demonstration Centre in Sydney.

Audience Questions and Answers below are from the August 2021 Forum, and are followed by a Postscript added in early March 2022.

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Selected Questions & Answers from the Forum

What are the status and availability of the various user-terminal types?

For SpaceX, residential terminals appear to be their focus. They are organisationally vertically integrated so are building their own satellites and user terminals. Obviously, they are also launching their own satellites, but I am not sure about their gateway or stations. So, they control the whole system, and their focus is on a residential terminal first. In comparison, OneWeb is structured horizontally and has collaborative "distribution partners". OneWeb is simply the operator of the satellites, so OneWeb hopes others will invent user equipment. Historically, it is a challenge to get enough devices built, so, when new products emerge, it is often the government who is the early mover.

The military is willing to try new technology at an early stage and is less concerned with cost. They want something small enough to fit in a backpack and are often prepared to pay a premium if it works. So that is typically the first adopter. Then there are other people for whom price is less important than connectivity. There will also be some people who absolutely must have new products. In a few years, perhaps 2025, pricing will be at truly wide-scale residential levels. Between now and 2030, many people will begin using a non-GEO for their communications. They will still have their terrestrial service, but it is likely that the GEOs will no longer be providing voice or Internet after that time, because there will be a better technology and GEOs will be used for something else other than two-way communications.

It is impossible to have low latency from much higher orbit GEOs, so what is their future?

Looking at six GEO providers, just three of those appear likely to survive. It does not mean GEOs will not still be used. But they will not be used anywhere near as much, and will not be used for two-way communication, except in an emergency, or where they need to provide temporary capacity, in which case they will be valuable, as 'something' in a crisis is better than nothing.

The Soviet era Molniya military satellite system used highly concentric elliptical orbits to achieve a long dwell time over high latitudes. Is that helpful?

The Molniya orbit was a brilliant idea for the Russian land mass, but it is not needed for a constellation with polar planes that wishes to serve the whole globe, not just the far-north land mass of Siberia. OneWeb's planes cover Australia without the complications of a Molniya-type orbit. None of the LEOs currently planned are considering this orbit. That does not mean that Russia might not use it for their own purposes. They might not want a full constellation but do need to cover their far north. There are political reasons why they might not want to use other systems being planned.

Are mining companies likely to be significant users of LEO systems?

Absolutely. Mining companies in Australia and the rest of the world are bigger than many cities and have enormous business data demands, together with quality-of-life data for their workers. The same applies to oil and gas platforms in the middle of nowhere, where enormous volumes of data are needed for the industry, and also people wanting to Skype, manage their bank account, and watch television. It is two-way traffic, so large enterprises are very much a big part of the market for OneWeb.

Is NBN Co likely to be interested in using LEOs for satellite services?

In areas where they do not have or cannot provide good coverage yet, LEOs provide opportunities to cover everyone: for all the islands which are part of Australia, all of the waters, all of the airways, and as you drive across country, in the middle of nowhere.

Without pricing information, what can be said about LEOs and the Digital Divide? Will non-governmental organizations (NGOs) be able afford your services in remote areas?

All satellite companies need and want to make money. But they also need to offer competitive pricing or their services will not be bought. Whatever it would cost for you to get a fibre or an alternative connection in unserved remote locations or in the middle of nowhere, satellites will be less expensive in such locations. They will probably never be as cheap as getting 4G in the city because it is already there. However, there are so many ways to bring the price down where there is dense population. But, if there is any way right now for you to get satellite in the middle of nowhere, LEOs will all be cheaper. For digital-divide reasons, some satellite services might also be subsidised. OneWeb will work with governments to help ensure it is affordable.

OneWeb knows it needs to be cheaper than the competition and, for a lot of NGOs, the technology just has not been there to provide connection. O3b was the first satellite company that really met the promise to connect the unconnected. That has brought along other competitors. OneWeb knows it has to be affordable, or no-one will use it. There cannot be promises that the service is going to be cheap, but it will exist and be reasonable. If you are a farmer in the middle of nowhere, you are going to expect to pay more than the guy in the middle of a large city.

What is the risk of interference with many LEOs in a small area?

There are two kinds of interference of concern. One is spectrum interference, and the other is physical interference. And, obviously, OneWeb is paying attention to both. Most engineers here are well familiar with spectrum interference. You do all kinds of coordination, including with other satellite operators, and the way the system works is that the newer system has to take into account whatever is there already: the system designed five years ago could not

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envision that a new system would come along later with a potential new interference issue. Spectrum coordination is now a mature and largely self-regulating regime. However, it is still very effective because, if you ignore it and proceed to broadcast your signal, both parties suffer. The coordination process itself is straightforward.

Space is big and there is no one "sweet spot" for NGSOs. There is no one altitude that is much better than others. There is no reason why the people operating at 500 km, say, could not be at 600, 700 or 800 kms, with virtually no difference in latency. OneWeb and others develop an architecture and then approach the ITU via their administrative countries. If several countries all want to use the same altitude, the question is: who is going to move? However, in practice, currently working satellites are not the problem in outer space.

If you have two objects that can both manoeuvre, there is not going to be a collision. Nobody wants a collision: you lose money. The problem is where you might have two objects that do not or cannot manoeuvre, or where one of the objects is so small, it cannot be seen. The objects that are smaller than about 10 cm are often not trackable. And those are the ones we are worried about, tiny bits of debris which, if hit, can cause trouble. The problem is not that six LEO constellations are going to go up and going to hit each other. That is not going to happen. And the LEOs are not going to collide with their own satellites either. Even if one of them were suddenly to become non-operational, that is not going to happen. The problem is the small bits of debris from other earlier accidents, and that is what the industry needs to address. The world needs to figure out how to readily remove debris from space and industry needs to continue to engage on this.

How do you deal with the visual impact of satellites, in particular for astronomers?

This conversation is active between OneWeb and the astronomy community. OneWeb goes to all associated conferences and talks with astronomers in the UK, the US and elsewhere. OneWeb has started collecting data from the GAL Hassin observatory in Sicily. Nobody wants to interfere with the astronomers' work. There is no upside to a constellation blocking the skies for astronomy, so OneWeb is actively exploring solutions with them. How can OneWeb design Generation Two satellites so they are not reflective? What can OneWeb do via software for the telescopes to mask the reflectivity, based on knowledge of where our orbit is going to be?

Alternatively, is there a way to put telescopes on our satellites as a hosted payload, effectively raising the telescope above the height of OneWeb's orbit? OneWeb's satellites are not visible to the naked eye. The Starlink satellites are visible as they rise on orbit. They are visible to the naked eye, and this is what shocked the world when astronomers saw a 'string of pearls' across their photographs, and of course were understandably troubled.

This is somewhat analogous to the early days of telephones and telegraphy and electricity, where ugly poles and aerial cables blocked or impaired the view, yet all needed electricity. So, the world put up with the visual pollution for a while until industry figured out how to address this, whether by burying cables or using wireless. There will be a similar compromise in this situation. The world will put up with some of the light pollution (because connectivity is a human right as well), while continuing the discussion of how the LEOs can decrease their impact on a dark sky. A huge amount of work is going on right now in this area of responsible space.

Will OneWeb be able to offer unlimited bandwidth services to individuals?

As I am unsure of what is meant by unlimited gigabytes, the answer must be no, because, even if the individual involved were our customer, there would need to be a contract for a specific amount of capacity. An individual customer could not have all of the, say, four terabytes available. However, if you are talking about a data plan for residential users, I am sure the answer is yes for the particular capacity offered with that plan. Again, OneWeb has terabytes of capacity over the world and expects to progressively scale up as demand expands. Remembering that the ISP is the customer, the answer will be what the ISP offers. OneWeb is not going directly to end-users. Over time, that overall capacity will increase.

Do you consider AST's satellite service connecting to standard mobile phones a direct competitor?

Direct links from a satellite to a personal mobile are the holy grail for the satellite industry. That is what the industry has to invent. The right batteries and the right power on the satellites are needed. AST is not planning to do that. They are going from their satellite to a cellular network, and then from the cellular network to your phone. As a competitor they are a few years behind OneWeb.

What can you say about OneWeb's innovation program and where it is heading?

The innovation program is really about hardware for the satellites and user terminals. Everyone is encouraged to get involved, and to reach out to OneWeb's Chief Technology Officer and explore what needs to be invented.

Other initiatives involve spectrum. The satellite industry has been working on NGSO issues since the 1990s. At the 2019 World Radiocommunications Conference, the industry suggested future agenda items that are being studied now to be addressed and resolved at the 2023 Conference. Retaining the 28 GHz band for satellites (the Ka band) is imperative.

Sharing between NGSO systems needs to be coordinated. The ITU rules are overwhelmingly designed for GEOs, and to protect the GEOs over other configurations (such as LEO). By 2027 there may be an agenda item to ease the restrictions imposed to protect the geostationary arc, as there will be fewer GEO satellites by then. There will be no need to protect the whole arc; systems can do a one-on-one coordination with whatever GEOs still exist.

The design and management software at the ITU also has to be improved to handle more NGSO coordination. Geostationary is comparatively easy. Once you are *not* geostationary, there are an infinite number of possible architectures for which their software was struggling to cope. So that is an issue for the ITU. NGSO sharing and protecting the Ka band are the big issues, as are the build-out milestones. There are six main systems that have been proposed. So, in 2019, the ITU's quadrennial World Radiocommunication Conference (WRC) agreed to the idea that you can bring a LEO system into use with one satellite, but then you have got to build it out within certain timeframes. If you do not build it out, you lose your right to that spectrum priority, which is only fair. There are a couple of planned satellite constellations that are not likely to make their build-out milestones, their first 10% milestone. So, the question will be — will their government go to the ITU, to the WRC, and say: please give us a waiver? They can argue that they are moving but it has taken longer than first thought, and that it has never been done before. It is likely that a government will go to bat for their LEO systems at least once to ask for a waiver.

Will OneWeb collaborate with non-satellite telcos to improve remote area service?

Absolutely yes. That is our ideal customer. We are pleased for a telco in a remote area to come to OneWeb and put an antenna wherever they need it to cover their entire population. It will be an overnight solution to universal access and coverage.

Can you share your retail service provider strategy?

OneWeb will be a wholesaler, business-to-business. Direct-to-consumer (or "retail") might come later but is not being discussed yet. OneWeb offers high throughput, 4G-quality broadband. OneWeb will also offer many 5G-quality connections, but the most latency-sensitive 5G and 6G applications are not going to use satellite: they will need small cells very close, with line of sight. However, those are only a few niche applications (financial, smart cars). Most applications will find the latency of LEOs to be as good as fibre. The commercial team does not discuss prices except directly to our distribution partners, and it is they who set the service prices in any country. Our partners know they must compete with mobile and fibre and will price accordingly.

What can you say about using LEOs as a terrestrial competitor?

One of the reasons that the UK government wanted to make sure its OneWeb asset in the sky continues is that the UK decided to leave the EU, thus depriving itself of access to the EU GPS competitor, the European system known as Galileo. Many countries now realise that being dependent on a single other country for vital information, such as positioning and location, is maybe not a good idea, especially when GPS was originally a US military product, although it is no longer military. So, Galileo came along, and then the UK, much to their surprise, were kicked out of Galileo when they decided they did not want to be part of the EU.

The UK were looking for a way to have a national positioning-navigation-timing (PNT) system and are talking to OneWeb about what it can offer. The current generation of OneWeb was clearly not designed to be a GPS-like satellite, but there are things OneWeb can do even with the current generation. Gen2 is wide open in this respect so, again right now, that is exactly the kind of thing being discussed.

Although a commercial question, will non-government organizations be able to afford your service in remote areas, and is it likely that you would have charging regimes that depend on the particular type of user?

Every government in the world wants its population covered. If that population or government does not have the money themselves, they often turn to the World Bank or the IMF or the UN for funding. There are many other nations like Australia that have an enormous universal service fund, but maybe the technology has not been there. So now, they have the technology.

You mentioned the polar orbits, which of course is very similar to Iridium. You also had, in some of your models, orbits about the Earth at an inclined angle at about 55 degrees and about 50 and also 45 degrees, and it looked like you almost had three different satellite skins going round in the later model. Noting that you had already asked for permission to go up to 48,000 satellites, what is the thought process behind that?

The answer is simply "options", as all the LEOs are still inventing their best architecture. OneWeb filed at the ITU back in 2015, and then did more filing in 2017 and 2019. And yet this system is not going to come to fruition until 2023, or later, so an ITU filing has a bit of brainstorming. What could the best architecture look like? What might be needed? Constellation architects may change their thinking as the system begins to actually operate, and the next generation of constellations may not need tens of thousands of satellites. At one point, SpaceX had filings of up to 42,000. In 2021, OneWeb thought briefly that it might need 48,000, but, honestly, it seems more likely that OneWeb will not need more than about 1,000, because the plan is for Gen2 to be more powerful, instead of needing more satellites.

Inclined orbits are a concept that would put more satellites directly over population centres. The downside of a polar orbit is that there is a huge capacity at the North and South Poles where there is very little demand. The idea with an inclined orbit, at say 50 degrees, is that the satellites will orbit right over many of the major cities of the world and all of the supply will be used.

Where will the ground stations be in South America?

The ground stations across the world are evenly spaced geographically. There are four in South America, two or three in Central America, and four or five in North America. Any country that is concerned about network security can have a PoP in their country, because the PoP is where the gateway connection to the Internet is, so every country does not actually need an SNP.

Postscript (written seven months after the Forum)

As of March 2022, OneWeb has successfully launched 428 satellites. Plans to launch the rest of this first generation (for a total of 648) are under discussion. The constellation will then cover the entire globe, and service could be provided in any country where there is a distribution partner to offer service. In Australia, OneWeb has announced three partners so far: Field Solutions Holdings Ltd. (FSG), Australia's leading rural and regional telecommunications carrier (OneWeb, 2022); Vocus, a carrier specializing in delivering reliable communications infrastructure to large enterprises in remote locations with limited or no connectivity, including resource-based projects, emergency responders, and infrastructure projects (OneWeb, 2021); and Telstra, which has signed a Memorandum of Understanding (MoU) to explore new solutions for improved digital connectivity across Australia and the Asia-Pacific region for Telstra customers. The SNPs outside Perth (Gnangara) and Toowoomba (Charlton) are ready to operate, and the SNP near Darwin is nearing completion.

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The Broadband Futures Forum

The Australian Broadband Advisory Council Agri-Tech Expert Working Group Report

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Abstract: On 21 October 2021, TelSoc hosted the tenth Broadband Futures Forum, held online, to discuss a report by the Australian Broadband Advisory Council (ABAC) on the future of Agricultural Technology (Agri-Tech). After an introduction by the chair of ABAC, the two co-convenors of the ABAC Expert Working Group that produced the report outlined its content. Discussion following the speeches focussed particularly on the usefulness and efficiency of local solutions to extending wireless coverage, and the role of government and private investment in regional areas.

Keywords: Broadband, agricultural technology

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 for Australia (Holmes *et al.*, 2020). The forums are hosted by TelSoc (the Telecommunications Association Inc, publisher of this *Journal*) and have been held regularly since July 2019.[i] The tenth in the series, held on 21 October 2021, was entitled "The Australian Broadband Advisory Council AgriTech Report" and provided an overview of the report by the Agri-Tech Expert Working Group for the Australian Broadband Advisory Council (ABAC) (ABAC, 2021).

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

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The NBN Futures Forum

The Forum was conducted online via Zoom, with at least 50 participants online. Dr Jim Holmes, President of TelSoc, chaired the Forum.

Introduction to ABAC

Ms Deena Shiff, the chair of the ABAC, noted that ABAC had been formed by the Minister for Communications in 2020 to stimulate the take-up of broadband applications and to improve the economic benefits from broadband. ABAC, after a short scoping study, has concentrated on sectors with a high likelihood of benefit from broadband but where take-up might be further expedited.

The report from the Agri-Tech Expert Working Group is the first output from ABAC. Other expert groups are working on eHealth (jointly with health stakeholders, including the Department of Health); Construction, with an emphasis on small and medium enterprises (SMEs) and regional activities; and Creative Industries, to tap into the growing market for developing streaming content.

Deena Shiff suggested that there are three common threads in these studies: better targeting of public funds in relation to telco developments and investments; skills development; and digital inclusion. There would be a continuing emphasis on development in regional Australia.

She indicated that ABAC sees its role as bringing people together to achieve a common understanding of issues, rather than just policy formulation. The emphasis, she said, is to stimulate action to effect change.

The Agri-Tech Expert Working Group Report

Ms Andrea Koch and Mr Peter Waters, the convenors of the expert working group, outlined the contents of the report.

The expert working group addressed the question: 'What are the challenges for digital agriculture in Australia?' The Commonwealth Government has adopted the ambitious goal established by the National Farmers' Federation of increasing the gross production value of Australian agriculture from $60 billion to $100 billion by 2030. A recent paper by the Bureau of Communications, Arts and Regional Research (BCARR, 2021) estimates that the additional economic benefit from digital technologies could be between $3.0 and $10.6 billion per year (in 2017–18 dollars) for the agricultural sector by 2029–30, which represents an additional boost to economic activity in agriculture of between 4.7% and 16.9% by 2030.

The Agri-Tech Working Group considered three questions.

Question One: Does a 'connectivity threshold' exist in regional and rural Australia where connectivity becomes an enabler of digital agriculture, rather than a drag on it?

'Yes' there is a connectivity threshold, and 'no' it has not been passed. Connectivity to support digital agriculture is required across the entire farming operation, and not just at the homestead: connectivity is needed out in the paddock for a range of digital technologies including soil moisture probes and controlling gates; down by the creek, dams and bores for real-time monitoring of water usage; on the move around the farm to support digitally enabled tractors' work; and above the farm as drones strike at weeds.

The report found that, beneath the broad brushstrokes of coverage from mobile networks and National Broadband Network (NBN) fixed and wireless networks, there are localised connectivity gaps on, across and between farms. The report called this patchiness 'salt and pepper connectivity'.

The report provides a case study of Tony, a cotton farmer 8 kms outside Narrabri. In an effort to achieve greater labour and water efficiency, Tony has spent $1.5 million on a large lateral irrigator with an onboard Subscriber Identity Module connected to the mobile network. The idea is that the 'robot' irrigator can roll across the farm watering at night and can 'call out' by messaging Tony's mobile phone when it has fallen over and needs him to get out of bed to right it. Tony's farm is within line of sight of a mobile tower on a mountain about 45 kms away. However, as coverage is patchy and variable on his farm, he cannot count on the 'robot' being online, and so he still has to get up during the night to manually check it.

Question Two: If the threshold has not been crossed, what connectivity is required for digital agriculture to be put in place and what measures can be taken to get it in place?

If the problem is 'salt and pepper' connectivity, the ultimate goal has to be ubiquitous connectivity across farms; or, as NBN Co puts it, "no paddock left behind". However, the report concludes that national-scale carrier mobile and fixed wireless networks are not necessarily the best way of achieving that goal.

National carriers may continue to be the primary providers of connectivity in rural Australia, but their focus – in terms of both technology and business outcomes – is on serving premises and 'people on the move' along transport corridors.

As Figure 1 from the report (ABAC, 2021, p. 34), adapted from Connected Farms (2022), illustrates, the connectivity option that is suitable for a particular application will depend on its bandwidth and performance requirements.

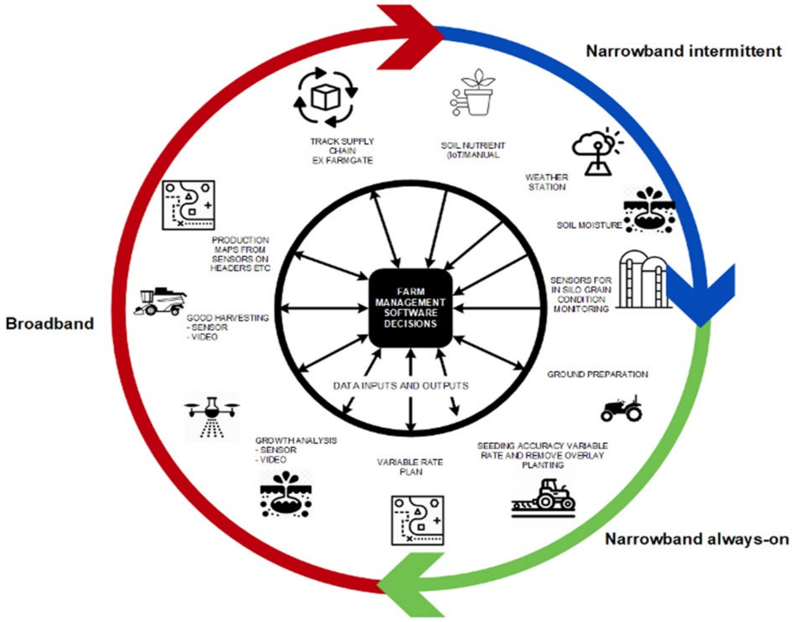

Figure 1. Matching the connectivity mix with the use-case requirements (ABAC, 2021, p. 34)

The report identified the emergence of alternative approaches in the market, including farmers installing bespoke solutions and a cohort of second-tier retail service providers (RSPs) who are filling in the 'salt and pepper', including some world leading Australian innovators such as Myriota ("Myriota Everywhere", n.d.), a low-earth-orbit satellite provider, and Zetifi ("Last-mile connectivity", 2021), which have developed a low cost Wi-Fi tower that a farmer can drop off the back of a utility vehicle.

As a principal of a regional agricultural college put it: "When as a local community we started to tackle connectivity issues, we thought it was all about mobile, but we have learnt there are more cost-effective options."

Question Three: If, or once, the threshold is crossed, what other measures would promote adoption of digital agriculture off the back of that connectivity?

Technology cannot exist in a vacuum without the skills needed to support users in their buying decisions, in operating the technology, and in making use of its outputs. The report identified a 'skill stack' (Figure 2) needed to support digital agriculture.

These support skills need to be 'close at hand' for farmers: if a farmer depends on remote telemetry to control irrigation pumps on the farm, there is the risk of significant production loss if the technician has to drive hundreds of kilometres to fix the problem.

More Government-supported training is needed to build up these skill sets. There are some good exemplars in place, including university demonstration farms like the University of New England Smart Farm, the private Longerenong College in Victoria and the South Australian Government AgTech demonstration farms. However, much more work is needed to deliver training across the whole skill stack, and not just at the application level.

