

4G MOBILE NETWORK SERVICE QUALITY ASSESSMENT

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Аннотация: В статье анализируются типы систем подвижной радиосвязи и их эксплуатационные характеристики, зоны обслуживания, технологические различия и взаимодействие между ними. Системы мобильной радиосвязи (СРС) делятся на классы, которые различаются по своим функциям, зонам обслуживания и типу услуг, предоставляемых абонентам. По размерам зон обслуживания системы делятся на следующие категории: системы спутниковой связи, системы сотовой связи, профессиональные сети мобильной связи (ПМС) и системы беспроводной телефонии. Каждая система имеет свои уникальные функции и услуги, например, спутниковые системы имеют глобальное покрытие, в то время как системы PMR, скорее всего, будут предлагать краткосрочные вызовы и групповые вызовы. В статье также отдельно анализируются новые поколения мобильной связи, в том числе технологии LTE и WiMAX. Эти технологии предоставляют уникальные возможности для повышения скорости передачи данных, качества обслуживания и внедрения новых функций. Технология LTE является ключевым фактором увеличения скорости передачи данных, сокращения задержек и улучшения интеграции с существующими мобильными системами. WiMAX играет важную роль в обеспечении широкополосной беспроводной связи, особенно для высокоскоростного доступа в Интернет в городах и сельской местности.

Ключевые слова: Системы мобильной радиосвязи (СМР), технологии LTE и WiMAX, системы спутниковой связи, системы сотовой связи, профессиональные сети мобильной связи (ПМС), Интернет.

Annotation: This article analyzes the types of mobile radio communication systems and their performance characteristics, service areas, technological differences and interactions between them. Mobile radio communication systems (MRC) are divided into different classes, which differ in their tasks, service areas and the type of services provided to subscribers. According to the size of the service areas, the systems are divided into the following categories: satellite communication systems, cellular systems, professional mobile networks (PMR), and wireless telephony systems. Each system is distinguished by its own characteristics and services, for example, satellite systems have global coverage, while PMR systems have more short-term calls and group calls. New generations of mobile communications, including LTE and WiMAX technologies, are also analyzed separately in the article. These technologies provide unique opportunities for increasing data transfer speed, improving service quality and implementing new features. LTE technology is a key enabler in increasing data rates, reducing latency, and improving integration with existing mobile systems. WiMAX plays a key role in providing broadband wireless connectivity, especially for high-speed Internet access in urban and rural areas.

Keywords: *Mobile radio communication systems (MRC), LTE and WiMAX technologies, satellite communication systems, cellular systems, professional mobile networks (PMR), Internet.*

Mobile radio communication systems (MRCS) can be divided into 4 classes depending on their purpose and service area size:

1. Satellite communication systems with a service area of 400-800 km in one beam and a diameter of 3000-8000 km for one satellite depending on the orbit altitude;
2. Mobile radio communication systems with a range of 0.3 to 35 km;
3. Professional mobile (trunking) radio communication systems operating in a radius of 2 to 50 km depending on the antenna elevation angle;
4. Wireless telephony systems with a cell size of up to 0.3 km.

The difference between systems of different classes lies primarily in the types and quality of services provided. Higher quality is provided by cellular networks and wireless telephony systems providing two-way radio communication services for both mobile and fixed (public telephone networks, ISDN, etc.) subscribers. The same services, but with fewer capabilities, are used in satellite systems. In PMR systems, the main types of services are half-duplex communication and group subscriber calls [19].

The sizes of service areas depend on the density and distribution of subscribers in the service area. In areas with a high subscriber density, femtocells and picocells with a radius of up to 100 m are created, and in areas with large buildings and a high population density - microcells (0.1-0.5 km). The radius of macrosatellite zones covering urban and suburban areas does not exceed 30-35 km. In remote and hard-to-reach areas, subscriber service in rural areas can be carried out using both cellular and satellite systems.

Cellular networks and wireless telephony systems can serve subscribers with a high density - up to 10,000 per square kilometer. Trunking networks are most effective when the traffic volume does not exceed 1-2 erl / sq. km. To increase spectral efficiency, cellular systems use wideband channels with TDMA and CDMA multiple access technologies. At the same time, PMR networks mainly use shortband channels with FDMA or TDMA.

