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Northern Ireland
Science Industry Panel

Advanced Wireless Networks

November 2023

Firetail
Strategy for social progress

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Contents

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Foreword

Patricia O’Hagan

Matrix Panel member
Project Steering Group Chair

In an era defined by relentless technological advancement, the pace of change we are currently witnessing is unprecedented. At the very heart of this rapid progression lies the unparalleled potential of advanced wireless networks (AWN). These networks, representing the next generation of connectivity, extend far beyond personal communication; they offer the prospect of connecting everything, transforming not only the way we live and work but also the very fabric of our society.

It opens the door to a wide range of applications and industries that will benefit from these advanced wireless capabilities, reshaping how we interact with technology and society as a whole. From revolutionising healthcare through telemedicine and enhancing industrial processes through the Internet of Everything (IoE) to enabling smart cities and powering the innovation of Artificial Intelligence (AI), the implications for economic and societal advancement are profound.

Northern Ireland has a thriving knowledge-based economy and a cluster of successful Advanced Communications and Cybersecurity companies. When combined with the ambition of the City Deals initiatives, Northern Ireland is well-positioned to reap the rewards of AWN, if it is effectively deployed.

However, Northern Ireland faces challenges that could limit the realisation of AWN’s potential, such as underinvestment in next generation connectivity infrastructure, the absence of cross sectoral (public / private / community) collaboration and limited participation in AWN industry dialogue.

This report illuminates Northern Ireland’s position regarding AWN and urges us to confront challenges head-on. It is a call to action, urging us to find practical solutions to propel Northern Ireland to the forefront of technological progress.

If we act quickly and decisively to invest in the next generation networks and infrastructure, we can harness the research talent and business acumen available in Northern Ireland to be at the forefront of technological advances and reap the benefits of exciting developments such as AI, Smart Cities and the Internet of Everything, to improve not only the local economy but also society.

William Revels

Matrix Panel member
Project Steering Group
Deputy Chair

I was delighted to support Patricia O’Hagan in the creation of this important report.

It describes the future needs driving wireless technologies and how we can ensure Northern Ireland will remain connected and competitive from a national and global perspective.

Of interest, the report describes the bridge between 5G and 6G and how creating an open platform to drive innovation through accelerated adoption of advanced wireless technology will be beneficial.

To my mind, the report findings are practical and pragmatic and will drive the correct thinking to support 10X aligned economic outcomes.

Acknowledgements

Matrix[1] commissioned Firetail to undertake this project and would like to thank the following individuals who contributed significant time, expertise, and guidance through their participation on the Project Steering Group.

Name	Role
Patricia O'Hagan, MBE	Chair of Advanced Wireless Networks Steering Group, Matrix panel member, and co-founder of Core Systems
William Revels	Deputy Chair of Advanced Wireless Networks Steering Group, Matrix ex-officio and Managing Director of Digital Catapult (NI)
Nell Watson	IEEE Ethics Maestro, Chair IEEE's ECPAIS Transparency Experts Focus Group, and Vice Chair of P7001 Transparency of Autonomous Systems Committee on AI Ethics & Safety
James Noakes	Belfast City Council, City Deals Team
Deborah Colville	Head of Belfast City Council Innovation Office
Dr. Sandra Scott-Hayward	Director, QUB Academic Centre of Excellence in Cyber Security Education (ACE-CSE) and Polymath Fellow, Global Fellowship Initiative at the Geneva Centre for Security Policy (GCSP)
Norbert Sangard	Head of Business Development for Wireless Innovation, QUB
Dr. Mike Short, CBE	Chief Architect - Satellite Applications Catapult, Former Chief Scientific Advisor, Department for Business and Trade (previously DIT) and Telecomms industry veteran
Michael O'Hara	Partner Combustion Marketing, former CMO GSMA and Mobile World Congress, and former head of Telecommunications business at Microsoft
Robert Hill	Director of the NI Space Office and fellow with UK Satellite Applications Catapult

Additionally, thanks go to the wide range of stakeholders from across industry, academia, and government who contributed through interviews and input. A full list of stakeholders and sources are available on request.

[1] *Matrix, The Northern Ireland Science and Industry panel, is an industry led engagement panel advising government and informing academia and industry on the commercial exploitation of R&D and science and technology. https://matrixni.org/*

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Project Context

Northern Ireland's (NI) science and industry advisory panel, Matrix, commissioned this project to better understand advanced wireless networks (AWN) and the benefits those networks can bring to NI's society, economy, business, and citizens.

The agreed scope of this project was to focus on 5G-Advanced and 6G and to cover 5-10 year and 10+ year time horizons.

There were 3 objectives:

1 **To provide an assessment of the advanced wireless network landscape in NI and globally**

This should include outlining existing research, development, investment, and standards work. This should also include understanding constraints and barriers to adoption of advanced wireless networks in NI, as well as identifying macro-drivers in the economy, policy, legislation, and market which may impact future adoption.

2 **To assess the opportunities offered by advanced wireless networks for NI economic sectors**

This should include both qualitative and quantitative analysis and align with NI's 10X economic vision, City Deals, NI Mobile Action Plan, and other related activities.

3 **Outline recommendations and a roadmap of actions to help position NI to benefit from advanced wireless networks**

This should include actions that can be taken across NI government, academia, and industry. It should also cover activity that can help to overcome barriers or manage constraints that currently prevent adoption. These recommendations should be aligned to, and deconflicted with, other ongoing initiatives in adjacent areas.

