Nokia response:

ACMA's "Future use of the upper 6 GHz band – Options Paper"

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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 standardization, 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: Nokia Corporation

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

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2 Submission overview

Nokia welcomes the opportunity to respond to Australian Communications and Media Authority "Future use of the upper 6 GHz band – Options Paper" consultation. 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.

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.

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.

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].

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.

6G will address the increasing need for network capacity, support the vast and growing device ecosystem, and harness and accelerate the power of AI along with many other emerging technologies. It will provide new ways for monetization thanks to an API-native platform design. It will realize the next level of digital inclusion by offering greater accessibility, affordability and consumability. It will be green by design and highly secure.

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

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Nokia welcomes the effort of ACMA on the regional and international discussions and its clear and transparent process in the planning of spectrum. It is for this reason why Nokia is encouraging ACMA to:

- Adopt Option 3 and ensure an optimal use of the upper 6GHz for IMT
- Support mechanisms to drive 5G adoption and prepare for Australia's 6G future

Nokia's position on Option 3 also aligns and supports the Australian Mobile Telecommunications Association (AMTA), the peak industry body of Australia's mobile telecommunications industry. AMTA and its members agree that Option 3 is the only option which maximizes the public benefit derived from the use of the spectrum.

Nokia believes the upper 6 GHz band – following the identification at WRC-23 for IMT use – should be assigned at national level to mobile operators as a crucial band for facilitating the high-performance and quality development of 5G services, while laying the basis for future 6G deployments. Nokia is committed on this path and support the use of this band to provide further capacity and coverage in efficient and sustainable manner, by reuse of existing macro cellular grids, as proved earlier this year (June 2024) with the outdoor trial with the Finnish operator Telia[2].

Nokia reemphasizes that any decision on the upper 6 GHz band should consider the socio-economic benefits associated with mobile connectivity as well as the consequences of the decision. The release of the spectrum for license-exempt use is an almost irreversible decision making it next to impossible to reclaim back any portion of a license-exempt band.

Nokia is of the view that a balanced approach of the 6 GHz band should allow the expansion of the ICT sector in Australia and serve the country's information-communication needs well into the future by providing additional spectrum for both licensed and license-exempt operations in the mid-term.

For Australia's economic benefits and productivity gains to be realized and its position as an early adopter of technology 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 which includes bands, such as the upper 6 GHz, to support the transition to 6G.

[2] https://www.nokia.com/about-us/news/releases/2024/06/04/nokia-and-telia-complete-successful-outdoor-trial-in-6-ghz-range-with-massive-mimo-radio/

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3 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).

3.1.1 6 GHz (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 percent of the world's population. While all Asia Pacific countries

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have the top 100 MHz identified for IMT, few countries have the full 700 MHz identified already in the WRC-23. Equally, 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. We also note recent statement from Hong Kong authorities[3] regarding the "allocation of spectrum in the frequency range of 6425-7075 MHz to mobile service on a co-primary basis and the associated arrangements for assignment of a total of 400 MHz of spectrum in the frequency ranges of 6570–6770 MHz and 6925–7125 MHz ("6/7 GHz band") for the provision of public mobile services including the fifth generation ("5G") services" as well as the announced[4] auction in Q4 2024 for assigning it to the MNOs.

We also highlight the 3GPP ongoing activities on developing the necessary specification on the conformance to the limits set at WRC-23 for the use of the 6 GHz range due to be finalized at the end of this year (2024).

Nokia acknowledges 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 has already 1067 MHz of mid-band spectrum allocated in Australia (across three bands: 2.4, 5 and L6 GHz). In contrast, the mobile industry has 935 1035 MHz MHz in total allocated to it below 6 GHz.
- Wi-Fi speeds in homes and smaller premises are usually constrained by the fixed broadband network speeds and not by the Wi-Fi radio capacity.
- The class licensing arrangements for Wi-Fi may create a disproportionately high interference management burden for existing licensees and for the ACMA compared to spectrum being licensed to IMT services which offer improved transparency due to the requirement to register devices with the ACMA.
- In case Wi-Fi needs additional spectrum, other spectrum opportunities exist for Wi-Fi. Since Wi-Fi is generally used for highly localized and static 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 needs).
- 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 and sustainably deliver high broadband speeds and wide coverage using macro sites.

