motorola

How 5G will change the world

Lenovo™

5G: THE NEXT GENERATION NETWORK

The mobile networks have evolved considerably in the last 30-40 years:

- 1G offered analog communication and brought mobile voice.
- 2G introduced digital communication and enabled further services like texting.
- 3G introduced higher bandwidth for data and apps.
- 4G with "always on" IP connectivity enabled the bandwidth needed for broadband services like mobile video, social media, and the app economy.
- 5G focuses not only on higher bandwidth, but also on low latency, higher reliability and convergence of mobile and fixed-line networks. 5G will have a much bigger impact on the economy and society, resulting in a transformational leap greater than any other in the history of wireless connectivity.

OVERVIEW

The industry is at the beginning of its implementation of the 5G network, launching in cities across the globe, including Motorola's hometown of Chicago.

The 5G network continues to evolve with the introduction of new features and enhancements. The convergence of technologies has already begun, with mobile operators, physical infrastructure providers, vertical industries and regulators coming together to realize the value of 5G. The businesses set to benefit most, will be those that join the network in its infancy, those that build an understanding of what's possible and those that take advantage of its vastly superior capabilities.

5G will be popularized via telecom carriers and the marketing of wire-cutting services, but the biggest impact will come from; service plans, data rate packages and connecting the Internet of Things (IoT), edge computing and analytics infrastructure with minimal latency.

Motorola has long been at the forefront of 5G, having been a part of its research and standardization and its testing from an early phase. The *moto Z3* with *5G moto mod*, a customizable add-on to Motorola devices, was the world's first 5G-ready smartphone. It launched in 2019 using ground-breaking millimeter wave technology enabling multi-Gbps data rates, months prior to the industry-wide deployment of 5G. The development of this 5G device acted as a test bed, enabling Motorola to look into important aspects, such as download speeds and device heating, and take learnings to be used for newly launched devices, such as the **motorola edge+**, **motorola one 5G UW**, and **motorola one 5G UW ace**.

Initially 5G products were available in the flagship tier, a relatively small part of the market. Manufacturers keen to make 5G attainable for all, are developing mid-tier 5G devices – like Motorola's *motorola one 5G* smartphones.

5G: INSIGHTS TO THE TECHNOLOGY

Operators have been the long-standing champions of 5G development and have been encouraging its development. Wireless traffic continues to increase year-on-year and it became clear that a network capacity increase beyond 4G was required to fulfill traffic requirements. 5G is expected to enable further economic growth and pervasive digitalization of an hyper-connected society. In a digital society, consumers, governments, corporations and industries will make use of mobile telecommunications to improve all kinds of processes. These so called 'vertical' sectors, often use specific applications, with a diverse set of requirements on mobile telecommunications. Rather than designing specific wireless technology for each of these vertical applications, it is expected that 5G technology is flexible enough to support all kinds of applications, even together on a single network.

