Paper

QoS Requirements as Factor of Trust to 5G Network

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Abstract—Trust to modern telecommunications networks plays an important role as a driver of technological and market success of any technology or telecommunication services. Most of the technological approaches to this problem are focused only on network security and do not include such a factor as the quality of service (QoS), which also plays an important role in the formation of trust both from the consumers and the regulator. The future 5G mobile technology will be the engine of development of telecommunications until 2020 and the formation of trust to the 5G networks is one of the main tasks for developers. The authors present the view on the trust to 5G networks in the plane of QoS requirements formation and QoS management. QoS requirements to 5G networks were determined on the basis of three main business models of services: xMBB, M-MTC and U-MTC and the need to ensure user trust to networks. Infrastructure requirements for QoS control and spectrum management network entities which are based on Network Function Virtualization (NFV) principles have been formed.

Keywords—network performance, network security, QoE, trusted network.

1. Introduction

Currently leading organizations in international standardization and development of telecommunication technologies such as: ITU, 3GPP, IEEE and ETSI have not formulated a strict definition of "trusted network". However, the trust to communication network significantly affects consumers' choice of communication operator, regulation of operators' activities by state bodies, as well as the market demand on communication services and equipment.

Trust to network or communication technology has market and regulatory aspects that can contribute to the development of the network and technology and increase attractiveness of the services. Therefore, networks and communication technologies should correspond to both market and regulatory requirements of trust.

Given the many factors affecting the trust to 5G networks, in this article authors will briefly review the major factors and examine in details the impact of service quality on the trust to 5G networks.

2. Factors Affecting the Trust to 5G Networks

The existing understanding of "trusted network" is based on the concepts taken by the developers of computer networks, which traditionally include [1]:

- secure guest access – guests obtain restricted network access without threatening the host network;
- user authentication – trusted network integrates user authentication with network access to better manage who can use the network and what they are allowed to do;
- endpoint integrity – trusted network performs a health check for devices connecting to the network. Devices out of compliance can be restricted or repaired;
- clientless endpoint management – trusted network offers a framework to assess, manage and secure clientless end points connected to the network, such as IP phones, cameras and printers;
- coordinated security – security systems coordinate and share information via the Interface for Metadata Access Points (IF-MAP) standard improving accuracy and enabling intelligent response.

According to Kaspersky Internet Security company definition [2], trusted network is a network that can be considered absolutely safe within which your computer or device will not be subjected to attacks or unauthorized attempts to gain access to your data.

Proposed comprehensive look on the issue of trusted communication networks complements the concepts of computer networks developers by the views of consumers, which also comprise quality of services provided by trusted network. The view on the trusted network from the quality aspects is not always taken into account when creating the new mobile technology that reduces trust to the network, both on the part of subscribers and the regulator.

To implement a systematic approach to the trusted communication network the trust of two major players in the telecommunications market should be considered: consumers and regulators that provide both market demand on the communication services and the effectiveness of operators' network infrastructure. As can be seen from Fig. 1, consumers' and regulator's requirements to trusted mobile communication network may either coincide or differ. The main factors affecting the trust of the subscriber and the regulator are shown in Table 1 taking into account their importance in descending order.

Most of consumers' and regulator's factors are the same but factors determining consumer trust, according to the author's evaluation, have the dominant influence on the mobile network.

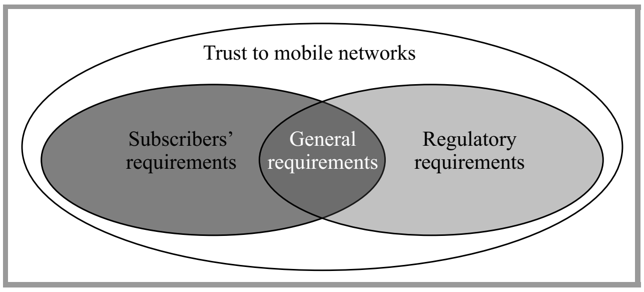

Fig. 1. Domains of trust to mobile networks.

Traditional factors of consumers' and regulator's trust to 5G networks are information security of confidential user data, security of subscriber's devices and network infrastructure. The basis for such security is the resistance to physical attacks on subscriber devices, such as illegal substitution of Subscriber Identification Modules (SIM card), installation of the malicious software on the user device and the impact on the user device configuration, resistance to network attacks on user devices and network infrastructure, such as DoS-attacks and Man-in-the-middle attacks, and resistance to attacks on confidential user data.

Table 1
The main factors affecting the trust of the subscriber and the regulator to network

Importance	Consumer	Regulator
1	Quality of Service	Network security
2	Quality of Experience	Information security
3	Information security	Network performance
4	Network performance	Network reliability
5	Network reliability	Quality of Service
6	Convenience and security of subscriber's equipment	

Ensuring the safety functioning of 5G networks, devices and applications, including the security of transmission and storage of user data, is a major priority for future 5G technologies and networks developers.
In addition to security performance, the trust of users and regulators to 5G networks will depend on quality performance since security of the mobile network itself does not guarantee that the communication service will be provided without interruption and with the stated quality. Reduced quality of 5G networks will lead to a decrease of trust to them, and as a result in an subscribers outflow. Also, given that the 5G network will be used in a variety of financial systems, public safety systems, traffic and energy management systems, the deterioration of their quality could lead to the human life loss, environmental disasters and financial frauds.

