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# THE POTENTIAL SOLUTIONS TO NEXT GENERATION WIRELESS COMMUNICATION:AI AND MASSIVE MIMO TECHNOLOGY DESIGN AND DEVELOPMENT.

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***Abstract:***

***The advent of Artificial intelligence into the wireless communications systems augurs new cutting-edge technologies, including self-driving vehicles, unmanned aerial systems, autonomous robots, the Internet of-Things, and virtual reality. These technologies require high data rates, ultra-low latency, and high reliability, all of which are promised by the fifth generation of wireless communication systems (5G). Many research groups state that 5G cannot meet its demands without artificial intelligence (AI) integration as 5G wireless networks are expected to generate unprecedented traffic giving wireless research designers access to big data that can help in predicting the demands and adjust cell designs to meet the users' requirements. Subsequently, many researchers applied AI in many aspects of 5G wireless communication design including radio resource allocation, network management, and cyber-security. In this paper, we provide an in-depth review of AI for 5G wireless communication systems. In this respect, the aim of this paper is to survey AI in 5G wireless communication systems by discussing many case studies and the associated challenges, and shedding new light on future research directions for leveraging AI in 5G wireless communications.***

***Keywords:*** ***Massive MIMO,AI,URLLC,Physical Layer,Machine Learning***

## 1. INTRODUCTION

The rapid advancement of wireless communication technologies depends mostly on the massive multiple-input and multiple output(MIMO) antennas, millimeter wave transmission and ultra-dense networking technologies, the enhanced mobile broadband (eMBB), ultra-reliable low latency communications (URLLC) and massive machine type communications(mMTC).These technologies have been recommended as most important for the fifth generation (5G) wireless communication systems. However, it is difficult for conventional wireless communication theory and methods to solve all issues of three typical applications, such as massive traffic and accessing, URLLC in 5G wireless communication systems [1]. With the fast development of artificial intelligence (AI) in recent years, AI technologies are expected to combine into the

future wireless communication systems and solve the massive traffic and accessing with ultra-reliable and low latency constraints [2]. Nevertheless, the revolutionary impact of AI applications on the future wireless communication systems has not been deeply understood. One of important challenges is to indicate the distinguished capabilities and define the features of future AI wireless communication systems.
Currently, the machine learning technology is emerging as one of the most attractive AI technologies for wireless communications. Utilizing the machine learning technology, a robust and efficient algorithm was developed to enhance the accuracy for time-of-arrival localization through identifying and mitigating non-line of sight (NLOS) signals in harsh indoor environments [3].

Except for the location issue in future wireless communications, the AI technologies have been also widely used for the cognitive radio systems. By categorizing learning problems into the decision-making and feature classification for cognitive radio systems, the working conditions of supervised and unsupervised learning algorithms on the decision-making and feature classification were presented in cognitive radio systems.The five foundations of 5G:

1- Milimeter Waves

2- Small Cells

3- Massive MIMO

4- Beamforming

5- Full Duplex

However the Massive MIMO and beam forming concept is the main important features to be considered.

**Massive MIMO:**

We know that for millimeter waves above, wireless communication suffers from attenuation ( power loss ) and interference ( spectrum collision with other signals ). Massive MIMO (Multiple Input Multiple Output) systems offer a solution against these problems. Many antenna arrays are placed in the base station. And instead of linking a single antenna to a single user, multiple antennas are linked to multiple users.

**Beamforming:**

In traditional communication systems, radial ( circular ) radiation is used. It means that the signals are radiated in every direction. However, users are not located uniformly over a circle. Rather, they are located on some discrete positions. This situation makes the use of circular radiation highly inefficient. It both wastes energy and also may cause interference. A solution to this problem would be to create more directive signals which aim specific users rather than a circular target. Each antenna ( or antenna array ) is linked to a specific target by amplitude and phase adjustment. We can visualize Beamforming solution as below. Each device is connected to the corresponding antenna by a directed signal. Beamforming method allows us to avoid consuming extra spectrum, saves energy and reduces interference.

