Nokia response:

ACMA's Spectrum Management Work Program "Five-Year spectrum outlook 2024-2029"

1 About Nokia

At Nokia, we create technology that helps the world act together. As a B2B technology innovation leader, we are pioneering networks that sense, think and act by leveraging our work across mobile, fixed and cloud networks. In addition, we create value with intellectual property and long-term research, led by the award-winning Nokia Bell Labs.

Service providers, enterprises and partners worldwide trust Nokia to deliver secure, reliable and sustainable networks today – and work with us to create the digital services and applications of the future.

Nokia is a global leader in 5G and 6G research, 5G and 5G Advanced standardisation, technology innovation and offers a world-class portfolio of products and solutions with a strategy specifically designed to support and drive the Australian market.

Nokia is proud to be a strong partner in the current roll-out of 5G in Australia, continuing our 120-year presence here. Nokia has been selected as a key supplier for the network deployments of 5G, including the required radio modules, as well as a major supplier to the National Broadband Network for fixed network technology solutions. Nokia is also a supplier to various enterprises and industries which have deployed private wireless networks deployed using apparatus licenses in Australia.

Leveraging the work of our research teams in the world-renowned Nokia Bell Labs, Nokia's industrial research lab, we innovate with purpose, pursuing responsible, sustainable technologies that will have a demonstrable impact on society. We are leading and fostering the digital transformation of society and industries by building end-to-end 5G networks that are faster, more secure and energy efficient. Nokia adheres to the highest ethical business standards as we create technology with social purpose, quality, and integrity.

For more information: https://www.nokia.com/networks/5g/

Disclaimer: This response is based on Nokia's current understanding of the market dynamics and various standards bodies; these dynamics are changing and hence our views may update with these changes

2 Submission overview

Nokia welcomes the opportunity to respond to Australian Communications and Media Authority Consultation Draft, "Five-Year spectrum outlook 2024-2029" (FYSO). As a leading player in the global communications sector, and contributor to the Australian market over many decades, Nokia is well placed to provide insight on market and technology trends, including industry structure and regulatory practice.

Nokia welcomes the effort of ACMA on the regional and international discussions and its clear and transparent process in the planning of spectrum. Additionally, Nokia acknowledges the ACMA's progress on mid-band spectrum allocations as this will facilitate a wide range of use cases including WISP, public mobile telecommunications services, enterprise and campus style private networks, such as mine sites, agricultural uses or industrial uses.

Nokia also applauds the ACMA for its focus on the facilitation of 5G throughout the FYSO, not least through the inclusion of several frequency bands either intended to be, or in the process of being, re-planned for 5G.

Over the past 30 years, cellular communications have brought unprecedented benefits to humankind. 2G and 3G unleashed the potential of human mobility and connectivity. 4G gave us greater access to information and social engagement. 5G linked us to the wealth of data from machines and sensors.

Connectivity has the potential to unlock billions of dollars in value-added industry uplift by 2030, across industries such as healthcare, mining, transport, manufacturing and utilities. Nokia anticipates 5G and 5G-Advanced will contribute up to $8 trillion in global GDP in 2030[1].

However, we note that the ACMA's Statement of Intent nor this year's draft FYSO highlight the enormous economic and productivity benefits of 5G to the broader economy. Research from Nokia and Nokia Bell Labs found that on average, whilst the importance of 5G adoption is well understood, a significant investment gap remains, and current levels of adoption suggests there are notable barriers to implementation.

This is why Nokia supports the Australian Mobile Telecommunications Association's (AMTA) call on the Australian Government to implement a National Mobile Tech Strategy to

[1] Nokia: 5G set to add $8trn to global GDP by 2030 | Nokia

"accelerate adoption of 5G enabled technologies," by incentivising specific industries such as healthcare, transportation, and agriculture to adopt 5G solutions[2].

At Nokia, we strongly believe that 5G adoption and digitization of industry will be created by an ecosystem of partners – government, industry and academia – working together to bridge industries and fuse the digital and physical worlds together. The 5G Innovation Initiative was just one example of a funding mechanism which provided an opportunity to bring technological advancements to life.

Additionally, as 5G enables a rich fabric of cutting-edge technologies powering smart cities, factories, precision farming, the Internet of Things (IoT) and robotics, the inevitable rising demand and strain on the network will require a new, highly agile and cognitive architecture that automatically deploys new services optimally tailored to these applications, while further pushing the limits for the support of ultra-low latency, massive capacity and widespread connectivity.

5G and 5G- advanced will lay the important foundations of 6G; which will see the fusion of the digital, physical and human worlds, opening the door to extrasensory experiences. Intelligent knowledge systems will be combined with robust computation capabilities, merging the roles of network, application and processor.

