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A History of Mobile Networks Development within the Scope of 5G and Support for Smart Solutions

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Abstract

With an ever-increasing volume of data and requirements for certain level of quality of service, mobile network technology need to be gradually adapted to changes to meet the demand of users. The individual generations of mobile networks are the evidence of the constantly evolving nature of connectivity through wireless technology. The fifth generation of mobile network or 5G is considerably different from previous networks due to novel infrastructure and designs. Previously unthinkable application cases across various sectors are now feasible with 5G. The key use cases are smart solutions congruent with Internet of Things (smart city, logistic, grids), autonomous vehicles with reliable communication of very low latency and enhanced broadband solutions for businesses and consumers. This paper is focused on the gradual historical development of mobile networks, from the discovery of radio waves and the possibility of signal transmission, through individual generations of mobile networks in chronological order. The main emphasis is on the 5G technology and its deployment in future smart solutions.

Keywords: mobile network, 4G, 5G, smart city

Introduction

History of mobile communication

It all started in 1860 with the discovery of James Clark Maxwell, who described the equations of electromagnetic waves and hypothesized that these waves could travel at speeds similar to speed of light. Few years later Heinrich Hertz transformed his idea into the generation, transmission, and reception of these waves into practice and called them radio waves. After this discovery, it became clear that it would soon be possible to use these waves to modulate and transmit information. [1]

In today's modern world of digital communication, the wireless technologies have become an underlying part of our daily lives. Modulated radio waves can convey the information via air transmission medium. The system of interconnected cellular technology provides signal coverage for the wide areas and enables access to wireless transfer of data for a wide range of end users. The cell phones no longer serve solely for voice communication purposes but have also become a smart and compact version of computers. Smartphones are now indispensable for providing the access to variety of applications, social networks, multimedia content and many more.

The higher data speeds go naturally hand in hand with more data consumption. A sharp increase in the number of user devices and connected machines will further cause a significant increase in the volume of data The fifth generation of mobile network or 5G was designed to provide for high-end solution to connectivity requirements of today's data-driven world. In simple terms, 5G is the new generation of mobile radio networks. The key aspects of this technology are higher bandwidth and reliable communication of low latency. 5G integrates technologies of previous generations, some only in part, as they have been replaced by newer, faster, or smaller ones, other components may be identical. In fact, each new generation generates and builds on the previous ones, does not change the rapid functioning, on the contrary, improves existing or replaces technologies with newer ones. In summary, in the

new 5G technology, we have moved compared to the previous 4G technology, especially in the increased data transfer rate, where we managed to cross the Gbit limit and reduced latency - a response that was compressed below the level of 1ms.

This paper is organized as follows: The individual chapters will focus on the features of individual generations of mobile networks as well as the possibilities they have offered so far. In the next part, we will focus on the technical parameters of the new generation of mobile networks, such as 5G technology. We will compare the currently used mobile technology with the technology of the near future and we will also look at the assumption of the capacity of the new mobile network, as well as the possibilities of expanding the current technology of the next generation element and the gradual transition to a completely new 5G technology. Finally, we look to the future, which brings us the further development of mobile networks in connection with the deployment of 5G technology.

Mobile networks and technologies

Generations of Mobile Networks

There are several generations and of mobile networks:

- 0G
- 1G
- 2G (2.5G and 2.75G)
- 3G (3.5G, 3.75G and 3.9G)
- 4G (4G/4.5G and 4.5G/4.9G)
- 5G

1970s: The 0G network was an analog network where cordless phones were first used. 0G was the forerunner of cellular systems.

1980s: The 1G network was the last analog network. It already used cellular technology - a radio communication network. The first generation was in the 80s of last century.

1990s: The 2G network was the first network to transmit a digital signal. Only a voice is being transmitted, no data at all. The name GSM (Global System for Mobile Communication) is also known. It operated on frequencies from 850/900 to 1800 MHz

We can also call the 2.5G network an intergenerational transition, where new technologies and data transmission have already arrived, but it still did not meet the standards of a full-fledged 3G network.

2000s: The 3G network was created by upgrading the existing 2.5G network. The minimum transmission speed of 144 kbps has already been declared here. Later came other extensions of the 3G network such as 3.5G and 3.75G, which supported broadband data transmission to smartphones and modems, which brought us now (available everywhere) telephony over the Internet - video calls. However, together with the superstructure, the stability of the network also improved, the transmission speed increased (14Mbit / s) and the latency decreased.

2010s: 4G - The predecessor of the full-fledged 4G was LTE (3.95G) where the speed has not yet reached the required parameters - so far only 144Mbit / s / 50Mbit / s. In cell technology, cell radius has been reduced to achieve higher velocities. The arrival of a fully compliant 4G connection has again brought higher speeds - the standard of at least 100Mbit/s (available also for moving vehicles/devices) and 1Gbit/s for stationary vehicles/devices or moving at low speeds. There has also been a change in communication - based on the Internet protocol (no interconnected circuits).