**Artificial Intelligence based solution :AI Solutions**

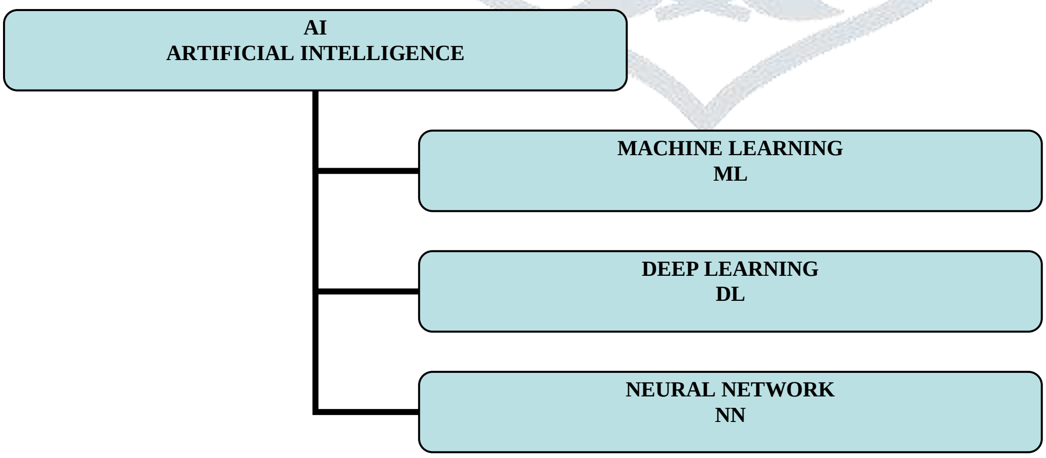
For base stations, it is often not easy to decide the optimal beamforming adjustment since they don’t have computationally powerful resources. On-site optimization processes would take a lot of time and power which the base stations can’t afford. To solve this problem, an external data training can be applied and only the prediction process might be left to the base station. Having a pre-built machine learning model would drastically reduce the time and power needed for beam forming optimization.Unlike other application fields of machine learning such as Computer Vision or Natural Language Processing, obtaining the real data is not as easy in Communication Systems. Especially for 5G, it is quite expensive to generate real data due to setup of various instruments. We should find a simple way to reach the data without having to spend a huge capital.So let us verify the key performance indicator(KPI) in 5G and 6G before moving to the major concept AI in recent wireless communication.

**KPI(Key Performance Indicator) in 5G and 6G:**

| **Key Performance Indicator(KPI)** | **5G** | **6G** |
|---|---|---|
| Peak data rate(Gbps) | 20 | 1000 |
| Experienced data rate(Gbps) | 0.1 | 1 |
| Peak spectral efficiency(b/s/Hz) | 30 | 60 |
| Experienced spectral efficiency(b/s/Hz) | 0.3 | 3 |
| Maximum channel Bandwidth(GHz) | 1 | 100 |
| Area Traffic Capacity(Mbps/$m^2$) | 10 | 1000 |
| Connection Density(device/$km^2$) | $10^6$ | $10^9$ |
| End to end latency(ms) | 1 | 0.1 |
| Energy efficiency(Tb/J) | NA | 1 |
| Packet error rate | $10^{-5}$ | $10^{-9}$ |
| Mobility(km/hr) | 500 | 1000 |
| Algorithm | AI driven | AI driven |

## II . ARTIFICIAL INTELLIGENCE IN WIRELESS COMMUNICATION:

Artificial intelligence, commonly termed as AI, is concerned with the design and development of intelligence in machines artificially. The primary goal of AI is to create systems that can work intelligently and independently. The concept of AI with its domain is shown in this below figure:




It is evident that AI is a broad concept, under which there is several branches covering interleaved research topics, such as robotics, natural language process- ing, machine learning (ML), computer vision, among others. In this section, we focus specifically on the ML algorithms and their applications in wireless communications under the AI umbrella. These two terms are thus used interchangeably in this section. Artificial intelligence can be applied to each layer of the wireless network. At the network layer, machine learning (ML) algorithms can be used for traffic clustering to further adapt the network resources to various scenarios. At the physical and MAC layers, deep learning can optimize resource allocation strategies for power distribution, and modulation and coding schemes, among others. Furthermore, machine learning algorithms can also assist with channel estimation and multi-user detection

