

EMF Explained Series

March 2018

5G and EMF Explained

The letters '5G' are rendered in a large, white, sans-serif font with a slight gradient. They are superimposed on a dark blue background featuring a network of glowing nodes connected by dashed lines, with wispy white clouds at the bottom.

**Mobile & Wireless
Forum**

www.emfexplained.info

5G and EMF Explained

The EMF Explained Series provides information on mobile technology and Electromagnetic Fields (EMF) referencing international health authorities, government, academia and the telecommunications industry.

The EMF Explained Series has been developed by the Australian Mobile Telecommunications Association (AMTA) in association with the GSMA and Mobile and Wireless Forum (MWF).

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What is 5G?

5G is the 5th generation of mobile networks, a significant evolution of today's 4G LTE networks.

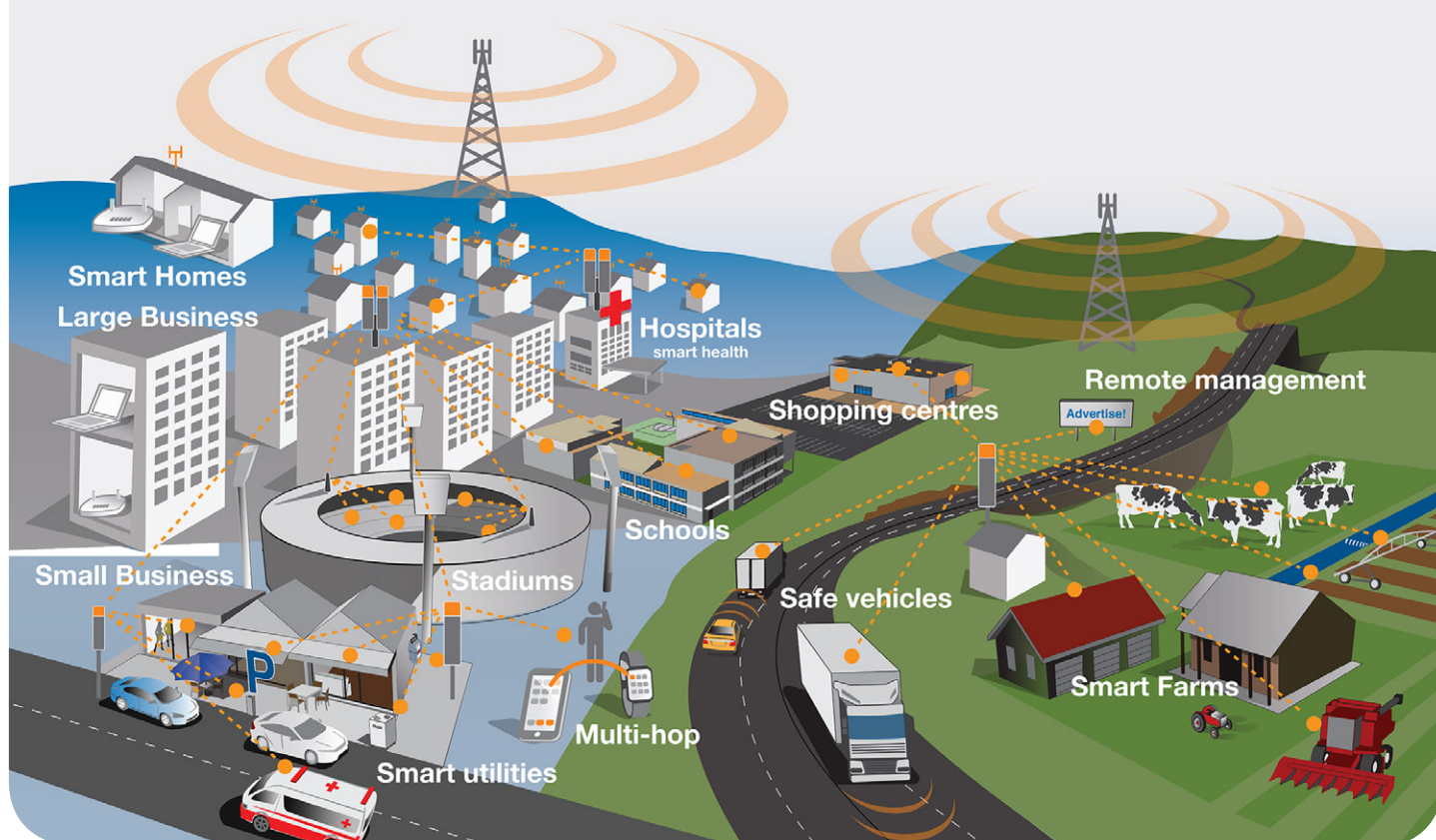
5G is being designed to meet the very large growth in data and connectivity of today's modern society, the internet of things with billions of connected devices, and tomorrow's innovations.

5G will initially operate in conjunction with existing 4G networks before evolving to fully standalone networks in subsequent releases and coverage expansions.

In addition to delivering faster connections and greater capacity, a very important advantage of 5G is the fast response time referred to as latency.

Latency is the time taken for devices to respond to each other over the wireless network. 3G networks had a typical response time of 100 milliseconds, 4G is around 30 milliseconds and 5G will be as low as 1 millisecond. This is virtually instantaneous opening up a new world of connected applications.

THE CONNECTED COMMUNITY



5G uses radio waves or radio frequency (RF) energy to transmit and receive voice and data connecting our communities.

What will 5G enable?

5G will enable instantaneous connectivity to billions of devices, the Internet of Things (IoT) and a truly connected world.

