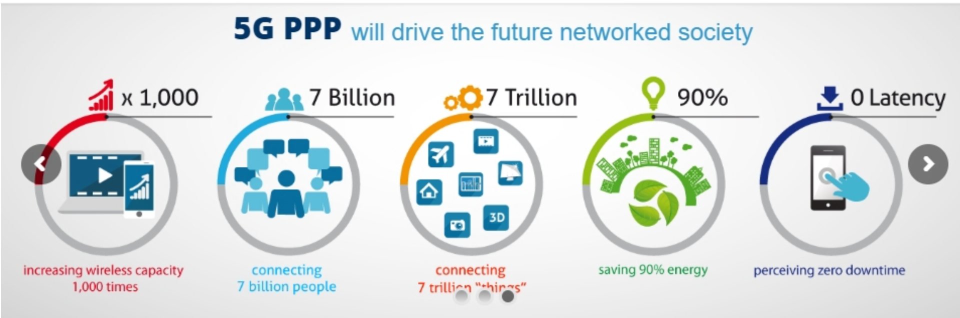
Cutting Through the Hype: 5G and Its Potential Impacts on Electric Utilities

A white paper prepared for the Utilities Technology Council by the Joint Radio Company Ltd

March 2019



Images © 5g-ppp.eu[1]

Utilities Technology Council™

[1] www.5G-PPP.eu *The 5G Infrastructure Public Private Partnership (5G PPP) is a joint research initiative between the European Commission and European ICT industry to deliver 5G solutions, architectures, technologies and standards for the ubiquitous next generation communication infrastructures of the coming decade.*

CONTENTS

Figure 1: Radio Base Station at 5G International Centre (5GIC), Guildford, Surrey, England

IMAGES

A Letter from Joy Ditto, Utilities Technology Council President & CEO

Dear UTC Members and Interested Stakeholders:

Joy Ditto

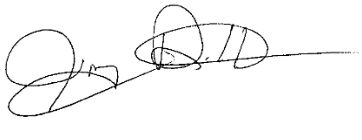
One of the Utilities Technology Council's (UTC) top priorities is to obtain recognition of utility spectrum requirements at the highest policy and regulatory levels both globally and in the U.S.

Therefore, on behalf of UTC, I am proud to release this report on the potential impacts of 5G wireless service on electric utilities. In reading this paper, it will become clear that the emerging 5G arena is a global issue akin to the next space race. It follows that, as the association representing the interests of electric, water, and natural gas utilities in their provisioning of Information and Communications (ICT) networks around the world, UTC commissioned this whitepaper to determine how electric utilities, in particular, might approach both the potential benefits and challenges of the expected transformations enabled by 5G.

This report is intended to frame the issue rather than provide a comprehensive plan or policy approach, although we anticipate that additional research, planning and recommendations will flow from it. In the meantime, UTC will continue to support our members to ensure that their requirements play a significant role in shaping the regulatory and commercial development of the 5G ecosystem. We are already participating on the global stage regarding the identification and alignment of spectrum by attending and presenting papers at the International Telecommunication Union (ITU), as well as in proceedings in individual countries, including the U.S.

As this issue evolves, we would appreciate your engagement and partnership.

Sincerely,



Joy Ditto,
President & CEO
Utilities Technology Council

EXECUTIVE SUMMARY

A. This report seeks to provide the reader with an understanding as to what is meant by 5G, gauge where we are in the development of 5G technology, what might be achievable, what may be beyond the perceivable time horizon, and what is marketing hype, particularly as it relates to the needs of utilities.

B. The vision of 5G is that users will have the impression of continuous connectivity with unlimited bandwidth everywhere. This is the culmination of four decades of technological progress in mobile communications. 5G refers to the Fifth Generation of mobile communication which is being presented as a communications network designed to give users nearly every feature and all the functionality they could ever want.

C. With the potential saturation of human needs for communication, the focus is now switching to machines and sensing. This potentially expands the market to cover every conceivable device on the planet, and every imaginable parameter.

D. In this environment, utilities are one of the prime targets for 5G applications as the energy sector has increasing requirements for monitoring and control driven by regulatory and commercial pressures given that the ways in which energy is generated and consumed are changing rapidly.

E. As with any new technology/evolution, much is promised but there is little evidence against which to judge these claims.

F. The big issues for utilities are cost, reliability and confidence in the supply chain. It is important to note that the availability and resilience of a communications system is more a feature of network design, operation and maintenance than it is of the technology employed. There is nothing inherent in 5G to make it more reliable and resilient than previous generations of technology; on the contrary, there is the potential that the extra infrastructure – located closer to the end service points - needed to provide 5G promises will increase the cost of enhancing reliability. Since all modern communications networks are software controlled, this must also be recognized as a common-mode failure point, especially with the increasing complexity of modern software systems.

G. Another major issue is security. Any wireless network is open to monitoring over the air, interception and/or tampering. However, provided the security system is designed with this vulnerability in mind, the network could potentially be better secured than legacy systems.

H. The report also looks at 5G applications and markets, suggesting where utilities might fit into these ecosystems. Cognizance is taken of the international situation with different constraints on spectrum availability in different geographic regions and markedly different starting positions and customer densities.

I. The various policy issues surrounding 5G and its deployment are discussed, together with opportunities for utilities to participate in the 5G revolution, both from the perspective of taking services from, and contributing to, the 5G infrastructure build.

J. Finally, conclusions are drawn, including the possibility of disruptive intervention coming from developments in the satellite sector and the roll of fiber in 5G.

> ***"Capacity, not speed, that will be the truly revolutionary aspect of 5G networks."***
>
> Dave Dyson, CEO of Three (Hutchison 3G UK Limited), December 2018.

1. The Purpose of this Paper

5G is heralded as the "must have" wireless technology igniting the world. The U.S., Europe, China, the rest of Asia and even the Arab world are competing to become world leaders in this new technology. Indeed, one could summarize the world's current perspective on 5G as, "we don't know what it is, but we must have it."

> ***"5G - we don't know what it is, but we must have it."***

One 5G vision sets an ambition to enable a world where everything is provided wirelessly to the end device by a converged fixed and mobile infrastructure that works everywhere. 5G infrastructure should be far more demand/user/device centric with the agility to marshal network/spectrum resources to deliver "always sufficient" data rate and low latency to give the users the perception of infinite capacity. This offers a route to much higher-performing networks and a far more predictable quality of experience that is essential for an infrastructure that is to support an expanding digital economy and connected society.[2]

5G is the next generation of mobile broadband that will eventually encompass all mobile connectivity. If we are to believe the hype, with 5G, we will see exponentially faster download and upload speeds; latency - the time it takes devices to communicate with each other - will also dramatically decrease and the density of connections will be massive.

This report describes what 5G is and assesses the likely impact and implications of 5G on utilities.

2. What is 5G?

5G is the term used to describe the next-generation of mobile networks. There is not, as yet, an "official" definition of 5G; however, while previous generations of mobile phone technology were purpose built for delivering communication services (as detailed below), 5G appears to be driven by use cases such as smart cities, smart grids and smart agriculture.

Previous generations of mobile communications have focused on a single technology or closely related system:

- 1G: The original analogue mobile phone technology introduced in the 1980s, typified by the "Advanced Mobile Phone System" (AMPS) and the derivative "Total Access Communications System" (TACS).
- 2G: The second-generation digital cellular telephony standard Global System for Mobile communications (GSM) introduced in the 1990s, enhanced by the

2 The Vision of the 5G International Centre https://www.surrey.ac.uk/5gic/5g-vision

"General Packet Radio Service" (GPRS) and further by the "Enhanced Data-rate for GSM Evolution" (EDGE).

- 3G: In the 2000s, the International Telecommunication Union (ITU) supported a set of standards that enhanced the data capacity of 2G to enable mobile Internet access, fixed wireless Internet access, video calls and mobile TV to be realized, although the data rates could not support widespread uptake of these services.
- 4G: In line with previous generations of wireless development on a roughly 10-year cycle, 4G started to become widely deployed in the 2010s. As opposed to previous generations of mobile telecommunications which were built on the foundations of the old concept of circuit-switched telephony, 4G is built around Internet Protocol (IP) technology with data-rates capable of delivering a sustainable mobile internet experience. The prevalent 4G technology is now "Long-Term Evolution" (LTE).