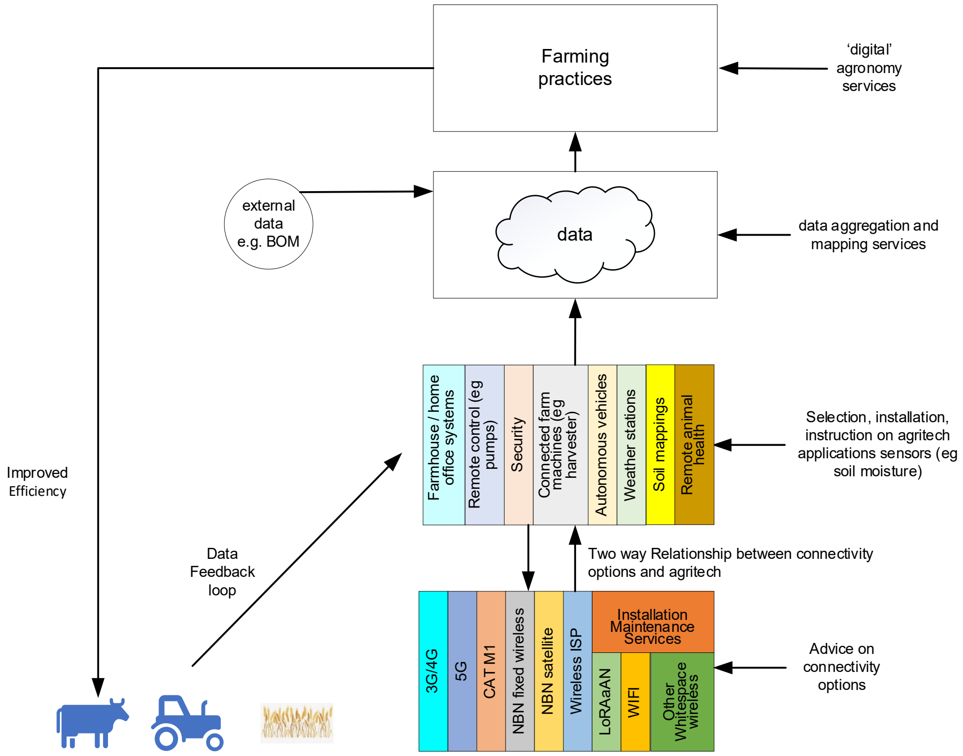

Figure 2. Local ecosystems of digital skills and support (ABAC, 2021, p. 56)

Recommendations

While the report has a range of recommendations, the key 'transformers' are:

- Pushing out more fibre backhaul in rural areas. Rural communities point in frustration at fibre cables running through their communities on the way to somewhere else, like a bullet train which rushes through a local station without stopping. Existing fibre also can be 'locked up' in state government agencies, like transport, health or electricity, because they do not have a remit to consider broader economic and social development goals. The report notes that we are on the cusp of a new wave of fibre deployment, such as by the Macquarie Bank-acquired Vocus and Bevan Slattery's HyperOne, which provides Governments with an opportunity to get in on the ground floor to plan more 'fibre off-ramps' in rural Australia.
- Combining fibre backhaul with low-cost wireless infrastructure using class licensed or white-space spectrum. This powerful combination is at the core of rural connectivity programs in the UK and US. While the Australian Communications and Media Authority (ACMA) is currently consulting on 6 GHz-band class licensing for Wi-Fi and 4/5G applications, it is taking a more conservative approach, such as by lower maximum transmitter power

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rules (which reduces coverage). However, ACMA has taken some positive steps, such as area licensing for apparatus.

- NBN Co needs to work with service providers and communities in rural areas on finding solutions which 'stretch' the boundaries of the NBN wireless footprint to migrate customers from the NBN satellite service, which provides a less satisfactory service on parameters such as latency and reliability. NBN Co, and the other carriers, need to be more open to using emerging network software which enables 'heterogeneous' networks, such as Zetifi's Wi-Fi cells hanging off carrier networks.
- 'Salt and pepper' connectivity is better solved by community-led or involved programs. Agricultural activities vary between regions, from broad-acre grain farming in the wheat belt, to cotton farming on the Western Plains, to horticulture in Northern Queensland. Local communities best understand the range of needs and priorities for connectivity across their region, and have demonstrated a willingness to co-invest. Local communities 'owning' the outcome also may help break down the current negative cycle between carriers and local communities.

The future is bright for digital agriculture in Australia. However, crossing the connectivity threshold and solving the problem of 'salt and pepper' connectivity remains a major gateway for future success. The ABAC Agri-Tech report shines a light on what is needed.

Questions and Discussion

In commenting on the emphasis on local solutions in the report, both Andrea Koch and Peter Waters noted that agriculture is a place-based activity and that local communities had shown initiative in providing community-based solutions to local requirements.

Jim Holmes noted that a number of questions could be summarized as: "What happens next?" Peter Waters described his aim as reframing the debate about rural connectivity. Rural communities had been upset about the lack of connectivity from mobile carriers. At the same time, governments had engaged in a 'push/pull' dynamic with carriers: 'push' through regulation of service provision; 'pull' through funding such as support to remove mobile blackspots. The report suggested that mobile carriers are unable to provide all the communications solutions needed for agriculture and that there are alternative solution providers who can.

When asked about the future of the expert working group itself, Andrea Koch indicated that it would not continue to meet, and that further work to progress the recommendations would be undertaken by ABAC and via the relevant Ministries. Deena Shiff noted that similar issues were being identified in the Health Expert Working Group: lack of connectivity in regional areas; lack of support for place-based initiatives; and insufficient coordination between the actions of State and Federal governments. She indicated that ABAC has requested funding for geo-mapping of needs so that governments could identify 'hot spots' of need. She suggested that greater continuity of actions (as, for example, with continuity between triennial rural telecommunications reviews), coordination of Federal funding with State-identified needs, and post-implementation reviews would lead to better targeted sets of investments.

There were questions about how to tackle the skills development that had been identified as a problem in the report. Peter Waters suggested that, while technical skills may be available locally to support in-building communications, support and confidence would be required to extend those skills to outside solutions, such as installing and supporting a wireless weather station. Andrea Koch noted that there was a general shortage of skilled labour for agriculture, made worse by the COVID crisis, and that there would be increased competition for the limited skills base for technical communications installation and maintenance. Deena Shiff remarked that training for advanced communications skills was often fragmented. One reform would be to have an agreed curriculum, promoted by the Digital Skills Agency, based on the needs of Australian agriculture. There could also be better coordinated use of highly skilled individuals to "train the trainers".

A questioner had suggested that public networks did not extend to supporting enterprise networks and that 'salt and pepper' connectivity on farms is really a business issue for the farm enterprise. Andrea Koch noted that, while significant private investment had gone into farm connectivity solutions, the majority of farms are still SMEs, which could attract government support for their generic needs, including communications. Digital technology has quite rapidly become a big issue for agriculture since the 2015 regional telecommunications review.

In contrast, another questioner suggested that multiple private network extension solutions for farms were economically inefficient and wasteful if a public wireless solution could be adapted to provide the solution. Andrea Koch responded that the issue was scale: the national-scale solutions provided by the carriers did not always meet the needs of individual localities — in all networks the "last mile" had to be adapted for local conditions. Peter Waters added that the report had identified many local solutions that could be used and that there are existing businesses, other than carriers, that can provide these solutions at scale.

The questioner maintained, however, that a public network solution for one farm would then be able to be used at neighbouring properties; this would be an efficient use of investment.

Deena Shiff noted that many regional extensions of communications networks are already being privately or locally funded, meaning that government-funded and carrier-funded investments are at increasing risk of being bypassed by local initiatives.

In response to a comment from the audience, Andrea Koch supported the idea of community workshops at the local level to identify communications needs for the area and propose solutions to be implemented. She hoped that such workshops would be held in many regional communities.

There was a question about whether or not the expert group had considered the power and energy needs for telecommunications solutions. Peter Waters replied that this had not been included in the report, but he pointed to the current US infrastructure program that included combining telecommunications and alternative energy sources in a "whole of utility" approach in underserved areas.

In concluding remarks, Deena Shiff foreshadowed the report of ABAC's Health Expert Working Group, which has subsequently been published (ABAC, 2022) and will likely be the subject of a future Forum.

Jim Holmes, in closing the Forum, noted that TelSoc had made a submission to the Regional Telecommunications Review and was hoping that this review would lead to substantive and ongoing action.

Conclusion

This was the tenth of a planned series of forums related to the future of the NBN and a broadband strategy for Australia. It was the first to review a report from the Australian Broadband Advisory Council.

The report identified that network availability, whether from public mobile networks or the NBN, was patchy in many regional areas. Notably, the NBN (geostationary) satellite services, which cover the whole country, were not seen as fulfilling the needs for agri-tech business operations. To overcome the patchiness, several businesses, some operating at scale, and many local solutions were identified for filling in the gaps.

The report recommended, however, that better use could be made of the telecommunications infrastructure that does exist. More fibre backhaul could be provided from existing fibre cables running through regional areas. NBN Co and its Retail Service Providers could look at ways to extend its Fixed Wireless Access service and move customers off the satellite services. NBN Co and the mobile carriers could be more open to connecting "extension" networks, such as wide-area Wi-Fi or low-cost wireless infrastructure.

Nevertheless, the report's authors believed that local solutions, based on a consensus on community needs, would identify a suitable pathway to providing the wide-area wireless services that agri-tech businesses need. To support and maintain such solutions, an array of digital skills and training would be required to provide the necessary regional workforce.

Providing communications across regional Australia has always required creative adaptations of existing technology. In the voice era, the Digital Radio Concentrator System (Martell *et al.*, 1986; Moorhead, 2019) extended the phone network across large areas of the country at low cost. Similar creativity will need to be applied to satisfy the new digital requirements across the wide agricultural areas with, mostly, a low density of end terminals. Whether this creativity will come from public carrier networks or private local solutions is yet to play out.

Acknowledgement

The summary of the discussion and the commentary in the Conclusion were written by Leith Campbell.

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Endnote

[i] 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), the sixth in March 2021 (Campbell, 2021a), the seventh in May 2021 (Campbell, 2021b), the eighth (Pritchard-Kelly & Costa, 2022) in August 2021, and the ninth also in August 2021 (Campbell & Mithen, 2021).

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Australian AgTech

A Commentary on the Report of the Agri-Tech Expert Working Group June 2021

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Abstract: The government AgriTech Expert Working Group has provided a detailed overview of the practical challenges domestic Australian farmers have to deal with when digitising their farms through the implementation of connected sensor technologies, motivated by the predicted growth of the sector to AUD 100 billion by 2030. In addressing these issues, of which connectivity and access to wireless technologies along with unreliable sensor performances over time remain prominent, domestic regional specific solutions are sought. A key solution being relied upon are low earth orbital satellites, perhaps the only communication infrastructure that cycles over territorial boundaries and has both regulatory and technical challenges that are not widely considered. The resilience of these solutions is assessed in the context of the agricultural technology, or AgTech, market which is arguably invented and shaped by broader, global interests mostly centred where end-user populations are based. The argument is made that government policy must include the latter within a larger holistic framework, including education, when assessing the future of both agriculture and AgTech markets in Australia. At the core, the AgTech report does highlight some challenges in Australia's wider research approach.

Keywords: Agriculture, AgTech, Connectivity, policy, Australia

Introduction

Agricultural technology (or AgTech) is a nascent industry that introduces connected technology, usually patented (Queensland Department of Agriculture and Fisheries, n.d.) and often reaching across from other industries, in various formats to aid and transform agricultural sectors spanning land and sea farms (both private and industrial), vineyards, cattle stations and other food or organic resource generating. It includes innovation across the value chain from supply to demand and so, arguably, may involve traceability and transport

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innovations and restaurant contributions that increase the value of the sector. It also includes hardware and software, business models, new technologies (sensors, robotics, smart vehicles, cloud and edge computing, augmented reality, virtual reality, cable and wireless networks, GPS, satellites, electronic currencies, and more) and new applications, much of it underpinned by mainly digital data and finance transfer and manipulation. AgTech increasingly includes disruption of the product itself for reasons that may seem far removed from immediate business alone (e.g., climate change). For the traditional Australian farm, both digital and analog sensors constitute a critical part of data collection, whether passively sitting in the field or on autonomous vehicles and robots. Data transmission into the Internet is via edge-computing phone, tablet or computer apps to increasingly smarter sensing-based transmission and/or online cloud services.

There will be three areas where technology at the farm is being revolutionised – from (1) the type of hardware including point, distributed and mobile sensors; to (2) the transmission of the data via a range of connected devices and transmission media that are either cable (fibre comes into its own here) or wireless (acoustic, optical, mm, microwave, RF, infrared and more); to (3) the software and signal processing that controls, reads and analyses the data at various points determined by customer or provider. In increasing proactive AgTech, signal delivery back to the sensor or to additional control devices will occur. These points can be local or global, with many providers having cloud-based analysis somewhere else on the planet, reflecting how the Internet of Things (IoT) has changed the way business is being done. The industry remains nascent because much of the sensor technology is not care-free nor reliable, often requiring regular maintenance, calibration and replacement (providing a subscriber model for businesses). As well, transmission media have serious connectivity, latency and potentially compatibility issues, given the heterogeneity of the technology and recycling of the electromagnetic spectrum. Further, that technology is continually evolving at an increasingly exponential rate, creating a unique challenge for constant reinvention. Opportunities for business beyond increasing supplied market volumes of current items with new disruptive products are growing and their impact on traditional markets may undo much of the smarter but traditional farm, which makes up the present bulk of Australian AgTech.

Here, the recent Agri-Tech Expert Working Group report on the implementation of AgTech in agriculture is assessed against the context of a comprehensive definition of AgTech that is seeing substantial investment overseas. Given the ad hoc implementation of technology in the field, there are many solutions that, in principle, can be available to address the agricultural sector, often developing outside of agriculture. The report points to many impediments to local implementation reflecting that much of the technology is immature. To address this, this review looks at whether deeper research commitment from government investment, along with a strategic understanding of new technology and its global market beyond agricultural produce, is needed. This may equate with more efficient longer term, robust and sustainable outcomes from government investment.

Agricultural and AgTech markets

The Agri-Tech Expert Working Group was established by the Australian Broadband Advisory Council (ABAC) to review the current state of the sector in Australia. Its report (ABAC, 2021), henceforth referred to as the Report, was motivated by improving the competitiveness of existing agriculture. The expected agricultural market boost from going digital is identified in the Report. It is anticipated that the sector can grow by approximately AUD 40 billion by 2030, a figure provided by the Department of Agriculture, Water and the Environment (2022). This is an interesting market because agriculture is extremely sensitive to various factors including geopolitical and environmental – according to Elders CEO, Mark Allen, for example, Australian agricultural value appears to have dropped more than AUD 10 billion over the last two years, mainly attributed to bushfires, climate change and COVID impacts on demand, from over AUD 60 down to 47 billion (Woodward, 2021). This is almost half the amount it is predicted to grow to by 2030. Thus, climate and environmental factors will increasingly impact investor decisions in this space, and especially the AgTech market itself.

Despite the obvious synergy, the agricultural market and the AgTech technology market are not the same and misalignment of these markets may create confusion. The specific AgTech technology market is presently much less, arguably negligible in Australia, reflecting how infant the sector is, characterised by farmer-led innovation. On the other hand, the recent pandemic demonstrated that global and domestic supply chain concerns are not one way, boosting arguments for more self-sufficiency within smart cites so they produce some of their own food. This can directly compete with traditional rural farming models. AgTech will grow and the value proposition will change because an AgTech company must also address larger global markets (assuming continuing growth in premium food by the global market) with a stable longer term platform ecosystem that may need to be able to profitably integrate rapidly changing technologies and products, including new agricultural products displacing existing ones.

In the US, the AgTech market is estimated to be valued at approximately $6.2 billion, expected to grow over $14 billion by 2025, remaining lower than Australia's anticipated agricultural market boost over the same period (Agricultural technology (Agtech) market value worldwide from 2020 to 2025, 2021). What is interesting is what is driving this market – alternative meat products will look to compete with traditional Australian beef markets, providing a solution to greenhouse-gas generation (Henshall, 2021; Carrington, 2020; Tangermann, 2021; George,

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2019). These are rapidly growing products through accelerated investment in the United States, but which have little presence to date within Australia. If that were to reach into the Australian market, then the business model of a smart but traditional cattle station as described in the Report, for example, would be challenged. Substantive refocusing to a more niche, lower volume but higher valued meat product would be required. These may be from non-methane-producing cattle perhaps fed on seaweed, one competing solution that can extend traditional farming over longer timeframes (Lean *et al.*, 2021; Abbott *et al.*, 2020; Vijn *et al.*, 2020).

An important consideration will be the return per unit area of land if, for example, alternative, indistinguishable cost-competitive meat or other products are grown in a laboratory at scale, as predicted by those investing. There is already pressure across cities worldwide to have in-city farms including vertical farms, such as Scottish Intelligent Growth Solutions, which has raised over US 57 million in Series B joint UK/US/ European funding (Lea, 2021), to address both climate change and biosecurity. These sustainable city-based farms bypass transport and other supply chain costs, which have been a notable concern during the pandemic. Socially, the increased removal of larger transport vehicles from shared roads is viewed favourably in cities. In other words, from an investment perspective the future of traditional markets and their scalability is being challenged by new agricultural products. Hence, an inward-focused approach on lowering costs doing more of the same and boosting current supplies is important but may seem short-sighted. That is a principal reason why government investment requires more strategic and long-term considerations – there is an analogy with Climate Change in that, whilst older industries may continue for many years, the transition time to growing customer-driven (even demanded) new industries is long; and therefore advanced, long-term preparation and education is central to government policy. Addressing salt-and-pepper connectivity is as much about ensuring that new viable disruptive products, with greater output per square metre, can occur on the land, generating effective competition for farmers.

The technology side itself relies on global and wider markets and global investment, precisely because the local market alone is relatively small and potentially insular. This is nothing new and applies to all of Australia's high technology activities. It means much of it will happen in our cities and offshore, being closer to critical mass funding and population, technology expertise and current and new global markets. Addressing variability between national and international standards, across both products and technologies, and accessible bandwidth is another consideration that arises from such a complex environment. Access to technology from other sectoral advances, particularly in the IoT space, will shape the type of regional training and education alluded to in the Report that can be supported within a holistic ecosystem. For example, certain sector-agnostic challenges include reducing power consumption through the growing deployment of low power wide-area networks (LoRaWAN). Some of these have been demonstrated outside of agriculture, in "smart" cities where profit margins for a technology business are potentially higher. They include France's Sigfox's low power meter monitoring (SigFox, n.d.) competing with Australia's Taggle (2019), which uses low power wide area network (LPWAN) radio technologies for smart IoT infrastructure. This type of technology has its limitations, but it can be deployed on farms where increasing numbers of sensors are necessary. Whilst the Report is extremely important within the entire AgTech ecosystem, it is focussed on the traditional end-user perspective and so may benefit from complementary analysis from other ecosystem viewpoints. Much of the technology that AgTech is predicting a future reliance on is being developed in other sectors with equally lofty market goals.

Connectivity and Reliability

The Report lays bare many of the significant challenges faced by AgTech applied within existing agriculture in Australia, and to some extent globally, from basic "salt and pepper" connectivity issues through to sensor technologies, which farmers are finding are also not working as promised, requiring constant maintenance and upkeeping. Global panacea solutions to connectivity, including low earth orbit microsatellites to reduce, but not eliminate, latency, appear attractive. This requires tens of thousands of satellites with seamless signal transfer between them to address drifting connectivity, superficially establishing a new modern technology marvel. Assuming the technology challenges associated with electromagnetic-field-resistant, reliable, directed beam-forming-based transfer handovers between satellites are resolved, they run the risk in time of facing political and environmental backlash by adding to growing "junkyards" in space (Garcia, 2021). Further, if not strategically planned for, these high density, large area moving communication hubs may threaten other markets, such as upper atmosphere flight and increased space tourism and travel. Because the upper atmosphere is not territorial and many of these satellites non-geostationary and planning to move over many nations, this requires global support and regulatory coordination — it is not something Australia can do on its own. Further, recent events have shown how vulnerable such a migratory hardware system can be, and there are other significant security aspects that need consideration. From an environmental perspective, astronomers are already lamenting the visual pollution of these clusters. More significantly, perhaps, the introduction of consumer-grade electronic satellites in their thousands is being undertaken with little understanding of the impact on the environment. For example, re-entry into the atmosphere of the recent Starlink mega cluster will introduce more aluminium into the upper atmosphere than that introduced by meteoroids (Boley & Byers, 2021). Given the increasing importance of climate change, this could end up being the most significant of the existential challenges such clusters bring — certainly, organic farmers may have reason to be concerned if such metals shower on their farms! Limited and flammable lithium battery and solar performances also need to be addressed to sustain practical longevity, requiring a push towards novel technologies and markets, such as Australian-led Silicon Valley start-up Orbit Fab's refuelling in space (Orbitfab). (Australia's long consolidation of divesting manufacture to focus on immediately larger gains digging up much of the world's lithium, rather than benefiting longer term from value-adding, is noted). Optimistically, there are potential opportunities if this approach proves sustainable, but it will require further fundamental research to create them. Of particular note are the international regulatory agreements that need to be in place — these will also both be determined by and influence combined technology network standards, a topic that goes beyond existing technology protocols but which will shape ultimate market-scale solutions. Putting aside these reservations, the Report recognises that, whilst this is seen to address many immediate issues for the agricultural sector with respect to salt-and-pepper connectivity, it does not address all, particularly broadband needs of sensors relying on image analysis.

The Farmer as Technology Engineer

If anything stands out in this Report, and in an impressive fashion, it is the overreliance on the farming communities, both small and large players, to conduct the Research and Development (R&D) in the AgTech space. Much of it is characterised by what seems a very early commercialisation stage. On the other hand, without their enthusiasm, engagement and financing (including founding many AgTech start-ups in Australia), it is questionable if Australian AgTech would exist in any sizeable way. Specific Australian AgTech companies, such as Agritech, have been able to pivot their business plan and technology multiple times to effectively move away from wireless sensor data back to manual USB-stick data collection by a well-trained customer (ABAC, 2021). This is also an indication of a tolerant, highly engaged customer base within an overall immature technology sector. By contrast, a young highly tech-savvy user in the city will hardly have the expertise, nor patience, to address connectivity issues should their TikTok transmission drop out or slow: this is not expected to ever happen. Many start-ups depend on seamless, near latency-free end-user engagement as a driving measure of their market access, regardless of whether it is narrowband or broadband. Interactive real-time gaming, for example, relies on latency times less than a few milliseconds at best, meaning that even within cities these businesses cannot operate beyond a few hundred kilometres. A reasonable rule of thumb from an investment perspective may be that it would be an unattractive proposition to invest in any technology service provider whose product requires the end-user to be a cooperative and trained expert with no clear end to a business co-dependency. On the Howe Farming Group case study described in the Report (ABAC, 2021),

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an investment of $400K on a LoRaWAN system, the farmers have reached their network capacity limits in terms of bandwidth. The increasingly sophisticated sensors, each with their own apps, will need to rely on improved mainstream wireless, which may or may not be compatible with the DIY solution developed by the group. This compares with the observation of a university-led DIY digital farm assessing similar technology with the time required to maintain a system at an operational level, requiring at least two days a week. Both are outcomes that may not instil confidence as working solutions for a profitable business, even before addressing market scalability issues. On the other hand, both clearly view AgTech as a necessary and worthwhile enterprise – engagement has led to a much stronger understanding of what appear to be formidable challenges, a key reason why the education focus of the Report has been on regional training and location.

