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5G key enabling technologies and use case

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Abstract: The evolution of 4G networks has led to the development of different applications based on its powerful network capacity. Although, in the future with the presence of 5G (the fifth generation of network), the network of network, it is predicted that an incredible number of new services, with different business actors will be involved, are going to stem, exploit and explore. This paper briefly introduces the fifth generation of mobile network, 5G, in terms of capabilities, use cases and key enabling technologies, provides key concepts of information security, including availability, integrity and confidentiality. It also highlights the important of security in 5G landscape.

Keywords: 5G; Key enabling technologies; Network slicing; 5G use cases; Massive connectivity.

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1. Introduction

The 5G simply stands for the fifth generation and refers to the next and newest mobile wireless standard based on the IEEE 802.11 ac standard of broadband technology [1], however technologies used in 5G are still being defined. Fifth generation (5G) is not as previous generations, an evolution of the existing, but it is rather considered as a cellular network revolution that builds on the evolution of existing technologies. These technologies are complemented by new radio concepts that are designed to meet the new and challenging requirements of some use cases today's radio access networks cannot support [2]. The anticipated capabilities of 5G will include massive system capacity, very high data rates everywhere, very low latency, ultra-high reliability and availability, very low device cost and energy consumption, and energy-efficient networks.

2. 5G requirements and capabilities

According to the Groupe Speciale Mobile Association (GSMA) [2], to qualify for 5G a connection should meet most of these criteria on the Figure 1.

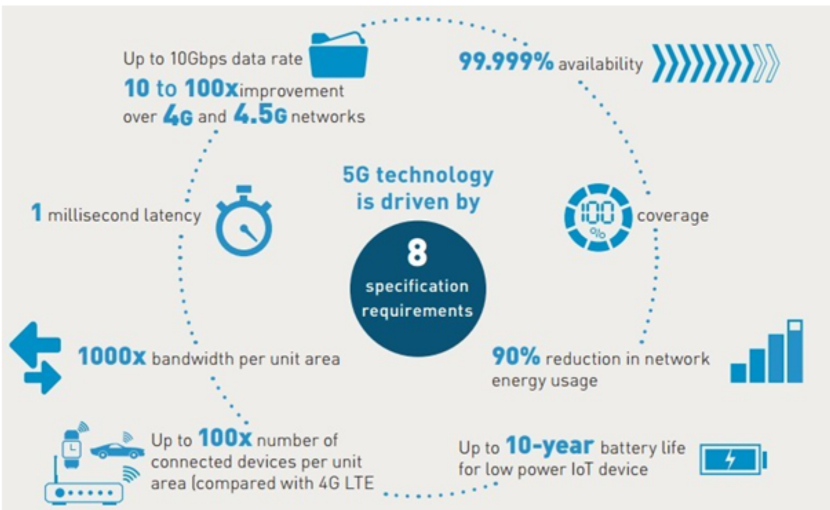

Figure 1. 5G capabilities

Because these capabilities are specified from different perspectives, they do not make an entirely coherent list - it is difficult to achieve a new technology that could meet all of these conditions simultaneously.

Equally, whilst these eight requirements are often depicted as a single list, no use case, service or application has been identified that requires all eight performance attributes across an entire network simultaneously

Very high data rates available everywhere and global coverage

Every generation of mobile communications has been associated with higher data rates compared to the previous generation. In the past, the development much focused on the peak data rate delivered under the ideal condition. However, future applications demand strictly on the actual data rate that the network can provide under real-life conditions in different scenarios [3].

- With 5G, it should support data rates exceeding 10Gbps in specific scenarios such as indoor and dense outdoor environments.
- Data rates of several 100Mbps should generally be achievable in urban and suburban environments.
- Data rates of at least 10Mbps should be accessible almost everywhere, including sparsely populated rural areas in both developed and developing countries.

The global coverage is achievable using any of existing wireless technologies, as well as 5G, and it depends on how network operators establish their own cells.

Very low latency and 99.999% availability

Some subjected 5G use cases, such as autonomous driving, public safety and control of critical infrastructure and industry processes, may require much lower latency compared with what is possible with the mobile-communication systems of today.