Other differences lie in the communication scheme. In fixed and wireless telephone systems, individual calls are made between subscribers. The average conversation duration can be several minutes. The typical operation mode of PMR systems is based on short transmissions, but frequent calls (less than 1 minute). Calls can be made directly or through a dispatcher. In PMR systems, the connection establishment time, as a rule, should not exceed 0.3 s.

Mobile radio communication systems are divided into two classes according to the method of using the frequency resource:

- communication systems in which channels are rigidly tied to subscribers;
- at the request of subscribers of the general service area systems that provide channels.

High communication efficiency is ensured in systems with unchanged channel connections. The principle of combining channels without replacing them has become widespread in traditional PMR systems. Trunking systems are freely connectable systems. They provide the ability to work

on any channel within the selected frequency group; Thus, a specific channel is assigned to the allocated resource. In cellular and wireless telephony systems, channels are provided on demand when the subscriber is in the same service area. The use of new system and technical solutions in X-ray location has improved the signal-to-noise ratio (Eb/N0). If in analog systems the Eb/N0 ratio was 17–18 dB, then in digital systems this figure was 7–9 dB.

Relative characteristics of terrestrial radio communication systems in motion (excluding satellite systems) are presented in Table 2.1. Although the presented list of systems is not exhaustive, it still allows one to evaluate the differences in the design of a particular system.

Signal-to-noise ratio is the ratio of the signal energy of 1 bit to the noise power density at a frequency of 1 GHz (Eb/N0). The lower the value of this parameter in XRT, the higher the quality of the system's communication. The ratio Eb/N0 is of great practical importance because the bit error rate is a (decreasing) function of this ratio. (Table 2)

Standard Characteristics	2nd generation total communication systems				Wireless telephony		PMR digital systems		
	GSM	D-AMPS	cdmaOne	PDC	CT-2	DECT	TETRA	APCO-25	Tetra pol
Frequencies Range , MGs	890-915/1710-1785 ; 935-960/1805-1880	824-849; 869-894	824-849; 869-894	810-826; 940 956; 1429 - 1453 1477 - 1501	864-868	1880-1900	380-400; 410 430 (450-470)	138-174; 406-512; 746-869	70... 520
Frequency strip width , MGs	25	25	25	25	24	20	20	n/a	5
Duplex delivery , MGs	45/95	45	45	48(130)	No	No	10	n/a	10
Channelby difference , kgs	200	30	1250	25 (50)	100	1728	25	12.5/6.	12.5/10
Duplex channels number	124	832	20	640	40	10	n/a	n/a	400
Multistation access	TDMA	TDMA	CDMA	TDMA	FDM A	TDM A	TDMA	FDMA	FDM A
Method duplexing canal	FDD	FDD	FDD	FDD	TDD	TDD	FDD	FDD	FDD
One to the sender correct coming channels number	8 years 16	3(6)	55	3(6)	1	12	4	1	1

Modulation method	GMSK	n/4 DQPSK	QPSK (BS) OQPSK K (M)	n/4 DQPSK	GFSK	GFSK	n/4 DQPSK	C4FM CQPSK	GMSK
Information transmission speed, <i>kbit/s</i>	270.8 (EDGE)	48.6	1288	42	72	1152	32 (9.6 including 4 log.channels)		8
Voice codec type	RPE-LTP	VSELP	QCELP	VSELP	ADPCM	ADPCM	ACELP	IMBE	RPC
Voice codec speed, <i>kbit/s</i>	13 years 6.5	7.95	13 years 8.5	6.7	32	32	4.5	4.4	6
Voice for channeled coding	R=1/2, K=5	R=1/2	R=1/3, R=1/2	R=1/2	n/a	CRC	R=2/3	R=1/2, Goalie	n/a
Frame length, <i>ms</i>	4.6	40	20	20	2	10	57	180	20
MS power average (maximum picovaya), <i>W</i>	GSM-900: (0.1-8 (0.6-20) GSM-1800: 0.25 - 1(0.03-0.125)	3.0 (9); 1.6 (4.8); 1.6 (1.8)	0.6 (6.3); 2.5; 1.0	0.66 (2)	0.005 (0.01)	0.01 (0.25)	2.5 (10); 0.75 (3); 1 (0.25)	n/a	10 (auto)
Relationship <i>Eb/No</i>	9	16	6-7	17	20	12	19	n/a	n/a
Handover	Yes	Yes	Yes (soft)	Yes	No	No	Yes	n/a	n/a

