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# SURVEY ON ARTIFICIAL INTELLIGENCE TECHNIQUES IN 5G NETWORKS

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**Abstract–Research subject.** Fifth-generation telecommunication networks are currently the determining direction of telecommunications development as a whole. At the same time, the complexity of the processes of functioning of fifth-generation telecommunication networks increases by an order of magnitude compared to existing networks. All this requires the use of new technologies, including artificial intelligence, to ensure the stable functioning of telecommunication networks. **Method.** System analysis. **Core results.** The scientific tasks for the fifth generation communication networks, in which the use of artificial intelligence seems appropriate, including machine and deep learning, are identified. **Practical significance.** The results of the work can be useful in the education process in the field of networks and telecommunication systems, as well as for setting new scientific tasks for PhD students.

**Keywords–**5G, Artificial Intelligence, Machine Learning, deep learning.

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# АНАЛИЗ ИСПОЛЬЗОВАНИЯ ТЕХНОЛОГИЙ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В СЕТЯХ 5G

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**Аннотация–Предмет исследования.** Сети связи пятого поколения в настоящее время являются определяющим направлением развития телекоммуникаций. При этом сложность процессов функционирования сетей связи пятого поколения возрастает на порядок по сравнению с существующими сетями. Все это требует использования новых технологий, в том числе и искусственного интеллекта, для обеспечения устойчивого функционирования сетей связи. **Метод.** Системный анализ. **Основные результаты.** Определены научные задачи для сетей связи пятого поколения, в которых представляется целесообразным использование искусственного интеллекта, в том числе машинного и глубокого обучения. **Практическая значимость.** Результаты работы могут быть полезны в процессе обучения в области сетей и систем телекоммуникаций, а также для постановки новых научных задач для аспирантов.

**Ключевые слова–**5G, искусственный интеллект, машинное обучение, глубокое обучение.

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## Introduction

In the last decades, Mobile Wireless Communication networks have experienced a remarkable change. The mobile wireless networks generation (G) generally refers to a change like a system, speed, technology, frequency, data capacity, latency, etc. Each generation has some properties, standards, different capacities, new techniques and new features that differentiate it from the previous one.

1G refers to the first generation of the mobile wireless communication network as the need arise, the first generation was developed around the 1980s by Nippon Telegraph and Telephone (NTT) in Tokyo. So, Japan was the first country to commercialize 1G. 1G is based on analog signals based on AMPS (Advanced Mobile Phone Service) and was used for voice calls only. FDMA (Frequency Division Multiple Access) schemes of multiplexing were used in 1G [1, 2].

Due to the disadvantages of 1G like very less capacity and analog technology, 2G was introduced in the 1990s based on GSM in Finland. 2G had many advantages like radio signals in 2G are digital, offered better security compared to 1G, made better and efficient use of spectrum available and had an added facility of text services. Its improved version also included GPRS (General Packet Radio Service) which allowed internet access.

With a greater number of users using mobile phones to access the internet, faster and robust internet connectivity was needed and 3G was introduced. The concepts of CDMA (Code Division Multiple Access) and WCDMA (Wideband Code division multiple access) were introduced in 3G. NTT DoCoMo first commercially launched it in Japan in the early 2000s. 3G also had an advantage that it was backward compatibility with present 2G systems [1, 2].

4G is the fourth generation of broadband cellular network technology, was first introduced in Finland in 2010. It integrates 3G with fixed internet to support wireless

mobile internet, which is an evolution to mobile technology, and it overcomes the limitations of 3G. It also increases the bandwidth and reduces the cost of resources. The concept of OFDM (Orthogonal Frequency division multiplexing) is used in 4G. The internet speed in 4G can reach up to 100 Mbps due to which applications that require very high speed like online gaming, high definition video streaming and interactive TV can be enjoyed [1, 2].