To support such latency-critical applications, 5G should allow for an application end-to-end latency of 1ms or less, although application-level framing requirements and codec limitations for media may lead to higher latencies in practice. Many services will distribute computational capacity and storage close to the air interface. This will create new capabilities for real-time communication and will allow ultra-high service reliability in a variety of scenarios, ranging from entertainment to industrial process control [4].

In addition to very low latency, 5G should also enable connectivity with ultra- high reliability and ultra-high availability. For critical services, such as control of critical infrastructure and autonomous driving, connectivity with certain characteristics, such as a specific maximum latency, should not merely be 'typically available.' Rather, loss of connectivity and deviation from quality of service requirements must be extremely rare. For example, some industrial applications might need to guarantee successful packet delivery within 1 ms with a probability higher than 99.999%.

Lower device and network energy consumption

The reduction of power consumption by networks and devices is fundamentally important to the economic and ecological sustainability of the industry.

Energy-per-bit usage should be reduced by a factor of 1,000 to improve upon connected device battery life. Since 5G will be the key enabler of IoT, with billions of wirelessly connected devices such as sensors, actuators, and most of them are required to have the operation life time up to 10 years, 5G should provide an appropriate scheme where connectivity is occasional, and the amount of throughput is minimal [5].

While energy consumption on device side has always been prioritized, energy efficiency on the network side has recently emerged as an additional KPI (Key Performance Indicator). It is an important component in decreasing operational cost, as well as a driver for better dimensioned nodes, leading to lower total cost of ownership. Energy efficiency enables off-grid network deployments that rely on medium-sized solar panels as power supplies, thereby enabling wireless connectivity to reach even the most remote areas. Energy efficiency is a key aspect to realize operators' ambition of providing wireless access in a sustainable and more resource-efficient way. In 5G, 90% of network energy usage will be reduced compared to previous generation.

Massive connectivity

5G differs from 4G LTE in that it will be planned not for one traffic type, but multiple types.

For example, a massive number of new IoT devices will be attached to a 5G network. While these devices will add little traffic compared to mobile broadband, they will require signaling to communicate with the network. Bell Labs estimates that a typical IoT device may need 2,500 transactions or connections to consume 1MB of data [5].

This explain why, 5G should provide 1000x bandwidth per unit area to support broad range of traffic types. Moreover, a single cell of 5G should be able to serve well up to 1 million devices.

It is important to highlight that not all of these above performance indicators will be required by every terminal everywhere and all the time. Each connected device will typically have its mix of latency, bandwidth and traffic intensity characteristics.

3. Use cases

5G will support countless emerging use cases with a high variety of applications and variability of their performance attributes: From delay-sensitive video applications to ultra-low latency, from high speed entertainment applications in a vehicle to mobility on demand for connected objects, and from best effort applications to ultra-reliable ones such as health and safety [6].

3.1. Mobile broadband access

This 5G segment encompasses the use of portable devices in a range of very diverse scenarios, specifically including the more challenging situations in terms of high density area, high mobility. 5G is expected to provide its service in densely-populated areas (e.g., multi-storey buildings, dense urban city centers or events), where thousands of people per square kilometer live and/or work, or in high speed vehicles (such as train, aircraft). The following are some typical use cases of this family:

- Smart office: In a future office, it is expected that most of the devices will be wirelessly connected. Users will interact through multiple and wirelessly connected devices. This suggests a scenario in which hundreds of users require ultra-high bandwidth for services that need high-speed performance of bandwidth-intensive applications, processing of an enormous amount of data in a cloud, and instant communication by video.
- o Live stream in public event: This use case is characterized by a high connection density in a large-scale event sites, such as stadiums or hall parks. Several hundred thousand users per km2 may be supported, possibly integrating physical and virtual information such as information on athletes or musicians, etc., during the event. People can watch high definition (HD) playback video, share live video or post HD photos to social networks. These applications will require a combination of ultra- high connection density, high date rate and low latency.
- o High speed transportation: Beyond 2020, all kind of transportations will be huge improved in term of speed, ensuring the persistent connectivity for traveler is an important feature. While travelling, passengers will use high quality mobile Internet for obtaining information, entertaining or working. Examples are watching a HD movie, gaming online, accessing company systems, interacting with social clouds, or having a video conference. Delivering a satisfactory service to the passengers (e.g. up to 1000) at a speed higher than 500 km/h may be a great challenge.

