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POSSIBILITIES OF IMPROVING THE VOICE SERVICES QUALITY IN 5G NETWORKS

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Background. The introduction of fifth-generation (5G) networks creates new opportunities for fast and continuous data exchange, but there are still some problems with the quality of voice services in such networks. With the rapid development of technology and the further spread of 5G, there is a need to understand the impact of key aspects of 5G on voice quality. This requires research that can systematically analyse the features of 5G networks that affect the quality of voice services.

Objective. Identification of ways to improve the quality of voice services in 5G networks. Assessment of key indicators of voice service quality in 5G networks. Determination of the best option for the gradual transition to the Standalone mode and the use of VoNR technology in the fifth generation networks.

Methods. Analysis of factors affecting the quality of voice services in fifth-generation networks. Analysis of well-known publications on the implementation of 5G networks. Comparison of the implementation of Non-Standalone and Standalone modes in the 5G network. Testing of the modern EVS codec, which provides an opportunity to improve the customer experience.

Results. Confirmation that 5G networks can significantly improve the quality of voice services compared to previous mobile communication technologies such as 4G and 3G. Certain factors that may affect the quality of voice services and require additional attention when planning and deploying 5G networks are identified. The optimal steps for the transition to the Standalone mode and the use of VoNR technology in fifth-generation networks are determined. The main differences in the QoS architecture between LTE and 5G are identified, and the purpose of DRB flows for separating traffic types and services is established.

Conclusions. It has been confirmed that 5G networks can significantly improve the quality of voice services compared to previous technologies such as 4G and 3G. This is possible due to the broadband capabilities of 5G networks, improved data transmission, low latency, the use of an advanced EVS codec and reduced response time. However, certain factors, such as network coverage, optimisation level and traffic characteristics, can affect the quality of voice services and require additional attention when planning and deploying 5G networks. The QoS management architecture consists of QoS flows, which allow separating packet assignment to flows (managed by the CN) from the assignment of DRB flows (managed by the RAN). As 5G networks are being rolled out gradually, it is important to properly integrate the 5G domain into the existing telecoms provider's network. The transition from Non-Standalone to Dual connectivity is a necessary step for the implementation of VoNR technology in Standalone mode. Using the modern EVS codec allows not only improving the customer experience, but also introducing new voice services.

Keywords: *5G; Voice service; QoS; VoLTE; CSCF; EPS FB; NSA; Delay; VoNR; 5QI; RAN; RRC; Codec; EVS.*

I. INTRODUCTION

When developing the 5G mobile network, not only was the ability to serve a large number of users or terminal machines (e.g., Internet of Things sensors) and increase the total volume (bandwidth) of data transmission implemented, but also important aspects were taken into account to ensure that the quality of voice communication is maintained [1-3]. It is important to note that the quality of voice services is a measure of efficiency and user satisfaction in the process of voice communication. It reflects the level of clarity, purity and intelligibility of the sound, the absence of distortion and noise, minimal delay and uninterrupted connection. Voice service quality also includes transmission stability, echo cancellation, high broadband, and compliance with user standards and requirements. The main goal of voice service quality is to ensure an adequate level of communication and satisfaction of users' voice communication needs [1].

At present, the voice channel remains quite complex, as it is supported by two standards: time division multiplexing (TDM) (a legacy of 2G networks with channel switching) and voice over IP (VoIP). Each of these standards requires its own configuration, separate maintenance and quality control policies.

Establishing a voice connection is a standardised process of exchanging signal data between fixed or mobile network operators. This exchange can take place directly via the open Internet, private or public peering using appropriate network protocols (IP, voice over IP, etc.).

During the heyday of 2G/3G mobile communications systems, the operator's core network provided voice solutions for users using channel switching technologies developed for fixed-line telephony systems.

