LANCOM White Paper

5G – Mobile Communications of the Future

The need for reliable, faster and more secure digitalization and connectivity continues to grow rapidly. For the first time, a mobile communications standard is opening up new fields of application requiring Gigabit bandwidths, where other mobile technologies such as Wi-Fi do not measure up—this is the key technology 5G. The abbreviation stands for fifth-generation mobile communications, a system so reliable as to be more than a backup, but also an alternative to wired connections. 5G focuses not only on digitally networking people: It also serves as a wireless, high-performance and fail-safe communication infrastructure for devices, sensors and machines. Following the publication of the 5G standard in December 2018, the global deployment of 5G technology gradually picked up pace.

What is 5G?

The 5G mobile communication standard is a further development of the 4G "Long Term Evolution" (LTE), which uses the global and standardized radio interface New Radio (NR). This is specified and standardized by the 3rd Generation Partnership Project (3GPP), a cooperation between standardization bodies. 5G provides not only higher transmission rates and capacities, it also delivers better accessibility and significantly lower latency than 4G. With 5G, real-time applications such as video streaming and augmented or virtual reality (AR, VR) work almost without delay, even where user density is high. Furthermore, the energy consumption of 5G is just a third of that with 4G. In early 2016, the International Telecommunication Union Radiocommunication Sector (ITU-R) compiled the following minimum requirements for the 5G standard under the name IMT-2020:

- Peak downlink rate: 20 Gbps
- Peak uplink rate: 10 Gbps
- Minimum downlink data rate for end users: 100 Mbps
- Minimum uplink data rate for end users: 50 Mbps
- Latency: no more than 1 or 4 ms depending on the infrastructure layer (see "Network slicing with three service categories")
- Connection density: up to 1 million devices per km^2
- Relative speed of movement increased to 500 km/h

How does 5G work?

As with previous mobile communications standards, high-frequency electromagnetic waves transport data packets from antennas and radio cells to receiving devices. The number of waves emitted per second, i.e. the frequency, is the primary indicator of range: Low frequencies means longer ranges, while higher frequencies achieve shorter ranges due to radio-signal attenuation. At the same time, the data throughput in lower frequency ranges is significantly lower than in higher frequency ranges. This is due, among other things, to the limited amount of channel width that the lower frequency spectrum offers. Consequently, low frequencies are better for covering large areas that do not require high data throughputs (see figure 1, left), while using higher frequencies with greater channel widths improves data-transmission performance in metropolitan areas where user densities are high (see figure 1, right).

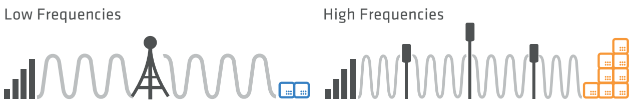

Fig. 1: Comparison of range and the data throughput for low and high frequencies

Speed and response time

Compared to previous standards, the increased bandwidth efficiency with 5G results in significantly higher upload and download rates, theoretically at double-digit Gigabit speeds*. In comparison: While downloading a 4.5 GB HD film on 4G took several minutes, with 5G the file is available on your own computer or smartphone within a maximum of 10 seconds. 5G also offers minimal latencies of just a few milliseconds to even less than a millisecond to connect a mobile device to the base station (air interface), making it many times faster than 4G. This saves significantly more energy per unit of data transferred than with 4G, and greater efficiency overall.

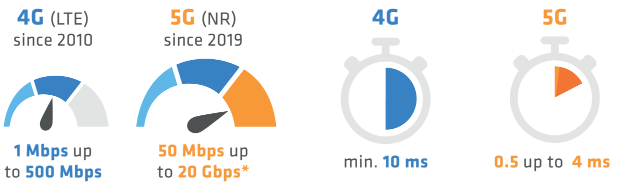

Fig. 3: Speed and latency comparison, 4G and 5G

Capacity and upgrade

To compensate for the lower range of radio waves at higher 5G frequencies, so-called small cells are operated in addition to the large mobile phone antennas in order to ensure full 5G accessibility. These miniaturized multi-antenna systems not only significantly increase the number of antennas per base station, they also simultaneously serve higher numbers of end devices on the same frequency band. This is referred to as **massive MIMO** (Multiple-Input, Multiple-Output) and, together with the higher concentration of available antenna locations, it ensures a significantly higher network capacity while reducing network congestion and failures. For example, 5G can support large events and other heavily frequented areas, such as train stations, airports and city centers, by reliably supplying up to one million devices per square kilometer. 5G antenna and cell systems use **3D beamforming** to reduce interference between the antenna signals and to increase the available data rates. Transmission power is controlled horizontally and vertically by means of 3D beamforming for an active, targeted servicing of a client according to its needs. In comparison: Former cellular standards operated only with a passive, non-directional signal, which drops off particularly strongly at the periphery.