5G therefore follows this 10-year generation cycle, realistically being a technology for the 2020s. And as with previous generations of wireless networks, although countries, networks and vendors are seeking to brand their offerings as "5G," it is likely to be another 10 years before 5G achieves the reliability, penetration and costs associated with previous generations.

> ***"5G is more than just a generational step; it represents a fundamental transformation of the role that mobile technology plays in society. As demand for continuous connectivity grows, 5G is an opportunity to create an agile, purpose-built network tailored to the different needs of citizens and the economy."***
>
> Mats Granryd, Director General, GSMA, 2007

However, unlike previous generations, 5G is a vision – the perception of unlimited bandwidth everywhere – and a combination of technical features rather than a single new wireless technology.

There will be a new 5G radio air interface coming - NR or New Radio. Current 4G/LTE standards only extend to 6 gigahertz (GHz), with maximum carrier bandwidth of 20 megahertz (MHz). 5G NR envisages a maximum channel bandwidth of 100 MHz up to frequency bands including 6 GHz, increasing to a maximum channel bandwidth of 400 MHz above 6 GHz. Ultimately, it is foreseen that 5G NR frequency bands might extend up to 86 GHz." But much development will be building on existing technology and honing of existing techniques, such as:

Figure 2: 5G New Radio Spectrum

- Carrier aggregation – the ability of a device to use several radio frequency bands at the same time to increase speed and reliability.

- Data rates on a wireless network previously only associated with fixed fiber networks.
- Very dense connectivity, either people or devices – enhanced mobile broadband (eMBB) and massive Machine Type Communications (mMTC).
- Massive MIMO – Multiple Input Multiple Output – combining a large number of antennas, possibly up to 256 antennas in an array to increase the capacity of a wireless data system.
- Seamless roaming – the ability to roam from one type of network to another without user intervention or awareness.
- Exploitation of millimeter wave radio bands for mobile use which previously have only been used for fixed networks.
- Ultra Reliable Low Latency Communications (URLLC) for critical applications.
- Network slicing, extending the concept of "Virtual Private Networks" to the mobile world so that users have an apparently separate private network with defined parameters which actually operates over a public mobile network.

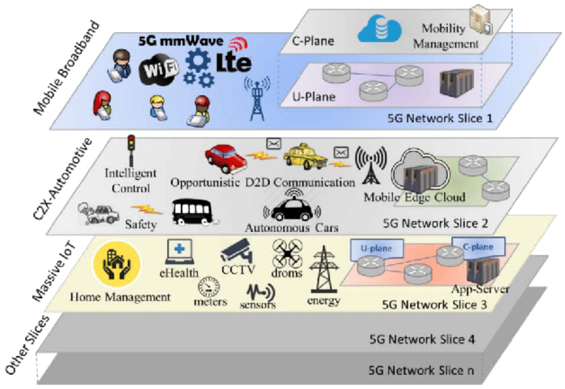


Figure 3: Network Slicing Graphic from paper by Samdanis, K & Costa-Pérez, Xavier & Sciancalepore, Vincenzo. (2016). From Network Sharing to Multi-tenancy: The 5G Network Slice Broker. IEEE Communications Magazine. 54. 10.1109/MCOM.2016.7514161.

> ***"Technologies for 5G and future generations of connectivity, when deployed in the 2020s, will provide higher bandwidth and lower latency than current-generation 4G technology. "5G and Beyond" will enable bandwidth in excess of 100s of Megabits per second (Mb/s) with latency of less than 1 millisecond (ms), as well as provide connectivity to billions of devices. Most importantly, these technologies are expected to enable fundamentally new applications that will transform the way humanity lives, works, and engages with its environment."***
>
> IEEE 5G AND BEYOND TECHNOLOGY ROADMAP WHITE PAPER

These features will not all be ready for delivery simultaneously. Applications will use a subset of these features tailored to their specific requirements as illustrated in the ITU graphic (Figure 4).

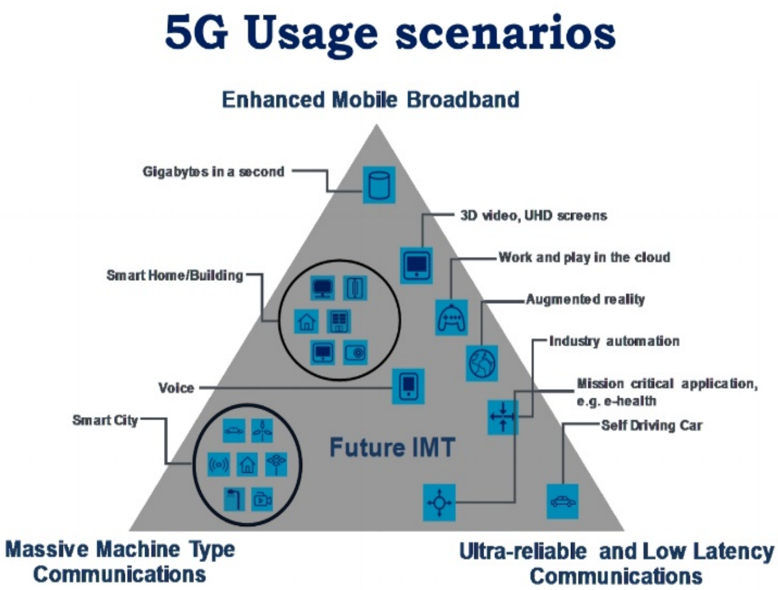


Figure 4: 5G Usage Scenarios

5G itself is not a technology, but service delivery is via a network, be it a private or public network, delivered over licensed or unlicensed (more correctly termed "license-exempt") radio spectrum. It is envisaged that 5G will ultimately embrace both terrestrial and satellite provision; and have services delivered via a network, or peer-to-peer like Bluetooth.

3. Evolution Path of 5G Relative to the Standards and Services of 3G/4G and 5G Standards

The 5G vision was established within the International Telecommunication Union (ITU) which is a specialized agency of the United Nations that develops technical standards for communication technologies. The ITU also sets frameworks for regulations regarding radio spectrum usage, telecommunications standards and interoperability.

The ITU Radiocommunication sector (ITU-R) has the lead role in 5G development through its Study Group 5, Working Party 5D (WP5D), together with other standards bodies, e.g. the European Telecommunications

Standards Institute (ETSI) and 5GPPP[3]. From a spectrum access perspective, this work will feed into the 2019 World Radiocommunications Conference (WRC 19) Agenda Item 1.13. Based on this work, 5G developments have progressed in the U.S. and Europe. In the U.S., developments have focused on commercial operators whereas in Europe the focus has been more on industry vertical markets such as automotive, health care and utilities.

The ITU has distilled these applications into three broad usage specifications:

- Enhanced Mobile Broadband (eMBB)
- Ultra Reliable and Low Latency Communications (URLLC)
- Massive Machine-Type Communications (mMTC)

This process began in 2012 when the ITU created a program called "International Mobile Telecommunications (IMT) for 2020 and beyond" (IMT-2020) to research and establish minimum requirements for 5G. In 2017, after several years of work, the agency created a draft report with 13 minimum requirements for 5G. Once the ITU had set the minimum requirements for 5G, the 3rd Generation Partnership Group (3GPP), a collaboration of telecommunications standards organizations, began work on creating standards for 5G. In December 2017, 3GPP completed its Non-Standalone (NSA) specifications, and in June 2018 it followed up with its standalone specifications (SA).

Both NSA and SA standards share the same specifications, but NSA uses existing LTE networks for rollout while SA will use a next-generation core network. Carriers are starting with the NSA specification so that subscribers will fall back on 4G LTE in a non-5G environment.

The standards set by 3GPP closely correspond with IMT-2020 performance targets with the overall objective of delivering:

- Peak data rates of up to 20 gigabits per second (Gbps) downlink and 10 Gbps uplink per mobile base station.
- Individual subscriber data rates of up to 100 megabits/s downlink and 50 megabits/s uplink speed.
- Latency of 4 milliseconds in ideal circumstances and 1 millisecond for special conditions.
- Radio interfaces should be energy efficient when in use, and switch into low-energy mode when not in use, ideally within 10 milliseconds of usage ceasing.
- Spectral efficiency (i.e., the optimized use of spectrum or bandwidth so that the maximum amount of data can be transmitted with the fewest transmission errors) greater than LTE with a target of 30 bits/Hz downlink and 15 bits/Hz uplink.

[3] https://5g-ppp.eu/

- Capable of supporting mobile connectivity up to 500 kilometers per hour (310 mph).
- Connection density of up to 1 million connected devices per square kilometer.