And while 5G and 5G-Advanced will tap into the real potential of AI/ML, in 6G, Nokia Bell Labs expects AI/ML will go from an enhancement to a foundation by taking a clean slate approach, allowing it to determine the most suitable interaction between two endpoints[3]. Not to mention better energy efficiency. 6G will meet these expectations and even go beyond by reformulating the very concept of network communications.

It is for this reason why Nokia is encouraging ACMA to:

1. Ensure an optimal use of the upper 6GHz for IMT use
2. Start initial investigation for 600 MHz and explore UHF band (470-614 MHz, as well as 450MHz and 410MHz bands for private broadband networks in Australia)
3. Completion of the extended C-Band 3.3-4.2GHz allocations
4. Support mechanisms to drive 5G adoption and prepare for Australia's 6G future

In summary, for Australia's economic benefits and productivity gains to be realized and its position as an early adopter of 5G to be maintained, there is an urgent need for a National Mobile Tech Strategy to drive 5G adoption whilst establishing a long-term perspective on spectrum demand, including bands to support the transition to 6G.

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[2] Australia losing 5G race: AMTA calls on Federal Government to implement National Mobile Tech Strategy - AMTA | The Voice of the Australian Mobile Telecommunications Industry

[3] In future networks, 6G radios will learn from one another - Nokia Bell Labs (bell-labs.com)

3 Priority band comments

3.1 World Radiocommunication Conference 2023 (WRC-23) Outcomes

In December 2023, the World Radiocommunication Conference 2023 (WRC-23) closed its doors. 151 members (out of 193) of the United Nations' (UN) International Telecommunication Union (ITU) reviewed and officially signed the Final Acts of the WRC-23 on global harmonized spectrum for various usage, including for mobile.

Nokia welcomed the outcomes of the WRC-23 - allocation of 700 MHz of spectrum for 5G/6G growth and decision to explore over 1 GHz of spectrum for potential regional/global 6G designation in the 2027-28 timeframe - that allow the mobile sector to continue the development and deployment of 5G and its advancements as well as planning for the next generation, 6G.

For the mobile community, the new spectrum bands agreed by the WRC will enable further growth of mobile services in a sustainable economic and environmental manner, addressing the increasing demand for capacity and connectivity towards 2030 and beyond.

As expected, the strongest debated subjects concerned the identification of the upper 6GHz (6425-7125 MHz) for IMT (mobile) in each of the Regions of the ITU, agreement on setting up an Agenda Item for WRC-27 on new bands to be studied for 6G, and the set-up of the evolution path of the lower UHF band (470-694 MHz) in EMEA (ITU Region 1).

Additionally, the further harmonization of the use of the 3.5 GHz band globally (portions of the 3.3-3.8 GHz for EMEA and the Americas), as well as improving the usability of the 4.8-4.99 GHz frequency band with least restrictive technical conditions were among the topics of importance for Nokia.

WRC-23 also agreed to study for WRC-27 possible allocations of MSS (Mobile Satellite Services) to provide satellite D2D (Direct-to-Device) communication in the frequency range between 694/698 MHz and 2.7 GHz to complement the terrestrial IMT network coverage.

3.1.1 6GHz (5925-7125 MHz)

With the identification of the upper 6 GHz band for IMT and licensed operation, significant economic benefits and boost of the 5G NR development for additional use cases such as industrial use case is expected to arise.

Upper 6GHz (6425-7125 MHz) band was a key discussion at WRC-23; finally, there was an agreement about the opening of additional 700 MHz of mid-band for the deployment of mobile (IMT) for EMEA and some countries in the Americas and Asia Pacific.

The adopted technical conditions would allow for a successful deployment of macro-cellular mobile services in the band whilst offering sufficient protection to incumbent services especially the fixed satellite service (FSS) uplink for now and the future. More stringent conditions for IMT to protect these services would have jeopardized the optimal use of this crucial band for mobile services and it would have deemed unproportionate.

The harmonization of the band paves the way for the expansion of mobile capacity for 5G-advanced and beyond, with countries that identified upper 6GHz for IMT at WRC-23 representing more than 60% of the world's population. Although all Asia Pacific countries have the top 100 MHz identified for IMT, it is only a few countries that have the full 700 MHz identified now. However, it is recognized that some key markets in Asia Pacific (including China) plan to use the band and other see potential and opportunity to have the entire 700 MHz identified for IMT at WRC-27, thus, extending the increase in mobile capacity and maturity of the ecosystem for the region in the future.

3GPP has started developing the necessary specification on the conformance to the limits set at WRC-23 for the use of the 6 GHz range and it is due to be finalised at the end of this year (2024).

