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5G RADIO ACCESS

RESEARCH AND VISION

5G will enable the long-term Networked Society and realize the vision of unlimited access to information for anyone and anything. This vision will be achieved by combining evolved versions of today's radio-access technologies (RATs), including LTE and HSPA, with complementary RATs for specific use cases, not by replacing existing technologies.

INTRODUCTION

Over the past few decades, there have been significant enhancements made to mobile-communication networks, as well as the introduction of new mobile communication device types, such as smartphones and tablets. This in turn has led to a massive increase in novel applications and use cases for mobile connectivity, as well as exponential growth in network traffic. However, we have still only just begun making the transition into a fully connected Networked Society in which everything that will benefit from a connection will be connected [1].

As mobile networks expand to accommodate new types of connected devices and corresponding services – from electricity meters to cars to household appliances to communication that supports industry applications – new and widely varying requirements are placed on them. A "one technology fits all" solution will therefore likely not be the most efficient option.

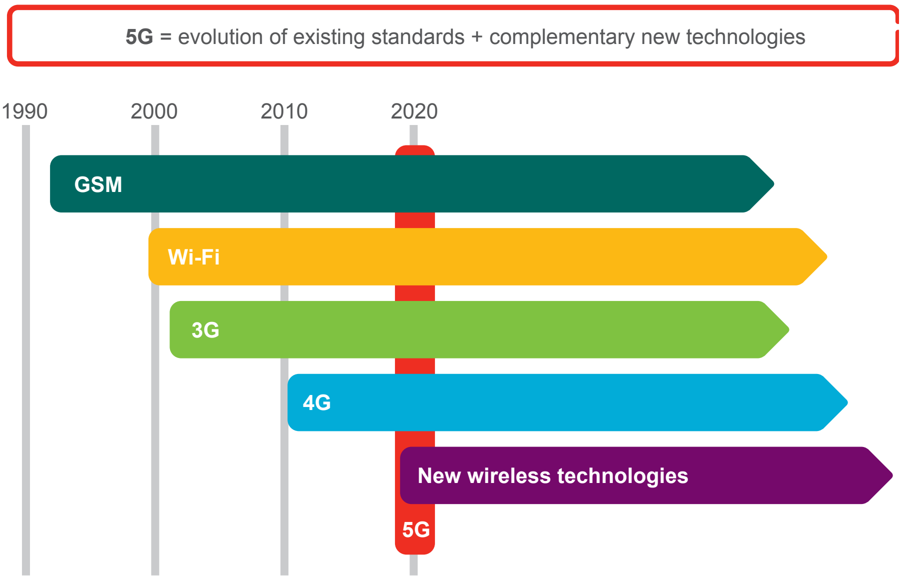

Figure 1: 5G is the seamlessly integrated combination of evolved versions of currently existing wireless technologies and complementary new technologies, jointly enabling the evolution of the Networked Society for 2020 and beyond.

Rather, today's wide area technologies will continue to evolve, resulting in enhanced system performance and extended capabilities. They will also be complemented with other technologies for particular use cases that are difficult to address with evolved versions of today's technologies. The seamless integration of such complementary technologies with evolved 3G and 4G will bring a new consumer experience and enable the introduction of a host of new services.

The long-term outcome of this trend is what we refer to as 5G: the set of seamlessly integrated radio technologies that will bring the Networked Society [1] to come to life by 2020. The evolution of LTE will be fundamental to this future, as will the evolution of HSPA and Wi-Fi. Even GSM will play an important role, continuing to be an important RAT in many parts of the world – even beyond 2020. Hence 5G is not about replacing existing technologies but rather about evolving them and complementing them with new RATs for specific scenarios and use cases.

CHALLENGES FOR 2020 AND BEYOND

The future mobile-broadband user should experience radio access with “unlimited” performance: data should be accessible instantaneously and the delivery of services should not be hampered by waiting times or unreliable access. This is valid both for regular private and professional users accessing the internet, as well as for professional users such as firefighters and paramedics who are addressing fundamental societal needs; for such users, reliable broadband communication can be a matter of life and death.

Further, new types of devices and services related to connected things are also going to appear in the future. Examples of these connected things include connected traffic lights, vehicles, medical devices, waste bins and electricity supply systems – basically anything that can benefit from a connection. This connectivity will bring significant benefits to people, business and society. The 5G system must be able to provide efficient, high-performing solutions for all such services. This is needed to bring the long-term Networked Society to life.

To enable the realization of this long-term vision, several key challenges should be addressed by the future radio access solution, as outlined in Figure 2 and described below.

