UNIVERSITY OF SURREY

# 6G WIRELESS:
## A NEW STRATEGIC VISION

5GIC Strategy Advisory Board

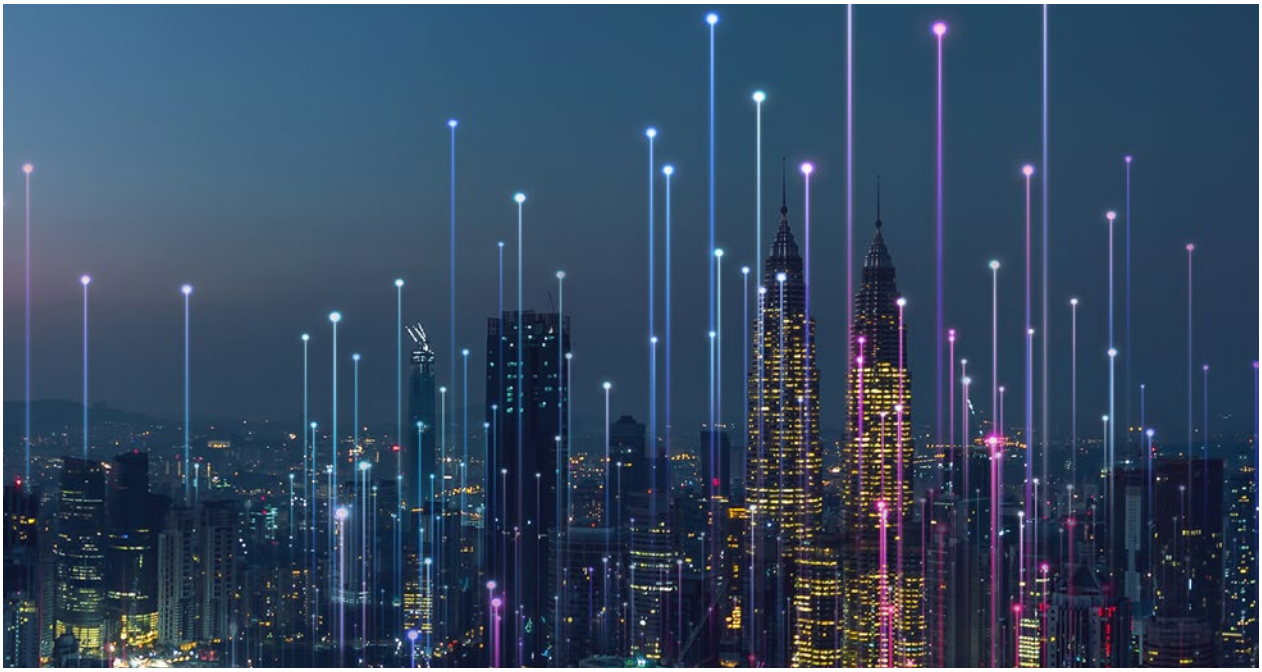
6GIC

## In this paper, we leverage the wealth of technical and commercial experience of the industry partners of the University of Surrey 5GIC and set out a commercially credible vision for the successor to 5G.

Why is a 6G strategic vision needed, and why now? As with any major innovation, commercial transformation, or research programme, strategic objectives are essential anchors, needed to ensure focus and cohesion. A commercially driven 6G vision, with forward momentum, leveraged in a coordinated way, will reduce potential for loss in efficiency as global research and development progresses, and will open essential opportunities for members and stakeholders. With a typical cycle of around 10 years for wireless generations, now is the critical time to begin the journey towards 6G.

Historically, mobile technologies have been developed by setting arbitrary or rather vague goals, such as 'higher data rates', 'increased mobility', or 'the mobile internet'. As markets have advanced however, so has our understanding of users' behaviours and industry economics. Effective strategic thinking has tended to follow the systems research and development phases, rendering a degree of inflexibility and 'architectural lock-in' often when it is too late. Operators are then driven to invest without clear economic rationale. We advocate a new approach, enabling strategic decisions to be made as research progresses. This reduces the risk that outcomes do not meet business requirements.