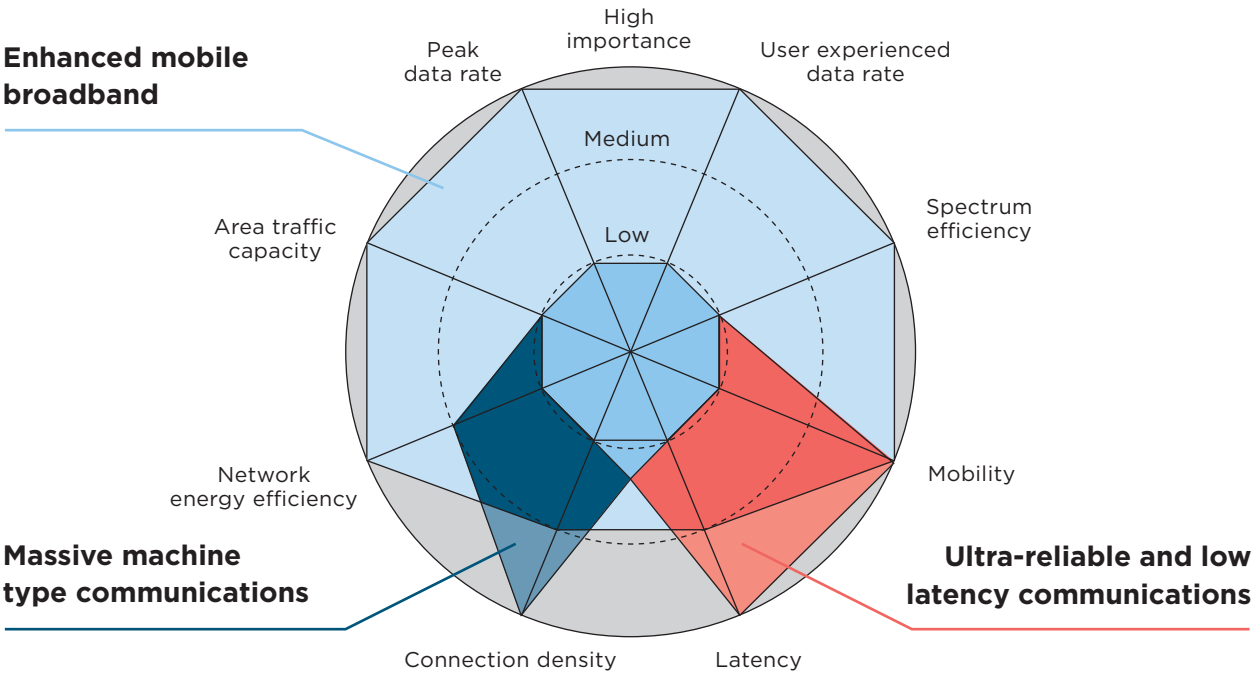
To meet the diverse industrial and market demands, the International Telecommunication Union (ITU) has identified three primary use cases that will bring about disruptive change and fuel the development of new applications and new business models, ultra-reliable low latency communications (URLLC), enhanced mobile broadband (eMBB), and massive machine-type communications (mMTC). See figure 1. The 5G technology as specified by 3rd generation partnership project (3GPP) has the target to meet all the 5G requirements specified by ITU.

MBB is about very high throughput rates to support applications like Ultra High Definition (UHD) streaming or virtual reality. mMTC is a communication paradigm where a number of devices or 'things' are attached to the Internet or directly connected and communicate with each other with little, or without, human intervention. In the 5G era, new applications for MTCs are developed to serve a huge number of 'things', introducing the so-called massive MTC, or massive Internet of Things (mIoT).

The popularization of the Internet of Things has also spurred a need to save energy on smaller IoT devices, like sensors, allowing them to last five to ten years on the same battery for machine-to-machine communication applications, and a need to support massive IoT in vertical markets like automotive, smart cities and Industrial Internet of Things (IIoT) for manufacturing, also known as Industry 4.0. 5G enables ultra-reliable and low latency communications, a new service category to accommodate those requirements especially for critical infrastructure, IIoT, AR/VR, and gaming. URLLC-focused applications require an end-to-end (E2E) delivery of data with reliability, security, and minimum latency. Such requirements have driven the 3GPP to set desired quality of service (QoS) requirements such as an air interface latency of 1 ms and 99.999% system reliability for URLLC.

To meet the needs of enterprise, Motorola has launched the motorola edge+, the fastest 5G phone in the world with class-leading battery life. This year, Motorola will begin offering smartphones globally that work on both millimeter wave and sub-6 GHz 5G networks. Motorola has partnered with Qualcomm to bring the very best solutions to the market.

Figure 1: Three primary use cases that will bring disruptive change



Source: ITU Recommendation M.2083

3GPP study item TR 38.913 describes the KPIs for the different deployment scenarios (eMBB, URLLC, mMTC), as well as vehicle-to-everything (V2X) requirements. Key Performance Indicators (KPIs) include target peak data rates, spectral efficiency, latency, reliability, UE battery life, and more, see figure 2.