There are three major categories of use case for 5G:

- **Massive machine to machine communications** – also called the Internet of Things (IoT) that involves connecting billions of devices without human intervention at a scale not seen before. This has the potential to revolutionise modern industrial processes and applications including agriculture, manufacturing and business communications.
- **Ultra-reliable low latency communications** – mission critical including real-time control of devices, industrial robotics, vehicle to vehicle communications and safety systems, autonomous driving and safer transport networks. Low latency communications also opens up a new world where remote medical care, procedures, and treatment are all possible.
- **Enhanced mobile broadband** – providing significantly faster data speeds and greater capacity keeping the world connected. New applications will include fixed wireless internet access for homes, outdoor broadcast applications without the need for broadcast vans, and greater connectivity for people on the move.

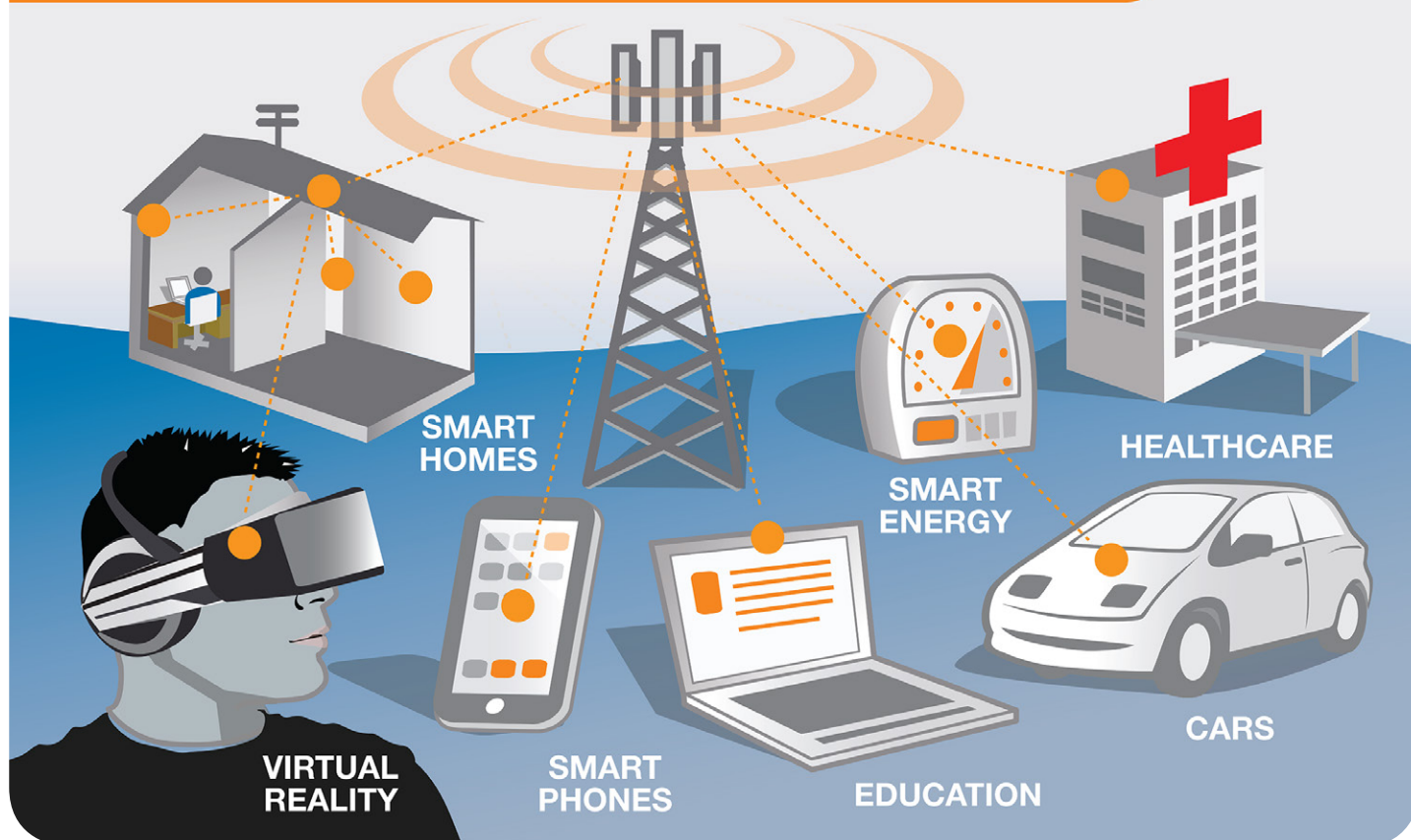
For communities, 5G will enable the connection of billions of devices for our smart cities, smart schools and smart homes, smart and safer vehicles, enhance health care and education, and provide a safer and more efficient place to live.

For businesses and industry, 5G and IoT will provide a wealth of data allowing them to gain insights into their operations like never before. Businesses will operate and make key decisions driven by data, innovate in agriculture, smart farms and manufacturing, paving the way for cost savings, better customer experience and long term growth.

New and Emerging technologies such as virtual and augmented reality will be accessible by everyone. Virtual reality provides connected experiences that were not possible before. With 5G and VR you will be able to travel to your favourite city, watch a live football match with the feeling of being at the ground, or even be able to inspect real estate and walk through a new home all from the comfort of your couch.

5G will keep us connected in tomorrow's smart cities, smart homes and smart schools, and enable opportunities that we haven't even thought of yet.

5G CONNECTING THE COMMUNITY



5G will provide the speed, low latency and connectivity to enable a new generation of applications, services and business opportunities that have not been seen before.

When will 5G be ready?

When will 5G be ready?

5G is currently being developed and trialled ready for commercial launch from 2020. Widespread availability of 5G services is expected by 2025.

What will be the first applications for 5G?

Fixed wireless access for homes and enhanced mobile broadband services are likely to be the first applications using new 5G wireless access modems and hot spots.

