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THE EVOLUTION TO 5G

Who are the key infrastructure players and how will they benefit?

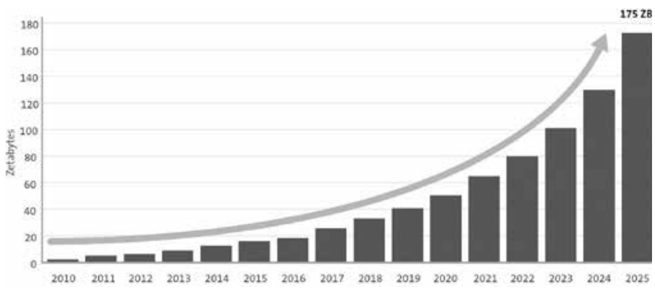
Giuseppe Corona and Jason Aront

Increasingly we are hearing about the revolutionary technologies that will fundamentally change the way we live our lives. This will be led by the internet of things, smart cities, artificial intelligence, autonomous vehicles, remote computing, virtual reality and many others.

However what is less often discussed, is that underpinning the development and application of these technologies is the Fifth Generation (5G) mobile communication network. With data usage projected to increase over five-fold by 2025, communication equipment and infrastructure will require significant enhancement in order to facilitate these new technologies and the explosion in data across almost all aspects of our lives.

This paper focusses on the defining characteristics and technologies behind 5G and what makes the new generation of communications revolutionary in enabling the applications of the future. We also look at the infrastructure requirements for 5G and the need for macro cell sites, small cells and fibre to work seamlessly in an integrated network in order to deliver the full benefits of 5G. Investment requirements will be significant across the whole value chain and we look at the key infrastructure players that are leveraged to this very attractive thematic.

Figure 1. Annual size of the global datasphere



Source: IDC, The Digitization of the World – From Edge to Core, November 2018.

Why do we need 5G?

Outlining the key benefits

By 2020, the number of connected devices is expected to reach 50 billion according to Cisco (see *The Internet of Things 2011*), which is four times the number in 2010. Whilst 4G was a transformational step in mobile technology, it was never designed to handle so many devices and as a result the network has become slower and more congested. This situation is only getting worse as ever more devices are getting connected, and therefore 5G is slated to be the solution for many years to come.

There are three key differences between the current 4G/LTE network and 5G that will address these congestion issues. These include:

- Using wider bandwidth channels of spectrum. Similar to prior

The quote

Another perhaps surprising benefit of 5G is significantly improved battery life for our devices.

technologies, there are no specific frequencies 5G must operate on, but currently it is expected that 5G will use three broad bands of coverage. These will consist of the coverage layer (Sub 1GHz and specifically the 700MHz band), the coverage and capacity layer (1-6GHz and centred around the 3.5GHz band) and – for the first time – the super data layer (above 6Ghz and centred around the 25GHz band).

- Reducing latency, which is seen as a necessity for enabling the technologies of tomorrow such as the internet of things and autonomous vehicles. In a 5G world, latency is expected to decrease by 50 times – reducing to one millisecond.
- Supporting more devices per cell site. In terms of capacity, specification for 5G technology requires it to handle at least one million devices per square kilometre, which compares to around two thousand wireless devices per square kilometre for 4G.