Figure 2: 5G New Radio Key Performance Indicators

Peak Data Rate	20 Gbps downlink 10 Gbps in uplink
Peak Spectral Efficiency	30 bps/Hz for downlink and 15 bps/Hz for uplink
Latency	0.5 ms UL/DL (URLLC), 4 ms UL/DL (eMBB), 10 ms control plane
Mobililty Interruption Time	0 ms
Reliablility	URLLC 1-10^{-5} for 32 bytes with a user plane latency of 1 ms. V2X 1-10^{-5}, and user plane latency = 3-10 ms
Connection Density	1,00,000 device/km^2 in urban environments
UE Battery Life	mMTC should be beyond 10 years, 15 years is desirable
Coverage	164 dB
Mobility (UE Speed)	500 km/h
Network Energy Efficiency	100 x better than IMT-Advanced

Based on 3GPP TR 38.923 KPIs

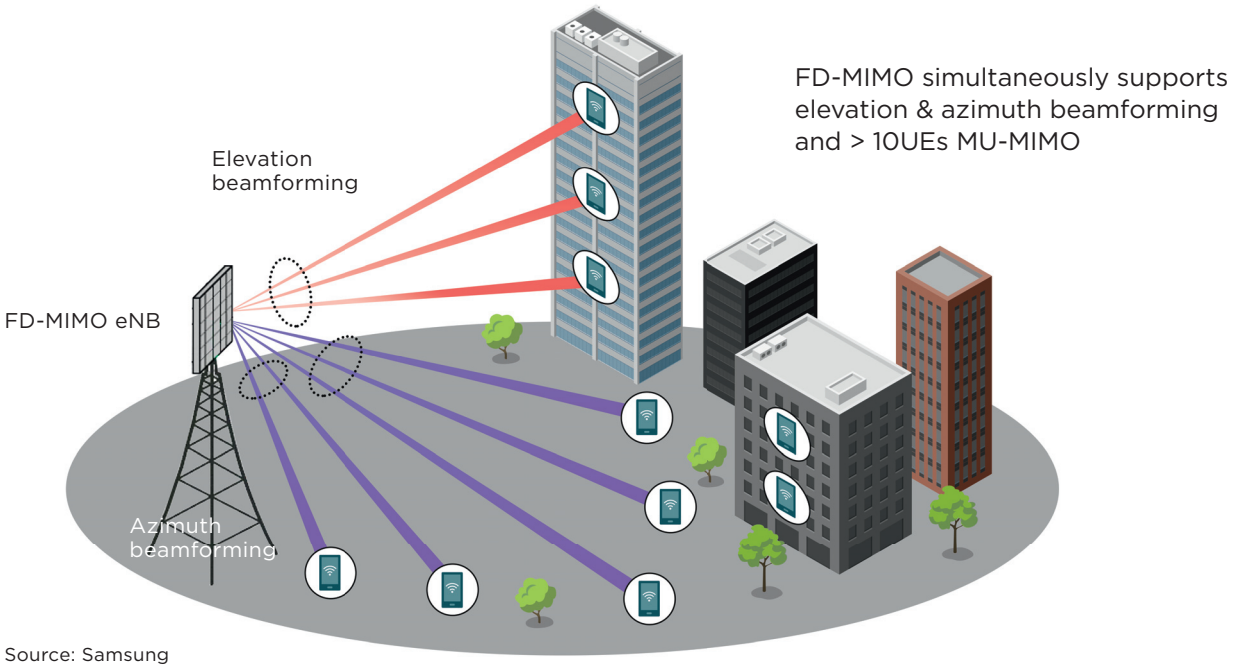
5G networks are developed with the ambition to support a wide range of highly demanding services and application, by pushing the network capabilities to provide extreme performance. With a flexible radio interface and software-driven network architectures, 5G can support network slicing, allowing portions of a network to be

quickly allocated to various use cases like broadband mobile, enterprise, IIoT, specific smart verticals, autonomous driving, and mIoT. In healthcare, for instance, a network could be sliced to allocate the data rate required for remote surgery to take place with very low latency of sub-ten milliseconds and ultra-high reliability, allowing a doctor to perform an operation in near real-time from an entirely different location. Rather than requiring multiple networks, 5G is optimized for a single software driven virtualized network that serves numerous verticals and traditional smartphone delivery at the same time, reducing operators' OPEX and CAPEX and time to market.

Many consider 5G more of an evolution of 4G since the radio waveform 5G (New Radio) uses is Orthogonal Frequency-Division Multiplexing (OFDM) based like 4G LTE, where OFDM efficiently enables the transmission of large amounts of digital data over a radio wave. One main difference between the 4G and 5G radio interface comes from the additional available frequency spectrum. 5G will primarily focus, at least initially, on using mid-band spectrum like 4G of 2.5GHz or C-band from 3.3 to 4.2 GHz, unlicensed spectrum in the 5 GHz and 6 GHz bands like Wi-Fi, and millimeter wave spectrum above 24.25 GHz due to the availability of larger contiguous frequency bandwidths spanning 100MHz or more. Large bandwidths facilitate high data rates, however, millimeter waves suffer from a relatively poor communication range.