The original scope of 3GPP in 1998 was to produce technical specifications and reports for a 3G Mobile System based on evolved Global System for Mobile communications (GSM) core networks, but it has been so successful that the subsequent growth of mobile telecommunications has developed through this process.

3GPP progresses through a system of "releases" which package together updates to the standards in an organized and regimented manner. It has thus been agreed that any product in conformance with Release 15 or later is officially "5G" [4] (Figure 5).

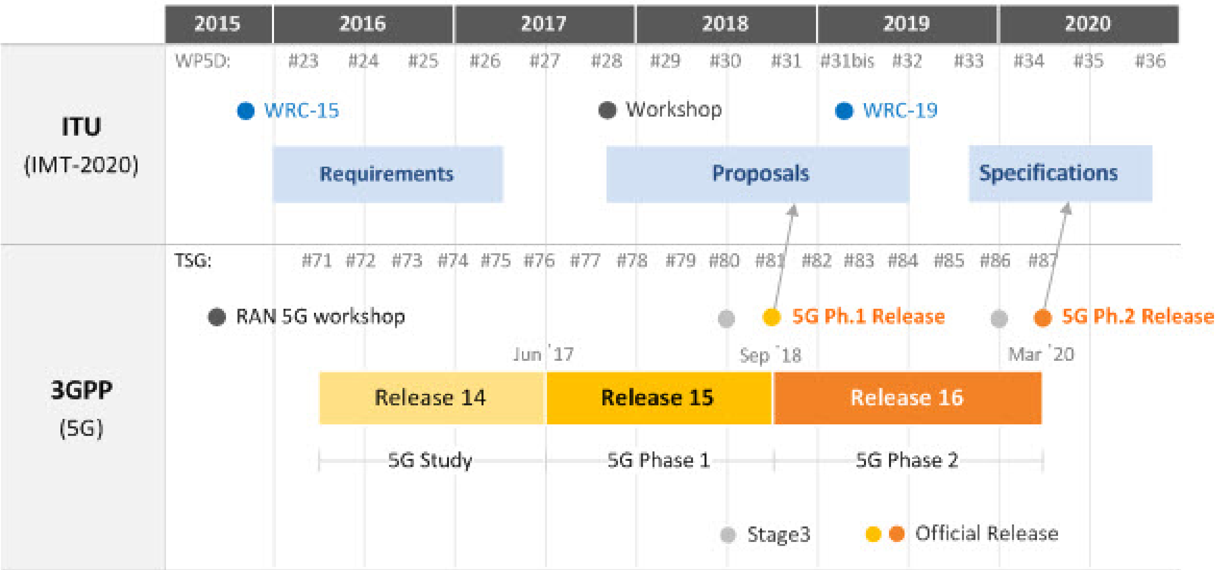


Figure 5: ITU & 3GPP Timeline Graphic

4. Launch Target Markets and Other Markets

What will drive the 5G Market?

Mobile voice telephony was the application which drove the large-scale adoption of first-generation mobile networks – 1G, the so called first "game changing" technology. 2G/GSM brought wide-area roaming, texting and extended battery life in small handsets. 3G showed us what data on the move could look like, but it took 4G/LTE to actually deliver mobile internet capability. The question therefore becomes, "what will be the 'killer application' to drive the 5G market?"

Since more than half the world's population already has a mobile device, 5G must compel them to want more data at higher data rates. If the benefits of enabling

[4] http://www.3gpp.org/about-3gpp

devices to communicate with each other can be made sufficiently compelling, machine-to-machine would also be attractive as there are far more machines and devices in the world than people. Finally, wireless may be able to challenge fiber to replace high speed fixed connections with the new millimeter wave radio bands.

In this context, it should be noted that many current 5G millimeter wave deployments are very similar to what is conventionally known as "fixed wireless access," networks delivering bi-directional high bandwidth data from a fixed base station into fixed receivers on customer premises. This may be particularly compelling where there is little legacy copper or fiber connectivity into domestic dwellings.

5G use cases include:

- Improved Broadband
- Autonomous Vehicles
- Public Safety & Infrastructure
- Remote Device Control
- Healthcare
- Internet of Things (IoT)

5G applications being envisioned include:

- Real-time interactive gaming
- Virtual reality on the move
- Downloading 4k resolution feature films in seconds
- Remote healthcare
- Driverless cars

The challenge, as always, is how to monetize these applications.

High-data rate 5G networks using millimeter wave technology will require much denser infrastructure – dense networks of small cells, an order of magnitude greater than currently. This presents enormous challenges in finding sites, powering the base stations and backhauling the data.

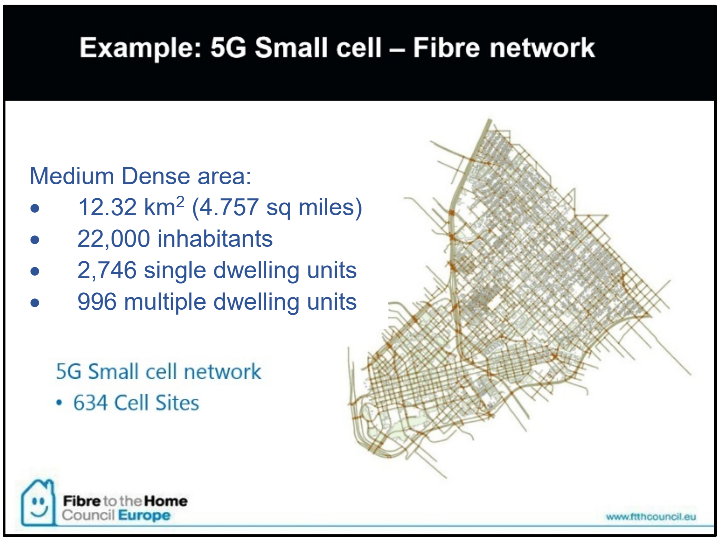


Figure 6: 5G Small-Cell Fiber Network

The backhaul will have to be either in-band wireless or dense fiber, or a combination of the two. The Fibre to the Home Council in Europe has developed models as shown in Figure 6 to illustrate the densification of wireless networks required for 5G with 634 base station sites required in the relatively small geographic area depicted and the consequential need for dense fiber backhaul.

People may be persuaded to pay more for mobile connectivity, but it is unlikely this will provide the revenue to build these new networks, hence new vertical markets must be developed.

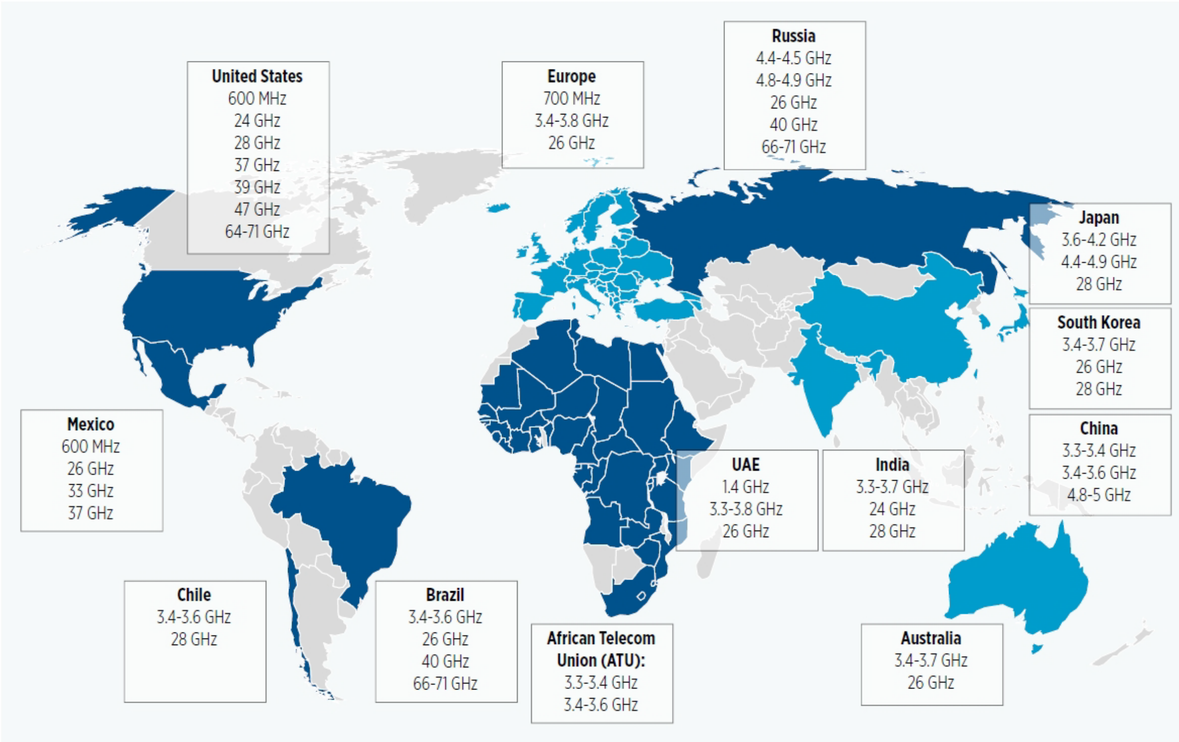
5. What Spectrum Allocations are being Used for 5G

As you can imagine 5G requires significant amount of spectrum.