Wireless mobile communication technology has grown and advanced significantly over the years through research and innovation. The time has come when we can connect various wireless communication technologies, networks, and applications simultaneously. This latest technology is 5G. 5G stands for 5th Generation Mobile communication technology and is now the next generation of wireless communication systems. 5G is the new stage in the development of mobile telecommunications standards beyond the current 4G It is going to be a new revolution in the mobile market which has changed the means to use cell phones within very high bandwidth. The user never is professional before such high-value technology which includes all types of advanced features and 5G technology will be most powerful and in huge demand soon. It moves us beyond network design for mobile devices alone toward systems that connect different types of devices operating at high speeds [1, 2].

Fig. 1 shows the evaluation of cellular mobile networks from 1G to 5G.

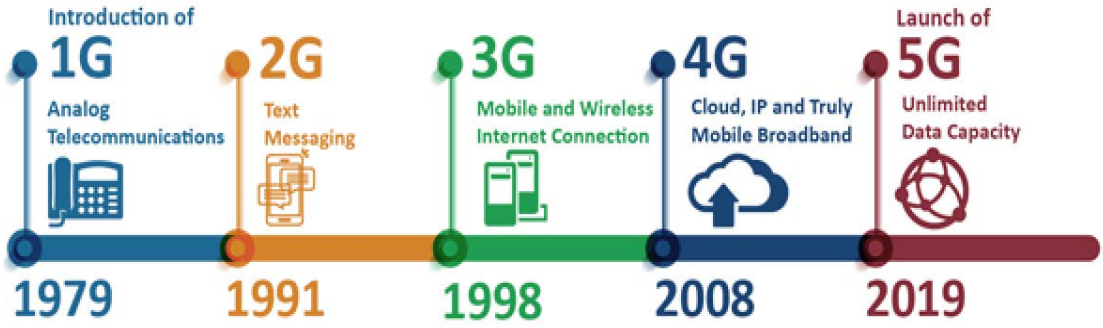


Fig. 1. the evaluation of cellular networks

The development of 5G networks will be large-scale, multi-layered, highly complex, dynamic, and heterogeneous. Also, 5G networks require to support seamless connectivity and guarantee several QoS requirements of many devices, as well as processing a large amount of data generated from physical environments. AI techniques with strong analytical ability, the ability of learning, optimization ability and the ability of intelligent recognition, which can be used in 5G networks to intelligently achieve a performance improvement, Discovering knowledge, complex learning, the structure of the organization and complex decision making.

Artificial intelligence is a computer science branch that aims to create "intelligent machines". a fundamental component necessary to make sense of the vast amount of data collected these days and increase its value to the business. AI will help wireless network (i. e. IoT) data analysis in the following areas: data preparation, data discovery, stream data visualization, time-series data accuracy, predictive and advanced analytics, as well as real-time geospatial and location (logistic data).

Machine learning is a branch of AI that can provide systems with the ability to automatically learn and improve from experience while not being explicitly programmed. It focuses on the development of computer programs that can access data and use it for the learning process. Machine learning is ideally suitable for working in 5G networks because it needs massive amounts of data for accurate predicting activities. This is an ideal situation for 5G since it can transmit higher volumes of data faster than current networks.

The next generation of mobile and wireless communication technologies also require the use of optimization to minimize or maximize certain objective functions. various problems in mobile and wireless communications are nonlinear or non-polynomial, and therefore, they require to be approximated. Artificial neural networks (ANN) is an AI technique that has been proposed to model the objective function of the non- linear problem that requires optimization [3].

Deep learning is a class of machine learning (ML) that uses the hierarchical structure of artificial neural networks to implement the machine learning process. Artificial neural networks mimic the human brain, are built with neural nodes connected as a network. However, traditional programs linearly build data analysis, the hierarchical function of deep learning systems allows machines to process data with a non-linear approach. Deep learning is AI function that mimics the functionality of the human brain when processing data for use in decision making. Deep AI learning can learn from data that is unstructured [4, 5]. Fig. 2 shows the relationship between artificial intelligence, machine learning, and deep learning.

