萨里大学 6GIC：6G 无线新战略愿景

临菲信息技术港

英国萨里大学 2020 年 11 月宣布成立第六代移动通信创新中心（6th Generation Innovation Centre，6GIC），并称该中心将专注于将物理世界和虚拟世界结合在一起的先进电信工程，成为全球领先的研究中心。

在 6GIC 之前，萨里大学的 5GIC（5G Innovation Centre）是有名的 5G 研究中心。萨里大学校长逯高清（Max Lu）教授说：“5G 创新中心自 2013 年成立以来，体现了萨里大学与业界合作应对社会和行业挑战的精神，以实现改变生活的创新。今天，我们以 6GIC 确立迈向数字化未来之旅的使命，这是我们未来十年的愿景和研究策略。”

萨里大学 6GIC 发布的 6G 白皮书为“6G 无线：新战略愿景（6G Wireless：A New Strategic Vision）”。

关于该白皮书，6GIC 主任 Rahim Tafazolli 教授说：“我们的行业成员正在告诉我们的是，以更高频段实现更高速率的传统方法正在走向尽头，需要全新的手段来激发新的服务，以应对巨大的全球挑战。6GIC 的白皮书正是阐述了这一新愿景。”

萨里 6GIC 主任 Rahim Tafazolli 教授，建立 5GIC（5G 创新中心）、6GIC 和 ICS（通信系统研究所）并担任主任

“6G 无线：新战略愿景”表明 6GIC 将致力于以下两方面的研究：

环境信息：通过高分辨传感、地理定位和无线技术的集成，支持物理世界和虚拟世界的融合，把连接人类感官与环境和远程数据的数字服务提升到一个新的水平。

无处不在的覆盖：通过显著改善室内覆盖、利用智能表面、以及研究卫星通信技术，使激动人心的 6G 服务无处不在，让数字鸿沟成为过去。

以下为“6G 无线：新战略愿景”的要点（包含原文的 pdf 文档可在临菲信息技术港网站下载）：

背景和趋势

BACKGROUND AND TRENDS

第一代移动通信（1G）是模拟技术；2G 可以提供 100kpbs 以上速率的数据服务；2001 年开始的 3G，采用 2GHz 以上的频段使数据速率达数十 Mbps；2013 年以来，4G（LET-A）可为用户提供数十至数百 Mbps 的数据速率。

在 5G 中，已经开发的 eMBB（增强型移动宽带），是业界追求更高数据速率的直接延续；而 URLLC（超可靠低延迟通信）则为工业现代化开放了巨大的潜力；5G 支持的 mMTC（大规模机器类通信）或物联网（IoT）仍在开发中。5G 的关键创新包括无线设计的增强、更大的天线阵列、允许“切片”的软件网络（网络主动可重配置以支持不同业务的服务需求），以及更高频段和具有适度频谱效率的更多频谱。

这里有一种趋势。 自 1G 以来，大约每十年就会出现新一代的移动技术。每一代移动技术，人们都在追求更高的数据速率，这就意味着需要更多的频谱，也意味着需要更高的频段，而频段越高就意味着在给定成本下的覆盖范围越小；另外，移动性的需求也各不相同，用户现

在可以在各种空间中使用无线服务，从室内到高速车辆。对于每一代新的移动通信，运营商都面临着管理投资回报的更大挑战。 公认的方法是不可持续的，需要新的方法来有效满足发展的需要。

新的全球挑战

NEW GLOBAL CHALLENGES

世界经济论坛《2020 年全球风险报告》将环境因素、信息安全和国际凝聚力列为主要问题。

另外，联合国制定的可持续发展目标，呼吁全球采取行动促进繁荣，同时应对气候变化和环境问题。

6G需要特色

6G NEEDS TO BE DIFFERENT

早期的技术工作已经开始，其想法包括沉浸式扩展现实（XR）、数字复制、无处不在的无线智能、远程呈现技术、全息通信、可穿戴网络、自适应材料，以及使用全新的无线电技术，如支持短距离传感功能的太赫兹（THz）频段。

