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Development Directions and Perspectives of Modern Telecommunications Systems

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Abstract. *In recent years, artificial intelligence technologies have demonstrated significant success in solving a number of tasks in various telecommunications systems. The application of artificial intelligence for predicting the load of telecommunications networks and modeling their future development allows for timely decision-making and improving the quality of service for subscribers. The article reveals the essence, nature, and characteristics of artificial intelligence technologies, presenting the results of substantiating and systematizing the trends in the development of artificial intelligence and its application areas in the field of telecommunications systems. It also highlights the main directions of development of generative artificial intelligence and the key areas of its application in the globalizing world. The article also outlines the tasks for applying artificial intelligence in telecommunications systems in the Republic of Azerbaijan. In the field of telecommunications, artificial intelligence approaches are briefly outlined, traditional methods and modern approaches are compared, and how they are applied in wireless communication is discussed. These methods include fuzzy logic, neural networks, reinforcement learning, and artificial intelligence techniques used in mobile communication. Some key and terminological issues are addressed, and it is explained how these issues will contribute to the stable operation of 5G and 6G mobile networks in the future, as well as the provision of various services through numerous mobile devices and data. An analysis of artificial intelligence methods used to improve the performance of mobile communication has been conducted.*

Keywords: *Artificial Intelligence, mobile communication, neural network, complex network, resource, mobile traffic*

Introduction

Artificial Intelligence (AI) is one of the methods for adapting the human brain or thought processes, the activities of other animals, biological systems, and species. In particular, artificial intelligence plays a significant role in mobile communication systems and is a promising approach for optimizing their productivity. Overall, artificial intelligence methods make substantial contributions to mobile communication through dynamic adaptation to the environment. Currently, the transition from traditional exploitation and management methods of complex network infrastructure to an intellectual approach is essential for increasing efficiency and scalability (Artvel, 2020).

Next-generation wireless networks are more complex and require more resources due to the increasing service demands of various devices, complex networks, and diverse applications. Additionally, network engineers must optimize systems and provide accessible resources to improve service quality. Artificial intelligence is aimed at creating an adaptive system that ensures better performance of both the system and the environment.

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With the advent of big data, a larger and more extensive dataset derived from mobile and wireless systems emerges. In other words, artificial intelligence applied to mobile communications will enhance the effectiveness of communication systems, increase productivity, and improve key performance indicators (KPI). As the network infrastructure and the hardware of mobile devices and their applications grow, the demand for mobile stations, as well as mobile traffic and the volume of processed data, will also rise (Zyuzin, 2023).

Research

Main Section. Approaches and Applications of Artificial Intelligence in Mobile Communications . Artificial Intelligence (AI) has several classical approaches, such as uncertainty and neural networks. Subsequently, the neural network will be expanded with more effective methods, such as machine learning and deep learning approaches. Machine learning is the process where systems analyze data and learn to make accurate predictions based on that data. The primary approach is uncertainty, where various values are processed to obtain correct and incorrect results. The second term is *learning through refinement*, which involves designing a computer or machine to learn on its own without precise programming (Bolyapkin, 2021). One of these methods is neural networks. Neural networks are used to process data, recognize patterns, and learn. For example, they are widely used in tasks such as image recognition, speech command understanding, and text interpretation. This technique allows problem-solving using a computer or machine with the ability to learn by itself. This process is based on mimicking the system and behaviors of the human brain. Currently, deep learning, as an advanced form of machine learning, is very popular. Deep learning is an interesting approach for managing mobile network traffic and future mobile communications. Two main types of learning are used in artificial intelligence in mobile communications: supervised learning and unsupervised learning (Borisova, 2019).

Decision Making in Mobile Communications. In mobile communications, when artificial intelligence makes decisions, not only the quantity but also the quality of the experience for various types of services should be considered. To achieve this, by using neural networks, the key indicators of mobile internet are combined and classified. That is, the indicators are analyzed and classified in a qualitative manner. In general, the artificial intelligence “assistant” used in content search offers a personalized content search service with a quality experience, which is divided into two types: 1. To accurately capture users' interests and experiences; 2. The process of accessing availability and appropriate recommendations.