At present, during the period of 4G systems operation, the operator's core network is fully based on the IP protocol stack. The VoLTE (Voice over Long-Term Evolution) technology provides IP-based voice services directly over IMS (IP Multimedia Subsystem) and LTE (Long-Term Evolution) networks. In order to ensure continuity of voice services at different stages of 4G network deployment, the network has implemented similar intermediate voice solutions with CSFB (Circuit Switched Fallback) channel switching and SRVCC (Single radio voice call continuity).

In addition to enabling the sharing of electronic communications traffic, interconnection agreements also include provisions for: mutual compensation, acceptable use of services, routing policies, QoS metrics, and conflict resolution. Such traffic sharing is standardised within business-to-business agreements and is further regulated by industry signalling standards that all telecoms operators must adhere to.

The quality of voice services is determined by the choice of network architecture and hardware. To meet the requirements of industry standardisation, an operator must be able to identify and address the following factors that affect voice quality in VoIP and TDM networks [4].

In the case of TDM networks:

- Noise levels should not exceed -60 dBm0;
- Signal levels must also be properly adjusted to avoid clipping (noise when the ratio is too low) or distortion (when the levels are too high);
- Echo, especially when combined with delay, can lead to particularly bad quality degradation;
- Legacy low bit-rate codecs;
- Frame erasures can affect voice quality during mobile calls.

In the case of VoIP networks:

- Jitter, which occurs when packets arrive at different intervals;
- Packet losses;
- Network delay, which can be caused by geographical distance and network usage;
- Codec, the use of different codecs allows you to vary the network bandwidth and the quality of voice services;
- Echo.

To support the operation of voice services in the 5G network, a new KPI (Key Performance Indicator) was introduced [5]. Such a KPI is a quantitative measure used to assess how effectively an electronic communications network achieves key technological goals, service availability and performance, call failures and congestion. KPIs should provide a clear picture of the current state of performance of the operational network.

One of the critical factors in ensuring voice quality is to ensure low network latency, which reflects the time it takes for a message to be transmitted between two network nodes. The lower the latency, the better the connection and customer experience, which helps to improve interaction and reduce the echo effect during a call. In 5G networks, latency is significantly reduced compared to 4G due to the use of One-Way Latency and can be calculated at the level of several milliseconds [6, 7]. However, the exact latency values will depend on various factors, such as network topology, technologies used, traffic volume, etc. This makes the 5G network the best option for voice services at the moment, providing advanced technologies and benefits that contribute to high quality communication. Another aspect that affects the quality of voice services is the high bandwidth of the 5G network, which allows for the transfer of large amounts of data both within the core network and between wireless terminals.

Another important factor that affects the quality of voice services in 5G networks is the quality of network coverage. To ensure the quality of voice services, it is necessary to have adequate network coverage to ensure a stable connection to the network at any location. To ensure adequate 5G network coverage, it is necessary to have a sufficient number of base stations and additional equipment, such as repeaters and signal boosters. The role of small base stations, which can be placed anywhere, including narrow streets, remote locations, etc., is particularly important. This allows for a reliable connection to the network at any time and ensures high-quality voice services [8].

In addition, in order to ensure the quality of voice services in 5G networks, it is necessary to have the appropriate equipment and software to ensure reliable transmission of voice data over the network [9].

It is clear that the introduction of fifth-generation 5G networks creates new opportunities for fast and continuous data exchange, but there are still some problems with the quality of voice services in such networks. With the rapid development of technology and further implementation of 5G, there is a need to fully understand the impact of key aspects of 5G on voice quality. This requires analytical studies that can systematically analyse the features of 5G networks that affect the quality of voice services.

Thus, the purpose of this article is to analyse the impact of technological features of 5G networks on the quality of voice services. The study is aimed at identifying and analysing the key aspects that affect the quality of voice communication in 5G networks. The results of this study can be useful for telecom operators, equipment manufacturers and standards developers to improve the quality of voice services in 5G networks and ensure a good customer experience in mobile networks.