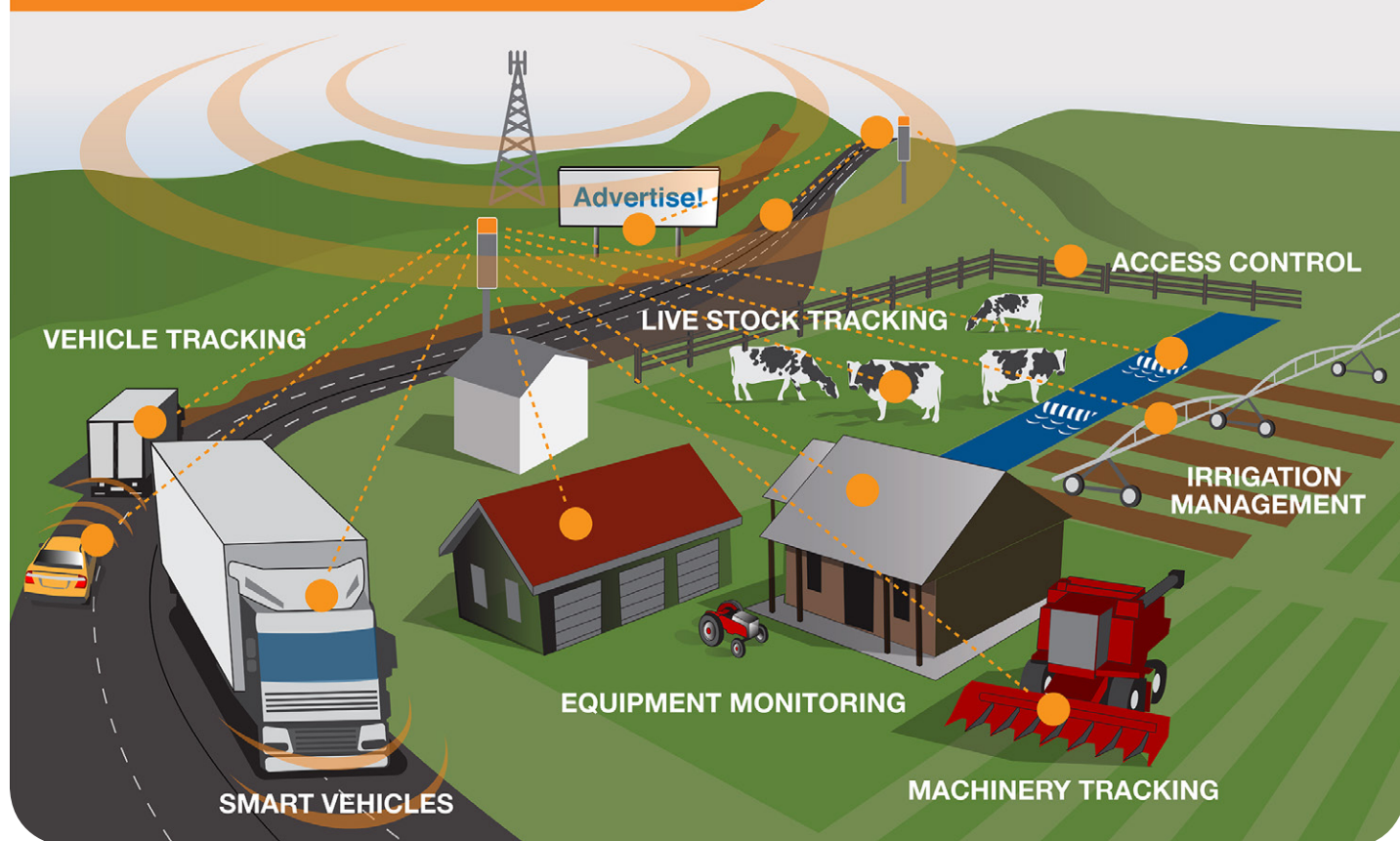
What will 5G devices offer?

The prime benefits of 5G devices will be significantly faster speeds in data access, downloading and streaming content. In addition, 5G devices will have increased computing power and make use of the lower latency, meaning that the devices will enjoy virtually instantaneous connections to the network, as well as greater connectivity when on the move due to the use of advanced antenna beam steering.

When will 5G devices be available?

Mobile handsets equipped with 3G, 4G and 5G connectivity are expected to become available in the 2020 – 2021 timeframe, and low latency and widespread machine to machine applications using 5G will be developed in the coming years.

CONNECTED FARMS



How does 5G work?

Most operators will initially integrate 5G networks with existing 4G networks to provide a continuous connection. A mobile network has two main components, the 'Radio Access Network' and the 'Core Network'.

The Radio Access Network – consists of various types of facilities including small cells, towers, masts and dedicated in-building and home systems that connect mobile users and wireless devices to the main core network.

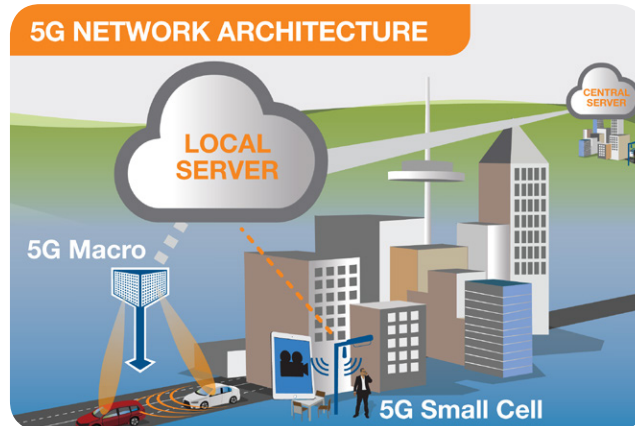
Small cells will be a major feature of 5G networks particularly at the new millimetre wave (mmWave) frequencies where the connection range is very short. To provide a continuous connection, small cells will be distributed in clusters depending on where users require connection which will complement the macro network that provides wide-area coverage.

