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REVOLUTIONIZING HEALTHCARE WITH AI AND 6G: NEXT-GENERATION SMART HEALTH SYSTEMS AND APPLICATIONS

Mani Goyal [1*], Navneet Garg [2]
[1*]Department of Computer Science and Engineering,
MMEC Maharishi Markandeshwar (Deemed to be University) Mullana-Ambala, India
[2]Department of Computer Science and Application,
Government College Chhachhrauli, Yamuna Nagar, Haryana, India

ABSTRACT:
Health and well-being is a key issue of concern hence leading to the introduction of superior technologies to ensure cost effective healthcare provision. The paper addresses the impacts of integrating Artificial Intelligence (AI) and wireless communication technologies (1G to upcoming 6G) in facilitating intelligent and real-time healthcare services. The AI-enabled systems can gather, transfer and process information through Wireless Sensor Networks (WSNs) and provide customizable and preventive treatment. The development of AI and communication technologies and their integration as a whole are analyzed, as well as the effects of such development on applications made in the sphere of healthcare, smart cities, logistics, and industrial automation. A list of wireless communication generations is shown with some of the most important parameters of spectrum, data rates, and deployment methods reported. The paper also reflects upon the issues that AI, with the help of machine learning and deep learning, solves regarding major difficulties of networks: reductions in latency, congestion management, saving energy, and the prevention of data security. Particular attention is paid to the capability of 5G and expected innovations of 6G, such as a capability of supporting ultra-reliable low-latency communications and massive machine-type connectivity. The combination of the world of wireless and the emergence of AI will not only increase the intelligence of systems but will also open up possibilities of real time-based resource efficient communication systems.

KEYWORDS: ***Artificial Intelligence (AI), Healthcare, IoT, Latency, Machine Learning, Network Optimization, Wireless Sensor Networks (WSN), 5G, 6G***

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1. INTRODUCTION

Health plays a central role in our daily lives, and individuals are increasingly conscious about maintaining their fitness. With these considerations in mind, the research community remains focused on these challenges, developing numerous methods to ensure individual health and well-being. Artificial Intelligence (AI) and communication technologies like wireless communication collectively provide services at doorstep. One of the examples of wireless healthcare services can be presumed to be as depicted in figure. 1, where people are engaged in their given tasks and working at their own pace. The intime data collection by the healthcare sensors is transferring to the cloud for long-term storage where various wireless communication technologies compete to each other using wireless sensor networks.

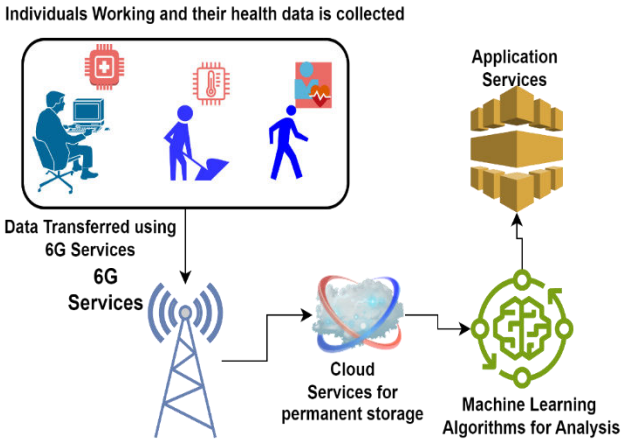

Figure 1: Healthcare Services using 6G and AI

A wireless sensor network (WSN) consists of nodes that collect data from various applications and transmit it wirelessly. The data travels through multiple hops before reaching its destination, where it connects to other networks via the internet. The features of WSN such as mobility and their quick access makes it more viable to various application areas. WSN has numerous application domains including in the fields of healthcare, logistics, environmental monitoring, and defence services, among others [1][2]. Nonetheless, the industry is ready to work with WSN by the integration of artificial intelligence (AI) in a variety of applications. Real-time data generation monitoring and its transformation into functional applications leads to a new era of industrial applications. AI has a wide range of applications, and it began by overcoming obstacles such data privacy and security, network traffic control, routing, and topological management. Moreover the impact of AI can be witnessed in a wide range of applications in many sectors. However, various applications suffered from issues such data latency, network congestion, and energy efficiency [3]. The exploration of expanding generation of wireless technologies brings new era of innovation with solutions to these challenges in emerging applications areas. The induction of AI and these expanding wireless technologies has provided solutions to routing, decreasing latency, congestion control, preserving privacy during communication etc.[4][5].