Toward seamless, reliable and education-free connectivity

For comparison, in telecommunications and data transmission, the expected hardware reliability of fibre deployment is 20+ years, determined by the International Telecommunications Union (ITU) (2019). These are cables that are laid across oceans (where there is no population) and are expected to have fewer than two catastrophic events over that lifetime because of the extremely high costs involved with dredging and replacing them. The dense populations being served at either end are not enough to economically allow for more catastrophic events. Without such operational lifetimes, a cable business would not be expected to survive. No IoT and therefore no possibility of AgTech would exist if the telecom industry had not moved to unified standards and technologies and, rather, had remained operating with the same salt-and-pepper approach experienced by today's farmers. Reliable, stable, long-term and, importantly, education-free connectivity is an essential longer term goal that ideally drives government policy in this space – what this means is that an adopted policy on education and training in regional towns would be focussed on exploiting the infrastructure to generate new business, and new types of business, rather than regularly maintaining it. The Report concedes this point when it refers to optical fibre access in certain towns having been central to supporting seamless education and banking access; and it calls for greater access to passing cables along the way.

5G and 6G and Low Power Technologies

In the wireless domain, the move to 5G, and in time 6G, and shorter wavelengths is designed to help the IoT, of which AgTech is a part, more generally. It is a much more complex, and costly, technology than prior generations, because beam forming to assist dynamic signal directionality, to reduce power consumption and increase wireless bandwidth, is required. To increase directionality, manipulation and bandwidth, shorter wavelengths are required, meaning reduced antenna spacings and therefore many more antennas to maintain connectivity. Provided a degree of reliability is maintained, this complexity is expected to scale up the IoT and make up for increased cost through higher-volume returns, including for the transmission and network providers. For an IoT solution, it nonetheless relies on a high density of factors, including reliable self-powered sensors, dynamic antennas, signal amplifiers and, importantly, paying populations, all factors that do not favour lower density locations such as farms. The right conditions are usually in cities, where directional beam forming is critical to reducing interference, increasing device selectivity through tracking, and boosting signal power largely to compensate for increasing attenuation in the atmosphere.

In rural areas, the business case for high density distributed and possibly moving antennas, to make up for a potentially increased salt-and-pepper connectivity challenge, is unclear. Fourth Generation (4G) connectivity covers a much wider region, but it is not deployed widely itself, so the case that deployment might increase with 5G and 6G is unclear if sensor and communications power consumption is not reduced, if only to extend both sensor and power-source lifetimes. By contrast, growing popularity in low power networking alternatives such as LoRaWAN (Fewkes, 2021), arguably designed for regional areas, has recently led to its recognition as a formal ITU standard. Low power becomes important and power extraction from the environment (solar, thermal, motion) needs to be coupled with longevity. Otherwise, rising costs may make sensor-to-optical-fibre connections and to wireless towers attractive over the longer term – power over fibre is already a commercial product that supports distributed sensors without batteries over long distances. In contrast to optical fibre cables, consideration of any potential impact of short wavelength absorption within soils, crops and animals may require special consideration in network design – RF heating of soil can even be used to assist soil remediation (Price *et al.*, 1999). Similarly, whilst there is an overriding view of the need to have multiple formats for connectivity to address the AgTech sector's peculiar heterogeneity, the market justification means this technology mix cannot be too discontinuous, because cost, complexity, maintenance and upkeep also become heterogenous with high specialisation. Scaling is critical to bringing costs down generally. All these factors mean it is reasonable to conclude that the sector has not yet identified a robust, profitable technology for a stable and dominant service solution to evolve.

More Basic Research and Funding Continuity

From an external observer perspective, in addition to these incredibly valuable field trials, there needs to be more basic research exploring alternative technologies, because the limits of current technologies suggest they appear unlikely to work longer term. The Report recognises optical fibre networks really provide the overall bandwidth, latency and physical reliability that make AgTech possible, but the reach and interest is less than ideal. The National Broadband Network (NBN) only provides limited access into centres of reasonable regional population density and there is a dearth of optical-fibre-based activity in AgTech. One outstanding area that is presently costly but useful for AgTech is the deployment of distributed acoustic sensing (DAS) (Bao, Zhou & Wang, 2021). It uses transmission fibres for both transmission and sensing of temperature, strain and acoustics on or near a farm or related infrastructure, including within towns. This technology is being deployed in cities using existing active and dark fibre, where statistical analytics interpret and identify incoming signals remotely, generating maps and tracking, for example, moving vehicles (FiberSense). The challenge for agriculture is the up-front costs of installing additional optical fibre in appropriate locations, and certainly an alignment with Internet delivery for other purposes is necessary. Nonetheless, the capabilities offered by such technology, including regional security, would provide additional leverage to justify national and private investment. Interestingly, one of the key US commercial narrow linewidth laser systems (RIO, 2021) used across a range of industries, such as energy infrastructure monitoring, and suitable for DAS applications, was founded in Australia as Redfern Integrated Optics more than two decades ago. Focussed on telecommunications at the time, the sale of that company supported a dozen other Redfern start-ups demonstrating what is possible within the Australian CRC model. However, the loss of continuity after the CRC demise in its second-phase funding demonstrates Australia's failure to have a continuing R&D approach that builds upon its successes. Instead, it often appears to prefer a string of inefficient stop-and-start, new-theme centres.

Unfortunately, there is an accessibility and upfront cost issue with optical fibre technology that appears to not be present for wireless technologies – a farmer can literally go into a local electronics store and equip a ready-made wireless sensor capability demonstration but cannot readily access any similar capability with optical fibre. Regardless of the other peripheral edge technologies, novel optical fibre solutions can potentially address many of the problems facing towers and satellites. For example, a workable direction is identified in technology proposed by an independent small Sydney start-up: successful electrical-to-optical sensor transduction into an optical fibre, originally intended for underseas communications (Brodzeli, 2021), can enable a novel connectivity solution on the farm. This retains the current use of sensors and avoids the reliance on wireless reach, another example of a left-field solution developed for other sectors that is critical for AgTech to continue. Importantly, it is a specific example of where government funding may be directed to ensure those kinds of technologies can be accessed and assessed. The challenge of accessibility to solutions such as optical fibre also raises questions about the Report's suggestion that regional-based education and training is a

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solo solution to addressing existing technology challenges. This ignores the location of other environments that enable vital cross-fertilisation between fields in high population density centres, not only in Australia but globally. Nearly all major universities around the world teach optical fibre communications and many sensing technologies but, unlike electronics, the technology is not easily accessible or affordable to the wider community. Conversely, many short-range IoT solutions that work best in dense cities may not translate profitably in many regional settings, so embracing a stronger symbiosis and understanding between city and regional towns is critical in ensuring access to future leading-edge technologies and solutions that simply will not come from too focussed programs and many businesses alone.

The Role of Research Centres

The Report itself does not mention organisations such as the Food Agility Cooperative Research Centre (Food Agility CRC), who's Chief Scientist is uniquely both an academic and farmer, which in many respects works on the same technologies. An example aimed at extending Zetifi's existing technology being developed by the Food Agility Cooperative Research Centre (CRC), similar to many other active groups world-wide, is turning tractors and other vehicle infrastructure into mobile antennas to help address salt-and-pepper connectivity on the land (Tudehope, 2021; Powertec, 2022; Marek, 2021; Klaina *et al.*, 2022; Jackson, 2014). Making smaller and more compact antennas to take on developments in 5G is reliant on metamaterial designs to control transmission, reception, beam shaping and steering, the latter requiring some further progress in tracking in the field. This is an outcome made possible with Charles Sturt University's digital farm. Whilst this may not solve many of the issues that require reliable connectivity to be on all the time, it can help at least permit intermittent collection of data, addressing low signal connectivity spots as they arise, and help Zetifi address strategic connectivity issues. The Food Agility CRC, with its high-level experience and expertise, might therefore be expected to be engaged directly in this policy debate, so its absence raises the perception that greater collaboration is required.

Like many contemporary CRCs, the Food Agility CRC is heavily focussed on addressing targeted problems for specific industry partners, a flavour that appeals to current political mindsets aligned with specific industries' immediate needs. However, escalating rapid disruptive change in technology is raising questions over the longer term effectiveness of this approach. The larger absence of more basic research that is not being led by industry, nor in Australia attracting the investment it does overseas, is a significant issue government must address. Optical technologies, for example, are perhaps the least recognised technology, presumably because of higher upfront costs, accessibility challenges and implementation. This includes not only optical fibres but the increasing presence of optical wireless solutions, such as Li-Fi that, within other sectors, are disrupting traditional longer wavelength Wi-Fi, whether it be between satellites (Ciaramella *et al.*, 2020; Granath, 2015), within autonomous vehicles (Ferraz & Santos, 2015) or indeed within buildings (Li-Fi). Further, the convergence of Wi-Fi and Li-Fi in the spectrum more generally, known as photonics, has been described elsewhere (Canning, 2020a). (This convergence contrasts with optical fibre's unique dominance over any cable technology, so much so that the use of Wi-Fi or Li-Fi might be considered more generally as Fi-Fi: i.e., fibreless fidelity). The bigger picture challenge for research in Australia is why some of our leading space companies pursuing really novel stuff, such as orbital gas stations, continue to have a presence or base overseas, including Silicon Valley (Orbitfab) – scaled money, vision, culture and "action", both technology and business wise, remains very much concentrated overseas. This is an important reason why any government strategic plan to address AgTech needs to be mindful of not losing "intellectual connectivity" to this expertise elsewhere, given its growing value in training and providing opportunities for Australians. This includes overseas capital investment. Along with the fact that most Australian tech. companies will need access to international markets, Australia's overseas landing pads are an extremely valuable resource for those seeking to learn more (Australian Landing Pads). For space tech., this involves very sophisticated collaborative programs and equally important those smaller relationships on the ground – it needs to be the same for AgTech to ensure Australian innovation, adoption and future implementation in next generation technologies is both seamless, world leading, desirable and competitive.

Summary

All this investment and effort in AgTech is broadly viewed as important in being able to address the fundamental salt-and-pepper connectivity issue that is at the core of the challenges this Report articulates. There is also a fundamental longevity issue – maintenance-free connectivity and sensing are crucial. Alternatively, it must be so cheap to install and maintain that maintenance is effectively free. It may be argued that getting this right is more than solving current local problems — as indicated above, technological change is rapid, expanding exponentially for some time but now arguably reaching a critical and transitional uncertainty, unlike any other time in history (Nazaretyan, 2020).

So, whilst new technologies offer solutions, new solutions are expected to continually disrupt the former — microsatellites as a (partial) solution to addressing the latency issue of traditional geostationary satellites, described in the Report, are one disruptive example. Since they are not in geostationary (Clarke's) orbit, they suffer from intermittent transmission, because they are moving relative to an end user on the ground, a reason why so many are needed to create what will seem like seamless connectivity to a farmer. It is difficult to see, as they are currently presented, that they can be a solitary long-term solution as bandwidth demands increase, creating other challenges that in turn will also need to be addressed. Many existing and proposed AgTech sensor networks may not be fit for purpose. Part of this analysis has had to be discursive to highlight the substantial heterogeneity in the AgTech sector. For example, new developments overseas that may potentially disrupt the central reliance on traditional farming are not anticipated in the Report.

Presently, there is only one technology today that has addressed all these matters and we know it works, because it has given us the Internet and therefore the IoT-enabling AgTech – optical fibre cable. But direct integration of all these on-site technologies (robots, sensors and vehicles) through communications directly to deployed cable alone, if doable, is overwhelmingly costly up front. This cost may be mitigated over time when compared to running and maintenance costs. Cables themselves offer significant sensing capabilities as well as transmission, a valid leverage for further fibre deployment. Further, this sector can also benefit from disruption in the future – for example, the possibility of one day printing your own optical fibres at home on a desktop additive printer and tower exists (Canning, 2020b) — another illustration why basic research to future proof all our sectors must also be part of government policy. In another example, a hybrid solution using a novel fibre-cable-based receiver offered by a new start-up for termite detection and for the defence sector (Oberst *et al.*, 2021–2025) may offer a more robust alternative for current farm connectivity. Otherwise, many of today's interim solutions potentially need to be either upgraded regularly or entirely replaced every few years, as in the case of Howe's farm mentioned in the Report. This is both a "followers' approach" and costly — for a supplier, the business model has to justify such costs and determine whether an extrapolated market makes it viable. Very quickly, a global market needs to be invoked. For this reason, a matching Report that addresses the technology supply side from overseas all the way to the small businesses hoping to make money in AgTech, as well as agriculture, in Australia may help build a more complete holistic picture of the AgTech sector. Scalability across IoT sectors will be attractive to investors.

The Report has described challenges facing the immediate uptake of smart technology and digitisation on the land, particularly farm-based agriculture. It does so through wide discussions with the customer base of such technology, reflecting an impressive and important awareness of the local technology problems that define heterogeneity in the wider agricultural landscape. It is an extremely valuable Report because, although these challenges may generally be known, the intimacy and impact at the local site lays bare to a wider audience just how inadequate much of the technology solutions are. Certainly, from this author's perspective as a distant observer of agricultural technology from a city, this insight is not often articulated well within many academic and centre presentations on similar topics, where the individuals

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presenting are not regionally based, nor necessarily representing the latest global trends in technology.

In conclusion, three aspects of policy concern arise from the current approach to AgTech in Australia reflected in the Report. Many technologies, often centred around connectivity issues for sensor networks, are already maxing out and not fit for purpose. There is a tendency to do more of the same, and the fact that many new IoT technologies centred on 5G are optimised for dense populations or dense sensor distributions presents ongoing challenges in this respect. From a market growth perspective, much of the sector relies heavily on farming communities carrying the load of the transformation, requiring a degree of consumer education and knowledge that has little parallel in the city. An underpinning challenge for Australia is to develop Australian policy beyond the economic value of growing the existing local Agricultural sector and addressing the commensurate value of growing the technology that underpins global growth of new, potentially disruptive agriculture. Access to and global participation in the creation of new ideas and new technologies, essential to build resilience to both product and technology disruption, including through multiple markets, remains Australia's key to overcoming the so-called tyranny of distance. This tyranny is not new but knows new forms — an Internet-based classical latency is already impacting security and remote economies based on market-insignificant populations and new tracing and transaction technologies (including electronic currencies) that are increasingly important to agricultural veracity. This means leading low latencies are needed, not compromised second-hand alternatives. Arguably, quantum teleportation (Cacciapuoti *et al.*, 2020) is the only visible solution on the horizon for a fair, globally connected world and for a fully standardised authentication protocol for future Australian AgTech and IoT products, services and businesses. Australian policy must target agricultural needs identified by the Agri-Tech Expert Working Group, but it must also, in the same breath, fit that into a broader plan that develops future technology continuity and cross-fertilisation and engagement, to ensure what is developed is long lasting and foundational, servicing a shared quality society.

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Collaboration Principles between Telecommunication Operators and Over-The-Top (OTT) Platform Providers in the Context of the Indonesian Job Creation Regulation

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Abstract: As anticipated, the existence of telecommunication regulations has become the focus of public attention as it can provide various protections. Further, the Indonesian Job Creation Law has provided new implications for the telecommunications operators in the form of Government support. Based on the principles of fairness, impartiality and non-discrimination, as well as maintaining service quality, it is expected that the telecommunications operator system in Indonesia will be able to develop and provide the best facilities in keeping with community needs. This has also opened up opportunities for the implementation of a new pattern of cooperation with the Over-The-Top (OTT) service that has been growing in popularity. This study applies a normative research method with online data collection techniques and seeks to produce an analysis, socialization and education with regards to the emergence of telecommunications operations principles, as well as the implementation of these principles in the Job Creation Law and its Implementing Regulations.

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Introduction

Nowadays, the Omnibus Law or Job Creation Law 11/2020 in Indonesia has played an active role in supporting the digital era. This support can be seen from how the Telecommunication cluster emerges in the Job Creation Law that surely can stimulate the acceleration of the Information, Technology and Communication (ICT) Industry. The ICT industry is basically supported by the technology and information sector that is becoming a basic need, especially in the economic sector. The emergence of technology is also followed by the development of electronic equipment, one of which is computer technology equipment that has given rise to communication satellites for telecommunications facilities (Koloay, 2016)

Supported by the ICT acceleration, telecommunications operations have become increasingly varied. As widely known, the telecommunications sector has become oxygen to support life with its extensive role. With regards to its role, telecommunication has a broad definition. Quoting the International Telecommunication Union (ITU) viewpoint, telecommunications is defined as transmission, emission, and reception of signs, signals, images, sound, writing, or various forms, optical, radio, or other means in an electromagnetic system (Orji, 2018). Then, ITU manages to include all the activity elements that may be classified within the scope of telecommunications, including:

a) transmission of signs, signals, writing, pictures, sound or intelligence of any kind by cable, radio, visual or other electronic means;

b) emission of signs, signals, writing, pictures, sound or intelligence in any form through cable, radio, visual, or other electromagnetic systems; and magnetic systems; and

c) reception of signs, signals, writing, images, sound, or intelligence of any kind via cable, radio, visual, or other electromagnetic systems.

Furthermore, telecommunication can be classified as it is divided by the General Agreement on Trade in Services (GATS) into basic telecommunications and value-added telecommunications services that are considered important to support human activities: value-added telecommunication services such as electronic mail (e-mail), voice messages (voice mail), electronic data processing using the Internet network (online data processing), electronic data transfer, and so on (Budhijanto, 2010)

As mentioned above, it can be seen that telecommunication services play an essential role. In Indonesia, the implementation of telecommunications indicates progress, especially since the issuance of Law Number 36 of 1999 on Telecommunications (Telecommunications Law). At that time, a conducive climate had been created for telecommunications operators: the Telecommunications Law changed the paradigm of previous telecommunications regulations to be anti-monopolistic, providing space for business competition, as well as oriented to the interests of consumers and telecommunications users. However, after more than two decades, it is considered that the law requires strategic updates.

Thus, it seems that the Job Creation Law is able to fulfil the need for ease of doing business in the context of improving the national economy. By using the concept of Omnibus Law, this law is able to simplify numerous laws and regulations that sometimes overlap with revisions or revocation of the previous laws (Putra, 2020). This can also be applied to laws and regulations that are no longer relevant, especially in supporting the national economy.

The telecommunications service industry in Indonesia has become a necessity, especially with the development of technology, information, and communication. Telecommunications operator companies are closely related to the cellular industry. In Indonesia, various companies are engaged in telecommunications, such as XL Axiata, Indosat Ooredoo (Indosat), Telkomsel, Telkom Indonesia (Flexi), Hutchison Tri Indonesia (3), Smart Telecom (Smart), Bakrie Telecom, Sampoerna Telekomunikasi Indonesia (Ceria), Mobile-8 Telecom (Fren), AXIS Telekom Indonesia (AXIS), and so on. The tight competition in this business leaves five big companies: Telkomsel, XL Axiata, Indosat Ooredoo, Smartfren, and Hutchison Tri (Octasylva & Rurianto, 2020). Competition in the cellular telecommunications industry in Indonesia occurs due to tariff wars and customer demands for the quality of services provided. Meanwhile, currently, the telecommunications service industry is aggrieved by the invasion of Over-the-Top (OTT) services on voice, messaging, multimedia, and cloud services. Of course, the invasion caused injustice for telecommunication operators due to a shift in people's consumption patterns towards OTT services.

The government, therefore, issued a policy that relies on collaboration between telecommunications operators and OTT service-provider companies through implementing regulations of the Job Creation Law, namely Government Regulation Number 46 of 2021 on Postal, Telecommunications and Broadcasting. This is precisely to follow up on Article 70, Article 72 and Article 185 letter b of the Job Creation Law. In the general explanation, it is stated that the Government Regulation on Postal, Telecommunications, and Broadcasting is to respond to digital transformation in Indonesia, with a focus on:

1) accelerating access expansion and improving digital infrastructure as well as Internet services provision;

2) accelerating the expansion and improvement of postal and logistics services to support the digital economy and inclusive financial services; preparing a digital transformation roadmap in strategic sectors: in the government sector, public services, social assistance, education, health, trade, industry, and broadcasting;
3) accelerating the integration of national data centres;
4) preparing the need of digital-talent human resources; and
5) preparing the regulations related to funding and financing schemes for national digital transformation.

The regulations governing telecommunications service industries are designed to create healthy competition in the market. Similar to the regulation in the European Union, namely to bring consumer prices to create a competitive market, the policy also aims to ensure a level of competition, avoid market failures, protect consumers, and increase investment and welfare. Thus, the telecommunications service industry can charge high fees for using its network (Savin, 2018). Likewise, in the United States, the telecommunications-related policy is promising, given the legal framework directed by the government and Regulatory Commissions, particularly the Federal Communications Commission. Two important acts are in force today, the Communications Act of 1934 and the Telecommunications Act of 1996. These laws were intended to revise the first law and specifically encourage competition in the telecommunications industry.

Strategic matters on telecommunications regulated in the Job Creation Law include facilities provided by the central and regional government to facilitate telecommunication infrastructure development, cooperation for telecommunications providers, mutual collaboration with the broadcasting sector, as well as ease of business licensing that can provide quick services based on the-same-day-principle through online media. In addition, as an effort to support digital acceleration with the use of the Internet in all sectors of life, it is becoming easier for broadcasters to converge and benefit from the ICT sector for flexible and expanding business development. The Job Creation Law also accommodates quality Internet services by escalating the equal distribution of signals throughout Indonesia, then emphasizes reliable supervision of service and experience quality in telecommunications.

One of the goals of equal signal distribution is that it can support the quality of digital platform services that increasingly fill all aspects of human needs, such as the existence of the OTT platform that utilizes the telecommunications industry. According to Greene & Lancaster (2007), OTT service, as a service carried over a network, provides value to users without control of telecommunications networks in arranging, selling, providing and serving users and, of course, there is no official collaboration with telecommunications network operators.