The paper is structured with some background; often it is useful to look backwards to look forwards. We then set out a commercial vision for 6G, including discussion on major drivers, enabling technologies, and an approach for development. We also address 'loose ends' with the 5G vision, which can be expected to result in commercial 5.5G solutions over the next decade, much as we have seen evolution with 4G systems. The paper concludes with comments on bringing elements of the new approach together, supported by a new collaborative, cross-functional, and pragmatic programme of work.



## BACKGROUND AND TRENDS

Wireless technology has, of course, been around now for some time. Marconi's early work is still remembered with the coming together of research and commercialisation which has now characterised the success of five generations of mobile technology.

Early mobile systems used analogue technology (1G), which set the ball rolling, but 2G GSM transformed the industry to a mass market with new enhancements via 2.5G GPRS and EDGE technologies delivering user data rates to 100kbps and beyond. 3G systems were launched in 2001, using higher bands above 2GHz, to meet ongoing market demands for mobile data and service access, with enhancements in HSPA+ (3.5G) technology enabling data rates to tens of Mbps. Since 2013, 4G Advance technology has been commercially deployed by many operators, offering peak channel capacity at over 1Gbps (over 100MHz bandwidth). In practice, 4G (LTE-A) offers users data rates of tens to hundreds of Mbps, depending on conditions.

5G, launched commercially only recently, was a more complex initiative, with objectives for multi-band operation and support for various use case types defined from the outset. One element, 'Enhanced Mobile BroadBand' (eMBB), has been developed as a direct continuation of the industry's quest for ever higher data rates, but a second element, 'Ultra Reliable Low Latency Communications' (URLLC) is opening up huge potential for industrial modernisation. A third element, 5G-enabled 'Massive Machine Type Communications' (mMTC) or IoT (Internet of Things), is still being developed. Key innovations with (and to some extent alongside) 5G have included enhancements in the radio design, larger antenna arrays, greater use of software networks allowing 'slicing' – active reconfigurations across the network to support the service needs of varied business sectors, and the usual – more spectrum in higher bands, with a modest increase in spectral (not necessarily cost) efficiency[1].

There is a trend here. New generations of mobile technology have appeared roughly every ten years since 1G. With each new generation, there is a push for higher data rates, which means more spectrum. More spectrum means higher bands, which means less coverage for given cost. And the need for mobility varies; users now consume wireless services across a variety of spaces: from indoors, to high speed vehicles. With each new generation, operators are faced with increased challenges of managing return on capital invested to viable levels. The accepted approach is not sustainable. A new approach is needed which meets developing demands effectively.

**The traditional approach to *next generation wireless* is not sustainable. A new approach is needed that is inspired by the great societal and economic challenges ahead.**

## NEW GLOBAL CHALLENGES

How should a new generation of wireless technology be developed to meet key new demands? The direction being set by the World Economic Forum (WEF), with its 2021 Annual Meeting, provides some insight. With the COVID-19 crisis, the meeting will not be held at its regular venue of Davos, Switzerland, but via a new configuration that will include both in-person and virtual dialogues[2].

Uniquely, the event will be open to virtually anyone with an internet connection. Key themes up for discussion will include: climate change, healthcare, and social equality.

A look at the WEF Global Risk Report 2020[3] lists environmental factors, information security, and international cohesion as major issues.

Separately, the United Nations (UN) has set out its Sustainable Development Goals[4], with a global call for action to promote prosperity, whilst tackling climate change and environmental imperatives.

[1] Note: where noise and interference can be minimised, 5G offers improved spectral efficiency.

[2] See: **https://www.weforum.org/press/2020/06/the-great-reset-a-unique-twin-summit-to-begin-2021/**

[3] See: **https://www.weforum.org/reports/the-global-risks-report-2020**

[4] See: **https://www.un.org/sustainabledevelopment/sustainable-development-goals/**


## 6G NEEDS TO BE DIFFERENT

6G must be designed with key global challenges in mind. These form a starting point for the global research community. And if 6G is to meet these grand challenges, it will be essential for the technology to support both cost-efficient coverage, and radically new innovative services.

