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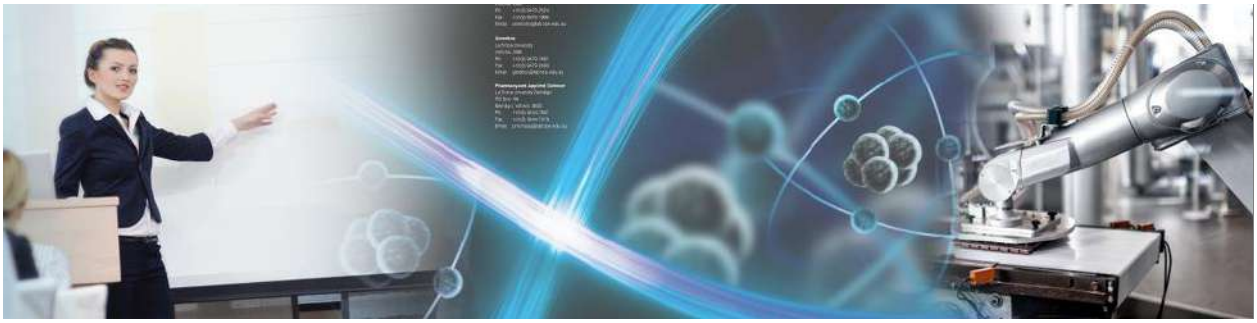

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ВИРОБНИЦТВО
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ЗМІСТ

Critical review of GSM network structure

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Anotation: In world where technology is changing at speed of light, GSM remains unchanging foundation of mobile communications. The study dives into heart of system, revealing its "anatomy and physiology". Each component of GSM, from Mobile Station to Operation Support System, is studied in detail, showing how coordinated work of all parts allows billions of people to communicate over distance. This work not only reveals mechanisms of GSM, but also looks boldly into future. It outlines problems that this technology faces in whirlwind of modern innovation and proposes solutions for its adaptation. The study lifts veil on challenges facing GSM in world of 5G and IoT and inspires us to find ways to harmoniously coexist past and future in telecommunications. This review is compass for those who want to understand how to keep legacy systems relevant in world that is constantly moving forward. The paper suggests that we think about how we can modernize time-tested technology without losing its reliability and versatility.

***Key words*:** GSM, network architecture, advantages, limitations, challenges, modernization.

I. INTRODUCTION

The Global System for Mobile Communications (GSM) remains one of most widely used cellular technologies in world [1-4]. Despite rapid development of newer standards, such as 4G and 5G, GSM networks continue to play critical role in providing basic communications, especially in regions where introduction of newer technologies is not yet complete. At same time, automation, robotization, and digitalization are rapidly evolving [5-14]. This development naturally affects evolution of GSM technologies, improving network management, increasing its efficiency and reliability. These innovations allow for more accurate monitoring and maintenance of network, as well as reducing human factor in operation process.

The relevance of GSM network structure critical review is driven by several factors:

- GSM still covers significant portion of world's population, especially in developing countries;
- time-tested GSM architecture provides stable communication in variety of environments;
- understanding GSM structure is important for development of hybrid systems that combine GSM with newer standards;
- GSM remains cost-effective solution for many operators and users;
- GSM continues to play important role in Internet of Things development and machine-to-machine communication.

The purpose of this paper is to conduct detailed analysis of key components of GSM network, and to do so, we need to:

- assess how GSM structure meets current requirements of telecommunications industry;
- consider problems of GSM compatibility with latest technologies.

II. GENERAL ARCHITECTURE OF GSM NETWORK

GSM is one of the most widely used standards for mobile communications, which provides voice and data transmission in mobile networks [1-4]. The GSM architecture consists of several main components and is based on clearly defined principles of operation that ensure its efficiency and reliability. Therefore, this paper discusses main components (Table 1) and principles of operation.