The paper is so structured, Section II contains the literature review on wireless technologies. In Section III, the author looks into the similar development of AI and communication systems. Section IV involves the performance analysis, and section V offers conclusions in form of key insight and future directions.

2. LITERATURE REVIEW

(i) Classification of various Wireless Communication Technologies

The expansion of wireless technology brings a revolutionary time in emerging applications enabled through IoT. Initially the usability of communication technology was limited to wired connections, near field communication, Bluetooth etc. However nowadays, billions of devices are connected through wireless communication within the range of thousands or lakhs of kilometres. The traffic on wireless communication was expanded so sharply that it reached at 11.5 billion by 2020 and it reached to 31.6 billion by 2023.

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(ii) Generations of Communication Technology

The expansion of such a huge number of wireless devices is possible just because of family of rising communication generation technologies such as 1G to 6G. The categorization of communication technologies can be seen in the figure 2 as well. The 1G (first generation) communication technology is used in 1980s [6] on analog mobile phones with a limited functionality. The first 1G mobile systems were introduced in 1979 by Nippon Telegraph and Telephone. The frequency division multiple access (FDMA) was used in this technology with a narrow band frequency of 25 to 30 kilohertz (kHz).

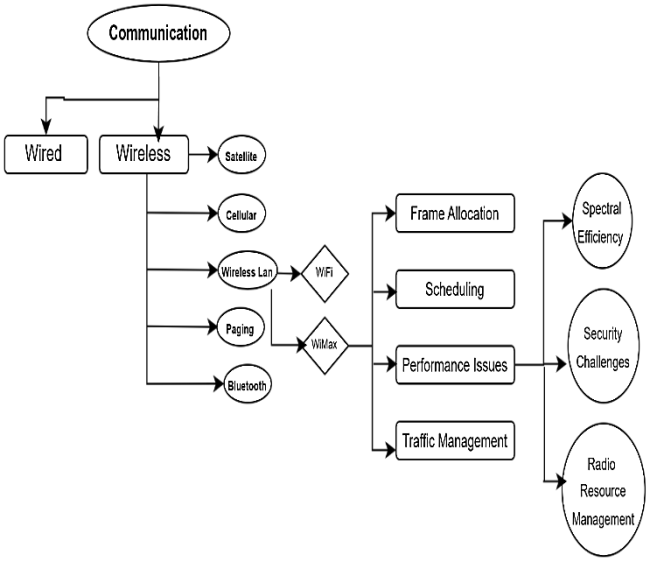

Figure 2: Classification of various wireless communication technologies

Then after this second generation of communication systems (2G) [7] were deployed by North American interim Standards 54 and 136, global system for mobile (GSM) in 1990s. The 2G system adopted the time division multiple access (TDMA) along with channel capacity ranging from 25 to 200 kHz. Along with FDMA and TDMA another technology used for frequency distribution technique was deployed was named code division multiple accesses (CDMA). It was standardized by Qualcomm in 1995 and channel spacing with this varied up to 1250kHz. Further, the fusion of wide CDMA (WCDMA) along with CDMA 2000 is introduced in 1998 with the diversity of bands such as 800, 900, 1800, 1900 MHz is known as 3G communication services [8]. The diverse number of bands provides communication services to users in different areas so that they can communicate at any place as much as possible. This facility is provided by NTT DoCoMo with the average speed of 2 Mbps. After this another technology introduced in 2009 with a higher data transfer rate of 1 to 1.5 Gbps known as 4G LTE is Fourth Generation Long-Term Evolution [9]. Then after 4G another set of applications were ready with some big benchmarks and demands high bandwidth rate became the reason of invention of 5G technology [10].