The overall traffic volume in wireless communication systems has grown tremendously in recent years, fueled primarily by the uptake in mobile broadband. This trend is expected to continue into the future. Based on extrapolations of different predictions [2] [3], it is possible to conclude that beyond 2020, wireless communication systems will have to support more than 1,000 times today’s traffic volume.

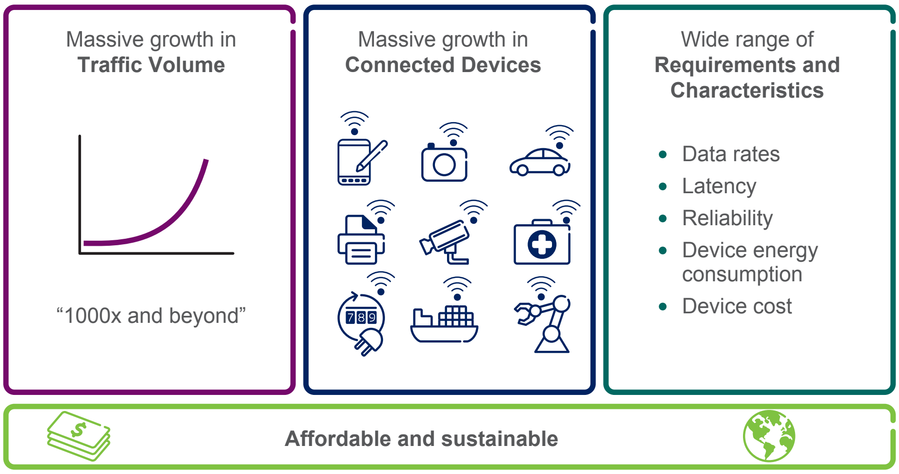

Figure 2: Key challenges for future radio access.

There are more than 5 billion wirelessly connected mobile devices in service today [2] [3], most of which are handheld terminals or mobile-broadband devices in portable computers and tablets. In the future, such human-centric connected devices are expected to be surpassed between 10- and 100-fold by communicating machines including surveillance cameras, smart-city, smart-home and smart-grid devices, and connected sensors. The transition from five to 50 or perhaps even 500 billion connected devices will present a formidable challenge.

However, an even greater challenge will be created by the dramatically expanded range of requirements and characteristics associated with all the new types of connected devices that will emerge.

Mobile-broadband services such as video streaming, data sharing and cloud services will remain, and will continue to drive a demand for higher consumer data rates. Reliably achievable multi-Gbps data rates should be available in special scenarios, such as office spaces or dense urban outdoor environments; these rates will support applications such as synchronization of device local storage to cloud drives, network hard drives, ultra-high-resolution video, and virtual and augmented reality.

Even more important, consumer data rates of hundreds of Mbps should be generally available as a step toward realizing the vision of unlimited access to information. Also the end-to-end latencies will need to be reduced further down to a few milliseconds to support the multi-Gbps data rates and enhance virtual- and augmented-reality applications.

In addition, the large-scale introduction of communicating machines will go hand in hand with the emergence of many new use cases and applications. These applications will have characteristics and requirements that differ from those associated with human-centric applications, and will vary significantly depending on the application:

- Some applications – such as remote meter reading for billing purposes – have very relaxed latency requirements. Other applications, such as safety or control mechanisms in the process industry, in the electrical-distribution grid, or for traffic safety, have very strict requirements regarding low latency; 5G needs to support a latency of a few milliseconds or below to address such use cases.
- Applications relating to the control of critical infrastructure (such as electrical grids), industrial control or vital societal functions, such as traffic, e-health and smart-city management, require very high levels of network reliability – higher than today's networks typically offer. The reliability requirements are much lower when it comes to, for example, temperature or moisture sensors in the home.
- Some applications, such as remote video surveillance, are associated with the conveyance of significant volumes of information, while other applications, such as cargo tracking in the shipping industry, are associated with very small data payloads.
- In some cases – for example, for battery-powered sensor networks – low device cost and/or energy consumption is extremely important while, for some other applications, this is less of an issue.

The cost of deploying, operating and maintaining a network, as well as the cost of the devices, should also be at a level that enables popular services to be provided at an attractive price for users, while maintaining attractive business cases for network operators.

Finally, energy efficiency should also be an important focus area, in order to achieve and retain a low network-operation cost. Although the ICT sector today contributes only about 2 percent of the global CO2e footprint [4], it is important to further enhance network-energy efficiency to help lower this footprint, even with the expected massive increase in traffic.

5G RADIO ACCESS SOLUTIONS

Evolved and extended radio-access solutions are needed to address the above challenges. Different solutions will be implemented to address different challenges.