Table 1. Main components of GSM

GSM components	Composition
Mobile Station (MS)	It is end device that subscribers use to make calls and transfer data. The MS includes cell phone or other mobile device, as well as SIM card that stores subscriber information and provides access to network.
Base Station Subsystem (BSS)	This is component responsible for direct connection to mobile devices. The BSS includes Base Transceiver Stations (BTS), which provide radio communication, and Base Station Controllers (BSC), which manage radio channel resources and transmit information between BTS and networks.
Network Switching Subsystem (NSS)	For routing calls and data in GSM network. It includes Mobile Switching Center (MSC), which processes calls, messages, and manages mobile stations. The NSS also contains Home Location Register (HLR) and Visitor Location Register (VLR) that store information about subscribers and their locations.
Operation Support System (OSS)	It is support system that is responsible for monitoring, managing, and maintaining entire network. OSS provides resource management, error handling, and technical support to ensure smooth operation of network.

The diagram of main components of GSM network is shown in Figure 1.

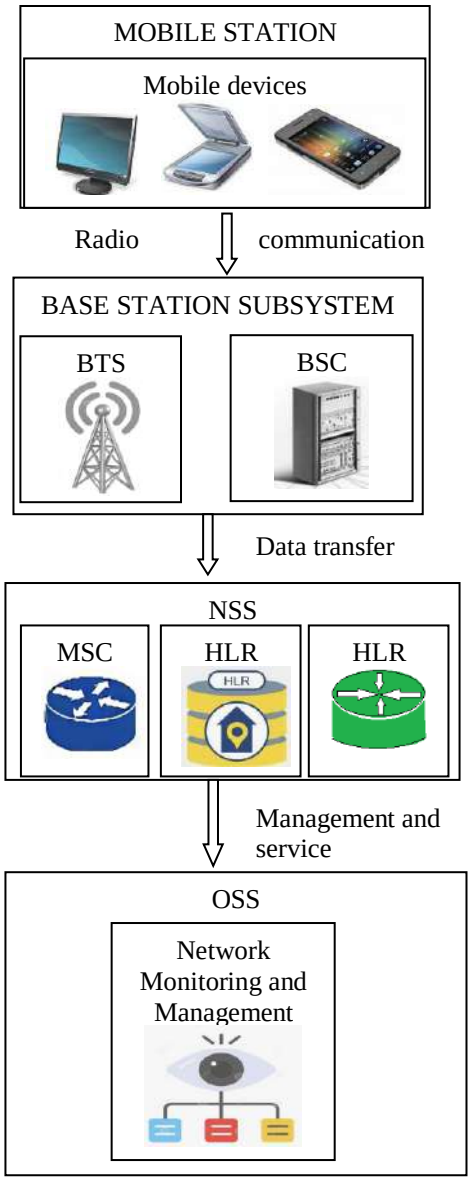

Fig. 1. Diagram of main components of GSM network

The principles of operation are as follows:

1. Resource allocation. GSM uses frequency division multiplexing technology to distribute radio frequencies among several subscribers. Each channel is time division multiple access (TDMA), which allows multiple subscribers to use same frequency without interference.

2. Network segmentation. GSM architecture distributes control and data transmission functions among different network components. This ensures modularity and scalability of system, which makes it easy to integrate new components and functions.

3. Authentication and security. GSM implements mechanisms for subscriber authentication and data encryption to protect against unauthorized access and ensure confidentiality.

4. Roaming. GSM network supports roaming, which allows subscribers to use their mobile devices in other GSM networks around world without having to change their SIM card.

Critical review of structural aspects of GSM network provides comprehensive analysis of this fundamental mobile communications technology. It provides in-depth understanding of GSM architecture and operating principles, identifying both its strengths and limitations in context of today's requirements.

III. CRITICAL REVIEW OF GSM NETWORK STRUCTURAL ASPECTS

Despite its long existence and advanced architecture, GSM has both advantages and limitations that affect its efficiency and ability to adapt to modern requirements.

The advantages of GSM architecture are shown in Table 2.