Nowadays, the digitalization era is accelerating amidst the COVID-19 pandemic, which has fostered the urgency of a reliable telecommunications infrastructure and a capable legal umbrella. This also encourages the primacy of Internet access and the telecommunications industry in stimulating social and economic cycles in Indonesia. The existence of the Job Creation Law that is integrated with the telecommunications sector and the ICT industry is confirmed by its derivative regulations.

OTT-related regulations are stated in Article 15 of the Government Regulation on Postal, Telecommunications and Broadcasting that regulates cooperation between OTT operators and telecommunications operators. Further, it is explained that OTT is included in the domain of Regulation on Postal, Telecommunications and Broadcasting because it is a business activity via the Internet, with the existence of a substituted form of telecommunications services, a content service platform in the form of audio and visual and other services stipulated by the Minister.

Therefore, in this study there are three issues raised as the research problems, namely:

a. How are the Principles of Telecommunications Cooperation on Job Creation Regulations applied?

b. What are the Principles of Telecommunication Cooperation with the OTT Platform in the Job Creation Regulation?

c. How should the cooperation principles be applied?

Based on these problems, this study can provide an understanding of how a law emerges as something that must be futuristic and relates to real entity theory. Gierke said it is not just artificial creations that come from the law but legitimate entities that exist apart from legal recognition. In other words, companies are as 'real' and 'natural' as anyone and exist independently of their shareholders and the country (Cásarez, 1991).

The application of this theory can be seen in Justice Marshall's statement at the Supreme Court in the case of Trustees of Dartmouth College v. Woodward, who states that a company or corporation is artificial (artificial being), invisible and intangible and its presence only exists in legal contemplation (Trustees of Dartmouth College, 1819). Meanwhile, this theory aims to strengthen the state power if so desired, and the company must comply with all legal provisions in a country in order to obtain this personality so that it has a legal position before the law. Thus, it can be understood that the presence of various digital innovations created by many companies has made it obligatory to remain compliant and not deviate from the various provisions and regulations that are the positive laws of a state.

Telecommunication Cooperation Principles in the Job Creation Law

In the digital era, the emergence of telecommunications in social life will not be separated from the telecommunication operation. In Indonesia, the support by the state for the telecommunications climate is expressed through its regulation and laws, such as the Job Creation Law, particularly Article 70 to Article 72, and Article 185 letter (b). These articles, then, are regulated more specifically in the Government Regulation on Postal, Telecommunications and Broadcasting.

The emergence of this regulation is essentially in line with the accelerating number of Internet users in Indonesia. This continues to encourage the birth of various digital media and application innovations that require clear and definite legal rules in their implementation. Referring to Article 1, Number 7 of Government Regulation on Postal, Telecommunications and Broadcasting, telecommunication operation is basically an activity to provide telecommunication services in order to enable the operation of telecommunications. In telecommunications, the implementation is carried out through a telecommunications network that can be understood as a series of telecommunications equipment and accessories utilized in telecommunications.

The emergence of various digital-based services and applications through telecommunications networks, of course, needs to be based on telecommunications principles. Especially with the emergence of OTT services on telecommunications networks, its presence must comply with telecommunications principles. In Article 15, Paragraph (1) of the Government Regulation on Postal, Telecommunications and Broadcasting, it is stated that national and foreign business actors who carry out business activities via the Internet, should act with the principles of fairness, impartiality and non-discrimination, as well as maintain service quality as regulated by the provisions of laws and regulations. This OTT activity is reflected in the substitution of telecommunications services, audio, visual content service platforms or both, as well as other services as stipulated by the Minister.

In the attempt to provide checks and balance of the Government over OTT so as not to cause arbitrariness that is dictatorial and corrupt, many provisions have been made, for instance in Article 71 of the Job Creation Law that amends Article 28, Paragraph (2) of the Telecommunications Law that regulates the number of tariffs, operation of telecommunications networks and/or telecommunications services based on a formula determined by the Central Government by taking into account the interests of the public and fair business competition. The provisions regarding fair business competition and the public interest guarantee the OTT services protection from arbitrary acts coming from the network

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and/or telecommunications service providers or from the Government. Meanwhile, if compared with Article 28 of the Telecommunications Law prior to the amendment, the article only mentions that it was stipulated by the Government without any reference to the public interest or fair business competition. This is increasingly guaranteed in the implementing regulations of the Job Creation Law, namely Article 15, Paragraph (1) of the Bill of Government Regulation on Postal, Telecommunications, and Broadcasting that, for national and foreign OTT-business actors as well as for Telecommunication Network operators and/or Telecommunication service providers, operations shall be implemented with the principle of fair, reasonable, and non-discriminatory actions in accordance with the applicable laws and regulations. These three principles further strengthen the OTT service position to obtain definite protection in the Job Creation Law and avoid various threats of harm.

The aforementioned principles, if examined, are the principles for the creation of cooperation in telecommunications; more specifically, the three principles in Article 15, of the Government Regulation on Postal, Telecommunications and Broadcasting visualize that the implementation of OTT services must be carried out in cooperation that upholds fairness, impartiality and non-discrimination, as well as maintaining service quality. Telecommunication Cooperation Principles on OTT services include the following three principles.

Principle of Fairness

This principle seeks to provide fairness, or an appropriate portion thereof, for foreign OTT operators and services entering Indonesia in order to create an equal climate and fair business competition for all parties. In supporting cooperation between telecommunications providers and OTT services, it is critical to put it in written form: hence, the boundaries between the rights and obligations of each party are clear.

As a realization of cooperation between the government and OTT services establishment, the application of the fairness principle is seen as the government clearly divides various business activities as the scope of OTT services, namely: replacement of telecommunication services, audio and/or visual content service platforms; and/or other services stipulated by the Minister. Furthermore, the provision of a fair share between telecommunications and OTT services is stated in the significant presence provisions that are based on: (a) the percentage of traffic from the domestic tariff used; (b) daily active users in Indonesia for a certain period and number; and (c) other criteria determined by the Minister.

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Principle of Impartiality and Non-Discrimination

Basically, the principle of impartiality and non-discrimination seeks to prevent and avoid unfair business competition in the operation of telecommunications and OTT services in Indonesia. The existence of the impartiality and non-discriminatory principle is a form of building good cooperation between telecommunications and OTT services; thus, all parties can receive equal treatment according to a fair portion, as described in the fairness principle.

The application of the principle of impartiality and non-discrimination is critical in supporting the economic progress of a country. Especially with the presence of the Internet, business opportunities among countries are increasingly borderless; hence, the application of this principle is increasingly necessary so that the presence of OTT services in Indonesia can properly contribute to the economy. Referring to the European Union (EU) that has already been aware of the importance of the Internet, the EU strictly prohibits discriminatory attitudes for various reasons, such as to protect effective business competition and maximize consumer welfare and fair business practices (Krämer, Schnurr & de Streel, 2017).

Principle of Maintaining Service Quality

With regards to maintaining service quality, the distribution of negative content on OTT services must be filtered without contradicting Indonesian laws and regulations. Thus, the public can enjoy quality content that does not conflict with national interests. As mentioned in Article 15, Paragraph (6) of the Government Regulation on Postal, Telecommunications and Broadcasting on the fulfilment of service quality to users, traffic management can be carried out.

This principle is also expected to strengthen cooperation between telecommunications operators to regulate traffic on OTT services if they conflict or threaten national interests, where cooperation between telecommunication providers and OTT services is realized through their emphasis on illegal content in OTT so that the presence of OTT services can be in line with Indonesia's positive law.

Application of the Telecommunication Cooperation Principles with OTT Platforms in the Context of the Job Creation Law

Referring to the Job Creation Law, especially related to telecommunications, this regulation can show its impetus for telecommunications operators to increase their competitiveness globally. Similar to the OTT Platform, this service often has difficulty being accessed by the public if it is not connected to a telecommunications network (Muslim, 2021) Despite the stigma on OTT is that it is a "hitchhiking" service, there are many conveniences provided by

OTT services in line with the needs and developments of the times. Thus, the government should utilize it through a pattern of cooperation based on the principles as regulated. In relation to the application of cooperation, this can refer to the Government Regulation on Postal, Telecommunications and Broadcasting that has been reflected in Article 15, where, at least in terms of the application of cooperation in carrying out business activities, this must be based on the principles of fairness, impartiality and non-discrimination, as well as maintaining service quality, as explained in the previous discussion.

Although the Job Creation Law does not explicitly utilize the term "OTT", it uses another term, namely "business activities via the internet". This can be traced to the explanation of Article 15, Paragraph (1) of the Government Regulation on Postal, Telecommunications, and Broadcasting as the implementing regulation of the Job Creation Law, which states that what is meant by business activities via the Internet is OTT. The specific form of OTT referred to in the Job Creation Law is OTT in the form of substitution of telecommunication services, audio and/or visual content service platforms, and/or other services determined by the Minister. Then, Article 15, Paragraph (2), letter a of the Government Regulation on Postal, Telecommunications, and Broadcasting states the forms of business activities via the Internet. Thus, it can be a limitation on the scope of OTT as referred to in the Job Creation Act as follows:

a. Telecommunication service substitution, in the explanation of Article 15, Paragraph (2) of the Government Regulation on Postal, Telecommunications, and Broadcasting. What is meant by telecommunication service substitution is a service that can replace services in the telecommunications sector, such as communication in the form of short messages, voice calls, video calls, conferences video, online conversations and/or sending and receiving of data.

b. Audio and/or visual content service platform, namely the provision of all forms of digital information consisting of writings, sound, images, animation, music, video, films, games, or as a combination of some and/or all of them including in streamed form or can be downloaded.

c. Other services as determined by the Minister.

The Job Creation Law, as re-specified in the Government Regulation on Postal, Telecommunications, and Broadcasting, has certain criteria for national or foreign OTT-business actors, referring to business actors who meet the provisions for significant attendance. This is based on Article 15, Paragraph (3) of the mentioned Government Regulation in terms of: a) the percentage of traffic on domestic traffic; b) daily active users in Indonesia within a certain period with a certain amount; c) and/or other criteria determined by the Minister. Meanwhile, the cooperation carried out by Telecommunication Network operators and/or Telecommunication service providers, based on Article 15, Paragraph (4) of the Government Regulation on Postal, Telecommunications, and Broadcasting obtains exceptions for business actors, namely account owners and/or users on social media channels, content platform channels, marketplace channels, and various other types of channels. Meanwhile, the form and material of cooperation are carried out according to the consensus of the parties. Then, regarding OTT implementation, in Article 15, Paragraph (7) of the said Government Regulation, the Minister in the field of communication and informatics is authorized to supervise and control the implementation of OTT as a business activity via the Internet.

Judging from the implementation of OTT in Indonesia, prior to accommodating regulations, OTT services relied on unwritten agreements with telecommunications operators, where, at the time a telecommunications operator opens access to its network, this reflects that the OTT and the telecommunications company already have unwritten cooperation. Hence, with regards to the existing regulations, in order to fulfil the principles of fairness, impartiality and non-discrimination, as well as maintaining service quality, the cooperation between OTT and telecommunication operators must be formalized in writing. A formal agreement is intended to provide clarity on the rights and obligations of the parties. As stated in Article 24 of the Government Regulation on Postal, Telecommunications and Broadcasting, it is provided that network leasing must be contained in a written agreement.

Basically, the application of cooperation by entering into a written agreement is usually a form of agreement carried out in business activities whose legal relations are much more complex, and usually include an authentic deed, a privately made deed and the title of the agreement. Thus, in a written agreement, it will be easier to prove if there is a default caused by the written agreement based on an authentic or underhanded deed (Artadi & Nyoman, 2010). Hence, in line with the presence of regulations related to the implementation of telecommunications cooperation with OTT services, it is expected that this service will become more controlled, reliable, and easier for the government to be able to choose OTT services to enter Indonesia.

Theoretically, as stated by R. Subekti, an agreement basically contains a promise to another person to carry out something that must be kept (Subekti & Tjitrosudibio, 1976). Thus, rights and obligations will arise and bind the parties, and the agreement must be carried out (Sinaga, 2018) In relation to the cooperation principles of telecommunications operators that include the principles of fairness, impartiality and non-discrimination, as well as maintaining service quality, fundamentally these principles must be contained in a written agreement to make it easier for the telecommunication operators and OTT service providers to fulfil their rights and obligations, as both are bound by an agreement.

With the application of cooperation principles as currently regulated, it is expected that the regulatory arrangements between the government and OTT services providers can be accommodated in a comprehensive manner, at least, by observing the principles of fairness, impartiality and non-discrimination, as well as maintaining service quality. This is in an attempt to create healthy business competition and is well accommodated by the government under the applicable law, i.e., the Law on Job Creation and Government Regulation on Postal, Telecommunications and Broadcasting as the implementing regulations.

Feasible Concept of Cooperation Agreement between Telecommunication Operators and OTT Service Providers in Indonesia

The essence of the Job Creation Law fundamentally lies in investment priorities and the creation of new jobs, including in the telecommunications industry. Therefore, the cooperation between telecommunication operators and OTT service providers in Government Regulation on Postal, Telecommunications and Broadcasting is a projection of the essence of the Job Creation Law. The cooperation can be opened globally to respond to the increasing entry of foreign players into the domestic market, but protection of Indonesia's digital sovereignty shall prevail. The regulation of the Job Creation Law and the Government Regulation on Postal, Telecommunications, and Broadcasting related to the obligation of cooperation between OTT and telecommunications operators is actually an attempt to accommodate the controversy between the two, which was previously considered to be against the neutrality of the Internet. In fact, Indonesia does not recognize this principle in its laws and regulations and it is intended that the government has the authority to protect the public from illegal and negative content in OTT services. Then, previously, the main challenge was the issue of the incompatibility of regulations in the Central and Regional Government, so that it had an impact on the emergence of obstacles in the construction of Based Transceiver Stations (BTS), fiberization, and costs for telecommunication providers. These obstacles can have an effect on OTT in Indonesia; hence, synchronizing regulations as carried out in the Job Creation Law and the said Government Regulation is a way to overcome these legal challenges.

As discussion on cooperation between OTT service providers has been accommodated in the previous section on cooperation principles, the cooperation concept in this discussion will focus on state sovereignty related to the presence of global/foreign players in the Indonesian domestic market and then proceed to preventing the control of the lives of many people by global OTT platform giants, ensuring the stability of the country's foreign exchange, and improving service quality in a way that does not burden the OTT service provider, such as by not imposing larger bandwidth.

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In general, digital sovereignty is related to the existence of state rights and obligations that are recognized by international law. Identically, state sovereignty is related to the principle of territorial sovereignty (Cahyadi, 2016). This means that there is a consensus regarding the authorities of the state in exercising its exclusive rights over the territorial domain of each country. For this reason, there is a development of terminology from sovereignty to digital sovereignty to accommodate activities that utilize the Internet in the cyber community. The concept of digital sovereignty applies to cyberspace, where the sovereign state can exercise control and supervision of all cyber activities in its territory. Hence, this is in line with the concession theory that strengthens state power over all activities that occur in its sovereign territory, namely in the physical state's territorial realm and in the cyber domain.

A concrete example of the relationship between OTT and telecommunication services can refer to the cooperation model issued by the Telecommunication Standardization Sector (ITU-T) in 2018 at the plenipotentiary conference that presents a collaborative OTT framework, with the telecommunications services industry stating that the losses incurred by OTT services can be profited by both parties when cooperating. (ITU News, 2019) Behind the losses caused by OTT service business so far, there are still benefits that can be achieved by both sectors if collaborating or cooperating. Collaboration or cooperation can actually be done such as between the Telecommunication Services Industry in Indonesia with OTT services engaged in media and content (Netflix and YouTube), in the field of communication (Facebook, Whatsapp, Line), in the field of marketplace (Shopee, Amazon, Tokopedia) and so on by putting forward the principles of cooperation — a) The principle of fairness, b) Reasonableness principle; and c) Non-discriminatory principle — as it is regulated and accommodated in the Copyright Law. Thus, the relationship between telecommunication services and OTT services can be mutually beneficial to each other, primarily in maintaining and developing the quality of a service

As for this, it can be justified through a statement by Ahmad M. Ramli, who said that the cooperation relationship that needs to be done to OTT is mutual collaboration (Ramli, 2020), where the collaboration is mutually beneficial to minimize the disruption that has occurred today and anticipate wider disruption in the future. Given the high number of Internet users in Indonesia, which is even alleged to increase to 196 million people or 73.7% of the total population in 2021 ("Peluang Penetrasi Internet", 2021), this is one of the golden opportunities for OTT services to develop their services in Indonesia and is also an opportunity for the Indonesian telecommunication services industry to cooperate with OTT services to increase investment that can boost national economic numbers to help develop equitable telecommunications in Indonesia. Thus, it is a concrete picture of how the reciprocal relationship between OTT Services and the Telecommunications Service Industry in Indonesia can operate.

It can also be understood that, when a company controls the domestic market, the company must comply with all the positive legal provisions that apply in that country. Hence, the existence of companies engaged in OTT services can also be legally recognized and can operate side by side with other domestic companies to create an advanced and developed investment climate. With regards to digital sovereignty, there is a mechanism that requires licensing of global OTT platform providers so that their services can enter into the domestic market. This is to prevent OTT platform providers acting beyond the limits of their existence as foreign players, even further to anticipate potential threats to Indonesian digital sovereignty. Moreover, the ambition for global domination with the giant global OTT platform has become more apparent with the construction of the Submarine Cable Communication System by large companies such as Google, Facebook, or Amazon Web Services (AWS) (Jati, 2019). The Submarine Cable Communication development is aimed at the Indonesian sea for the need for OTT service connectivity with full control by service providers. However, if this is left unattended by the state, there will be indications of huge losses both in the security and economic sector that ultimately threaten Indonesian digital sovereignty. Therefore, to anticipate this, the aforementioned cooperation mechanism provided in the Government Regulation on Postal, Telecommunications, and Broadcasting is a reflection of citizen protection carried out by the government.

The cooperation carried out by the government can also prevent foreign control of the lives of many people in Indonesia, especially with regards to national information. The essence of digital sovereignty is focused on benefiting Indonesians in this digital era. The Indonesian government, in this case, has managed to accommodate the legal aspects in cooperating with OTT platform service providers. Thus, Indonesia benefits from the global OTT platform providers from taxation, such as online tax transactions regulated in Law Number 2/2020 on the Establishment of the Government Regulation in Lieu of Law Number 1/2020 on State Financial Policy and Financial System Stability for Handling the Corona Virus Disease 2019 (Covid-19) Pandemic and/or in the Context of Facing Threats that Endanger the National Economy and/or Financial System Stability into Law. Therefore, the synergy between the Ministry of Communication and Information as well as the Ministry of Finance is mandatory to carry out the direction of the Indonesian President by seeking to implement rules for cooperation between the global OTT platforms and national/domestic network organizers (in a position as a strategic partner of the government) in managing the business activities of global apps/OTT-platform providers in Indonesian territory.

Furthermore, with regards to the service quality of the OTT platform, there is a constant increase in video quality that requires a larger channel. Moreover, the high rate of overall public visual consumption will certainly burden the operators of the cable network or cellular network. In this case, the network operators have to increase network capacity and have to add large investments. They also need to import costly technology products; this will cause deterioration in Indonesia's trade balance. On the contrary, OTT platforms are constantly benefiting from a high-quality service image with increasing revenue. On the other hand, if the public is dissatisfied with the content service, then a lawsuit will be submitted to the network operator. Therefore, cooperation between network operators and OTT platform providers needs to be encouraged so that mutual respect and mutual benefits occur based on a mutual symbiosis. The government can regulate (acting as a referee) the scope of cooperation that benefits the state and is fair to domestic operators.

Conclusions/Recommendations

The rapid development of Internet-based services in digital applications has become a new challenge that must be addressed by the Indonesian telecommunications sector. As widely known, the telecommunication sector now plays a critical role in life. In Indonesia, State support for the telecommunications climate is projected through the regulation in Law Number 11 of 2020 on Job Creation that is further elucidated and specified by Government Regulation Number 46 of 2021 on Postal, Telecommunications, and Broadcasting that contains the principle of cooperation between telecommunications operators and OTT platform service providers in the form of the principles of fairness, impartiality and non-discrimination, as well as maintaining the quality of the services offered. The Job Creation Law was implemented to support the acceleration of digital transformation and to make the technology, information and communication sector the drivers in the telecommunications sector. The fundamental change from the conventional to digital telecommunications industry is expected to encourage national economic recovery and bring Indonesia into a new era of the global economy. The Job Creation Law as a regulation that also changed the previous telecommunication regulations provides answers to the dead-ends of unfair competition between telecommunication operators and OTT service companies by encouraging collaboration in facing digital transformation.

Furthermore, the application of the telecommunications cooperation principle certainly requires concrete fulfilment. It starts from the provision of OTT services that only relied on unwritten agreements with telecommunications operators. Nowadays, collaborative cooperation must be carried out in written agreements. Through a formal agreement, it is expected the rights and obligations of the parties become clear and certain. Thus, in line with the emergence of regulations related to telecommunications cooperation implementation with OTT services, it is expected that this service will be easier to control and more reliable, so that it is easier for the government to choose OTT services that enter Indonesia.

In reality, the laws and regulations certainly cannot be separated from politics, because politics serves as a determinant of the direction of a country's legal policy. The legal politics of the Copyright Law begin from the presence of political will of the President to form the Copyright Law with omnibus law legal methods intended to simplify regulation and the deregulation of regulations that inhibit the creation of employment and business empowerment in Indonesia. Before the enactment of the Copyright Law, there were political challenges in Indonesia to harmonize central and regional policies and overcome overlapping regulations. Through the omnibus law system, Indonesia began to eliminate this with the issuance of the Copyright Law consisting of several sectors or clusters of laws and regulations to encourage investment, accelerate economic transformation and eliminate sectoral egos. However, political challenges arise in the Copyright Law, which still attracts controversy over the omnibus law system used, the alignment of central and regional policies, and the simplification of existing regulations. Therefore, the Copyright Law still requires procedural review and adjustment to be able to maintain its material content and present various other technical regulations, so that the political challenge can be resolved with the existence of adequate legal products.

Therefore, the Job Creation Law and the Government Regulation on Postal, Telecommunications, and Broadcasting are a reflection of the spirit of ease of investment. Potential job creation is also manifested in the telecommunications sector that is facing a new paradigm with the arrival of OTT services. Global collaborations are conducted to safeguard Indonesia's digital sovereignty with more comprehensive arrangements for global platforms that enter the domestic market. Thus, cooperation between network operators and OTT platform providers definitely requires encouragement to create mutual respect and mutual benefits based on mutual symbiosis by providing benefits for the country and providing justice for domestic operators.