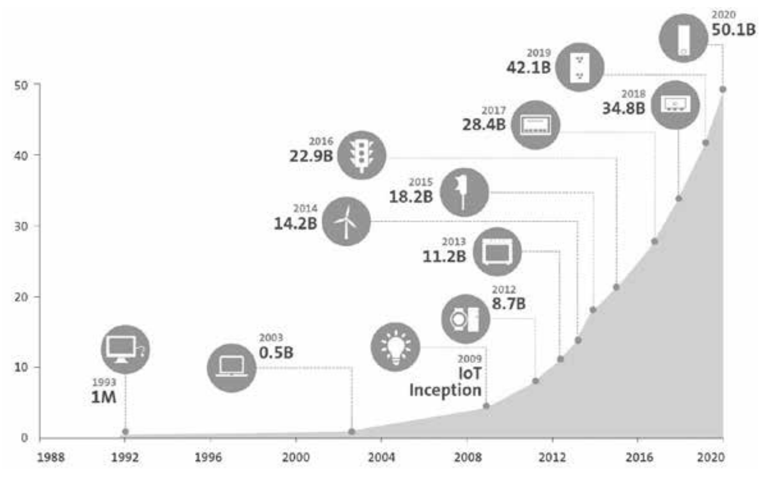
Another perhaps surprising benefit of 5G is significantly improved battery life for our devices. The reduction in latency will enable a lot of the computing power to move from the device to the mobile network, which Verizon CEO Lowell McAdam told IBM's Think 2018 Conference could see battery life on a mobile phone increase to one month! However, as we will see in the next section in terms of the various technologies required, we are still a long way away from such a claim becoming reality.

What is 5G?

Technology behind 5G explained

In order to deliver a faster, denser and more reliable mobile network, 5G will utilise various technologies and communication techniques working together in a seamless way, which is the reason the transition from 4G won't be instantaneous. These technologies and communication techniques are explained in more detail below.

Figure 2. Billions of devices



Source: Dash Magazine, The Most Promising Internet of Things trends for 2018, November 2017

Millimetre waves

Utilising high frequency millimetre waves is possibly one of the most important 5G technologies, as this part of the spectrum will enable the highest intensity data applications. From the launch of the First-Generation mobile networks, connected devices have been operating in the 3KHz to 6GHz frequency spectrum, which as we know have become very congested. Millimetre waves are broadcast at frequencies between 30GHz and 300GHz, which are currently only utilised by satellite operators and radar systems. The significant amount of data that can be broadcast at these frequencies will enable all current and future connected devices to operate as designed. It is important to note that this entire spectrum won't be available for commercial uses as a significant portion will be dedicated to mission critical activities requiring very low latency. However, the trade off in using higher frequencies is their range and the potential for interference from obstacles. One of the key negatives to using millimetre waves is that higher frequencies have high 'atmospheric attenuation' (i.e. they are easily absorbed by gases in the atmosphere, humidity and rain) and are blocked by building walls, hence propagate only by 'line-of-sight' path.

Massive MIMO

Massive Multiple-Input Multiple-Output (MIMO) will play a key role in the 5G mobile network of the future. MIMO technology effectively enables multiple signals to be transmitted and received over the same radio channel. Compared to standard MIMO networks which tend to use two to four antennas, massive MIMO systems can have over 100 antennas. With the requirement to pack many more antennas in a small space, higher frequencies will be required. The key advantage of massive MIMO is a significant increase in capacity of a wireless network without utilising additional spectrum. However, given the utilisation of much shorter wavelength spectrum, massive MIMO systems are more susceptible to interference and therefore technologies such as beamforming will be used to minimise interference.

Beamforming

Beamforming technology represents one of the key pillars of the 5G ecosystem. As radio base stations are usually transmitting signals without pointing to a specific target, there is a high likelihood of interference. Beamforming is a data transmission system that identifies the most efficient route of delivery whilst also reducing interference. It works by focussing a signal in a concentrated beam that points in the direction of the user, as opposed to sending a signal in multiple directions at once.

Small cells

Small cells are low-powered mobile radio access nodes with a short range (up to few kilometres) designed to handle fewer simultaneous calls or sessions. Although small cells are not technically a new technology, they also represent a key pillar of 5G mobile networks. Given their size, they can be deployed almost anywhere (i.e. traffic lights, on top of buildings, offices' ceilings) and will play a significant role in expanding mobile network coverage, while reducing interference and propagation loss of millimetre waves, which will deliver a high speed, low latency environment.

Full duplex

Full-duplex is a technology that can solve one of the biggest constraints in radio frequency, which is that a transceiver is not able to transmit and receive signals at the same time using the same radio frequency, given the significant amount of interference that signals themselves create. Current mobile networks use different frequency bands to transmit and receive information, which results in using double the frequency spectrum. Full-duplex could solve this issue by allowing for ways for the signals to travel around each other; its adoption would double the frequency band, thus increasing the wireless capacity by a factor of two.