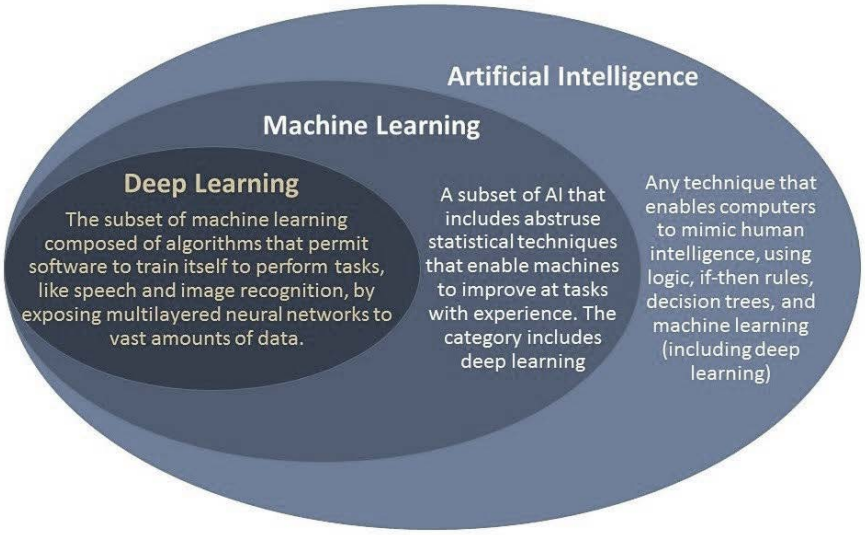


Fig. 2. The relation between artificial intelligence, machine learning, and deep learning

In this article, we introduce a comprehensive survey in the development of 5G wireless mobile communication and the applications of artificial intelligence (AI) techniques in 5G networks for improving the performance of 5G networks and overcome problems that can affect overall performance.

Investigating the potential features of Beyond 5G, providing future research directions for the contribution of AI to realizing 5G. Discussion on the role that AI can play to the limitations for a wide deployment of autonomous 5G mobile and wireless communications.

This article is organized as follow: section (2) discusses the combination of Artificial Intelligence with 5G Networks; section (3) discusses machine learning, applications in wireless networks; section (4) introduction about deep learning; section (4) conclusion.

Table

List of abbreviations

| | |
|---|---|
| 5G | Fifth generation Network |
| 4G | fourth generation Network |
| 3G | Third generation Network |
| 2G | Second generation Network |
| 1G | First generation Network |
| AI | The artificial intelligent |
| RNN | Recurrent neural network |
| CNN | convolutional neural network |
| ANN | Artificial Neural Network |
| MLP | Multilayer perceptron |
| ML | Machine Learning |
| RL | Reinforcement learning |
| DRL | Deep reinforcement learning |
| DT | Decision trees |
| SVM | Support vector machine |
| SVR | Support vector regression |
| KNN | K-nearest neighbors |
| GPR | Gaussian process regression |
| SLA | Service level agreements |
| IoT | Internet of Things |
| QoS | Quality of Service |
| CDMA | Code Division Multiple Access |
| WCDMA | Wideband Code division multiple access |
| OFDM | Orthogonal Frequency division multiplexing |
| MRB | multi-armed bandit |
| MDP | Markov decision process |
| AC | actor-critic |
| LSTM | long short-term memory |
| DNN | Deep neural network |
| ISOMAP | Isometric mapping |
| PCA | Principal component analysis |
| ARIMA | Autoregressive integrated moving average |
| NARX | A nonlinear auto-associative neural network with external input |

## The combination of Artificial Intelligence with 5G Networks

5G wireless communications are expected to fulfill various service requirements in different aspects of our daily life, from residence, work, leisure, to transportation. Because of the ultimate range of 5G requirements for user experience, efficiency, performance and complex network environments, the design and optimization of 5G networks become very challenging.

The future 5G network will require robust smart algorithms to adapt network protocols and resource management for different services in different scenarios. Artificial intelligence (AI), which is defined as any process or device that realizes its environment and take actions that maximize the opportunities of success for some predefined goal, is a practical solution for the design of emerging complex communications system. The recent developments in deep learning, convolutional neural networks, and reinforcement learning hold important promise for the solution of very complex problems considered intractable until now.