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Mobile Advertising Modelling for Telecommunications Industry: Focusing on the Boosting of Value Co-Creation

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Abstract: The telecommunications industry has turned into social and communication-oriented services, along with declining voice services. In line with these changes, the telecommunications industry must adjust to market changes. One of the service changes that occurred was the emergence of mobile advertising services. The aim of this research is to build a mobile advertising service model that serves to form value co-creation for the industry of mobile telecommunications in Indonesia. The study used a sample of the broadband community of users from the largest mobile telecommunications provider in Indonesia. They involved their customers as part of service delivery in the company to co-create the value. The number of participants was 284. The sampling technique that was used was non-probability sampling. The data analysis was carried out using Structural Equation Modelling (SEM). The result of this study is to find a mobile advertising model for the formation of value co-creation for the industry of mobile telecommunications.

Keywords: mobile advertising, service-dominant logic, structural equation modelling (SEM), telecommunication, value co-creation

Introduction

The process of co-creation in marketing is undergoing very rapid changes, becoming more complex, following digital processes, and more systemic (Hartmann, Wieland & Vargo, 2018; Moncrief, 2017; Akaka & Vargo, 2014). This is due to the changes in the business itself where

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the digitalization approach is increasingly used. This change makes the process of value co-creation not only occur in the sales process between customers and companies, but also influenced by other things, both external influences, such as technological changes, and influences within customer interaction and the company itself, such as different levels of customer preferences (Steward *et al.*, 2019; Lemon & Verhoef, 2016). This condition presents a challenge in understanding the value of co-creation further, as the buying process is not only limited to the relationship between customer and company, but also includes various factors and other entities. (Lemon & Verhoef, 2016).

According to Lim, Yap & Lau (2011), the success of mobile advertising services depends mostly on the interaction between customers and the content of the products that are being offered. Because of that, the empowerment of information, ease of access to technology with the support of network strength, and active customers are expected to encourage value co-creation.

Purchase decisions by customers are closely related to business relationships within a company. This decision-making is influenced by several factors, including emotional and rational aspects (Kotler & Keller, 2015). The rational aspects such as product quality, technology, and after-sales service are more important than the emotional aspects, such as risk reduction, certainty, trust, and the close relationship between the company and customer (Lin *et al.*, 2018). Although the rational aspect is more important than the emotional aspect, the emotional aspects such as how to form a close reciprocal relationship between the customer and the company still cannot be ignored completely.

The strength of the rational aspects of a product, which are compared to the emotional aspects in the context of the establishment of co-creation value, especially in the Mobile Advertising industry of the telecommunications market, became one of the research gaps in previous studies. A study of Bae & Zamrudi (2018) on social media mentioned that the introduction of the characteristics and needs of each customer is very useful to increase consumer satisfaction. Research that was conducted by Gaber, Wright & Kooli (2019) investigated the customer experience of the community using Instagram ads, concluding that the high interaction between communities is influenced by customer perceptions about content usability, entertainment, credibility and lack of irritation from ads on Instagram itself. This issue was another research gap and it became one of the reasons underlying this study. Besides, previous studies had paid less attention to the study of value co-creation in digital marketing because of the opinion that the decision-making process is more rational and focuses on the assessment of rational quality, so that there is no individual emotional aspect that is involved (Sinclair & Seward, 1988). However, other studies have shown that the emotional aspect needs to be further studied, as value co-creation is important and able to affect the purchase decision-making process (Lin *et al.*, 2018) and is expected to increase value co-creation (Murillo, Merino & Núñez, 2016).

Based on the above background, the research questions can be formulated as follows: What is the right mobile advertising service model and can it be used as a guide to implement the concept of value co-creation in the cellular telecommunications industry in Indonesia?

Material & Methods

Location and research object

In this study, the purposive method approach was used by choosing a location where 80% of national advertisers were located and made ad bookings.

This study was conducted in Jakarta for six months (October 2020–March 2021). The research object that was used in this study was broadband users, who get a mobile advertising campaign with certain profiling. They should have active Internet status. Besides, they had to be smartphone users whose phones used a modern operating system such as Android or IOS (because in Indonesia there are many people who use old handsets with Symbian, Java, etc.). The other requirement was their average revenue per unit (the total revenue divided by the number of subscribers) must above IDR 100,000. They also were always getting a mobile advertising campaign in the first half of 2020 and doing a performance-based activity (install, acquisitions, purchases).

Data analysis methods

Based on these criteria, there were 284 respondents. The basic method that was used was mixed methods that combined qualitative and quantitative approaches (Creswell, 2015). This study applied the descriptive analysis method and Structural Equation Modelling (SEM). Descriptive analysis aimed to get an overview of the characteristics of respondents (profile and behaviour of respondents), while SEM analysis aimed to test the static and causal model. SEM had the facilities that were needed in this study, namely: having causality facilities that examined the relationship between variables as a unit; facilities that measured variables indirectly and detected measurement errors; as well as facilities that identified the interactions between variables. (Hair *et al.*, 2019).

Research variables

The variables included both independent and dependent variables. An independent variable was a variable that described or affected another variable (an exogenous variable with an X indicator), while a dependent variable was a variable that was described or was affected by an independent variable. Dependent variables were referred to as endogenous variables, with a 'y' indicator. These variables, both exogenous and endogenous latent variables, were measured by several questions where each question was made according to its indicators. The scale of the data that was used in the measurement of indicator variables was performed using the Likert and Semantic Differential rules with a scale of 1 to 5, where 1 = strongly disagree and 5 = strongly agree.

The structural model of the study describing the interaction between the research variables can be seen in Figure 1.

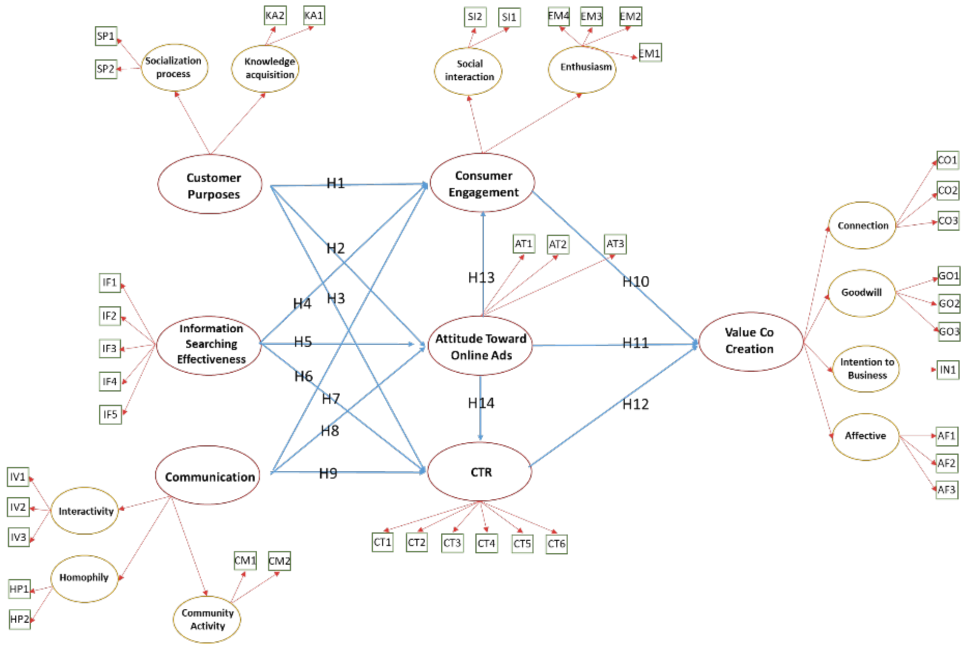

Figure 1. Conceptual Framework

Hypotheses

H1: Customer Purposes have significance positive effect on Consumer Engagement

Erat *et al.* (2006) and Joshi & Sharma (2004) in the context of customer knowledge management stated that the customer's goal to exchange knowledge is the key to success in attracting customers to engage in participation. This proved to be applicable in the context of an online community. The stronger the fulfillment of customer goals, the stronger the courage of consumers to participate and interact with the company will be.

H2: Customer Purposes have significance positive effect on Attitude Toward Online Ads

Menon & Soman (2002) investigated that the power of a customer's goal is based on customer curiosity about the ads that appear on the Internet. Their research resulted in the fact that curiosity about an ad will improve the quality of the customer aiming to get information from a particular product. In another study, Zhang & Katona (2015) stated that the goal of customers to get clear information from advertisers can encourage customers to have both positive and negative attitudes towards ads that appear.

H3: Customer Purposes have significance positive effect on Click-through Rate (CTR)

Baltas (2003) argued that one of the factors supporting the high Click-through Rate (CTR) in online advertising is the emergence of a sense of pleasure, where the value of pleasure is obtained by customers from the results of customer interaction in online activities. The purpose of pleasure and entertainment includes aspects of pleasure, entertainment, escape, and the like.

H4: Information Searching Effectiveness has significant positive effect on Consumer Engagement

Williams (2013) stated that the fulfillment of significant information searching effectiveness will further improve the customer engagement process. The study found a new causality in the context of online communities, stating that information searching effectiveness significantly affects online consumer engagement. Another study by Garman (2013) also mentioned a similar thing, that information searching effectiveness causally affects customer engagement.

H5: Information Effectiveness has significant positive effect on Attitude Toward Online Ads

Smith Ducoffe, Tromley & Tucker (2006) found that Internet advertising must have information searching effectiveness that is effective to support the attitude of ad acceptance from customers, including that those ads must have informative, entertaining, useful, valuable, and important characteristics. Schlosser, Shavitt & Kanfer (2009) corroborated this opinion by conducting a survey of 400 respondents and found that there was no opinion of most respondents about the use of advertising on the Internet: respondents' opinions were divided into three parts (likes, dislikes, and normal attitudes) to ad acceptance.

H6: Information Searching Effectiveness has significant positive effect on CTR

The MMA (Mobile Marketing Association), an organization that regulates the standardization of Mobile Advertising services, mentions that effectiveness in the search for product information can increase the effectiveness of a CTR campaign (Mobile Marketing Association, 2018). Several previous studies have also confirmed a positive relationship between effectiveness in the search for product information and an increase in the effectiveness of CTR (Jin & Jun, 2011; Ju, 2013).

H7: Communication has significant positive effect on Consumer Engagement

Communication has a significant effect on the formation of engagement. This statement is in harmony with Wagner & Majchrzak (2006), who state that communication built on interactive attributes can build customer engagement. Wagner & Majchrzak (2006) also state such causality in the context of the relationship with the offer or activity provided by the company. Narayen (2007) added that consumer engagement is the intensity of customer participation with both company representation and other customers in the process of knowledge exchange collaboration.

H8: Communication has significant positive effect on Attitude Toward Online Ads

Previous research has shown that the similarity of communication between individuals (homophily) who are targeted by mobile advertising services affects customer acceptance attitudes towards the advertising that appears (Chung & Holdsworth, 2012; Brynjolfsson, Hu & Rahman, 2013). Research by Murillo, Merino, & Núñez (2016) also confirms that not only homophily, but also good communication is needed, which is reflected by the homophily dimension and community activity level in each customer.

H9: Communication has significant positive effect on CTR

Customers are less likely to be attracted to uncommunicative ads and annoying ads (Smith Ducoffe, Tromley & Tucker, 2006). According to other studies, the same customer profiling factor when obtaining ads makes customers further encourage the level of customer activity in buying products offered by advertisers, so that proper customer profiling becomes a keyword (Kim & Sundar, 2010; Tassi, 2013).

H10: Consumer Engagement has significant positive effect on Value Co-Creation

Vivek (2009) builds a model of consumer engagement in which the intensity of consumer engagement relates positively to the value received by both consumers and companies, both extrinsic and intrinsic values. In addition, Prahalad & Ramaswamy (2004) also built a consumer engagement construct where consumer engagement encourages the process of value co-creation.

H11: CTR has significant positive effect on Value Co-Creation

CTR is the number of click-throughs as a percentage of the number of ad units that appear. According to Nihel (2013), CTR analysis of banner ads is believed to be the most common way to attract customers and engage them in the selection of brands or products from advertisers. Some previous studies (Dreze & Hussherr, 2003; Faber, Lee & Nan, 2004; Gong & Maddox, 2003) stated that CTR activity is directly proportional to the value of co-creation.

H12: Attitude Toward Online Ads has significant positive effect on Value Co-Creation

Some previous studies have believed that acceptance of online advertising has a significant influence on the value of co-creation (Bauer *et al.*, 2005; Jayawardhena *et al.*, 2009). Jayawardhena *et al.* (2009) further stated that the purpose of receiving a positive attitude also makes customers re-purchase the products offered, so the positioning of advertisements must be appropriate to support the creation of a positive attitude from customers.

H13: Attitude Toward Online Ads has significant positive effect on Consumer Engagement

The Marketing Science Institute (MSI) tracks consumer engagement based on the background of changing communication technologies and market globalization. Rapid changes in communication technology as well as the globalization of the market have created greater prospects and customer communities than many previously isolated conditions. Fremlin (2012) proves that the online environment increases the engagement and activity of members interacting.

H14: Attitude Toward Online Ads has significant positive effect on CTR

Attitude of acceptance towards online advertising becomes a major factor in various research on online advertising (Achadinha, Jama & Nel, 2014; Muk & Chung, 2015). When customers already have a positive attitude towards the acceptance of ads, this will encourage customers to do buying activities (click) in the ad, so this will encourage the high CTR value of mobile advertising services.

Results

Descriptive statistics

There were 284 respondents who were involved in this study. The questionnaire (in Indonesian) is given in the Appendix. The distribution of the respondents was dominated by males (56%), people who were aged between 31-40 years (40%), married people (67%), people who lived in DKI area (Jakarta) (47.5%), people who worked as an entrepreneur (68%), and people with undergraduate education (37%). Customer profiling was the main reason to use mobile advertising services, with the percentage of 50%. A total of 40.8% of customers were accessing mobile advertising services for 6 to 7 times every day. The revenue level of advertisers increased by 72.9% after using mobile advertising services.

Mobile advertising model

Based on the structural model that had been presented in the mind map as shown in Figure 1, the study was carried out with SEM tools using the unweighted least squares (UL) rules to determine the coefficient values in the model and the contribution of each exogenous latent variable to its endogenous latent. The results of the model coefficient test can be seen in Figure 2.

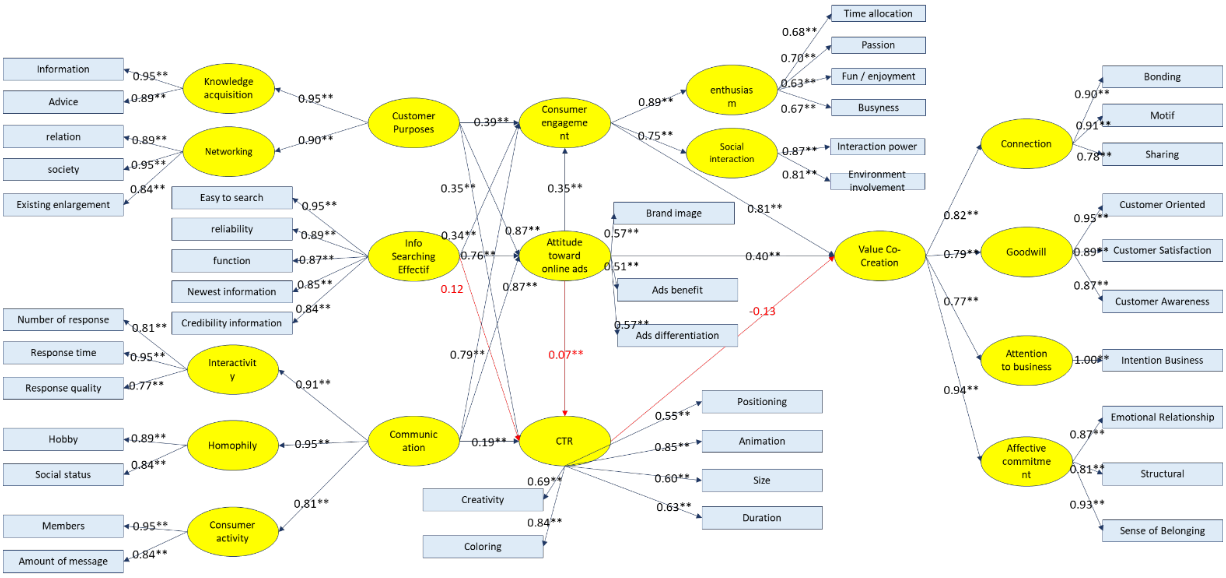

Figure 2. Coefficient of Structural Equations Model of Mobile Advertising

Hypothesis testing, validity, and reliability of the model were conducted using the P-value indicator, RMSEA (Root Mean Square Error of Approximation), and t values. It is a stable and reliable model if the P-value > 0.05 or RMSEA ≤ 0.08 and t value > 1.96 (Hair *et al.*, 2019). P-value or significant probability showed how well the model described the population, while RMSEA indicated the total error. The result of the model test showed that the P-value was 0.10386 (it would meet the criteria if the P-value > the requirement of 0.05) and RMSEA 0.012 (it would meet the criteria if the RMSEA ≤ 0.08). Thus, it met the criteria, showing that the data taken is in accordance with the developed model.

The detail results for the SEM modelling are shown in Table 1.

Table 1. Goodness-of-Fit Test Results

Item	Standard value	Result	Remark
Root Mean Square Residual (RMR)	≤ 0,05 or ≤ 0,1	0,01	*Good Fit*
Root Mean square Error of Approximation (RMSEA)	≤ 0,08	0,012	*Good Fit*
Goodness of Fit (GFI)	≥ 0,90	0,94	*Good Fit*
Adjusted Goodness of Fit Index (AGFI)	≥ 0,90	0,92	*Good Fit*
Comparative Fit Index (CFI)	≥ 0,90	0,92	*Good Fit*
Normed Fit Index (NFI)	≥ 0,90	0,93	*Good Fit*
Non-Normed Fit Index (NNFI)	≥ 0,90	0,93	*Good Fit*
Incremental Fit Index (IFI)	≥ 0,90	0,96	*Good Fit*
Relative Fit Index (RFI)	≥ 0,90	0,96	*Good Fit*

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An overview of the coefficients (loading factors) of the structural equations and t-values can be seen in Table 2.

Table 2. The Coefficient of the Model and t-values

Hypothesis	Description	Coefficient	t	Remark
$H_{1.}$	Customer's Purpose significant positive effect on Consumer Engagement	0.39	2.03	Accepted
$H_{2.}$	Customer's Purpose significant positive effect on Attitude Toward Online Ads.	0.87	5.90	Accepted
$H_{3.}$	Customer's Purpose significant positive effect on CTR	0.35	2.70	Accepted
$H_{4.}$	Information Searching Effectiveness significant positive effect on Consumer Engagement	0.34	2.40	Accepted
$H_{5.}$	Information Searching Effectiveness significant positive effect on Attitude Toward Online Ads.	0.76	5.19	Accepted
$H_{6.}$	Information Searching Effectiveness significant positive effect on CTR.	0.12	1.82	Not Accepted
$H_{7.}$	Communication significant positive effect on Consumer Engagement.	0.27	2.49	Accepted
$H_{8.}$	Communication significant positive effect on Attitude Toward Online Ads.	0.79	5.21	Accepted
$H_{9.}$	Communication significant positive effect on CTR	0.19	2.31	Accepted
$H_{10.}$	Consumer Engagement significant positive effect on Value Co-Creation	0.81	5.41	Accepted
$H_{11.}$	CTR significant positive effect on Value Co-Creation.	-0.13	1.23	Not Accepted
$H_{12.}$	Attitude Toward Online Ads significant positive effect on Value Co-Creation.	0.40	5.31	Accepted
$H_{13.}$	Attitude Toward Online Ads significant positive effect on Consumer Engagement	0.35	6.31	Accepted
$H_{14.}$	Attitude Toward Online Ads significant positive effect on CTR	0.07	0.20	Not Accepted

Discussion

The formation of value co-creation in mobile advertising was directly influenced by the attitude toward online ads (= 0.40) and consumer engagement (= 0.81). On the other side, it was indirectly influenced by customer purpose (= 0.39), online community engagement (= 0.2), and communication (= 0.27). The attitude towards online ads was significantly positive on the value of co-creation (= 0.40 and t = 5.31). The customer attitude towards the company and the brand that gets stronger will increase the value co-creation, and the more value co-creation in the company, the more valuable the mobile advertising platform will be.

In the long run, the value co-creation is beneficial for increasing consumer engagement, customer loyalty, and customer interaction with the company. On the other hand, the value co-creation provides useful values for both consumers and companies for short-term purposes. In general, there are three values that can be generated in the value co-creation process on the mobile advertising platform, namely: the value that is generated from the existence of a platform that unites consumers with certain interests and demographics; the value that is generated through content contributions or co-production; and the value that is generated through commerce or commercial activities. A platform that is able to survive and is sustainable will provide a value to all stakeholders.

The consumer engagement significantly influenced the value co-creation (= 0.81 and t = 5.41). The results of this study reinforce the statement of Vivek (2009), which built a model of

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consumer engagement where the intensity of consumer engagement related positively to the value that is received by both the consumers and companies, both extrinsic and intrinsic values. The results of the study are also in line with the construct of consumer engagement from the study of Prahalad & Ramaswamy (2004), where consumer engagement encouraged the occurrence of the value co-creation process. The study also reinforces the statement of Jacobson (2015) that there is a positive correlation between online interactions and the value of intrinsic experiences that are felt by the customers. Stronger consumer involvement tends to potentially generate intrinsic values in addition to extrinsic values, which in turn creates the value co-creation for companies and consumers.

The variables of the attitudes towards online ads, CTR, and consumer engagement are generated from customer purpose, information searching effectiveness, and communication. The causality that states that the attitude toward online ads and consumer engagement significantly affects the value co-creation is a new causality in the context of mobile advertising research.

Moreover, CTR is a percentage form to calculate the number of clicks and the number of ad units shown. As explained by Nihel (2013), CTR analysis of banner ads is believed to be the most common way to attract customers and engage them in the selection of brands or products from advertisers. From this study, CTR did not have significant and direct effect on the formation of value co-creation. The tests showed that t = -0.13 (smaller than 1.96) and so was insignificant. The effect of this CTR hypothesis was that the establishment of the value co-creation was not accepted or rejected. However, if we look further in this study about the variables forming the CTR variables, there are two variables that have significant effect, namely customer's purpose and communication.