What are frequencies?
The frequency refers to the number of waves generated in a set period of time and is measured in hertz (Hz). Eg.1Hz means one wave per second, 1MHz is one million waves per second and 1GHz (gigahertz) one billion waves per second.
What is spectrum?
Range of frequencies over which electromagnetic radiation extends. Radio spectrum refers to the part of the spectrum with frequencies from 3 KHz to 300 GHz, which are used in telecommunication technology.
What is bandwidth?
Bandwidth is the amount of data that can be transmitted in a fixed amount of time, usually expressed in bits per second.

The applications of 5G

Implications of the technology explained

The move to 5G technology is expected to have a significant economic, social and environmental impact on our lives. Enabling improved mobile broadband, massive machine-type connectivity and very reliable and low latency communication, 5G technology will be embraced in areas as diverse as transportation, the home, healthcare and entertainment. Examples of some of these applications are below.

Entertainment

With video streaming accounting for a very large share of traffic currently, 5G will enable a HD video to be downloaded in seconds and enable HD TV channels to be streamed without interruptions. Further, lower latency will enable live streaming of events, as well as augmented and virtual reality.

Internet of things

Whilst often a broad description, the internet of things will connect appliances, devices, sensors and applications to the internet. Through collecting incredibly high quantities of data from devices and sensors, the internet of things will enable real-time optimisation and efficiency in areas such as smart cities (i.e. energy and water management, smart lighting and traffic monitoring), the home, logistics and transport, agriculture and healthcare.

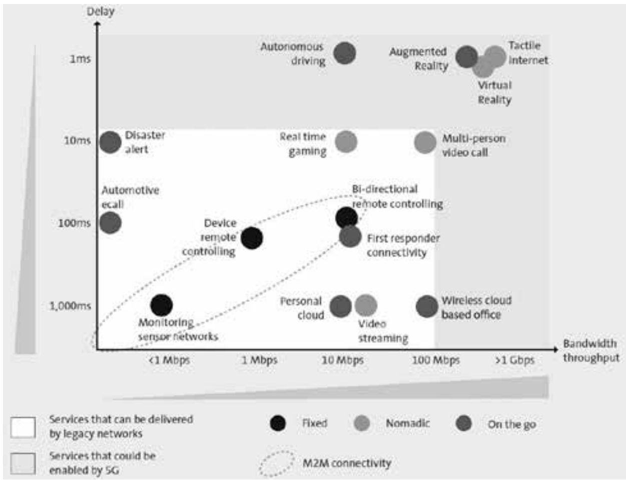
Healthcare

5G technology will enable real-time monitoring of people's health and through 'tactile' internet (defined as a network that combines ultra-low latency with extremely high availability, reliability and security), it will allow humans and machines to interact in real time and therefore have the potential to perform a complex medical procedure by a surgeon on the other side of the world.

Transport

5G technology is a key enabler of self-driving cars as very low latency is necessary for effective communication between cars and smart traffic signs, objects and other vehicles. Even milliseconds of latency could result in fatal collisions. Future applications and technologies that will be enabled by 5G are likely to include areas we cannot even imagine. Whilst the timeline is inherently uncertain, consensus is that widespread availability of 5G applications will be seen in the mid-2020s. The race to 5G is also having geopolitical and security implications with superpowers such as the US, China and Russia in a race to deploy 5G as they seek to lead in the design and development of global standards for the network. China has made 5G a key pillar in their 'Made in China 2025' strategy and other economic initiatives. The US has committed to developing a national spectrum strategy with the aim of winning the global race to 5G.

Figure 3. Potential 5G use cases



Source: GSMA Intelligence, Understanding 5G: Perspectives on future technological advancements in mobile, December 2014.

5G network infrastructure

Understanding the engine room

To facilitate this communication revolution, the wireless infrastructure network will consist of several heterogeneous components all working together. Key elements will include macro towers, small cells and fibre networks.