Quality parameters of 5G networks can be divided into three levels: Network Performance (NP), Quality of Service (QoS) and Quality of Experience (QoE), as shown in Fig. 2. NP and QoS are objective indicators that can be

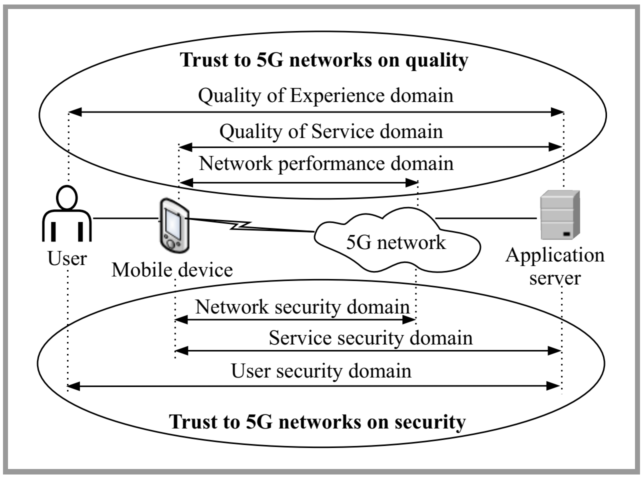

Fig. 2. Quality and security levels of trust to mobile networks.

measured using specialized analyzers while QoE indicators are subjective, estimated by users based on their personal experience. The deterioration of QoS and NP will primarily lead to lower trust to 5G networks of regulators and Business-to-Business (B2B), Business-to-Government (B2G) customers, while the QoE deterioration will lead to lower trust of mass market.

3. Services in 5G Networks

METIS and 5GIS projects consider three basic business models of 5G services: extreme mobile broadband (xMBB), massive machine type communications (M-MTC) and ultra reliable machine type communications (U-MTC) [3].
Forecasts of the leading specialists working in international 5G projects [4], [5] show that video services, such as HD and UHD, with high quality resolution will have a dominant position among 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 [4] 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 (Closed Circuit TV) video surveillance monitoring in M2M networks. In addition, by 2020 the volume of mobile M2M connections will grow with CAGR index of 45% [6] 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 subscribers by 2025 to choose how to connect to TV broadcast: via 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.

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. Video services accounted for around 45% of mobile data traffic in 2014, and 60% of all mobile data traffic will be from video by 2020 [7]. Mobile video traffic will grow by 55% annually from 2014 to 2020 [8]. 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 per user.

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 Gb/s in the network. Technological capabilities of mobile networks of various generations to broadcast video for various video image qualities are shown in Fig. 3 [9], [10]. Capability of video broadcasting depends on data transmission speed in the radio access network.

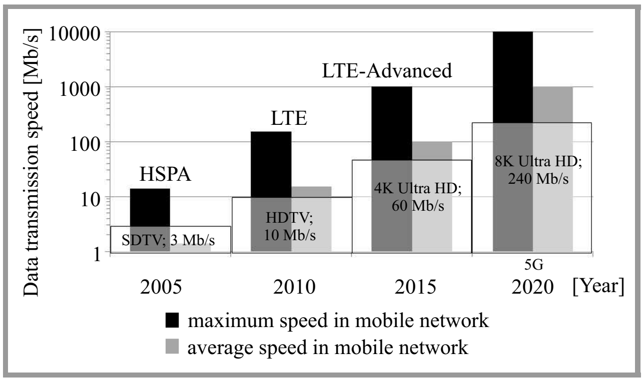

Fig. 3. Technological capabilities of video transfer for mobile networks of various generations.

According to forecasts shown in Fig. 4, in year 2019 the number of M2M connections in the networks of mobile operators (2G, 3G, 4G) will exceed 2.2 billion [11], which is 4 times more than in 2014. The share of M2M connections of the total number of connections in the mobile operators' networks will increase from the current 7% to 22% in 2019.

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.

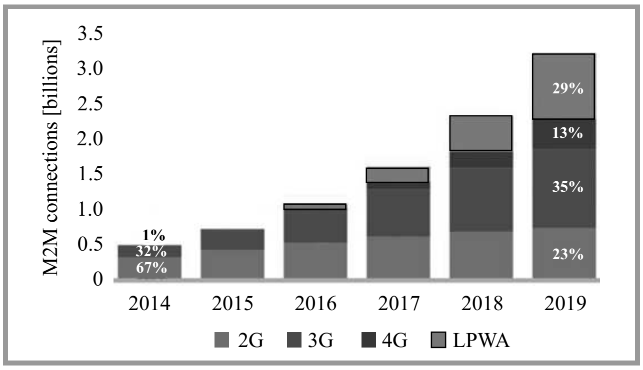

Fig. 4. Number of M2M connections in mobile networks.

