

Concept and QoS requirements in 5G networks

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1. Introduction

5G mobile technologies that are expected to appear on the market in 2020 should significantly improve customers' quality of service (QoS) in the context of snowballing growth of data volume in mobile networks and the growth of wireless devices and variety of services provided [1-3].

It is expected that mobile communication networks built on the basis of 5G technologies will provide data transfer speed of more than 10 Gbit/s.

Previous 4G generation technologies (LTE/LTE Advanced) provide flexible quality of service management based on the division of data transfer characteristics into 9 classes. These classes cover both 4G quality principles - services provision without quality assurance (best effort or non-GBR) and guaranteed quality of service provision (GBR) [4].

Unfortunately, these LTE technological advances in the field of QoS management cover only part of the "end user - end user" (E2E) chain, in particular "5G-5G" and "4G-4G" intranetwork connections. The quality management system does not extend to the part of connections appeared between 5G subscribers and other mobile 2G/3G/4G and fixed networks. Absence of possibility for coordinated and flexible quality management in fixed IP and mobile networks of previous generations will still be for a long period a brake on the new level of subscribers' service quality in 5G networks.

In this article the requirements to some number of KPI that determine the quality of service in 5G networks are formulated. The proposed QoS requirements are based on the analysis of functional requirements to 5G networks and traffic parameters for HD video and massive M2M services which will be highly demanded in 2020. One of the 5G development paradigms is the virtualization of network functions (VFN) including cloud radio access network and cloud core network. The authors have proposed the concept of function blocks CQMF and CQCF to control and monitor QoS, which are implemented as part of the cloud infrastructure of 5G network.

2. Services in 5G networks

Forecasts of the leading specialists working in international 5G projects [5, 6] show that video services, such as HD and UHD video, with high quality resolution will have a dominant position among the services rendered in 5G networks. According to reports of leading 4G networks operators, video services dominate in the subscribers' traffic and will continue to dominate in 5G networks content.

For instance now the traffic volume of video services is estimated by different operators [5] from 66 to 75% of the total traffic in 4G network, including 33% for YouTube services and 34% for clear video as well as CCTV monitoring (video surveillance) in M2M networks. In addition, by 2020 the volume of mobile M2M connections will grow with CAGR index of 45% [7] up to 2.1 billion connections. Given the growing mass scale of M2M services in all industries they will dominate over basic services (voice & data) in 4G and 5G networks.

5G European development strategy also aims to enable for subscribers by 2025 to choose how to connect to TV broadcast: 5G modem or antenna with DVB-T, so this will require appropriate quality management mechanisms.

Therefore, the efforts of developers to improve the quality management mechanisms will focus on video and M2M services traffic, improvement of quality checking algorithms and creation of new quality assessment methods.

3. 5G technological image

Technological development of 5G networks will be aimed at the creation of ultra-dense networks (UDN) of wireless access with heterogeneous cells arrangement and radius of not more than 50 meters. Networks 5G will be based on new methods of modulation and transmission that will significantly increase the spectral efficiency compared with 4G networks and ensure data transfer speed of more than 10 Gb/s.

To provide such data transfer speed in 5G networks the use of broadband channels in the downlink (DL), as well as in the uplink (UL) with a continuous spectrum width of 500 to 1000 MHz will be

required. This amount of spectrum is 25 - 50 times wider than the channels width used in 4G. Allocation of these bands for 5G channels is possible only at the upper boundary of the centimeter and in millimeter wave bands that will significantly reduce base stations coverage up to 50-100 meters [8].

The increase in spectral efficiency of 5G networks can be achieved using non-orthogonal access methods (NOMA) in RAN networks and using non-orthogonal signals (e.g.: FTN-signals, F-OFDM-signals, etc.) [9]. Requirements to the cell's spectral efficiency in 5G networks for different transmission channels are shown in Fig. 1. Comparison of these requirements with the same requirements to 4G networks shows the growth of spectral efficiency by 3-5 times.

5G network infrastructure will be based on the use of cloud technologies, both in radio access networks (Cloud RAN) with using SDR (software defined radio) infrastructure and in core network (Cloud CN) with using SDN (software defined network) infrastructure. Full virtualization of NFV network functions implemented in 5G infrastructure will take place. This virtualization of NFV network functions should cover the control and management of QoS, the service policy and prioritization of traffic.

New solutions for 5G networks will be the appearance of moving 5G nodes (base stations) and moving 5G backhaul that are dictated by the need to implement 5G during the construction of intelligent transport network.