Macro towers

Macro towers are high powered cell sites that are typically large vertical structures that lease vertical space on the tower. Macro sites typically have a range of up to 20km and are situated outside of urban areas. Below are some of the common types of macro towers.

Small cells and fibre

Small cells are low-powered nodes that operate in both licensed and unlicensed spectrum (Wi-Fi) and have a range of 10m up to a few kilometres, depending on the type of small cells and the amount and type of obstacles.

For this new network architecture to function in a seamless way, the different components (i.e. macro towers and small cells) will need to be interconnected by the core network. This interconnection can be done wirelessly, through copper wiring or fibre. However, given the capacity requirements of 5G, fibre will be the key backbone to the core network infrastructure.

The choice of which infrastructure and communication equipment to deploy will largely depend on the density, interference, capacity needs and applications, as well as the economics for a particular area. Macro towers will continue to be the optimal solution for less urban areas and are likely to feature equipment operating on the low and mid band part of the spectrum. In dense urban areas where there is less space and many obstacles, small cells will be used to enable high capacity and low latency applications. These will be installed inside buildings, on rooftops and on various types of public infrastructure such as lamp posts and traffic lights. Small cells will predominantly feature the super data layer and utilise the mmWave part of the spectrum.

However, as we move into a 5G world, 4G will continue to play a role and will need to work seamlessly alongside it. Devices will connect to both 4G and 5G networks, with 4G providing the backbone and 5G enabling the higher capacity connections. Further, as 5G will at least initially be focussed in dense urban areas, the 4G network will ensure there is a continuous connection, as is the case with 3G today in less urban areas.

Network splicing is another concept that will play an important role in the new network architecture as it will enable operators to customise the design of networks in order to deliver dedicated services for particular customers or use cases. This will be particularly important for applications such as driverless cars or remote computing where low latency and a continuous connection are imperative. The splicing of the network to guarantee particular levels of performance will be used predominantly for wholesale or business applications, rather than consumer applications where perfect reliability is less important.

Figure 5. 5G network infrastructure

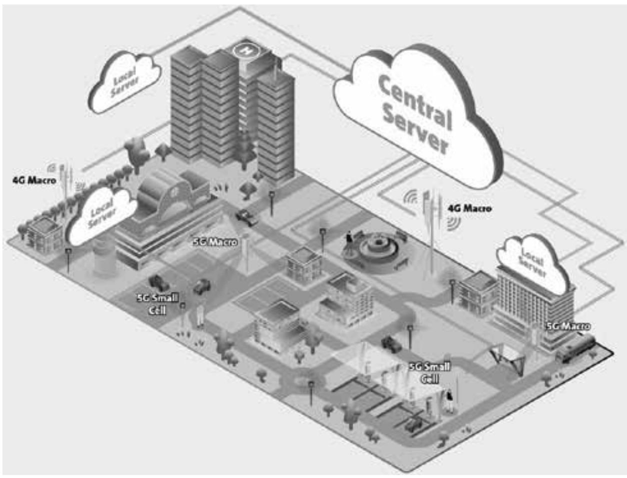
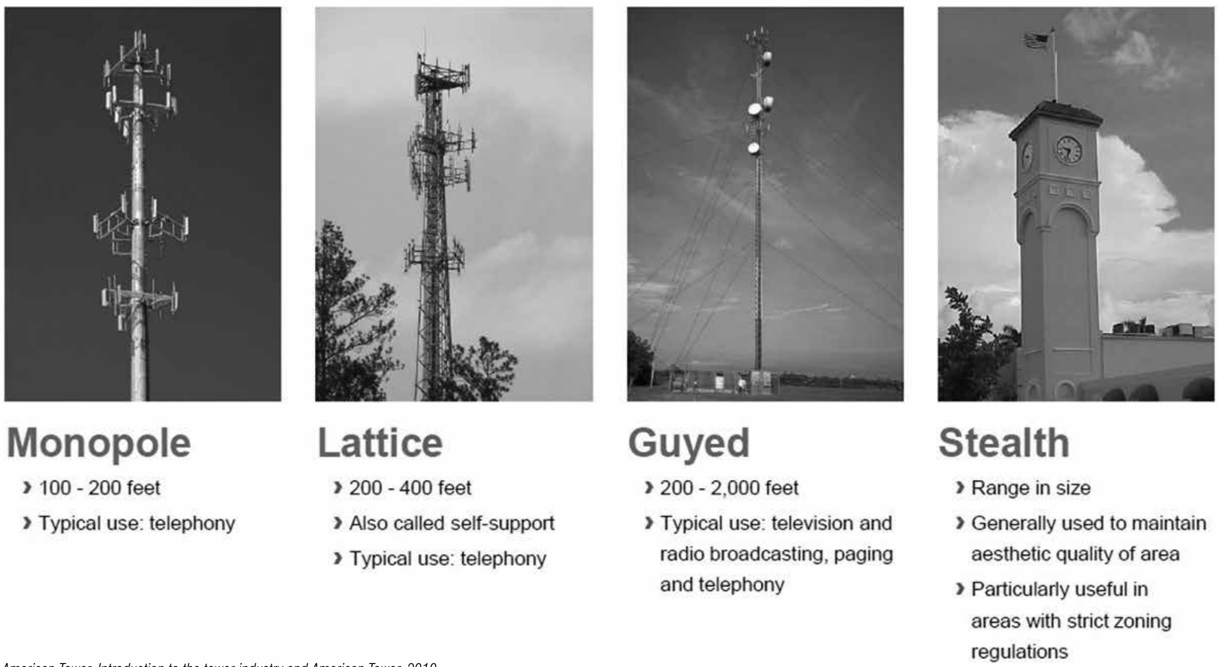