[3] https://www.coms-auth.hk/filemanager/statement/en/upload/632/ca_statement_20240301.pdf
[4] https://www.info.gov.hk/gia/general/202406/11/P2024061100545.htm

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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 solid end-to-end ecosystem.

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

We consider 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, given the available bandwidth that can offer reasonable wide channels for mobile macrocellular deployments providing capacity and coverage in urban and sub-urban high traffic areas in efficient and sustainable manner.

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4 ACMA Planning Options

Nokia preference among the options the ACMA proposed is option 3 – enable WA WBB in entire upper 6 GHz band – followed by option 1 – maintain existing arrangement and decide at a later stage.

We do not see a need to consider only part of the band for WA WBB under the option 3, unless to assure specific incumbent services are protected, by excluding respective portions of the spectrum at the auction time. We do not see necessary – for the reasons mentioned above – to favour RLAN in the entire band or any part of the upper 6 GHz.

Any such arrangement under options 2 and 4 would irreversibly reduce value of the band for wide area mobile deployments for mobile operators creating scarcity of spectrum to sustain the continuous growth of mobile data traffic and support advanced applications in 5G and 6G in the future.

4.1.1 Option 1: Maintain existing arrangements

Nokia are of view that maintaining existing status and reconsider band arrangements at a later stage, considering developments at global level, is the second-best option among those proposed in this paper. This would give the ACMA the necessary time to run the process for reorganization of the band and clearing it in the event of auctioning the band for WA WBB to the mobile operators. Under this option, the ACMA may want to consider ways to assure coordination between FS and future IMT systems in the areas of main interest for IMT – the dense urban environments. However, Nokia are of the view that under option 3 this can also be considered if the decision of allowing WA WBB in the entire upper 6 GHz at an identified date. While the ecosystem might not be in place at the time of the response to the consultation, several tests have been conducted around the world by mobile operators as indicated in APT Report 136[5]. Nokia has conducted several field trials including the latest one in early June 2024[6].

However, a specific date from the ACMA (while maintaining the status quo) regarding the timeline of making the 6425-7125 MHz spectrum available for IMT will send a signal to the industry to consider mass-market development of the end-to-end ecosystem, including end-user devices. From this perspective, we would like to draw ACMA's attention to the renewed support of the mobile industry towards the use of the upper 6 GHz band in the

[5] https://apt.int/sites/default/files/report/2024/06/APT_AWG_REP-136_APT-AWG-REP-136.docx
[6] https://www.nokia.com/about-us/news/releases/2024/06/04/nokia-and-telia-complete-successful-outdoor-trial-in-6-ghz-range-with-massive-mimo-radio

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near future, with both major mobile operators across the world and global mobile equipment suppliers, joining the GSMA's statement[7] at the WRC-Shanghai earlier this June.

4.1.2 Option 2: Introduce arrangements to enable RLAN access to some or all of the upper 6 GHz band

Nokia do not see any need for additional spectrum for RLAN from the upper 6 GHz band, considering the imbalance in favour of RLAN of spectrum in the sub-7 GHz range and the fact that the spectrum is not the bottleneck for Wi-Fi speeds in fixed networks[8]. Moreover, any decision at this time to introduce RLAN in part or whole band will make difficult to reconsider it at a later stage and will create artificial scarcity of adequate spectrum for mobile onward.

Opening any portion of the upper 6 GHz band to RLAN without any counter-measurements (indoor-only/AFC, as in USA) will create additional and uncontrollable interference into FS services. More specifically, we would like to highlight that ACMA should consider that in Europe multiple technical groups in CEPT are currently investigating the impact of RLAN potential introduction in the band, as – based on measurements – the RLAN bursty beacons will severely interfere with FS[9].