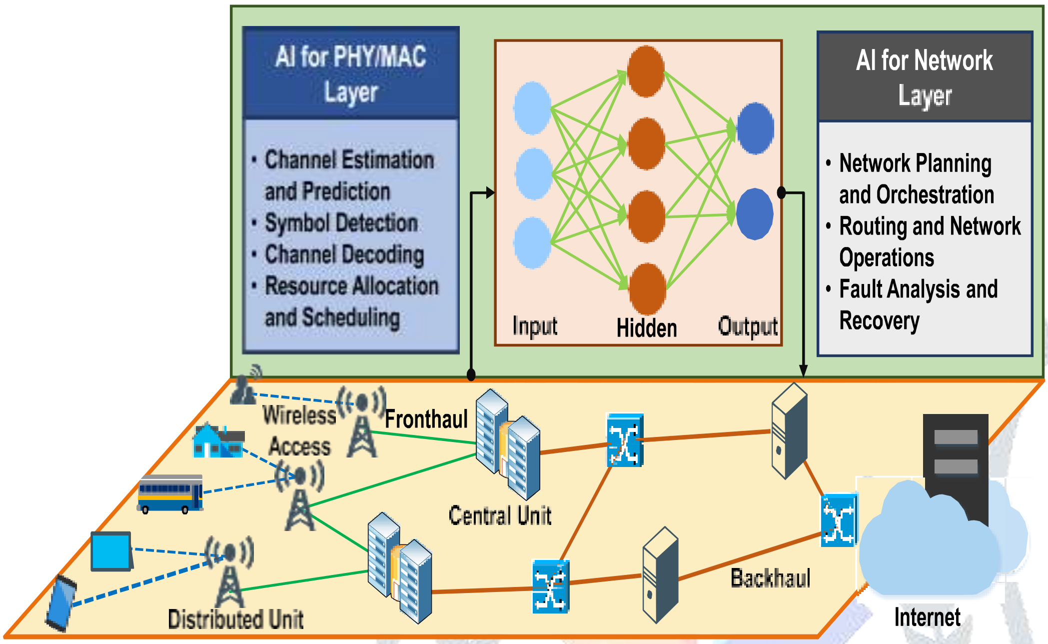



**Fig:Applications of artificial intelligence at different layers of wireless systems**
(I.F.Akyildiz et al.6G and beyond communication)

**AI IN PHYSICAL LAYER:**

Traditionally, physical layer modeling has been model oriented—a practice in which mathematical models following a certain framework are proposed and optimized under constraints to satisfy a series of pre-determined performance requirements. For example, in order to conduct channel estimation, a channel model is assumed along with other parametric configurations. These model-based solutions usually perform well if the derivation of mathematical models is relatively straightforward or there exists a closed-form solution. The models can then be validated by field measurements or numerical simulations. However, in real-world scenarios, the applicability of such model-based solutions falls short in complicated environments, due to factors such as non-linearity inside systems and uncontrollable interference, among others. On the other hand, another approach, which is based on statistics, or data sets, builds the model through learning from the data. This method is particularly useful when theoretical analysis is intractable or when a closed-form solution is difficult to obtain. Furthermore, a deep learning method based on the deep neural network architecture also demonstrates improved channel estimation accuracy under the effects of nonlinearities of power amplifiers, I/Q imbalance, and quantization errors induced by hardware impairments. An auto encoder-based communication system is proposed to reconstruct the transmitted signals from channel impairment based on trained deep neural networks in an end-to-end manner. Furthermore, self-supervised learning is becoming a trend for user localization since it has been demonstrated that relevant methods can significantly reduce the size of labeled dataset for efficient processing.

## AI IN WIRELESS NETWORKS AND ITS MANAGEMENT:

Artificial intelligence and its associated of algorithms can be applied in varied ways in wireless networks like autoencoders for predicting traffic flow , *k*-means clustering for traffic congestion control, and *Q*-learning for intelligent resource management, among others . In the Internet of Space Things, with our envisioned multi-band communication capabilities in both inter-satellite and ground-to-satellite links, we have proposed a deep neural network-based resource allocation strategy to enable a flexible scheme for CubeSats to stay connected without human intervention from the ground. AI, or more specifically ML, has an integral role to play in the management of networks. More recently, with software defined networking (SDN) and network function virtualization (NFV) becoming mainstream, large-scale data acquisition has become easier than ever before, making a strong case for ML-based management and orchestration primitives within 6G, ultimately leading to full network automation.

**Supervised Learning:** Supervised learning is typically applied to problems relating to traffic prediction and classification, as well as slice resource prediction. .