3.2. Critical communication

This family of use cases are usually related to ultra- reliable and ultra-latency requirements. It will consist of drones and air traffic control, cloud driven virtual reality, smart factories, collaborative robotics, public safety, connected transportation and e- health. However, each use case will have their specific demand, for instance, may require one or more attributes such as extremely high throughput, mobility, critical reliability, etc. For example, the autonomous driving use case that requires ultra-reliable communication may also require instant reaction (based on real-time interaction), to prevent road accidents. Others such as remote computing, with stringent latency requirement, may need robust communication links with high availability [7]. The following are some typical use cases of this family:

- Automotive driving: Vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and other Intelligent Transport Systems (ITS) applications require very low latency - much lower than is currently offered by LTE. Driverless cars and the next generation of driver- assisted cars will need real-time safety systems that can exchange data with other vehicles and infrastructure around them.

- Collaborative robotics in industrial automation: Automation will complement human workers, not only in jobs with repetitive tasks (e.g., production, transportation, logistics, office/administrative support) but also within the services industry. As 5G networks are rolled out, traditional robots programmed to carry out specific functions will be replaced by new models connected to the cloud. These new robots will have access to almost unlimited computing power, making them more flexible, more usable and more profitable to own and operate. For many robotics scenarios in manufacturing a round-trip reaction time of less than 1ms is anticipated.
- Drones: The ultra-fast, ultra-reliable of 5G will open the huge potential of sky transportation, especially the use of drones. Governments and disaster-relief organizations will use 5G-connected drones to aid in emergency efforts. Drones in the sky will communicate and share real- time information with each other and teams on the ground, increasing the speed and effectiveness of search-and-rescue missions. Drones may be exploited for logistics such as autonomous delivery of packages on routes with no/low civil population. The network will support a multitude of autonomous drones to navigate your local skies safely, and even send notifications to your devices announcing their arrival. Another amazing drone practice in 5G can be deployed is internet drones, to provide reliable ubiquitous connectivity.
- eHealth: Extreme Life Critical: Beyond 2020, remote treatment will emerge based on the development of monitoring devices as sensors for electrocardiography (ECG), pulse, blood glucose, blood pressure, temperature. 5G specificities will make the command-response time close to zero and provide the practitioner with great operation comfort and accuracy. In the near future, a patient who needs an urgent or specific operation could be operated by a practitioner remotely located.

3.3. Massive IoT

This segment is extremely broad, containing not just M2M but consumer based services too. It is likely to consist of an ecosystem of potentially very low cost devices such as sensors or trackers. Typical use cases are highly varied and may include camera surveillance, driverless cars, smart home, some wearables and machine type communications including metering, sensors and alarms with a wide range of characteristics and demands. The following describes some typical use cases of this family:

- Smart wearables: It is predicted that the use of wearables consisting of multiple types of devices and sensors will become mainstream. For example, a number of ultra-light, low power, waterproof sensors will be put in people's clothing. These sensors can monitor various environmental and health attributes like pressure, temperature, heart rate, blood pressure, body temperature, breathing rate and volume, skin moisture, etc. A wearable device be able to communicate to other devices will lead to rich experiences for users. A key challenge for 5G to enable fully this use case is the management of the number of devices as well as the data and applications associated with these devices.
- Connected home: Our future homes will be full of connected devices, not only providing data on their environment, but also connecting with each other. A smart thermostat may "talk" to a smoke detector, so that the collective information can provide more reliable information in the event of a fire at home. In case no one is present, this information can be remotely communicated to mobile devices and bring the fire brigade to the rescue. Homes are anticipated to become enormous sources of information and data will be shifted to mobile devices for remote monitoring, control and eventual decision. 5G is expected to support such connected home scenarios, whilst bringing down the service costs.
- o Smart grids: The consumption and distribution of energy, including heat or gas, is becoming highly decentralized, making the need for automated control of an extremely distributed sensor network. A smart grid interconnects such sensors, using digital information and communications technology to gather and act on information. This information can include the behaviors of providers and consumers, allowing the smart grid to enhance the efficiency, reliability, economics and sustainability of the production and distribution of fuels such as electricity in an automated fashion. A smart grid can be seen as another sensor network with low delays. 5G is expected to handle massive amount of low cost devices communication as in smart grids.