Figure 4. Towers in the wireless infrastructure network



Source: American Tower, Introduction to the tower industry and American Tower, 2010.

The opportunities for infrastructure investors

Who are the key players and where do the opportunities lie?

While it is still early in the lifecycle of 5G, there have already been some exciting developments and products announced.

The first market-ready product is 5G fixed wireless broadband, with Verizon in the US launching the product in four cities in October 2018 and offering speeds between 300Mbps and 1Gbps. These services make use of Verizon's ultra-wideband network which utilises small cells, fibre and the mmWave spectrum.

AT&T in the US is also investing heavily in 5G and is seeking to be the first provider of mobile 5G using wireless access modems and hot spots. However, one of the key issues at the moment is the availability of 5G compatible handsets, as these are only expected to appear in mid to late 2019. Widespread adoption of 5G is expected by 2025.

Carriers have historically owned their own communication infrastructure (specifically macro towers) and considered them strategic, as they enabled a true differentiation of network performance. But with coverage now built out by each of the main carriers in most countries and the increasing costs of deploying new sites and equipment with each successive mobile generation technology, an independent tower operator model has emerged.

Under this model, a tower operator offers long term leases to carriers, the price of which tends to increase annually by the rate of inflation. These tower companies are able to host equipment from multiple carries and therefore can provide coverage on a much more cost-effective basis than if a carrier was to do it themselves.

As an example, independent tower operators can have over four carriers on one tower, which compares to just one tenant for towers owned by carriers. Adding an additional tenant results in only a small marginal increase in operating costs and therefore this business model has very attractive operational leverage.

Whilst the US has led the way in terms of this model, the rest of the world is following as carriers around the world are progressively selling towers in order to reduce capex needs and improve their profitability and balance sheet by monetising these assets, which are much more valuable in an independent operator's hands than their own.

The US tower companies American Tower and SBA Communications have been particularly active in seeking to replicate their independent tower operator business model internationally, and in emerging markets in particular. In Europe, Cellnex Telecom has set its sights on being the leading independent tower operator for the region. However, interest in this sector has been growing over the last few years, with private equity and infrastructure funds seeking to get involved given the very stable, inflation linked and highly cash generative assets. This increased interest has resulted in a significant increase in valuations of these assets.