4.1.3 Option 3: Introduce arrangements to enable WA WBB access to some or all of the upper 6 GHz band

From Nokia's perspective this is the most desirable outcome that would allow mobile operators to start planning on how to provide wide area coverage and mobility in urban areas in an efficient and sustainable manner to consumers and businesses. Together with technology upgrades, the additional spectrum from the mid-band range will accommodate economically and sustainably the projected mobile traffic growth. Equally, timely decision will allow operators to engage in planning the potential deployments and the measures required to coordinate and protect their FS links in the band. The regulatory provisions decided at WRC-23 are sufficient to protect the incumbent services, even if Australia and other countries in Region 3 are to deploy IMT for the entire 6425-7125 MHz frequency band.

[7] https://www.gsma.com/connectivity-for-good/spectrum/wp-content/uploads/2024/06/6-GHz-Statement-Shanghai-FINAL.pdf
[8] Page 5 in https://6ghzopportunity.com/wp-content/uploads/2022/06/22-06-09-Licensed-6-GHz-opportunity-v2.pdf
[9] CEPT Group SE19 (Work Item SE19_43) and CEPT Group SE45 (Work Item SE45_04). The discussions extends to ETSI ISG mWT (https://www.etsi.org/committee/1426-mwt)

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We encourage the ACMA to consider this approach as the most appropriate one and reserve the entire band for WA WBB, considering that within the overall 700 MHz of available spectrum potentially portions will need to be considered for guardband and/or for allowing some services (e.g., TOB) to still operate. From a technical perspective, we advise ACMA to consider reserving 200 MHz/operator for optimal efficiencies in using the band to enable future developments in the mobile domain. Any less than 200 MHz/operator, this spectrum band will become unattractive and disincentivize operators from acquiring spectrum as it will be unable to support the growing needs efficiently.

4.1.4 Option 4: Introduce arrangements to enable both RLAN and WA WBB access to different frequency segments within the upper 6 GHz band

Nokia are of view the ACMA should pause option 4. Regarding this option, it is worth noting similar discussions in Europe in a different context where the focus is on shared use of the band through different mechanisms. We note band segmentation is not the focus of the discussion at the moment, but if it does become so, no decision is taken and work is still in progress; moreover European framework is likely not to be defined earlier than end of 2027 (timeline for EC Decision). It is without doubt harmonization is important from the equipment cost perspective. At this stage, it is worth noting while European discussions are ongoing, it appears options under ACMA's consideration seems unattainable from industry's perspective:

- Area-based segmentation is unlikely, as both technologies are mainly targeting urban area usage of the band where the high traffic density happens
- Indoor-outdoor segmentation is also unlikely, as the coexistence of indoor Wi-Fi with outdoor MFCN (WA WBB in European context) would require diming down the power of mobile base stations, rending the band unattractive for macrocellular deployments and reuse of existing macro infrastructure of the mid-bands.

While the views of the mobile and Wi-Fi industries in the European fora are polarized, it is commonly agreed these two options the ACMA seems to retain are not satisfactory for any of them.

With this in mind – and agreeing with the consultation paper's assessment of the expected benefits of any sharing option and the potential complexities involved – Nokia are of view the ACMA should pause option 4 for the time being. If any sharing is to be considered in the future, then the ACMA could temporarily consider Option 1, follow international/European developments and reassess opportunities at a later stage.

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4.1.5 Other comments

At least 200MHz/MNO should be considered for the deployment of macro cellular base stations and reuse of the C-band grid. Noting the Australian mobile sector counts for three national mobile operators, Nokia recommend 200MHz channels that would allow for optimal deployment of the band and assure optimized.

In 5/6GHz ranges there are 5 channels of 160MHz and one of 320MHz suitable for Wi-Fi 6E/7. Noting Wi-Fi 7 allows aggregation of two 160MHz channels in different bands, Nokia's preference is to favour a WA WBB based segmentation with channels of 100 MHz, aligned with existing specifications of the 3GPP band. While currently, the 3GPP standardization of the n104 band allows channelization of up to 100 MHz and 200 MHz bandwidths can be achieved with Carrier Aggregation, channelization of 200 MHz is foreseen in future 3GPP releases.