Nokia also appreciates there are competing demands for the upper 6 GHz band from the Wi-Fi sector, which has already been allocated access to spectrum in the lower 6 GHz (L6) band. However, it is important to note that:

- The Wi-Fi sector now has 1067 MHz in total allocated to it in Australia (across three bands: 2.4, 5 and L6 GHz). In contrast, the mobile industry has 935 MHz in total allocated to it below 6 GHz, with 100 MHz of mid-band spectrum coming in Q4 2023, bringing the total to 1035 MHz.
- Wi-Fi speeds in the home and smaller premises are usually constrained by the fixed broadband network speeds and not Wi-Fi radio capacity.
- The class licensing arrangements for Wi-Fi may create a disproportionately high interference management burden for existing licences and the ACMA relative to spectrum licensed IMT services, which offer improved transparency due to the requirement to register devices with the ACMA.
- There are other spectrum opportunities for Wi-Fi. Since Wi-Fi is generally used for highly localised coverage (and often indoors), higher frequency bands, such as mmWave and 60 GHz, are likely to be more suitable for additional Wi-Fi requirements in the future (compared to outdoor mobile broadband coverage).
- The same opportunities do not exist for mobile services as they will continue to be highly dependent on access to sufficient mid-band spectrum to economically deliver high broadband speeds and wide coverage using macro and small cell sites.

Nokia are supportive of technical rules that are harmonized at a greater extent with other markets for this band, to ensure the development of a harmonized ecosystem. Moreover,

we note a momentum within the mobile industry to set 6 GHz as priority for future IMT spectrum.

Ensuring that the mobile industry has the future opportunity to access spectrum in this band is critical to realising the economic and social benefits of 5G and 6G technologies for the benefit of all Australians now and into the future.

We consider that the upper 6 GHz band (6425-7125 MHz) is the only viable option remaining to support the future expansion of 5G and launch of 6G services. Nokia looks forward to contributing on the ACMA's upcoming consultation on the upper 6 GHz band.

3.1.2 UHF spectrum (470-694 MHz)

The UHF (470-694 MHz) agenda item was also discussed at WRC-23. Agreement was reached enabling mobile usage in the future in all EMEA subregions: - Primary mobile in 600 MHz (614-694 MHz) with IMT identification for 11 Arab countries (e.g., UAE, KSA, Qatar, Egypt) under strict conditions - Secondary mobile for the full band (470-694 MHz) for 43 CEPT countries and Uzbekistan, with review towards primary in 2031 - Secondary mobile for 8 African countries (e.g., Namibia, Nigeria, Tanzania) in the 600 MHz band (614-694 MHz).

The new mobile allocations in the full or portion of the low UHF band are an important win, allowing more flexibility in the band. It also enables reducing the urban/rural connectivity divide and achieve efficiently the digital equality in EMEA in the future. Some countries like the KSA, the UAE, Nigeria plan auctions soon allowing for 600 MHz network rollouts. In Europe, discussions on solutions and a new ecosystem covering the full band 470-694 MHz gain momentum for future business development. Nokia has efficiently led GSA and teamed up with GSMA during the WRC23 preparation and in engaging in many discussions with Administrations in the conference, helping to move a large majority for No Change towards accepting change in a significant part of the EMEA region with large economic weight.

Availability of additional UHF spectrum (in the 470-694/698 MHz range) can bring great benefits to achieve improved coverage, capacity and performance in sparsely populated areas and some suburban areas as well as in hard-to-reach locations (e.g., deep indoors). Beside enhanced mobile broadband services, it is necessary to address a growing range of applications requiring good propagation characteristics in an economically efficient manner.

ACMA should consider the feasibility study and potential migration of existing services especially for the whole UHF spectrum. We encourage ACMA to further investigate the potential use of these bands and look to move 600 MHz under initial investigation.

3.1.2.1 450MHz and 410MHz

The 450MHz and 410MHz bands could also be considered for private broadband networks in Australia (initially LTE) e.g. for public safety and the utilities, as this usage is occurring in other countries and so an equipment ecosystem is developing. Additionally, the 380-400MHz historically used for TETRA and Tetrapol public safety networks is another candidate band for private LTE broadband networks.

In Germany, 450connect GmbH is currently building and will operate the fail-safe platform for the digitalisation of critical infrastructures in Germany. The Cologne-based company is thus creating a decisive prerequisite for the decarbonisation and resilience of our national economy. For this purpose 450connect recently received the exclusive assignment of the 450MHz spectrum until 2040. 450connect is backed by more than 70 utilities, including Alliander, E.ON, a consortium of regional energy companies and the Versorger-Allianz 450, which includes numerous public utilities, energy and water suppliers with the participation of the EnBW-subsidiary Netze BW.

With 450connect's new nationwide, highly available and secure LTE450 radio network, operators of critical infrastructures will receive the platform they need to digitalize their infrastructure, implement the energy transition to decarbonization, and further secure the energy supply.