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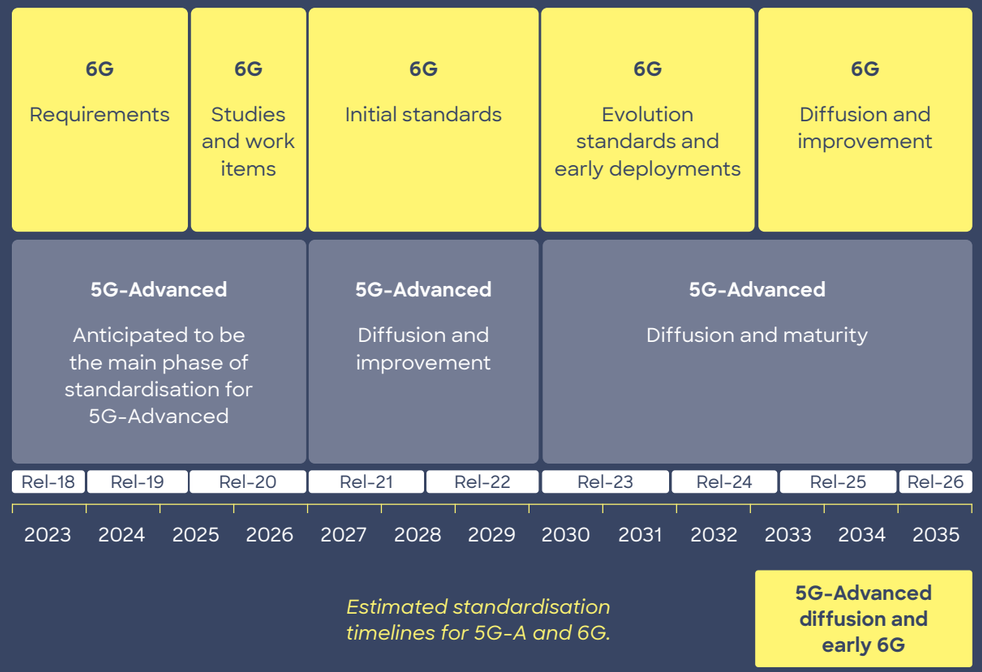
Project Scope

The original scope of this work was to focus on 6G advanced wireless networks. Following conversations during the project's inception, it was agreed that there is additional value in including opportunities from 5G-Advanced.

Additionally, it is recognised that these technologies must be considered in the wider context of connectivity technologies, including current mobile wireless, Wi-Fi, Satellites, and fixed connectivity. A detailed analysis of these adjacent technologies is beyond the scope of this project.

Anticipated first commercial deployments of '6G'



Estimated standardisation timelines for 5G-A and 6G.

Timelines beyond 2023 are indicative and based on multiple sources available at the time of collection.

Headline Conclusions

Advanced wireless networks can offer transformative benefits for Northern Ireland citizens, businesses, and public services. These go beyond benefits to NI's economy and include wider benefits to the environment, sustainability, and society. With the right foundations, including a strategy that looks at advanced wireless alongside a wider advanced connectivity[2] context, Northern Ireland has an opportunity to be an exemplar for the transformative possibilities of advanced connectivity.

These transformative benefits are driven by the diverse range of use cases that advanced wireless can support across NI sectors. It should be noted that these use cases are not exclusive to 5G-Advanced or 6G, and alternative wireless or wired technologies—such as Wi-Fi, satellite connectivity, and fixed broadband—can also play a role. Additionally, it should be noted that some use cases or sectors—such as advanced manufacturing and engineering—may be more likely to be delivered through private 5G or 6G networks, rather than public.

The sectors explored in this report are:

- **Advanced Manufacturing and Engineering**
- **Public Services**
- **Digital, ICT, and Creative Industries**
- **Health and Social Care**
- **Financial Services**
- **Energy and Utilities**
- **Agriculture**

[2] *Advanced connectivity is used to refer to the wider suite of wired and wireless connectivity technologies, beyond just 5G-Advanced and 6G.*

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Advanced Manufacturing and Engineering Use Cases

5-10 years | 5G-Advanced

Connected Industry refers to connecting industrial applications and machinery to the internet using advanced connectivity. It can be thought of as the umbrella term for the application of advanced connectivity in industrial settings. The aim is to enhance automation, monitoring, control, optimisation, and decision-making by allowing seamless data exchange between machines, devices, sensors, and humans. Public and private 5G- Advanced networks, combined with edge computing approaches, can play a role in supporting reliable, high density, low-latency connected industry networks.

Connected supply chains use advanced connectivity to integrate and coordinate various processes, activities, and stakeholders across the value chain. They enable data exchange, automation, visibility, and collaboration in real time, which can lead to cost reduction, quality improvement, customer satisfaction enhancement and risk mitigation. 5G-Advanced can support connected supply chains through more robust and persistent sensor networks and through expanding connectivity to rural and hard-to-reach areas.

Remote Inspection is the process of inspecting, testing, and verifying the quality and condition of assets, products, or processes from a distance. It enables faster, safer, and more cost-effective inspection services than traditional onsite methods and can improve industry performance by reducing downtime, enhancing productivity, ensuring compliance, and preventing failures. Remote inspection can be performed using various technologies, such as drones, robots, cameras, sensors, and augmented reality—all of which are key areas for 5G-Advanced networks.

Closed-loop control enables automatic feedback and adjustment of systems based on real-time data. It makes use of controlled advanced wireless networks that enable the coordination and adaptation of various machines, devices, and robots. Using 5G- Advanced in a closed loop allows a large amount of data to be collected and wirelessly transmitted, with applications such as industrial system monitoring (such as machine vibration) or high-quality video streaming for inspection.

Timing-sensitive devices require precise and accurate synchronisation of their operations with other devices or systems. They are essential for many applications that require precise timing and synchronisation such as industrial automation, robot fleets, and autonomous systems. 5G-Advanced developments in providing precision timing capabilities can play a role in supporting these types of devices and systems.

Avatar technology is a form of teleoperation that allows a human operator to remotely control a physical or virtual representation of themselves or another entity. Avatar technology can enable new possibilities for remote inspection, maintenance, training and collaboration in advanced manufacturing and engineering. 5G-Advanced can help provide the necessary network performance, robustness, and functionality to enable avatar technology. For example, 5G-Advanced can offer high data rates and low latency to support high-definition video streaming, haptic feedback, and real-time synchronisation between the operator and the avatar. 5G-Advanced can also offer high reliability and security to ensure the safety and integrity of the avatar operations. Avatar technology can also support safety of operators, through allowing operators to remotely perform tasks in hazardous or inaccessible environments.