Technologies that make up the 4G generation of mobile communications. The fourth generation of mobile systems is characterized, first of all, by high data transfer speeds and improved quality of voice communication. As noted above, the fourth generation of mobile and broadband communication systems includes technologies that allow data transfer at speeds of more than 100 Mbit/s. Today, Wi-Fi (IEEE 802.11n standard) and WiMAX (IEEE 802.16m standard) are among the KSU systems with a theoretical data transfer speed of up to 1 Gbit/s, as well as mobile communication technology - LTE (more precisely, its improved version LTE-Advanced). Since Wi-Fi and WiMAX KSU technologies have many similarities, in this manual we will limit ourselves to only a brief description of Wi-Fi technology and focus on the analysis of LTE and WiMAX technologies.

LTE technology. 3GPP Long Term Evolution (3GPP LTE) - is the full name of the project to improve the UMTS standard to meet future requirements for data transfer rates [18]. These improvements can include, for example, increasing system efficiency, reducing response latency, expanding the range of services provided, as well as improving integration with existing mobile communication technologies.

In the 3GPP LTE standard, the data transfer rate can theoretically reach 326.4 Mbit/s on the downlink (download) and 172.8 Mbit/s on the uplink (uplink) (for 3GPP release 8).

In addition, the response latency (i.e. the time between sending a request and receiving a response) has been reduced in the LTE system. The working bandwidth in the LTE system is variable, ranging from 1.25 MHz to 20 MHz. (in which the network can operate in a wide frequency range from 450MHz to 2.6GHz). LTE is built on the basis of packet switching of full channels, while Dual Transfer Mode (DTM) allows simultaneous voice and data transmission. It is expected that LTE technology will provide an evolutionary transition to the fourth generation for existing cellular communication networks and will allow cellular operators to create high-speed and efficient broadband mobile networks. At the same time, it will not only increase the connection speed, but also allow to expand the range of functions. WiMAX technology. Worldwide Interoperability for Microwave Access (WiMAX) - (worldwide cooperation for connection in the 802.16 band) - is a broadband wireless connection technology that complements wired lines and cable technologies, standardized by the IEEE Institute (802.16 group) as an alternative solution to the problem of the "last mile" over long distances. WiMAX technology can be used to create metropolitan area networks (MAN), create wireless access points (point-to-multipoint mode), establish high-quality communication between remote objects (point-to-point mode), and solve similar problems. In general, the basic characteristics of the IEEE 802.16 standard provide for a range of up to 50 kilometers, the ability to work outside the line of sight, and a maximum (peak) data transfer rate of up to 70 Mbit/s per sector of the BS (a BS can have up to 6 sectors in total). WiMAX network equipment can operate in several channels with a width of 10 MHz in the 2-11 GHz range. Such a wide selection of frequency bands was made to take into account the specifications of many countries around the world. Thus, WiMAX is a technology designed for high-speed Internet access, comparable in data transfer speed to wired networks and superior in performance and coverage to modern Wi-Fi networks. In turn, the continuation of the WiMAX "backbone networks" can be local Wi-Fi networks or various commercial and household wired networks of users. Ideally, WiMAX is a technology based on industry standards and designed to provide high-speed, at the same time, relatively inexpensive communication for home users, enterprises and mobile wireless networks in cities and villages. Ensuring quality of service in LTE systems. Quality of service in communication networks is determined by QoS (Quality of Service). QoS determines the degree to which the communication network complies with the agreed-upon quality of the communication services offered. For most cases, the quality of communication is determined by four parameters:

- Bandwidth describes the nominal throughput of the information transmission system, measured in bits/s, kbit/s, and Mbit/s;

- Delay in packet transmission determines the time it takes for packets to travel from the sender to the receiver, measured in milliseconds (ms);
- Jitter is the fluctuation (unstability) of packet transmission, measured in dgas;
- Packet loss determines the number of packets lost during transmission, measured in percent of the total number of transmitted packets.

For a simpler explanation, a communication channel can be imagined as a conditional pipeline, and its throughput, in terms of its internal parameters, is a function of the width and length of the pipeline [16]. The "bottleneck" problem in data transmission routers is solved by using the FIFO (First In -First Out) method. In intensive traffic, this creates very easily solvable congestion. All packets that do not enter the FIFO queue are rejected by the router and, accordingly, are lost. The best way is to use "smart" queues, in which the priority of packets depends on the type of service provided, i.e. ToS (Type of Service). In order to create "smart" queues, packets must carry a type of service indication. For example, it is desirable to give higher priority to voice packets (VoIP) over representative connections than to TR or SMITP packets. In practice, the term QoS based on such prioritization (object-based system) is widely used. Quality of service can be based on several QoS models.