3.1.2.2 600 MHz

The 600 MHz band is rising in importance in countries in the Americas and in some countries in Asia-Pacific for IoT use in remote areas and for indoor penetration in urban areas. In the United States, following the Voluntary Incentive Auction of the 600 MHz band, T-Mobile and Nokia completed the world's first 5G data transmission over "low-band" 600MHz radio spectrum back in November 2018. T-Mobile uses this band to deploy its 5G services across the United States. A low-band cell site can cover hundreds of kilometres and its wide-area coverage offers potential to build out the base for the Industrial Internet of Things (IIoT) and to contribute to 5G innovations like manufacturing and smart agriculture.

For 3GPP band 71/n71 (DL 617-652 MHz, UL 663-698 MHz, 2x 35 MHz), there is wide ecosystem support in the market with devices ranging from very affordable ones ~USD 100 to the high-end range. 3GPP band n105 (DL 612-652 MHz, UL 663-703 MHz, 2x 40 MHz) is still to be developed. Current band 71/n71 devices, despite covering 2x 35 MHz of band n105 and the same duplex gap, cannot operate under a band n105 band plan due to the different duplex distance, unless they support 3GPP Rel 17 variable duplex.

4 Further comments:

4.1 1427 – 1518 MHz band

Nokia acknowledges that there is a range of spectrum uses across mobile (aeronautical mobile), fixed (both point-to-point and point-multipoint), radio astronomy, and meteorological satellite services along with support services used to meet Universal Service Obligations (USO).

With regards to the USO, Nokia acknowledges that part of the 1.5 GHz band has been used for fixed point-to-point links and to deploy microwave systems for telephony services to meet USO requirements in remote and low-density areas.

Nokia notes, several options have been considered over the last years in L-band. For the 1452-1492 MHz range of this band, the 3GPP band 32 is considered for Supplemental Down link (SDL). Following the previous ITU-R World Radio Conference in 2019 (WRC-19), additional options for the entire 1427-1517 MHz band started to be considered, including not only SDL, but also FDD option (e.g., in Japan) and an all TDD option (e.g., as adopted now in the MENA region). Those options, as defined in the ITU-R Recommendation M.1036, are represented below. Nokia equally note corresponding 3GPP bands are available for all these arrangements for both LTE and 5G NR:

- SDL bands b32 (1452-1496 MHz), n75 (1432-1517 MHz), n76 (1427-1432 MHz);
- FDD bands b11 (1427.9-1447.9/1475.9-1495.9 MHz) and b12(1447.9-1462.9/1495.9-1510.9 MHz) in Japan, and the n74 (1427-1470/1475-1518 MHz) for Japan;
- TDD bands b50/n51 (1432-1517 MHz) and b51/n51 (1427-1432 MHz).

If ACMA is to take a decision of the future use if the L-band, Nokia recommends considering the possibility to open the entire 90 MHz of the band 1427-1517 MHz. In case the decision is to proceed with opening only a part of the spectrum for IMT, decision of how to make best use of it should be taken in accordance with the market demand.

4.2 1880–1920 MHz band

Nokia has contributed to the discussion paper and the options paper on replanning of the 1.9 GHz band and welcomes the ACMA's decision on arrangements consistent with a modified Option 3. The rail system of the future will be characterized by data-intensive and partially latency-critical applications, which is one of the reasons why European railway operators are currently striving to soon introduce the 5G-based Future Railway Mobile Communication System (FRMCS).

In support of ensuring alignment between the Australian Rail Industry and FRMCS standards being developed for the Global Rail environment, Nokia recommended that ACMA aligned any technical decision with global standards such as 3GPP to allow licensees to benefit from the associated global economies-of-scale and more diverse product ecosystem, hence supporting overall 5G deployment. The ECC Decision 20(02) Harmonised use of the paired frequency bands 874.4-880.0 MHz and 919.4-925.0 MHz and of the unpaired frequency band 1900-1910 MHz for Railway Mobile Radio (RMR) clearly indicates 1900-1910 Band for FRMCS as a way forward but more importantly is that this band will be part of 3GPP Rel. 17 for the initial planned deployment.

From Australian railway operators' perspective, alignment with the larger European market means access to wider choice of suppliers and User Equipment's. However, it is important to note that GSM-R and FRMCS will co-exist for a certain period.

Railway operators have an opportunity to update their legacy networks and move to a new world of supreme safety, high operational efficiency and on-train mobile broadband. Offering high speed, high capacity and low latency, 5G can provide enormous benefits and will help rail operators move to a new era in automated operations and customer service.

The FRMCS, based on 3GPP evolution towards 5G, has been proposed as a single global standard for railway communications. With GSM-R expected to be supported until around 2030, rail operators (including those in Australia) need to start planning early to migrate their existing networks to the new standard if they are to take full advantage of the opportunities.

4.3 2 GHz

Nokia welcomes ACMA's outcomes on the 2GHz spectrum consultation in acknowledging the support for deployment of a complementary ground component (including direct air-to-ground (A2G) communications services . As A2G is internationally deployed in the 1980-1995/2170-2185 MHz (UL/DL) portion of the band and benefits of a complete off-the-shelf ecosystem.