Simulation-centric design uses digital twins to simulate, design, and test physical systems or products before building them. This enables faster, cheaper, and more accurate design and testing of complex and innovative solutions in the design of machinery and products. Simulation-centric design is enabled by various technologies, such as cloud computing, AI, Extended Reality (XR)3[3], and 5G-Advanced offers a solution to enable the huge data transfer quantities required.

[3] *Extended Reality refers to both Augmented Reality and Virtual Reality technologies.*

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Advanced Manufacturing and Engineering Use Cases

10+ years | 6G

Intelligent industrial-control networks use AI to optimise the operation and management of industrial processes, such as manufacturing, transportation, energy, and logistics. They can leverage the advanced features of 6G networks, such as high throughput, massive connections, pervasive coverage, and low latency, to enable real-time data collection, processing, and analysis from various sensors and devices. They offer new opportunities for automation, remote control, predictive maintenance, digital twins, and zero-defect manufacturing.

They can also improve operational efficiency by reducing costs, waste, downtime, and environmental impact.

Robot and cobot integration is the process of using advanced wireless connectivity, such as 6G, to enable the seamless interaction and collaboration of various robots and cobots with humans and other systems.

In manufacturing, robots and cobots can be deployed in reconfigurable and flexible production lines, enabling customisation and optimisation of processes and resources.

High-resilience subsystem networks are small scale sensor networks within systems (such as machinery, equipment, or human bodies) that are connected within the system and are not reliant on connection or power beyond the system. These are often reliant on wired connections, but 6G offers the possibility of high-reliability, wireless sub-system networks.

This could include providing highly reliable sub-system connectivity for machinery and industry equipment. The ability to connect sub-systems with wireless technologies can help to reduce maintenance costs and complexity.

Massive digital twinning in manufacturing is the creation of virtual representations of entire factories, supply chains, or industrial ecosystems. It involves collecting and processing massive amounts of data from various machines, products, workers, and environmental factors, and synchronising them in real time between the physical and digital worlds. It enables new applications and services that require seamless integration of digital and physical domains, such as smart logistics, immersive training, and collaborative design. This also supports simulation-centric design, where digital twins can be used to design and test systems within simulations of their wider environment.

Public Services

5-10 years | 5G-Advanced

Connected public infrastructure includes smart city approaches and using connected infrastructure to better manage public services, systems, and spaces. This also includes connection of rural and hard to reach areas, helping to tackle the digital divide in society. Connected infrastructure can also allow for infrastructure to connect with devices, for example allowing road infrastructure to provide real-time information to connected vehicles.

Traffic management and monitoring through more persistent and pervasive sensing to allow richer real-time monitoring of conditions and help inform more dynamic traffic management, helping to tackle congestion, prevent accidents, reduce emissions, and provide faster emergency response.

Support public safety and delivery of mission- critical services by providing public safety organisations with rich, robust, and real-time data, including in hard-to-reach areas (such as rural) and hard-to-serve situations (such as natural disasters).

Enhancing the reliability and robustness of public service coverage for example providing reliable connectivity on public transport networks and public spaces.

Allowing more immersive approaches to education and training, through providing connectivity to support the use of Extended Reality to support experience-led and vocational training, and the use of synthetic training to reduce costs and increase safety.

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Public Services

10+ years | 6G

Predictive monitoring of public services, using more persistent and pervasive sensor networks, combined with AI and Machine Learning, to allow more dynamic management of public services, helping to predict and prevent social issues and inequalities, and increasing public safety through emergency prevention.

Deployable, self-organising networks are almost certain to be enabled by 6G networks, especially with Artificial Intelligence being designed as a core feature of how the network operates. These deployable, self-organising networks could be used in disaster and emergency response situations, to provide reliable and robust connectivity in remote and hard to reach areas that can also dynamically respond to changing conditions.

Interactive mapping through collection of geospatial data via sensor networks to allow for interactive mapping that can reflect real-time changes in conditions or situations. This will also be enhanced by greater integration between data sources, sharing data from across networks to inform these interactive mapping solutions. The precision sensing and timing capabilities of 6G will also mean these maps provide high granularity, accuracy, and real- time condition information. These types of real-time, dynamic, and interactive maps are especially critical in ‘smart city’ situations to support monitoring and management of public services and infrastructure such as waste, energy, and traffic. The application of Augmented Reality can also support more immersive approaches to navigation.

Massive digital twins for public services and infrastructure using connected sensors and data from across public infrastructure to create and maintain virtual replicas of public services and public infrastructure. These virtual replicas can then be used to help better understand, monitor, and manage public services and infrastructure, including supporting resource allocation, demand prediction, and maintenance scheduling. Additionally, these digital twins can deliver more flexible, effective, and efficient design and testing of changes to those services and infrastructure.

Digital, ICT, and Creative Industries

5-10 years | 5G-Advanced

Low latency, remote collaboration, allowing for better collaboration in creative industries, especially collaborative streaming, music, and multimedia production which are particularly sensitive to latency.

Connective and immersive culture using augmented and virtual reality to enable immersive experiences in arts, entertainment, tourism, and culture.

E-sports is a growing sector and reliable, low-latency networks are critical for e-sports events, both for players and viewers. 5G-Advanced can help to provide this connectivity, especially for supporting more mobile and remote events and reducing the reliance on physical infrastructure.

Enhanced consumer shopping experiences for example using Augmented Reality to allow customers to see themselves in a garment in a shop or being guided to specific areas of the store to find a product. Commercial businesses may also use data from sensor networks to better understand consumer behaviour and better target advertisements, offers, and enhanced consumer experiences.

Broadcasting is another area where 5G-Advanced can help to support high-quality broadcast and streaming, including in remote areas. This use case was demonstrated in May 2023 by Vodafone and ITN, who partnered to broadcast the Coronation of King Charles III via a 5G-Standalone network slice.

Delivery of online gaming and Over the top media, 5G- Advanced offers capabilities which can increase the capability and reliability of mobile gaming and immersion. From a reliability standpoint, lower latency and higher bandwidth increases the reliability of mobile broadband connections, allowing for more reliable online gaming on the move.