Thanks to these solutions, international highways with cars moving at a speed exceeding 200 km/h will introduce moving 5G communication networks constructed on the basis of M2M



Figure 1. Cell spectral efficiency in 5G networks (Source: 5G Forum)

applications and devices for V2V (vehicle-to-vehicle) scenario and ensuring the safety traffic and multimedia data exchange. The role of 5G base stations will carry out the 5G vehicle devices united in mesh network.

4. Traffic in 5G networks

When forming requirements to QoS in 5G networks two key traffic models should be firstly considered: high-speed video flow "server - subscriber" and massive M2M.

Video transmission services will be an important stimulus to development and a rapidly growing segment of 5G networks traffic. In 2013 the volume of video services in the total traffic of 4G networks subscribers already exceeded 50%, and by 2019 it is forecasted to increase at least by 13 times [3]. Thus we can already observe the first wave of oncoming "tsunami" of subscribers' traffic in 4G networks. Monthly consumption of data transmission traffic in 4G networks has already reached 2,6 GB and monthly consumption of traffic in 5G networks will exceed 500 GB.

The growth of video services traffic volume will be associated with the implementation of various technologies of video services image quality from standard SD TV to UHD TV (8k), which in its turn requires a data transmission speed of up to 10 Gbit/s in the network. Technological capabilities of mobile networks of various generations to broadcast video for various video image quality are shown in Fig. 2 [10-11]. Capability of video broadcasting depends on data transmission speed in the radio access network.

According to forecasts shown in Figure 3, in 2018 the number of M2M connections in the networks of mobile operators will exceed 1,5 billion [12], which is 5 times more than the current rate, and in 2022 mobile operators will have more than 2,6 billion M2M connections. At the same time the share of M2M connections of the total number of connections in the mobile operators' networks will increase from the current 5% to 15% in 2018 and to 22% in 2022.

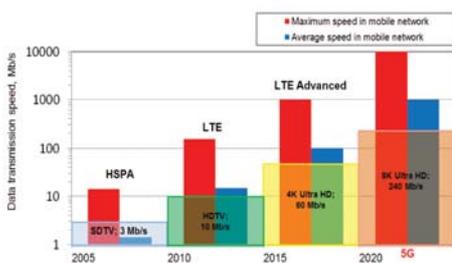


Figure 2. Technological capabilities of video transfer for mobile networks of various generations

Strategies of M2M operators are aimed at creating universal M2M platforms capable of operating in multiple vertical economic sectors. This will lead to the possibility to implement approaches, tools and processing methods for structured and unstructured Big Data derived from M2M networks.

According to ABI Research forecasts, the M2M Big Data and analytics industry will grow a robust 53.1% over the next 5 years from US\$1.9 billion in 2013 to US\$14.3 billion in 2018. This forecast includes revenue segmentation for the five components that together enable analytics to be used in M2M services: data integration, data storage, core analytics, data presentation, and associated professional services.

5. Quality requirements in 5G networks

During the evolution of QoS management mechanism in 3GPP (GSM/UMTS/LTE) networks there was a migration from QoS management at the user equipment level to the QoS management at the network level. This approach to QoS management will be maintained in 5G networks as well.

QoS management mechanisms in 5G networks should provide video and VoIP traffic prioritization towards web-search traffic and other applications tolerant to quality.

The service of streaming video transfer without buffering is very sensitive to network delay, so one of the most important parameters that determine QoS requirements is the total packet delay budget (PDB), which is formed on the RAN air interface, and is treated as the maximum packet delay with a confidence level of 98%.

Table 1 lists the requirements for delay in 3G/4G/5G networks formed in 3GPP [4] and METIS project [13]. These data demonstrate that with the increase in mobile network's generation the requirements for the lower boundary of the total data delay across the network decline. Also the analysis of the requirements for the overall 5G network delay revealed that given the accumulation effect the delay in 5G RAN network should be less than 1 ms.

