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# Artificial intelligence in mobile communication: A Survey

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**Abstract.** In this paper, we elaborate on artificial intelligence (AI) techniques used to improve the performance of mobile communication. This article describes brief AI approaches in mobile communication, several classics AI techniques, and the current AI approaches in wireless communication. The techniques contain fuzzy logic, neural networks, reinforcement learning, and AI techniques implemented on mobile communication. Some keys or terms challenges between AI and future mobile communication, not only 5G generation issues but also how the sixth generation (6G) of mobile networks will be driven to give stable networks and service types on huge mobile devices and data.

*Keywords—Mobile communication, 5G generation, 6G Generation, MIMO, Edge Computing*

## 1. Introduction

Artificial Intelligence (AI) is one of the techniques to adopt the human brain or thinking [1], others act of animals [2], [3], biological systems, and species [4]. Especially, AI in the mobile communication system has an essential role, promising way to optimize its performance. In the general issue, AI techniques significantly contribute to the dynamic adaptation of mobile communication in an environment. Currently, the complicated network infrastructure needs to migrate from the traditional operation and management methods to the intelligence approach to reduce inefficient and expansiveness [5].

The next generation of wireless networks is more complex and needs more resources because of the need to improve a service requirement with various devices, complex networks, and various applications [6]. Furthermore, the network programmers must adapt their system to give the best and available resources to increase the service quality. Furthermore, In 2021, the industry forecasts that the IP traffic consumption will reach 3.3 zettabytes (1015 MB), and the smartphone traffic would outpacing PC traffic in the same year [7]. AI presents to build an adaptive system, providing a system and the environment better in performance. This big data era causes the increasingly massive datasets available from a mobile or wireless systems. In other words, applied AI on mobile communication will ensure communication systems are more efficient, better in performance, and increase key performance indicators (KPIs) [6], [8].

The increasing network infrastructure and hardware uptakes of mobile devices and their application will increase the need for mobile stations or exploding mobile traffic volumes and huge data to be processed. Zhang et al. [7] said that one of the important solutions is implementing advanced artificial intelligence techniques, such as machine learning and deep learning in mobile communication, to manage base stations' huge data and performance to provide full mobile stations.

Some researchers have elaborated AI approaches in wireless or mobile communications. Kibria et al. [6] discuss the relationship between data analytics and AI for wireless networks to be intelligent. Furthermore,

Zhang et al. [7] draw a review deep learning approach in mobile and wireless networking research, and Cayamcela and Lim [9] explore the AI approaches for 5G mobile and wireless communications technology. However, these surveys failed to elaborate on various AI approaches in mobile communication occasionally.

This paper aims to introduce Artificial Intelligence in a basic term to advance viewed and applied AI on the infrastructure, mobile management, security management, and software spectrum. We organize this paper into several sections. In section II, we discuss the challenges of artificial intelligence (AI) in mobile communication. In section III, we describe AI approaches and mobile communication applications, while the problem in mobile communication will be discussed in section IV. In the last section, we overview the AI applications in mobile communication.

## 2. Challenges of Artificial Intelligence in Mobile Communication

Artificial intelligence will have an essential role in managing big data as advanced data analytics and organizing various communication devices in the future of mobile or wireless networks. In short, Xhang et al. [6] stated that the mobile intelligence system should be self-adaptive, self-aware, proactive, and prescriptive. On the other hand, The infrastructure of mobile communication needs to be adaptive to diversified services and efficient and reliable, such as improving the performance of mobile broadband, minimize the peak-to-average power ratio (PAPR) [10], improving orthogonal frequency division multiple access (OFDM) [5], improved link quality [11].

In the 5G mobile communication system, the challenges will be appeared because of the huge nodes and mobile devices with fast data interchange and communication [5]. It was explained by Kibria et al. [6], who have overviewed data analytics, Machine learning, and AI in network communication. It supposed that the network management was and would be more complex within the new mobile communication generation network. Banupriya et al. [12] forecast that the traffic will rise to 1000 times in 5G mobile communication according to mobile end-user data speed and growth. Hence, traditional network management and techniques are not supported in the next generation of mobile communication [12]. Next, the traffic control issues are still open to topic research because the previous researchers still focused on the core network issue on the network layer side, such as applied AI on the routing problem [13]. However, few AI techniques are used for traffic control according to user experienced recommendations on the application and the semantic layers. Another challenge is how to apply AI to the next-generation mobile communication system. For example, in 5G, there are three types of challenges as hoe to provide broadband multimedia based on user experiences (enhanced mobile broadband(eMBB)), tactile internet application (ultra-reliable low latency service (URLLC)), and how to connect the amount of mobile device with real-time interconnection (Massive machine-type communications (mMTC)) [12].