Therefore, while Nokia acknowledges the ACMA comments that demand is likely to exceed supply, Nokia still recommends that at least 15 MHz of paired spectrum in the lower half of the band should be granted to the direct air-to-ground communication service on an exclusive basis, in the same spectrum range used by the European Aviation Network. Assigning the same band by ACMA for A2G services will benefit from the existing ecosystem and the international status: de-facto-standard, roaming, airworthiness-certified equipment.

4.4 The (extended) C-Band (3300-4200 MHz)

Global 5G harmonization is happening now, and the 3.3-3.8 GHz spectrum range is at the epicenter of this, being the spectrum for near-term deployment of robust 5G services. The 3.5 GHz range of bands will support a variety of applications, including enhanced Mobile Broadband, Fixed Wireless Access and Industry 4.0, with an ecosystem driven by two 3GPP defined bands: n77 (3300-4200 MHz) and n78 (3300-3800 MHz). Spectrum harmonisation also helps to achieve economies of scale, enables global roaming and reduces equipment design complexity.

The 3300-4200 MHz band offers the unique opportunity for largest amount of spectrum below 6 GHz. The amount of contiguous spectrum that can be made available in the 3300-4200 MHz range offers an interesting opportunity for the exploitation of the innovative capabilities of the latest IMT technologies, with reference to the 5G New Radio air interface which will deliver increased capacity and connectivity. 5G New Radio (NR) Band n77 has been defined for 3.3-4.2 GHz covering the proposed range of 3.8-4.2 GHz. With demand also from other regions such as USA and Japan, Nokia expect a quickly evolving ecosystem for Band n77.

Nokia has long been an advocate of opening the entire 3.5 GHz range of bands, from 3.3 to 4.2 GHz, for 5G use. Indeed, the speed of 5G network deployment in the mid-bands, such as 3.5 GHz, can be significantly faster due to its propagation characteristics, which generally permit the reuse of the existing macro site grid that uses 1.8 GHz spectrum.

Nokia has also noted in past submissions that ACMA continue to investigate the potential future use of 3800-4200 MHz for private wireless networks. Therefore, Nokia welcomes ACMA' s outcomes in 2023 to look to allocate remote areas of the 3.4–4.0 GHz bands using apparatus licensing, with additional allocations occurring in regional and metropolitan areas through a mixture of spectrum and apparatus licensing.

However, it should also be highlighted as it was via AMTA at the end of 2023, unwanted emission limits defined for the 3.4 and 3.7GHz spectrum licenses above 3840MHz does not allow the deployment of equipment that is able to support the carriers above 3800MHz (i.e. in parts of the AWL range that has been assigned in remote areas and is currently being allocated in metro and regional areas).

This effectively rules out opportunities for the holders of new AWLs to reduce their network investment costs by partnering with spectrum licensees either directly or via carrier neutral third parties to deploy and operate shared infrastructure.

Nokia see large economical value in 5G bringing transformative benefits to a range of diverse industries at a time when commercial challenges remain for operators to invest and deploy 5G infrastructure in regional Australia. As such, Nokia believes an immediate opportunity exists for ACMA to align the emission limits in the spectrum licenses with those

in the AWLs to harness significant cost savings for industry. Additional investment into private networks can significantly speed up overall 5G adoption.

As AMTA highlights in its Pre-budget Submission, "spectrum underpins the digital economy as well as core infrastructure, including critical sectors like telecommunications, aviation, manufacturing, energy, and defence. Spectrum is a scarce resource, and one that requires careful management for Australia's innovation and security"[4].

Nokia expect that the digitization of the industries will continue to grow and, as such, their demand for spectrum to increase over time across the different sectors. Their spectrum needs will depend on the use cases in terms of coverage, capacity and performances and will be addressed by a combination of local access and wide national coverage, via private networks and public ones. It is therefore important to consider efficient mechanism to ensure the best usage and management of the scarce spectrum resources.

4.5 4.5 GHz – 4.8 GHz (n79)

We are observing an interest from countries in Asia to further investigate the potential use of this band. The 4.5GHz has been allocated in Japan in April 2019 and China is also considering this band for future deployment. In 2019, Taiwan's government released 100 MHz of spectrum in the 4.8–4.9 GHz band for public and private organisations to test 5G applications while South Korea has allocated 100 MHz.

it is important to note that in all cases 4.8–4.99 GHz spectrum has been allocated primarily as a back-up or supplementary band to 3.5 GHz, or for specific localised use cases. In Hong Kong and Japan, the main use case is localised private network deployments, with additional use in Hong Kong to provide eMBB coverage in specific locations where there is an issue with satellite interference. As indicated in the ACMA paper, the migration can be challenging, therefore we encourage ACMA to start study on potential use for 5G for additional capacity or for specific localised used cases.