It is now suitable for adding AI technology to 5G wireless communications to address the optimal design of the physical layer, complex decision making, network management, and resource optimization tasks in these networks. Moreover, the emerging big data technology has provided us with an excellent chance to study the basic characteristics of wireless networks and to help us to get more clear and deep knowledge of the behavior of 5G wireless networks.

In studying of 5G wireless technologies and communication systems, AI will be a robust tool and interesting research topic with several potential application areas, e.g., wireless signal processing, channel modeling, and resource management.

Here, we present some popular AI techniques as follows first. Artificial intelligence techniques include interdisciplinary techniques including machine learning (supervised learning, unsupervised learning, and reinforced learning), deep learning, improvement theory, game theory, and meta-logic. Between them, machine learning and deep learning are the most common AI subfields which are broadly endorsed in wireless networks.

## Machine learning

Machine learning (ML) is an advanced branch of artificial intelligence that uses mathematical algorithms to learn and make informed provisions of the data without being directly programmed for each situation. When introducing new entries, ML then uses this data to provide smart insights or predict a specific outcome. Properly applied, ML is well-suited to deal with complex problems like Wi-Fi optimization or detecting attack within an organization.

The main purpose of ML is to allow the machines to learn automatically. It has been applied successfully in many applications in wireless networks. Resource management (power control, backhaul management, cache management, spectrum management) in the MAC layer, networking and mobility management in the network layer, localization in the application layer- are some of the main applications of ML in wireless communication. ML perform proactive prediction and adjustment from learned behavior in next generation networks to achieve high efficiency and reliability in networks [6, 7].

AI and machine learning offer various ways to robustify the network performance. Machine learning can assist in optimizing the overall network management and monitoring, efficiently motivating resource consumption, and enable customized network slicing to provide owners with more control over the use of their network. Also, ML will facilitate setting up of network slices on a 5G network because of the setup is limited right now.

By analyzing the use of the system, ML and AI systems can specify and improve device mobility patterns and quality of service (QoS) usage to better predict network usage and congestion at specific locations throughout the day. They can arrange traffic and allocate resources more efficiently, finally providing better network service to users with lower resource consumption. Also, ML provides additional observations into the health of the network by providing other capabilities and functionality for fault, performance, and security management.

For example, ML help in increasing energy efficiency further by optimizing the energy consumption of the whole process, use cases include

- Estimation and prediction of energy consumption [8].
- Anomaly detection: Once the close fit output has been established, output and input data can be compared for forecasted data to detect anomalies.
- Energy reduction: Change in processes may be evaluated to achieve minimal energy evaluation.

Also, ML algorithm is successfully used in traffic estimation and prediction based on our live traffic estimated data. The output of our services is surprisingly robust and accurate with high accuracy. Moreover, our traffic prediction or estimation has shown brilliant results except in case of presence of anomalies the result is not accurate.

There are many kinds of traffic prediction algorithms like ARIMA, NARX, Kalman filter, particle filter, and theoretical traffic propagation methods. But in case of we have a huge amount of corrupted data, employing these methods does not seem to be working. So can use multistep prediction technique for overcoming the problem of prediction in presence of anomalies [6].

On the other hand, in case of traffic estimation with the presence of anomalies in data. To overcome the possibility of presence of anomalies, many robust estimators which are not very sensitive to deviation of assumptions on which they depend are being used recently such as M-estimators (Maximum-likelihood estimators) [8, 9, 10, 11, 12] and work as robust performance function to replace MSE traditional performance function.

ML is classified into three classes of supervised, unsupervised and reinforcement learning:

*A. Supervised Learning*

Supervised Learning: Supervised learning uses a group of exclusive classified data to build the model of learning (also called training), Supervised learning is generally divided into two subcategories classification and regression. Classification analysis aims to assign a categorical label to every input sample, which mainly includes neural networks (ANN), Bayesian networks, decision trees (DT), Logistic regression, Random Forest, support vector machine (SVM) and K-nearest neighbors (KNN). Classification algorithms could be used to group and prioritize alarms.

Regression analysis includes ANN, KNN, Linear regression, support vector regression (SVR) and gaussian process regression (GPR) algorithms. A regression algorithm indicates a statistical relationship between two, or more, variables (e. g., temperature and noise) and it estimates or predicts continuous values based on the input statistical features [8, 9, 11, 12, 13].