On the other hand, antennas for millimeter waves can be realized with a small form factor, so that base stations for these bands will have many more antenna elements to allow for MIMO (Multiple Input – Multiple Output) techniques including beamforming, concentrating transmitted as well as received energy to very narrow beams between the base station and the device. See figure 3. This helps to maintain coverage and avoid interference as higher frequencies are reached, and allows a very efficient simultaneous use of the available spectrum for concurrent data links to a multitude of devices. Other radio improvements over 4G include mechanisms to prioritize delay-critical transmissions over the air interface as well as increased data reliability. Delay-critical service also benefit from higher sub-carrier spacings in the OFDM waveform compared to 4G allowing transmissions in a much shorter time frame.

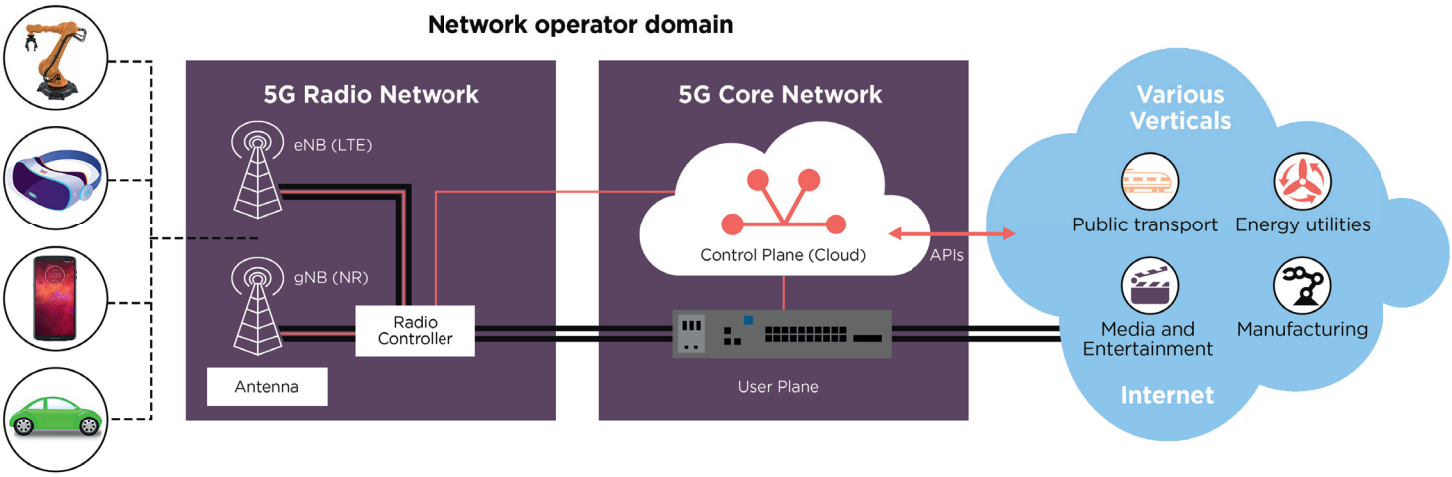
Figure 3: Full-Dimension MIMO (FD-MIMO)



Source: Samsung

As shown in Figure 4, a typical mobile network consists of a radio network and a core network. The difference of the 5G network is that the radio network may deploy multiple access technologies, e.g. LTE and NR (new radio). Furthermore, Wi-Fi access and fixed-line access can be connected to the 5G Core network (not shown in the Figure 4). Due to the virtualization of the network functions, the control plane of the Core Network has been developed to be deployed as a cloud service, which brings flexibility and the opportunity to increase or decrease the resources whenever needed. Mature 5G deployments (e.g. expected for the mid-2020s) would also implement virtualization of the radio network functions.