由于 5G 已经在某些领域大力推动了技术的发展，因此，对于 6G 的发展，必须弄清楚在何处可以获得更大的收益。例如，在物理限制下，从经济角度来看，提高频谱效率越来越困难。频谱的创新使用将仍然是一个关键问题。同时，我们也可以预期一系列新的商业模式的发展。

萨里大学5GIC的新方法

UNIVERSITY OF SURREY 5GIC'S NEW APPROACH

5GIC 将以 5G+继续支持 5G 开发。

6GIC 将是一个主要设立于英国的无线全球创新合作研究中心，涉及政府、监管机构、移动运营商、供应商、企业和领先的研发中心。

6G愿景

OUR 6G VISION

为了实现 6G，需要一个丰富的跨功能的技术和科学研究计划，见下图。

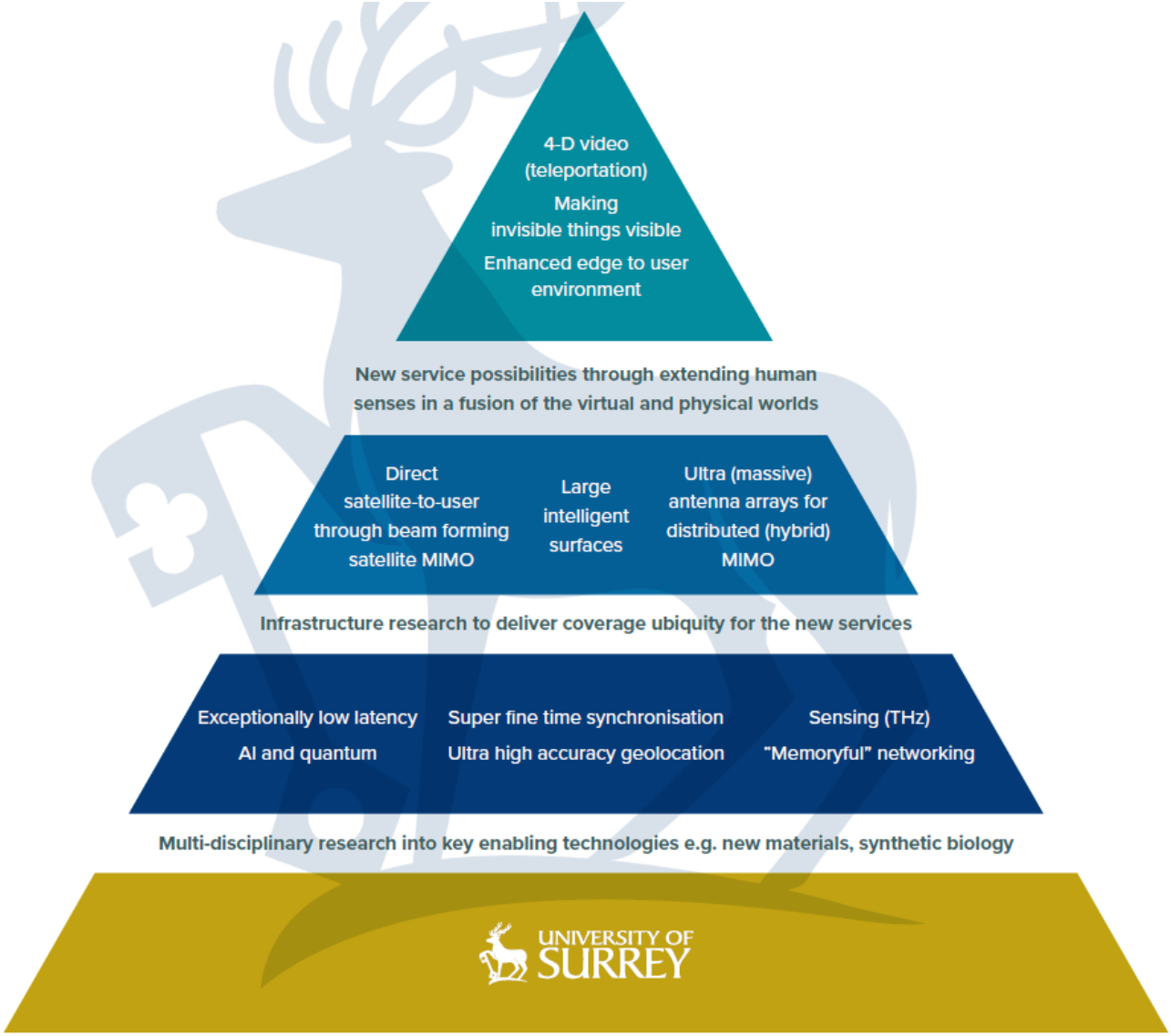

Figure 1: 6G vision supported by new cross-functional research and development programme