Table 2. Advantages of GSM

Advantages	Description
Reliability and stability	The system was designed to provide high level of availability and uninterrupted communication, making it highly resistant to failures and technical problems.
Wide coverage and accessibility	GSM has huge coverage around world, providing access to mobile communications even in remote and rural areas. This is made possible by extensive network of base stations and roaming support.
Distribution of functions and modularity	GSM architecture distributes control and data transmission functions among different components (MS, BSS, NSS), which ensures scalability and flexibility of system. This facilitates integration of new components and technologies.
Support for roaming	GSM ensures uninterrupted operation of subscribers in different networks thanks to roaming support. This allows users to use their mobile devices outside their home network without having to change their SIM card.
Authentication and security	The system implements mechanisms for subscriber authentication and data encryption, which ensures high level of security and protection against unauthorized access.

Although GSM architecture has numerous advantages that ensure reliable and stable mobile communications, it is not flawless. The system has certain limitations that can affect its efficiency and ability to meet modern user requirements. The following section will discuss main limitations of GSM architecture to help understand which aspects need to be improved and enhanced.

One of the main limitations of GSM is limited data transfer speed, which does not meet requirements of modern users who need high-speed Internet and large amounts of data. GSM provides only basic data transmission speeds, which limits ability to use modern applications and services.

As example, GSM provides low data rates (up to 9,6 kbps for standard channel), making it difficult or even impossible to watch high quality video without delays and buffering. This limits possibilities for video

streaming services such as YouTube or Netflix, which require faster internet connection.

Another limitation is inability to adapt to latest standards. While GSM is effective in providing basic mobile communications, it has limited ability to integrate with new technologies such as 4G and 5G. This creates difficulties in transitioning to new standards and implementing modern features.

Other limitations include fact that GSM networks tend to consume more energy than latest communication technologies, which can lead to high energy costs and affect environmental friendliness of system.

The GSM architecture may have compatibility issues with new technical solutions and devices using other communication standards. This can create additional costs for modernization and integration.

The cost of supporting and maintaining GSM network can be significant, especially when it comes to upgrading equipment and integrating with new technologies.

Therefore, an analysis of advantages and limitations of GSM architecture allows us to understand which aspects of this technology remain strong and which challenges need to be addressed in context of mobile communications rapid development.

IV. PROBLEMS OF COMPATIBILITY WITH LATEST TECHNOLOGIES

The GSM architecture, despite its widespread adoption and reliability, faces compatibility issues with latest mobile technologies. The development of new standards, such as 3G, 4G (LTE) and 5G, creates challenges for integration and adaptation of GSM in modern networks (Fig. 2).

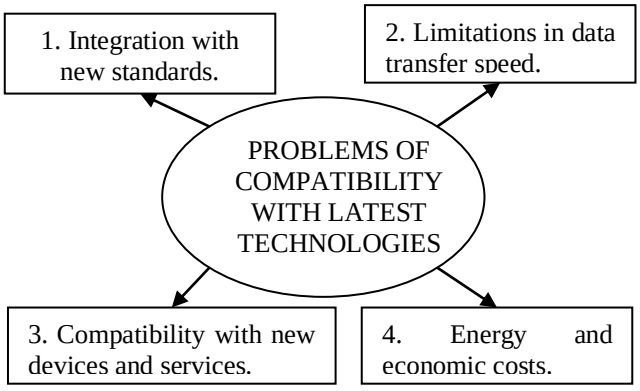

Fig. 2. Diagram of existing problems of GSM compatibility with latest technologies

1. GSM was developed in era when need for mobile communications was lower. Newer standards such as 3G, 4G and 5G offer significantly higher data rates and new functionalities such as support for high-speed Internet and modern mobile applications. Integrating GSM with these new technologies requires sophisticated solutions to ensure interoperability between different standards.

To address GSM compatibility with new standards such as 3G, 4G and 5G, comprehensive approach is needed, including modernization of existing infrastructure, integration of new components and protocols, and software interoperability. This may involve installing specialized gateways and controllers that allow different standards to interoperate, upgrading base stations and network elements to support new frequency bands and data rates, and implementing new technologies such as network virtualization and software-defined networking (SDN) to facilitate integration and management of multi-standard environments.