According to the results of this study, it is known that communication significantly affects the CTR (= 0.19 and t = 2.31). Stronger communication will build a greater CTR. Communication as a second-order variable is built from the first-order variables of interactivity, homophily, and community activity level. Causality that states that communication significantly affects CTR is a new causality in the context of mobile advertising research. Communication is one of the factors that influences CTR and then builds customer loyalty behaviour in the context of financial services (Auh *et al.*, 2007). Innovation in improving CTR is a form of communication (Gustafsson, Kristensson & Witell, 2012). Johansen & Andersen (2012) added that integrated communication generates benefits in the context of marketing and corporate communication. Causality that states that communication affects CTR is also proven to be significant and can be applied in the context of mobile advertising platforms.

Furthermore, customer's purpose has a significant effect on the formation of the value co-creation with a positive coefficient (= 0.35) and t = 2.7. This causality is new in the context of mobile advertising studies. Breazeale (2010) explained the concept of customer bonding in the context of marketing in general and stated that the process of integrative customer formation began from the process of customer reaction to select, consume, and build relationships with the company. The results of this study showed that the stronger the customer's purpose, the stronger the formation of the CTR. The biggest contributor to the customer's purpose is the fulfillment of networking objectives and knowledge acquisition objectives. The fulfillment of customer's purpose against all dimensions in a balanced manner will build the CTR. The results of this study also corroborate the theory of Service-Dominant Logic (SDL) as the formation of value co-creation, where, in mobile advertising services, any individual or group that wishes to benefit more from this exchange must have understanding and knowledge, and must contribute to the exchange process itself.

Managerial implications that can be proposed to follow up on the study are enhancing the capabilities of the companies and customers to have an open dialogue, provide a large customer role to share, and implement transparency to build long-term relationships. Companies can also build an idea creation system to engage as many customer ideas as possible as part of the innovation process by establishing evaluation methods, implementing ideas as well as incentivizing those who are involved in the co-production process. Another important implication is to segment mobile advertising customers and build customer's purpose fulfillment programs according to their segment in the formation of value co-creation. Customers in a segment of young people and dominant to the purpose of pleasure are involved in co-production programs in the form of sharing articles, stories, or games that can create pleasure in customers. Adult segment customers who are dominant towards the purpose of socialization are involved in professional sharing activities as well as offline meeting activities.

Companies can provide education to customers that mobile advertising platforms can be applied and utilized for many aspects, not only for pleasure, such as advertising, games, and the like, but also for more useful purposes, such as research, education, knowledge sharing, health, finance, productivity and so on. Companies also must ensure the effectiveness of information search by providing fast information access, developing a wide network of infrastructure, providing the right application tools, and updating the design of mobile advertising platforms by engaging customers in the co-production process.

Conclusion

This study shows that the formation of value co-creation in mobile advertising is shown by the formation of customer's purpose, information searching effectiveness, and communication, which results in a positive attitude toward online ads and strong consumer engagement, both for the brands and the companies. The process eventually forms value co-creation as a benefit that is felt, by both customers and companies. It is measured based on some indicators, such as the connection with the company, goodwill, intention to do business, and affective commitment.

The company's strategies in managing mobile advertising in building value co-creation are as follows:

a) Improve the company's ability to have an open dialogue with customers, provide greater customer roles, and support customer innovation ideas as part of the value co-creation process;
b) Build a customer idea creation system as part of the innovation process by establishing evaluation methods, implementing ideas, and incentivizing those who are involved in the co-production process;
c) Provide leadership support from the company by ensuring the presence of a facilitator who can encourage the customers to be more actively interactive and share, and at the same time collaborate on, existing thoughts.

Limitation and suggestions

The limitation of the present study and proposed suggestions for future studies are as follows.

a. This study used objects oriented in the common interest of a mobile advertising platform in one mobile telecommunication company in Indonesia. The next study can be developed on other types of mobile advertising platforms with the same and different industries to strengthen the mobile advertising model in producing value co-creation in the broadband industry in general. Generalization of the results of the study is more appropriate if the mobile advertising platform that is used as a research object has a high level of member participation in subsequent research.
b. A mobile advertising platform that generates value co-creation for the mobile telecommunications industry requires customer education that is conducted comprehensively by the businesses of mobile telecommunications companies, regulatory bodies, and academics to show that mobile advertising can be used for more useful purposes, such as research, education, knowledge sharing, and other things.

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Appendix: Questionnaire

Lampiran Kuesioner Penelitian

Judul Penelitian:	PEMODELAN MEDIA *MOBILE ADVERTISING* SEBAGAI UPAYA PEMBENTUKAN *VALUE CO-CREATION* DALAM INDUSTRI TELEKOMUNIKASI SELULAR DI INDONESIA

Identitas responden :

1. Nama responden :
2. Alamat email :
3. No HP :

Demografi :

D1	Usia	:	
D2	Jenis Kelamin	:	[1] Pria [2] Wanita
D3	Pekerjaan utama	:	[1] Wirausaha / Wiraswasta [2] Karyawan swasta [3] Pelajar / mahasiwa [4] PNS [5] Tidak / belum bekerja [6] Lainnya (____________________)
D4	Pendidikan terakhir	:	[1] Lulus SMA [2] Lulus Diploma D3 [3] Lulus Sarjana S1 [4] Lulus Magister S2 [5] Lulus Doktoral S3
D5	Domisili (Tempat tinggal)	:	Kotamadia / Kabupaten : Provinsi :
D6	Status perkawinan	:	[1] Kawin [2] Belum kawin [3] Cerai hidup [4] Cerai mati
D7	Rata-rata pengeluaran pribadi dalam sebulan (Rp)	:	[1] < 1 juta [2] 1 – 3 juta [3] 3.1 – 5 juta [4] 5.1 – 7 juta [5] 7.1 – 9 juta [6] 9.1 – 10 juta [7] > 10.1 juta

Screening

Apakah bapak/ibu/saudara/saudari bekerja di perusahaan atau organisasi sebagai berikut:

	Ya	Tidak	
Operator Telekomunikasi Selular	1	2	Jika terdapat kode 1 yang terpilih, maka **STOP**, jika keduanya terpilih kode 2 **LANJUT** Pengisian Kuesioner
Perusahaan riset pasar	1	2	

TTD Responden	Tanggal Wawancara	Lokasi Wawancara	Jam mulai – selesai wawancara	TTD Interviewer

Catatan.

1. Kuesioner ini ditujukan kepada pelaku usaha yang menggunakan layanan Mobile Advertising yang terlibat dalam proses pengambilan keputusan pembelian iklan. Pelaku usaha dalam kuesioner ini adalah responden dalam tiga tahun terakhir. Setiap responden diminta mengisi atau memberikan pendapat terhadap pertanyaan yang diajukan pada kolom tingkat persetujuan.
2. Kuesioner ini diperlukan untuk kepentingan penelitian ilmiah.

PROFIL USAHA *

P1. Sejak kapan Anda memulai usaha yang Anda lakukan saat ini: Tahun______________

P2. Berapa modal Anda saat memulai usaha

Item	Pilihan
5.000.000,- s/d 10.000.000,-	1.
10.000.001,- s/d 15.000.000,-	2
15.000.001,- s/d 20.000.000,-	3
20.000.001,- s/d 25.000.000,-	4
> 25.000.001,-	5

P3. Berapa omset usaha Anda pada Tahun 2019 lalu : Rp ___________________________

P4. Sebutkan jenis usaha yang Anda jalankan saat ini :

Item	Pilihan
Bisnis Kuliner	1
Bisnis Fashion	2
Bisnis Pendidikan	3
Bisnis Otomotif	4
Bisnis Agribisnis	5
Bisnis Tour & Travel	6
Bisnis Produk Kreatif	7
Bisnis Teknologi Internet	8
Bisnis Kecantikan	9
Bisnis Event Organizer	10
Bisnis Jasa Kebersihan	11
Bisnis Kebutuhan Anak	12
Bisnis lainnya	13

P5. Bagaimana Anda memasarkan usaha Anda (Jawaban boleh lebih satu)

Item	Pilihan	Keterangan
Memasarkan secara *online*	1	Lanjut ke P6
Memasarkan secara *offline*	2	Berhenti

P6. Platform pemasaran online apa saja yang Anda gunakan dalam memasarkan usaha (Jawaban boleh lebih dari satu).

Item	Pilihan	
MyAds	1	Jika Kode 1 (MyAds) tidak terpilih→**STOP,** jika terpilih Lanjut ke P7
Adsqoo	2	
Pasangiklan.com	3	
Adsmart.com	4	
Platform lainnya	5	

P7. Sejak kapan Anda bergabung dengan MyAds : Bulan:__________Tahun_____________

P8. Sejak bergabung dengan MyAds bagaimana omzet usaha Anda ?

Item	Pilihan	Keterangan
Meningkat	1	Terjadi peningkatan %
Tetap	2	-
Turun	3	Terjadi penurunan %

P9. Selain menginginkan adanya peningkatan omzet, alasan Anda menggunakan MyAds adalah (Jawaban boleh lebih dari satu)

Item	Pilihan
Profiling pelanggan yang tepat	1
User interface	2
Bonus/reward yang diberikan	3
Kemudahan pembayaran	4
Kemudahan user experience	5
Kemudahan submit iklan	6
Kemudahan submit campaign	7
Call center 24/7	8
Alasan lainnya	9

P10. Dalam 1 bulan berapa kali Anda membuat iklan/mempromosikan produk menggunakan MyAds

Item	Pilihan
2 s/d 3 kali	1
4 s/d 5 kali	2
6 s/d 7 kali	3
8 s/d 10 kali	4
> 10 kali	5

*Lingkari yang sesuai dengan pilihan Anda.

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Anggota Komunitas *Online* "MyAds" Yth.

Kami membutuhkan umpan balik anda untuk membantu penelitian mengenai "PEMODELAN MEDIA *MOBILE ADVERTISING* SEBAGAGAI UPAYA PEMBENTUKAN *VALUE CO-CREATION* DALAM INDUSTRI TELEKOMUNIKASI SELULAR DI INDONESIA".

Kami mengharapkan kesediaan anggota Komunitas *Online* 'MyAds' untuk mengisi kuesioner ini. **Semua jawaban benar, tidak ada jawaban yang salah.** Pernyataan dan data responden hanya akan digunakan untuk keperluan penelitian dan dijaga kerahasiaannya. Pernyataan dan data responden juga akan diolah menggunakan kaidah-kaidah ilmu pengetahuan yang komprehensif.

Atas kesediaan dan partisipasi anggota Komunitas Online 'MyAds', kami ucapkan terima kasih.

Pada setiap pernyataan di bawah ini, mohon lingkari PADA ANGKA YANG TERSEDIA sesuai tingkat persetujuan Anda.

Sangat tidak Setuju	Tidak Setuju	Antara Setuju-Tidak setuju	Setuju	Sangat Setuju
1	2	3	4	5

A. Akuisisi pengetahuan

1	Informasi	KA1	Saya mengikuti layanan *mobile advertising* ini untuk bisa aktif memberikan informasi produk yang tepat kepada pelanggan	1	2	3	4	5
2	*Advice*	KA2	Dengan menggunakan layanan mobile advertising ini pelanggan menjadi lebih mudah menyampaikan saran atau pendapat kepada Saya	1	2	3	4	5

B. Networking

3	Relasi baru	SP1	Saya mengikuti layanan *mobile advertising* ini untuk meningkatkan peluang mendapatkan relasi baru dari pengiklan lain.	1	2	3	4	5
4	Kelompok/ *Group*	SP2	Saya mengikuti layanan *mobile advertising* untuk mendekatkan saya pada kelompok pengiklan yang sama dengan keinginan saya.	1	2	3	4	5
5	Jaringan/ *Networking*	SP3	Saya mengikuti layanan *mobile advertising* ini untuk mengembangkan jaringan kelompok pengiklan yang sudah saya ikuti.	1	2	3	4	5

C. Efektifitas Pencarian Informasi

6	Kemudahan pencarian	IF1	Saya menggunakan layanan *mobile advertising* ini untuk memberikan kemudahan bagi pelanggan dalam proses pencarian informasi.	1	2	3	4	5
7	Keandalan	IF2	Saya merasa layanan *mobile advertising* ini dapat diandalkan untuk memasarkan produk kepada pelanggan dengan akurat.	1	2	3	4	5
8	Kegunaan	IF3	Saya merasa layanan *mobile advertising* ini dapat dugunakan untuk memasarkan produk kepada pelanggan dengan akurat.	1	2	3	4	5
9	Kebaruan informasi	IF4	Saya menggunakan layanan *mobile advertising* ini untuk memberikan informasi produk yang *up to date* bagi pelanggan.	1	2	3	4	5
10	Kredibilitas informasi	IF5	Saya menggunakan layanan *mobile advertising* ini untuk memberikan informasi produk yang terjaga kredibilitasnya bagi pelanggan.	1	2	3	4	5

D. Interaktifitas (*Interactivity*)

11	jumlah tanggapan	IV1	Saya menggunakan layanan *mobile advertising* karena layanan ini memiliki jumlah interaksi tanggapan pelanggan yang tinggi	1	2	3	4	5
12	Waktu tanggapan	IV2	Saya menggunakan layanan *mobile advertising* ini karena iklan yang ditampilkan cepat ditanggapi oleh pelanggan.	1	2	3	4	5
13	Kualitas respon	IV3	Saya menggunakan layanan *mobile advertising* ini karena kualitas respons pelanggan terhadap iklan yang ditampilkan sangat cepat.	1	2	3	4	5

E. Tingkat Kesamaan (*Homophily*)

14	Hobi	HP1	Saya meyakini bahwa pengiklan lain yang berpartisipasi dalam layanan *mobile advertising* ini, memiliki hobi yang sama dengan saya.	1	2	3	4	5
15	Status sosial	HP2	Saya meyakini bahwa pengiklan lain yang berpartisipasi dalam layanan *mobile advertising* ini, berasal dari kelas sosial yang sama dengan saya.	1	2	3	4	5

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F. Tingkat Aktifitas Konsumen

16	Jumlah anggota	CM1	Saya meyakini bahwa layanan *mobile advertising* ini secara umum memiliki jumlah pengiklan yang cukup untuk berinteraksi.	1	2	3	4	5
17	Jumlah pesan	CM2	Saya meyakini bahwa layanan *mobile advertising* ini secara umum memiliki jumlah pesan interaksi antar pengiklan yang cukup.	1	2	3	4	5

G. *Consumer Engagement*

G (1). Antusiasme

18	Alokasi waktu	EM1	Saya mengalokasikan waktu yg cukup untuk beraktifitas dan menggunakan waktu saya dalam layanan *mobile advertising* ini	1	2	3	4	5
19	Semangat	EM3	Saya sangat bersemangat saat memasarkan produk kepada pelanggan menggunakan layanan *mobile advertising* ini.	1	2	3	4	5
20	Kesenangan	EP1	Saya menggunakan layanan *mobile advertising* ini karena mendapatkan rasa senang saat pelanggan bisa memahami produk saya dengan baik.	1	2	3	4	5
21	Kesibukan	EP2	Saya menggunakan layanan *mobile advertising* ini untuk menghabiskan waktu berinteraksi dengan pelanggan	1	2	3	4	5

G (2). Interaksi Sosial

22	Kesukaan interaksi	SI1	Saya mendapatkan manfaat dari ruang untuk interaksi yang diberikan oleh layanan *mobile advertising ini*.	1	2	3	4	5
23	Keterlibatan lingkungan	SI2	Saya mendapatkan manfaat dari keterlibatan pengiklan di sekitar saya saat berinteraksi menggunakan layanan *mobile advertising* ini.	1	2	3	4	5

H. *Attitude Toward Online Ads*

24	Citra merek	AT1	Saya mendapatkan citra positif dari pelanggan saat menggunakan layanan *mobile advertising* ini untuk memasarkan produk.	1	2	3	4	5
25	Manfaat iklan	AT2	Saya bisa memberikan manfaat yang lebih kepada pelanggan saat memasarkan produk menggunakan layanan *mobile advertising* ini.	1	2	3	4	5
26	Diferensiasi iklan	AT3	Saya bisa memberikan pengalaman / hal yang berbeda kepada pelanggan saat memasarkan produk menggunakan layanan *mobile advertising* ini.	1	2	3	4	5

I. *CTR*

27	Posisi iklan	CT1	Saya merasa penempatan posisi iklan yang muncul di *handset* sangat penting bagi pelanggan layanan *mobile advertising*	1	2	3	4	5
28	Animasi iklan	CT2	Saya merasa bentuk animasi iklan yang muncul di *handset* sangat penting bagi pelanggan layanan *mobile advertising*	1	2	3	4	5
29	Ukuran iklan	CT3	Saya merasa ukuran iklan yang muncul di *handset* sangat penting bagi pelanggan layanan *mobile advertising*	1	2	3	4	5
30	Durasi iklan	CT4	Saya merasa durasi iklan yang muncul di *handset* sangat penting bagi pelanggan layanan *mobile advertising*	1	2	3	4	5
31	Creative content iklan	CT5	Saya merasa kreatifitas iklan yang muncul di *handset* sangat penting bagi pelanggan layanan *mobile advertising*	1	2	3	4	5
32	Coloring iklan	CT6	Saya merasa warna iklan yang muncul di *handset* sangat penting bagi pelanggan layanan *mobile advertising*	1	2	3	4	5

J. *Value Co-Creation*

***J (1). Connection with the Company* (Hubungan dengan Perusahaan)**

33	Keeratan/ *Bonding*	CO1	Saya merasa memiliki ikatan dengan operator penyedia layanan *mobile adverting* ini	1	2	3	4	5
34	Motif tanggapan	CO2	Saya termotivasi untuk menanggapi komunikasi yang diprakarsai operator penyedia layanan *mobile adverting* ini	1	2	3	4	5
35	Berbagi/ *Sharing*	CO3	Saya merasa operator penyedia layanan *mobile adverting* ini memiliki keinginan untuk berbagi tujuan yang sama dengan pengiklan dan pelanggan.	1	2	3	4	5

J (2). Goodwill (Itikad baik)

36	*Customer Oriented*	GO1	Saya merasa layanan *mobile advertising* ini memberikan ruang bagi saya untuk mendekatkan diri dengan pelanggan.	1	2	3	4	5
37	*Customer Satisfaction*	GO2	Saya merasa puas dengan keputusan saya menggunakan layanan *mobile advertising* untuk memasarkan produk kepada pelanggan.	1	2	3	4	5
38	*Customer Awareness*	GO3	Saya merasa layanan *mobile advertising* ini memberikan ruang bagi saya untuk memberikan perhatian lebih kepada pelanggan.	1	2	3	4	5

***J (3). Intent to do business* (Intensi berbisnis)**

39	Intensi Berbisnis	IN1	Saya cenderung untuk membangun hubungan bisnis/tetap berhubungan bisnis dengan pelanggan layanan *mobile advertising* ini	1	2	3	4	5

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***J (4). Affective Commitment* (Komitmen mempengaruhi)**

40	Hubungan emosional	AF1	Saya merasakan kedekatan emosional dengan operator penyedia layanan *mobile advertising* ini	1	2	3	4	5
41	Struktural	AF2	Saya merasa operator penyedia layanan *mobile advertising* ini seperti bagian dari perusahaan saya.	1	2	3	4	5
42	*Sense of Belonging*	AF3	Saya merasa ikut memiliki operator penyedia layanan *mobile advertising* ini.	1	2	3	4	5

TERIMA KASIH

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Enhancements to the Deep Learning Signal Detection Model in Non-Orthogonal Multiple Access Receivers and Noisy Channels

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Abstract: This paper presents an enhanced deep learning-based Non-Orthogonal Multiple Access (NOMA) receiver that can mainly be used in low signal-to-noise channels. We show how a better dataset generation strategy for training Deep Learning (DL) could result in better generalization capabilities. Then, we apply hyperparameter tuning using exhaustive search to optimize the DL network. A Long-Short-Term-Memory (LSTM) DL architecture is used. The results show superior Symbol Error Rate vs Signal-to-Noise Ratio performance compared to the state-of-the-art methods such as Maximum Likelihood, Minimum Mean Square Error, and Successive Interface Cancellation, even though the network is only half as complex as previously proposed DL networks in the literature.

Keywords: NOMA, Deep Learning, LSTM, hyperparameter tuning, SIC

Introduction

Next-generation wireless networking has promised extensive capacity and a wide variety of interconnected devices. Not only is it required to support a vast amount of multimedia-based data traffic, but it must also support explosively growing, large-scale Internet-of-things (IoT) networks and an ever-growing user base (Chin, Fan & Haines, 2014). Although current multiple-access techniques such as Orthogonal Frequency Division Multiple Access (OFDMA) have allowed multiple users to share common network resources, they are, in terms of spectral usage, still inefficient enough to support the demands of the next-generation wireless communication systems (Hasan *et al.*, 2020).

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Fortunately, the rise of Non-Orthogonal Multiple Access (NOMA) techniques has promised many advantages over OFDMA (Islam, Zeng & Dobre, 2017) and has drawn extensive research interest in recent years. These advantages include more spectral efficiency (Khan *et al.*, 2020), reduced latency (Ye, Y., *et al.*, 2020), diverse power management policies (Park, Truong & Nguyen, 2019), and a vast increase in the simultaneous number of users it serves (Shin *et al.*, 2016).

Unlike OFDMA, where guard intervals are used to reduce the effect of interference, NOMA uses no guards at all, thereby increasing spectral efficiency tremendously (Hasan *et al.*, 2020). NOMA works by superimposing user signals, typically with different power levels, in a non-orthogonal fashion, which are then transmitted (Liu *et al.*, 2017). Successive Interface Cancellation (SIC) is performed where the user with the stronger channel condition is detected first while treating all other user signals as noise. Next, it is subtracted from the original stream at the receiver. The result is considered the user's signal with the weaker channel conditions and detected next (Chen, Jia & Ng, 2018). Maintaining perfect or near-perfect Channel State Information (CSI) is vital for NOMA if its superiority over OFDMA is to be realized, which is a challenging task (Hasan *et al.*, 2020).