6G 将是一个混合网络，包括短程、广域和卫星网络，以及无缝集成和边缘计算的必要使用。它还将 5G 使能服务提升到新的功能和性能水平。见下图：

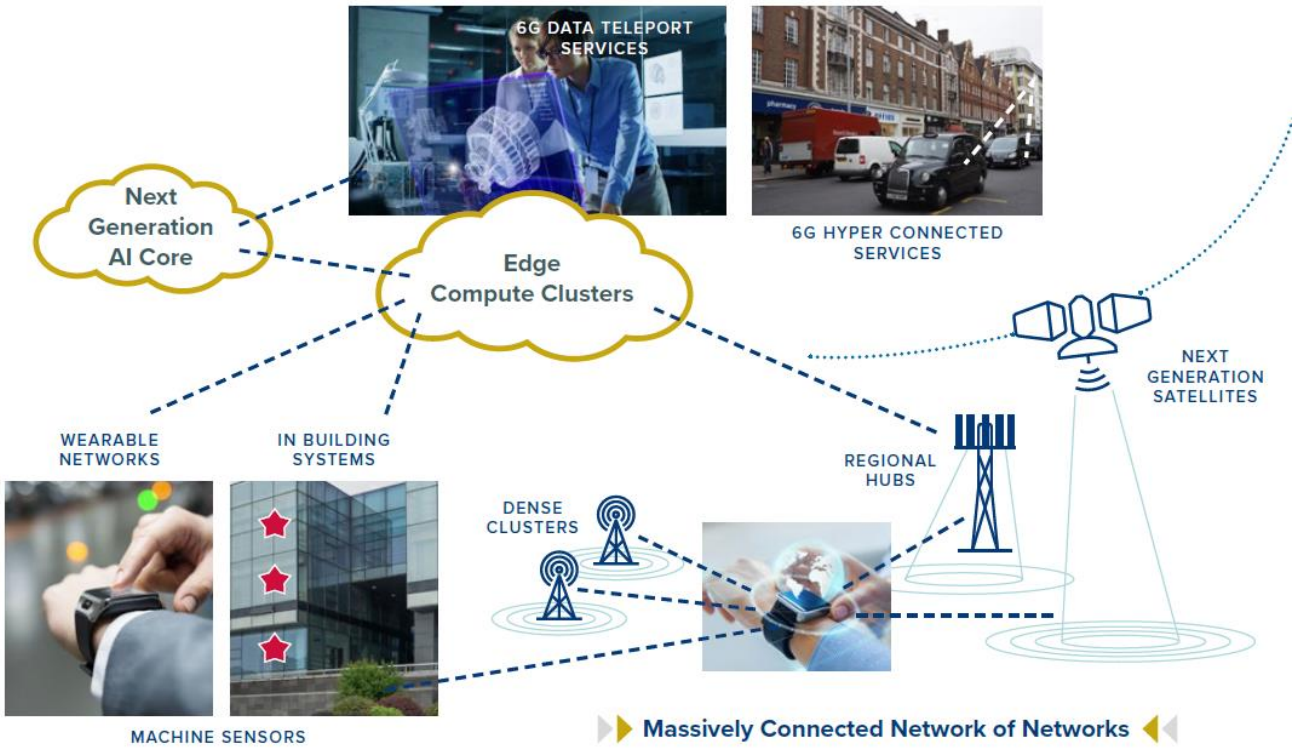

Figure 2: 6G services supported by next generation AI and a network of networks comprising short range, wide area and satellite networks

6G路线图

DELIVERING THE 6G ROADMAP

5GIC+和 6GIC 计划将分别支持 2020-30 年和 2030+年期间的商用 5G 和 6G 解决方案。

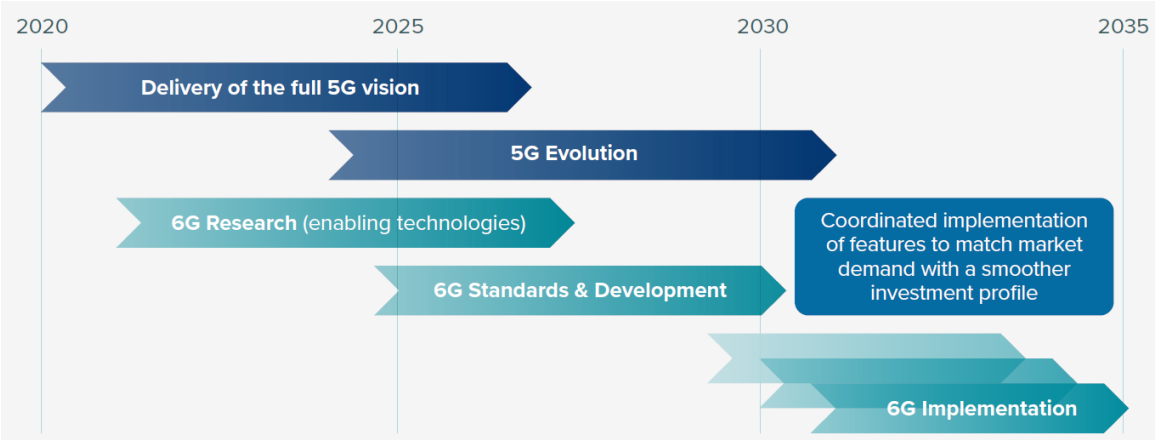

Figure 3: Roadmap timelines

5G继续提供巨大潜力

5G CONTINUES TO OFFER GREAT POTENTIAL

从 2020 年到 2040 年以后，5GIC 在 5G 方面的工作将继续进行，我们对 5G+的愿景和支持将集中在商业效率和更广泛的接入上，涵盖 5G 技术的预期寿命。

目前正在计划中的 3GPP Releases 17 和 Releases 18，预计将在 2020-25 年期间推动 5G 产品的发布。

可以预期，无线电设计和架构会发生变化。移动无线电已经严重依赖于数字处理，但是当前用户设备的电池极限，使得不能应用充分灵活的软件定义无线电（SDR）。一旦这些技术可行，系统将更灵活地支持直接数字操作的多无线接口设计。在网络内部，密集光纤网络的接入将支持数字处理向区域集群转移，进而将支持跨多个网络站点的设备连接。

结论

CONCLUSION

我们的 6G 愿景将远程传输重新定义为一种全新的无线模式，它结合了超高分辨率和沉浸式用户体验、人类感官和环境数据的集成、物理和虚拟世界的融合，并得到大规模机器智能和横向集成网络的支持。6G 必须采取新的方向，不仅要满足新的和持续的市场需求，而且要确保可行性和经济生存能力。