5G Macro cells will use MIMO (multiple input, multiple output) antennas that have multiple elements or connections to send and receive more data simultaneously. The benefit to users is that more people can simultaneously connect to the network and maintain high throughput. MIMO antennas are often referred to as 'Massive MIMO' due to the large number of multiple antenna elements and connections however the physical size is similar to existing 3G and 4G base station antennas.

The Core Network – is the mobile exchange and data network that manages all of the mobile voice, data and internet connections. For 5G, the 'core network' is being redesigned to better integrate with the internet and cloud based services and also includes distributed servers across the network improving response times (reducing latency).

Many of the advanced features of 5G including network function virtualization and network slicing for different applications and services, will be managed in the core.

The following illustration shows examples of local cloud servers providing faster content to users (movie streaming) and low latency applications for vehicle collision avoidance systems.

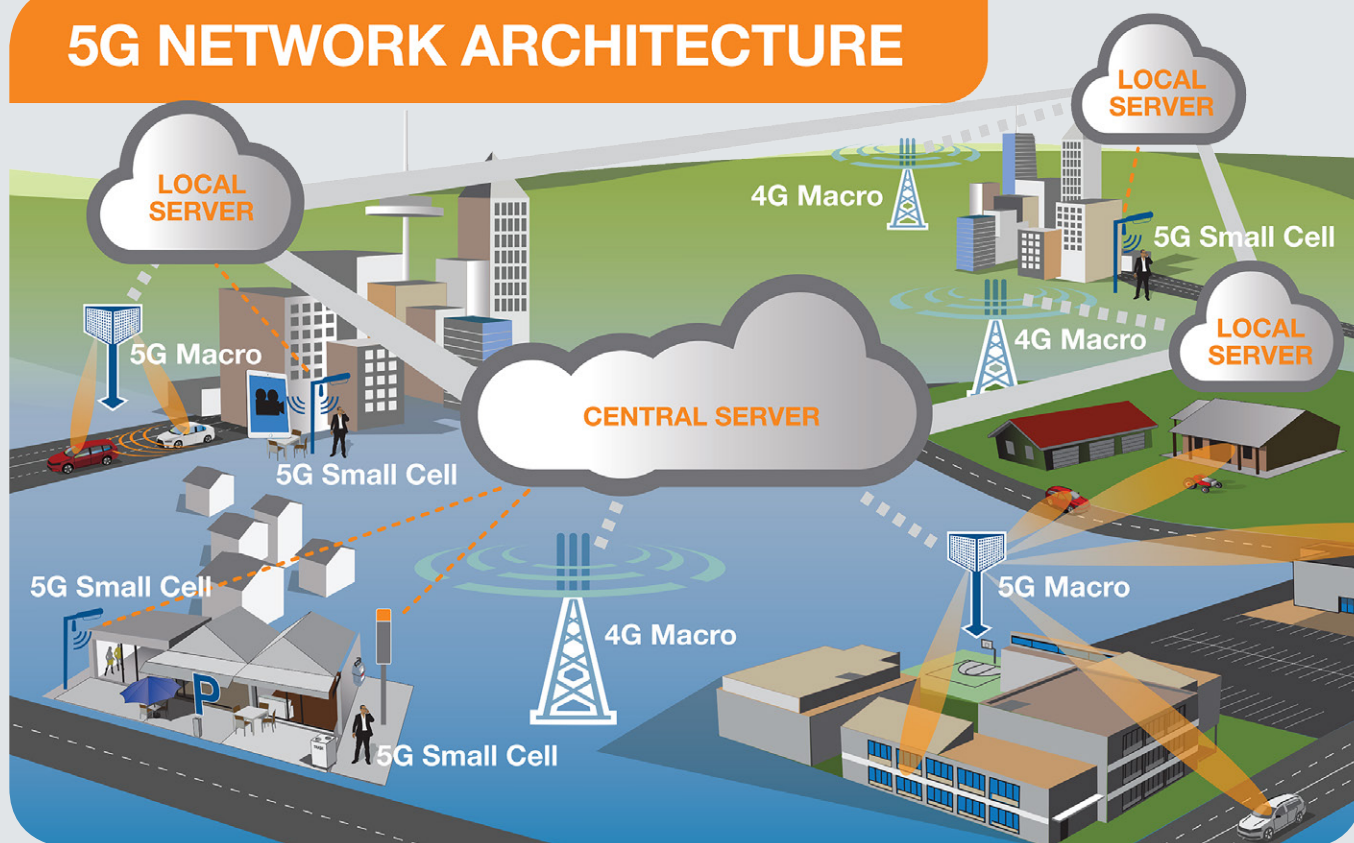


Example of a local server in a 5G network providing faster connection and lower response times.

Network Slicing – enables a smart way to segment the network for a particular industry, business or application. For example emergency services could operate on a network slice independently from other users.

Network Function Virtualization (NFV) – is the ability to instantiate network functions in real time at any desired location within the operator's cloud platform. Network functions that used to run on dedicated hardware for example a firewall and encryption at business premises can now operate on software on a virtual machine. NFV is crucial to enable the speed efficiency and agility to support new business applications and is an important technology for a 5G ready core.

