The Institution of Engineering and Technology

6G for policy makers

An IET guide on shaping the direction of the evolution of wireless-based services, networks and technology over the coming 20 years

theiet.org/digital

6G for policy makers is published by the Institution of Engineering and Technology.

Please note that the views expressed in this publication are not necessarily those of the IET. The guide only intends to identify the relevant issues and provide an informed starting point for a policy debate around the topic and not a definitive solution.

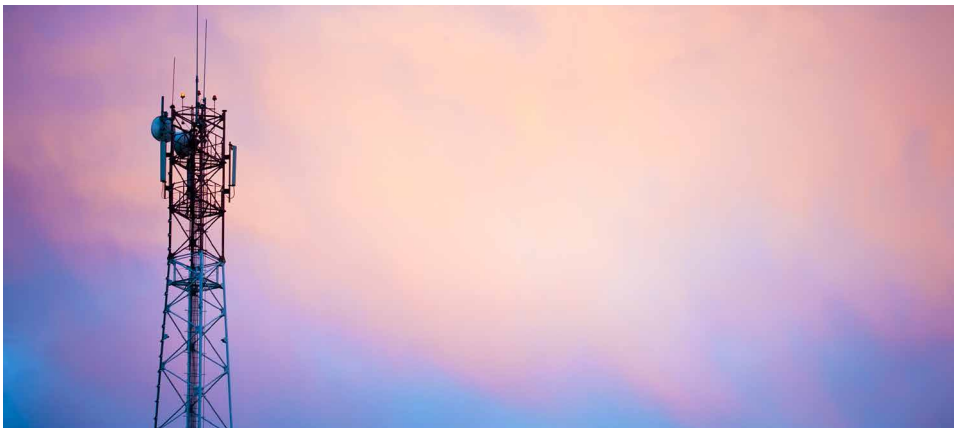
The IET Digital Panel would welcome any comments you may have on the contents of this guide, and your ideas for future digital publications. Please get in touch by emailing sep@theiet.org.

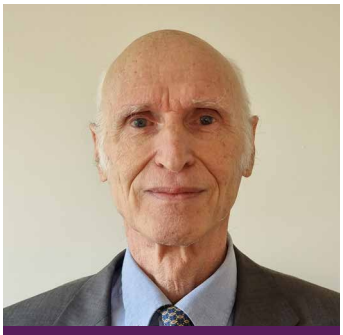
The Institution of Engineering and Technology

The Institution of Engineering and Technology (IET) is working to engineer a better world. We inspire, inform and influence the global engineering community, supporting technology innovation to meet the needs of society. The Institution of Engineering and Technology is registered as a Charity in England and Wales (no. 211014) and Scotland (no. SC038698).

Contents

1. About this guide





Guide editor
Prof Stephen Temple
CBE, FREng. CEng FIET.

This IET guide aims to show policy makers the longer-term opportunities 6G provides to improve on today's national wireless infrastructures.

The '**next generation**' of mobile technology has become a prize the global wireless industry awards itself every ten years. Vendors secure a new market, mobile operators reduce the risks of introducing technology disruptions, countries see sustained investment in national wireless infrastructures and its global scale guarantees that the benefits will be affordable to consumers.

The common thread amongst generations has been the relationship between a handful of key vendors and their principle customers; the mobile operators. What has varied considerably has been the engagement of policy officials.

The purpose of this guide is to equip these policy makers with an understanding of the opportunities from 6G to shape a better future, national wireless infrastructure and inform research priorities.

This guide is timely as 6G is currently a blank sheet. Conversations are just starting in various parts of the world, and these will begin to define what sort of 6G emerges a decade from now.

2. Recommendations

Below are our recommendations for a successful 6G initiative:

1. The traditional approach to a next generation mobile technology – seeking ever higher data speed in ever higher spectrum bands – is no longer sustainable. A new approach to mobile generation change is needed in which 6G breaks out of this unsustainable business model.

2. A high ambition should be set for 6G, inspired by societal challenges such as sustainable economic growth, pandemics and climate change. To this end, 6G needs an adequate pre-standardisation research phase.

3. 6G should be the catalyst to bring everything that needs to be modernised at the same time. The principle justification for inclusion should be the need to sustain interoperability or secure global scale economies through a coordinated introduction of common standards.

4. The research phase of 6G needs to be guided towards building a consensus on the most promising lines of research. This is to secure scale while keeping the door open for 'left field' breakthrough discoveries. A promising candidate is the Internet of Senses; arising from the fusion of the physical, digital and non-physical worlds. The research phase should be viewed as a competition of ideas with the standards body pulling the best ideas into standardisation.

5. 6G should be planned and implemented as a rolling programme of improvements well into the late 2030s to smooth out the investment profile.

Role of governments and regulators.