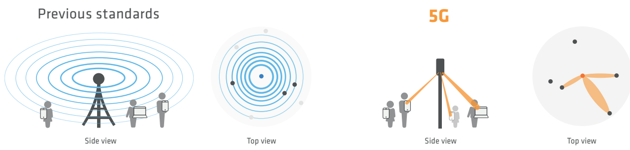

Fig. 4: Signal coverage of former standards and 5G

The required 5G upgrade of existing 4G antennas is achieved through **Dynamic Spectrum Sharing (DSS)**: The available bandwidth is dynamically divided between 4G and 5G as required so that 4G- and 5G-compatible end devices are always supplied with the maximum possible capacity. In the early phase of introduction, the backwards compatible 5G standard is being operated as a **non-standalone network (NSA)**, so the 4G and 5G standards continue to operate in parallel.

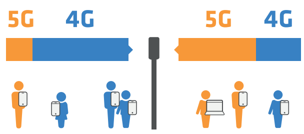

Fig. 5: Example of bandwidth allocation with Dynamic Spectrum Sharing (DSS)

Network slicing with three service categories

The 5G mobile communications standard ensures the expedient division of the available network resources, and

* Note: These are maximum speeds under ideal conditions that cannot always be achieved in practice. Currently, data rates between 50 Mbps and 1.5 Gbps are achieved in 5G networks, depending on frequency, carrier aggregation, channel bandwidth, and modulation.

infrastructure layers are defined to optimally address the respective network requirements. This virtual division of the functions of a physical radio network is known as **network slicing**. Here is a simple example: For the communication with smart traffic lights, low latencies are much more important than the kind of high bandwidths required by video streaming services. For this reason, the ITU-R has specified three service categories or infrastructure layers for applying the 5G standard: They offer either high data rates, a high number of connected devices, or low latencies:

eMBB (Enhanced Mobile Broadband) for high data rates

Thanks to 5G Internet and the resulting enhanced mobile broadband (eMBB) connection, end devices can be supplied with extremely high data rates that are suitable for real-time applications. Applications benefiting most from this have large data transfer requirements, such as video chat, high-resolution (3D) video streaming in 4K or 8K, as well as augmented and virtual reality. This kind of high-performance and lag-free multimedia experience requires a high level of device connectivity and large bandwidths that only 5G can offer for mobile communications.

mMTC (Massive Machine Type Communication) for large numbers of devices

The high capacity of 5G guarantees machine-to-machine communication (mMTC) when networking large numbers of end devices across an area if they only require low data rates. The energy-efficient communication of these 5G devices allows processes to be accelerated in high-density environments. This includes, primarily, the networking of IoT devices and sensors (Internet of Things) in traffic control, logistics and industry.

uRLLC (Ultra-Reliable and Low-Latency Communication) for low latencies

For applications that require reliable connection quality, availability, and Quality of Service with the lowest possible latency (uRLLC), 5G ensures lightning-fast and fail-safe system stability. This for the first time realistically facilitates guaranteed stable primary access via mobile communications. Areas of application requiring uRLLC include, above all, the transmission of control signals to autonomous vehicles or robots, Industry 4.0, and security-critical applications such as the automated management based on cloud services in SD-WAN scenarios.

Fields of application

Each “slice” therefore has different demands on the dimensioning of the radio network. The 5G standard thus provides a flexible, made-to-measure response to the individual requirements of a wide range of applications:

Backup of wired access

Sudden interruptions to the wired Internet line due to a damaged cable on a construction site can mean days until it is repaired. In the event of unforeseen failures or unstable connections, 5G mobile communications are a fast backup alternative that ensures reliable Internet connectivity. This guarantees the highest level of availability and largely prevents costly downtimes.

Primary access and load balancing

In contrast to previous cellular standards, 5G is also suitable for expanding bandwidth and load balancing on the network: The active/active mode, the individual bandwidths of multiple Internet connections are combined as an intelligent way of increasing performance. The low latencies and very high throughput rates make 5G ideal as a reliable full-time primary access for remote employees or branches.

Temporary access and mobile operation

The 5G technology with its flexibility and rapid availability is suitable for temporary, mobile or remote deployments and construction sites, such as seasonal pop-up stores or even offshore ships. Furthermore, 5G provides Gigabit speeds easily and securely and without the expensive and laborious laying of physical Internet lines.

Campus networks with private 5G

The larger the areas to be networked, the less efficient the coverage by Wi-Fi becomes due to the short ranges and the very large number of antennas required. These gaps are reliably closed with the help of a private 5G cellular network, otherwise known as a campus network. With "Private 5G", companies can control how the network is set up and secured, and who has access to which applications. This assures data sovereignty and minimizes risk.

Summary

High-performance communication infrastructure has never been more important. With reliability exceeding any previous mobile communications standard, 5G technology is leading the way over wired connections and Wi-Fi in various fields of application: Apart from its use in Industry 4.0, IoT, and as a backup or primary access in the corporate environment, private individuals with 5G mobile communications also benefit, for example, from ultra-high resolution, real-time applications (AR and VR). Thanks to reliable Gigabit data rates and minimal latency even with a high density of users and devices, 5G is helping to overcome the bottleneck for landlines in small towns and remote locations. Furthermore, 5G technology extends the network coverage of large campus sites where Wi-Fi alone is inefficient. In these cases, the coexistence of Wi-Fi and 5G provide maximum stability and reliability. Even though 5G in Germany is not expected to be available nationwide until 2025, initial research into the next generation of mobile communications technology has been ongoing since 2017: The 6G standard offering terabit speeds promises continued dynamic developments in the mobile communications market.

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