Evolved versions of existing RATs will be complemented with new ones targeting specific scenarios and use cases that would not otherwise be accommodated. The result (an overall future radio-access solution consisting of evolved versions of existing RATs, such as HSPA and LTE, and other new technologies, operating and interacting in a fully integrated way) can be referred to as 5G radio access as it takes user experience and overall system performance a step beyond what 4G can currently provide.

VERY HIGH MOBILE-BROADBAND SERVICE LEVEL EVERYWHERE

Existing mobile-broadband technologies such as HSPA and LTE will continue to evolve and will provide the backbone of the overall radio-access solution of the future beyond 2020. Their capabilities will continue to expand. For example, consumer data rates of hundreds of Mbps will become available essentially at any time, everywhere. Smart antennas including a very large number of steerable antenna elements, more spectrum and coordination between base stations will help to provide such very high service levels. The mobile-broadband technologies will also expand into new deployment scenarios, such as dense small-cell deployments, and new use cases, such as different kinds of machine-type communication.

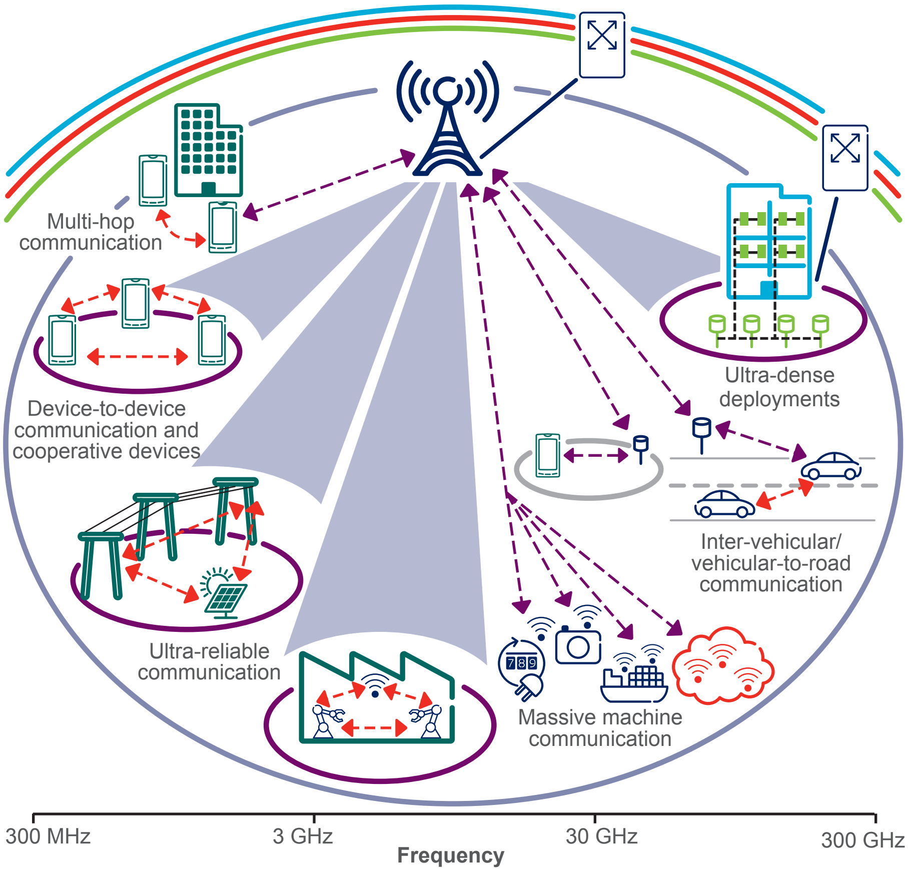

Figure 3: 5G radio access is an integrated set of technologies addressing a wide variety of use cases and requirements.

ULTRA-HIGH TRAFFIC CAPACITY AND DATA RATES

To address the challenge of being able to provide extremely high traffic capacity and multi-Gbps data rates in specific scenarios, we foresee the introduction of ultra-dense network deployments with nodes operating with very wide transmission bandwidths in higher-frequency bands relying on new RAT.

Ultra-dense networks will consist of low-power access nodes being deployed with much higher density than the networks of today. In extreme cases, we foresee indoor deployments with access nodes in every room and outdoor deployments with access nodes at lamppost distance apart.

To reliably support multi-Gbps data rates, ultra-dense networks should support minimum transmission bandwidths of several 100MHz with the possibility of an extension up to a few GHz of bandwidth.

Ultra-dense networks will primarily operate in the 10-100GHz range.

> While there are still many question marks regarding the use of such frequency bands for wide-area deployments, including outdoor-to-indoor propagation properties, they appear more

suitable to the shorter-range communication of ultra-dense networks.