Additionally, the increased bandwidth allows for greater fidelity and complexity of games to run on phones or via games streaming services on the move. From an immersion angle, the addition of Augmented Reality capabilities with 5G-Advanced offers the possibility of more immersive mixed reality games, combining mobile gaming with the physical world to create immersive experiences.

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Digital, ICT, and Creative Industries

10+ years | 6G

Mixed reality co-design, could allow for a richer and more immersive ability to creatively collaborate and co-design using immersive communications mechanisms, including VR, AR, haptic and touch, and holography. 6G can help to enable these use cases by providing the extreme low latency and high bandwidth networking capability required, including in remote or other areas hard to reach by wired connectivity.

Fully immersive telepresence is the concept of bringing together new forms of immersive communication methods for personal and business users, including beyond the smartphone, to consider technologies like holography, XR, haptics and touch, and other multimodal forms of communication.

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Health and Social Care

5-10 years | 5G-Advanced

Assisted care using connected health and social care technologies that can enhance the quality of life and wellbeing of people who require assistance in their daily activities. This may include technologies such as remote monitoring, telemedicine, smart home devices, and wearables to help monitor, support, and protect those requiring daily assistance.

Immersive training to support first responders to learn and practice skills in safe and controlled virtual environments, guided by experts. 5G-Advanced can help enhance this through remote Augmented Reality applications, allowing for more realistic and immersive training in the field.

Distributed and remote health and social care to provide support for people located long distances away from services, facilities, or professionals and those who cannot travel easily.

Drone-enabled medical logistics 5G-connected drones can support timely delivery of critical medical supplies to remote and inaccessible areas, especially in emergency and disaster situations.

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Health and Social Care

10+ years | 6G

Massive digital twins in health care including of patients, organs, devices, facilities, and processes, helping to provide real-time and dynamic monitoring of health care systems. These can also be used to analyse and predict medical outcomes, prevent health problems, and personalise treatments.

Life-critical connectivity systems, the combination of reliable and robust connectivity, coupled with the potential that 6G offers for highly reliable sub-system networks, opens the possibility of 6G supporting life-critical connectivity applications, such as in telesurgery and health telemonitoring.

Intelligent implants and wearable devices offer healthcare applications such as monitoring of key health system vitals and biometric data. 6G can enable more real-time and predictive monitoring of this data and, especially when combined with digital twins, allow for more personalised and targeted health interventions.

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Financial Services

5-10 years | 5G-Advanced

Advanced insurance tracking uses connected sensors and the precision location capabilities of 5G-Advanced to monitor the location of insured assets, such as vehicles or cargo. This allows for more accurate risk assessment, dynamic pricing, and faster claims processing, all of which could provide a boost for the insurance industry. An example of this technology is usage-based insurance policies that can more accurately adjust premiums based on the user's driving behaviour and usage.

Reduced losses from fraud, 5G-Advanced will help facilitate security advances, such as facial recognition to quickly verify customers' identities when using ATMs and completing other financial transactions.

This can reduce the need for physical authentication methods, such as cards and pins, and reduce the opportunities for fraud.

Trading mobility, the low latency offered by 5G-Advanced could offer an alternative means of connection for High Frequency Trading, providing resilience for wired fibre connections and offering low latency connections to areas where fibre connections are either not available or not cost effective.

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Financial Services

10+ years | 6G

Innovative security and authentication approaches for phones and other wearable devices through using patterns of usage to identify and authenticate users. One area of research in this space is looking at measuring the unique way each user interacts with the antenna from their devices.

Implementation of new physical layer security methods will be another key barrier to prevent future instances of fraud, with the potential in 6G for monitoring through the radio spectrum offering further possibilities for continuous authentication.

Additionally, the integration of AI into the core of the network opens the possibility of authenticating using the unique patterns of how an individual uses their device and how that device interacts with the network.

Energy and Utilities

5-10 years | 5G-Advanced

Smart grids and energy system, including the use of a denser network of connected sensors to help with real-time monitoring of flow and consumption and dynamically manage the balance of energy supply.

There is also the potential of using millimeterWave radio frequencies to transmit and harvest power, offering the possibility of remotely powering and charging remote sensors.

Enhanced waste management through 5G-Advanced enabling more persistent sensors that can support waste monitoring and ‘e-waste’ solutions, including sensors for tracking commercial and consumer waste and help optimise waste management systems.

Water resource management can be improved through sensors and analytics that 5G-Advanced networks can enable. This can greatly reduce water loss, through smart sensors monitoring the pressure and flow of water in their pipes, to identify leaks or bursts quickly and precisely in real time.

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Energy and Utilities

10+ years | 6G

Zero energy devices are a concept where devices, from the end user perspective, have no power source (such as a battery). Instead, the devices harvest energy from their surroundings. These kinds of devices, connected through 6G, offer opportunities in the energy and utility sector to support persistent monitoring of energy, waste, pollution, water, and other key utilities.

This can greatly increase the energy efficiency of massive connectivity and reduce reliance on batteries and power sources.

Agriculture

5-10 years | 5G-Advanced

Connected robot and drone integration, these kinds of devices can support autonomous and remote ploughing, sowing, spraying, harvesting, monitoring, and inspecting and can potentially do so with increased efficiency, productivity, and safety compared to traditional methods. This is sometimes referred to as 'precision agriculture' and 5G-Advanced aims to provide networking capability that can integrate these into a wider network of connectivity, supporting dynamic management and sharing of data, including in remote areas.

Augmented Reality for farming to help provide real-time data, information, and intelligence to farmers about key crop or stock conditions. This technology can also help with remote monitoring of equipment and parts, increasing safety by reducing exposure to hazardous environments and equipment. AR can also support training and education in agriculture, helping to increase safety by allowing for hazardous skills training in safe, virtual environments.

Integrated sensing and communication to help collect and analyse data from various agriculture systems and sensors to monitor soil, water, plants, animals, and weather—including in remote and rural environments. This can help to optimise agricultural operations and support earlier detection and prevention of adverse conditions such as disease or pests.

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Agriculture

10+ years | 6G

Persistent and pervasive sensor networks enabled by the ultra-dense, ultra-reliable, and ultra-low power consumption sensor of networks that 6G could offer, including allowing for low-power devices with better sensing capabilities, increasing the richness of data and insight that can be gathered. With 6G likely to put AI at the core of the network, this can also support better real-time analysis and dynamic management of 6G sensor networks.