If 6G is to be different, a global consensus is needed from the start on what exactly should be embraced by the term 6G. Our proposal is that it should include both digital and communications infrastructures and a future converged fixed-mobile world (in which "mobility" will always be an important component part). The need to sustain interoperability or secure global scale economies through a coordinated introduction justifies inclusion and setting a high bar to justify adding in anything that is not backwards compatible.

Early technical work has already begun around the world on exciting new services and applications. Ideas include immersive extended reality (XR), digital replication, ubiquitous wireless intelligence, telepresence, holographic communications, wearable networks, adaptive materials, and use of entirely new radio technologies such as with TeraHertz (THz) bands supporting short range sensor functionality[5].

As 5G has already pushed technology hard in some areas, it will be important with development of 6G to be clear where the big gains may be realised; for example, with physical constraints, it is getting increasingly difficult, in economic terms, to improve on spectral efficiency. Innovative use of spectrum, however, will remain a key issue. We can also expect a range of new commercial models to develop.

## UNIVERSITY OF SURREY 5GIC'S NEW APPROACH

With 5G now in commercial deployment, it is now time to launch a programme of research and development to support 6G. 5GIC will continue to support 5G developments under a 5G+ label.

6GIC will be a key UK-based hub for global innovation and collaboration on 6G wireless, involving governments, regulators, mobile operators, vendors, enterprises, and leading research and development centres.