- Higher frequency bands make it easier to provide the very wide transmission bandwidth needed to reliably support multi-Gbps data rates.
- Ultra-dense networks will include advanced network solutions, such as integrated wireless multi-hop self-backhaul and advanced node coordination.

Although they will operate in different spectrum and will most likely be based on new RAT, the ultra-dense networks should be well integrated with the overlaid cellular networks, providing a seamless user experience as devices move in and out of ultra-dense network coverage.

HUGE NUMBERS OF LOW-POWER MACHINE-TYPE COMMUNICATION DEVICES

Activities focused on extending existing cellular technologies (primarily LTE) to support huge numbers of low-power machine-type communication devices are already ongoing in the 3GPP. However, it will be difficult to evolve LTE to meet certain applications with extreme requirements. Therefore, alternative technologies will be needed – for instance, to support devices with extremely challenging energy-consumption constraints. Such technologies will then be seamlessly integrated into the cellular technologies so that ubiquitous connectivity can be provided. As an example, capillary networks communicating using some alternative technology will connect to the rest of the world via cellular technology.

PROXIMAL COMMUNICATION

For situations where users are close to each other and particularly where information has a local context (traffic safety, national security and public safety (NSPS) and general proximity services in which the user interacts with and exchanges information with the immediate environment) it can be more efficient to let devices communicate directly over a device-to-device (D2D) link than via the network infrastructure. Under network control, D2D will offer carrier-grade reliability to local communication services since the network can manage the D2D traffic in licensed spectrum. In LTE standardization, the first steps of D2D integration into a network-based communication technology are now being taken. D2D will also be an important component for NSPS applications, since it enables local communication, even when the network infrastructure is damaged.

ULTRA-RELIABLE COMMUNICATION

For industrial communication and societal functions, such as traffic safety, e-health and smart-city management, the reliability requirements cannot always be met by today's radio networks. Certain use cases involving particular smart-grid communication applications and traffic safety, for example, require a network latency that is lower than what today's systems can provide – down to just a few milliseconds end-to-end.

Reliability is to a large extent dependent on network deployment and the provision of enough resources to handle traffic peaks. On the radio access side, it will be important to be able to differentiate between traffic types and to give priority to critical traffic. A significant challenge lies in the combination of ultra-low latency and extreme reliability. This will require different tradeoffs than those made for today's mobile-broadband systems, which are primarily designed for capacity, coverage and data rates. Control-channel design, coding, link adaptation and Radio Resource Management are areas in which tradeoffs will need to be made differently to optimize networks and ensure low latency. Where extremely low latency is required, for example around one millisecond or below, new technology with shorter transmission time intervals will be needed.

ENERGY EFFICIENCY AND SUSTAINABILITY

As mentioned, energy efficiency will be of even greater importance in the future and should be a main design target for all 5G radio access solutions. Reduced link distances in a densified network as well as smart functionalities for node sleep and minimization of signaling for network detection and synchronization will significantly bring down the energy consumption of future networks.

NEW SPECTRUM ASSIGNMENTS

The 5G system for 2020 and beyond will require much more spectrum and larger bandwidths to support the expected increase in traffic and even higher data rates; this is in addition to the work ongoing to find more spectrum for today's LTE and HSPA systems. By 2020 and beyond, more spectrum will be needed both in the frequency ranges of today's systems and also in higher frequency ranges. The former is needed to improve the service levels in the wide area, whereas the latter can provide larger bandwidths, enabling extremely high service levels for special scenarios.

CONCLUSION

The 5G system for 2020 and beyond will meet our long-term vision of unlimited access to information and sharing of data available anywhere and anytime to anyone and anything. To do this, it is clear that a much wider variety of devices, services and challenges than those accommodated by today's mobile-broadband systems will have to be addressed. Due to this diversity, the 5G system will not be a single technology but rather a combination of integrated RATs, including evolved versions of LTE and HSPA, as well as specialized RATs for specific use cases, which will jointly fulfill the requirements of the future.

The research required for the development of 5G is now well underway. The recently founded European METIS (Mobile and wireless communications Enablers for the Twenty-twenty Information Society) project [5] is aimed at developing the fundamental concepts of the 5G system and aligning industry views. The 5G concept developed by, for example, the METIS project, can be assumed to reach standardization phase within a few years. In this case, the transition to full 5G capability will take place gradually from around 2020.

GLOSSARY

CO2e	carbon dioxide equivalent
D2D	Device-to-Device
METIS	Mobile and wireless communications Enablers for the Twenty-twenty Information Society
NSPS	national security and public safety
RAT	radio-access technology

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