5G NETWORK ARCHITECTURE



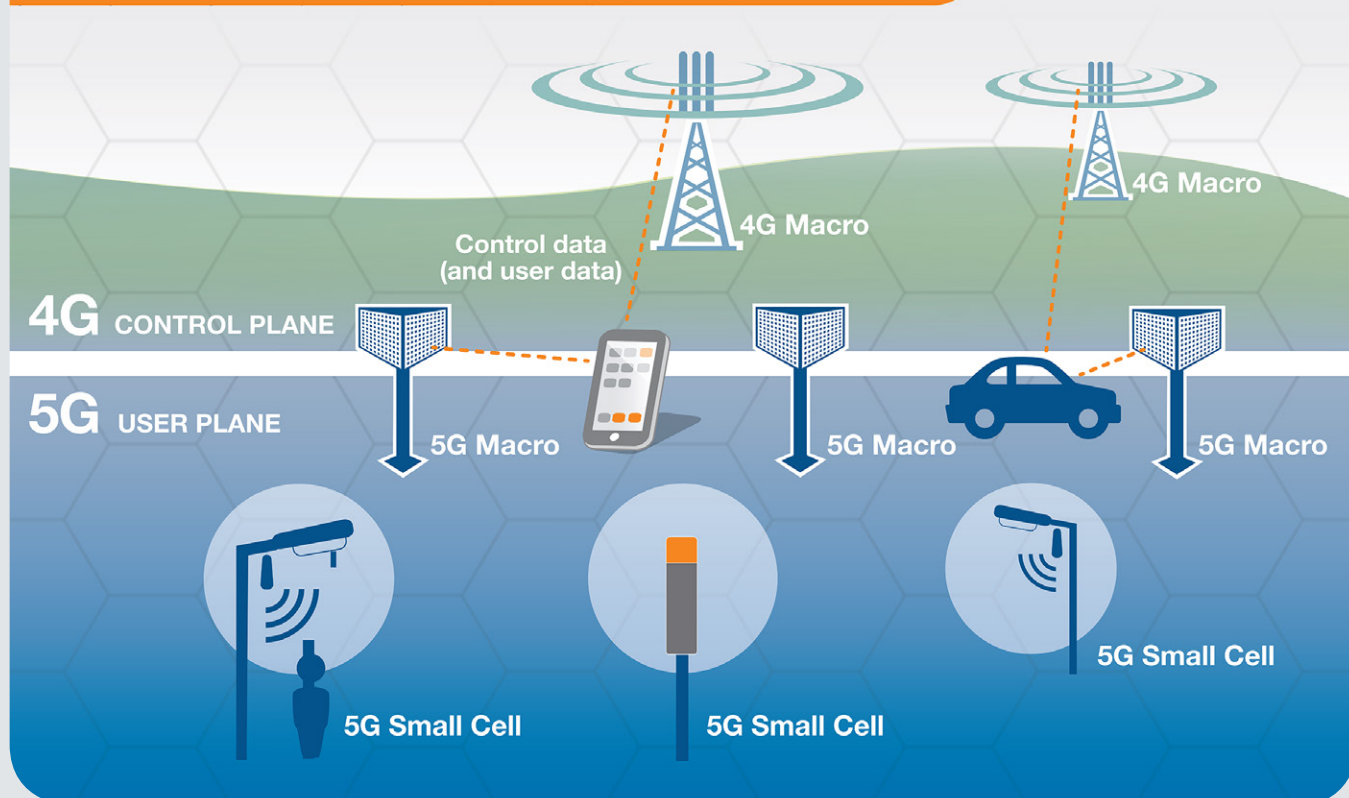
5G network architecture illustrating 5G and 4G working together, with central and local servers providing faster content to users and low latency applications.

5G working with 4G

When a 5G connection is established, the User Equipment (or device) will connect to both the 4G network to provide the control signalling and to the 5G network to help provide the fast data connection by adding to the existing 4G capacity.

Where there is limited 5G coverage, the data is carried as it is today on the 4G network providing the continuous connection. Essentially with this design, the 5G network is complementing the existing 4G network.