6. 6G initiatives offer a good framework for governments to consider the long-term goals for their national infrastructure. It should embrace digital and communications infrastructures and a future converge, fixed mobile world, in which mobility will always be an important component.

7. Governments need to engage with industry from the outset to shape the right conditions to sustain long-term research and, eventually, new investments in upgrading national infrastructures.

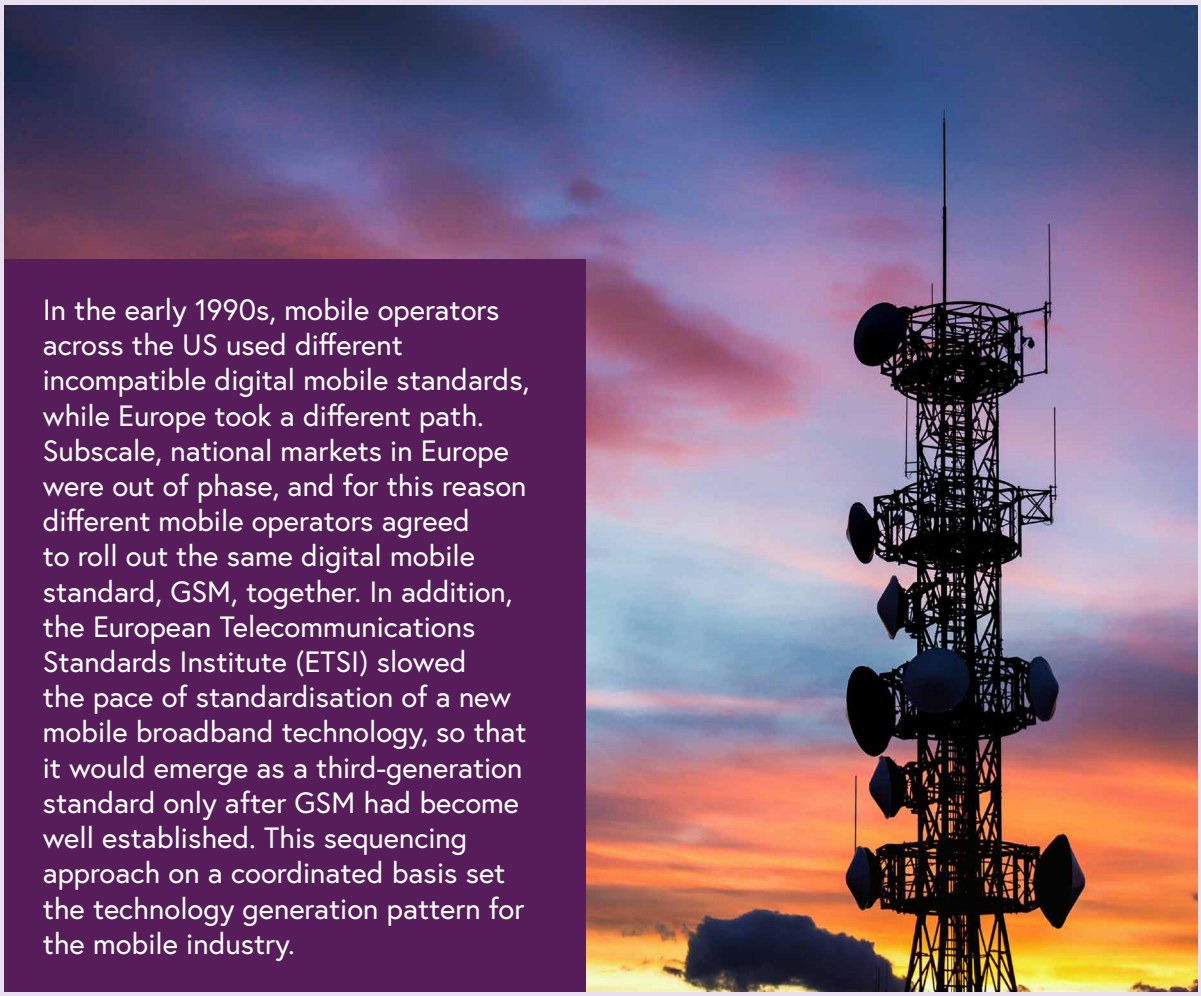
8. A successful 6G mobile infrastructure will need a supportive 6G spectrum policy. This especially needs to drive far more effective use of bands below 6GHz that are particularly suitable for wide area coverage.

9. The competitive market and industry will inevitably look vastly different 10 to 15 years from now. The most impactful benefit of 6G to consumers, and national economies, will come from regulation and 6G technology innovation developing in sync.

Modernisation of the standard's body.

10. The 3rd Generation Partnership Project (3GPP) standards body must modernise to meet the challenges of the next 10 to 15 years. Its founding fathers, the regional standards bodies, seem best placed to do this. The General Assembly of the European Telecommunications Standards Institute should be encouraged to initiate some early thinking on what reforms may be needed to global standardisation, so that 6G builds upon current excellence.