II. IMPROVING THE QUALITY OF VOICE SERVICES IN 5G NETWORKS

The new generation of 5G networks greatly simplifies the approach and process for creating advanced voice services compared to previous generations of networks. This in turn allows service providers to integrate Augmented Reality (AR) into the phone call, enhance video calls and enable interactive calls for a truly immersive customer experience. 5G technologies enable users to experience high data speeds with extremely low latency, higher network capacity and better availability, which provides greater reliability. The increased performance will provide a better user experience and accelerate communication between different industries. This will allow for the uploading and processing of large amounts of data in a short period of time. Fig. 1 shows the average speed of mobile networks of different generations [10].

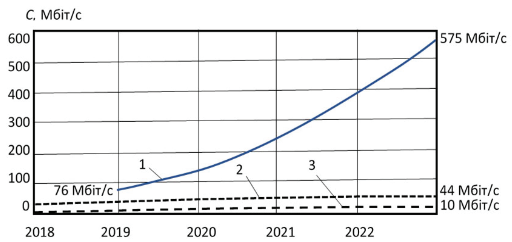

Fig. 1. Changes in the average speed of mobile networks of different generations: 1 - 5G; 2 - 4G; 3 - 3G

As it shows on the figure 1, the average connection speed in 5G is growing steadily and is already more than 20 times faster than 4G networks. This creates a great opportunity for Communication Service Providers (CSPs) to modernise existing voice services using cloud solutions and create a special platform for developing new voice services using cloud programming [10].

At the initial stage, the implementation of 5G systems will be based on the existing VoLTE network. The 5G NSA (non-standalone) network structure makes it possible to implement VoLTE by connecting to the EPC (Evolved Packet Core) and eNodeB (3GPP-compliant implementation of the 4G LTE base station), and VoNR (Voice Over New Radio) by connecting to the EPC and gNodeB (3GPP-compliant implementation of the 5G-NR base station).

The EPS FB (Evolved Packet Switched Fallback) packet mode allows 5G users to use the 5GC (5G Core Network) with NR (New Radio) for all data traffic, but the RAN (Radio Access Network) can initiate the movement of the user terminal connected to the EPC, making it possible to redirect 5G terminals from the 5GC to the EPC to make a VoLTE call during the transition phase.

To understand the further analysis in this paper, Fig. 2 shows the current architecture of the mobile communications network, which integrates existing networks of mobile operators of different generations through the IMS network.

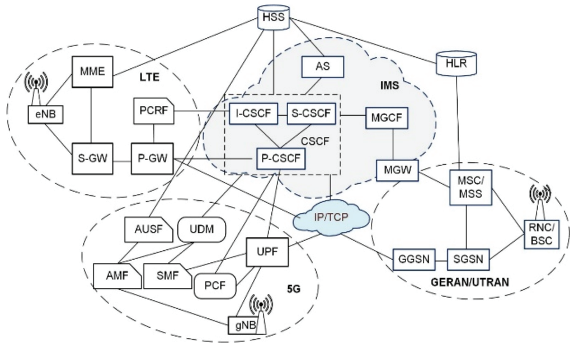

Fig. 2. Unified architecture for connecting mobile networks of different generations via IMS:

eNB – e-UTRAN Node B; MME – Mobile Management Entity; SGW – Signalling Gateway; PGW – Packet Data Network-GateWay; PCRF – Policy and Charging Rules Function; HSS – Home Subscriber Server; HLR – Home Location Register; AS – Application Server; MGCF – Media Gateways Control Function; CSCF – Call Session Control Function; I-CSCF – Interrogating (Call Session Control Function); S-CSCF – Serving CSCF; P-CSCF – Proxy-CSCF; MGW – Media GateWay; MSS/MCS – MSC Server / Mobile Switching Center; GCSN – Gateway GPRS Support Node; SGSN – Serving GPRS Support Node; RNC/BSC – Radio Network Controller / Base Station Controller; AUSF – Authentication Server Function; UDM – Unified Data Management; UPF – User Plane Function; PCF – Policy Control Function; SMF – Session Management Function; AMF – Access and Mobility Management Function; gNB – gNodeB.