It is noted that 4.4-4.8 GHz is one of the bands under consideration by WRC-27 for IMT identification for Region 3 (Asia).

4.6 40 GHz (37–43.5 GHz)

The 37-43.5 GHz band presents an excellent opportunity for global harmonisation and implementation (also by use of a tuning range). The 37-40 GHz band (39GHz) has already been decided in the United States and Nokia considers that this band will be used for deployments in later stage. In Europe, the 40.5-43.5 GHz frequencies are not extensively

[4] 20240125_AMTA-Pre-Budget-Submission_FINAL.pdf

used by incumbents and therefore, could provide large additional 5G capacity in subsequent upgrade steps to 5G networks as more and more services will be put onto 5G networks. This 40.5-43.5 GHz frequency band is now harmonised across Europe.

4.7 100 GHz (Terahertz)

Nokia has been a major contributor in 6G and Terahertz communications in various research bodies and industry fora (e.g., ITU-R, Hexa-X, Next G Alliance, etc.) and is also providing guidance to regulatory agencies (e.g., as a member of the Technological Advisory Council of the Federal Communications Commission).

Recent research in Terahertz spectrum has opened up many new avenues to overcome the inherent limitations of this spectrum band, and thus raised the possibilities of implementing new services that were unimaginable even a few years ago.

There are many use cases that are either not realizable or cannot deliver the required user experience in today's networks, including 5G, through the lower parts of the radio spectrum currently in use. It is expected that most of these applications will be implemented with 6G networks and through accessing higher frequency bands such as the Terahertz that can provide the necessary quantities of contiguous spectrum.

Global harmonization of Terahertz spectrum to encourage use of similar frequency bands globally will pave the way for collaboration among different countries to bring this fledgling technology to maturity. ACMA should consider its role given Australia's strong position in spectrum management.

Possible fragmentation may be due to diverse frequency usage by national regulatory agencies across the regions, various authorization schemes and/or regulatory frameworks. Terahertz technologies being in such a nascent stage, this type of fragmentation can lead to innovation silos, not conducive to a global ecosystem, resulting in higher cost of solutions and eventually slowing down the technology growth.

It should also be noted that it is likely a major early adaptor of Terahertz spectrum technologies would be vertical industries and large enterprises who often have a global presence. Therefore, it would be desirable for such entities to have same spectrum range available across borders to be able to operate similar sets of equipment with same specifications in different countries.

International consensus is thus critically important for the evolution of THz spectrum technologies. Given the nascent nature of the technology, economy of scale will be critical for nurturing it. Without the support of a globally harmonized ecosystem, its development will be fragmented, and its benefits will take a very long time to reach the society.

One crucial element of a potential activity could the development of a common international set of radio spectrum regulations. It is highly desirable that standards and regulatory bodies from all relevant industry sectors (e.g., 3GPP, ITU-R, IEEE, etc.) are brought together in a common forum to agree upon a common set of requirements.

Finally, it should be noted that some countries are already considering certain segments of the THz spectrum to provide opportunities for new technology development. An example is the decision from Ofcom to enable greater access spectrum in the 100-200 GHz frequency range on flexible service neutral basis. As another example, the Federal Communications Commission (FCC) in the United States has created a new category of experimental licenses for the 95 GHz to 3 THz range (called Spectrum Horizons License) and stated “These licenses would offer increased flexibility compared to conventional experimental licenses by providing for longer license terms, license transferability, and the ability to sell equipment during the experimental term. 21.2 gigahertz of spectrum within this range has also been made available for unlicensed use (116-123 GHz, 174.8-182 GHz, 185- 190 GHz, and 244-246 GHz) to encourage innovation and solutions testing.”

Nokia considers that access to the THz spectrum should be done in a timely and affordable manner to allow for the testing of technologies, applications and ensuring innovation can happen.

5 Increasing technology adoption for a productive and efficient Australian economy

Underpinning the digital transformation of society and industries is some form connectivity; for example, but not limited to, advanced materials and manufacturing, sensing, timing and navigation and transportation, robotics and space.

Low latency technology was designed to enable business transformation in addition to providing faster connectivity for consumers. Considering, one of the key enablers to emerging technologies such as computer and machine vision, sensors and sensing systems, and artificial intelligence (AI) and machine learning is some form of connectivity.

In fact, energy and manufacturing firms show the highest awareness of technology adoption and are exploring its potential for advanced use cases including infrastructure maintenance, remote machine control, and cloud robotics.