3. Introduction



In the early 1990s, mobile operators across the US used different incompatible digital mobile standards, while Europe took a different path. Subscale, national markets in Europe were out of phase, and for this reason different mobile operators agreed to roll out the same digital mobile standard, GSM, together. In addition, the European Telecommunications Standards Institute (ETSI) slowed the pace of standardisation of a new mobile broadband technology, so that it would emerge as a third-generation standard only after GSM had become well established. This sequencing approach on a coordinated basis set the technology generation pattern for the mobile industry.

There has been debate around whether 5G should be the last of the "mobile generations" and even whether a better innovation model might be competing proprietary standards that one observes in the computer industry. Many attempts to introduce proprietary standards into the mobile network market – such as WiMax and WiBro – have failed. The reason behind this is mobile network operators' loyalty to the standards developed by the 3rd Generation Partnership Project (3GPP) global standards body. Applying these has reduced investment risks, enabled roaming and guaranteed massive economies of scale.

Global scale economies translate into low prices for consumers and stimulates take-up. Support for this successful approach remains strong but the traditional goal of every higher data rates in every higher spectrum bands may no longer be viable. 6G will need new thinking that considers the fresh challenges ahead, as well as factoring in lessons learnt from the past.

4. The case for change

A significant driver of mobile technology generation changes has been the quest for ever higher data speeds. This has been a good thing, as higher cell data rates also mean higher capacity. 3G arrived a few years ahead of market demand, 4G a few years behind – at least in Europe – and 5G looks to be just about right.

Higher data speeds, however, require wider channels that can only be accommodated in higher frequency bands. These make wide area coverage much more expensive as the frequencies have a much shorter range. This has led to a shrinkage in national coverage of the higher data speed capability.

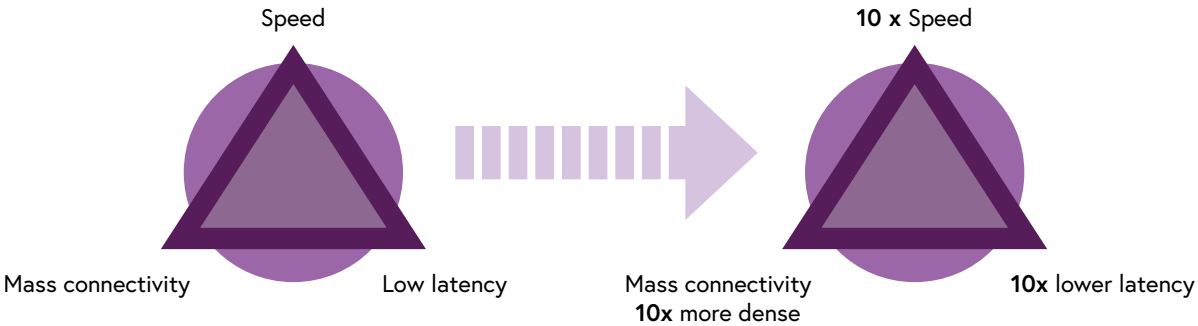
The risk of continuing with this path is that the outcome becomes less and less a 'mobile' service. The switch back in Europe from 26GHz to 3.6GHz as the prime pioneer band for the roll out of 5G enhanced mobile broadband was the first warning sign that the old model is running out of road.

But coverage shrinkage hasn't been the only problem. The high cost of providing even reduced coverage has put mobile operator business models under more and more stress. The majority of consumers have consistently been unwilling to pay for higher data speeds. Competition keeps prices low. Net neutrality regulation prevents over-the-top enterprises, selling high data-consuming services like video, from being charged a carriage fee as they would on satellite or cable distribution networks. The need to use higher spectrum bands to support higher data rates – and the consequential rise in the number of base stations – leads to a sharp increase in investment levels needed for next generation infrastructure.

Today we're at a point where 5G data speeds as high as 1Gb/s are possible in urban areas, but mobile network operators can't justify the necessary investment in dense small cell networks. This sits alongside a recent Ofcom study on coverage obligations, which showed a guaranteed universal data rate of 2Mb/s was all that would be economically feasible to impose.

The traditional focus on ever higher data speeds for a new mobile generation is no longer sustainable. A new approach is needed that positions 6G innovation as an opportunity to break out of this unsustainable business model.

Figure 1: The traditional approach sets arbitrary goals at the start.



5. A new approach to 6G

5.1 Connecting 6G to societal and global challenges

The majority of the value that next generation mobile broadband networks offer society and the economy lies in the applications and services they support. Instead of starting by setting arbitrary 6G technology goals like data speeds, we should begin by identifying where the value is likely to be over the next 20 years.