Comparative analysis with other technologies. Detailed comparison of GSM with 3G, 4G and 5G in Table 3.

Table 3. Comparison of GSM with 3G, 4G and 5G

Characteristics	GSM (2G)	3G	4G	5G
Data transfer rate	Up to 384 Kbps	Up to 42 Mbps	Up to 1 Gbps	Up to 20 Gbps
Delay	300-1000 ms	100-500 ms	20-30 ms	< 1 ms
Frequency range	900/1800 MHz	850/900/1900/2100 MHz	700/1700/2500 MHz	600 MHz – 71 GHz
Basic technology	TDMA / FDMA	CDMA	OFDMA	OFDMA/ MIMO
Channel width	200 kHz	5 MHz	20 MHz	Up to 100 MHz
Main application	Voice communication, SMS	Internet, video calls	High-speed internet	IoT, AR/VR, autonomous vehicles
Network capacity	Low	Medium	High	Ultra-high
Energy efficiency	Low	Medium	High	Ultra-high
Security	Basic	Improved	Advanced	Reinforced
IoT support	Limited	Basic	Extended	Full-scale

A comparative analysis of GSM, 3G, 4G and 5G technologies illustrates evolution of mobile communications, reflecting significant advances in data rates, latency reduction and functionality. From basic voice communications in GSM to support for sophisticated applications like IoT and AR/VR in 5G, each generation has significantly expanded capabilities of mobile networks. Technological advances in data transmission methods, expanded frequency bands, and increased energy efficiency have been accompanied by enhanced security measures and increased network capacity. This comparison not only illustrates current state of mobile technologies, but also helps to understand GSM compatibility issues with modern requirements, substantiates need for network modernization and allows forecasting future trends in telecommunications development.

2. GSM provides slow data rates compared to newer technologies such as 4G and 5G. This can lead to

problems when trying to integrate GSM with networks that support high-speed Internet.

To address slow data rates of GSM when integrating with 4G and 5G networks, hybrid solutions such as upgrading equipment to 4G/5G standards, using gateways for interoperability, and implementing channel aggregation technologies to increase speeds are needed.

3. The latest mobile devices designed to work with 4G and 5G may have compatibility issues with GSM networks, especially if these devices use new technologies that are not supported by older networks.

To solve problem of latest devices compatibility with GSM, it is necessary to provide backward compatibility through adapters or modems that support older standards, or to integrate multi-standard modules that can work with different technologies.

4. Increasing demands on data transfer speeds and volumes can increase energy costs, which can be problematic for older networks that were not designed to meet modern requirements.

To address problem of increasing energy costs, energy-efficient technologies should be implemented, equipment should be modernized to reduce energy consumption, and network infrastructure should be optimized to reduce load.

V. CONCLUSIONS

Therefore, paper is devoted to GSM network structure critical review in context of current technological challenges. This study presents main components of GSM: Mobile Station, Base Station Subsystem, Network Switching Subsystem, Operation Support System. The principles of GSM functioning are described, including resource allocation, network segmentation, authentication and security, roaming. The advantages of using GSM are determined. The limitations of GSM application are identified. The problems of compatibility with latest technologies are analyzed. Some solutions to overcome compatibility problems are proposed. The presented work helps to understand current state of GSM technology and identifies challenges faced by GSM in modern telecommunications environment. Thus, this review outlines directions for further development and adaptation of GSM to new technologies. A comparative analysis of GSM, 3G, 4G and 5G technologies has been carried out. Such analysis is important for telecom operators, technology developers, providing basis for making decisions on infrastructure development, investments and research directions in the field of mobile communications. Overall, paper provides comprehensive analysis of GSM technology, highlighting its strengths and limitations in context of modern telecommunications needs. This study is important for understanding ways to modernize and integrate GSM with latest mobile technologies.

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