The spectrum efficiency varies from 1 to 4 GHz under 5G where average speed of communication varies up to 10 Gbps. The 5G technology was based on OFDMA, Massive MIMO, and Beamforming which is first invented in 2017. The industry was not ready to stop up to 5G, and here comes another communication technology known as 6G [11] with spectrum efficiency up to 3 GHz to 60 GHz. However, the detailed public information about 6G is not available as much, though the top feature of 6G is its communication speed varies from 10 to 100 Gbps. The metrics comparison of various generation of communication technologies are mentioned below in table 1.

Table 1: Comparison of communication technology with respect to their Generations (1G to 6G)

Communication Technology	Spectrum Frequency	Technique Used	Standard for Deployment	Data transfer rate	Deployment Year
1G	25 to 30 KHz	FDMA	IS-54/136	2.4 Kbps	1980

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2G	25 to 200 KHz	TDMA	NA	9.6 Kbps to 64 Kbps	1990
CDMA	1250 kHz	CDMA	IS-95	14.4 Kbps to 115 Kbps	1995
3G	800, 900, 1800, 1900 MHz	WCDMA & CDMA 2000	UMTS, 3GPP, CDMA	2 Mbps	1998
4G	800 MHz, 2.6 GHz	OFDM (Orthogonal FDMA)	LTE	1 to 1.5 Gbps	2009
5G	1 to 4 GHz	OFDMA, Massive MIMO, Beamforming	5G NR (New Radio)	Up to 10 Gbps	2017
6G	3 GHz to 60 GHz	STBC-NOMA	NOMA	10-100 Gbps	2030 onwards

Having learned about the categories of wireless communication technologies and their evolution across the generations; it is crucial to delve into how Artificial Intelligence developed in conjunction with the wireless communication technologies. The next section attempts to show the concurrent development of the wireless systems and the AI systems and how they are becoming interlinked in contemporary use.

3. PARALLEL EVOLUTION OF AI AND WIRELESS COMMUNICATION

The evolution of AI started in 1950s as to examine the nature of intelligence [12]. As per the printed papers of Feigenbaum and Feldman classics, one of the three most important aims of AI was to develop intelligent computer programs and starts building the intelligent systems capable of having decisions of their own. The second goal is to examine the human mind intelligence and to make our computer programs in the similar way. The third aim was to make computer programs that can copy human intelligence to performs some general tasks such as humans do.

AI formally appeared in 1956 during a breakthrough research project that was organized at Stanford University by Marvin Minsky and John McCarthy who are the fathers of AI [13]. It is regarded as the onset of AI as a science. With the advancement in communication technologies, usage, and applicability of AI in general has increased tremendously and this has within modern applications found relevance in a very broad spectrum. One of the greatest achievements in the field of AI was the invention of DENDRAL, the first expert system aimed at mimicking the functions of human experts, which was invented in 1965 [14]. DENDRAL was a knowledge-based system, developed with heuristics-based programming, which was domain-specific and large-scale, and which formed the basis of later AI applications in scientific reasoning and search for hypotheses.

Table 2: Advancements in AI and Communication technologies (1950s-Present)

Duration	AI development	Communication Technologies
1950s - 1960s	The symbolic and rule-based systems developed for machine learning models	The development of First generation 1G analog communication technologies developed
1970s - 1980s	The time when expert systems almost mimic the human expertise in specific domains	Second-generation communication (2G), introduction of digital voice and SMS services
1990s	Various advancements done in machine learning, neural networks revival, AI applied to games and data processing	Third-generation communication (3G), mobile internet and multimedia services
2000s	Advancement in big data analytics, AI-enabled automation, natural language processing	Fourth-generation communication (4G), high-speed data transfer for mobile internet
2010s -	Deep learning breakthroughs, AI	Fifth-generation communication (5G), ultra-

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Present	applications in vision, speech, and autonomous systems	reliable low-latency communication for IoT and AI-powered systems

The various advancement done in AI and communication technologies has been shown under the Table 2; where evolution of artificial intelligence and wireless communication technologies were developed such as 1G to 5G [15][16][17].