Technology-led versus market-led is not a new argument, however it's clear that 6G should be outcome-led, rather than predominantly technology-led. This is because, globally, we're all changing how we work, stay safe and play in response to societal challenges such as pandemic control, climate change and sustainable economic growth.

6G infrastructure challenges need to be shaped by identifying what digital and communications networks must be capable of to meet these challenges. This approach has already been embraced by the European Commission in their 6G research strategy.

Figure 2: 6G spearheaded by services that address the challenges ahead.

https://www.surrey.ac.uk/sites/default/files/2020-11/6g-wireless-a-new-strategic-vision-paper.pdf

5.2 Deciding the scope of 6G

If 6G is to be different, a global consensus is needed from the start on what exactly should be embraced by the term 6G. Everything that needs to be modernised together should be brought together. 6G should include digital, communications and sensing infrastructures and a future, converged fixed mobile world in which mobility will always be an important component.

The principle justification for inclusion should be the need to sustain interoperability or secure global scale economies through a coordinated introduction of a common standard. A high bar should be set in justifying adding in anything that's not backwards compatible.

The three characteristics essential to a 6G initiative are to be open, inclusive and global.

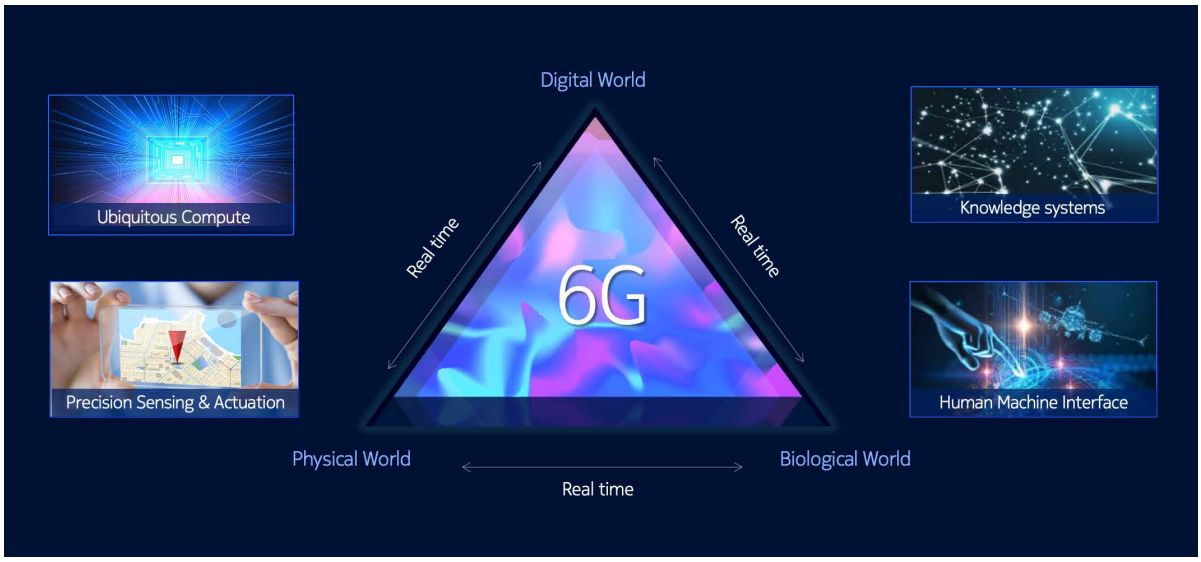
5.3 New 6G services within the fusion of virtual, physical and non-physical worlds

Long-term 6G research needs to be thought of as a competition for the best ideas. These can then be taken into standardisation further along the road map.

That said, collaborative research is essential to control costs and this requires a consensus on the best areas to explore.

Digital technology is increasingly offering a fusion of the physical and virtual worlds. The integration of high-resolution sensing, geolocation and wireless technologies will enable a new level of digital services that merge physical and virtual experiences and link human senses with ambient and remote data. If synthetic biology is added into the 6G fusion mix, the potential for new 6G services looks highly promising. See figure 3.

Figure 3: Nokia's vision of 6G unifying the experience across the physical, digital and non-physical worlds.



5.4 Infrastructure priorities

A new 6G infrastructure is likely to be added to rather than replace the 5G infrastructure in place beyond 2030 to bring new capabilities that 5G cannot be stretched to meet. These have yet to be identified. However, we already have sufficient evidence that coverage of high-performance mobile connectivity will lag behind other improvements.

Therefore, we can currently put delivering high capacity, ubiquitous coverage at the top of infrastructure research priorities. In the past, satellite advances have travelled down their own road map. 6G provides an opportunity for a far more integrated approach.

5.5 Enabling technologies

In policy terms it's helpful to set potential 6G services and technologies within a strategy context. The 6G spear proposed by the University of Surrey 6GIC is helpful in doing this (See Figure 4).