附：6G Wireless：A New Strategic Vision （原文）

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UNIVERSITY OF SURREY

6G WIRELESS:
A NEW STRATEGIC VISION

5GIC Strategy Advisory Board

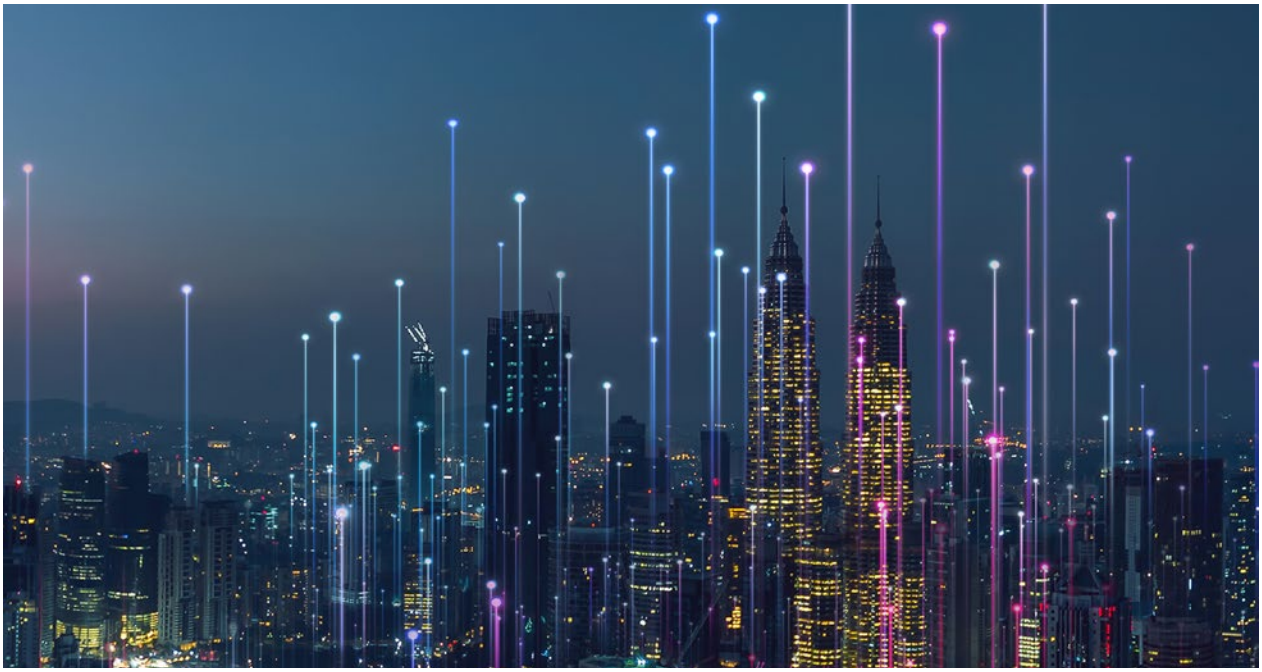