The other AI challenges in the mobile communication system are decision making, network management, and resource optimization [8] with faced to mobile intelligent communication with has characterized proactive system, self-aware, self-adaptive, predictive, efficient, and cost-effective operation and optimization [6], [8]. Another essential in mobile communication is how AI can be applied to various wireless communication scenarios such as power control, radio resource management, mobile management, and interference management [12]. The evolution of mobile communication networks, from the 1$^{st}$ generation to the 6$^{th}$ generation, has been reported [10].

## 3. AI Approach and Application in Mobile Communication

There are some classic artificial intelligence approaches, such as fuzzy logic and neural network. Then, the neural network would be extended to be better performance techniques such as machine learning and deep learning approaches. The basic approach is Fuzzy logic, which is processed any values and resulting in true and false. Another term in AI is reinforcement learning, a technique to design a computer or machine for learning by itself instead of being precisely programmed [12]. One of the techniques is Neural networks (NN). This technique can be made by a machine or computer able to self-learning to solve a problem. NN process adopts the brain human system and behavior. In the current issues, also deep learning (DL) has been popular as an improved machine learning (ML). ML and DL are interesting approaches for advanced network traffic and management of future mobile communication. The two types of AI learning have been used in mobile communication: supervised learning and unsupervised learning.

### 3.1. Decision making in Mobile Communication

An AI decision making in mobile communication has been reported by several researchers such as Banupriya et al. [12], estimate QoE (Quality of Experience) for different types of services by using neural network approach, and also NN for classifying the KPIs, which is bridge a KPI's with QoE in mobile internet services.

AI assistant content retrieval on QoE. Fu et al. propose QoE of a personalized content retrieval service that is divided into two sections: 1) accurate to catch the user interest and experiences, and 2) The process to access convenience and suitable recommendation [13]. Data analytics, ML, and AI techniques can be used in analog, digital, and hybrid beamforming to generate the optimal beam patterns, dynamically selecting the most suitable beam, and performing the beam-steering operation [6].

To strengthen the evidence on research trends regarding "decision making" in mobile communication, data from scopus.com was used with a total of 188 articles. The keywords of the articles were analyzed based on using the VOSViewer application. The type of analysis used is co-occurrence with the author-to-words analysis unit. The minimum number of occurrences of a keyword is 2 of the 625 keywords, 82 meet the threshold. From Figure 1, it can be seen the analysis of the relationship between variable keywords, the circle shows the number of keywords used, the color shows the renewal of the keywords, and the line shows the relationship of the keywords.
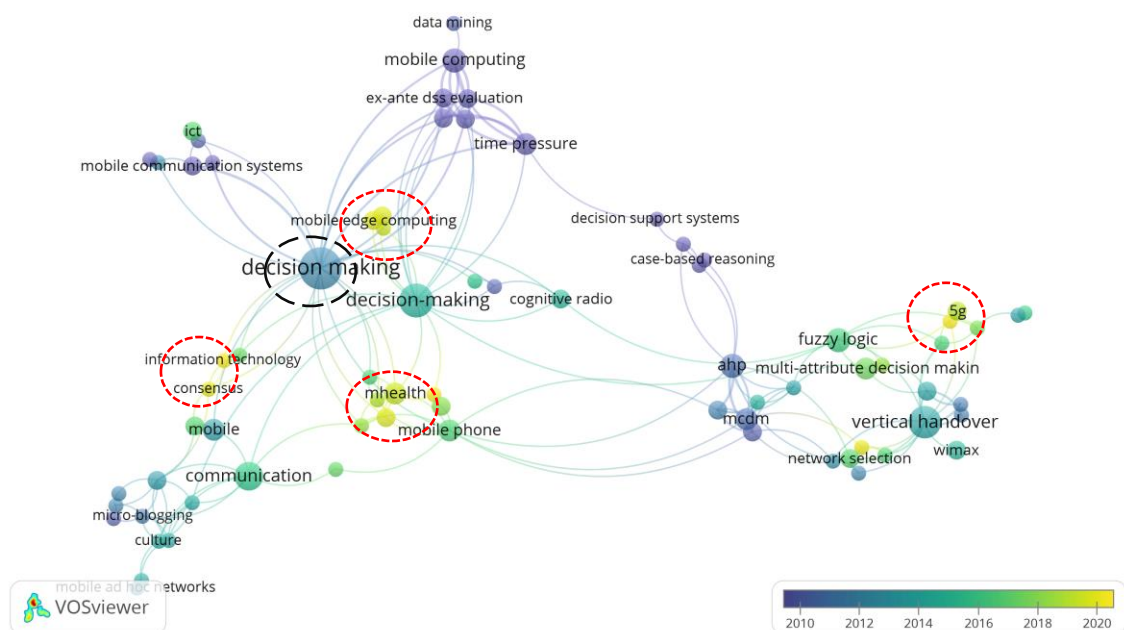