Agriculture digital twins, enabled by the sensor networks made possible by 6G, can allow for more efficient and effective real-time monitoring of agriculture systems. They can also provide enhanced ability to test different agriculture interventions and enable better planning and management of resources. Additionally, they can help increase safety by reducing the exposure to hazardous environments by allowing remote monitoring and testing.

Radio spectrum sensing for monitoring is based on the concept of using the radio signals transmitted by the network as a sensor. The terahertz spectrum being discussed in the early 6G discussions could allow for extremely high-fidelity sensing using this technique and could be used to monitor the condition and quality of fields, crops, water, and food.

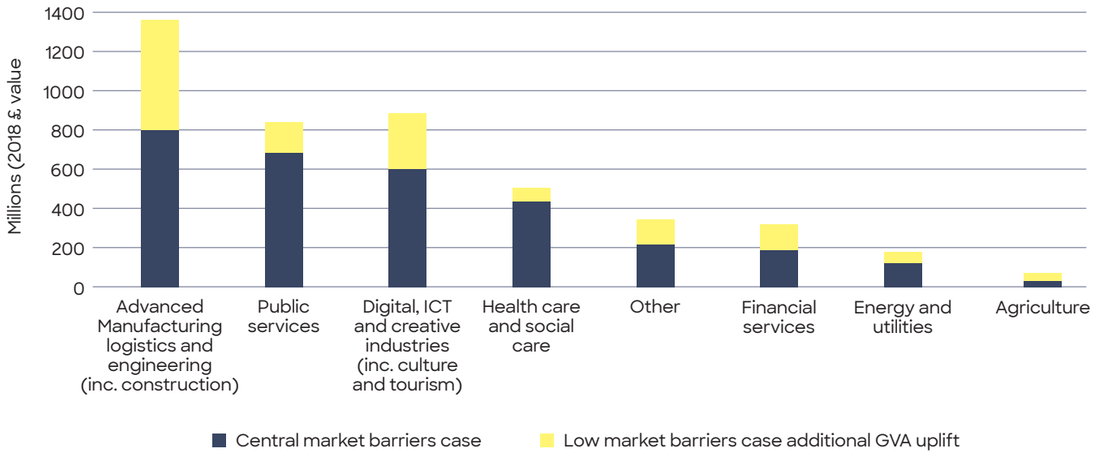
Economic Benefits

Advanced wireless networks[4], if deployed and diffused widely, offer significant economic uplift potential across NI sectors

By 2035, the forecasted uplifts[5] in Gross Value Added (GVA)[6] for NI across all sectors is £3.1 billion assuming supply and demand-side market barriers[7] continue to impact adoption (central market barriers case in the Figure 1), or £4.5 billion if market barriers were addressed (low market barriers case in Figure 1).

Individual NI sector uplifts range between c. £34 million and c. £797 million in the current market barriers case, and c. £77m to c. £1.4 billion with market barriers removed.

Figure 1: Sector breakdown of NI GVA uplift[8]



4 *5G inc. 5G-Advanced are the focus for the economic analysis, due to a lack of reliable and robust source data for 6G.*

5 *The data used for these forecasts is primarily based on Data provided by DSIT, from their commissioned report "Realising the benefits of 5G". A full data pack is available as an Annex to the main report, at matrixni.org.*

6 *Gross Value Added is defined by the Office of National Statistics as the value generated by any unit engaged in the production of goods and services.*

7 *In the reference data, the 'central market barriers case' refers to the baseline assessment of how existing demand and supply side barriers are expected to impact 5G adoption in the UK over the period. The 'low market barriers case' then shows the additional uplift if market barriers were addressed through proactive government policy.*

8 *The 'Other' category includes economic activity that falls outside the categories of interest for this study. It consists mainly of real estate, legal, rental and leasing, and other personal service activities. A full breakdown can be viewed in the accompanying data pack which is available at matrixni.org.*

Wider Benefits

The environment and sustainability

One of the key areas of development in 5G-Advanced, and central to the discussions around 6G, is how to increase the efficiency– and reduce the environmental impact of– mobile telecoms networks. 5G networks are expected to be significantly more efficient than 4G networks, with some tests indicating up to 90% more efficient in terms of energy consumption per unit of traffic. Not only this, but 5G and 6G networks are additionally anticipated to support the environment through the avoided greenhouse gas emissions in other sectors. A meta-analysis of studies looking at these avoided greenhouse gas emissions provides a conservative figure of a 2.3% reduction in greenhouse gas emissions for NI by 2030[9]. The more persistent and pervasive network of sensors can also help support environmental monitoring and management, including the tracking of externalities, identifying hidden patterns to help identify emission sources, and providing richer data for analysing environmental and climate trends[10].

Benefits for consumers

5G-Advanced and 6G will almost certainly create a 'consumer surplus' for end-users. Consumer surplus refers to the concept that consumers will experience a surplus by paying less for their data usage than they have previously been happy to pay. This is highly likely in the telecoms market when looking at expected growth in usage versus likely growth in price paid. For usage, the monthly average data for users in Western Europe may grow by as much as 1,600% by the end of 2028[11]. It is almost certain that the monthly average cost of data will not rise by 1,600% by 2028, resulting in a significant consumer surplus for mobile users. This is also evidenced by looking at 'willingness to accept', where consumers are surveyed to see how much they would be willing to accept to lose access to a service, with multiple studies finding 'willingness to accept' figures for application and internet-based services at higher values than the fees consumers pay for wired and wireless connectivity access, leading to a surplus.

9 *full data pack is available as an Annex to the remain report at matrixni.org*

10 *Externalities refer to the 'positive or negative outcomes of a given economic activity that affects a third-party that is not directly impacted by the activity', as defined by the International Institute of Sustainable Development. For example, an oil tanker that spills oil and that oil then pollutes the water and impacts habitats and local coastal populations.*

11 *Based on an analysis of taking Ofcom monthly per user figure for 2019, compared to Ericsson Mobility Report forecast for 2028.*

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Social inclusion and societal value

Advanced wireless networks also offer value to society as a whole and help increase social inclusion. This includes helping support the bridging of the digital divide through greater support to rural networks and hard-to-reach areas, including areas underserved by fixed broadband through providing Fixed Wireless Access[12] services.