Data analysis, machine learning, and artificial intelligence methods can be used in analog, digital, and hybrid beamforming techniques for creating optimal directional diagrams, dynamically selecting the most suitable beam, and performing beam management operations (Kolesnikov, 2020).

Resource Optimization in Mobile Communications. For resource optimization, numerous mobile-specific networks have utilized multi-addressed branching algorithms. Additional objectives for this optimization include minimizing handover delay and improving energy efficiency. Furthermore, neural networks and various methods are applied in solving the task of reducing PAPR (Peak-to-Average Power Ratio). This is used for online learning. One of the key components for enhancing the efficiency of OFDM (Orthogonal Frequency Division Multiplexing) channel estimation can be solved using artificial intelligence methods (Boychenko, 2020).

The cognitive radio system is discussed, where several secondary users work together to ensure proper spectrum allocation and attempt to achieve efficient and reliable spectrum access. Additionally, artificial intelligence methods are proposed for eliminating inter-cell interference between independent networks, which can negatively affect the performance of wired communication users in mobile networks. Existing artificial intelligence algorithms enhance performance in

peripheral computing by integrating Graphics Processing Units (GPU) and Central Processing Units (CPU) (Kuzovkova, 2021). The application of artificial intelligence for mobile communications is related to complex statistical methods, taking into account devices, infrastructure, end users, technologies, and other resources.

Network Management in Mobile Communications. An example of applications for network management in wireless communications can be seen in routing within the communication section. Artificial intelligence has already been applied in some studies on this topic. For instance, both the self-tuning and self-optimization of radio resources and routing are handled using neural networks (Muzata, 2021). Muzata, in other studies, machine learning methods have been used to solve various routing problems from the past. These include routing based on the shortest path, adaptive routing, and multicast routing.

Another method of network management in wireless communication networks is the monitoring of network activities and the detection of anomalies (such as unusual activities, for example, viruses), meaning events that deviate from the network's normal behavior. Artificial intelligence has also been used for traffic forecasting in communication networks (Rustamov, 2023). Artificial intelligence technologies can minimize interventions in traditional network traffic management and ensure greater network reliability, more adaptive systems, and higher performance. Other Applications of Artificial Intelligence. In general, the artificial intelligence methods applied in mobile communications can be seen in table 1. (Volodina, 2023).

Table 1

Mobile Communication Technology	**Applications of Artificial Intelligence**
Autonomous vehicles and medical assistance devices	- Automation and its associated artificial intelligence. - Modern and core algorithms in the specific field of artificial intelligence for autonomous vehicles. Such systems are particularly suitable for high-level decision-making, as they inherently need to perceive the environment and respond to it to achieve certain objectives.
Internet of smart devices	Network solutions for utilizing the artificial intelligence methods used to create such intelligence and the benefits provided by this capability.
Mobile cloud computing	Applications with high resource demands, such as augmented reality, artificial intelligence, computer vision, object tracking, image processing, and natural language processing, are becoming increasingly popular in the management of mobile cloud computing systems.
5G Network	Artificial intelligence and its subcategories, such as machine learning and deep learning, are developing as a scientific field, enabling these mechanisms to be predictive and proactive in fifth-generation (5G) wireless networks, which is of great importance for the implementation of the 5G concept.
Wireless sensor networks	- Artificial intelligence tools are used to assist in intellectual radio channels. The tool known as machine learning is considered an important means in solving the aforementioned problem.