Many countries and regional organizations have identified and allocated spectrum for terrestrial (as opposed to satellite) 5G. Unlike LTE, 5G operates in three different areas of the radio spectrum. While this may not seem important, it will have a dramatic effect on users' experience of 5G:

- Lower band sub 1 GHz spectrum - 600/700 MHz: These UHF bands will form the foundation of the wide-area coverage for 5G for rural coverage and building penetration. They cannot provide the high capacity needed for dense environments, but they travel well over undulating terrain and can penetrate or circumvent many man-made and natural obstructions. In addition, in a multi-carrier type scenario where a network is using several different frequency bands to deliver the required data rate (carrier aggregation), a base band is needed to co-ordinate traffic to and from the mobile terminal at the higher frequencies.
- Mid-range 3.4-3.6/3.8 GHz: This band will handle the bulk of the traffic. Just above the UHF band, it does not penetrate obstructions well, and cannot bend its way around obstructions to a great extent, but nevertheless it can carry a significant amount of traffic and is more suited to the small antennas which are necessary in devices carried about the person (smart phones, watches, etc.).

Figure 7: Summary of Priority Frequency Bands for 5G in Select Countries



Source: TMG.

- Super high frequency 24-28 MHz: These millimeter wave bands (mmWave) carry the vast amounts of data forecast to be necessary for the densities supported by 5G, but they are easily blocked by obstructions and do not travel very far within the earth's atmosphere (even though they can travel thousands of kilometers through space). The major drawback of high-band is that it has low coverage area and building penetration is poor. Since high-band spectrum trades off penetration and user area for high speed and coverage area, small cells are required to enable network functionality.

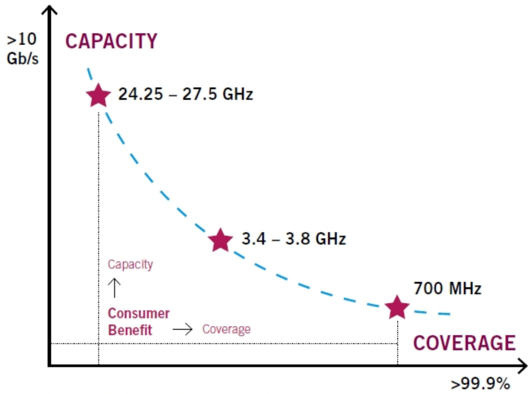


Figure 8: Purely Illustrative Curve to Show How the Spectrum Band Choice Shapes the Network Capacity or Coverage Outcome

Developments in worldwide spectrum policy take place in the ITU's World Radiocommunications Conference. The next conference, WRC19 scheduled for November 2019 will take place over four weeks in Egypt. The agenda was set at the last WRC in 2015, and Agenda Item 1.13, the identification of "pioneer bands" in Europe and spectrum release plans in the US will qualify the extent to which 5G bands and their roll-out have the potential to support the needs of utility applications across their operational network footprint. [5]

The Utilities Technology Council (UTC), with support from its global regions[6], are undertaking a concerted effort to raise the importance of radio spectrum for the monitoring and control of utility networks at WRC19 with the long-term goal of obtaining recognition of the need to identify harmonized spectrum for utility operations on a global basis.

New spectrum: Bands under study for WRC-19

Existing mobile allocation	No global mobile allocation
24.25 GHz – 27.5 GHz	31.8 – 33.4 GHz
37 – 40.5 GHz	40.5 – 42.5 GHz
42.5 – 43.5 GHz	
45.5 – 47 GHz	47 – 47.2 GHz
47.2 – 50.2 GHz	
50.4 – 52.6 GHz	
66 – 76 GHz	
81 – 86 GHz	

Figure 9: New Spectrum: Bands under study for WRC-19

Although the main focus for 5G is on licensed spectrum, operators are intending to continue to offload traffic onto Wi-Fi networks wherever possible to increase network capacity using both 2.4 GHz and 5 GHz spectrum. As future unlicensed bands are added to the portfolio, it is likely these will be assimilated as well.

6. 5G for Mission-Critical Applications

5G is highlighted as a solution for critical applications such as those needed for utility operations where reliability is paramount. These center on the Ultra Reliable Low Latency Communication (URLLC) profile of 5G with latencies around 1-2 milliseconds (ms). Other discussed and potential use cases include:

- Autonomous vehicles with driverless cars interacting with one-another and the road infrastructure.
- Real-time train control.
- Remote surgery with medical specialists operating on patients many miles away using robotic surgery.
- Remotely piloted aircraft.
- Factory and industrial automation.

Whilst the 5G standard is intended to offer the functionality/characteristics to support mission critical systems such as those operated by utilities, we will demonstrate below that there are major questions about how 5G systems might be deployed in an appropriate manner to address the needs of the utilities.

An example is the prospect of using the URLLC feature headlining 1-2 ms latency for teleprotection, a system for monitoring electricity transmission lines that requires communications latencies down to 6 ms for the most demanding applications.

---

[5] IET "5G Networks for Policy Makers"
[6] UTC's global regions include UTC America Latina (UTCAL), European UTC, and Africa UTC

Light travels about 300 kilometers or 186 miles in a millisecond – a thousandth of a second. Radio, being essentially a similar type of electromagnetic wave, travels at a similar speed through the atmosphere. In contrast, light travelling in a fiber-optic telecommunications cable may only be travelling at 2/3 of the speed of a radio wave in the earth's atmosphere, the equivalent of 200 km or 120 miles per millisecond. This may not be an issue in most low latency applications, but in teleprotection terms where end points are separated by a substantial distance, a dedicated utility fiber connection may be adequate , but a 5G network where the backhaul cable does not take a direct route, and signal processing and coding times have to be taken into account in the journey means 5G is unlikely to be able to meet an electricity utility's end-to-end latency requirement over a wide area.

Even if the 5G network were optimized for this particular application by deployment of infrastructure closer to the end points, the costs of this additional equipment would be prohibitive if only required for this specialist application.

7. Opportunities for Utilities to Operate Private Networks within a 5G Umbrella Network

Despite these challenges, there may be opportunities for private networks to be deployed utilizing 5G technology to deliver the critical operational telecommunications needs of the energy utilities. They are likely to be part of multi-band systems to support a range of functionalities seamlessly across private/public networks.

Initially, 5G networks will be built in areas of high-density usage, such as sports and music venues, shopping malls, university campuses, airports and railway stations. Because these 5G hot spots will not cover large areas, they will have to be integrated into wide-area 4G LTE networks, and capable of accommodating Wi-Fi hotspots in coffee houses, etc. Thus, integrating private LTE or 5G networks with public networks should also be possible.

If the vision of industrial and factory automation is realized, a whole factory or industrial process would not want its critical telecommunications dependent on a service delivered by a remote third-party telecommunications network but would want to own and possibly operate its own private (non-carrier provided) 5G networks. Indeed, as the market develops, if 5G becomes as indispensable as forecast, it is likely that venues such as airports, shopping malls and sports stadia will want to own the 5G networks on their premises.

This would be a logical progression in the development of the telecommunications market. The disaggregation of the market is seen in that telecommunications operators increasingly provide the network, but not the services running over the network. This trend will accelerate with 4G and 5G networks being data only (not having a native voice or text service as in 1G/2G/3G). We already observe a trend where innovation in services and profitability are derived by 'over the top' applications which do not typically make contributions to the cost of the network, such as Google, Amazon, Facebook, Uber, Air bnb, instragram, Twitter, etc. With digital data becoming the most valuable element in a telecommunications network, the future may well see property owners not being willing to allow commercial carriers to operate telecommunications networks on their properties unless they can derive some financial benefit from the data generated therein.