2020s: 5G - In a cellular network, allow all devices to be connected to the Internet and voice services. The concept of devices is already being extended to intelligent devices, IoT devices since the 5G network has a much larger capacity, so the connected devices do not have to be only those we know today. However, there are used higher frequencies, but at the cost of lower range. The speed has been increased up to 10Gbit/s and the latency is decreasing again - in ideal conditions up to 1ms.

Technology of 5G

What is 5G network and technology? There is no exact definition, but it is a new generation of mobile radio networks. We can describe it as a new technology that incorporates all the useful features of previous generations of mobile networks and thus creates a system that has far better features than previous 4G, LTE systems.

This technology is intended to offer increased data transfer rates to exceed the 1 Gbit per second limit and with a latency below 1ms. [1]

The technology to provide the functionality required to run a 5G system is very challenging to achieve. For this purpose, 5 new technologies are developed [1]:

- Massive MIMO,
- Beamforming,
- BDMA,
- Microcells,
- Full duplex.

Massive MIMO (Multiple in Multiple Out) is one of the basic principles of 5G network operation.

Traditional (also 4G) networks used classic standard MIMO, where the bases used two to twelve antennas. Massive MIMO uses many antennas, in the order of tens to hundreds. Thanks to this, we can connect many more devices in one cell at the same time (in the order of up to millions) and only minimal interference is created between individual devices in the cell. [1]

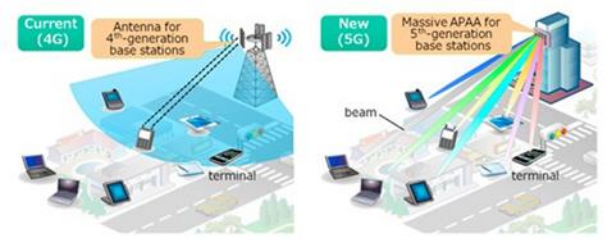

Figure 1 – Difference between signal propagation in 4G network and 5G network [4]

Beamforming is a wireless technology that directs the signal directly to devices. This increases the transfer rate and stability. Works with frequencies up to 6GHz. The disadvantage of beamforming is the impenetrability of concrete obstacles, trees, or rain. [1]

BDMA (Beam Division Multiple Access) - gradually, the network is placed higher and higher demands on capacity, transmission speeds but also communication between individual devices. Various schemes are used for this, which gradually evolve as the demands of society evolve. BDMA technology divides the signal-beams from the antennas according to the location of mobile devices, allowing them multiple access and thus increasing the capacity itself. Thus, a base station that transmits a signal knows exactly where the terminal is located, so it can transmit without having to interfere with other devices at the edge of the cell. [1]

Microcells - the concept of microcells brings a new principle in which the problem of obstacles in signal transmission is addressed. Instead of overcoming them, they try to get around them, which are well served by millimeter waves. Massive MIMO solves this problem by adding small, unpretentious transmitters, to which the device switches in the event of a weak or blocked system, which can basically bypass the obstacle. [1]

Full Duplex - at present, the transmission worked on the principle that the device operates on the same frequency for receiving and sending the signal, which in practice meant that the receiver first had to wait for the transmission to end before it could start transmitting. If he needed to transmit and receive at the same time, he had to use an additional frequency. This has been solved in technology by creating high-speed switches that allow signal redirection. [1]

Current situation in the world of mobile networks

The fourth generation of mobile networks, 4G, was first used in Oslo, Norway, and Stockholm, Sweden, in 2009. This technology, known commercially as LTE (Long Term Evolution), brought a significant increase in data rates, where downloads ranged in the hundreds of Mbits per second and uploads about 50Mbit per second. However, there is a significant improvement in security and encryption. The biggest benefit is the very low latency, which reaches a response time of up to 50ms, which was enough for any conceivable role at the time of the release of 4G technology.

Comparison of characteristic 4G and „Full 5G" technology

The following table shows a simple comparison of the parameters of the 4G and Full 5G networks.

Table 1. Comparison table for selected modes

	4G	**Full 5G**
Frequencies	Up to 6GHz	Up to 6GHz, range 26-28 GHz, future 5G up to 86GHz (4)
Multiplex	OFDMA	BDMA
Max. download speed	hundreds of MBits per second	1-10 GBit per second
Latency	50ms	below 1ms
Cells parameter	Small cells (femtocells), from 10 to 1000 meters	Microcells (even below 10 meters)
Technology	MIMO with OFDM	Beamforming with massive MIMO

Transition to 5G

In practice, it is common practice that the transition to the next generation of the mobile network is not implemented immediately. In the case of the transition to Full 5G, the transition of a part of the network called the Radio Access Network (RAN) will be carried out first, and then, after a certain time, the reconstruction of a part of the network called the Core Network will be carried out.