**Reinforcement Learning:** Reinforcement learning typically finds use in problems associated with resource management.

**Unsupervised Learning**: In the cases of optimizing the end-users', Quality of Experience (QoE) and network security the unsupervised learning gets its application.

## III.MIMO VS MASSIVE MIMO IN RECENT WIRELESS COMMUNICATION SYSTEM:

Multi-user Multiple-Input Multiple-Output (MIMO) offers big advantages over conventional point-to-point MIMO: it works with cheap single-antenna terminals, a rich scattering environment is not required, and resource allocation is simplified because every active terminal utilizes all of the time-frequency bins. However, multi-user MIMO, as originally envisioned with roughly equal numbers of service-antennas and terminals and frequency division duplex operation, is not a scalable technology. Massive MIMO (also known as "Large-Scale Antenna Systems", "Very Large MIMO", "Hyper MIMO", "Full-Dimension MIMO" and "ARGOS") makes a clean break with current practice through the use of a large excess of service-antennas over active terminals and time division duplex operation. Extra antennas help by focusing energy into ever-smaller regions of space to bring huge improvements in throughput and radiated energy efficiency. Other benefits of massive MIMO include the extensive use of inexpensive low-power components, reduced latency, simplification of the media access control (MAC) layer, and robustness to intentional jamming. The anticipated throughput depend on the propagation environment providing asymptotically orthogonal channels to the terminals, but so far experiments have not disclosed any limitations in this regard. While massive MIMO renders many traditional research problems irrelevant, it uncovers entirely new problems that urgently need attention: the challenge of making many low-cost low-precision components that work effectively together, acquisition and synchronization for newly-joined terminals, the exploitation of extra degrees of freedom provided by the excess of service-antennas, reducing internal power consumption to achieve total energy efficiency reductions, and finding new deployment scenarios.

**Massive MIMO Advantages are:**

- Increased data rate, because the more antennas, the more independent data streams canbe sent out and the more terminals can be served simultaneously;
- Enhanced reliability, because the more antennas the more distinct paths that the radiosignal can propagate over;
- Improved energy efficiency, because the base station can focus its emitted energy into thespatial directions where it knows that the terminals are located; and
- Reduced interference because the base station can purposely avoid transmitting into directions where spreading interference would be harmful.

| | **MIMO** | **MASSIVE MIMO** |
|---|---|---|
| Number of Antenna | ≤8 | ≥16 |
| Pilot Contamination | Low | High |
| Throughput | Low | High |
| Antenna Coupling | Low | High |
| Bit Error Rate | High | Low |
| Noise Resistance | Low | High |
| Diversity/Capacity Gain | Low | High |
| Energy Efficiency | Low | High |
| Cost | Low | High |
| Complexity | Low | High |
| Scalability | Low | High |
| Link Stability | Low | High |
| Antenna Correlation | Low | High |

**Benefits of Massive MIMO for 5G Networks and Beyond:**

Some of the benefits of massive MIMO technology are:

- Spectral Efficiency: Massive MIMO provides higher spectral efficiency by allowing its antenna array to focus narrow beams towards a user. Spectral efficiency more than ten times better than the current MIMO system used for 4G/LTE can be achieved.
- Energy Efficiency: As antenna array is focused in a small specific section, it requires less radiated power and reduces the energy requirement in massive MIMO systems.
- High Data Rate: The array gain and spatial multiplexing provided by massive MIMO increases the data rate and capacity of wireless systems.
- User Tracking: Since massive MIMO uses narrow signal beams towards the user; user tracking becomes more reliable and accurate.

- Low Power Consumption: Massive MIMO is built with ultra lower power linear amplifiers, which eliminates the use of bulky electronic equipment in the system. This power consumption can be considerably reduced. •
- Less Fading: A Large number of the antenna at the receiver makes massive MIMO resilient against fading.
- Low Latency: Massive MIMO reduces the latency on the air interface .
- Robustness: Massive MIMO systems are robust against unintended interference and internal Jamming. Also, these systems are robust to one or a few antenna failures due to large antennas.
- Reliability: A large number of antennas in massive MIMO provides more diversity gain, which increases the link reliability.
- Enhanced Security: Massive MIMO provides more physical security due to the orthogonal mobile station channels and narrow beams
- Low Complex Linear Processing: More number of base station antenna makes the simple signal detectors and precoders optimal for the system.