Nokia is of view any decision on hybrid approaches should be deferred for a later date, to avoid Australia taking a divergent path from discussions ongoing in other parts of the world and avoid unnecessary global market fragmentation.

To this end, as already highlighted in Nokia's response, discussions are ongoing with a decision to be taken not earlier than 2027. Nokia therefore recommend ACMA to consider at this stage to maintain existing arrangements and plan reevaluate options in a two/three-year timeframe.

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5 From 5G, 5G-Advanced to 6G: Bringing Benefits to the Australian Economy

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.

The positive impact from technology such as 5G and 5G-Advanced in major critical industries such as agriculture, energy, smart cities, transport is expected to contribute up to $8 trillion in global GDP in 2030[10]. Example real-life use cases here in Australia include:

Mining and energy

TPG Telecom signed a Memorandum of Understanding (MoU) with Nokia in a partnership to develop mobile private network (MPN) innovations for the mining and energy sectors. The agreement describes collaboration across both companies' extensive portfolios to provide flexible technology solutions and encourage digital and operational technology transformation in mining.

It is expected new innovations will come from the partnership, specifically in productivity and worker safety, as 5G terminals will connect machinery and sensor assets to an internet of things (IoT) or operations platform to monitor productivity and safety of workers.

Agriculture and on-farm connectivity

TPG worked with Nokia to demonstrate how 5G networks can complement image processing, computer vision and edge computing technologies to deliver benefits and improve efficiencies to the agricultural sector. Livestock counting is a critical component of livestock management.

Livestock including sheep are manually counted at exchanges and ports, with the potential for errors and inconsistencies. The project uses 5G to enable multiple high quality 4K video streams to count livestock at regional exchanges, automating the process and removing human error. A supporting 5G edge network process the counting on-site and relay the data in real time back to farmers on a tablet or mobile device. By minimizing counting errors, especially during unfavourable conditions, will directly contribute over $13.2 million to the livestock industry each year.[11]

[10] Business readiness for 5G | Nokia

[11] Media release_5G and AI make counting cattle easy as 1 2 3 for smart farms of the future.pdf (tpgtelecom.com.au)

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Smart and sustainable cities

Nokia and the City of Melbourne conducted trials using Nokia Scene Analytics artificial intelligence (AI) technology to develop a deeper understanding of waste disposal behaviour. This allows the City to tackle the issue of waste dumping more efficiently and keep laneways – the busy and narrow city streets and pedestrian areas – even more clean, safe and free of garbage.

Under its 'emerging technology testbed' initiative, the City of Melbourne worked with Nokia to leverage an existing network of installed cameras as internet of things (IoT) sensors to monitor one of the compactors. The Nokia Scene Analytics solution employed an AI-powered algorithm to filter and collate data from the cameras, while also combining other data sources, such as operational data on the compactor itself, to create real-time alerts and produce reports. Initial trial results demonstrate that Scene Analytics can support the City's objectives for better, safer citizen experiences while simultaneously lowering maintenance and down time costs for waste management services.[12]

Transport

In Perth, Western Australia Nokia was selected by the Public Transport Authority of Western Australia to modernize rail communications with private wireless and mission critical IP/MPLS covering 250 km of railway track and tunnels. The project includes designing and building and 5 years of maintenance for the PTA's communications system, with options for two additional lots of 5 years of maintenance. [13]

[12] Nokia and City of Melbourne trial AI technology to keep city streets safe and clean | Nokia

[13] Nokia selected by The Public Transport Authority of Western Australia to modernize rail communications in Perth with private wireless and IP/MPLS technologies | Nokia

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Robotics

The '5G Connected Cobot' project located at the University of Technology, Sydney demonstrates how the higher speeds and lower latencies made possible by 5G technologies can enable cobots to interact with their surroundings – including nearby humans – in real-time.