Figure 1. Overlay visualization keywords on Decision making in Mobile Communication

The "decision making" keyword becomes a motor theme that has a relationship with other keywords. Future research needs to pay attention to the aspect of the relationship between the keyword "Decision making" in Mobile Communication and the keywords circled in red with the keyword dot color in yellow. The brighter the dot color on keywords indicates the renewal of the keyword trend based on the article year..

### 3.2.  Resource optimization in Mobile Communication

In resource optimization, Genetic algorithms have been used to optimize the construction of multicast trees mobile ad hoc networks. Additional objectives such as bounded end-to-end delay and energy efficiency are added to this optimization [9], [14].  Another research is neural networks and set-theoretic method used PAPR reduction problem which is used for online learning. A key ingredient in enhancing the efficiency of OFDM channel estimation can also be solved by Artificial intelligence techniques [14].

Considers a cognitive radio system with cooperative spectrum sensing where multiple secondary users cooperate in obtaining robust spectrum sensing results. To enable efficient and reliable opportunistic spectrum access. AI has also been proposed to tackle the inter-cell interference problem, which may have a detrimental impact on the performance of wireless users in mobile networks [14].  Existing AI algorithms integrate graphics processing units (GPU) and central processing units (CPU) to improve performance in edge computing [13].  Applied AI for mobile communication is about complex statistical methods and should take a look at devices, infrastructure, end-user, technology, and other resources [13].

To see the research trends on "resource optimization" in mobile communication, Biblioshiny application (R-Package) was used to analyze 130 articles from scopus.com. Figure 2 shows that the most used keywords in this trend are resource allocation (n=18), mobile edge computing (n=14), optimization (n=9), network optimization (n=6), quality of service (n= 6), wireless networks (n=5), Mobile communication (n=4), and QoS (n=4).



Figure 2. WordCloud analysis Resource optimization in Mobile Communication

### 3.3. Network management in Mobile Communication

An example of an application on network management in wireless communication is routing, a topic in communications. Some studies have already implemented AI for this topic. For instance, is a neural network is applied to realize self-configuration and self-optimization for both the radio resource and routing [12]. In another research, Machine learning methods have been used for tackling different types of routing problems in the past. It contained shortest path routing, adaptive routing, and multicasting routing [14]. Other networks management in Wireless communication is to monitor various network activities and detect anomalies, i.e., events that deviate from the current network behavior. AI also has been used for predicting traffic in a communication network.  AI technologies can minimize traditional interventions in network traffic management and enable reliability, more adaptive systems, and better network performance.

To strengthen the research trends evidence on network management in mobile communication, the keywords from the 69 articles collected from scopus.com had been analyzed using the Biblioshiny application (R-Package). The unit of analysis is a document with the type word dynamics (Figure 3).