The Core network is managing all traffic in network (mobile voice and data, internet connections). [4] The Radio Access Network is a layer of all connected devices (home systems, wireless devices) and small cells.

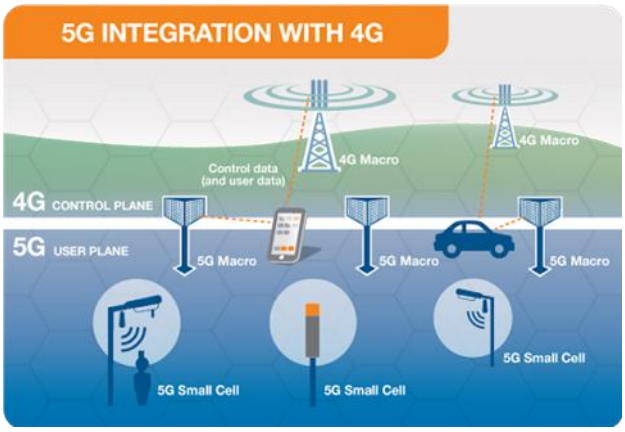

Figure 2 – 5G technology operates in 4G [4]

The transition to a partial 5G network will be realized by using the device connection with 5G technology, but the network management will still be solved using a 4G network. The 5G network will ensure fast connection of the device to the already existing 4G infrastructure. If there is a case that the 5G coverage will be insufficient, the data will be transmitted over a 4G connection, which will mean supplementing the current 4G network with 5G network elements. [4]

Future vision of technology 5G

After reconfiguring the entire mobile network to 5G, it will be possible to take advantage of several benefits of this network. The first is low latency and high reliability. By implementing a dynamic and configurable RAN, it will be possible to work with very low latency as well as high network throughput. At the same time, it will allow the network to adapt to network failures, new expansion, and topology requirements, as well as changes in network operation. [4]

This will reduce the time between user request and network response, even for critical applications. An example is video-on-demand streaming services, where a copy can be stored on a distributed server, providing faster access. [4]

Integration of 5G with smart solutions

The development of communication technologies for telecommunications operators is a top priority so that they have a greater position and opportunities in developing and managing smart solutions, whether in the field of:

- *Smart/Safe City,*
- *Edge Computing,*
- *Etc.*

One of the main factors influencing the further development of the market is the introduction of 5G services. This service is a key turning point in the development of smart cities precisely because of the high transmission speed, low latency, better ability to handle a larger number of connected devices, as well as the sharing of this connection between devices compared to today's used 4G network.

Smart/Safe City

The European Commission defines a smart city as: "a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business." [1] Smart City urgently needs the availability of new technologies to transform, contributing to an improved quality of life for citizens as well as to achieving a high level of continuous urban development.

5G services will open new possibilities for using artificial intelligence services, new hardware solutions such as drones or robots, new possibilities of learning, healthcare, and energy opportunities, and many more. We will highlight the 3 main sectors where 5G services have the greatest potential, namely [5]:

- *Transport,*
- *Public security,*
- *Services for citizens.*

Transport

Innovation of transport systems using 5G is a priority market area within the Smart City service. One example of the solution is Verizon Wireless in the US, which is introducing a traffic management system in Sacramento, California. IoT sensors are located inside the roadway, on streetlamps and wherever they help traffic authorities provide better traffic flow information. The company believes that such solution can reduce car inactivity by 44%, which will also reduce CO2 emissions. [5]

Traffic management systems are only an initial milestone. Once deployed at the national level, 5G networks will become an integral part of autonomous vehicles.

Disaster preparedness and public safety

Population in many countries is not well prepared for disasters. Achieving the appropriate level of population preparedness requires the existence of a comprehensive system of training and education. [6]

As was mentioned in [7] it is not simple to address disaster preparedness factors especially due to the multidisciplinary nature of preparing the population for disasters. 5G infrastructure could support disaster preparedness level among population.

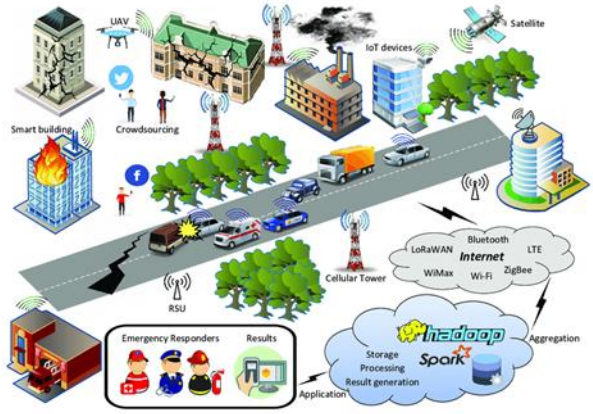

Figure 3 – Public security supported by 5G networks [8]

The use of 5G networks will improve public safety and security services enormously. Real-time hazard identification associated with automatic analysis of biometric identification records will be able to alert security forces immediately, such as car crashes, robberies, terrorist attacks, etc. With 5G support, it will be possible to update information to data management platforms integrated in all services and systems in a short time with the low latency (images taken urban cameras, drone images or portable devices).