Initial testing showed that utilizing Nokia's 5G capabilities to offload the processing required from the cobot to a computer "at the edge" extended its battery life as well as enhanced its performance. This approach can lead to significant power and cost savings, all while increasing the capabilities of the cobot.

During the testing phase of the project, the team added a variety of sensors measuring the world around the cobot. Multiple lidars were used to view the world as a dense collection of 3D points, like how autonomous cars operate. This allowed the robot to easily measure the distance and direction to people and objects around it with high accuracy.

Early findings suggest that fitting the cobot with a 5G modem to allow off board processing of its data marks a significant step towards ensuring collaborative robots can be the co-workers we want them to be in the future.[14]

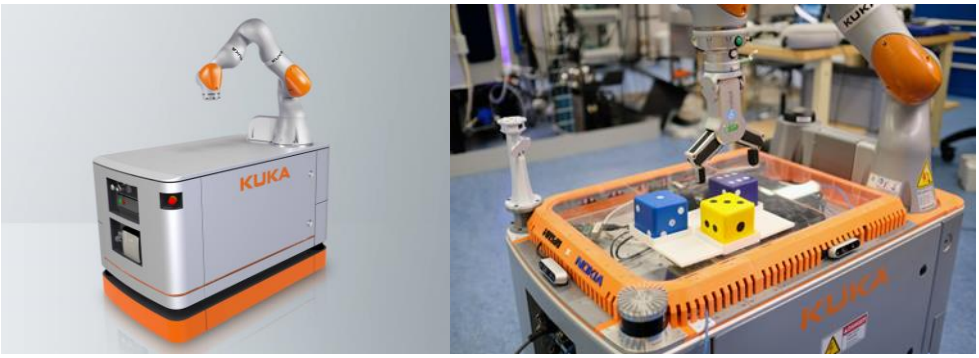

Figure 1 – Left: The Kuka KMR iiwa cobot use as one of the robotic platforms in the project.

6G will be a technology evolution building on the existing 5G and 4G technologies. In the 6G era, networking will move beyond mere connectivity. 6G will fuse 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.

6G will support the vast and growing device ecosystem and harness and accelerate the power of AI along with many other emerging technologies—besides addressing the

[14] Next-gen robotics advanced by Nokia 5G technologies - UTS Tech Lab

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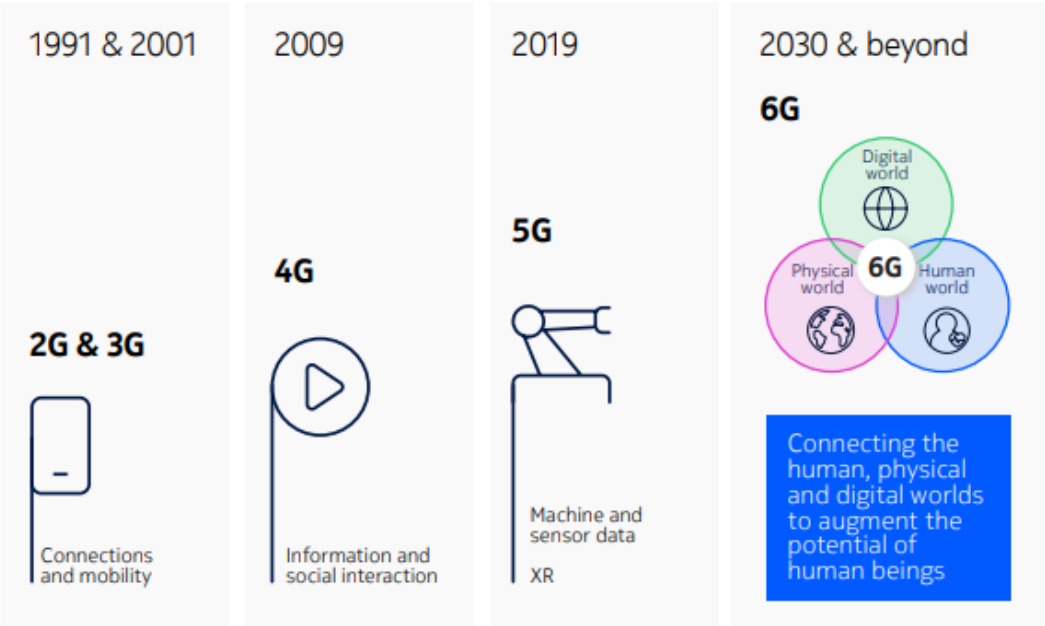
increasing need for network capacity. 6G will realize the next level of digital inclusion by offering greater accessibility, affordability and consumability. It will be sustainable and "Green" by design, trustworthy and highly secure.