[5] See: **http://www.6gsummit.com/2019/program/the-1st-6g-wireless-summit/**

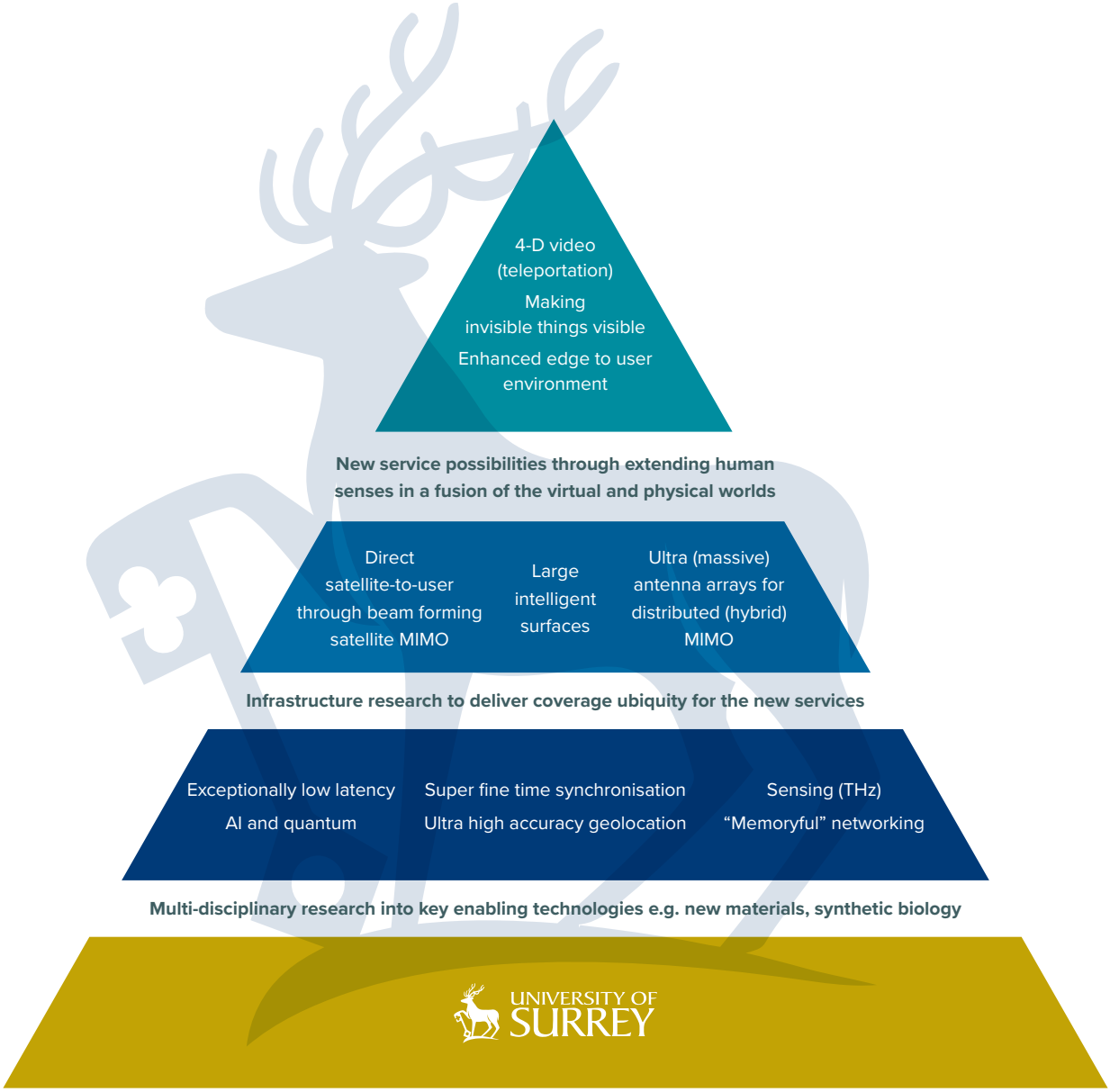



Figure 1: 6G vision supported by new cross-functional research and development programme

## OUR 6G VISION

6G will enable a rich new fabric of digital services, including extending human senses and ambient data in a fusion of the virtual and physical worlds. Imagine a world where one can interact with colleagues and friends from different continents, from different cultures, without any perception of not being in the same room.

Imagine extending the human experience, via digital solutions, into a realm of new sensory and tactile perceptions. Imagine interacting seamlessly with machines, and enjoying personally tailored healthcare and well-being programmes supported by extensive and yet non-intrusive sensors.

Imagine hyper-fine geolocation, with context-aware digital services supporting human scale activities such as physical product browsing and machine tracking.

We refer to this as data teleportation[6]. This is not the movement of atoms, as in science fiction, but the movement of information, as in science fact[7].

As time synchronisation to microseconds and low latency levels are required, this is beyond the capabilities of 5G technology, but will be within reach with 6G. Teleportation in this form will support a range of new applications including e-health, telecare, beyond industry 4.0, and many others.

To enable 6G, a rich cross-functional programme of technology and scientific research will be needed (see Figure 1). We envisage a ground-breaking programme of work that will involve collaboration across multiple scientific and engineering disciplines, critically advancing 6GIC members to leadership positions in the field.

6G will be a hybrid network of networks, comprising short range, wide area and satellite networks (see Figure 2) and seamless integration and essential use of edge computing. It will also lift 5G-enabled services to new levels of performance and functionality.

**6G will enable a rich new fabric of digital services, including extending human senses and ambient data in a fusion of the virtual and physical worlds.**

[6] Note: some have used the term 'extended reality (XR)' to refer to the same concept. Not to be confused with data teleportation as in quantum physics (quantum teleportation).

[7] See: **https://www.etsi.org/images/files/Magazine/Enjoy-ETSI-MAG-October-2020.pdf**