While sharing of infrastructure is the optimal model from an economic perspective, we may still see a mix of carrier ownership and infrastructure sharing as we enter the 5G world. This is because carriers may see offering 5G products and services as a differentiated offering and seek to gain market share. This will be most likely in the small cell and fibre domain, given in most developed countries there are few new macro towers being built and many have already been outsourced.

In our view, the determining factor of whether fibre and small cells are shared will depend on who owns the high capacity dense urban fibre, as small cells are not feasible without a fibre link. As an example, whilst Verizon has been developing their own fibre and small cells in some cities, Crown Castle, an independent tower operator, has also been investing significantly in fibre and small cells as they look to establish themselves as an independent provider of these assets and replicate the macro tower business model in the fibre and small cells domain.

The 5G environment is an exciting opportunity for communication infrastructure operators given the requirements of upgrading equipment on macro towers and also due to densifying the network through fibre and small cells.

Table 1. Sample tower economics1

	One tenant	Two tenants[2]	Three tenants[1]
Construction / upgrade costs	$275,000		
Tenant revenue	**$20,000**	**$50,000**	**$80,000**
Operating expenses (including ground rent, utility, monitor)	$12,000	$13,000	$14,000
Gross margin	$8,000	$37,000	$66,000
Gross margin (%)	40%	74%	83%
Gross margin conversion rate (%)		97%	97%
Return on investment3	3%	13%	24%

[1] For illustrative purposes only. Does not reflect any American Tower financial data.
[2] Co-locating tenants typically pay higher rents than anchor tenants on build-to-suit towers.
[3] Calculated as Gross Margin divided by Construction/Upgrade Costs.

Investor insight: History of telecommunication networks – from 0G to 5G

With society on the cusp of another technological advance, we revisit the different roles that mobile network generations have played in the communication industry and our day-to-day life over the last 70 years.

0G

'Mobile Radio Telephone' systems, often referred as Zero Generation mobile network, are considered the predecessor of the modern cellular mobile. These technologies used in pre-cellular world should be distinguished from earlier closed radiotelephone systems as they were offered as a commercial service and part of the public switched telephone network, rather than part of a closed network such as a police radio or taxi dispatch system. Commercial 0G mobile network technologies became available in the 1950s in both North America and Europe and were sold through telephone carriers, radio companies and two-way radio dealers. While at the beginning the devices were usually large and mounted in cars or trucks, this technology become truly mobile in the early 1970s, as the devices were made small enough to be carried by a person.

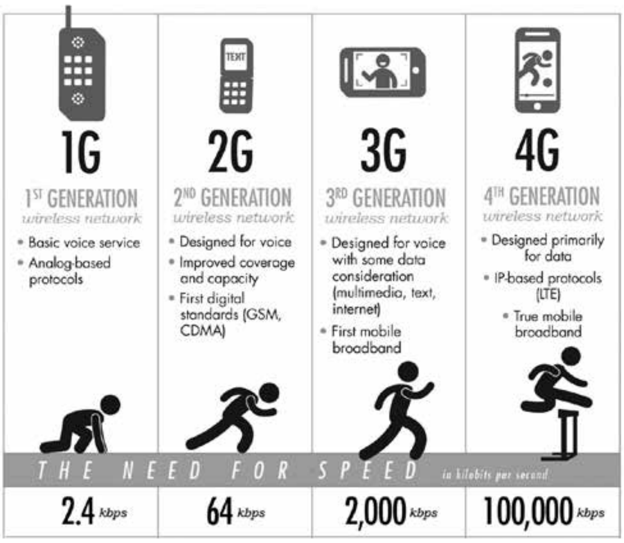
1G

The First-Generation mobile networks were established in 1980s using analogue telecommunication standards and continued for a decade until being replaced by 2G. Given the reliance on analogue standards, similarly to 0G, this technology was limited to providing basic voice services with a speed up to two kilobits per second.