Business models for mobile broadband are becoming increasingly complex, and utilities will have to find their place in this market.

8. Will 5G be Implemented in South America & Larger Economies in Southern Africa?

Every developed country in the world is eyeing 5G development, almost akin to the latter-day space race. The table below, produced by the EU Commission's 5G observatory, illustrates a snapshot of the developed markets timelines.

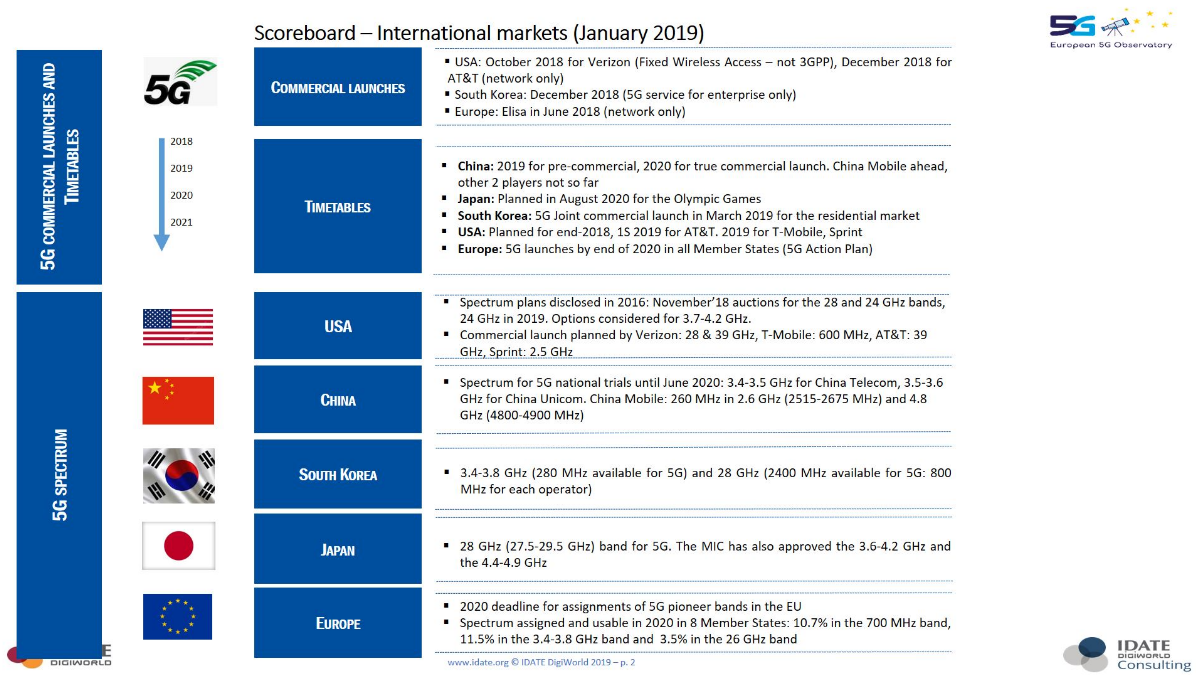


Figure 10: Scoreboard—International Markets (January 2019)

Accordingly, it appears that at least two countries within UTC global affiliates, UTCAL and AUTC, will likely not see 5G being rolled out until after 2020. One reason for this was declared by South African Minister of Telecommunications Siyabonga Cwele, who in September 2018 said he would not be releasing 5G licenses until standards have been agreed by the ITU.

In addition, the business case for deployment of 5G based networks across developing economies in South America and Southern Africa is very different to that of the U.S. and Europe because of the limitations of existing fixed communications infrastructure in these territories. We have already observed debates about and a trend of developing countries skipping the universal copper provided telecommunications and broadband stage and going straight to a fiber and wireless delivery model.

As observed earlier, a major issue is the backhaul infrastructure required. If 5G delivers the stated objective of about 1 gigabit/second (Gbit/s) continuous download data rate with a peak of 10 Gbit/s peak per user, the backhaul requirement will be massive, in the region of 100 Gbit/s up to 1 terabit/s (Tbit/s). This is most probably only achievable with fiber backhaul. In developed western economies with relatively substantial fiber coverage, this is technically achievable, but the economics are uncertain. However, in countries with less-developed fiber infrastructure, whether this is achievable is more likely to depend on deployment conditions. If fiber can be strung from existing infrastructure without constraints, or placed in the ground along highways, it may be possible to lay fiber cost effectively to service the growing 5G infrastructure. However, reliability of the backhaul may be in question in this type of environment.

9. Policy Challenges

5G faces some policy challenges which experts in the field are discussing openly in technical briefings but receive little attention in high-profile public pronouncements. A few illustrative examples may help.

Base Station Sites

5G will require many more base station sites, one order of magnitude or more possibly. Finding suitable sites will be a major challenge. Massive MiMo antennas (e.g.,256 separate antennas) required to deliver the advanced beam steering and enhanced data rates may be physically quite large. Technological developments will not be able to reduce their size as space diversity is an essential component, although disguising them or concealing behind other features such as advertising billboards or shop signs is an option in some locations.

Figure 11: Nokia & Sprint 5G Deployment (Source: Nokia)


Figure 12: Environmental Factors Which Might Adversely Influence 5G Base Station Locations

At the higher frequencies being envisaged for 5G (24 GHz and above), physical obstructions and rain become a significant blockage to the wave path, and base station coverage areas are likely to be less than 100 meters. Thus, for example, in many cities where it has been suggested base stations can be incorporated into street lights, trees may well block or diminish coverage, especially when the leaves are wet.

Backhaul

One of the problems with the rapid roll out of existing 4G/LTE networks has been backhaul. Creating base stations with multiple antennas and multi-frequency bands has created the requirement for gigabit backhaul which many existing sites have not been able to accommodate. Ideally, 5G sites will have fiber backhaul, but connectivity with backhaul fiber for the dense network of base stations envisaged for small 5G cells is likely to be expensive, especially in areas not already well served by fiber. One solution may to use high frequency radio backhaul up to 100 GHz and beyond, although at these frequencies (as noted above) obstruction becomes the challenge. "In band" backhaul using the same radio frequency as the link to the consumer device to the base station may make planning easier. In addition, possibly hopping from one base station to another and then into the core in a similar manner as a mesh network may offer low cost solutions at the expense of reduced data rate.

The policy challenge here is the availability of space for these antenna as well as the expectation of reliable electricity service.

Electricity Power Supply

The vast number of small radio sites envisaged will require electricity supply. The cost of installing and maintaining these power sources reliably may create a significant overhead cost. In a world of increasing energy costs and sensitivity to power consumption and emissions, these supplies may need to be metered independently of power supplied to the building or infrastructure to which the base station is attached.

Power Consumption

Related to the power supply issues described above, the power consumption of the dense network of base stations with complex signal processing requirements needs to be assessed. The power consumption of individual base stations must be reduced by an order of magnitude just to keep costs level if the number of base stations increases as predicted. The way in which this is achieved may have an impact on the 5G services utilities might want to access. Two scenarios that might deliver these savings, but also might have a negative impact on the reliability of utility services are:

- Base stations being shut down when traffic is light, either during the night, e.g., midnight to 6:00 am; or when facilities are provided to a venue but not in use, e.g., sports venues. In these situations, it might be conceivable that capacity is reduced by closing down the small cells, retaining macrocells for wide-area coverage, but there are likely to be coverage blackspots from such a strategy.
- Using only renewable/sustainable energy to power base stations with batteries powered by solar cells and/or wind turbines. In these scenarios,

base stations would be planned to a given availability, possibly even 99%, but unlikely to be 99.999% as required by utilities to meet the expectations of their customers and regulators (where applicable).

Radiofrequency (RF) Safety

When mobile phones first started to become commonly used, there was a lot of concern about possible detrimental health impacts from using radio emitting devices for sustained periods close to the body. These fears have largely evaporated in recent years, but the growth of 5G in microwave bands could reignite health concerns. The new 5G microwave bands around 24-28 GHz are 10 times the frequency of previous mobile devices using 800 MHz to 2400 MHz. Determining public response to new technology is always tricky: for example, there were concerns about Wi-Fi in the 2.4 GHz band with some schools initially banning Wi-Fi networks on school grounds, whereas there is no obvious concern about infrared devices at 24,000 GHz or children using pocket flashlights emitting electromagnetic radiation at 700,000 GHz. [Note: the energy density is more important than the frequency.]