6GIC

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/**

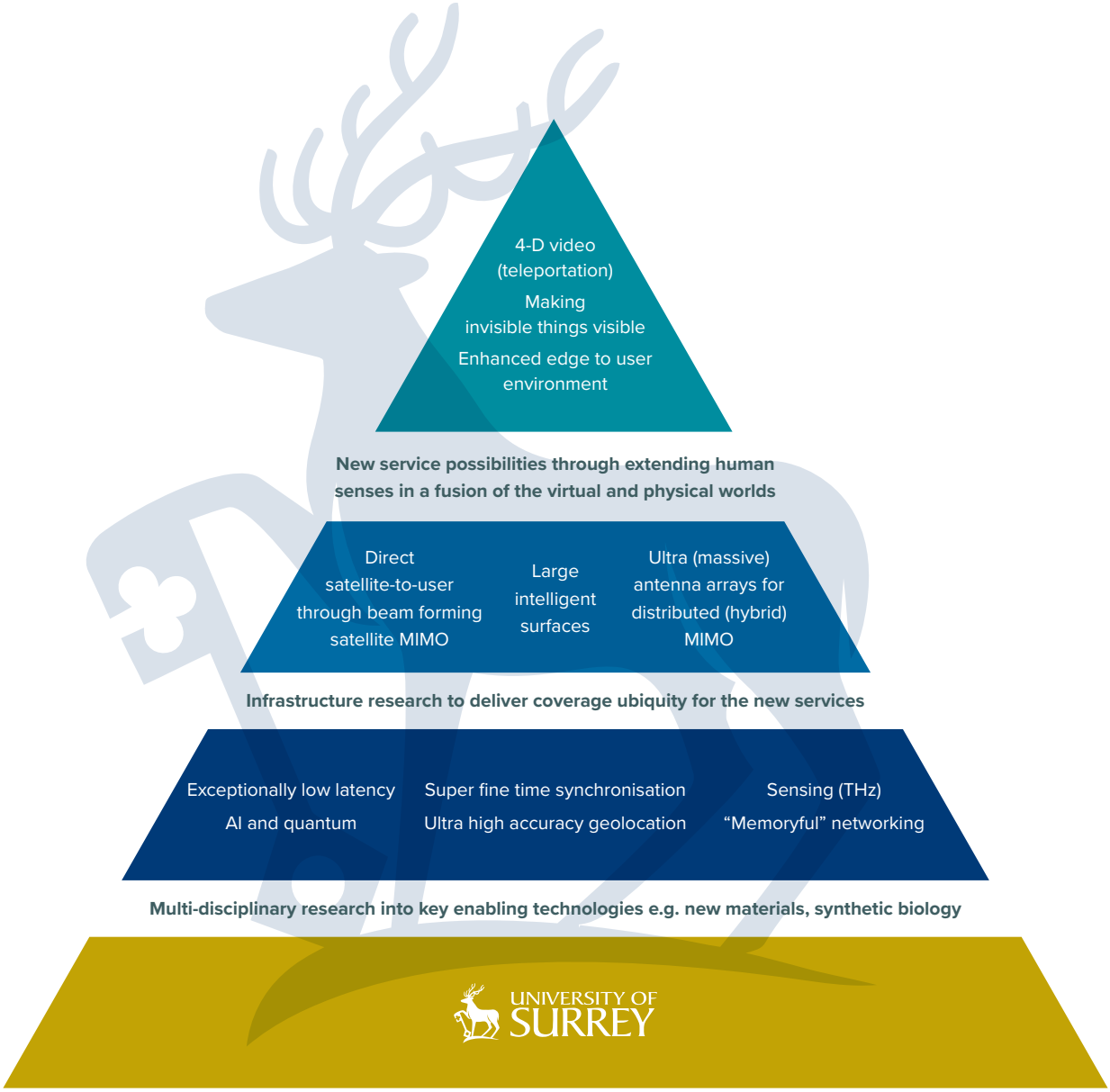


Figure 1: 6G vision supported by new cross-functional research and development programme