- The "Best Effort Service" model is not a smooth adjustment mechanism, but serves only to simply increase the ability to adjust and transfer different classes of traffic without any separation;
- The "Integrated Service" model (IntServ) provides seamless service (End to end) with guaranteed required bandwidth on all signal paths;
- The "Differentiated Service" model (Differentiated Service) provides QoS based on the allocation of resources in the network core and certain classifications and restrictions at the network boundaries that combine to provide the required services. This model introduces a division of traffic into classes, each of which is assigned its own QoS level. DiffServ consists of traffic shaping control (packet classification, marking, intensity control) and policy control (resource allocation, packet deletion policy). DiffServ is a good example of intelligent traffic management.
- Quality of service in LTE systems. As mentioned above, after studying a number of technologies for multi-signaling, the 3GPP project settled on OFDM technology for the output channel and SC-FDMA technology for the input channel. The choice made was not only due to the specificity of the spectrum, but also to the strict requirements for channel capacity, efficient use of the spectrum, as well as QoS quality of service. Therefore, the existing concept of QoS for GSM and W-CDMA systems was an attempt by the developers of complex LTE systems to use a QoS concept that could combine the simplicity and compactness of the connection with the support of backward compatibility. The LTE system uses the concept of class-based quality of service. It provides operators with a simple and effective solution for differentiating different packet services. Significant attention in 3GPP developments is paid to ensuring quality of service, tariff recovery and the use of identification data. For example, the emergence of box-mode terminals designed to work in Wi-Fi and cellular networks allows subscribers to be served using different radio technologies. In this regard, the LTE system provides a mechanism for restoring a more convenient

infrastructure to provide the services needed by the subscriber. The authors of the identifications for subscriber and network devices used for addressing, mobility, connection integrity, data protection and other purposes have demonstrated maximum compactness. In new types of networks, the use of identifiers used in GSM and VMTS networks and identification data reflecting the emergence of new functions in E-UTRAN networks are allowed. In addition, 3GPRS Release 8 introduces a number of features aimed at increasing the level of information security in next-generation mobile networks. As LTE system developers have noted, the architectural changes they introduce will significantly reduce data transmission latency, which is especially critical for applications such as VoIP or online interactive games. For example, for short IP packets and a small network load, the total latency when a packet is sent over an LTE network should be less than 5 ms on a 5 MHz bandwidth and more than 10 ms for smaller bandwidths. These values are marginal and 50% better than similar indicators of today's advanced 3G networks. The requirements for reducing latency during connection establishment lead to a potential evolution of the current concept of 3GRR quality of service, which provides operators with simple and effective mechanisms for controlling QoS. In LTE networks, a logical connection is associated with a given QoS level (such a connection can be called a tuple). A user can have many different tunnels with different QoS levels (in modern 3G networks, such a tuple consists of a PDP and an associated radio access channel (RAB - Radio Access Bearer). The latency during connection establishment can be reduced if the tunnels are pre-established (i.e., before the start of a duplex connected communication session). Such pre-establishment requires fewer system signals during session establishment, thus reducing the latency. Consequently, the tunnels can be established immediately after the subscriber device is turned on. This approach can also be used for tunnels related to services that require a guaranteed GB (English Guaranteed Bandwidth) data system, similar to VoIP services. For pre-established tunnels to be used and effective, the following procedures must be followed:

- Splitting the connection control (admission control) and the tuple establishment into two separate procedures, since otherwise the resources required for pre-established tunnels would be unnecessarily reserved;
- Providing operators with better control over the quality of service levels assigned to pre-established tunnels. This can be done with special network-controlled procedures for establishing tuples;
- Providing operators with better control over the concentration of application flows in pre-established tunnels. This can be done if control is given over the packet filters that serve to distribute the load to different nodes (mapping).
- This quality of service architecture provides operators with full control over the QoS levels associated with each individual tunnel, over determining when individual tunnels are switched, and over the application flows that are reflected to individual nodes.
- In conclusion, we can say that having concluded the topic of studying the quality of service in the 4G generation of mobile communications, it is possible to summarize several aspects, traditions, difficulties and prospects of their further development from the point of view of today as follows.

