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Review Article

Artificial Intelligence in Radio Communication: A Facile Overview from the Nigerian Perspective

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ABSTRACT

Recent advancements in communication technologies employ and use artificial intelligence (AI) algorithms to provide quality network services and efficiency to the end user. AI has evolved and progressed in virtually every aspect of human endeavour since its inception a few decades ago. Likewise, radio communication in the telecommunications sector has gained momentum in AI applications to solve problems encountered with network operations. This paper therefore aims at providing a precise overview of AI advancement in radio communication and the challenges of AI implementation in radio communication in Nigeria.

1. INTRODUCTION

The evolution and development of artificial intelligence (AI) has greatly increased since its emergence at the Dartmouth meeting in 1956 in the United States of America (Buchanan, 2005). Remarkable achievements have been made over the years in the applications of AI, especially in medical diagnosis, environmental and agricultural processes, and education, as well as in the telecommunication domain (Ukhurebor, et al., 2019; Ukhurebor, et al, 2020; Ukhurebor, et al., 2021).

Telecommunications and information and communication technology (ICT) are critical components of achieving the Sustainable Development Goals (SDGs), which aim to create a world in which economic, social, technological, and environmental development are available, accessible, and sustainable for all people, regardless of location. Even since the discovery of wireless communication technologies, which are a major aspect of telecommunications, ICT has played a vital role in evolving telecommunication technology and climatic conditions (Ukhurebor, et al., 2019; Odesanya and Ukhurebor, 2020). Figure 1 shows the evolution of the cellular (wireless) system.

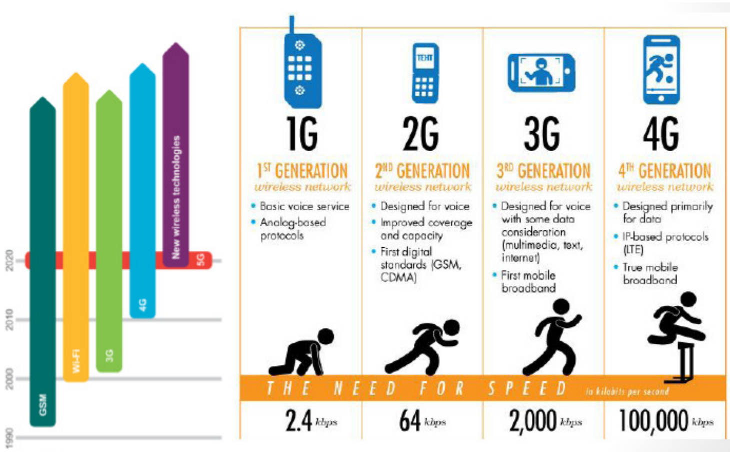

Figure 1: Cellular (wireless) system evolution (adapted from El-Banna,2014)

Radio communication networks can deliver ultra-low latency, high data rates, and high quality of service in the communication industry. Radio communication in mobile networks is relatively large and multifaceted. The complex nature of radio technologies demands innovative approaches, especially in advanced algorithms, in order to fully utilize the signal space. With the growing number of users of radio communication, there are bound to be differences in individual preferences in service packages. Without an advanced algorithm, it may be difficult to meet the special demands of individual users (Bhandari et al., 2017; Wasilewska, et al., 2021).

Beginning with the design complexity of radio frequency (RF) systems, AI promises to overcome this issue by utilizing strong machine learning algorithms and vastly enhancing RF factors including channel bandwidth, antenna sensitivity, and spectrum monitoring (National Instruments, 2022).

Engineering efforts have so far been focused on using technologies like cognitive radio to make individual wireless network components smarter. These piecemeal optimizations, however, have been proven to be labour-intensive and involve efforts to hand-engineer feature extraction and selection that can take months to create and deploy (Bhandari et al., 2017; Tyokighir et al., 2023). They are aimed at applications like spectrum monitoring. However, AI manifestations such as deep learning and machine learning can use data analysis to communicate radio signal types in a matter of hours. In contrast to conventional approaches based on iterative and algorithmic signal search, detection, and classification, a trained deep neural network performs these tasks in a matter of milliseconds. Just a few seconds after signal recording, deep learning enables the training of RF signals (Figure 2) (National Instruments, 2022).

It's vital to remember that such improvements also result in a significant decrease in power consumption and computing needs. Additionally, a good communication system enables wireless designers to give top priority to important design factors like throughput, latency, range, and battery usage (National Instruments, 2022). A greater understanding of the operational environment is made possible by deep learning-based training models, which also promise to provide end-to-end learning for developing the best possible radio system. A training model that includes RF components, antennas, and data converters and can simultaneously learn an encoder and a decoder for a radio transmitter and receiver is a good example. Additionally, the commoditization of the physical layer and signal processing architecture is what emerging technologies like deep learning promise for the wireless sector. Active radio waveforms and deep learning-based sensing work together to produce a new class of use cases that can function intelligently in various radio environments (National Instruments, 2022). Hence, the paper briefly and precisely discusses the evolution, development, and advancement of AI in radio communication and some of the utmost challenges of AI implementation in radio communication, as drawn from the Nigerian scenario.