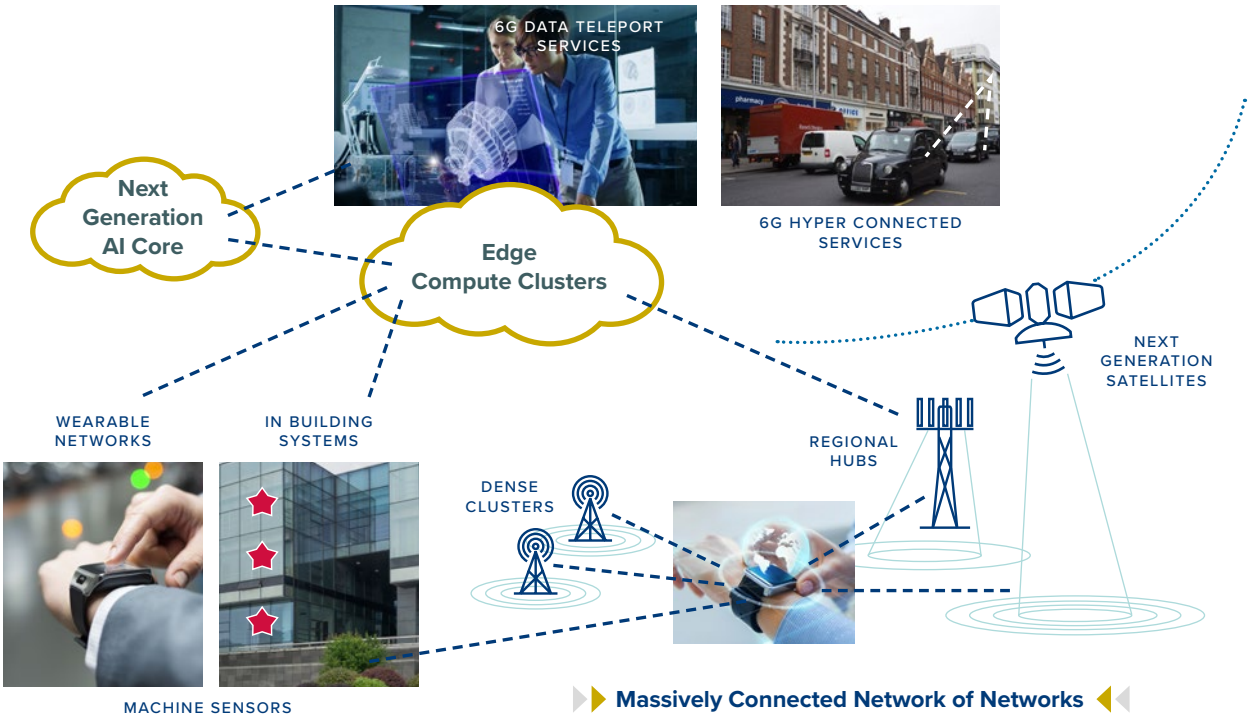



Figure 2: 6G services supported by next generation AI and a network of networks comprising short range, wide area and satellite networks

**6G will involve our members in national and international collaboration across many disciplines, building supply chain diversity.**

Key areas for multidisciplinary research will include: O-RAN and standards enabling supply chain diversity; advanced wireless engineering – extending beyond the ideas developed with 5G, including high definition and integrated sensing and use of new radio bands including THz frequencies, distributed MIMO and cell-less architectures, satellite systems, and predictive and memoryful systems; network interworking – supporting pervasive coverage; materials science – enabling new forms of antennas and wireless communication, including large intelligent surfaces (LIS); massive and distributed antenna systems and architectures – supporting ultra-high definition communications with a variety of human, machine, and ambient data; advanced, massive computing and next generation artificial machine intelligence (AI) – supporting automated and context-aware systems, security and threat management, and advanced human interactions; cloud quantum computing – supporting robust encryption and machine learning; even lower latency, and synchronisation to microseconds; high accuracy pervasive geo-location methods – reducing barriers between the physical and virtual worlds; bio-engineering – enabling direct interaction between machine and human systems; and leverage of advanced psychology – supporting machine-enhanced human activities, safety, and intelligent behaviours.

Next generation AI will be a key technology, deployed across edge and core computing domains, supporting both integrated network control functions, such as networks orchestration and QoS management, and intelligent user and machine level services.

AI will build upon dynamic spectrum access introduced in the 5G era to deliver further improvement in spectrum efficiency. In addition, it will allow spectrum refarming to become a parallel process of introducing a new technology and phasing out an older one in an existing band, by mapping spectrum resource to demand and Quality of Service requirements. This could make next generation spectrum auctions a thing of the past.