With the advent and evolution of artificial intelligence, applications of new era evolved and to exploit their features, the wireless communication technology need to be updated [18]. Keeping these things in view, the vast number of AI enabled applications has been developed where 3G, 4G, 5G and now soon 6G will going to play a vital role in technological advancement. The data rates and network connectivity at high bandwidth rates in 5G is a significant improvement, where latency is also at minimum side. However, the power consumption in 5G is more and to optimize power consumption in 5G network is a big challenge. The 5G network systems basically offers three type of core services such as massive machine type communications (mMTC), ultra reliable low latency services (URLLC) and enhanced mobile broadband (eMBB). First, mMTC offers high connectivity with low data rate and ess power consumption as well. such technologies can be employed in IoT application such as smart agriculture, smart health devices etc. Secondly, URLLC offers ultra reliable communication with latency less than 1ms and used in time bounded applications such as robotics healthcare services, industrial robotic services. Smart meters, train management etc. Thirdly, eMBB is employed for rapid data rate where it does not concern about the energy efficiency; however the latency is very low.

Various applications are available where 5G facilities are employed along with AI such as smart education, smart business smart agriculture, smart health, smart home, smart security, smart traffic, smart wearables, smart grid, smart agriculture etc [19]. Various notable studies have shown the employment of 5G with AI in application such as autonomous vehicles. The 5G with AI can be used for high-definition simulations (using AR & VR) and big data maps. Further the use of 5G and AI can be witnessed in optimized path selection for wireless sensor networks using whale optimization algorithm, whereas the various types of resources can also be managed using AI. Moreover, the fundamentals of machine learning and deep learning which is a branch of AI itself can be used for managing the network traffic in more optimized way. Further AI can provide more security, privacy and can defend from various attacks while data communication through wireless medium. Consequently, the fusion of AI and new world communication technologies save ample of resources during communication for enhancing the duration of services.

AI mechanisms gain popularity with communication technologies such as 4G, 5G, 6G due the early detection of network traffic, reduced latency, and less power consumption [20]. AI is known as diverse number of names such as machine learning (ML, supervised learning), reinforcement learning (RL, unsupervised learning). Although the similar development of wirelessly-based communication technologies and AI make it evident how the technologies in question evolve by themselves, their joint adoption is the driver that leads to groundbreaking evolvement of real-world performance. To analyze and gauge performance effect of this integration to communication systems, the following section will be performed.

4. Analysis Of AI-Driven Wireless Communication Systems

To comprehend the relative advantages of deploying AI in wireless communication systems better, an example of performance assessment on four important dimensions namely latency reduction, energy efficiency, quality of service (QoS), and security & privacy is provided. The traditional communication systems follow rigid protocols and have very limited flexibility but the AI enabled communications dynamically adapt themselves to a varying network environment and hence improve the overall performance. This gap improvement in terms of the performance is demonstrated in the figure below in the form of a comparative bar chart, which indicates that AI models perform much better than traditional methods in real-time wireless scenarios.

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(i) Latency Reduction

AI models, particularly Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) networks, have demonstrated significant potential in reducing latency in 5G and upcoming 6G networks [21]. These models predict traffic congestion in real time, allowing for dynamic rerouting of packets and minimizing end-to-end delays. AI-driven scheduling algorithms further ensure timely delivery of data, especially in ultra-reliable low-latency communication (URLLC) scenarios such as autonomous vehicles and telesurgery.

(ii) Energy Efficiency

AI can be used to optimize the energy consumption in wireless communication systems to a considerable extent. Idle times in base stations and user apparatus are predicted by applying methods e.g. reinforcement learning and supervised predictive models. The predictions allow energy-conserving behavior, including scheduling of sleep mode, dynamically scaling resources, and energy-efficient routing. Consequently, AI helps to extend device lives and minimize running cost, more so in densely populated IoT environments.