Figure 2 – The evolution to 6G[15]



The need for 5G advanced and the future development of 6G is driven by several factors:

- The increasing data demands - The industrial metaverse, spatial computing, AI-generated content and ubiquitous XR are hungry for capacity, require unbending reliability and brook no compromises in latency. We're creating 6G for the sole reason of meeting those relentless demands. In the Global Network Traffic 2030 report, Nokia projects end-user data traffic demand will increase at a compounded annual growth rate (CAGR) of 22 percent to 25 percent from 2022 through 2030. Global network traffic demand is expected to reach between 2,443 to 3,109 exabytes (EB) per month in 2030. For networks to support the increasing demands of the future, they will need to be more cognitive and automated utilizing AI and ML, as well as address the transformative needs and operating models of organizations and consumers.

[15] Transforming the 6G vision to action - Nokia Bell Labs (bell-labs.com)

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- The quest for a more sustainable and resilient system - we believe the 6G platform will be natively designed with energy sustainability in mind. It should play a pivotal role in reducing carbon emissions, improving energy efficiency, and enhancing social governance efficiency.
- The desire to push the boundaries of technology further - the next-generation networks are expected to introduce new capabilities, such as sensing related capabilities. These advancements will unlock new possibilities for industries and pave the way for innovative applications and services.
- The evolving device ecosystem - the massive success of 4G and 5G has been fueled almost single-handedly by the smartphone ecosystem. While smartphones will still be with us for 6G era, there are strong signs of a more diversified device ecosystem on the horizon that will bring a true immersive experience to both commercial and professional users. These devices could take the form of new wearables, from XR glasses and connected clothing to AI-assistants. We are seeing the beginnings of a massive innovation cycle in this space driving a substantial shift in the way people go about their lives. The next-generation network should natively support a much wider variety of devices in the most efficient way.

These immersive experiences will fundamentally change the way people perceive cellular service, and hence opens the door for differentiated and tailored value propositions. 6G systems should natively support a much wider variety of devices in the most efficient way: from architecture design to protocol design to radio design.

Collaborative robots, mass digital twinning, sensing, extreme autonomation and many more services are all in the realm of possibility for the 2030 era. 6G will bring the connectivity features required for all and any of these use cases to take off.

6G builds on 5G in a more efficient, economical, scalable, and sustainable way by initially addressing NextGen MMB, FWA, immersive/cloud gaming, XR, broadband IoT and wearable use cases and services. Upon this established revenue base, it will expand in stages by providing more services and supporting more use cases by moving over time from connectedness to togetherness experiences, such as immersive holograms, and by moving from information to knowledge (e.g., through cognitive and complete context awareness, sensing, digital twins, etc).