This encourages increased social inclusion through supporting the maintenance of social and familial relationships enabled by digital communications; bettering equality of opportunity through remote access to work opportunities; and supporting mental health and wellbeing, especially helping to tackle loneliness and social isolation. By supporting connection of rural, hard to reach, and underserved communities, advanced wireless can also support financial inclusion, by providing the connectivity required for reliable digital and online banking.

[12] *Fixed Wireless Access (FWA) offers an alternative to wired broadband, by instead using wireless radio signals to provide connectivity to a premises. This was possible in earlier generations of mobile technology, but 5G increases the speed, robustness, and reliability of FWA.*

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5G-Advanced

The above use cases and benefits are made possible by various advancements in network capabilities that 5G-Advanced and 6G look to introduce through developments in the underlying technology and network architectures.

For 5G-Advanced this includes the drive to proliferate mobile networks across a much broader range of use cases, beyond traditional consumer-focused mobile broadband; increasing the efficiency and sustainability of networks; and increasing the reach, robustness, and reliability of networks.

5G-Advanced relies on 5G-Standalone networks, the first of these went live in the UK with Vodafone's announcement of 5G Ultra in June 2023, although this is still focused on major population centres and does not include the rollout of small cells to enable the use of millimeterWave spectrum, which will be required for some high-bandwidth, low-latency use cases.

6G

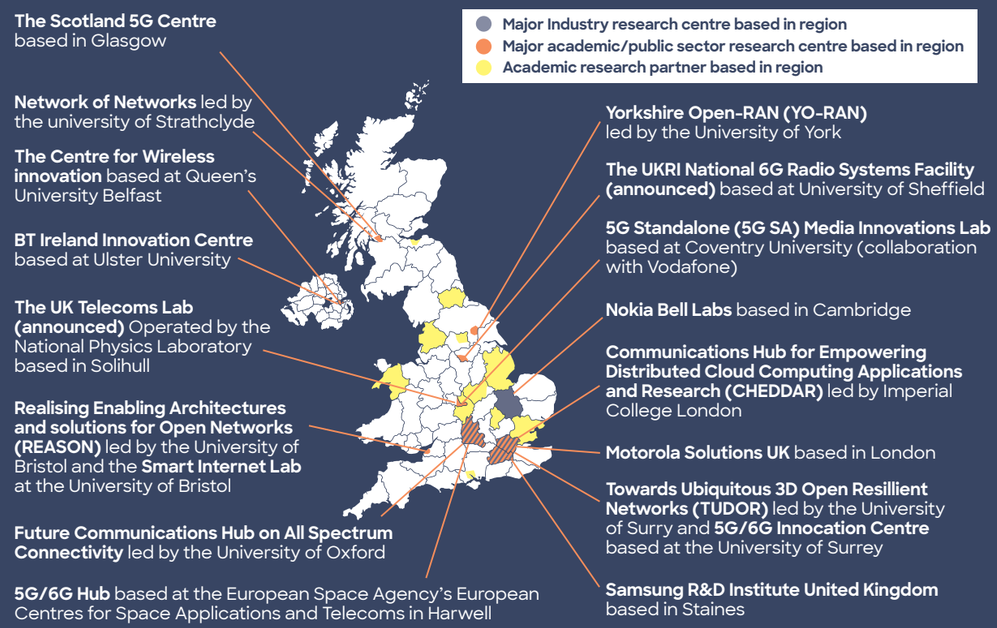
As 6G is so early on in its development, there is no definitive view of what advancements it aims to bring. The initial release for 'IMT-2030' which will set out the vision and early requirements, is expected in 2023. In early conversations, it is anticipated that 6G will build on the 5G foundation, and not require another significant infrastructure investment at the same scale of 5G. Themes in current discussions around 6G focus areas include:

- A move away from maximising performance metrics towards looking at how to create the most useful and valuable network for society. A concept of 'Key Value Indicators'[13] in the 6G discussion includes looking at how the network can support areas such as digital inclusion, cultural connection, environmental sustainability, privacy and confidentiality, trust, and others.
- Looking at how to create a more robust, available, and reliable network, through the integration of drones and satellites; the integration and interoperability of other connectivity technologies; and looking at how to provide better rural, remote, and indoor coverage.
- Putting AI at the core of the network as a foundational part of its operation is another concept central to the discussion, allowing for intelligent and dynamic network management and orchestration.
- A focus on 'integrated sensing and communication', with much greater integration and intelligence of sensors into the network.
- The scale of data the network can capture, analyse, and transmit is another theme, with massive digital twins and large-scale, real time interactive maps. New spectrum is a part of this discussion, including ultra-high frequency Terahertz (THz) spectrum. However, THz spectrum exacerbates the challenges already faced with millimeterWave spectrum being seen with 5G[14].
- A central focus on the environment and sustainability, recognising the need for efficient networks that can handle much larger volumes of data without using more energy.

[13] *6G Infrastructure Association. Vision and Societal Challenges Working Group, Societal Needs and Value Creation Sub-Group. May 2022. What societal values will 6G address?*

[14] *Higher frequency wavelengths have shorter range and worse propagation characteristics—so are more easily blocked by buildings, trees, walls, and other obstacles. This requires a much denser network of smaller radio cells to be deployed, driving up cost and increasing the deployment challenge. Further information on THz spectrum is available in this Ofcom paper. Terahertz radio spectrum: a discussion paper. December 2021. ofcom.org.uk.*

Research Initiatives



There is a wide and diverse range of research exploring 5G-Advanced and 6G technologies, with some research areas where NI already plays a critical role. Northern Ireland, through Queen's University Belfast and Ulster University, already delivers world-leading research into key aspects of advanced wireless technologies, especially the research into the physical layer of networks at QUB's Centre for Wireless Innovation.