(iii) Quality of Service (QoS)

AI has an increased QoS, intelligent traffic classification, and prioritization according to real-time applications. Jitter, throughput, loss of packets, and bit error rate are also monitored constantly through AI models. AI provides a stable delivery of network services, allowing smooth streaming of multimedia, voice over IP, and augmented reality, or virtual reality, despite changes in network loads.

(iv) Security and Privacy

Anomaly detection systems that use AI, such as supervised classification models and deep autoencoders, are central in enhancing wireless networks security. Such systems recognize abnormal traffic activity, and such helps to detect Distributed Denial of Service (DDoS) attacks, jamming, spoofing, and unauthorized access. Moreover, AI promotes privacy-protecting methods, including federate learning, which enables training the model on the local device without disclosing the raw information.

(v) wireless systems across key performance metrics

The results of the comparative analysis shown in figure 3 clearly illustrate that AI-enhanced wireless communication systems imply the significant benefit of improvement in the most critical performance parameters. Through the utilization of smart algorithms to do predictive, optimization, and anomaly detection, these systems will overcome the prolonged drawbacks of latency, energy efficiency, and adaptation. With the development of wireless networks to the 6th and even 7th generations, AI will not only prove beneficial to but also indispensable in realizing ultra-relies, low-, latency, secure, and resource-efficient networks. Leveraging on the in depth performance analysis of AI based communication systems, the next section serves as a summarized conclusion and addresses the possible future research and implementation paths.

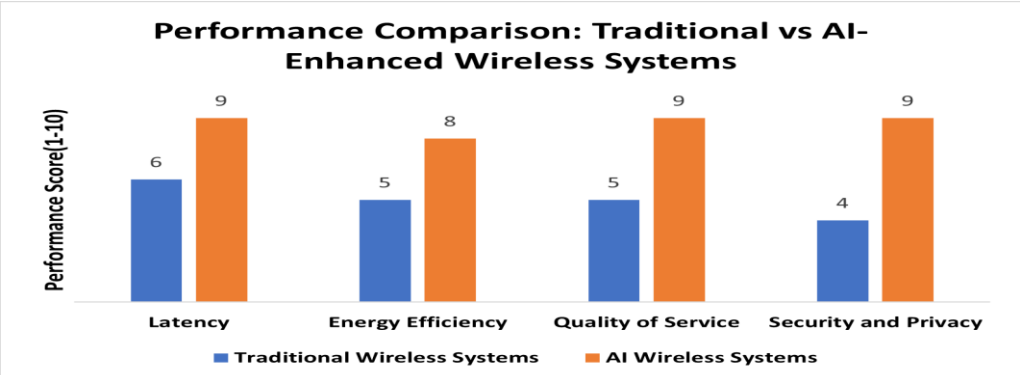

Figure 3: Comparison of traditional and AI-enhanced

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5. Conclusion And Future Scope

The AI and the next generation of wireless broadband communications and technology are poised to change the healthcare domain with the introduction of smart, real-time, resource-efficient services. Healthcare systems are becoming more predictive, individualized, and available, using AI-based analytics and WSNs. The integration is also relevant to specific fundamental issues like latency, congestion in the network, energy waste, and security especially in essential devices functioning like a remote surgery, elderly care, and emergency response. Moreover, AI will enhance the intelligence of the general system by enabling dynamic routing, threat detection, and an efficient process of allocating resources, which will make wireless healthcare systems stronger and more adaptable.

As 6G enters its commercialization phase, its ultra-high bandwidth, THz communication and low-latency would take healthcare to new heights, including haptic internet enabled remote surgery, holographic communication in diagnostics, and instant digital twin of a patient. Possible future work will create AI models that enable running on lightweight edge devices, privacy of the data (federated learning and explainable learning aspects), and connecting heterogeneous networks and devices. Also, to provide smooth, smart health services all over the world particularly in remote or underdeveloped locations, collaborative systems among AI, cloud, fog and edge computing need to be structured to achieve this objective.

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