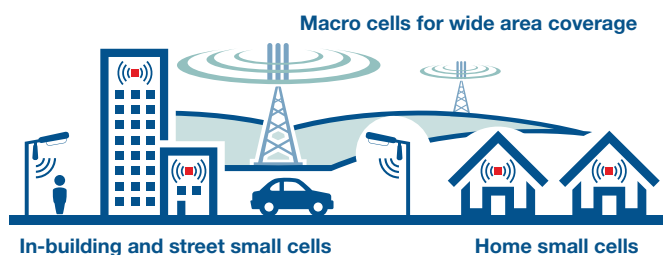
5G INTEGRATION WITH 4G



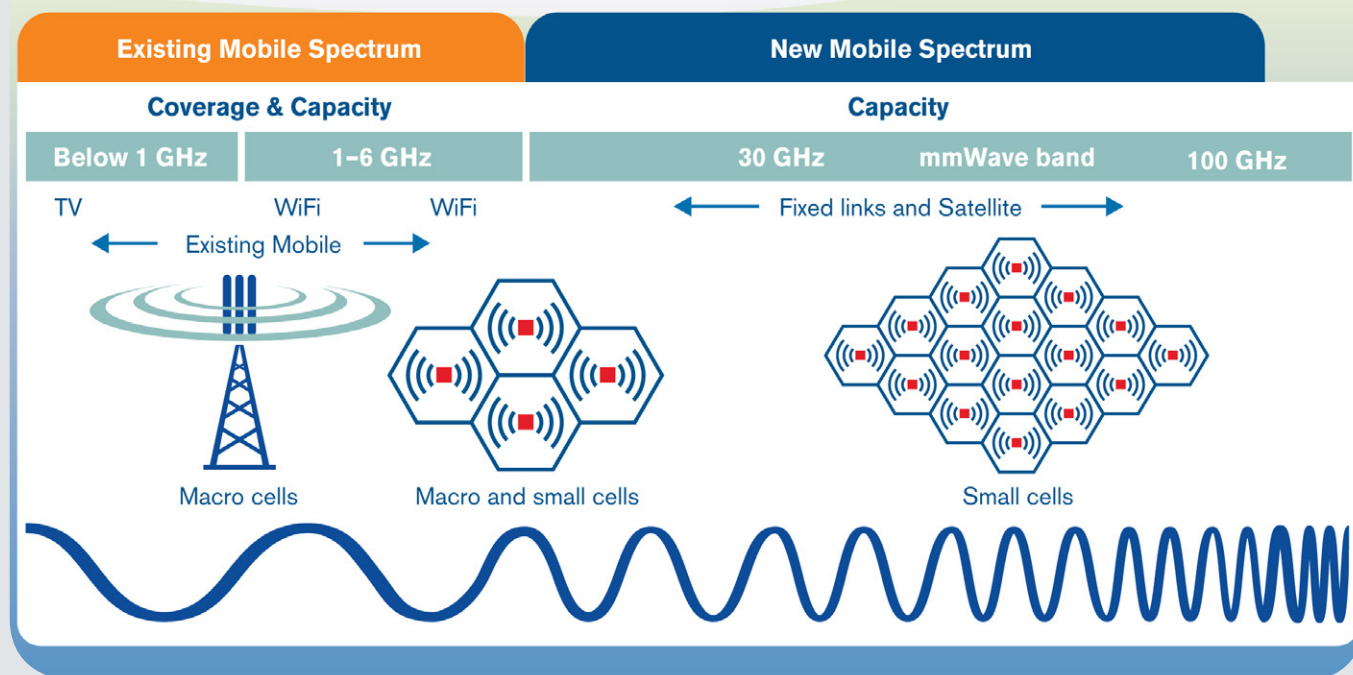
How does 5G deliver continuous connection, greater capacity, and faster speed and response times?

Better Connection – always connected

5G networks are designed to work in conjunction with 4G networks using a range of macro cells, small cells and dedicated in-building systems. Small cells are mini base stations designed for very localised coverage typically from 10 metres to a few hundred metres providing in-fill for a larger macro network. Small cells are essential for the 5G networks as the mmWave frequencies have a very short connection range.



5G SPECTRUM



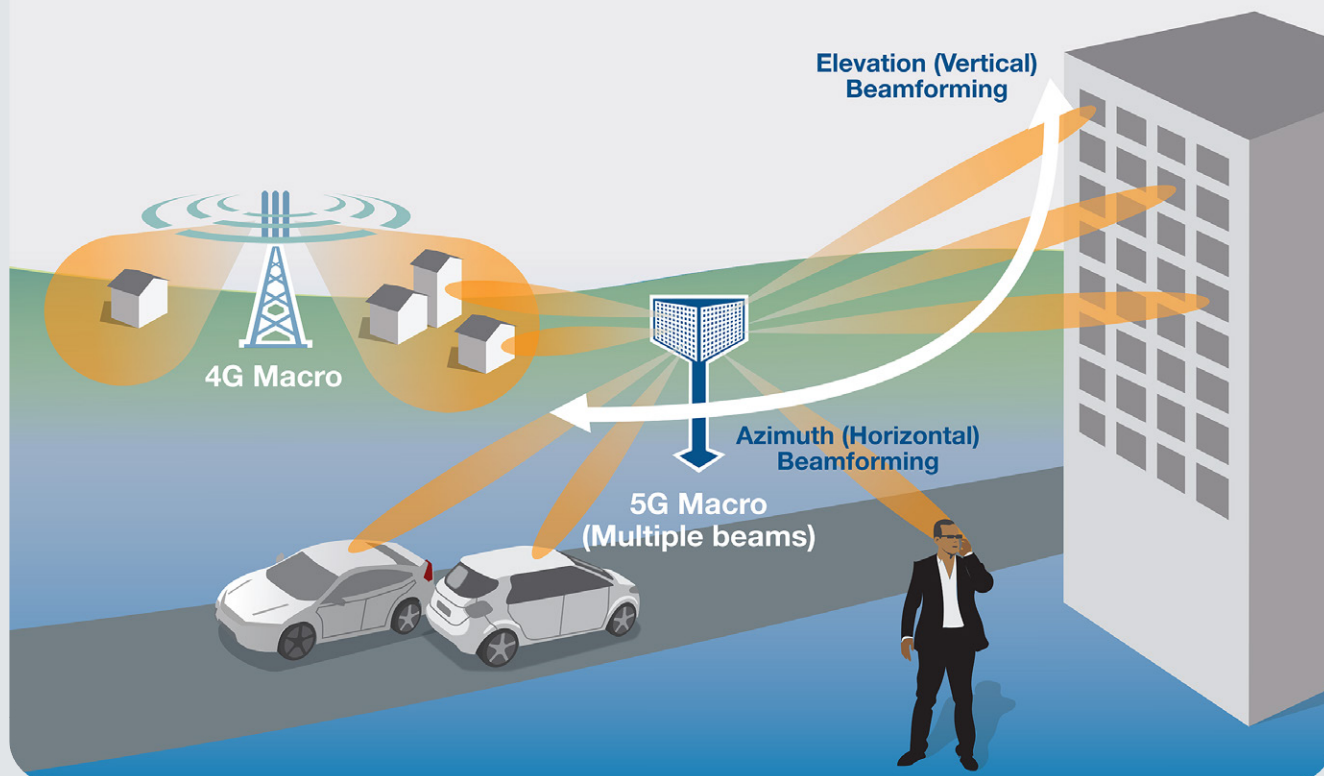
Mobile spectrum showing the radio frequency range from 3-100 GHz with new 5G spectrum above 6GHz. Other radio services (TV, Wi-Fi, Fixed links & Satellite) are shown for reference.

Increased Spectrum – greater capacity, more users and faster speed.