## IV: EFFICIENCY OF MASSIVE MIMO AND SUBSEQUENT BENEFITS IN WIRELESS COMMUNICATION:

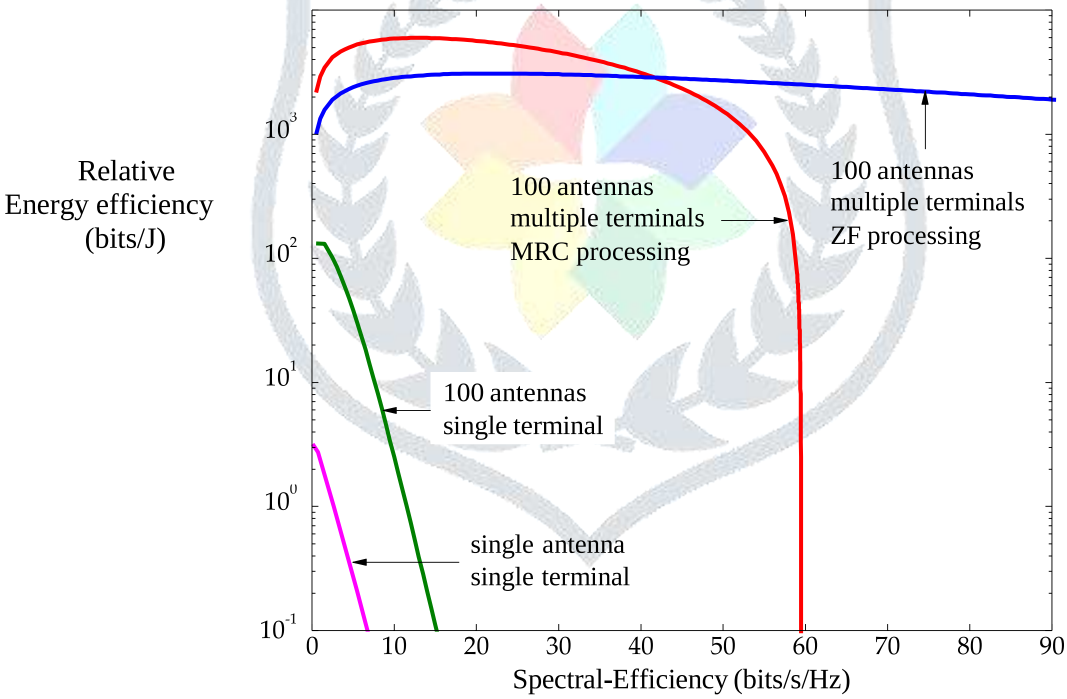



Fig: Improving uplink spectral efficiency in massive MIMO technology in wireless communication.

- Massive MIMO enables a significant reduction of latency on the air interface.

The performance of wireless communications systems is normally limited by fading. The fading can render the received signal strength very small at some times. This happens when the signal sent from a base station travels through multiple paths before it reaches the terminal, and the waves resulting from these multiple paths interfere destructively. It is this fading that makes it hard to build low-latency wireless links. If the terminal is trapped in a fading dip, it has to wait until the propagation channel has sufficiently changed until any data can be received. Massive MIMO relies on the law of large numbers and beam forming in order to avoid fading dips, so that fading no longer limits latency.

- Massive MIMO simplifies the multiple-access layer.

  Owing to the law of large numbers, the channel hardens so that frequency-domain scheduling no longer pays off. With OFDM, each subcarrier in a massive MIMO sys- tem will have substantially the same channel gain. Each terminal can be given the whole bandwidth, which renders most of the physical-layer control signaling redundant.

  Massive MIMO increases the robustness both to unintended man-made interference and to intentional jamming.

## V.CONCLUSION:

In this paper, we presented AI for 5G wireless communication systems. We studied several case studies including modulation classification, channel coding, massive MIMO, caching, energy efficiency, and cyber security. As a conclusion of this in-depth study, AI enabled 5G wireless communication and networking is a promising solution that can provide wireless networks with the intelligence, efficiency, and flexibility required to manage the scare radio resource well and deliver high quality of service to the users. However, some efforts are still needed to reduce the complexity of deep learning so it can be implemented in time-sensitive networks and low power devices and test the models in more realistic scenarios.

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