*B. Unsupervised Learning*

The task of unsupervised learning is to discover hidden patterns as well as extract useful features from unlabeled data. With unsupervised learning, the system tries to find patterns in the input data without knowledge of any specific output conditions of the data. An example may be the detection of abnormal behavior that refers to a security threat. The key difference is that supervised learning uses a labeled training set of data, while unsupervised learning must discover patterns from unlabeled data.

Unsupervised learning is generally divided into clustering and dimension reduction. Clustering seeks to group a set of samples into different clusters according to their similarities, although these clusters are not predetermined and hence clustering is generally an unsupervised form of ML. Examples of clustering algorithms include ANN, apriori algorithm, distribution-based (Gaussian mixture models), hierarchical clustering algorithms, and K-Means clustering.

Clustering might be used for anomaly detection, i.e., spotting events that are outside normal cluster behavior. Dimension reduction transforms a high-dimensional data space into a low dimensional space without losing much useful information. Principal component analysis (PCA) and isometric mapping (ISOMAP) are two classic dimension reduction algorithms [13].

*C. Reinforcement Learning (RL)*

Reinforcement learning (RL) is a field of ML, inspired by behavioral psychology. The system is given a goal and adjusts its behavior to maximize its performance. Feedback is provided in rewards and punishments as the system explores the problem, trying to find the optimal solution. In RL, each agent learns to map situations to actions and makes suitable decisions on what the actions to take through interacting with the environment, to maximize a long-term reward. Classic RL algorithms include Markov decision process (MDP), Q learning, policy learning, actor-critic (AC), DRL and the multi-armed bandit (MRB). Reinforcement learning differs from standard supervised learning in that correct input/output pairs are not required. An example of reinforcement learning is learning to play a game such as chess.

Reinforcement learning is particularly well suited to dynamic environments where one does not just need to make a prediction based on some historical data, but also must adapt to a changing environment that one is trying to control. The system monitors the environment, takes measures to maximize performance, performs new monitoring of the environment, and then takes more measures depending on whether the system is now closer to or further from the desired state [14].

## Deep Learning

While the three techniques described above are learning approaches, deep learning is a class of ML algorithms which in turn class of AI. Most modern deep learning models are based on an artificial neural network that is inspired by the

structure and function of the human brain. It consists of multiple layers of neurons, and the learning model can be supervised, semi-supervised and unsupervised. Classic deep learning algorithms include deep neural network (DNN), convolutional neural network (CNN), recurrent neural network (RNN) and long short-term memory (LSTM).

A deep neural network learning uses a cascade of processing layers, whereby each layer transforms the input data into more abstract representations. For example, the first layer may recognize the edges in an image, the second layer may identify a face, the third layer a feature on the face like the nose. The output layer combines those features to make predictions such as that the image is the face of a person or a specific person whose likeness is known to the system. Deep learning has been used for image recognition (computer vision), speech recognition (audio to text) and natural language processing (meaning extraction from audio/text) [15].

## Conclusion

In this article, we introduced a survey on the combination of artificial intelligence with the 5G network. The deployment of 5G will enable a new era of opportunity for everyone. It will open the creative minds of technology professionals when they think of new and innovative ways to improve our businesses and lives. The combination of AI and machine learning to the 5G will make things even more interesting.

From a strict technology perspective, AI and machine learning offer several ways to robustify the network performance. ML can help in improving overall network management and monitoring, increase resource consumption efficiently, and enable custom network slicing to give owners more control over the use of the network. ML provides additional awareness into the health of the network by providing other capabilities and functionality for fault, performance, and security management.

ML and AI systems can be able to identify and improve the patterns of mobility and quality of service to better predict using the network and congestion in specific locations during the day. They can arrange traffic and allocate resources more efficiently, and ultimately support with better network service for users with less resource consumption.

It's progress in the integration of IoT devices in a business setting that's helping companies control access to physical locations, monitor IT systems for intrusions and faults, and AI software that's optimizing network traffic to enable edge computing and help us process information more efficiently.

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