2G

The Second-Generation mobile networks were introduced in the early 1990s, marking the beginning of the mobile phone revolution as smaller and more affordable phones started to be adopted by the general public. By relying on digital technology, 2G networks were more efficient than their predecessors as phone conversation were digitally encrypted, thus allowing for a more efficient use of the spectrum and greater mobile phone penetration levels. Data services were also introduced, starting with SMS (Short Message Service). Although the original speed ranged between 14 and 64 kilobits per second, further enhancement to the technology (2.5G, 2.75G) allowed for a speed of up to 144 kilobits per second. The benefits and advantages of digital technologies over analogue technologies resulted in 2G mobile network eventually replacing 1G technology almost everywhere. Whilst 2G has been surpassed by newer technologies such as 3G and 4G, at the beginning of 2018 it still represented the network with the highest percentage of connected mobile devices in the world.

Figure 6. The evolution of wireless networks



Source: Commscope, Cellular Wireless 1G, 2G, 3G, 4G, 5G – Watch the evolution, July 2017.

3G

A decade after the introduction of 2G, the Third-Generation mobile network was launched in the early 2000s, representing the first mobile broadband solution, by integrating voice, data and video, thus bringing the mobile phone 'online', with initial speeds ranging between 144 kilobits and 2 megabits per second. Further improvements to the technology (3.5G, 3.75G) have allowed for an upgrade in speed levels, from two megabits to 10 megabits per second, which ensures 3G can be applied to wireless voice telephony, mobile internet access, fixed wireless internet access, video calls and mobile TV technologies.

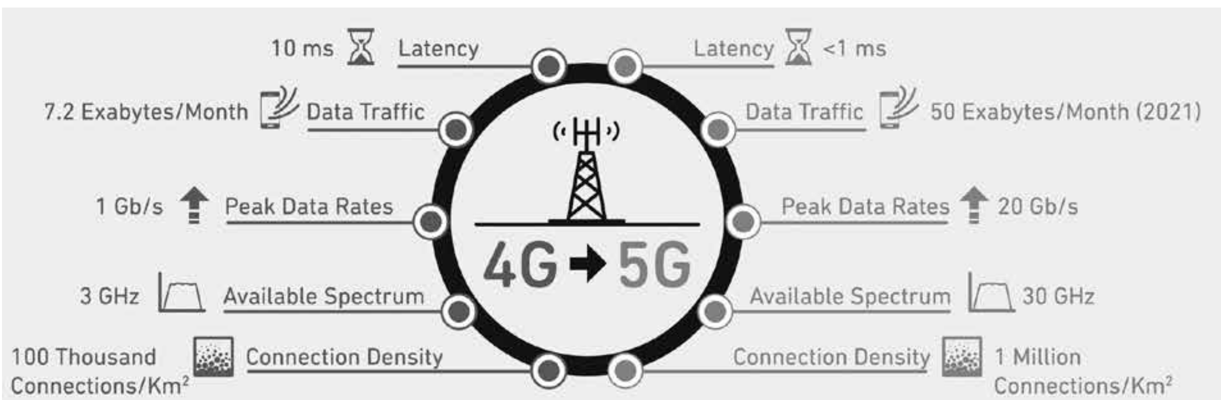
4G/LTE

4G was commercially introduced in the early 2010s and it represents the current generation of mobile networks, providing a true mobile broadband solution. Unlike other technologies which brought to market new functionalities, the primary objective of 4G was to bring faster speed, having peak speed requirements of 100 megabits per second (high mobility communications) and one gigabit per second (low mobility communication). Although the theoretical peak speed requirements have not been yet achieved, 4G's potential and current applications include IP telephony, gaming, HD mobile TV, video conferencing and 3D television.

5G

The Fifth-Generation mobile networks are the next telecommunication standards, which are currently under development and seek to surpass 4G standards in terms of bandwidth, speed, latency and energy consumption. Based on current forecast, 5G should be able to deliver a much faster network (up to 20 gigabytes per second, or 20x faster than 4G), increased reliability (less than 1 millisecond of latency) and higher data density (more than 1 million of connected devices per square km), thus allowing for a whole array of new applications and usage cases, such as internet of things, virtual reality, remote computing and much more. **FS**

Figure 7. Comparing 4G and 5G



Source: Qorvo, Getting to 5G: Comparing 4G and 5G systems requirements, September 2017.