Planning Consent/Zoning

Network operators sometimes highlight planning /zoning processes as major constraints on network construction, pressing for automatic rights to attach their base stations to public – or even private – assets at regulated low-cost rates. Although not necessarily a major issue, the fact that operators raise the issue in advance of widespread network rollouts indicates the scale of their concerns. The issue may be more related to the time taken to obtain permits and the bureaucracy involved rather than the on-going cost. In some countries, the regulatory authorities have granted accelerated rights for small cell deployment, but this has become a major issue in the U.S. in recent years as some carriers have sought to bypass local jurisdictions' and even safety processes.

5G carries a risk of traffic congestion such that critical data does not get through within the necessary time frame. Because of the massive potential capacity of 5G networks, this is seen as less of a problem than previous 4G networks, and before them 3G/2G/1G and the original analogue manual telephone service.

Security

Cybersecurity is frequently raised as a major issue for 5G networks, particularly related to equipment vendors, although it is not clear that 5G will be any more vulnerable than previous generations of mobile networks. If all telecoms networks are treated as "untrusted" (which radio networks must usually be as no one can prevent over the air monitoring and attack), then appropriate security measures can be applied to the traffic conveyed via the network.

Denial of Service is a key threat to radio networks which is difficult to counter if the source is radio jamming. However, this can only be a local issue, and is not a likely method for serious attack as it discloses the location of the source of the interference which can then be traced and eliminated.

Traffic Prioritization/Net Neutrality

What still appears to be an issue is the concept of net neutrality and the freedom of a carrier to prioritize one organization's traffic over another. [Not to be confused with priority afforded to different services such that a real-time video call can be prioritized over a video download.]

Some operators claim that they cannot prioritize utility SCADA traffic over email as it is all data; or utility emergency voice over general commercial voice. This is more of a policy or regulatory issue than a technological one. It will be important that utilities stress to regulators that if utilities are to make use of 5G commercial networks, their traffic has to be prioritized. Thus far, utilities have been unsuccessful in efforts treated in the same category as public safety, so it is critical to ensure that the future does not replicate the past.

ITU policy challenges

5G is presented as a global race with those at the back of the pack relegated to nearly third-world status. This has led to the debate in the ITU becoming politicized. In spectrum bands, this relates to:

- The number of bands a chip has to support which is constrained by the capability of the silicon designers; and
- Those bands which are globally harmonized and therefore incorporated into every chip and handset.

At the lower end of the frequency range, 600 MHz/700 MHz appear to be favored bands, although only in developed countries. One might have expected these bands to be a priority for countries with larger geographic land masses to cover as this is easier at lower frequencies, but it may indicate that most countries foresee 5G as a dense urban area technology/hot-spot solution, and are therefore focusing on spectrum more suited to this environment than wide-area coverage which will remain with 4G/LTE for the foreseeable future.

3.4-3.6 GHz is the center of the band on which most international activity is focused, with extensions to 4.2 GHz. There is little resistance to refarming or reassigning this band to 5G apart from "C" band satellite (3.7 – 4.2 GHz) users worried about loss of a valuable band relatively immune to weather effects, but their voice is not powerful enough to resist the 5G steamroller. This was demonstrated recently in a 2018 proceeding in the U.S.'s Federal Communications Commission whereby incumbent 3.5 GHz band's needs were ignored in favor of 5G arguments.

Existing incumbents using WiMAX or LTE in 3.5 GHz bands are less vocal as they may get a windfall commercial gain.

The “pioneer” futuristic region is the microwave or millimeter wavebands of 24-28 GHz where there is intense competition between the U.S., Europe and Asia. Europe is driving hard at 24.25-27.5 GHz as they have a lot of fixed links in 28 GHz, whereas the U.S. has decided on the 28 GHz band. There is potential for a compromise at 26-28 GHz using the top of the European band and bottom of the U.S. band to be within the tuning range of a single device which, as of this writing, may likely be the outcome of the World Radiocommunications Conference in November 2019.

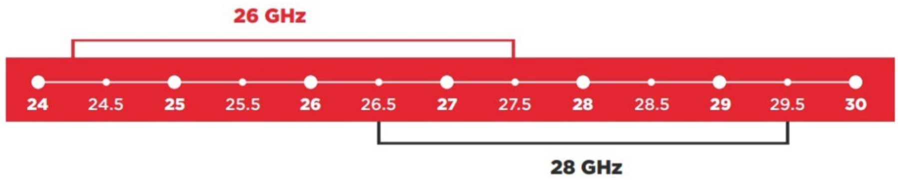


Figure 13: 26-28GHz 5G spectrum bands

Europe has harmonized the 27.5-29.5 GHz band for broadband satellite and is supportive of the worldwide use of this band for ESIM (Earth Stations in Motion, e.g., satellite terminals on trains to deliver broadband internet to passengers). In Europe’s opinion, this band is therefore not available for 5G.

The GSM Association (GSMA), the global trade association for mobile network operators wants the best of both worlds. 26 GHz is one of the bands WRC-19’s Agenda Item 1.13 is looking at. In GSMA’s view:

> “For regulators and governments, it is a great opportunity to lay the groundwork for successful 5G rollouts. At the same time, the global marketplace is driving the need for additional frequencies to meet 5G demands, such as the 28 GHz band. The GSMA recognizes and supports actions by governments and operators in many countries to test and allocate the 28 GHz band for 5G under an existing mobile allocation in the ITU’s Radio Regulations. In the end, it is up to countries to decide how they want to move forward. The important part is that operators get the opportunity to show 5G’s true potential.”

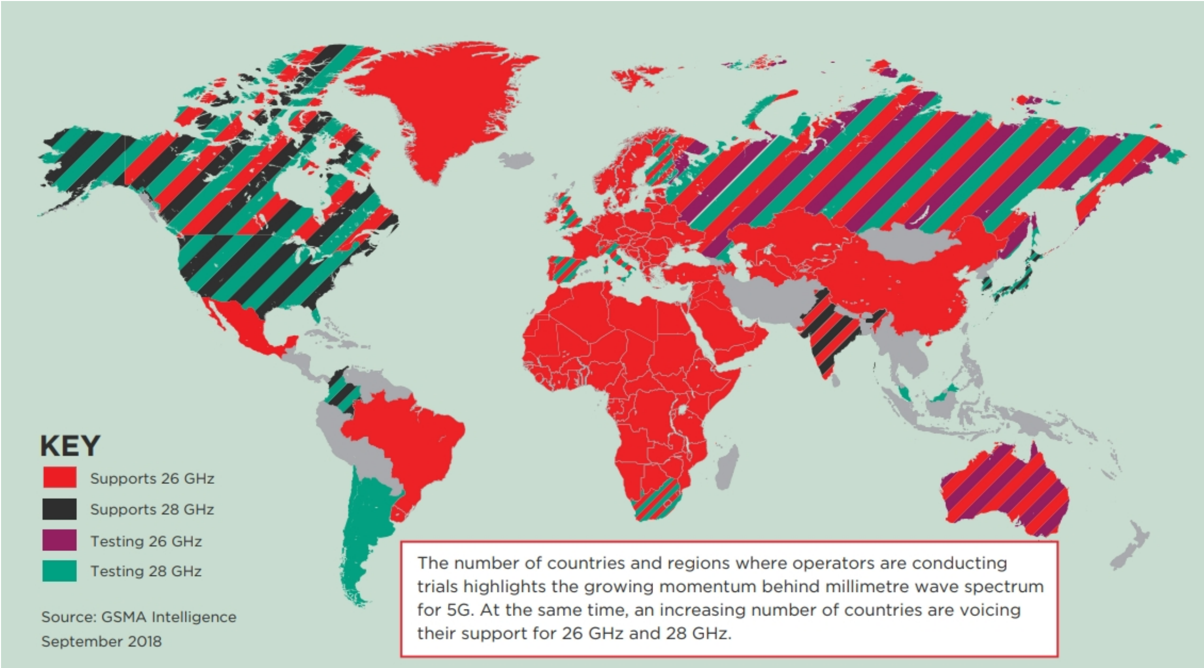


Figure 14: 5G World Map

10. Opportunities for Utilities to Become Involved

Utilities may be able to provide suitable sites, power supplies and backhaul capacity more cost effectively in many areas than alternative operators. Examples may include:

- Joint ventures between utilities and telecommunications providers to deploy fiber backhaul connectivity.
- Provision of utility infrastructure for small cell sites, if safety, electricity reliability, and fair pole-attachment rates are considered.
- Facilitating power supplies to base station sites.
- Utilities providing 5G services to remote locations where they have a presence.
- Sharing spectrum with a commercial carrier so that the utility can lease the spectrum in areas where it is not being used by the commercial carrier.
- Disguising 5G antennas in utility infrastructure, again, where safe, feasible, and affordable.