The transition from the previous generation networks to 5G allows for improved quality of service (QoS), which includes faster data transfer speeds and network availability, lower latency and jitter, and increased reliability. These changes in QoS will eliminate a number of voice issues during connection sessions, such as dropped voice and call interruptions, which users have experienced for a long time on 3G and 4G networks. Fifth-generation networks need to provide a much more granular approach to QoS management, enabling more flexible and independent QoS processing in the network core and RAN, and differentiating traffic for specific packets if necessary. Typically, when transmitting traffic in the form of data packets, it is desirable to assign a higher priority to packets related to TCP connection requests and responses to avoid unnecessary delay in connection establishment time. A key limitation of the LTE QoS architecture is that mobile data differentiation occurs only at the level of unidirectional radio channels. Specifically, within a single carrier channel, which can be set to reflect traffic with guaranteed or non-guaranteed bit rates and is characterised by a QoS class identifier (reflecting priority, allowable delay and packet loss rate), all packets are treated equally. In addition, there is an unambiguous mapping of radio channels to EPS channels. If a single wireless link is to carry data related to very different service requirements, then separate unidirectional radio channels must be configured to be able to sufficiently differentiate the traffic, which would be extremely inefficient. Also, LTE cannot treat packets differently in a PDU session, i.e. TCP packet prioritisation associated with TCP session setup is not possible.

The QoS management architecture for 5G is based on the concept of QoS flows, which are identified by QFI QoS flow IDs and managed by the SMF in the CN. The key point is that a single PDU session can refer to several QoS flows, which are characterised by:

- a QoS profile provided by the SMF for the access network;

- one or more QoS rules provided by the SMF to the UE;

- classification of SDF (Service Data Flow) services and QoS related information provided by the SMF in the UPF [1].

The QoS profile contains information on whether the flow is a guaranteed or non-guaranteed data rate traffic, the 5QI (5G QoS Identifier) and the ARP (Allocation and Retention Priority).

Fig. 3 shows a comparison of QoS architectures between LTE and 5G. In the case of LTE, the left-hand side shows a unidirectional channel approach with a strict unambiguous mapping between unidirectional EPS channels, unidirectional EPS radio access channels (E-RAB), S1 and unidirectional radio channels. In the case of 5G, the right-hand side shows a flow-based approach that allows for the separation of packet assignment to flows (managed by the CN) from the assignment of DRBs (managed by the RAN). The specific example of three different QoS flows mapped to two different DRBs should be considered as an example only [1].

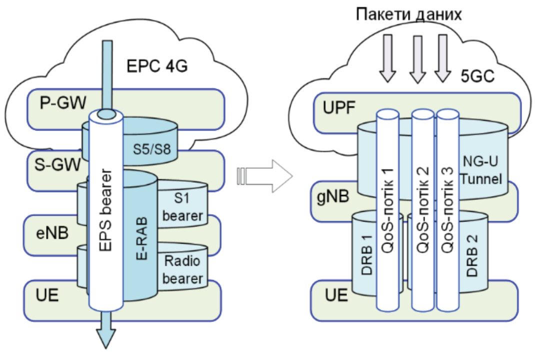

Fig. 3. QoS architecture comparison between LTE and 5G

According to this figure, in the downstream/channel (DL), the UPF maps data packets to QoS streams (based on the SDF classification rules provided by the SMF) and the gNB maps QoS streams to unidirectional data radio channels. In the uplink (UL) direction, the UE maps packets to QoS flows for unidirectional data radio links based on the QoS rules from the AMF.

Fig. 4 shows multiple PDU sessions, each of which may generate packets with different QoS requirements. For example, packets from the Internet may occur because users are browsing a website, streaming a video, or downloading a large file from an FTP server. Latency and jitter are important for video, but less important for FTP downloads.