There are a wide range of other research centres across the UK conducting fundamental and applied research into advanced wireless technologies, supported by various national and international streams of research funding. The recent UK Government Wireless Infrastructure Strategy and 6G Strategy calls for even further investment into advanced wireless research, with £100 million set aside for 6G research. The Scotland 5G Centre, and network of innovation hubs, is tasked with realising the benefits of advanced wireless networks for Scotland.

The CONNECT Centre in Dublin brings together a network of research institutes from across the Republic of Ireland to act as a 'one stop shop for all things to do with future networks and communications in Ireland' and has a strong model of industry collaboration. Additionally, there are a wide range of international research centres, collaborations and industry networks exploring 5G-Advanced and 6G. Including, but not limited to, HEXA and HEXA-II under Horizon Europe; the EU's 6G Smart Networks and Service Industry Association (6G-IA); Finland's 6G Flagship programme; the CELTIC-NEXT consortium of European industry; the US Platforms for Advanced Wireless Research (PAWR); the US Next-G alliance; and South Korea's K-Network 2030 with $500 million of 6G investment. China is another key player in research in this space but there is limited public information available on specific centres or priorities.

Investment Initiatives

There are also a diverse range of investment initiatives looking at applying advanced wireless research to test, demonstrate, deploy, and deliver innovative advanced wireless applications across sectors.

Within NI, Belfast Harbour have invested in a private advanced wireless network to help optimise their operations and the Belfast Region City Deals Digital Innovation programmes have made commitments to support advanced wireless implementation.

Across the UK, there is a mix of public and private investment into advanced wireless networks. This includes the UK Government 5G Trial & Testbed programme, the £40 million investment for local and regional government to become '5G Innovation Centres', and initiatives like Liverpool's successful project providing a public 5G network for health and social care, and Sunderland's Smart City Programme.

Alternative, adjacent, and enabling technologies

It is important to view 5G-Advanced and 6G in the context of other alternative, adjacent, and enabling technologies.

5G-Advanced and 6G must be considered alongside other wireless and wired connectivity technologies—such as existing mobile telecoms, fixed broadband, Wi-Fi, and satellite—to understand how these technologies come together to form an advanced connectivity supply that is matched to NI's current and future demand.

It is also important to consider key enabling technologies and approaches, including open technology approaches—such as Open RAN; cloud technology; quantum technologies; Artificial Intelligence and Machine Learning; and security, trust, and privacy– the latter of which will be especially critical to ensure secure, ethical, and proportionate implementations of these advanced wireless technologies.

Challenges and realities impacting advanced wireless

Privacy, trust, security, governance, and ethics

Advanced wireless networks are almost certain to enable far greater persistence and pervasiveness of sensing, tracking, and monitoring, including of sensitive and personal data—especially in areas like healthcare. These sensing, tracking, and monitoring capabilities can offer significant benefit, as outlined by the above use cases, but also bring significant risks around privacy, trust, security, and ethics—especially when coupled with greater integration of Machine Learning and Artificial Intelligence technologies into networks.

Governance of these technologies—and the organisations who own, design, and implement them—will also be crucial as these technologies take an increasingly central role in public, private, commercial, and industry environments. Fair, proportionate, and secure implementation of these technologies will be a critical enabler to deliver the economic and societal benefits outlined in this report.

Policy, regulation, and government

As telecoms is a reserved matter, NI's ability to shape and direct connectivity policy is constrained. Engagement with, and within, NI government can be challenging as it often requires engagement with multiple national and local departments, without a clear single point of engagement—although the NI Barrier Busting Taskforce is delivering positive change in this area. Fragmentation of relationships and responsibilities for policy ownership related to advanced wireless deployment constrains supply and demand side investment and implementation.

Additionally, whilst many streams of funding do exist for innovation and investment into advanced wireless, these funding streams and associated policy can lack the scope, flexibility and/or adaptability to support long-term sustained delivery with advanced wireless as an enabler. NI's unique policy landscape and constraints can act as an inhibiter to accessing, or making best use of, available funding streams.

Telecoms market

The supply-side of advanced wireless face a range of challenges that impact investment in, and roll-out of, advanced wireless networks. These include a challenging investment climate– exacerbated by a lack of clear and committed demand signal; the complexity of, and significant capital investment requirements for full 5G roll-out; challenges achieving return on that investment; the debate between consolidation and competition within the telecoms market; NI's shape and size as a market; and the overpromise of 5G early on in its lifecycle.

Macrotrends and uncertainties

It is also critical to view any responses set out to these challenges and the future development of connectivity in Northern Ireland, within the wider context of macrotrends and uncertainties.

This is especially critical with the extended time horizons that can be involved in connectivity policy, development, and provision. The UK Government's Wireless 2030 report outlines five themes of critical uncertainties and future drivers.

These are:

1

Governance Agenda

How infrastructure and 'experience design' decisions are made and by whom.

2

Public Perception

The extent to which users interact with systems and their level of trust in providers..

3

Network design

How the network is distributed and directs flows of data and investment.

4

Sustainability & resources

The availability of resources and the UK's ability to support innnovations to market.

5

Stores of value

How people, business and sectors will derive/exchange value via new wireless capabilities.

Recommendations summary

For NI to realise the benefits offered by advanced wireless networks, and advanced connectivity more generally, there is a need to bridge the gap between the current realities and future possibilities.

To begin the process of bridging that gap, this report sets out six recommendations.

1 **Department for the Economy (DfE), NI** to engage with NI Local Government and relevant NI Civil Service (NICS) Departments to establish their appetite to jointly develop a long-term NI Connectivity Strategy.

2 **DfE NI** engage with NI Local Government, relevant NICS Departments and other stakeholders to explore delivery of an advanced connectivity platform that can be used for ideation, innovation, and testing.

3 **DfE NI** to use the Communication Subgroup work of the NI Barrier Busting Taskforce to include collection and consideration of demand-side blockers for innovation and implementation of advanced connectivity.

4 **DfE NI** to engage with NI Local Government and other NICS Departments to design and define a lead sector approach for demonstrating benefits of advanced connectivity.

5 **DfE NI** to work with NI Local Government and relevant NICS Departments to commission the design and development of a NI Connectivity Collaboration & Co-ordination hub.