Figure 3. Word dynamics analysis on network management in mobile communication

From figure 3, it can be explained that since 1991 the keyword "mobile telecommunication systems" has been a word that often appears in the articles. After that, then "quality of service" is appeared in 2000 and has grown to this day. To sum up, "mobile telecommunication systems" theme is being the most popular keyword accompanied by other trends such as "mobile communication networks", "quality of service", "telecommunication networks", "wireless networks", "network management", "wireless telecommunication systems", "computer simulation", "network protocols", and "information management".

### 3.4. Other AI Application

As a sum, applied AI on Mobile Communication can be seen in Table I.

Table 1. Applied AI on Mobile communication

| Mobile Communications Technology | Applied AI |
|---|---|
| Autonomous vehicles and medical assistance devices | Automation with inherent artificial intelligence (AI) [15]<br>Current and major algorithms in the specific field of artificial intelligence for autonomous vehicles. Such systems are particularly suited for high-level decision making since they must, by definition, be able to perceive and react to their environment in order to reach given objectives [16] |
| Internet of Intelligent Things | Artificial intelligence techniques employed to create such intelligence, and network solutions to exploit the benefits brought by this capability [17] |
| Mobile Cloud Computing MCC | Resource intensive applications such as augmented reality, artificial intelligence, artificial vision, object tracking, image processing, and natural language processing are becoming popular to manage MCC[18] |
| 5G Networks | AI and its subcategories like machine learning and deep learning have been evolving as a discipline, to the point that nowadays, this mechanism allows fifth-generation (5G) wireless networks to be predictive and proactive, which is essential in making the 5G vision conceivable [9] |
| Wireless Sensors Networks | In order to assist the smart radio channels, artificial intelligence tools are used. The tool called machine learning is considered to be the important tool in solving the above issue [19]<br>Machine learning techniques for localization in WSNs using Received Signal Strength Indicator [20]<br>The new approach in a wireless sensor network for selecting the cluster-head by making use of the artificial neural network in order to increase the network's lifetime [21] |
| Mobile heterogeneous networks (HetNets) | Machine learning, bio-inspired algorithms, fuzzy neural network, and so on, because AI techniques can naturally handle the problems of large-scale complex systems. [22]<br>These promising architectures adopt artificial intelligence (AI) principles that incorporate learning, reasoning, and decision-making mechanism as natural choices for designing a tightly integrated network. [23] |
| Revealing mobile malware hidden communications | To spot malware covertly exchanging data using two detection methods based on artificial intelligence tools, such as neural networks and decision trees [24] |
| Mobile and Wireless Networking | Deep learning [7] |
| Vehicular mobile networks | Artificial intelligence (AI) based edge caching [25] |

| Next-generation wireless networks | Machine Learning, Artificial Neural Networks (ANNs) [26]<br>Big data analytics for user-activity analysis and user-anomaly detection [27] |
| Mobile Multimedia | Deep Learning (DL) has become a crucial technology for multimedia computing [28] |
| Wi-Fi Based Indoor Location System | Artificial Neural Network ANN [29] |
| Cognitive Radio Networks | Development of cognitive routing protocols envisioned as routing protocols that fully and seamlessly incorporate artificial intelligence (AI)-based techniques into their design [30] |
| Data science and artificial intelligence (AI) for communications | The innovation in AI, machine learning (ML), and network data analytics provides a huge opportunity to revolutionize the world's communications systems and user experience [31] |
| Cellular Network System | AI concept and reviews its applications in cellular network design, operations, and optimization [32] |

## 4. Conclusion

Artificial intelligence (AI) has an essential role in increasing the mobile communication system's performance: proactive system, self-aware, self-adaptive, predictive, efficient, and cost-effective operation and optimization. This article describes several classic AI techniques and the current AI approaches in wireless communication. The techniques contained fuzzy logic, neural networks, reinforcement learning, and some AI techniques implemented on mobile communication. Some keys or terms challenges between AI and future mobile communication are how to manage such as big data, data analytics, higher frequency transmission, device-to-device communication, the reliable architecture, ultra-dense network, Massive MIMO, 3D Beamforming, V2X, Drone Base Station, Multi-Access Connectivity, mm-wave, Cloud-RAN, Edge Network, and Micro Base Station. The challenges are 5G generation issues and how the sixth generation (6G) of mobile networks will be driven to give stable networks and service types on huge mobile devices and data.

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