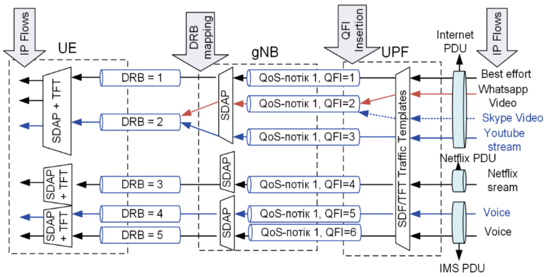

Fig. 4. Scheme of QoS implementation for downstream packets

PDU sessions and service data flows (SDFs) are established between the UE and the DN. Each application receives its own SDF. In the example, we assume that Internet, Netflix and IMS are PDU sessions. An Internet PDU session has four SDFs, and an IMS PDU session has two SDFs.

Multiple IP flows can be mapped to the same QoS flow. QoS stream 2 is an example that carries both WhatsApp video and Skype video. At the radio interface, QoS streams are mapped to unidirectional DRB radio data channels that are configured to deliver that QoS. Multiple QoS streams can be mapped to a single DRB. DRB2 is an example that carries QoS streams 2 and 3.

The rollout of 5G networks is gradual and at the beginning, voice and data networks are separated. Voice is provided over EPC+LTE with VoLTE. With the adoption of 5GC, voice services continue to be provided over EPC+LTE, and EPS becomes a backup solution for voice. Only after deep optimisation of the 5G network is the VoNR function gradually introduced.

Consider Fig. 5, which compares the implementation of Non-Standalone and Standalone modes in a 5G network.

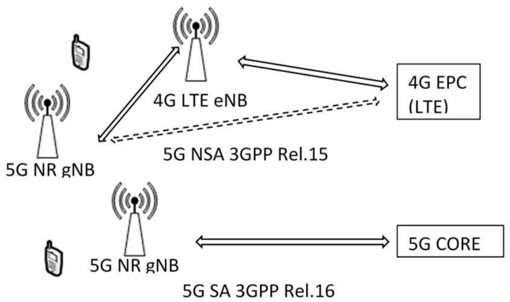

Fig. 5. Comparison of the implementation of Non-Standalone and Standalone modes in a 5G network

Initially, 5G is being implemented in Non-Standalone mode, as described in 3GPP Release 15. Thanks to the RAN consisting of dedicated 5G New Radio gNodeB base stations operating on 5G-specific frequencies, all 5G UE call processing and routing functions are performed using the 4G LTE EPC. In this way, 5G NSA helps operators to leverage their 4G LTE investments before switching to full SA mode. Dual connectivity was introduced in the 3GPP Release 16 standard. The technical term for 5G NSA is Evolved-Universal Terrestrial Radio Access-New Radio-Dual Connectivity or simply EN-DC.

5G EN-DC allows users to exchange data with the nearest 5G NR gNB while establishing a connection with a neighbouring 4G LTE eNodeB base station. Dual Connectivity is possible when signal links are established between a 4G LTE eNB and a 5G NR gNB. In Dual Connectivity mode, UEs simultaneously connect to a 4G LTE eNB for the control plane and a 5G NR gNB for the user plane. The control plane handles all signalling between the UE and the network, while the user plane provides data transmission between the network and the UE [11].

In fifth-generation networks, it was determined that voice should be digital and transmitted as data, while the mobile Internet would not be interrupted. This solution made it possible to use frequencies more efficiently, increase the number of voice sessions per base station and use advanced codecs. One of the main codecs in 5G is the EVS (Enhanced Voice Services) codec, which is designed specifically for voice transmission over the network using VoNR and VoLTE technologies. It is a new standard for delivering high-quality voice services, which is backward compatible with the AMR-WB codec, which is positioned as an HD codec. EVS uses advanced compression techniques to reduce the amount of data required to transmit high-quality voice signals over a 5G network. EVS is designed to work effectively in a variety of network conditions, including low-bandwidth and high-latency environments. It can deliver better voice quality than previous codecs such as AMR-WB, even at lower bitrates. This means that EVS can deliver clearer, more natural voice quality even in challenging network conditions. EVS also supports a number of advanced features, such as noise reduction, echo cancellation and voice activity detection, which can further improve the quality of voice services in a 5G network [12].