6G will provide advanced services through combinations of ultra-high definition sensors and devices, edge processing for very low latency, and high accuracy timing and geolocation functions, with core processing to be taken to new levels of machine intelligence. Over the next 10-15 years edge compute could be an interim step towards network infrastructure becoming a set of distributed compute resources, supporting both network and application functions.

Security across the whole system will be critical, and will be embedded in the design. This will require the use of intelligent firewalls, context-aware domain level protection, and advanced cryptography supported by cloud quantum computing.

6G will extend the network to the human scale with wearable sensors and integrated short-range communications. These will support a range of new services including healthcare monitoring and ultra-high resolution 4D interactions.

**Advances will be required in a number of critical areas including cell-less systems, large intelligent surfaces, time synchronisation resolution, geo-positioning accuracy, and sensing (THz).**

## DELIVERING THE 6G ROADMAP

An important objective for 6G needs to be ubiquitous coverage to ensure no digital divide, and where the satellite and terrestrial connectivity is fully integrated and seamless from a user point of view.

It is, of course, all too easy to list out a raft of 'fashionable' emerging technologies. It is also way too early to call technologies, characteristics and use cases '6G'. The right time to close off options should be at the start of the standardisation phase. It will take experience and effort to deliver on the selected options taken into standardisation. We know from the global success of GSM, that collaboration across industry, governments, regulators, and industry bodies was instrumental in driving progress: research cannot be done in isolation.

The 5GIC+ and 6GIC programmes will support commercial 5G and 6G solutions for the periods 2020-30, and 2030+, respectively (see Figure 3).

Funding will be needed to drive this progress. Effort and support will be required to enable collaboration. Cohesion and shared goals will be needed to realise synergies and deliver efficiencies. How can we learn from the past to ensure that research progresses effectively?

Technical standards have for decades provided a platform for the development of mobile systems, ensuring global economies of scale, regulatory alignments, and vendor inter-working. Here the challenges will be retention of ETSI and 3GGP's excellence in standards production whilst ensuring agility and increased use of open solutions, and inter-working across a variety of industry sectors.

Effective strategic management of 6G research will be essential. It will only be effective with a hub where decades of experience in bringing together industry and policy makers, and world-class research and commercial strategy, is available. 6GIC will carry forwards the success that 5GIC has enabled. Priorities will be set according to clear commercial potential, in concert with research across other disciplines.

Where it is well-known that incremental cost and effort brings only modest gains, work should proceed cautiously. We see 6G as a fabric and an ecosystem, bringing together a number of new technologies providing ultra-high resolution communications at the edge, supported by massive intelligence in the core. But it must be grounded with well thought-out accompanying economics and commercial strategies.

Also, our strategy has to recognise the commercial pressures that continue to be faced by many in the sector. In many cases, incumbents continue to wrestle with the challenge of revenue leakage to 'over-the-top' and cloud-based providers, whereas innovative start-ups, with new commercial models, are running to EBITDA margins at well over the 30-40% industry norms. Financial valuations reflect both book value, and market value – with harsh reality based on expectations for growth. As ever, innovation is key. 6G must ameliorate not conflate these pressures, ensuring cost efficiency and new revenue potential. More explicitly, where more data or much higher data rates are needed, 6G innovation needs to assist in breaking out of unsustainable business models.