The 6G spear model shows the research being spearheaded by the services 6G will enable. The top triangle aligns with Nokia's vision illustrated in Figure 3. Similar visions for 6G are coming out of major research centres around the world.

The middle layer is a statement that these new services need to reach everyone and everywhere. The base is the long lead time enabling technologies. Figure 4 is only intended as a shop window of some of the more promising technologies.

Projects that draw on these technologies in a combination, to deliver new service possibilities such as 4D video, will be invaluable in pacing and purposing advances in enabling technologies.

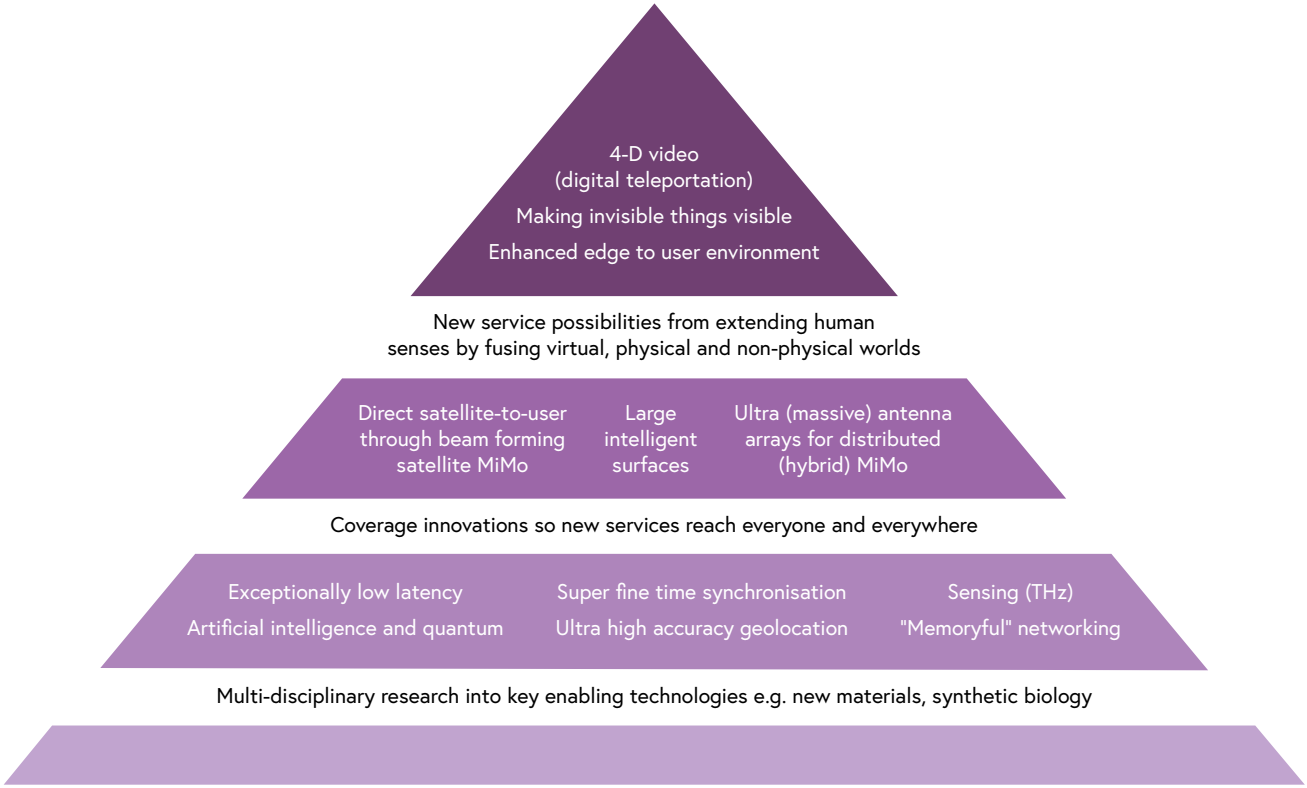
5.6 Net-zero carbon emission goal

Having an aspirational goal for 6G to contribute to net-zero carbon emission is only useful if it gets delivered. There's not a lot of evidence of this being the case for 5G, so how could this be improved with 6G?

The long odds solution is a technology breakthrough. The short odds solution is to treat net zero as a revered design parameter, much as the wireless industry has always treated spectrum efficiency. This goal should be considered whenever different technical options are evaluated. The cumulative impact of this could be significant.

It's useful to note that energy efficiency, spectrum efficiency and minimising radiofrequency (RF) exposure all help align the radio component of 6G, as they all demand the lowest RF power level to do the job.