The EVS codec is a hybrid codec that combines waveform and parametric coding techniques to achieve high quality voice transmission. It uses a broadband signal with a bandwidth of up to 20 kHz and supports a bitrate range of 5.9 kbps to 128 kbps, depending on network conditions and the desired level of voice quality. One of the key features of the EVS is its ability to adapt to different network conditions and dynamically adjust data rates and other parameters to optimise voice quality. This is achieved through the use of an advanced adaptive bit rate control algorithm that adjusts the bit rate in real time based on the available network bandwidth and the complexity of the audio signal. The waveform coding component of EVS is based on the Code-Excited Linear Prediction (CELP) algorithm, which is used to model the voice signal and generate a set of parameters that can be efficiently transmitted over the network. The parametric coding component uses a combination of spectral analysis, harmonic modelling and other techniques to extract additional information about the voice signal and improve overall quality. The EVS codec also includes a number of advanced features for noise reduction, echo cancellation and other signal processing tasks. These functions are implemented using a variety of algorithms, including adaptive filters, spectral subtraction, and other methods [12].

When the 5G network has been comprehensively optimised, it becomes possible to switch to VoNR technology, which is used for voice services in 5G networks. It is a successor to existing voice technologies used in previous mobile networks, such as 2G, 3G and 4G/LTE. VoNR is designed to provide high-quality, reliable and efficient voice communications in 5G networks. One of the main advantages of VoNR is that a dedicated frequency band is used for voice calls, separated from data traffic in the network. This ensures that voice calls are not affected by congestion on the data network, resulting in better call quality and a more reliable connection. VoNR also features a wider range of audio codecs and low latency, which provides better audio quality for real-time communications such as voice and video calls. VoNR achieves low latency by using a simplified signal transmission process and a faster handoff procedure between different network cells. Voice over NR also supports other advanced features such as multimedia services, video calling, and provides integration with other 5G services such as augmented and virtual reality. In addition, VoNR technology allows operators to offer voice services over a standalone 5G network, meaning that users can make voice calls even when they do not have access to a 4G network [13].

Fifth-generation networks have the ability to handle more simultaneous voice calls due to increased network capacity. 5G networks use higher frequency bands than previous generations of networks, which allows more data to be transmitted at higher speeds. The increased bandwidth means that the network can support more voice calls without being overloaded, resulting in a smoother and more reliable voice experience. In addition, 5G networks use advanced technologies such as beamforming and massive MIMO (multiple input, multiple output) to further increase network capacity. These technologies allow the network to focus data transmission on specific devices, which helps reduce interference and improve signal quality. As a result, more voice calls can be supported simultaneously in high-traffic areas such as airports and stadiums, where many people are likely to make calls at the same time. In addition, the introduction of 5G networks with standalone (SA) architecture enables even more simultaneous voice calls. In previous generations of mobile networks, voice calls were carried over a circuit-switched network that had limited bandwidth. However, in 5G SA networks, voice calls are made over an IP (Internet Protocol) network, which has much higher bandwidth and can support many more simultaneous voice calls [14].

5G networks are designed to be more reliable than previous generations of mobile networks, which can lead to fewer dropped calls and improved overall call quality, especially in areas with poor network coverage. There are various ways in which 5G networks achieve this increased reliability, including Redundancy (redundancy makes 5G networks more resilient to network failures and ensures that users will experience fewer dropped calls), Network slicing (allows the network to be divided into virtual networks optimised for specific use cases), Low latency (low latency can improve overall call quality, especially for voice calls, as there is less delay between when a person speaks and when the other person hears them), Advanced features (advanced features help improve network coverage and reduce interference, resulting in more reliable connectivity and better overall call quality).