- As we noted above, LTE technologies in their current versions have not been approved by HEAI as 4G technologies. As specified in the requirements for the characteristics of 4G technologies, such systems should have a maximum (peak) speed of not less than 100 Mbit/s in high mobility (at speeds of 360 km/h) and a speed of not less than 1 Gbit/s in the fixed mode. The second version of the WiMAX system (IEEE802.16m standard, expected in 2012) and LTE Advanced technology (3GPP Release 10, expected in 2012) correspond to such requirements.
 - In this regard, the future “peaceful coexistence” of these two competing technologies causes heated debates in expert circles. And, as always, there are supporters and opponents of this or that technology, there are optimistic and pessimistic expectations about the future, and, importantly, there are different scenarios for the development of these technologies and the industry as a whole. It is possible to name a few of them.
 - For the success of a new telecommunications technology, such factors as productivity (i.e., bandwidth, radio coverage, network capacity, spectral efficiency, etc.), substitutability, compactness and universality (i.e., support for previous technologies, compact channel width, access to operating frequencies for many regions, etc.) and availability of devices (base, subscriber, peripheral devices) are important.
 - In many of these parameters, LTE technology clearly outperforms WiMAX technology:
 - LTE technology is currently ahead of WiMAX technology in terms of radio coverage and capacity;
 - About 1300 cellular networks with a total number of subscribers of more than 5 billion people have been built in the world (by the end of 2010), while the number of SKPRE networks of the WMAN class built in the world is almost 600 with a total number of 1.5 billion subscribers. Existing cellular communication networks prefer to develop in the direction of LTE rather than WiMAX;
 - Although today the reach of WiMAX devices is more sufficient than LTE, for the most part LTE will eventually overtake WiMAX in this parameter. The similarity of LTE FDD and LTE TDD technologies and the possibility of reusing technical solutions from large cellular markets will lead to the rapid emergence of both LTE network infrastructure and subscriber equipment. But it should be noted that LTE technology was developed after WiMAX technology, and accordingly, the experience of WiMAX technology was taken into account and errors were corrected. In addition, at this time the microprocessor industry stepped forward, new efficient signal processing algorithms were developed, which allowed LTE technology to be used in advanced technologies. With the advent of the IEEE 802.16m standard, which in its characteristics surpasses LTE technology in its 8th release, WiMAX technology should reduce its position (place). However, after the release of 3GPP release 10 (LTE Advanced), the “palm of first place” will again be on the side of LTE technology. In this case, the marketing steps of manufacturers and operators, as well as the positions of regulators (allocation of frequency resources, licensing conditions for operator activities, etc.) may be decisive factors.
- There is also an assumption that in the future WiMAX and LTE technologies will merge. Bill Morrow, CEO of Clearwire (Bill Morrow), spoke about this idea at the CTIA Wireless exhibition

in 2010, saying that the wireless industry should focus on the integration of WiMAX and LTE technologies, not their separation. Motorola, in turn, added that by creating a device for LTE technology, it will use many things from WiMAX technology. According to Mr. Morrow's proposal, in the future both technologies will be brought to a single network standard. If necessary, Clearwire can add support for LTE technology to its WiMAX networks. However, to date, WiMAX networks are at least a year ahead of LTE technology in terms of commercial deployment and continue to increase their geographical coverage. In its current state, the transition to WiMAX technology is the most likely way to move from DSL networks and modems. WiMAX technology provides increased data transfer speeds, provides affordable devices, and is also a bridge to higher speeds in the future. In the near future, this will be the "higher speed" LTE technology. But for this, it will be necessary to wait for it to be widely available. For now, according to various assumptions (predaolozheniya), in the future operators will support their 2G and 3G networks and provide voice services and short-range Internet access in the main coverage area. In turn, WiMAX and LTE networks will be built as a "broadband" addition to 2G and 3G networks. Hybrid networks and multi-mode subscriber devices (for example, EV-DO/WiMAX and HSPA/LTE), which combine the best qualities of these technologies, will become widespread.

In this, more than anything, the end user wins in the end. The world is changing before our eyes. Modern man intelligently allocates his time and perceives the world as a single information environment that allows him to think quickly, work, live and use his creative ideas.

The life safety part of the graduation qualification work considers the ergonomic requirements for the workplace in computer rooms, the effects of electric current, electromagnetic radiation on the body and protection in them, and the possibility of emergency situations.

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