Figure 4: The 6G spear that puts new services at the sharp end.



https://www.surrey.ac.uk/sites/default/files/2020-11/6g-wireless-a-new-strategic-vision-paper.pdf

6. Wider policy implications

6.1 The role of governments in 6G

No single government or company can dictate the final outcome for what has the potential to be the world's largest open "collaborative technology project" over the coming decade. Nevertheless, many governments will engage with 6G in a variety of ways:

1. Often consensus building can begin most easily "at home" and governments are well placed to facilitate this. It will maximise the influence of their research community in the global debate on the direction of 6G.

2. Governments funding national research have it within their gift to make mobile radio research outcomes greater than the sum of incoherent, fragmented parts through supporting regional and international research collaboration.

3. The way in which radio waves travel across frontiers makes "regional" cooperation essential on the new ways mobile bands will be used. Governments and/or national regulators have a role to play here.

4. Governments have a responsibility to ensure long term improvement plans are in place for national wireless infrastructures. 6G has the power to get people responsible for different parts of a national, digital and telecoms infrastructure around the table and work together to synchronise diverse but interdependent upgrades. The 5G label has already shown the value of this.

5. Governments have a role in preparing their industries and society to be ready to take-up and benefit from the 6G technology when it eventually arrives.

Today, governments have a lot of short-term problems to address and, in some cases, this is squeezing out capacity for long-term thinking. This guide is intended as a wakeup call that now is the moment that governments need to begin to be a part of the national, regional and global 6G conversations.

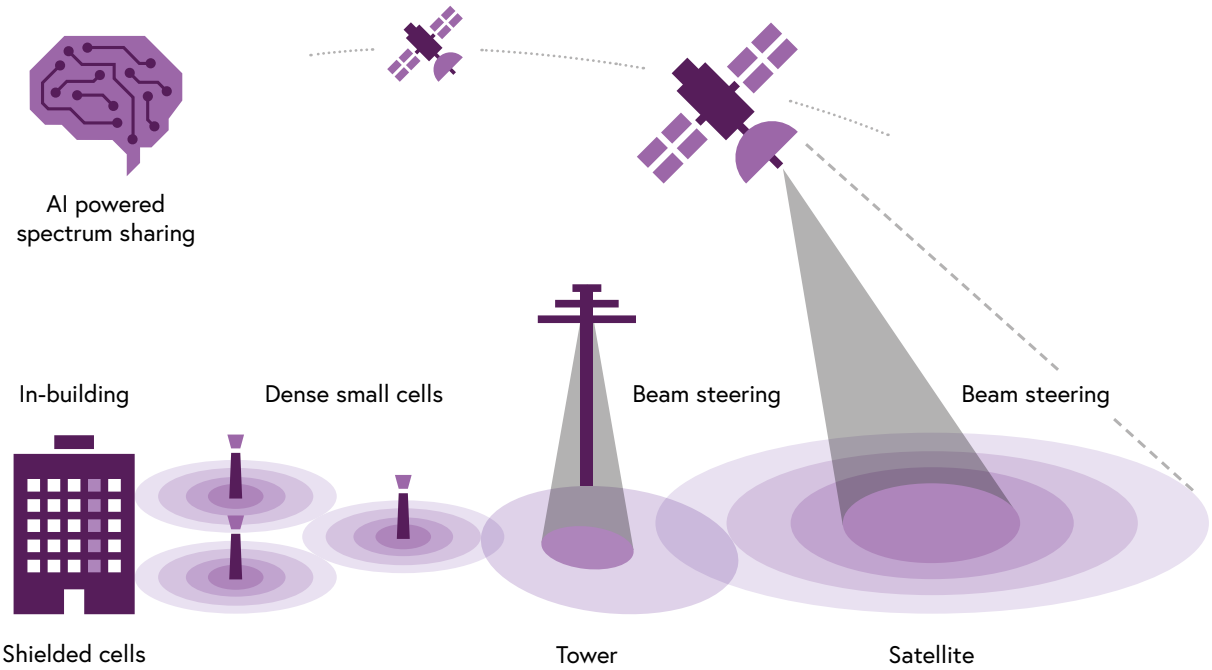
6.2 Radio spectrum policy

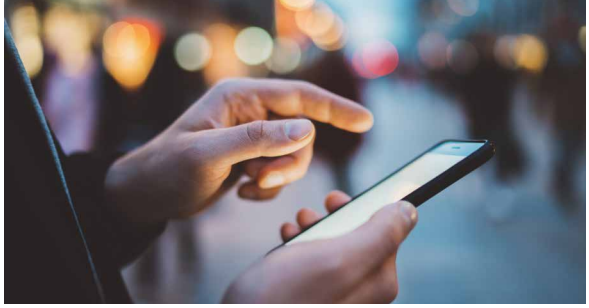
The promise of a mobile network has always been to deliver connectivity everywhere, all the time. This requires pervasive wide area coverage. For this reason, it's no longer useful to look higher in the spectrum for the next generation mobile band. In particular, terahertz bands are not viable mobile bands. However, they fit well with a 6G vision of integrating short range radar with short range communications; to enhance the edge to user environment, for example.