According to ABI Research forecasts, the M2M Big Data and analytics industry will grow a robust 53.1% over the next 5 years from 1.9 billion USD in 2013 to 14.3 billion USD 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

METIS project has identified 12 use cases for 5G networks and formed QoE requirements for them [12]. QoE performance requirements that provide trust to network 5G are presented in Table 2. The highest requirements for Experienced user throughput are formed for "Virtual reality office" use case. End-users should be able to experience data rates of at least 1 Gb/s in 95% of office locations and at 99% of the busy period. Additionally, end-users should be able to experience data rates of at least 5 Gb/s in 20% of the office locations, e.g. at the actual desks, at 99% of the busy period. The highest requirements for network latency are formed for "Dense urban information society" use case, device-to-device (D2D) latency is less than 1 ms. The highest requirements for availability and reliability of 5G network are identified for "Traffic safety and efficiency" use case, 100% availability with transmission reliability

Table 2
The main factors affecting the trust of the subscriber and the regulator to network

QoE indicators	Requirements
Experienced user throughput	5 Gb/s in downlink and uplink
Latency	D2D latency less than 1 ms
Availability	$\approx 100\%$
Reliability	99.999%

of 99.999% are required to provide services at every point on the road.

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 3 lists the requirements for delay in 3G/4G/5G networks formed in 3GPP [13] and METIS project [14]. 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 Radio Access Network (RAN) should be less than 1 ms.

Table 3
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

On air interface level, the need to transmit control and user data quickly in time domain leads to the demand of fast link direction switching and to short transmission time interval (TTI) length [5]. New 5G frame structure for low latency has been proposed in [15]. Requirements to 5G Radio Access Technology (RAT) delay components in comparison with LTE-Advanced TDD and FDD technologies presented in Table 4. The maximum possible TTI must be less than 0.25 ms for 1 ms radio latency.

Another parameter is the proportion of packets lost due to errors when receiving data packets – IP Packet Error Loss Rate (PELR). 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 5 [16].

For M2M services, the quality also will be determined by the proportion of packets lost when receiving in 3G/4G/5G networks. Given service conditions of M2M subscriber devices determined for both cases: with a guaranteed quality of service and without guarantees, requirements to the share of lost packets differ by three orders. Requirements to the PELR for M2M services are shown in Table 6.

Table 4
Requirements to 5G RAT delay components

Delay component [ms]	5G requirements	LTE-Advanced TDD	LTE-Advanced FDD
User equipment processing	0.2	1	1.5
Frame alignment	0.125	1.1-5	
TTI duration	0.25	1	1
eNB processing	0.3	1.5	1.5
HARQ Re-Tx (10% x HARQ RTT)	0.1	1.16	0.8
Total delay	0.975	5.8-9.7	4.8

Table 5
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}

Table 6
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^{-3}	10^{-7}

The development of NFV 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) [8] shown in Fig. 5.

CQCF function of QoS control provides real-time control of traffic flows in 5G network based on 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

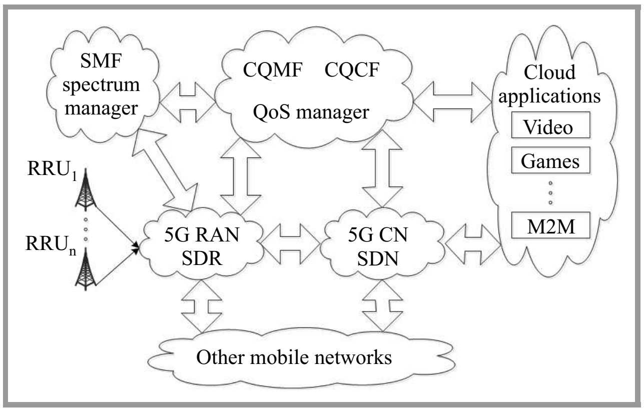

Fig. 5. Virtualization of control and management functions in 5G networks.

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.

In addition to QoS management functions in 5G network, related to traffic management and prioritization, the scope of service quality management also includes management of radio frequency resources used by mobile network (spectrum toolbox). Capabilities of access to the radio spectrum on the principles of Licensed Share Access (LSA) in 5G networks require QoS guarantees to operators who granted access to their spectrum for other operators [17], [18].

The Spectrum Management Function (SMF) in the 5G network is designed to a Spectrum Manager entity. In case of shortage of frequency resources to provide service with required QoS, 5G network must decide to use additional frequency channels for aggregation and select the channel from the frequency ranges which use spectrum based on LSA or Licensed Exempt (LE) principles [17].

Therefore, QoS manager must have information exchange with Spectrum Manager to effectively manage the spectrum resources in the interest of 5G network QoS and trust.

6. Conclusion

The emergence of 5G networks on the market in 2020 will be focused on a significant improvement of characteristics of mobile networks including quality of service that will provide a high level of trust to these networks.

One-sided view on trusted 5G network from security position will limit the growth of trust of customers and regulators. Forming of high level requirements in QoS field will allow 5G developers obtain the trust to 5G on early stage.

Given that the principles of QoS control will be preserved 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. Also QoS architecture of 5G should provide information exchange between QoS manager and Spectrum Manager for effective management of spectrum resources for the benefit of ensuring QoS and trust to 5G networks.

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