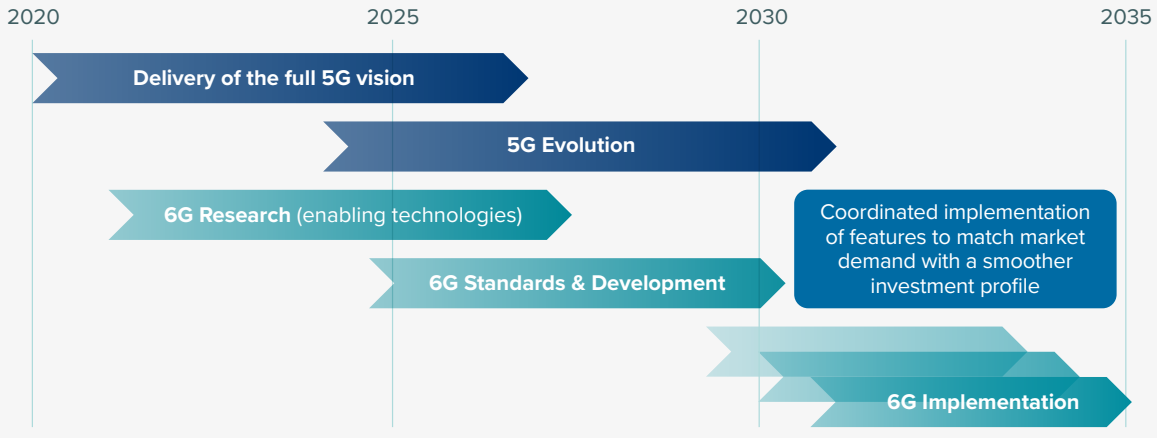



Figure 3: Roadmap timelines

## 5G CONTINUES TO OFFER GREAT POTENTIAL

Our work on 5G will continue, and our vision and support for 5G+ is focused on commercial efficiency and wider accessibility, covering the expected lifespan of 5G technology, from 2020 to beyond 2040. 5GIC will continue to support advances in 5G over the next decade.

The 3GPP technical standards group is continuing its work on 5G[8]; new product developments stemming from Releases 16 and beyond. These are likely to include: vehicle and transport communications (V2X), 5G-based IoT, support for license-exempt and shared spectrum, efficiency improvements, indoor location sensing, carrier aggregation, meshing, private networking, and array antenna enhancements. These all essentially render a more pervasive, flexible, and feature-rich 5G experience. The next wave of 3GPP Releases 17 and 18, currently in planning, can be expected to drive 5G product releases over the 2020-25 timeframe.

**Our 5GIC+ programme will continue research in challenging areas such as: coverage, automated networking, and applications such as e-healthcare, broadcast techniques and Intelligent Transport Systems.**

Looking further, shifts in radio design and architecture can be expected. Mobile radios are already heavily dependent on digital processing, but battery limitations in user devices currently prevent use of fully flexible software defined radios (SDRs). Once these become available, it will be possible for systems to more flexibly support multiple radio interface designs with direct-to-digital operation. Within the network, access to dense fibre networks will support shifting of digital processing to regional clusters, and in turn this will support device connectivity across multiple network sites.

Deeper inside the network and within the cloud, artificial intelligence (AI), self-optimisation, automation, context-awareness, and adaptive network technologies are becoming hugely important. Other key areas will include energy efficiency, advanced co-operative antenna array systems, seamless interworking across different types of networks, and security.

[8] See: **https://www.3gpp.org/release-17**

## CONCLUSION

**5GIC+ and 6GIC welcomes membership from industry and collaboration with international partners who share our vision.**

With 5G now commercially launched, and the complexity in developing new internationally standardised technologies, it is now time to set in motion a programme of research and development towards the next generation of wireless: 6G, likely to be commercialised from 2030 and beyond.

Experience has shown that 'linear' development in wireless systems, with objectives for ever higher data rates, places increased demands on scarce resources such as radio spectrum, and is becoming commercially unsustainable. A new approach is needed, ensuring that a range of developing economic, societal, and commercial challenges, are met.

The University of Surrey's 5GIC will continue to support developments on 5G technology, which continues to offer great potential. 6GIC will leverage beyond this as a global centre of excellence for 6G.

Our vision for 6G redefines teleportation as a new wireless paradigm combining ultra-high resolution and immersive user experiences, integration of human senses and ambient data, and fusion of the physical and virtual worlds, supported by massive machine intelligence, and horizontally integrated networks. 6G must take a new direction, not only to meet new and ongoing market needs, but to ensure feasibility and economic viability.

This will be supported with a ground-breaking programme of work spanning multiple scientific fields and industry sectors. Extending the principles developed within 5GIC, strategic planning, collaboration, and commercial focus will be at the heart of the 6GIC model, ensuring market-driven outcomes and 6G leadership for members.

5GIC+ and 6GIC welcomes collaboration and membership from partners who share our vision.

**We look forward to working with you.**

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