Participating in 3GPP to standardize the functionality required by utilities would be very welcome by the 5G community, but the level of commitment required to pursue this strategy should not be underestimated. 3GPP advises that:

- The process is contribution-driven: delegates must submit detailed material and respond to other inputs if they wish to achieve their goals.
- 3GPP operates to rigid timescales to which contributors must conform.
- Meetings are organized globally which require representation in person.
- Delegates to meetings need to be well versed in the process and industry they represent and prepared to see the process through to the end.

- The industry must agree on their requirements and priorities amongst themselves.
- Any particular industry must talk to other vertical sectors to develop common requirements.
- Individual vertical sectors must engage with other sectors to develop elements of common interest.
- Complex requirements need to be divided into manageable blocks for standardization.

5G will not by itself solve the rural broadband dilemma or replace fiber.

Justifying the granularity of 5G infrastructure may become a social issue because of the sheer cost of the density of infrastructure needed. Potential revenues in low population density areas (i.e., rural) will not support the required investment by conventional mobile carriers. However, in the same way as rural broadband has become a potentially attractive opportunity for some electric utilities, deploying 5G radio networks in areas which might not otherwise be served may be a beneficial service enhancement for power utilities, especially where the utility already has fiber connectivity

11.. Opportunities for Utilities to Use 5G

Network operators need new sources of revenue to fund 5G networks. Their offerings to utilities include "Ultra Reliable Low Latency Communications" (URLLC) and massive Machine to Machine Communications (mMMC). It is not clear that there is a business case for utilities to become engaged in processing the volume of data generated by mMMC to better inform electricity network operations, and it is difficult to understand how this new URLLC technology will lead to higher levels of reliability since that is a function of network design and operation, not technology.

The areas where 5G may be able to add value to utility operations include:

- Unmanned aerial vehicle UAVs or more commonly termed drones. Utilities need visibility into their infrastructure for routine inspections and to discover and assess damage after storms. Helicopters often fulfil this role but are expensive and not able to access all parts of the electricity system. At present, drones cannot routinely be used beyond visual range, but when regulations are introduced to allow them to fly autonomously and beyond visual line of sight, their capabilities will be much enhanced. Although they could overfly power lines, gas pipelines and water resources recording data for later examination, the ability to relay video images in real time will dramatically enhance their value. Thus, when overflying assets, the ability to see the equipment and control the drone to steer it around an incident to inspect damaged assets will be invaluable. Current mobile networks and satellite connectivity are very restrictive by comparison with the promise of 5G. Such developments may radically enhance inspection capabilities and

reduce restoration times following faults, generating a real business case for 5G deployment.
- Enhanced and virtual reality. When undertaking repairs and maintenance, demonstrations of virtual reality safety helmets are impressive. The helmets have head-up displays and voice activation to enable operatives to call up detailed work instructions, manuals, videos, network status information and infrared images whilst leaving their hands free for work. Such information enhances productivity and safety but requires high data bandwidth. 5G would be an essential facilitator for this enhanced method of working.

Utilities will also wish to participate in the 5G world by acquiring spectrum in order to have the option to construct their own private 5G networks and integrate them into a 5G world. These private 5G networks will take a variety of forms but will need to be able to integrate and interwork with commercial 5G infrastructure operated by telecommunications providers. Reasons that utilities might want to operate private 5G networks might include the need to have:

- Networks able to operate for extended periods in the absence of primary power.
- Greater security than offered by commercial networks.
- Deterministic low latency services.
- Coverage into areas not served by commercial operators being either remote rural areas, industrial sites with poor coverage, underground locations, tunnels, etc.
- Redundant telecommunications provision.

12. Conclusions

At present, there is public enthusiasm and immense government momentum behind 5G, facilitating progress in facing the challenges above. There are however areas where public opinion could easily reverse itself driven by environmental, cost, or safety concerns, slowing progress and hampering deployment of the 5G system.

The biggest issue is likely to be cost. Deploying, maintaining and powering the massive increase in the number of base stations will be expensive. The business cases supporting this growth are not yet proven, hence the focus on developing new vertical markets such as remote healthcare, education, transportation, utilities, etc.

While technological progress may address some of the functional challenges outlined above, physics will not change. Potential terrestrial radio development is well articulated, but the unknown future contributor may be satellite – or even unmanned aerial vehicles – drones. Drones – high altitude platforms as described in radio regulatory terms – may well be several decades away from widespread practical deployment because of the need to provide power to stay in the air as well as operate the "base station in the sky."

13. UTC Global Affiliates

Utilities Technology Council: UTC was founded in 1948, to advocate for the allocation of additional radio spectrum for power utilities. Over the last 70 years, UTC has evolved into a dynamic organization that represents electric, gas and water utilities, as well as natural gas pipelines, critical infrastructure companies and other industry stakeholders.

From its headquarters in Washington, D.C., UTC provides information, products and services that help members:

- Manage their telecommunications and information technology more effectively and efficiently
- Voice their concerns to legislators and regulators
- Identify and capitalize on opportunities linked to deregulation worldwide
- Network with other telecom and IT professionals.

UTC is an authorized certified frequency coordinator for the Private Land Mobile Radio Services below 512 MHz and 800-900 MHz frequencies. UTC is the sole frequency coordinator authorized to coordinate channels previously allocated exclusively to the Power Radio Service. In addition, UTC maintains the national Power Line Carrier (PLC) database for the coordination of PLC use with licensed government radio services in the 10-490 kHz band.

For more information, please visit: www.utc.org

Africa UTC (AUTC): Africa Utilities Technology Council (AUTC) is the newest regional operation of the global Utilities Technology Council (UTC) – a global trade association with more than 200 members.

Established in 2015, AUTC seeks to shape the future of utility mission critical technologies by driving innovation, fostering collaboration and influencing public policy for African utilities.

AUTC is the trusted advisor to utilities and other critical infrastructure providers in Africa. The Council serves as the source and resource for our members who deploy technologies and solutions that deliver secure, reliable and affordable mission critical services.

For more information, please visit: africautc.org/

European UTC: Technology is rapidly changing the role of telecom in Europe's electric, gas and water utilities, energy companies and other critical infrastructure companies. Many are using their vast experience in building and managing sophisticated telecommunications networks to enter Europe's new competitive telecoms markets. Many are also facing issues introducing new wireless communications systems and managing internal telecoms businesses in a shared services environment.

To meet this need, the Utilities Technology Council developed a uniquely European program that will build on UTC's 60 years of experience, existing strengths and services. EUTC programs are led by Europeans, designed by Europeans, and uniquely European in focus.

For more information, please visit: eutc.org/

UTC America Latina (UTCAL): UTC Latin America is a professional association prepared to meet telecommunications specialists working in energy companies, gas and water. Bringing together the leading technology providers in Latin America, UTCAL enables a constant exchange of knowledge and information, keeping their members updated properly in an area where technology is constantly changing.

The UTCAL works in partnership with Brazilian institutions, Latin American, North American and European, seeking and disseminating the main news on spectrum allocation, technology, regulation and the development of future energy systems.