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Table 1. Summary of key technologies and their benefits for 6G[16]

Item	Description	Benefits
Energy efficiency	Enhanced energy efficiency saving toolbox for devices and network, including embedded green-by-design principles at all layers of 6G	• Significant savings in operators OPEX and reduced carbon footprint • Superior end-user experiences from having devices with reduced charging needs
6G radio protocols	Modernized 6G radio protocol stack with APS, FPS, and RPUs for parallelization	• Faster processing with less overhead and more efficient parallelization. • Easier support for introduction of different device types
6G PHY & MIMO	Modernized PHY mechanisms, building on the 5G-Advanced base PHY numerology, but with many new procedures and innovations on top, including extreme MIMO with unified TCI framework	Much-elevated performance baseline: • Improved coverage • Higher spectral efficiency • Lower power consumption • Superior support for new mid-bands
AI/ML-native	Pervasive support for AI/ML at all layers of the system, including the network and terminals	• Making 6G deployments much faster and more cost-effective • Superior network automation and operational excellence • Improved air interface performance with a higher degree of robustness
6G NTN support	NTN connectivity for 6G LPWA/RedCap and smartphones. Integration between TN/NTN, as well as TN spectrum reuse for NTN under control of the terrestrial operator	• True digital inclusion for areas without traditional terrestrial communications access • Affordable digital access makes the vision of global connectivity a reality • Opens new use cases and business opportunities
Architecture	Simplify and streamline architecture: single 6G standalone architecture for Day-one. Focus on essential commercially viable open interfaces Detailed architecture and protocol design to be natively optimized for key 6G trends and technologies: AI, energy efficiency, a wide variety of devices, and rich network APIs. Functional split between UE, RAN, Core, OAM maintained as in 5G	• Optimal balance between re-using existing HW/SW assets and well-justified enhancements and extensions to achieve 6G objectives such as green by design, reduced costs and complexity, etc. • Single step migration path from 5G standalone to 6G standalone
Exposure and programmability	Common network exposure and programmability API framework	• New API monetization opportunities
Automation	Replacing manual operations with adaptive autonomy for deploying, managing, and optimizing the network resources and services, powered by AI/ML, incl. Generative AI	• Ensuring efficiently running network with high degree of autonomy • In short, operational excellence with significant OPEX savings
Privacy and security	Enhanced security and privacy, including automated identity management, cloud security, and more	• Quantum-resistant security • Holistic AI-native security and trusted framework • Next level privacy

[16] Transforming the 6G vision to action - Nokia Bell Labs (bell-labs.com)

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6 6G Research Initiatives

Collaborative research on 6G technologies is in full swing across the world. Today, there are major 6G research programs in Europe, Asia and the US. In Europe, 63 projects from the Smart Network and Services 6G research program (SNS-JU) are already contracted, including the 6G flagship project Hexa-X-II.

Hexa-X-II, the second phase of the European 6G initiative, leads the way to the end-to-end (E2E) system design and the enabling platform delivering novel services for the next generation (6G) of wireless networks. The project will continue the tracks of the Horizon Europe project Hexa-X, which has laid the foundation for the global communication network of the 2030s by developing the 6G vision and basic concepts.

In North America, Next G Alliance remains very active. It is an initiative to advance North American wireless technology leadership over the next decade through private-sector-led efforts. With a strong emphasis on technology commercialization, the work will encompass the full lifecycle of research and development, manufacturing, standardization and market readiness.

In Japan, Beyond 5G Promotion Consortium (B5GPC) is the main driving force, with aim to strengthen the international competitiveness of Beyond 5G to realize the strong and vibrant society expected in the 2030s. In India, 6G activity is accelerating with the government announcing the Bharat 6G Vision.

Governments need to consider allocating funding for research and development initiatives focused on technology adoption and development. Encouraging innovation and collaboration between academia, industry, and government will contribute to the development of technology solutions and applications in Australia.

Given the recent Joint Statement on 6G Principles[17], Nokia believes an opportunity exists for the Australian Government to consider initiatives as part of its critical technologies list which captures “Advanced information and communication technologies”[18] and allocated $1 billion to expand Australia’s critical technology capability.

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

[17] Joint Statement Endorsing Principles for 6G: Secure, Open, and Resilient by Design | Australian Government Department of Foreign Affairs and Trade (dfat.gov.au)
[18] Critical Technologies Statement | Department of Industry Science and Resources

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7 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.[19]

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[20]:

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.

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

[20] 5G powers global business growth and productivity | Nokia

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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[21] 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 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.

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

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