A supportive 6G spectrum mobile policy should firmly focus on advancing the effective use of bands below 6GHz. This will help catalyse:

- **Research into more advanced spectrum sharing** in bands good for coverage. An objective could be to get this down to the Internet Protocol (IP) level.
- **Very long-term replanning** of the international table of spectrum allocations to widen existing bordering mobile bands below 6GHz where possible.
- **Spectrum refarming** to become a parallel process of introducing a new technology and phasing out an older one in an existing band. This would make next generation spectrum auctions a thing of the past.
- **Making ready a common band below 6GHz** for a single frequency network of networks comprised of direct satellite and terrestrial links to a common consumer device.
- **Making ready a common THz band** for a merging of sensing (radar) and very short range communications.
- **Identifying a plausible road map** for getting to a 6G world of artificial intelligence (AI)-powered spectrum sharing, potentially with embedded regulation.
- **Advancing AI-powered 'sleep-mode'** to a whole new level would help both spectrum sharing and net-zero carbon objectives simultaneously, as well as helping allay exposure concerns.

Figure 5: 6G network of networks with AI-powered spectrum sharing.





6.3 Standards body modernisation

Historically there has been strong links between the research community and the 3rd Generation Partnership Project (3GPP). This has worked well, but two challenges lie ahead. The first is the need for the mobile industry to engage more deeply with other industry sectors; ones with quite different standards cultures. The wider the net is cast, the more complex the challenge. Solutions will require new thinking. The second is the emergence of serious geopolitical tensions.

There is change coming. What would damage 6G prospects is to lose the existing standardisation excellence in a chase for something better that's unattainable due to geopolitical reasons.

3GPP emerged through a conference of regional standards bodies and that would be the best group, from the geopolitical perspective, to come together to produce a blueprint that helps 3GPP modernise itself. In this way the standards body isn't distracted from its critical operational role of delivering the future 5G releases.

Europe is particularly fortunate in having a regional standards body, European Telecommunications Standards Institute (ETSI), with a superb track record. Its General Assembly, or a high level group spun off from it, might be the best place to begin some early thinking on long-term reforms.

6.4 Regulatory framework for 6G

The most successful periods for the mobile industry have been when regulatory changes were in sync with technology changes. This should be the objective for 6G. Even at this early stage of thinking, some longer-term regulatory issues can be identified.

- In the future, how will regulatory burdens and competitive pressures be equalised between embedded enterprises, such as mobile network operators, and massively dominant players in overseas jurisdictions that play by different rules?
- The future mix of mobile network operator investment, investment by other economic actors, such as building owners, and public subsidy in future wireless infrastructure is likely to benefit from a re-optimised regulatory framework.
- Net neutrality has been good in driving an explosive growth of video streaming over broadband wireless networks, but is there a case to replace it with regulated neutrality, which shares cost benefits more equally in the 6G era?

If a 6G initiative is to connect with the global challenges we face, governments and regulators must engage with industry from the outset to shape regulatory changes that will support the desired 6G technology outcomes.

6.5 Trust and security

It's almost guaranteed that any new digital service of any economic or societal importance will become a target for bad actors to attack. The most acute 6G challenge will result from the need for the various distributed AI locations to work both vertically and horizontally across many commercial boundaries and jurisdictions.

What may be best technically may not be ideal from the viewpoint of trust and security. Quite different AI policy issues arise for the machine-to-machine and machine-to-human interfaces. The right balance will be as much a public policy decision as a commercial or technical one. The lowest costs in meeting public policy demands of trust and security will be incurred if there's the right level of policy and regulatory engagement with the research community very early on.

6.6 Geopolitical challenges of 6G

National industrial politics in the mobile industry are not new. Industrial rivalries in Europe were intense for first generation (analogue) cellular technology. One of the reasons for the GSM standard's success was the common political will to find a time sufficiently far into the future – and a neutral technology space (new digital mobile technology) – where destructive competition could be more readily replaced by fruitful cooperation. 5G finds itself at the centre of even more intense geopolitical industrial rivalries.