For more information, please visit: www.utcamericalatina.org/

14. Glossary

1G	Generally refers to the first generation of wireless cellular technology (mobile telecommunications). These are the analogue telecommunications standards that were introduced in the 1980s and only supported voice-only calls.
2G	The second generation of wireless technologies and introduced call and text encryption, along with data services such as SMS, picture messages, and MMS. Although 2G replaced 1G and is superseded by later technology versions, it's still used around the world. It is frequently referred to as GSM (Global System for Mobile (GSM) communications).
3G	The third generation of wireless technologies. It comes with enhancements over previous wireless technologies, like high-speed transmission, advanced multimedia access, and global roaming.
3rd Generation Partnership Group (3GPP)	A partnership of seven telecommunications standard development organizations including ARIB, CCSA, ETSI, TSDSI, ITA and TTC originally formed to promote 3G standards, but now evolved to develop 4G/LTE and 5G standards.
4G	The fourth generation of mobile phone technology. It follows on from the existing 3G (third generation) and 2G (second generation) mobile technology. It is based on standards developed by 3GPP.It supports even higher data rates and is around is around five to seven times faster than 3G. It has additional functionality for MIMO antennas systems, traffic prioritization and machine to machine functionality. Often interchangeably used with the term LTE (Long-Term Evolution).
5G	The fifth generation of mobile technology, GMSA considers that its definition falls broadly into two schools of thought: (i) a service-led view which sees 5G as a consolidation of 2G, 3G, 4G, Wi-fi and other innovations providing far greater coverage and always-on reliability; and (ii) a view driven by a step change in data speed and order of magnitude reduction in end-to-end latency. Note**:** -these definitions are often discussed together, resulting in sometimes contradictory requirement and therefore illustrates the difficulty of defining 5G.
Advanced Mobile Phone System (AMPS)	An early analogue mobile phone solution (1G) originating in the U.S. based on FCC spectrum which also gained extensive market share in other parts of the world.
Association of Radio Industries and Businesses (ARIB)	The Association of Radio Industries and Businesses (ARIB) was established to promote research and development (R&D) of new radio systems, and to serve as a Standards Development Organization (SDO) to advance the unification of international standards and related activities in the telecommunications and broadcasting fields. www.arib.or.jp
Alliance for Telecommunications Industry Solutions (ATIS)	The Alliance for Telecommunications Industry Solutions an organization that represents companies in the information and communications technology (ICT) industry come together to address common, critical priorities. www.atis.org
Backhaul	The transportation of data or voice between the wireless access points to the public data or telephony network, or the Internet.
China Communication Standards Association (CCSA)	The China Communication Standards Association is a non-profit legal organization established in China for carrying out standardization activities in the field of Information and Communications Technology (ICT) across China. CCSA is organized with the approval of MII and registration in the Ministry of Civil Affairs. The membership of CCSA is open to corporate bodies only, including R&D institutes, design institutes, manufacturers, operators, universities and other societies.

	www.ccsa.org.cn
enhanced Mobile Broadband (eMBB)	A key element 5G development connected with significant increases in consumer connectivity speeds compared to 4G.
European Telecommunications Standards Institute (ETSI)	The European Telecommunications Standards Institute (ETIS) is a non-for-profit entity and is one of only three bodies officially recognized by the EU as a European Standards Organization. Its primary task is to produce high-quality standards for information and communication technologies across all sectors of industry and society. The list of these technologies is long and wide-ranging. www.etsi.org
General Packet Radio Service (GPRS)	GPRS is a packet oriented mobile data standard on the 2G and 3G cellular communication network's global system for mobile communications (GSM) It provides moderate-speed data transfer.
Global System for Mobile communications (GSM)	GSM is an alternative term used to describe 2G networks and is a digital mobile network that is widely used by mobile phone users in Europe and other parts of the world.
GSM Evolution (EDGE).	EDGE is an intermediate upgrade path for higher data rate provided on 2G networks before 3G was available.
Institute of Electrical and Electronic Engineers (IEEE)	IEEE is the U.S.-based parent organization for a suite of world-wide technology standards.
International Mobile Telecommunications (IMT) System for 2020 and Beyond (IMT-2020)	A term developed by the ITU's Radiocommunication Sector in 2012 to cover 5Gdevelop the vision of "IMT for 2020 and beyond." The ITU has set a timeline that calls for the standard to be finished in 2020.
International Telecommunication Union (ITU)	Founded in 1865 to facilitate international connectivity in communications networks, the ITU allocates global radio spectrum and satellite orbits, develop the technical standards that ensure networks and technologies seamlessly interconnect, and strive to improve access to ICTs to underserved communities worldwide.
Internet of Things (IoT)	The Internet of things is the network of devices such as vehicles, and home appliances that contain electronics, software, sensors, actuators, and connectivity which allows these things to connect, interact and exchange data.
ITU Radiocommunication sector (ITU-R)	One of the three sectors (divisions or units) of the International Telecommunication Union **(**ITU**)** and is responsible for radio communication.
Internet Protocol (IP)	IP is the method or protocol by which data is sent from one computer to another on the Internet.
Latency	Latency is the time it takes data to travel from one point to another.
Long-Term Evolution (LTE)	A standard for wireless broadband communication for mobile devices and data terminals, based on the GSM/EDGE technologies. It increases the capacity and speed using a different radio interface together with core network improvements.
massive Machine to Machine Communications (mMMC)	Same as IOT
Machine Type Communications mMTC.	Data communication between devices without the need for human interaction
Multiple Input Multiple Output (MIMO)	The use of multiple transmitter antennas and multiple receiver antennas to increase the maximum amount of data that can be transmitted between two radio units and enhance the robustness of a communication link.
Net Neutrality	The principle that Internet Service Providers should enable access to all content and applications regardless of the source, and without favoring or blocking particular products or websites.

Network slicing	The separation of services running over a telecommunications network so that each service has the appearance of having their own dedicated network.
New Radio (NR)	A completely new air interface being developed for 5G. It is being developed from the ground up in order to support the wide variety of services, devices and deployments 5G will encompass, and across diverse spectrum, but it will build on established technologies to ensure backwards and forwards compatibility.
Non-Standalone (NSA) Specifications	5G terminology relating to the overlay and interdependence of new 5G networks on existing 4G infrastructure and hardware i.e. 4G will still be used for voice in a 5G network and will occupy some of the same rooftop locations.
Pioneer Bands	Pioneer bands are three spectrum bands have been identified as most suitable for the introduction of 5G in Europe: 700 MHz, 3.4–3.8 GHz and 26 GHz.
Spectral efficiency	The optimized use of spectrum or bandwidth so that the maximum amount of data can be transmitted with the fewest transmission errors.
Supervisory, Control and Data Acquisition (SCADA)	SCADA systems are computerized industrial control systems that connect large industrial pieces of equipment with centralized facilities to transmit data. For utilities, SCADA systems refer to the data networks that connect remote pieces of infrastructure to control centers, providing utilities with real-time situational awareness on the status of their systems. Utilities deploy ICT networks to run these SCADA systems. SCADA systems can include Energy Management Systems which optimize generation and high-voltage transmission of energy, for example[7].
Teleprotection	A system of monitoring an electricity transmission line using low latency telecommunications circuits to detect and isolate faults before they have time to cause damage to the electrical equipment.
Total Access Communications System' (TACS).	A variant of the 1G analog mobile phone system. Now obsolete.
Telecommunications Standards Development Society (TSDS_I)	The Telecommunications Standards Development Society, India, comprising of operators and manufacturers, Academia and R&D organizations. www.tsdsi.in
Telecommunications Technology Association (TTA)	The Telecommunications Technology Association, based in Korea establishes and, revises, and distribute Korean ICT standards in communication networks, ICT convergence, security, software, broadcasting, radio/mobile communications. www.tta.or.kr
Telecommunications Technology Committee (TTC)	The Telecommunications Technology Committee, based in Japan is an incorporated association that contributes to standardization activities in the field of information and communication technology (ICT) by developing and disseminating standards for information and communications networks. It thus participates in the creation of a safe and comfortable society supported by the rapid development of ICTs. www.ttc.or.jp
Ultra Reliable Low Latency Communications (URLLC)	Coupled with 5G developments to serve many vertical markets, the term URLLC is used in particular when considering sectors such as autonomous vehicles, rail networks, manufacturing and utilities – where reliability and/or low latency are mission critical.
Virtual Private Networks (VPN)	VP refers to programming that creates a safe and encrypted connection over a less secure network, such as the public internet.
Wi-Fi	An IEEE 802.11 standard based technology using license-exempt spectrum in the 2.4 GHz and 5 GHz bands to provide connectivity between portable devices and a local internet access point.

[7] https://utc.org/wp-content/uploads/2018/10/Definitions_Final-Version_October-2018.pdf

Worldwide Interoperability for Microwave Access (WiMAX)	A variety of standards developed by the IEEE and given various 802.16 x variants denoted by a letter after the main standard number. WiMAX was a competing technology to LTE (developed by 3GPP). Some deployments of WiMAX still exist and specific versions of the standard have optimized functional capabilities (e.g. 802.16 s for utility use).

JRC Ltd
25 February 2019