Figure 4: 5G system architecture



The great variety of use cases, as described above, result in a great variety of devices which can be connected to the 5G network. Figure 4 also shows that the various devices may belong to different vertical industries, or vertical customers from the network operator point of view. Each vertical customer may have a contract with the network operator to be provided with a tailored connectivity service. To meet similar business requirement, the network slicing concept is introduced in 5G. A network slice is an end-to-end logical network that runs on a shared physical infrastructure and provides connectivity services tailored for the vertical customer. Network slicing can be used to provide a kind of private network to a vertical customer.

Devices which require higher data rate or higher reliability may use several access technologies in different frequency bands simultaneously, but also multiple network slices. For example, an advanced device (e.g. connected car) may use simultaneously connection to LTE for voice and other low-bandwidth services, and NR for high-bandwidth (e.g. video) and or low-latency (e.g. autonomous driving) services. When the car is parked at home, it can simultaneously use the home Wi-Fi access for software updates, while other services can use NR access.

The enhancements of the radio interface and the core network with new features have also implications to the security aspects of the 5G system: new concepts of virtualization and technologies from the web/internet domain, as well as the desire to fix discovered security issues from 4G was leading to a new security architecture. It starts from privacy aspects of the secret user identity called Subscription Permanent Identifier (SUPI) to fight against International Mobile Subscriber Identity (IMSI) catcher, integrity protection of user data over the air interface to mitigate man in the middle attacks with Domain Name Service (DNS) hijacking or the authentication in the home network before revealing the secret user identity

to the serving network (e.g. roaming network). Further authentication enhancements were introduced with an EAP (Extensible Authentication Protocol) based method for registration with the network, as well as additional procedures where the access to a specific data network or to a specific network slice can be granted only after an successful additional authentication with the service provider. Network Functions (NFs), representing the core network entities, interconnect with each other either with Transport Layer Security (TLS) and preconfigured certificates or based on Network Domain Security (NDS, e.g. IPSec tunnels) or both together. The extension of the key length for the air interface protection of currently 128 Bit to 256 Bit are under discussion in different organizations in order to guard the data on the most vulnerable transmission part even better. Further extensions are provided that suit the service enhancements of the vertical industries for providing a secure service over the 5G system.

By 2030, when 5G is expected to be fully evolved and as mainstream as 4G is today, capacity requirements will have once again increased. With higher data rate usage, lower latency requirements and potential use cases requiring data rates of 100 gigabits per second or higher, 5G will need to evolve again and 6G may be needed.

5G: THE BENEFITS

It's also important to understand how 5G will positively impact how business is conducted. It provides more advanced connectivity, superior capacity, lower latency and greater speed in transmissions. Some of the main benefits include:

- 5G provides flexible content consumption (e.g. low latency and high bandwidth for delay sensitive applications, as well as energy efficiency for small data applications) and the best connectivity on the market. For businesses depending on devices to connect and operate, 5G offers more flexibility compared to the current network.

- 5G devices will also form part of a much wider ecosystem, from the devices themselves and the networks they utilize, to the physical infrastructure and antennas required for widespread use. Capitalizing on all of this will provide the most benefit to businesses.

- At present, organizations have to pay for wired internet, installation and management. 5G will create a convergence of technology where all of this will be possible through basic connectivity, devices and existing networks, dramatically reducing cost.

- It will increase the efficiency of people working away from the office. Working remotely has become the norm due to the COVID-19 pandemic. 5G will provide huge benefits to companies that continue to support remote working, through ubiquitous connectivity (i.e. providing connectivity to everyone and everything, everywhere, anytime).

- Industries that rely on connected devices will be able to send vast amounts of data, instantly and across a superiorly powerful network. Whether businesses are using devices for specific tasks or for general purpose, they will benefit.

For these benefits to be realized, it's essential that the devices available are capable of enabling 5G and the information that it processes.

5G: MAKING A TANGIBLE DIFFERENCE TO THE WORLD

The impact 5G will have on the workplace barely scratches the surface of the network's capabilities. 5G will help revolutionize so many aspects of everyday life. Some exciting real-world examples include:

Entertainment

Although virtual reality (VR) technology has improved dramatically in recent years, it is primarily used for gaming. 5G will completely change this, taking VR beyond the existing immersive experience to virtually transport people across the world to watch a sporting event or concert. 5G devices are vital to this, a smartphone could be used to render and power the goggles, while a strong battery will be essential for effective performance.