The rise of Deep Learning (DL) in communication systems has provided another potential solution to channel estimation and detection in NOMA. DL is a method of learning from massive data with superior performance than traditional machine learning in many fields (Goodfellow, Bengio & Courville, 2016). Neng Ye *et al.* (2020) have proposed using deep multi-task learning to train several modules for channel estimation, mapping, and detection purposes of NOMA streams. However, their approach was not purely data-driven as some domain knowledge was exploited, and no evidence of parameter sharing makes it hardly a multi-task learning approach (Ruder, 2017). The researchers in Lin, Chang & Li (2019) have proposed a seven-layer neural network that can analyse CSI and detect transmitted sequences. While a seven-layer neural network is technically called a deep neural network, it often needs to comprise far more layers with varieties of architecture to warrant the badge of deep learning. Other researchers have suggested deep learning for various tasks in NOMA communication systems, like power minimization (Luo *et al.*, 2019), long-term power allocation (Sun *et al.*, 2019), and even joint precoding and decoding optimization (Kang, Kim & Chun, 2019). The literature is far more detailed to be listed in this short paper. Hence, we suggest Andiappan & Ponnusamy (2021) for a more comprehensive survey.

This paper improves the research effort in Thompson (2019), where a single DL network was used for channel estimation and detection. We chose this research for the following reasons. Firstly, their approach is end-to-end, where no pre-processing and/or domain knowledge are required. Secondly, it does not require channel estimation, which is a drawback of the

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traditional SIC detector. Thirdly, user signals are detected simultaneously in a single-shot fashion, rather than successively. However, their approach suffers from overfitting. Overfitting is when a DL fails to generalize from the training data, leading to poor classification performance. In addition, we have not, to the best of our knowledge, found any research, in the context of NOMA deep-learning-based receivers, where bias/overfitting and optimization are discussed and/or proved. We will show how a better-crafted dataset, training scheme, and simplified architecture can significantly reduce overfitting and increase performance.

The rest of the paper is divided into four sections. We will elaborate on the basic assumptions and scenario setting throughout the simulation. In the next section, we discuss the modelling of the DL network and our workflow. Then, we discuss the modelling procedure and hyperparameter tuning phase. Finally, we report on the simulation result and compare the performance of our approach to other state-of-the-art methods.

Basic Assumptions

This paper is essentially an improvement over the work presented in Thompson (2019). We will show how a better dataset generation strategy and careful fine-tuning of hyperparameters would improve accuracy and reduce overfitting. We will adhere to the same OFDM model assumptions. We repeat the details here for the reader’s convenience.

For a fair comparison, we will also consider the case of two user terminals connected to a base station via a NOMA uplink, as illustrated in Figure 1. Each user will have a single antenna for transmitting data. The base station will receive superimposed signals from user terminals 1 and 2, and added noise. Since the mechanism for determining CSI is not considered in this paper, we will assume perfect CSI knowledge at the transmitters, i.e., the users, and the receiver, i.e., the base station.

With the assumption of $\mathcal{M}$-subcarriers and $\mathcal{N}$ users, we can write the amount of received signal in the frequency domain on subcarrier $\mathcal{K}$ as (Thompson, 2019):

$$\mathcal{Y}(\mathcal{K}) = \sum_{i=1}^{\mathcal{N}} \sqrt{\mathcal{P}_i(\mathcal{K})}\mathcal{H}_i(\mathcal{K})\mathcal{X}_i(\mathcal{K}) + \mathcal{W}(\mathcal{K}) \quad (1)$$

where $\mathcal{Y}(\mathcal{K})$, is the received signal, $\mathcal{P}_i(\mathcal{K})$ is the amount of transmitted power by user (i) on subcarrier $\mathcal{K}$, $\mathcal{X}_i(\mathcal{K})$ represents the transmitted symbol by user (i), and $\mathcal{W}(\mathcal{K})$ models additive white Gaussian noise. It is assumed by Thompson (2019) that the total power is ($\mathcal{P}$), whereas the power allocation coefficient for user (i) is $\sigma_i(\mathcal{K}) = \mathcal{P}_i(\mathcal{K})/\mathcal{P}$ and is constrained to have a unity sum. Finally, $\mathcal{H}_i(\mathcal{K})$ is the discrete Fourier transform of the multi-path channel $\hbar_i(t)$ given by (Thompson, 2019):

$$\hbar_i(t) = \sum_{\ell=1}^{\mathcal{L}} \vartheta_{i,\ell}\, \delta(t - \tau_{i,\ell}) \qquad (2)$$

where $\vartheta_{i,\ell}$ is the complex channel gain and $\delta()$ is the impulse function with a $\tau_{i,\ell}$ delay for user (i) along path ℓ. We will assume a Rayleigh fading channel and total paths ($\mathcal{L}$) of 20.

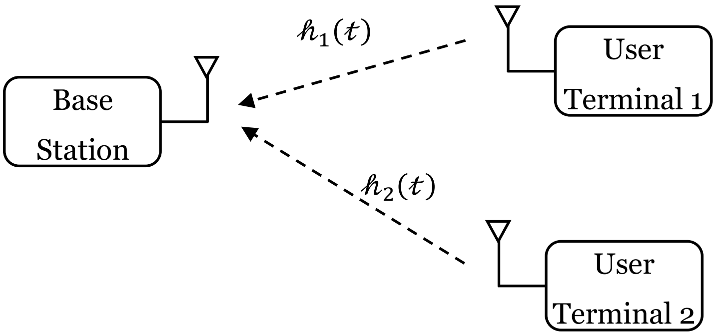

Figure 1. NOMA scenario of Thompson (2019) showing an uplink scenario of user terminal 1 & 2 sending packets to base station.

Modelling and Workflow

Since this research effort is based upon a data-driven modelling approach, we have followed a standard machine-learning modelling procedure, as shown in Figure 2(a). Figure 2(a) is a typical supervised classification scenario. For it to work, we need pairs of input-output examples. Firstly, we artificially generate samples of received OFDM data packets. To that end, a 64-subcarrier OFDM system is assumed. Each received packet has three symbols per user in which the first two packets are fixed pilots, while the third is a data symbol. The output of the training examples is one of 16 different combinations of the symbols that could be transmitted by users 1 and 2 in a QPSK baseband modulation. The reader is encouraged to refer to Thompson (2019) for more details.

However, our improvements compared to Thompson (2019) are that the training dataset is generated at different E_s/N_o levels ranging from 5 to 40 dB. The reasoning behind that is that the training dataset should be sampled *uniformly* from the probability distribution function of the data model, rather than sampled at only the highest modelled E_s/N_o value. The latter would result in a DL bias towards cases with high signal-to-noise levels. In contrast, if the generated training dataset were at only low E_s/N_o levels, then the resulting DL model would have difficulties learning the underlying structure of the mapping between input-output pairs, as much of the training data comprises high uncorrelated noise. In perfect scenarios, the training dataset should have a balanced number of samples per output label/class and samples that depict all the "extremes" and typical cases the input is expected to have.

Next, we construct the DL model using Long-Short-Term-Memory (LSTM) layers. LSTMs are types of Recurrent Neural Networks used widely to model data sequences (Goodfellow, Bengio

& Courville, 2016). Each LSTM layer comprises hidden units representing the amount of information that should be remembered between time steps. The number of LSTM layers and the number of units within each layer are hyperparameters that we have tuned using exhaustive search to optimize the model's performance. The LSTM layer is often preceded by an input layer, which acts as a buffer and data preparation for the LSTM layer. On the other hand, the LSTM layers are often followed by fully connected neural-network layers to linearly separate the features obtained by the LSTM layer, and a Softmax layer to output the probability of the predicted class for each label. Finally, a classification layer converts these probabilities into a verdict representing the predicted label (see Figure 2(b)). MATLAB Deep Neural Network is used for both modelling and simulation.

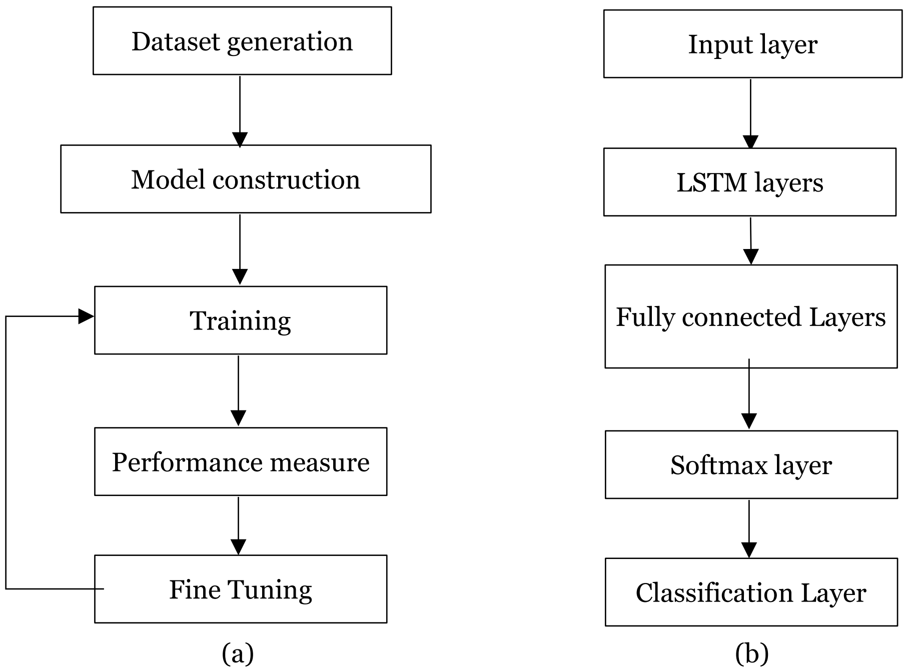

Figure 2. (a) Workgraph showing the major steps from modelling to LSTM training, testing, and fine-tuning; (b) layers details of the LSTM deep learning network

After testing its performance following the training phase, performance and fine-tuning are carried out in the DL model. The accuracy of both the training and testing data subsets is registered and compared to reduce bias and overfitting. For fine-tuning, we have considered: the number of LSTM layers, the number of hidden units, and the number of neurons in the fully connected layer.

Modelling Results

In this section, we report the simulation results of the scenarios presented in the previous section. Firstly, we have generated a training dataset at six E_s/N_o levels, namely: 5, 12, 19, 26, 33, and 40 dB. Each level had 1,000 samples per class for a total of 96,000 samples. This is only one-fifth of the training set size used by previous research efforts. While having a larger dataset size could help overcome potential overfitting, it substantially increases training time. The shorter the training time, the more simulation runs can be performed to fine-tune the model's hyperparameters. The training dataset has been divided into 90% training and 10% validation. Table 1 shows how we have varied some of the model hyperparameters and the number of layers for that end.

Table 1. Hyperparameters tuning by exhaustive search

Run No.	No. of LSTM layers	No. of LSTM units per layer	No. of Neurons in the fully connected layer	Training accuracy (%)	Validation accuracy (%)
1	1	16	16	48.18	43.81
2	2	16	16	53.95	49.66
3	3	16	16	47.48	42.8
4	1	32	16	78.11	70.73
5	2	32	16	79.91	70.73
6	**1**	**64**	**16**	**90.28**	**74.8**
7	1	128	16	93.09	65.4
8	1	64	two layers [4 16]	70.4	49.3
9	1	64	two layers [16 16]	88.1	66.45
10	1	64	two layers [32 16]	89.03	68.46

Our procedure was to change only one hyperparameter while keeping all others fixed. This hyperparameter was increased gradually until no further enhancement to the accuracy was possible. Then, we changed to another hyperparameter and so on. From Table 1, we started with a straightforward LSTM layer that has 16 units only. We noticed that increasing the number of layers in runs number 2 and 3 did not substantially increase accuracy but, rather, a slight decrease in validation accuracy was noticed. Furthermore, increasing the number of the fully connected layers or the number of neurons beyond 16 did not significantly impact accuracy. The setup of Thompson (2019), shown here as run number 7, suffered from overfitting, as there is a high difference of about 27 percentage points between training and validation accuracy.

The highest validation accuracy was registered in run 6 while, at the same time, keeping overfitting to a minimum. Overfitting is problematic in machine learning as it cripples the model's ability to generalize and, therefore, "learn" from data. However, we expect to have some generalization error because, when noise becomes dominant in low E_s/N_o levels, there would not be anything for the model to learn from, as the underlying signal structure is deeply buried inside the highly random nature of noise. We, therefore, settled with a value of hyperparameters obtained in run number 6, as it is a compromise between simplicity, higher validation accuracy, and "acceptable" overfitting. However, this issue could be investigated in future research.

Symbol Error Rate of User 1 and 2

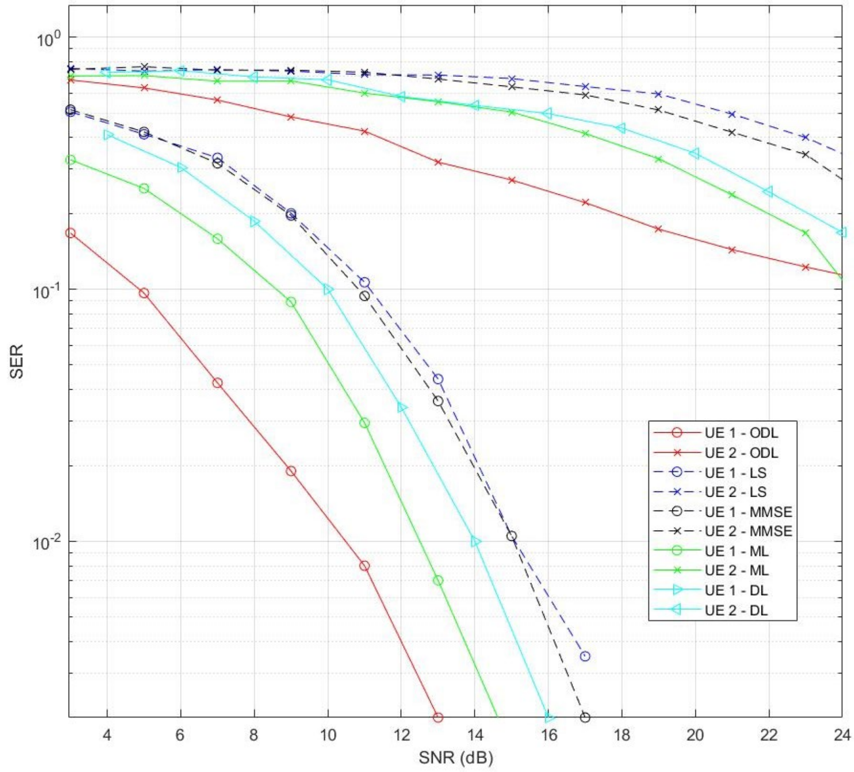

Figure 3. SER Curves for users 1 and 2 vs SNR. Our proposed optimized receiver is shown in red. LSTM of (Thompson, 2019) shown in sky blue. Other traditional methods are displayed in solid green (ML), dashed blue (LS) and dashed black (MMSE).

This section reports the results of using the trained deep-learning network on some test datasets and compares the results to that of Thompson (2019) and other standard methods. We will consider these standard methods: Maximum Likelihood (ML), Least Squares (LS), and Minimum Mean Square Error (MMSE) based SIC receivers. A typical procedure is followed for these methods, starting by estimating the channel using Least Squares (LS) and Minimum Mean Square Error (MMSE). We have varied the Signal-to-Noise Ratio (SNR) while registering the Symbol Error Rate (SER) value per-channel basis. To keep a fair comparison, we used a fixed phase shift and a cyclic prefix (CP) length of 20. Figure 3 shows the simulation results.

Our method is shown in red, marked with circles and crosses for users 1 and 2, respectively, and named ODL. In contrast, Thompson (2019) is shown in cyan marked with triangles for users 1 and 2 and named DL. The other curves are that of ML, LS, and MMSE. Figure 3 shows that the performance of our method exceeds that of all others, especially at low SNR. It proves how a better training strategy and careful optimization procedure can result in powerful and robust networks. However, as the SNR increases, the gap between the DL approach and the ML receiver becomes smaller, particularly for the weaker user 2. Hence, our approach is more suitable for channels with low SNR levels.

Conclusion

NOMA has become a de facto method for modern mobile communication systems because it promises superior spectral efficiency over OFDMA. With NOMA, the issue of reliably detecting users sharing the same resources in non-orthogonal settings is an ongoing research problem. One method to that end is to use deep learning and its capabilities to generalize from examples.

We have shown how we can improve one of the state-of-the-art deep learning approaches by generating a training dataset at different SNR levels, registering both the training and validation accuracy and optimizing the hyperparameters of the network. We have also shown how to decrease the impact of overfitting on the network capability of generalization.

The results prove our approach's superiority over state-of-the-art DL, ML, and SIC approaches, in particular at low signal-to-noise ratios. However, we recommend more network testing using various CP lengths, channel phase fading, and pilot symbols, though the robustness of DL in such situations has already been proven by other researchers.

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Gavan Edmund Rosman (1934–2022)

James Richardson

Robert Ayre

Peter Gerrand

Former colleagues of Gavan Rosman

Abstract: Gavan Rosman was valued at the Telecom (later Telstra) Research Laboratories, Australia, for his expertise as a research engineer in radio and coaxial cable technologies and, in particular, for his pioneering work on optical fibre technologies. He was also valued for his wide-ranging intellect and gentle, satirical sense of humour. His fluency in speaking Japanese was appreciated by visiting Japanese researchers. In retirement from TRL, he worked at Optiscan Imaging in Melbourne on developing an optical endoscope.

Keywords: Obituary, Gavan Rosman, Australian telecommunications, Telecom Research Laboratories

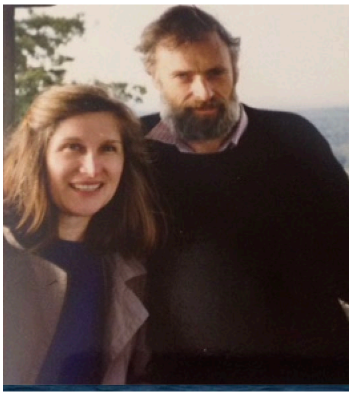

Figure 1. Gavan and Beth Rosman

Gavan Rosman was born on 16 October 1934 in Fairfield, Melbourne. He was the eldest of five sons and spent much of his early life in the suburb of Malvern. His father worked for a catering firm; then, from 1950, both parents ran several mixed businesses (milk bars) in Waverley Road, Malvern Road and in Mordialloc, finally moving to Burke Road, Caulfield. All five boys attended De La Salle College in Malvern. During his childhood, Gavan became fascinated with radios and with radio transmission, which led to the start of a splendid career.

After matriculating in 1952, he won a cadetship with the Postmaster General's Department (PMG), enabling him to study electrical engineering at the University of Melbourne, beginning in 1953. He graduated in 1956 as a Bachelor of Engineering (Electrical). That same year, he built a small 5" (12.7 cm) television so that his family could watch the Melbourne Olympic Games.

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Early Research and Family Life

In 1957, the PMG assigned him to work in their Research Laboratories (later Telecom Research Labs, and even later Telstra Research Labs), initially on radio transmission and aerial design. His initial work was to assess the performance of point-to-point microwave radio systems, via a mix of measurement and analysis. This included investigating the effect of ground-wave interference for different antenna heights, and the refraction of microwave beams due to the atmospheric temperature and humidity gradients. Such complex problems were analysed with the crude computation tools of the day: a desktop mechanical calculator and a slide rule.

As a diversion, for the Royal Visit in 1963, a need arose to transmit TV signals between Melbourne and Adelaide. This was made possible by arranging for an aircraft, carrying a pair of VHF TV receivers and transmitters, to position itself between the two cities for some hours each day. Gavan was involved with propagation and interference calculations to determine the optimal flight altitude profiles for the aircraft carrying the airborne repeater to fly each day.

In 1963, he won a scholarship from the Japanese government to spend a year in the Electrical Communications Laboratory of the Nippon Telephone and Telegraph (NTT) company, where he contributed to developing radio links between the southern island of Kyushu and Okinawa. He was particularly impressed that Japanese researchers and their projects of the day had a long-term focus, with application horizons of 10 years and more, rather than the more immediate one-to-three-year focus common in Australia. Keeping in mind longer term trends and their benefits were to become a feature of his own work, and his guidance to his teams, throughout his career. This period of Gavan's life also led to an enduring interest in Japanese culture, especially in the Japanese language in which he became very proficient.

Upon returning to Melbourne in 1964, he resumed his career with the PMG Research Labs. In 1969, he married Beth Clover who had come over from Perth, and they settled in a flat in St Kilda, which he had already purchased, known as Rocklea Gardens.

At this time, Gavan was also developing a keen interest in another mode of electromagnetic transmission, long-range coaxial cable. It became the dominant mode of broadband cable transmission from about 1960 until 1980. In 1970, he submitted several of his research papers on coaxial cable performance to the University of Melbourne, for which he was awarded the degree of Master of Engineering. The outcome of this work (for what became Telcom Australia in 1975 and Telstra in 1991) was improved cable design, installation precautions, and termination methods.

In 1970, Gavan took leave from the PMG to broaden his industrial experience. He and Beth moved to England where he continued his work on cable transmission with the British Post Office. Their first son, Carl, was born in England in 1971. Later that year, the family returned to Melbourne where their second son, Stephen, was born in 1972. Soon afterwards, the family moved to Upwey in the Dandenong ranges where both sons attended community schools. It was quite a joyful time in their lives. The next and final move was back to Melbourne, settling down in Camberwell.

The Advent of Optical Fibre

In the 1970s a new form of cable transmission had emerged from many early investigations into the production of light beams and their propagation through glass fibres. However, fibre losses in the early 1970s were prohibitive at 100 db and more per km. CSIRO developed a liquid-filled fibre with vastly lower losses, and Gavan put together a demonstration of TV transmission over this fibre. This involved a few hundred metres of the fibre, an analog TV transmitter using an infrared light emitting diode source, and a low noise optical receiver. This created considerable excitement at the time.

By the early 1970s, Gavan was leading the Visual Communications Section at TRL, looking at new techniques for the efficient transmission and processing of TV images, and wider applications of TV beyond "just entertainment". Digital coding of a TV signal to compress its transmission requirements was one such activity. However, the digital circuit technology of the day meant that the Section's coding demonstration system involved many hundred TTL logic ICs (integrated circuits) spread across about two dozen circuit boards, and a 30 kB memory that occupied most of a two-metre-tall equipment rack. Nonetheless, a signal compressed to less than ¼ of its initial transmission requirement showed a quality indiscernible from its source. A celebration was held when the price of memory fell to just $1 per bit: it was seen as a milestone on the road to feasibility. Nobody could foresee how far electronic technology and digital processor power would evolve to what we take for granted today.

It quickly became apparent that optical fibre cable would soon supersede coaxial cable. The transmission capacity of electromagnetic waves through glass fibres is enormously greater than along copper tubes. A new era in transmission technology had arrived!