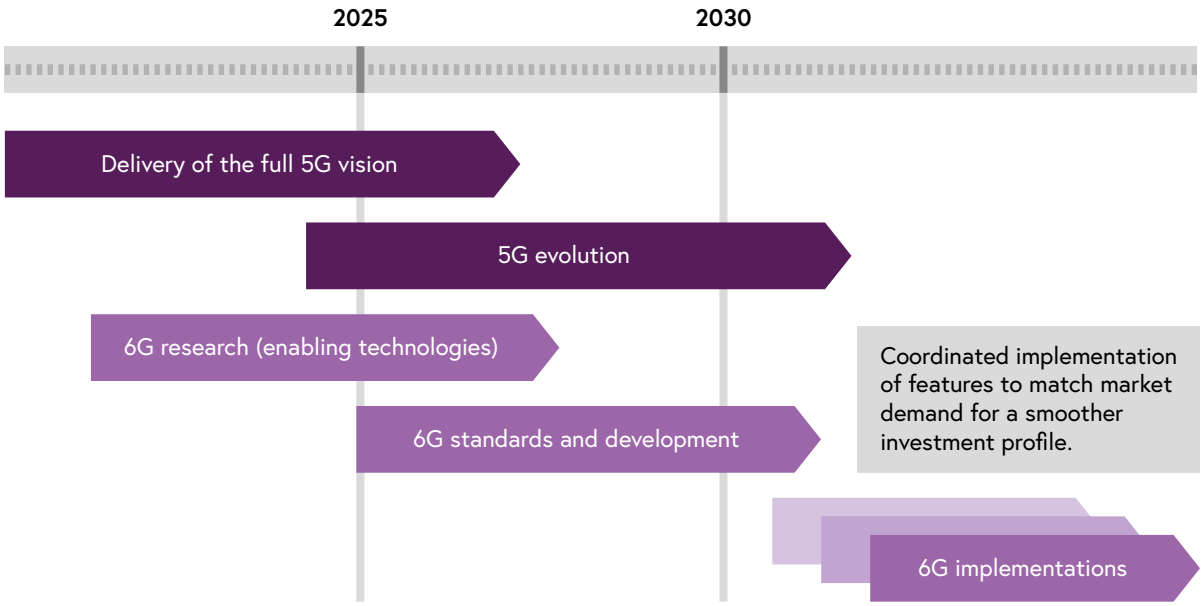
6G offers the possibility to leapfrog these immediate global tensions and find a neutral technology space to reset global cooperation. It's prize worth the effort, particularly as the recommended direction for 6G is to address global challenges like climate change, which affect the entire planet.

7. A timeline of 5G and 6G

Even before anyone knew what 5G was, the first global consensus was that it would be rolled out by 2020. This curtailed the time for basic research and some quite exciting early ideas were abandoned in the rush. 6G needs an adequate pre-standardisation research phase. The right time to begin calling things 6G is only when they are taken into standardisation.

6G also needs to be a rolling programme of improvements that might start from 2030. However, it should also be able to accommodate groundbreaking improvements that might take a further three to five years to come to fruition. This would also help smooth out the investment profile and make standardisation easier to manage.

Figure 5: The parallel 5G and 6G road maps.



8. Conclusion

While some mobile technology generations have been more successful than others, not even one has failed. What makes this nothing sort of a miracle is that they were based on relatively loose cooperation bound only by the sharing of a common goal, a willingness to seek out a consensus and coordinate the new technology's introduction. It is one of the great technology phenomena of the last half a century.

Yet, with the possible exception of 4G, none were plain sailing, and a few came close to collapse. This is a warning that there's no guarantee 6G will be a comparable success, or even happen. It depends upon the willingness of many mobile network operators, system vendors and device suppliers across the world to seek a consensus on the common goals for 6G and a strategy for getting there. This can be substantially helped or hindered by government and regulatory policies.

This guide has set out the policy areas where government and regulatory officials can play a constructive role in shaping a 6G initiative. One that can deliver the advanced services and upgraded infrastructures needed to meet the great societal challenges of 2030 and beyond.

9. About the IET

We are the IET - a charitable engineering institution with over **167,000 members in 150 countries** – working to engineer a better world. Our mission is to inspire, inform and influence the global engineering community to advance technology and innovation for the benefit of society.

As a diverse home across engineering and technology, we share knowledge that helps make better sense of the world to solve the challenges that matter. It's why we are uniquely placed to champion engineering. We bring together engineers, technicians and practitioners from industry and business, from academia and research, and from government and the third sector.

We are member-led, independent and impartial. We cover engineering across industry from design and production, digital and energy to healthcare, transport and the built environment. We champion engineers and technicians by offering networking, volunteering and thought leadership opportunities.

To find out more contact **sep@theiet.org**

The Institution of Engineering and Technology

Our offices

London, UK
T +44 (0)20 7344 8460
E faradaycentre@ietvenues.co.uk

Stevenage, UK
T +44 (0)1438 313311
E postmaster@theiet.org

Beijing, China
T +86 10 6566 4687
E china@theiet.org
W theiet.org.cn

Hong Kong
T +852 2521 2140
E adminap@theiet.org

Bangalore, India
T +91 80 4089 2222
E india@theiet.in
W theiet.in

New Jersey, USA
T +1 (732) 321 5575
E ietusa@theiet.org

@TheIET theiet.org

E6D21002/Digital/0221