Services to citizens

In a significant benefit that will affect the quality of life of citizens after the launch of 5G networks is:

- Ultrarapid connection,
- online health,
- across-the-board Internet coverage,
- remotely controlled robots,
- etc.

In the UK, mobile operator O2 has estimated that using so-called "telemedicine" with the support of 5G can reduce patient visits to hospitals by 9.4 million a year and save £1.3bn a year in lost work productivity. [5]

Thanks to this high-resolution remote video calling option, older people, disabled or immobile people will be able to save a significant amount of time and transport costs and do not expose themselves to possible risks in case of health problems.

Internet of Things (IoT)

Smart cities use the Internet of Things (IoT) to collect real-time data from different hardware devices to better understand the situation and respond more promptly. The entire ecosystem of such a city is designed on the basis of ICT frameworks that connect mobile devices, sensors connected in cars or strategically deployed areas of public communications, household appliances to large data centers. By 2025, the number of connected devices worldwide is estimated to rise to 75 billion. [9]

To achieve this vision, it is necessary to ensure sufficient scalability, safety, capacity, and efficiency of interconnection of individual devices, which will allow advanced functions in the form of longer battery life or a wider coverage area. [8] However, the existing 4G network is restrictive and not designed to handle extremely large amounts of data and ensure low latency. Another drawback is high power consumption and high price per bit.

With the launch of 5G networks, these shortcomings will be covered and the real potential of IoT will be unlocked, and it will be the driving force of a smart city.

Edge Computing

Edge Computing is a computational paradigm that works on the principle of mini cloud. Their efficiency allows peripheral servers to expand cloud capabilities at the edge of the network by performing computational tasks and storing large amounts of data near user equipment. [11]

In the long term, the question is how to combine this technology together with 5G to provide benefits for different uses. There is a need to develop and integrate the Edge Computing paradigm is for achieving a significantly lower latency compared to centralized clouds is essential for various applications such as autonomous vehicles, remotely controllable drones, simulations, information transfer between integrated smart city systems. Thus, mentioned above, it is a necessary to use combination of 5G and Edge Computing.

Applications and systems that require enormous data transmission, high-resolution images or videos,

data analysis will require high transfer speeds and low latency of 5G networks. Sending to the central cloud is expensive – in terms of spent time and transferred amount of data. The solution is to filter this enormous amount of data into the edge cloud, where it will be analyzed which information and data should be stored in the centralized cloud. [10]

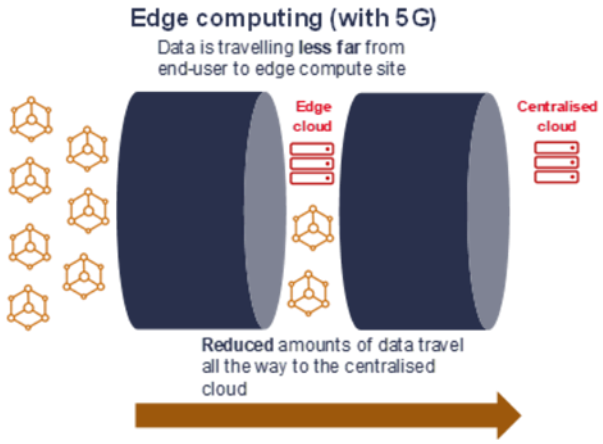

Figure 4 – Use of Edge Computing with 5G networks [10]

Conclusion

This paper described the development of wireless technology through individual generations of mobile networks. The current wireless standard of LTE is compared with its innovative successor—5G technology. In addition, the 5G standard is being discussed as a major asset for the technology of the future.

5G wireless technology together with data collection through IoT allows for fast and reliable communication of connected devices and machines providing an advanced solution for smart cities or factories. 5G can be of immeasurable importance in real-time hazard identification such as the automatic recognition of car collision on highways where saving lives is a matter of seconds. 5G can provide for instantaneous alerts to traffic management or other vehicles on road. Finally, 5G will enable citizens to save time and money with novel online services.

There is the clear need for a link between 5G and the Edge Computing paradigm, which will increase demand for services and applications such as augmented reality, mass Internet of Things, robotics, drone use and many others. It can also give developers the ability to create new 5G apps that are unknown to us today and cannot exist without the benefits 5G provides us.

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