Research from Nokia and Nokia Bell Labs found that on average, whilst the importance of 5G adoption is well understood, a significant investment gap remains. 86% of decision makers said they have some kind of strategy for 5G, and over a third fear being outpaced by the competition should they not invest in 5G in the next 3 years. However, only 15% are currently investing in its implementation, and over a quarter (29%) of businesses are not planning any 5G investment in the next 5 years.[5]

The gap between enterprise awareness of 5G's benefits and current levels of adoption suggests there are notable barriers to implementation. Nokia Bell Labs research identified five principal barriers to 5G adoption for[6]:

1. **Ecosystem availability:** Limited availability of key infrastructure outside urban centers was cited by 28% of decision-makers.
2. **Education and understanding:** 17% said a key barrier is that decision-makers within their business do not understand 5G, while 14% said they don't know enough about it themselves.
3. **Awareness**: Over a fifth of technology buyers (22%) said that 5G implementation is not a current priority for their business.
4. **Cost and complexity:** 15% said they were not confident their company would be able to implement the necessary technologies.
5. **Security:** Over a third (34%) said that they are concerned about the security of 5G.

[5] Nokia: 5G set to add $8trn to global GDP by 2030 | Nokia
[6] 5G powers global business growth and productivity | Nokia

To bring about improved understanding, confidence and ultimately adoption of technology, industries and consumers alike need more information about the technology and how it can both improve operations and solve real world problems, ranging from enterprise use cases including the use of robotics to telehealth to green technology.

An opportunity exists for Government to consider allocating funding for research and development initiatives focused on technology adoption and development. There needs to be appropriate programs and policies which foster a collaborative ecosystem across industries as well as between industry and academia.

AMTA also highlights that governments, globally are making significant investment to support research and development of new, open wireless technologies[7] and states:

"We have seen the US Government invest more than a billion dollars into wireless innovation. AMTA and the telecommunications industry are calling on the Australian Government to establish a national policy or strategy for the utilisation of 5G and future generations, including 6G, to fund research and development initiatives that would lead to the development of wireless solutions and applications for Australian businesses."

In addition, it is critical that these mechanisms do not just consider programs for emerging technology but also current technology such as 5G to ensure Australia is maximising its investment and providing opportunities for industry to test this technology and its applications.

Given the recent Joint Statement on 6G Principles[8], Nokia welcomes and supports any plans Australia has to support funding and standardization efforts. Nokia alongside industry, academia has been involved in flagship projects such as Europe's Hexa-X-II[9] and the German 6G lighthouse[10] initiatives and believes an opportunity exists for the Australian Government to consider initiatives as part of the Australian Government's critical technologies list which captures "Advanced information and communication technologies"[11].

Encouraging innovation and collaboration between academia, industry, and government will contribute to the development of technology solutions and applications in Australia.

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[7] Australia losing 5G race: AMTA calls on Federal Government to implement National Mobile Tech Strategy - AMTA | The Voice of the Australian Mobile Telecommunications Industry

[8] Joint Statement Endorsing Principles for 6G: Secure, Open, and Resilient by Design | Australian Government Department of Foreign Affairs and Trade (dfat.gov.au)

[9] Vision - Hexa-X-II

[10] Nokia to lead German 6G lighthouse project | Nokia

[11] Critical Technologies Statement | Department of Industry Science and Resources

6 No green without digital

Nokia also welcomes the Australian Government's commitment to achieving net zero emissions by 2050. In addition, it also welcomes the ACMA's comments that the "efficient use of spectrum can help in the effort to reduce emissions in a variety of ways through smart technologies."

Almost every significant step towards decarbonization, from building more renewable energy to rolling out millions of electric vehicles, requires digital technologies such as 5G, AI and private wireless networks.

Recognize that digitalization is a green investment underpinning net zero: The world will not achieve its net zero ambitions without large-scale digitalization; Fully digitalized and AI-managed energy systems can identify who needs energy and when they need it, drawing stored renewable energy from batteries and, in future, from dormant assets like base stations and electric vehicles.

Digitalization brings similar system-level gains across many of the world's most polluting industries. Even heavy industries that have traditionally found it hard to rapidly decarbonize, such as steel production, can use digitalization to find new and important sustainability gains. Hence, there is no green without digital.

Encourage the inclusive rollout of digital technologies, ensuring all countries and sectors can digitalize to decarbonize: The International Telecommunication Union estimates that about 2.6 billion people remain offline today. Lower-income and developing countries need funding to deploy green technologies. Those countries also need to work with the providers of digitalization to map out the best way forward, focusing on established, adaptable technologies that can be deployed at scale, such as microgrids.

Support the responsible use of artificial intelligence in climate action: AI is a powerful tool for improving resource efficiency in almost any industry. For example, Nokia's AVA AI solution powers network assets up and down depending on network traffic, cutting energy use by up to 30%. Ordinarily, networks would be too complicated for a software program to do this, but AI allows data to be converted into actionable insights. Smart regulation can ensure the positive power of AI is unleashed while preserving public trust. But smart regulation, which encourages rather than stifles innovation, requires constant collaboration between business and regulators in order to match the rules to the reality of AI.

Encourage collaboration – no-one can tackle climate change alone: Many individual countries and businesses, including Nokia, have committed to their own sustainability targets. These are important, but the scale of action required means collective action is also required.