Initial frequency bands for 5G are proposed around 600-700 MHz, 3-4 GHz, 26-28 GHz and 38-42 GHz which will add significantly more capacity compared to the current mobile technologies. The additional spectrum and greater capacity will enable more users, more data and faster connections. It is also expected that there will be future reuse of existing low band spectrum for 5G as legacy networks decline in usage and to support future use cases.

The increased spectrum in the millimetre (mm) Wave band above 30 GHz will provide localised coverage as they only operate over short line of sight distances. Future 5G deployments may use mmWave frequencies in bands up to 86 GHz.

MIMO BEAMFORMING



Massive MIMO antenna and advanced beam steering optimises EMF and increases efficiency.

Massive MIMO - multiple element base station - greater capacity, multiple users, faster data

5G will use 'Massive' MIMO (multiple input, multiple output) antennas that have multiple elements or connections to send and receive more data simultaneously. The benefit to users is that more people can simultaneously connect to the network and maintain high throughput.

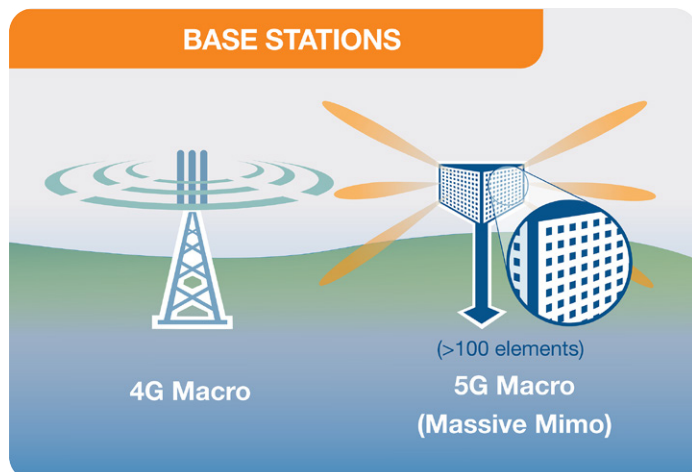
The overall physical size of the 5G Massive MIMO antennas will be similar to 4G, however with a higher frequency, the individual antenna element size is smaller allowing more elements (in excess of 100) in the same physical case.

5G User Equipment including mobile phones and devices will also have MIMO antenna technology built into the device for the mmWave frequencies.

MIMO – Beam Steering

Beam steering is a technology that allows the Massive MIMO base station antennas to direct the radio signal to the users and devices rather than in all directions. The beam steering technology uses advanced signal processing algorithms to determine the best path for the radio signal to reach the user. This increases efficiency as it reduces interference (unwanted radio signals).

BASE STATIONS



4G sector base station and 5G base station with a new multi element Massive MIMO antenna array. The overall physical size of the 5G base station antenna is expected to be similar to a 4G base station antenna.

Lower latency - Faster response times

Lower latency with 5G is achieved through significant advances in mobile device technology and mobile network architecture.

Technology	Response time (milliseconds)
4G - LTE systems	20-30 ms
5G - enhanced mobile broadband	4-5 ms
5G - URLLC (Ultra Reliable Low Latency Communications) systems	1 ms

5G Devices (User Equipment)

Improved technology and computing power in the User Equipment and devices is a major contributor to faster response times. As the device chip sets become more advanced, they can process data faster and reduce the response time called latency.

5G Network - Mobile Network Architecture

Significant changes in both the Core Network (Core) and Radio Access Network (RAN) are required to deliver low latency.

Core Network Changes

With the redesigned core network, signalling and distributed servers, a key feature is to move the content closer to the end user and to shorten the path between devices for critical applications.

Good examples are video on demand streaming services where it is possible to store a copy or 'cache' of popular content in local servers, so the time to access is quicker.

Radio Access Network Changes

To achieve the low latency, the Radio Access Network (RAN) will need to be re-configured in a manner that is highly flexible and software configurable to support the very different characteristics of the types of services that the 5G system envisages.

Low latency and high reliability over the air interface requires new radio techniques to minimise the time delays through the radio within a few TTIs (time transmit intervals) along with robustness and coding improvements to achieve high degrees of reliability (e.g. one message is delayed or lost in every billion).

Implementing a virtual, dynamic and configurable RAN allows the network to perform at very low latency and high throughput, but it also allows the mobile network to adjust to changes in network traffic, network faults and new topology requirements.

What will be re-configured? The new architecture will exist as a 4G/5G split RAN where the user plane (5G) and the control plane (4G) are separate. This requires the separation of general purpose hardware and specialised network hardware. The functionality of general purpose hardware (nodes) are suitable for network functions virtualisation (NFV), where the specialised hardware in the RAN will become dynamically configurable.



5G and EMF Safety

Are there safety limits for 5G and radio waves?

Yes. Comprehensive international guidelines exist governing exposure to radio waves including the frequencies proposed for 5G. The limits have been established by independent scientific organizations, such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP), and include substantial margins of safety to protect all people against all established hazards.

These guidelines have been widely adopted in standards around the world, and are endorsed by the World Health Organization (WHO).

What do the experts say about 5G and health?

In relation to radio frequency exposures and wireless technology and health, the general conclusion from the World Health Organization (WHO) is:

“Despite extensive research, to date there is no evidence to conclude that exposure to low level electromagnetic fields is harmful to human health”

WHO - About Electromagnetic Fields – Summary of Health Effects
Key Point 6

In relation to wireless networks and health, the conclusion from the WHO is:

“Considering the very low exposure levels and research results collected to date, there is no convincing scientific evidence that the weak RF signals from base stations and wireless networks cause adverse health effects”

Source WHO Backgrounder on base stations and wireless technologies

On mobile phone safety the World Health Organization advises:

“A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. To date, no adverse health effects have been established as being caused by mobile phone use.”