This development is especially important given the number of fans that live miles from their favorite sports team or musician. For example, according to Forbes, there are 325 million Manchester United Football Club fans in Asia. 5G capabilities could enable these fans to watch Manchester United games as though they are in attendance, from 5,000 miles away.

Bringing these capabilities into the world of work could revolutionize internal correspondence, particularly for companies with offices based around the globe. VR, enhanced by 5G, could virtually transport an overseas colleague into the meeting room, bringing a widespread workforce closer together.

Transport

While 5G roads will not look drastically different, they will fundamentally change transport networks. 5G will enable the much-hyped autonomous vehicles to finally become a reality, due to the improved data sharing and connectivity it brings.

5G will enable sub-ten millisecond latency creating near instant exchanges of information, which is vital in cars taking safe decisions and reacting to ever changing road conditions. The network will allow vehicles to talk to one another, to highways, to traffic lights and to cities by enhancing IoT connected devices. Connectivity and the instant exchange of information will optimize roads and vehicles as one entity, creating efficiencies that will make autonomous journeys safe.

Education

According to a study conducted by Learning House and Aslanian Market Research, nearly 67 percent of students now use mobile devices to complete their online coursework. That represents a huge proportion of students learning primarily through devices such as smartphones or laptops. As the capabilities of mobile devices increase, this figure can only be expected to grow as 5G makes online work faster .

With 5G unlocking the full potential of VR, students could join virtual classrooms anywhere in the world and interact in real time. VR can also be used to travel to the time of dinosaurs, visit volcanoes, look at organs inside the human body and interact with events of historical significance, revolutionizing education as we currently know it.

Greater connectivity through IoT will also significantly improve the efficiency in running schools and classrooms. Virtual assistants will be able to check registers, collect homework and mark papers. With schools closed, the Covid-19 outbreak has highlighted the need for

this more than ever. If a similar scenario were to ever occur again, 5G would enable optimal preparation for remote schooling.

Manufacturing

By putting 5G nodes around a factory, businesses can change the way that processes are happening in a manufacturing environment. 5G can instantly adjust, receive and send orders autonomously and to order. Greater connectivity will result in vastly improved supply chains. From source to delivery, every step of the way will be monitored and optimized, creating autonomous processes that negate many traditional steps along the chain.

In industry, robots and machines are replacing people in roles that involve the 'three Ds' of dirty, dull and dangerous work. How these machines work with people and each other will be improved through greater connectivity. As industry creates more data points, 5G will be essential in their management, analysis and execution. This will be a vital part of the Fourth Industrial Revolution, an era of accelerated technological process which will fundamentally change the way people live, work and interact with each other.

Gaming

5G is set to provide higher bandwidth and lower latency, enabling a level of streaming and gaming quality akin to consoles and computers on mobile devices. Streaming, gaming and sharing will be revolutionized, paving the way for the next generation of gamers. Mobile gaming will graduate to the level of consoles in terms of capability. With physical copies of games heading to the history books, games will be powered and played through the cloud. Cloud-based gaming alone is projected to be worth more than $8 billion by 2025 as a result of 5G advancement.

Similarly, with the continual rise of esports, gaming fans will have access to live tournaments at a speed never previously encountered. Milan Games Week 2019 saw the first live 5G e-gaming competition, which enabled hundreds of millions across the globe to watch with ultra-low latency, indicating the potential set to come.

5G will also coincide with the development of haptic technology, which will allow users to create and feel physical impact, enhancing gaming experiences.

5G: WHAT HAPPENS NOW?

While the potential for 5G across numerous industries is inherent, the technology is still in its early phases. So far, 5G services have launched in 40 countries by 70 out of 800 operators. Despite a large presence in the media, the infrastructure necessary for its mainstream adoption is still in the early stage of commercial deployment in many countries and has not yet started in others.

For now, the importance lies in raising awareness of its future potential. The responsibility falls with those early adopters to inspire others of its benefits, both in business and in personal life, to help individuals to prepare and for uptake to accelerate. The businesses that take the lead now and bring 5G into their digital transformation strategies will stay ahead of the competition and increase efficiencies, while avoiding the need to refresh their framework in a few years' time.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