Over the next few years, as solid core fibre achieved lower losses and became viable, the discrete core structure gave way to a multi-mode graded-refractive-index structure. However, Gavan took the longer view and always maintained, against 'classic wisdom' from a number of sources, that the future would centre on single-mode fibre, with laser diode sources, and digital transmission of all signals — none of which were feasible at the time. By the 1990s, Gavan was proven right.

On the TV application side, Gavan's Visual Communications Section designed and operated Telecom Australia's original TV conference facility, which went on to provide services for business users between studios in Melbourne and Sydney. A number of experimental conference calls were also made between Australia and the UK, but the cost and propagation delay associated with satellite transmission forestalled work in that area at the time.

Video telephony was an exciting possibility, but initial demonstrations involving bulky TV cameras and studio monitors were unconvincing. However, as the Visual Communications team returned from a group lunch, Gavan and a couple of the group spotted in a store window a cute plastic pyramid marketed as a desktop TV receiver. Somewhat futuristic in appearance, the top of the pyramid unfolded to reveal a 20 cm TV screen. Gavan immediately recognised its potential for a videophone demonstration. With some surgery to partially recess a small TV camera into the pyramid case, and with a few other mechanical and electronic modifications, the 'Camel Phone' was born. Several were made for various displays and to stimulate interest, and in research trials to gauge user reaction as to how such a service could evolve in the future.

Figure 2. Gavan Rosman with the Federal Minister for Science, Barry Jones, on a visit to TRL in the early 1980s

Following a restructure of TRL in 1979, Gavan was able to relieve himself of his roles in management and to resume full-time work on optical technologies. He continued to study the problems that would arise as more optical carriers were transmitted on the same fibre, or higher optical signal power was employed to lengthen repeater spacings. Single-mode fibre systems (as he had predicted) were now considered to be the dominant future transmission technology, but silica-based fibres would face a performance limit in terms of fibre attenuation.

Gavan thus turned his attention to different fibre materials, in particular fluoride fibres fabricated from zirconium tetra fluoride and related compounds. If fluoride fibres could be made with the same purity as silica glass, and operated at wavelengths in the mid-infrared, they offered transparencies at least one hundred times greater, and hence a similar increase in distance could be achieved without repeaters.

Fluoride glasses had been discovered by French researchers trying to create crystal materials, only to find they had made a glass. TRL, Monash University Chemistry Department and CSIRO Materials Science combined their expertise to create fluoride fibres. Despite all the promise, these materials preferred to form crystals rather than glass and thwarted attempts to produce long defect-free fibres. Nevertheless, techniques were developed that allowed the construction of highly effective lenses and small instrument windows at these wavelengths, which are critical in defence applications and thermal engineering.

Gavan could be a thorn in the side of senior management. But he was well-read, and an astute predictor of technological change and the evolution of telecommunications. He recognised the achievements of his young engineers and technical staff, and was always prepared to share his insights on developments. He was highly capable in both theory and practical experimentation, and able to apply these skills across a range of technologies and tasks.

Gavan continued his work in the development of fluoride glass for optical fibres until he retired from TRL and Telstra in 1996.

In Retirement

According to Beth, Gavan was appalled at the prospect of Telstra's privatisation, planned to begin in 1997, and chose to retire in 1996 at age 62, after 39 years with the PMG, Telecom Australia and Telstra. He then continued his work in optics with Optiscan Imaging, a local company founded in 1994, where he devoted himself to developing an optical endoscope, a device used in medical investigations of the body. He also lectured in optical technology at the Swinburne Institute of Technology, completing a long and productive career in 2012.

Gavan's self-assessment of his work was that he was primarily an inventor, skilled in both electronics and photonics.

The last few years of his life were quite difficult with continuing health problems, which he tackled scientifically until the end. Bicycle riding with Barry, and flute playing with Thad, former colleagues from the Labs, were important parts of his efforts to stay healthy. He passed away on 4 February 2022.

On Gavan's Sense of Humour

Peter Gerrand writes:

> "My first encounter with Gavan was memorable. He was one of a panel of engineering graduates asked to address my cohort of final-year electrical engineering students in 1966 on the opportunities to work in their fields of engineering. He had a much lighter touch than his co-panellists. Gavan began his talk by invoking biblical authority for his field of radio transmission: 'Go forth and propagate!'
>
> "Later, when I too had joined the PMG Research Laboratories (later TRL), I took part in the Public Open Day held in 1973 to celebrate the 50th anniversary of the Labs. I was

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amused to find that Gavan had organised his own 'exhibit', not on the approved official list. He had produced a detailed flowchart showing the sequence of approvals required in the PMG in order to purchase test equipment needed for his research. From memory, the decision chart required fourteen signatures, most of them by clerks in an ascending order, from very junior to very senior, in the staff-overweight Purchasing Division of the PMG. Gavan was very happy to explain this bureaucratic nightmare to any interested visitors.

"During his career within TRL, Gavan frequently used humour to stimulate interest in his technical talks and papers. In 1985 he delivered a paper at the annual convention of the Institute of Radio and Electronic Engineers (IREECON) with the arresting title "Fleet Footed Photons Flatten Faltering Fermions" (Rosman, 1985). When this novel title drew one in to read his paper, one found that it carefully explained the theoretical reasons for optical fibre's superiority over telephone cables for transferring information at high speeds.

"His love of satire was given play when invited to contribute to the 'Eye on the Future' column of the *Telecommunication Journal of Australia* (TJA) in the 1990s. The first, 'Your Future in the Stars (Incorporating Lifestyle Tips)', uses the format of a weekly astrology column to gently mock management fashions such as Best Practice and Matrix Management, as well as the excessive use of emails (Rosman, 1996a). His second column, 'Computer Assisted Living', satirises the way in which personal computers were starting to dominate our lives (Rosman, 1996b).

"Gavan was a delightful colleague whose playful and sceptical manner complemented a deep, wide-ranging intellect and a commitment to excellence in engineering research."

Acknowledgements

The authors thank Beth Rosman for her help in compiling this obituary and Harvey Sabine for sharing his memories of Gavan's research work at TRL.

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The Iridium Satellite Network

Simon Moorhead
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Abstract: An historic paper from 1991, republished here online, describes the features of the Iridium low earth orbit satellite system, which provided continuous line-of-sight coverage to any point on the earth's surface via L-Band mobile handsets.

Keywords: History, Telecommunications, Iridium, Satellite, Starlink

Introduction

The Iridium Satellite System was developed and patented by Motorola in the late 1980s and became operational in the late 1990s. It was designed to have a constellation of 77 satellites (77 being the atomic number of Iridium) orbiting in a low earth orbit (LEO) approximately 780 km above the earth's surface. The Iridium mobile handsets operated in the L-Band (1–2 GHz) and effectively provided continuous line-of-sight coverage to any point on the earth's surface.

The historic paper (McIntosh, 1991) describes the proposed Iridium satellite system before it was launched. A constellation of 11 satellites per plane and 7 polar orbits were required to provide continuous coverage. In the end, 66 satellites were deployed in 6 polar orbits to reduce the significant cost of deployment. Iridium utilised American, Russian and Chinese launch vehicles. According to Graham (2018), the total set-up cost for the first-generation fleet was around USD 5 Billion.

The satellites effectively created cellular-like coverage over the entire earth. They provided inter-satellite communications at 20–30 GHz and the same frequency was used for satellite-to-gateway communications. The inter-satellite links were dimensioned for 3,000 channels and the gateways for 2,000 channels. The historic paper provides details of the Iridium communications system, including its modulation schemes and proposed link budgets.

While the system was a technical success, it suffered from several practical drawbacks, which limited its commercial uptake. The handsets were bulky, and L-Band did not penetrate buildings very well. At the time, people were very familiar with the performance of analogue

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cellular phones and the Iridium handsets were considered inadequate by comparison. The post-launch airtime cost of around $10 per minute also dampened the market demand.

In 1999, Iridium went into Chapter 11 bankruptcy after falling short of revenue forecasts, but the company was never wound up. A number of changes were made to the company structure and, with American Government support, the system was eventually rescued. Through prudent management the Iridium system has survived, and the original satellites have been subsequently replaced and are back challenging traditional competitors like Inmarsat.

Fast forward to today and the Starlink LEO system from Elon Musk's SpaceX is the new broadband competitor to Iridium. Each Starlink end-user terminal is a satellite-fed, fixed broadband hotspot (Arevalo, 2020), rather than a true mobile service. With 1,900 satellites currently deployed and 12,000 proposed, it is easy to see that Starlink has considerably more capacity than Iridium.

In Australia, Starlink has a one-off set-up cost per user of around AUD 800 and Internet access costs around AUD 130 per month. Download speeds are up to 100 Megabits per second and upload speeds are up to 20 Megabits per second, with a latency of only 50 milliseconds. This contrasts with a latency of around 600 milliseconds for satellites in geostationary orbit and the reason LEO solutions are favoured for near-real-time satellite-to-ground communications, where lower latency is necessary.

Starlink uses SpaceX as its launch partner and currently has the capability to launch 60 satellites at a time. SpaceX are currently planning between 300 and 400 satellites per launch, using reusable first-stage rockets and are actively working to develop reusable second-stage rockets. This would mean that SpaceX would have a totally reusable launch vehicle that could deploy hundreds of satellites at a time, significantly lowering launch costs. It remains to be seen whether Starlink will be successful in the long term, but the larger capacity and reduced launch costs will certainly assist the business model to break even.

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The Historic Paper

Iridium — A Global Satellite Cellular Network

Glyn R. McIntosh, Telecom Australia

This paper provides an introduction into the technical concepts of the Iridium system. Iridium is the name of a proposed global satellite communications system capable of providing voice and data communications to small handheld terminals. The system operates via a constellation of low earth orbiting satellites circling the earth in North South planes at a height of 760 km.

Introduction

Iridium is the name that has been given to a new satellite based global communications system that is being developed by Motorola. Telecom is assessing the likely impact of Iridium and the possible role it may play in its implementation. The system will use a constellation of 77 small, smart satellites that are placed in a low earth orbit to provide continuous line-of-sight coverage to any point on the earth's surface. Iridium was chosen as the name for the system since the Iridium atom has 77 electrons encircling its nucleus. This constellation in conjunction with associated earth station gateways, that interface to the public switched network, will provide a packet switched digital communications system. Voice, data and paging services will be provided, with users able to communicate using small low-cost handheld transceivers similar to those currently in use with the existing Cellular Mobile Telephone System (CMTS). Dick Tracey communicator here we come.

In addition to the handheld terminals, mobile terminals may also be used on virtually any type of vehicle. Since the system will use a small omnidirectional antenna with low cost terminals the service will find application in many areas where it has not been possible to provide reliable communications in the past due to both economic and/or size limitations. Also since the satellites are in a polar orbit the service will be as good in the polar regions as it is at lower latitudes, whereas geostationary satellite systems have to tolerate inadequate polar coverage.

Motorola aims to develop a consortium of international companies to establish and operate the Iridium space segment, and a meeting of possible members was recently hosted by Motorola in Arizona. Telecom attended this meeting along with several international organisations.

Recently Motorola announced that Lockheed would be teaming with Motorola and that Lockheed would be responsible for the overall spacecraft design and manufacture. Hutchison Telecom was also reported recently in the press as intending to join the consortium.

Satellite Constellation

The constellation consist of 7 planes with 11 satellites in each plane circling the earth in the same direction in a polar orbit at a height of around 760 km. The separation between adjacent planes is approximately 27°, with the separation between planes 1 and 7 of about 17.7°. Satellites in adjacent planes are around 180° out of phase with minor corrections made to eliminate collisions at the poles. A schematic of the constellation is shown in Figure 1.

The satellites are small and relatively cheap ($25 — 30m in orbit) and will have a 5 — 8 year life. These satellites are suitable for use with a low cost launch vehicle such as the Pegasus. Such a low cost launch vehicle is required because to maintain the constellation after it is established, a replacement satellite will be launched on average every month.

The antenna system on each satellite is able to generate up to 37 spot beams and a 7 cell frequency reuse pattern is used to conserve spectrum in a similar fashion to CMTS. The 37 spot beams are projected onto the earth in a contiguous hexagonal pattern as indicated in Figure 2. Such a cell pattern is analogous to the cell pattern used for CMTS. The diameter of each cell at the surface of the earth is approximately 670 km, and as the satellites approach the poles the outer cells are progressively turned off in order to conserve power, and control interference with satellites in adjacent planes. Because these outer cells are progressively turned off only about 56% of Iridiums 2849 cells are on at the same time.

Currently Motorola and Lockheed are undertaking a detailed analysis of the satellite parameters in order to achieve the best compromise between system performance and satellite mass and cost. As a result of this analysis some of the parameters mentioned may change. These design changes would have some impact on the traffic capacity of the network however since the satellites only have a relatively short life it will be

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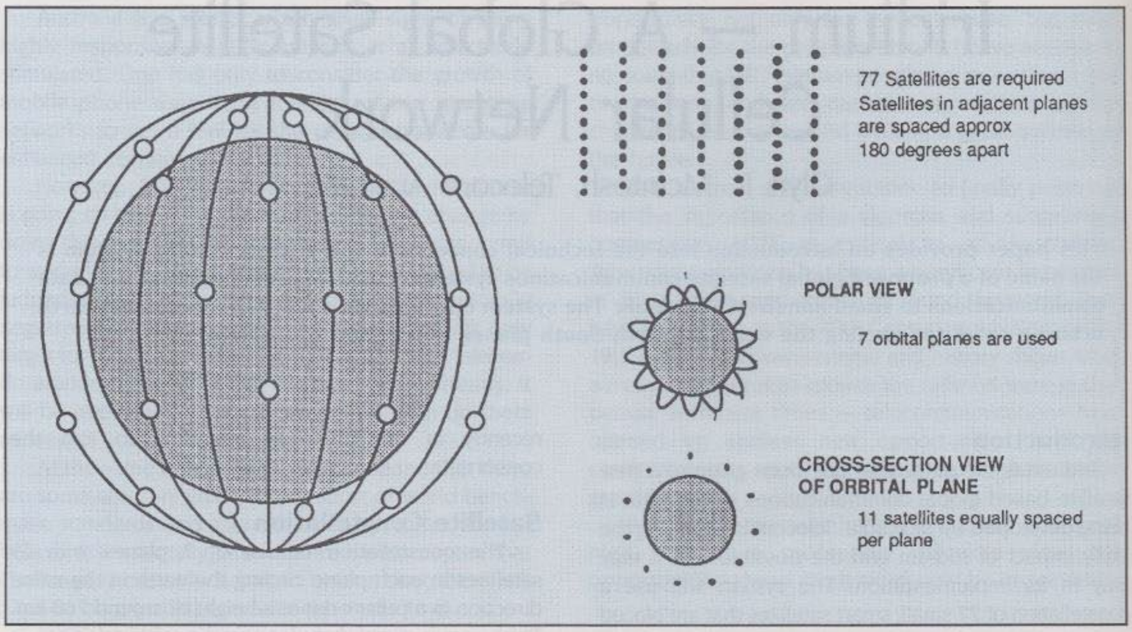

Figure 1: Satellite Constellation

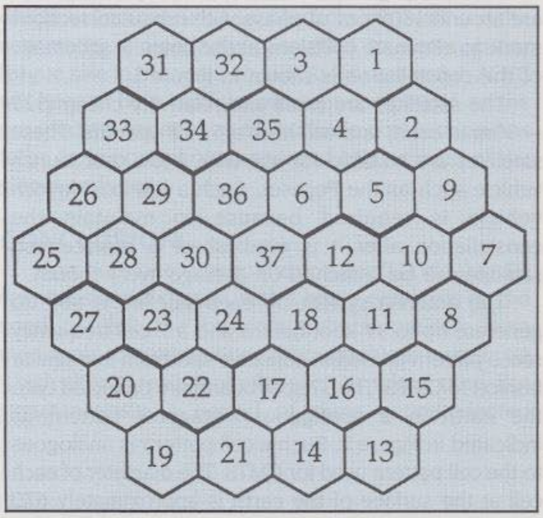

Figure 2 Satellite Antenna Spot Beam Pattern

possible to upgrade the network as technology improves.

Communications System

The cells formed by the satellite spot beam antennas travel across the surface of the earth at an approximate speed of 7400 metres per second, and the system provides automatic handover of calls between cells. Because of the high cell speed, users appear stationary on the earth with respect to the cell and this simplifies handover since the potential handover is typically to one of two cells and not one of six as in CMTS. Handovers will occur whether the user is moving or stationary and occur every 60-90 seconds.

Calls are routed from the user to the nearest satellite and then via inter-satellite links between adjacent satellites in the same plane and between satellites in adjacent orbital planes until the desired terrestrial gateway can be reached.

The key parameters of these communications links may be summarised:

Satellite / User

- QPSK modulation, packet format used with error detection and correction.
- multiple access format that uses both time division (TDMA) and frequency division (FDMA).
- transmission in band 1 GHz — 3 GHz.
- 2.2 : 1 digital speech interpolation (DSI) used.
- support voice operation on a circuit with a BER of 10^{-2}.
- 12 dB margin allowed for shadow losses.

Satellite / Satellite

- High rate QPSK with TDMA/FDMA access control used for round the world transmission.
- Satellites communicate with the satellite that is leading and following in the same orbital plane and also with 2 satellites in each adjacent plane (4 cross-links per satellite).
- 20 and 30 GHz band is proposed.
- Capacity of each link is approximately 3000 channels.

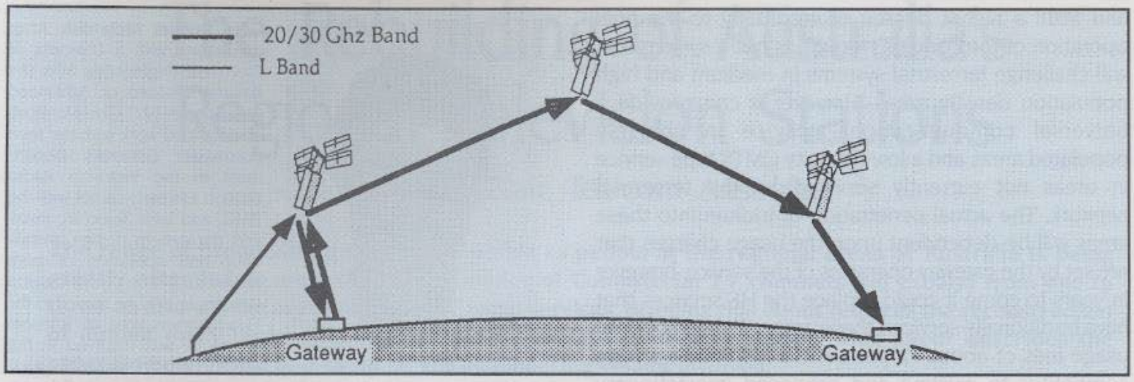

Figure 3: Typical Call Routing

- designed to support a BER of less than 10−7 using ½ rate FEC coding.

Satellite / Gateway

- Each satellite can communicate to the terrestrial network via a Gateway. Each gateway has steerable antennas for satellite tracking.
- 20 and 30 GHz band is proposed.
- High rate QPSK modulation with TDMA access control.
- Capacity of each link is approximately 2000 channels.
- The satellite/gateway link is also used for communications to the System Control Centres which control the allocations of channels between the user and the gateway and for general system housekeeping functions.
- designed to support a BER of less than 10−7 using ½ rate FEC coding.

Typical call routing is indicated in Figure 3 showing these three communications links.

Each gateway requires a minimum of two 3.3 metre tracking antennas separated by approximately 40 km in order to provide space diversity. Space diversity is necessary because propagation at 20/30 GHz is very dependent upon atmospheric conditions. In the initial system configuration 5-20 gateways will be provided, however the system can support up to 250 gateways. Access to the system will be co-ordinated via two System Control Centres which may be co-sited with gateway stations.

The final capacity of the system is related to the frequency spectrum that will be available for the user/satellite links. The preferred frequency band for these links is the L-Band (1500 MHz) and the demand of services using this band is already high. However an allocation of 20 MHz will provide a capacity of more than 300,000 simultaneous voice or data channels world-wide. This may seem like a large capacity however, it must be remembered that a large number of these channels will lie in sparsely populated areas where demand will be minimal. Also on average each individual cell will support just over 200 simultaneous calls. Since the cell diameter is about 670 km, Iridium is not, and cannot be used as a substitute for the terrestrial network in areas of medium or high density population. The cell diameter user for the initial implementation may also be larger than this initial design specification in order to meet satellite weight constraints.

Since the system relies solely on digital communications channels, voice will be digitised via an encoder into a 4.8 kbit/s data stream, and depending upon technology development at the time even 2.4 kbit/s encoding could be used. Data transmission at 2.4 kbit/s will also be supported with a ½rate Forward Error Correcting (FEC) code being provided within the system.

Implementation Timetable

The construction of the Iridium system is a massive project requiring a capital investment of more than $US2b for the space segment and the two system control centres. This capital requirement is spread over a period of several years. Satellite construction is due to commence in 1992, testing of the final service is expected to start in 1996 with services being provided during 1997. This timetable is very optimistic and delays of up to two years are quite feasible.

Summary

As can be seen Iridium is a very ambitious project requiring in excess of two billion dollars of capital investment. However Motorola are very keen to proceed with the service and have already filed a system application with the U.S. Federal Communications Commission. They have also been active in the international arena in relation to spectrum allocation and the development of a consortium to supply and operate the required space segment. Motorola's teaming arrangement with Lockheed to design and manufacture the satellite segment does indicate their high degree of commitment to the system and instil a higher degree of credibility to the final operation of the concept. Iridium is not a system that will challenge terrestrial systems in medium and high population density areas. However it can provide a universal communications service in sparsely populated areas and a low capacity CMTS type service in areas not currently serviced by the terrestrial network. The actual penetration of Iridium into these areas will be dependent upon the usage charges that are set by the gateway operators of the service, however in years to come it could replace the HF services that have traditionally serviced these areas. With anticipated usage fees of about $2 per minute it will be a strong competitor to existing and proposed geostationary mobile satellite services such as INMARSAT and the local domestic MOBILESAT service being implemented by Aussat.

Glyn Robert McIntosh After graduating with a Diploma of Electronic Engineering from the Ballarat Institute of Advanced Education in 1971 Glyn McIntosh commenced work with the then Postmaster General's Department in the Victorian Radio Section. His early career with the PMG, and later Telecom, involved the system design, installation and operation of both radio and line transmission systems. In 1982 he moved to the Headquarters area of Telecom where he was involved in the introduction of display paging into the Telecom Telefinder network. In 1986 he moved to the Satellite Services Product Team in Telecom where he is now the Manager of the Project Management and Customer Consultancy Section.

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