4. Key enabling technologies

Wireless technology will be the starting point to enable novel capabilities of 5G. The following briefly introduce key technological components supporting the evolution of 5G in future:

4.1. mmWave

In 5G networks, spectrum availability is one of the key challenges of supporting the vast mobile traffic demand. Nowadays, the current spectrum is crowded already. Especially in very dense deployments it will be necessary to go higher in frequency and use larger portions of free spectrum bands. This means that 5G networks will operate in a wide spectrum range with a diverse range of characteristics, such as bandwidth and propagations conditions [8]. The mmWave bands provide ten times more bandwidth than the 4G cellular-bands. Therefore, the mmWave bands can provide the higher data rates required in future mobile broadband access networks. The main reason that mmWave spectrum lies idle is that, it had been deemed unsuitable for mobile communications because of rather hostile propagation qualities, including strong path loss, atmospheric and rain absorption, low diffraction around obstacles and penetration through objects, strong phase noise and exorbitant equipment costs. However, semiconductors are maturing, their costs and power consumption rapidly falling, and the other problems related to propagation are now considered increasingly surmountable given time and focused effort. These adaptive directional beams with large antenna array gain are key in tackling the large propagation loss in the mmWave [9].

4.2. Advanced small cell

To achieve significant throughput enhancement in a practical manner, it is necessary to place a large number of cells in a given area and to manage them intelligently. The 5G system is expected to utilize higher frequencies to take advantage of the large bandwidth in the mmWave bands. Hence, the considerably high propagation loss of mmWave makes it suitable for dense small cell deployment, which leads to higher spatial reuse. Cell shrinking has numerous advantages, the most important being the reuse of spectrum across a geographic area and the resulting reduction in the number of users competing for resources at each base station. Distributed and self-configuring network technologies will make it easy to deploy many small base stations in urban and suburban areas.

4.3. Massive MIMO

One promising technology for meeting the future demands is massive MIMO. Well-established by the time LTE was developed, MIMO was a native ingredient by using two-to-four antennas per mobile unit and as many as eight per base station sector shown in Figure 2. The proposal was to equip base stations with a number of antennas much larger than the number of active users per time frequency signaling resource, and given that under reasonable time- frequency selectivities accurate channel estimation can be conducted for at most some tens of users per resource, this condition puts the number of antennas per base station into the hundreds. This bold idea, initially termed "large-scale antenna systems" but now more popularly known as "massive MIMO", offers enticing benefits: huge enhancements in spectral efficiency, smooth out channel responses because of the vast spatial diversity, and simple transmit/receive structures. The promise of these benefits has elevated massive MIMO to a central position in preliminary discussions about 5G.

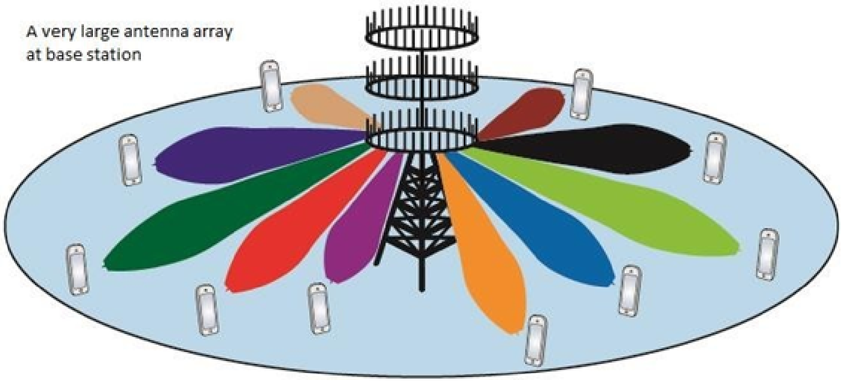

Figure 2. Massive MIMO technology [3]

4.4. Multi RAT

An important feature therein will be increased integration between different RATs, with a typical 5G-enabled device having radios capable of supporting not only a potentially new 5G standard (e.g., at mmWave frequencies), but also 3G, numerous releases of 4G LTE including possibly LTE-Unlicensed, several types of WiFi, and perhaps direct M2M communication, all across different spectral bands. Techniques for interworking and integrating the 5G system with other RATs will be exploited based on advanced PHY/MAC/network technologies and efficient methods of cell deployment and spectrum management. By taking advantage of multiple RATs, the 5G system will be able to use the benefit of the unique characteristics of each RAT and improve the practicality of the system as a whole. For instance, the 4G system is used for transferring the control messages to maintain the connection, to perform handover, and to provide real-time services such as VoLTE. The technology operating in mmWave unlicensed frequency band would offer the gigabit data rate service. Multiple mmWave cells can be overlaid on top of the underlying 4G macro cells. Moreover, user equipment is an integrated part of the network, any change in the network would affect the operation at the UE. And it requires a corresponding change in the UE side, such as UE with multi - RAT policy. There may be a need for new security solutions for key exchange or derivation protocols in UE side upon handover or when interworking with other Radio Access Technologies (RATs).