Broad collaboration means pooled expertise. For example, industry can provide the solutions required to address emissions, such as digitalization, as well as expertise on rolling out technologies at scale. NGOs can use their presence on the ground to identify most at-risk locations, while governments can legislate and regulate to accelerate the private sector's deployment of technologies.

Ensure the macroeconomic situation doesn't halt financing for the twin transition: According to the International Energy Agency, emerging markets and developing economies, which together emit roughly two-thirds of greenhouse gases, will need about $4 trillion of investment annually by 2030 to hit net zero by 2050[12]. That represents a 5x increase from current planned climate investments. Policymaking can create an environment in which businesses find it easy to invest – for example via policies that strengthen macroeconomic fundamentals, deepen capital markets, and improve governance.

Establish global standards that ensure the scalability of technologies underpinning the fight against climate change: In the telecoms industry, the security and constancy of shared standards helps to create significant economies of scale, lowering research, development and hardware costs, not least by increasing competition. As a result, they make the rapid and widespread rollout of digitalization much easier.

Standards will remain important to the next generation of digitalization technologies, such as 6G. We need governments and businesses to collaborate with international bodies, supporting the development of universal, innovation-friendly standards so the private sector can develop scalable solutions and communities can trust new technologies.

[12] Net Zero by 2050 – Analysis - IEA

7 Artificial Intelligence in networks

Artificial Intelligence (AI) is an increasingly pervasive tool that allows machines to perform complex tasks that once required human input. AI is capable of such varied tasks as automotive crash avoidance, refining industrial processes, reviewing the resumes of job candidates, and drafting legal documents.

At a high level, AI can be divided into two groups: (1) AI systems with a fixed purpose; and (2) AI systems that do not have a fixed purpose. Systems with a fixed purpose that are designed to perform specific tasks.

Nokia's use of AI to advance communications networks is a prime example of "fixed purpose" and is used to optimize communications networks and enhance service quality, security, increase performance, efficiency, and meet sustainability goals. The following section provides examples of Nokia's "fixed purpose" AI use cases:

Leveraging Data and Analytics

Nokia refers to its AI tools that leverage network data as the Nokia AVA Telco AI Ecosystem. This suite of AI solutions enables CSPs to automate network operations and service assurance, cut costs, increase agility, and boost subscriber experience.

Accelerating Energy Efficiency and Sustainability

AI-driven software and hardware help CSPs achieve real environmental, sustainability and governance (ESG) results by introducing more power-efficient equipment and integrating AI/ML intelligence into the network, across all domains, to monitor and take action to conserve network energy.

Shutting down unused network elements during periods of low traffic is an excellent way for CSPs to realize significant energy savings.

Optimizing Open RAN Performance and Efficiency

The primary focus of AI/ML use cases in 5G radio is improvements in radio network performance and efficiency. While performance gains and optimization are analyzed periodically, the efficiency gains in the network are targeted in near-real time. Some examples of performance improvements in radios using AI/ML include multi-cell network optimization, dynamic beamforming, and traffic steering.

Nokia has made significant investments in Open RAN leading the early deployment of the RAN Intelligent Controller (RIC) which enables external applications to control aspects of the 5G radio network.

In the future, the AI/ML capabilities embedded in the RAN will be capable of performing radio and cell-level performance optimization with Layer 2 hardware accelerators (under research). In Layer 1, Radio Frequency and Layer 1 optimization is possible with hardware accelerations in real time with latency as low as 10 microseconds.

Unleashing the Full Potential of 5G-Advanced and 6G

In the telecom sector, AI/ML is expected to upend how products are designed, built, and deployed. The design of such solutions requires augmenting the engineering process with a data-driven approach that considers data quality, selection, and governance. Data will become a pivotal element of solution engineering. The benefits are solutions that can be constantly retrained and improved, taking advantage of powerful AI/ML models and Continuous Integration and Deployment (CI/CD).

3GPP, the leading standards organization for mobile networks, envisions AI/ML that is embedded across device, radio and RAN. It will create the foundation for AI/ML features for all future releases to come, including 6G.

Examples of AI/ML solutions include:

- Enhancements in the devices and network for more efficient radio transmission and radio resource management. Ongoing work in 3GPP reports significant gains of up to 30% for cell edge throughput and other significant KPIs.
- AI/ML baseband solutions that outperform conventional approaches already today by up to 3dB in terms of receiver performance with throughput gains of 30%.
- Decreased power consumption and improved energy efficiency of network nodes and devices.
- Improved end-user perception for high-demand applications like AR/XR by reducing latency and network link failures.
- Full end-to-end automation of network management, including faster and more accurate predictions and reactions to network conditions and faults.

Governments should fund research and standardization efforts to advance the development of AI technology and policymakers aware that most industrial use cases of AI carry little risk and should be allowed to thrive.