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**

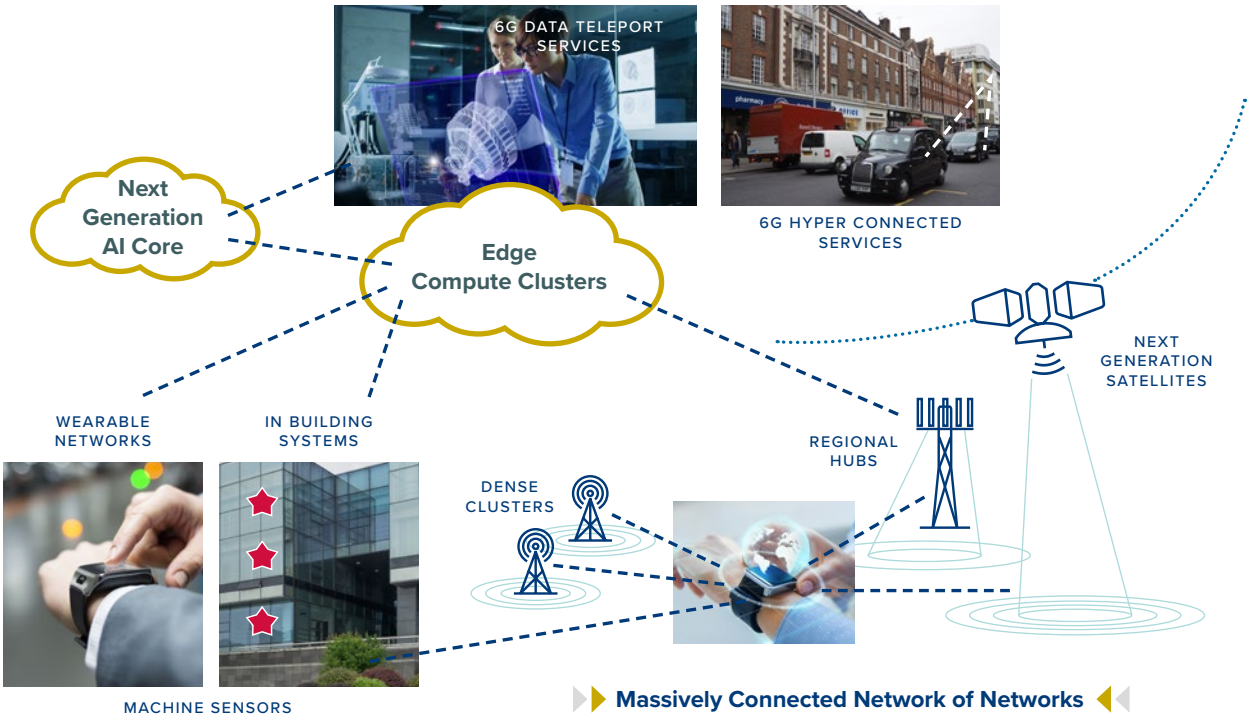


Figure 2: 6G services supported by next generation AI and a network of networks comprising short range, wide area and satellite networks

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.

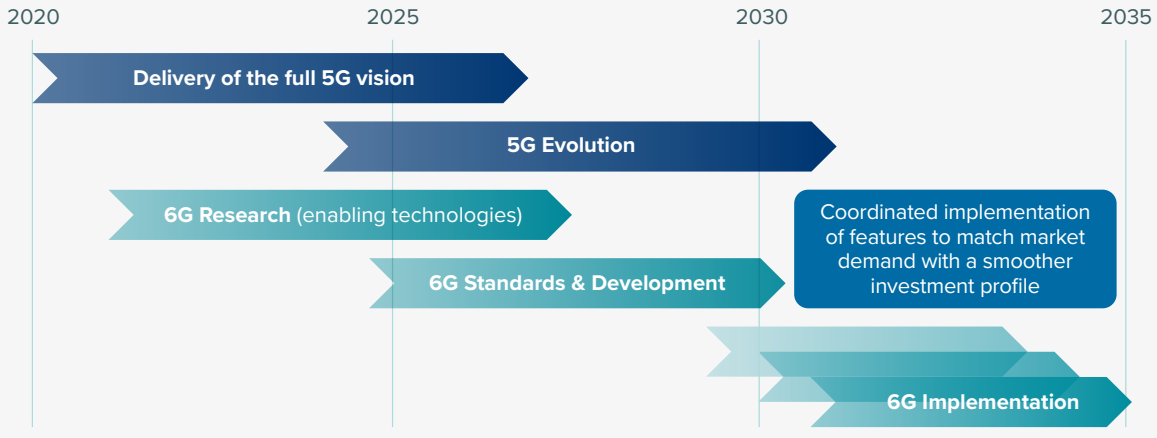


Figure 3: Roadmap timelines

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.

Contact

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