4.5. Advanced D2D

Advanced D2D communication is an attractive technology that improves spectral efficiency and reduces end-to-end latency for 5G. Not entirely depending on the cellular network, D2D devices can communicate directly with one another when they are in close location. Hence, D2D communication will be used for offloading data from network so that the cost of processing those data and related signaling is decreased. For example, the cars can communicate with each other to share the information for safety alarm and infotainment without cellular base station. The home appliances communicate with each other for home automation service. Since the data is directly transmitted and not going through the core network, the end- to-end latency can be considerably reduced as shown in Figure 3

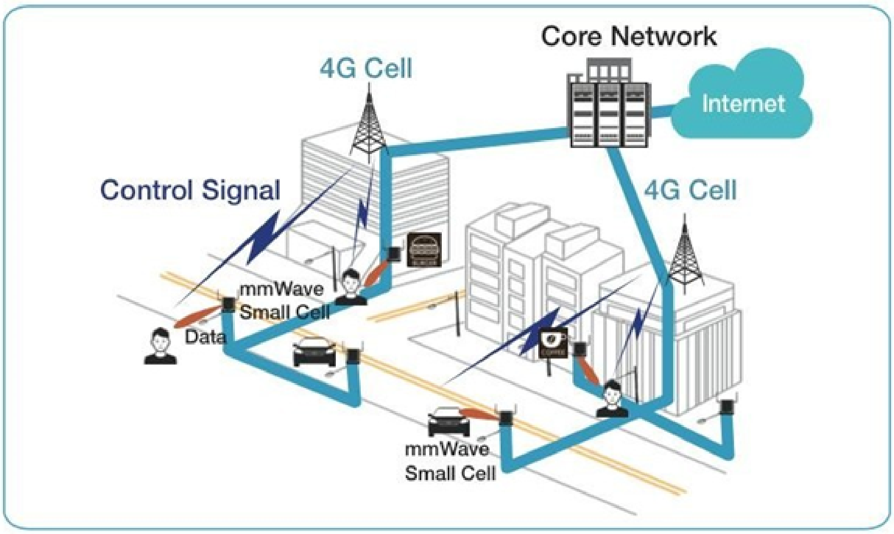

Figure 3. Device-to-device communication

4.6. Network slicing

With network slicing technology, a single physical network can be coupled into multiple virtual networks allowing the operator to offer optimal support for different types of services for different types of customer segments. The key benefit of network slicing technology is it enables operators to provide networks on an as-a-service basis, which improves operational efficiency while reducing time- to-market for new services [10].

In the future development, 5G architecture still being driven by its applications, technologies, from the various use cases to diverse types of communications (human- to-human, human-to- machine and machine-to-machine communications).

5. Conclusion

The motivations behind the development of 5G are: the explosive increase in demand for wireless broadband services needing faster, higher-capacity networks that can deliver video and other content-rich services; and the IoT that is fueling a need for massive connectivity of devices, plus a need for ultra-reliable, ultra-low-latency connectivity over Internet Protocol (IP). The current wireless networks are struggling to deal with those distinct application requirements, its limitation of performance led to the slow adaption of these new services. From that reason, the need to introduce a new advanced architectural framework for the processing and transport of information is required, which will bring new unique network services and capabilities that far beyond those previous generation of mobile networks [11]. The 5G appears to satisfy all these above service demands.

Furthermore, use cases will be delivered across a wide range of devices (e.g., smartphone, wearable, sensors) and across a fully heterogeneous environment. For the sake of simplicity, we divide 5G use cases into three main families: Mobile Broadband Access, Critical Communication and Massive IoT. Each of these families contains load of different use cases that are possible to deploy in the future

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