	- Machine learning methods for localization using the signal level indicator received in WSNS.
Mobile heterogeneous networks (HetNets) (networks that integrate various types of technologies, devices, or network protocols)	Machine learning, algorithms based on biological structures, abstract neural networks, etc., as artificial intelligence methods, can naturally solve the problems of large-scale complex systems.
Detection of covert communications in mobile malware	Artificial intelligence tools, such as neural networks and decision trees, are used as two detection methods to identify malicious programs exchanging data.
Mobile and wireless networks	Deep Learning
Vehicle mobile networks	Cache boundaries based on artificial intelligence
Next-Generation wireless networks	- Machine learning, artificial neural networks. - Big data analytics to analyze user activity and detect user anomalies (a situation that deviates from normal patterns).
Mobile multimedia	Deep learning has become the most important technology for multimedia computing.
Wi-Fi-based indoor positioning system	Artificial neural networks
Cognitive radio networks. These networks provide significant advantages, especially in environments where the spectrum is congested and resources are limited.	The development of cognitive routing protocols refers to routing protocols that are intended to fully incorporate artificial intelligence-based methods in their own development.
Artificial intelligence and data science for communication	Artificial intelligence, machine learning, and innovations in network data analysis present significant opportunities to revolutionize global communication systems and enhance user experience.
Mobile Network Systems	The concept of artificial intelligence and its application in the design, operation, and optimization of mobile networks.

Challenges of Artificial Intelligence in Mobile Communications. The challenges of artificial intelligence in mobile communications are based on various technical and practical issues. These problems arise from the integration of (Zyuzin, 2020). AI development and applications into mobile communication systems:

- The data used in mobile communication networks is often inaccurate. This makes it difficult for AI models to operate correctly. Additionally, the diversity of data types and formats across the network (e.g., voice, video, IoT data, etc.) creates further challenges for AI applications (Rustamov, 2025).

- Implementing AI requires powerful computational resources, especially in areas such as deep learning and machine learning. The limited computational power and energy capacity of mobile devices make it difficult for such systems to function effectively.

- AI applications in mobile communication networks require real-time data processing and response. However, network latency, long data processing times, or connection interruptions can prevent these processes from functioning properly.

- Privacy concerns become even more critical when using AI in mobile communication systems. The data used by AI, particularly users' personal information, can potentially be leaked or manipulated.

- Mobile communication networks collect large volumes of data. Effectively analyzing this data and converting it into useful insights can be challenging. Additionally, the quantity and diversity of the data can complicate the model's learning process.

- The simultaneous sharing of the same frequency channel by numerous users in mobile communication networks can create additional problems for AI systems. In particular, network congestion and interference can make it difficult for AI applications to function properly (Klausman, 2017).

The application of artificial intelligence in mobile communications offers a wide range of possibilities, from network optimization to enhancing user experience. However, resolving the challenges outlined above is crucial for this technology to function effectively and sustainably. With further development of artificial intelligence and mobile communication technologies, these issues can be addressed over time.

Artificial intelligence will play a key role in the management of big data, advanced data analytics, and the organization of various communication devices in future mobile or wireless networks (Rustamov, 2025). On the other hand, it is essential for the mobile communication infrastructure to be adaptable to different services, efficient, and reliable. This means that it should help increase the productivity of mobile broadband communication, minimize the peak-to-average power ratio (PAPR), improve quality through multiple access methods (Orthogonal Frequency-Division Multiplexing, OFDM), and enhance overall communication quality (Volodina, 2023).

Other challenges of artificial intelligence in mobile communication systems include decision-making, network management, and resource optimization. As for mobile intelligent communication, it is characterized by a proactive system, self-management, self-regulation, forecasting, and economic efficiency. Another important aspect of mobile communication is the application of artificial intelligence in wireless communication for various scenarios, such as energy management, radio frequency management, mobile communication, and interference management (Rustamov, 2024).

Conclusion

Artificial intelligence plays a significant role in enhancing the performance of mobile communication systems: predictive systems, self-awareness, self-adaptation, forecasting, efficiency, and optimization. Several classical artificial intelligence methods and modern approaches are reviewed and analyzed for their applications in the mobile communication field. These methods include uncertainty logic, neural networks, reinforcement learning, and some artificial intelligence techniques applied in mobile communication. Some key challenges between artificial intelligence and future mobile communication, such as big data, how to manage data through exploration, ensuring transmission at higher frequencies, communication between devices, reliable architecture, high-density networks, and 3D beamforming, are addressed. These challenges are related to the existing difficulties of 5G fifth-generation technologies. The issues of how 6G mobile networks will be used in the provision of stable networks and service types are brought to the forefront.

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