“While an increased risk of brain tumors is not established, the increasing use of mobile phones and the lack of data for mobile phone use over time periods longer than 15 years warrant further research of mobile phone use and brain cancer risk. In particular, with the recent popularity of mobile phone use among younger people, and therefore a potentially longer lifetime of exposure, WHO has promoted further research on this group. Several studies investigating potential health effects in children and adolescents are underway.”

WHO Fact Sheet 193 June 2014 - Electromagnetic fields and public health: mobile phones

What research into health effects has been done on 5G?

The electromagnetic frequencies used for 5G are part of the radio frequency spectrum which has been extensively researched in terms of health impacts for decades. Over 50 years of scientific research has already been conducted into the possible health effects of the radio signals used for mobile phones, base stations and other wireless services including frequencies planned for 5G and mmWave exposures.

The data from this research has been analysed by many expert review groups. Weighing the whole body of science, there is no evidence to convince experts that exposure below the guidelines set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) carries any known health risks, for adults or children.

The EMF-Portal (www.emf-portal.org) is an open-access extensive database of scientific research into the effects of EMF, including studies on the effects of RF on health. It is managed by the RWTH Aachen University, Germany and linked from the WHO website. EMF-Portal contains more than 25,000 published scientific articles on the biological and health effects of EMF and 2,500 studies on mobile communications.

In terms of research specifically on 5G frequencies, the database lists approximately 350 studies on mmWave EMF health related research. Extensive research on mmWave and health has been conducted on radar, microwave and military applications.

■ Is the research on 5G, mmWave and health continuing?

Yes – the current research on mmWave frequencies is focused on the alignment of the human exposure guidelines at frequencies below and above 6 GHz where the measurement parameter changes from Specific Absorption Rate (SAR) below 6 GHz to Power Density above 6 GHz. For more on SAR see <http://www.sartick.com/>.

The research is also focused on the dielectric properties of human skin to ensure that the power density levels and averaging area across the skin align with the temperature values that are the basis of the human exposure guidelines.

For example, a mobile device operating at 5 GHz will be assessed for compliance by measuring the SAR. The SAR levels are set to limit the absorbed power so that the temperature rise in the head or body from the device operating at maximum power is below the equivalent relevant limit. If the same device was operating at 6.5 GHz, a power density measurement would be required, so the measurement parameters would need to ensure the same limit in temperature rise is maintained.

■ Will 5G devices comply with the safety guidelines?

5G technology will be used in a wide range of devices and will be the backbone for the Internet of Things (IoT). All these devices will be evaluated to ensure that they conform to the RF safety limits adopted by agencies around the world.

■ Is 5G safe for children?

Yes – The EMF safety limits cover the 5G frequency range and include substantial margins of safety to protect all people including children from all established hazards.

■ What about children wearing RF transmitting devices or wearables for security or entertainment?

The radio transmitters in such devices are generally transmitting with very low power. When tested they are required to comply with national or international exposure limits. When watching a video the device is mostly receiving information and only transmits information for brief periods. Other types of devices such as personal trackers also transmit for short periods of time.

■ Will 5G devices automatically minimise transmitter power?

Yes – 5G devices will automatically minimise the transmit power to the lowest level in order to complete a satisfactory communication with the network. Such automatic power control has existed in previous generations of mobile technologies (2G, 3G and 4G) and helps to minimize interference, prolong battery life and also has the effect of limiting the EMF exposure of the user. The transmit power of the device is controlled by the network.

■ Does 5G mean higher power and higher exposure levels?

No – 5G networks are designed to be more efficient and will use less power than current networks for similar services.

With the introduction of new technologies, there may be a small increase in the overall level of radio signals due to the fact that new transmitters are active. In some countries deployment of 5G may occur as part of closure of earlier wireless networks. Based on the transition from previous wireless technologies we can expect that the overall exposure levels will remain relatively constant and a small fraction of the international exposure guidelines.

■ What types of base stations are used for 5G?

Base stations used for 5G will consist of various types of facilities including small cells, towers, masts and dedicated in-building and home systems.

Small cells will be a major feature of 5G networks particularly at the new mmWave frequencies where the connection range is very short. To provide a continuous connection, small cells will be distributed in clusters depending on where users require connection and this will complement the macro network 5G base stations.

5G networks will work in conjunction with 4G networks. In many cases, existing 4G base stations will be used for additional 5G equipment.

■ Do 5G base stations automatically minimise transmitter power?

Yes – 5G networks are specifically designed to minimise transmitter power, even more than existing 4G networks. 5G networks use a new advanced radio and core architecture which is very efficient and minimises transmissions consistent with service requirements which results in optimised EMF levels. The network also controls the power level of the device to the lowest level in order to complete a satisfactory communication with the network.

■ What will be the size of compliance zones around 5G network antenna sites?

The technical standards for the 5G networks and devices are still under development however it is expected that the size of the compliance zone for 5G antennas will be similar to that of other mobile technologies using similar transmitter powers.

Mobile network antennas are typically directional. Compliance zones extend in front of the antenna and a small distance above and below.

Mobile networks are designed to use only the power needed to provide quality services. Too much power would cause interference and affect all users. One of the goals of 5G is a substantial increase in network energy efficiency.

Where 5G is added to an existing site with other mobile technologies, the existing compliance zone may increase due to the addition of the 5G technology however this will depend on the site design and network configuration.

■ Is 5G similar to the Active Denial System used by the military?

No – Active Denial Systems developed by the military use very high powered mmWave directional signal, sometimes called a 'heat ray' in the 90 GHz band designed to heat the surface of targets such as the skin of a human, and through the heat, control or restrict access.

5G and other mmWave radio communications use different frequencies and a fraction of the power. The human exposure limits for mobile communications technology prevent heating occurring.

Additional information on ADS systems is available here.

<http://jnlp.defense.gov/About/Frequently-Asked-Questions/Active-Denial-System-FAQs/>

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