III. CONCLUTION

Studies have shown that 5G networks can significantly improve the quality of voice services compared to previous mobile technologies such as 4G and 3G. This is possible due to the broadband capabilities of 5G networks, improved data transmission, low latency, use of an advanced EVS codec and reduced response time. However, certain factors, such as network coverage, optimisation level and traffic characteristics, can affect the quality of voice services and require additional attention when planning and deploying 5G networks. The QoS management architecture consists of QoS flows, which allow separating packet assignment to flows (managed by the CN) from the assignment of DRB flows (managed by the RAN). As 5G networks are being rolled out gradually, it is important to properly integrate the 5G domain into the existing telecoms provider's network. The transition from Non-Standalone to Dual connectivity is a necessary step for the implementation of VoNR technology in Standalone mode. Using the modern EVS codec allows not only to improve the customer experience, but also to introduce new voice services.

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Можливості покращення якості голосових послуг у мережах 5G

Проблематика. Впровадження мереж п'ятого покоління (5G) створює нові можливості для швидкого та безперервного обміну даними, але все ще існують певні проблеми з якістю голосових послуг у таких мережах. Зі стрімким розвитком технологій та подальшим поширенням 5G виникає потреба зрозуміти вплив ключових аспектів 5G на якість голосового зв'язку. Це вимагає проведення досліджень, які можуть систематично аналізувати особливості мереж 5G, що впливають на якість голосових послуг.

Мета досліджень. Визначення шляхів покращення якості голосових послуг у мережах 5G. Оцінка ключових показників якості надання голосового сервісу у мережах 5G. Визначення оптимального варіанту поступового переходу до режиму Standalone та використання технології VoNR у мережах п'ятого покоління.

Методика реалізації. Аналіз факторів, що впливають на якість надання голосових послуг у мережах п'ятого покоління. Аналіз відомих публікацій, присвячених впровадженню мереж 5G. Проведення порівняння реалізації режимів Non-Standalone та Standalone у мережі 5G. Тестування сучасного кодеку EVS, що надає можливість покращити клієнтський досвід.

Результати досліджень. Підтверджено, що мережі 5G можуть значно покращити якість надання голосових послуг порівняно з попередніми технологіями мобільного зв'язку, такими як 4G і 3G. Виявлено певні фактори, що можуть впливати на якість голосових послуг та потребують додаткової уваги при плануванні та розгортанні мереж 5G. Встановлено оптимальнікроки для переходу до до режиму Standalone та використання технології VoNR у мережах п'ятого покоління. Визначено основні відмінності у архітектурі QoS між LTE та 5G, а також встановлено призначення потоків DRB для розділення типів трафіку та сервісів.

Висновки. Підтверджено, що мережі 5G можуть значно покращити якість надання голосових послуг порівняно з попередніми технологіями, такими як 4G і 3G. Це стало можливим завдяки широкосмуговим можливостям мереж 5G, покращеній передачі даних, низькій затримці, використанню передового кодеку EVS та зменшенню часу відповіді (latency). Однак, певні фактори, такі як: територіальне покриття мережі, рівень оптимізації та особливості трафіку, можуть впливати на якість голосових послуг і потребують додаткової уваги при плануванні та розгортанні мереж 5G. Архітектура управління QoS складається з потоків (QoS flows), які дозволяють відокремити призначення пакетів потокам (керованим CN) від призначення потоків DRB (за які відповідає RAN). Оскільки впровадження мереж 5G відбувається поступово, то важливо коректно інтегрувати домен 5G в діючу мережу постачальника телекомунікаційних послуг. Перехід від режиму Non-Standalone до Dual connectivity це необхідний етап для впровадження технології VoNR у режимі Standalone. Завдяки використанню сучасного кодеку EVS, з'являється не тільки можливість покращити клієнтський досвід, але й впроваджувати нові послуги голосового зв'язку.

Ключові слова: *5G; голосовий сервіс; QoS; VoLTE; CSCF; EPS FB; NSA; затримка; VoNR; 5QI; RAN; RRC; кодек; EVS.*