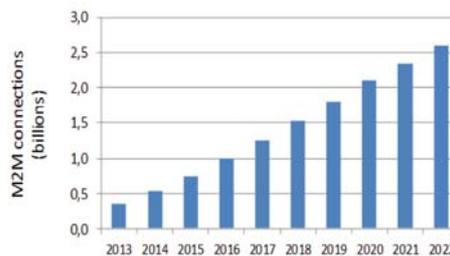


Figure 3. Number of M2M connections in mobile (Source: Machina Research)

Table 1 Requirements for delay in 3G/4G/5G networks

QoS terms	Packet Delay Budget, ms		
	3G	4G	5G
Without quality assurance	Not determined	100 – 300	Not determined
With guaranteed quality	100-280	50 – 300	1

Comparison of requirements to delay in control and user planes for signaling traffic and user traffic respectively, presented on Figure 4, show that requirements to 5G networks will be twice more rigid for traffic in the user plane and 10 times more rigid – in the subscriber traffic plane [6].

Another parameter is the proportion of packets lost due to errors when receiving data packets (IP Packet Error Rate). Values for this parameter, that determines requirements for the largest number of IP packets lost for video broadcasting through 3G/4G/5G mobile networks, are shown in Table 2 [14].

Table 2 Requirements to the Packet Error Loss Rate for video broadcasting

QoS terms	Packet Error Loss Rate			
	SDTV	HDTV	4k UHD	8k UHD
Possibilities of mobile communication generation	3G/4G	4G	4G	5G
Video broadcasting with guaranteed quality	10 ⁻⁶	10 ⁻⁷	10 ⁻⁸	10 ⁻⁹

For M2M services the quality also will be determined by the proportion of packets lost when receiving in 3G/4G/5G networks. Given that service conditions of M2M subscriber devices will be determined for both cases: with a guaranteed quality of service and without guarantees, requirements to the share of packets lost may be different by three orders. Requirements to the Packet Error Loss Rate for M2M services are shown in table 3.

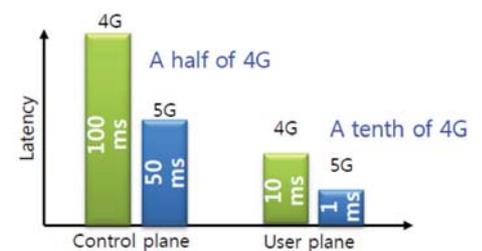


Figure 4. Requirements to delay in control and user planes for 4G/5G networks (Source: 5G Forum)

Table 3

Requirements to the Packet Error Loss Rate for M2M services

QoS terms	Packet Error Loss Rate		
	3G	4G	5G
Without guaranteed quality (non-GBR)	10^{-2}	10^{-3}	10^{-4}
With guaranteed quality (GBR)	10^{-2}	10^{-6}	10^{-7}

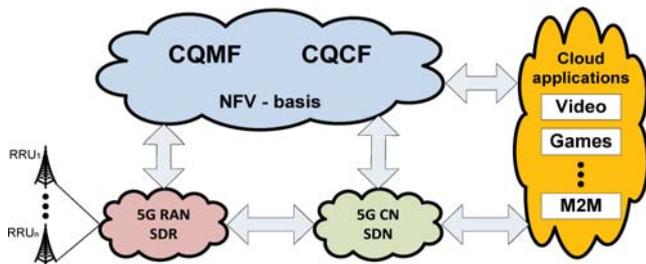


Figure 5. Virtualization of control and management functions in 5G network

The development of NFC concept will lead to virtualization of quality management function that could be introduced in the form of two main functions: Cloud QoS management function (CQMF) and Cloud QoS control function (CQCF) shown in Figure 5.

CQCF function of QoS control provides real-time control of traffic flows in 5G network on the basis of QoS levels established during the connection. Basic QoS control mechanisms include traffic profiling, planning and management of data flows.

CQMF function of QoS management provides QoS support in 5G network in accordance with SLA service contracts, as well as provides monitoring, maintenance, review and scaling of QoS.

Implementation of algorithms for traffic prioritization in 5G networks will be based on traffic classification procedures with a focus on video traffic priorities and M2M traffic. Traffic classification procedure should be done taking into consideration the adaptation possibility, as the traffic characteristics will dynamically change with the emergence of new applications, both in M2M area and in the field of video services.

6. Conclusion

The emergence of 5G networks in the market in 2020 will be focused on a significant improvement

of characteristics of mobile networks, including quality of service. Given that the principles of QoS control will be maintained during the transition from 4G to 5G, main effort of 5G developers should be focused on the virtualization of network functions, responsible for the management and control of QoS in the network.

Another direction for development will be algorithms for traffic classification that will support market's changes including change of demand for services and needs of customers. Future mobile services will be grouped around video services and services based on the massive use of M2M devices in most industries and consumers' households.

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