6 **Matrix** to commission further analysis to map demand-side requirements for advanced connectivity from NI demand owners across business and government.

Recommendations detail

1 **Department for the Economy (DfE), NI** to engage with NI Local Government and relevant NI Civil Service (NICS) Departments to establish their appetite to jointly develop a long-term NI Connectivity Strategy.

This project has identified five potential areas this strategy might wish to consider, those are:

1. Possibility

Demonstrating the possibilities and benefits offered by advanced connectivity for NI citizens, business, and government. A focus on demonstrating and evidencing the possibility of long-term, sustained benefits. Evidence how advanced connectivity can deliver positive transformation for NI citizens, business, and society.

2. Proposition

Developing and communicating a compelling advanced connectivity proposition to NI government, business, and citizens. This is a critical step in achieving buy-in for prioritising investment and resource into advanced connectivity in NI. Develop an advanced connectivity proposition, not just advanced wireless, to align wired and wireless connectivity priorities, policies, and investments. The proposition should balance coverage and choice, encouraging market competition and diversity, whilst recognising the unique size, shape, and scale of NI as a market.

3. Partnerships

Building and strengthening a diverse range of active partnerships across government, research, demand, systems integration, and supply sides of advanced connectivity in NI, the UK, and internationally. Show how all stakeholders have a role in ensuring that advanced connectivity can support a wider vision for NI society. Build on existing engagement from the NI Barrier Busting Taskforce and existing engagement in NI, including the proposed digital champion network, asset owner engagement, and local council engagement on advanced connectivity—for example, the engagement conducted by Belfast City Council. Leverage NI, UK, and international partnerships to access funding for advanced connectivity, especially through funding mechanisms like City and Region Growth Deals and Department for Science, Innovation and Technology (DSIT) funding streams. As well as inward investment, also explore international partnerships for exporting NI research, expertise, or services—especially in areas where NI has strengths, such as cybersecurity. Build on NI international research and industry partnerships. Engage with UK government to ensure that NI has its unique requirements reflected in wider UK advanced wireless strategy and standards development processes.

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4. Platform

Providing platforms of connectivity, open data approaches and standards, collaboration, investment, and skills to allow supply and demand sides in NI to innovate and implement advanced connectivity. Reflect on, and learn from, proposals for alternative platforms and models of advanced connectivity delivery. Ensure interoperability of platforms both within NI and with wider UK and international partners, platforms, and networks.

5. Policy

Clarifying the option space for NI in advanced connectivity with telecoms as a reserved matter and exploring the possibility of longer-term timeframes for connectivity policy planning for NI. Exploring policy options for advanced connectivity but also supporting others to see how advanced connectivity can offer transformative policy options in other policy areas. Alignment, engagement, and policy support between national and local levels of government to help unblock supply and demand side investment, including exploration of innovative cost models, implementation approaches, and investment streams. Leverage existing work from across UK, such as the Wireless Infrastructure Strategy and 6G Strategy. Ensuring sunset dates of legacy technologies (such as 2G/3G switch-off) are factored into early thinking about future connectivity.

2 **DfE NI** engage with NI Local Government, relevant NICS Departments and other stakeholders to explore delivery of an advanced connectivity platform that can be used for ideation, innovation, and testing.

Any activity under this recommendation should:

- Recognise connectivity as an enabler to a wide and diverse range of projects and prioritise open, flexible approaches to allow usage from across supply and demand sides.
- Link with the platform aspect of the strategy in recommendation one, providing a platform to enable testing and incubation.
- Look to build on existing knowledge, networks, proposals, and platforms in NI and wider UK, and seek to make use of existing funding streams for advanced wireless.

3 **DfE NI** to use the Communication Subgroup work of the NI Barrier Busting Taskforce to include collection and consideration of demand-side blockers for innovation and implementation of advanced connectivity.

Any activity under this recommendation should:

- Include input from academia, industry, NICS, and local government demand-side stakeholders.
- Be undertaken alongside the existing work on identifying and addressing supply-side barriers in NI and the wider UK barrier busting activity.

4 **DfE NI** to engage with NI Local Government and other NICS Departments to design and define a lead sector approach for demonstrating benefits of advanced connectivity.

A lead sector approach would look to identify a sector in NI where there is strong demand, high relevance of advanced connectivity, and availability of supply-side partnerships in connectivity and enabling technology.

Any activity under this recommendation should:

- Include input from academia, industry, NICS, and local government demand-side stakeholders.
- Explore the most appropriate sector based on a combination of NI's unique demand and supply characteristics. Health and social care is recommended as a candidate lead sector to be further explored, as NI has strong demand signal and expertise in critical enabling technology areas, such as MedTech, Life and Health Sciences, and Cybersecurity. Another candidate sector for further exploration is Advanced Manufacturing and Engineering (AMME), building on the existing activity across NI, such as the Advanced Manufacturing Innovation Centre (AMIC) at Queen's University Belfast.
- Any lead sector approach should be taken alongside, rather than instead of, a wider portfolio approach looking at supply and demand side innovation across sectors.

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5 **DfE NI** to work with NI Local Government and relevant NICS Departments to commission the design and development of a NI Connectivity Collaboration & Co-ordination hub.

Any activity under this recommendation should:

- Aim to help clarify and simplify engagement and collaboration across research, demand, and supply sides of connectivity within NI.
- Not be about control, but rather about convening, coordination, collaboration, and coherence.
- Build on the existing network of NI innovation centres and clusters across local government, industry, and academia; as well as other UK wide initiatives such as the UK Telecoms Innovation Network, Digital Catapult, and DSIT strategies and funding stream.

6 **Matrix** to commission further analysis to map demand-side requirements for advanced connectivity from NI demand owners across business and government.

Any activity under this recommendation should:

- Include a view of current and future drivers of demand and used to inform the wider strategy work from Recommendation one.
- Be conducted in close consultation with the engagement stream of the NI Barrier Busting Taskforce to coordinate cross departmentalNICS engagement and support analysis of NI government demand.

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Northern Ireland
Science Industry Panel

Advanced Wireless Networks

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