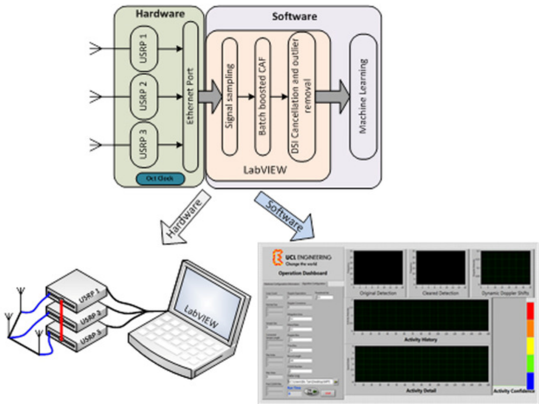

Figure 2: Deep learning allows training of RF signals just a few seconds after signal capture (National Instruments, 2022)

2. INTELLECTUALIZATION

The telecommunications sector has developed over the years from the first-generation network that was basically a voice and circuit switch gate service (Adelakun, et al., 2019; Ukhurebor and Nwankwo, 2019; Odesanya and Ukhurebor, 2020). The circuit switch gate of the 1G network was also capable of transmitting faxes to the 5G network, with network algorithms becoming more advanced and heterogeneous in nature (Ajiboye, et al., 2007; Bhandari et al., 2017; Tyokighir et al., 2023).

Operators in the telecommunications industry have witnessed some advantages in AI applications in terms of computing power, big data research, a large customer base, and numerous investment opportunities in AI algorithm research. Also, the communication industries have a large data infrastructure base with a teeming number of users worldwide; this makes AI a readily available tool in the telecommunication industry. The development of 5G wireless cellular networks and its applications in virtually all areas of human endeavour pose a great and interesting future for AI developers. 5G-supported devices will require wireless networks in order to attain reliability, a minimum transit time, and availability in service delivery (Weiner, et al., 2014).

Systems and nodes must be aware of their operational context in the age of ubiquitous information access and pervasive communication networks. To do this, they must use knowledge of ambient networks, linkages, devices, and applications. Contextual awareness will make it possible to personalize services and increase the effectiveness of currently offered services. For instance, networks will need to be more knowledgeable about application requirements, quality of experience (QoE) and quality of service (QoS) metrics, local (or more global) operational conditions, and precise methods to adapt application flows to meet users' needs in particular environmental conditions (Wasilewska, et al., 2021).

According to Wasilewska, et al. (2021), the context-based adaptations of various transmission and network parameters will have to take into account the device-level, user-level, link-level, network-level, and application-level context. The context information itself consists of different parts and components, each of which affects the individual steps of the decision-making process in a different way. More specifically, various parts that constitute the context are related to the following levels:

- the hardware platform, which poses specific hardware constraints and implementation issues;
- radio environment conditions in terms of location-specific parameters, wireless channel quality, spectrum availability, other users' characteristics and signal features, traffic patterns, interference levels, etc.
- required performance (QoS) parameters that can be identified in all layers of the system protocol stack and are considered to be the basis for the evaluation of decisions made,

- network management policies as a set of rules used to control the behaviour of nodes, manage available resources, regulate interference with other deployed systems, obtain identified trade-offs, etc.

3. BENEFITS OF ARTIFICIAL INTELLIGENCE

In general, AI has numerous advantages over other computing devices in their reasoning and understanding abilities, their capability of collaborating with other networks, and most especially, their learning abilities.

3.1. Reasoning and Understanding Capability

The dynamic nature of the computing network means that the information network system may change when being transmitted to system network management. In this case, the network is only aware of the local information state and may not have knowledge of the internal state of the system. AI has the strength to solve this type of uncertainty problem by constructing a hidden layer model using deep learning techniques to transform sample representation into a new feature space. Before dealing with the uncertainty problem, AI may not have to define the system's mathematical model precisely.

3.2. Collaboration Capability with Other Networks

As a result, AI has the ability to handle the complex structure of communication networks arising from the expansion in scale and size of the network (Guibao, et la., 2018). Tasks and control management are frequently distributed across the network, resulting in task distribution and collaboration in management nodes. By introducing the collaborative and distributive properties of AI into the management network, the system experiences collaboration among distributed network managers.

3.3. Learning Capabilities

A network operator requires smart and intelligent choices in managing complex situations. Already in its cognitive stage, AI is being used in deep learning. AI systems can make use of the training data to process huge amounts of data via data mining, thereby enhancing AI's ability to learn the features inherent in the data and manage and control these features routinely. The learning ability of AI enhances the prediction accuracy and intelligent services of communication in the network.

4. ARTIFICIAL INTELLIGENCE IN RADIO COMMUNICATION

There are various tools developed over the years by AI developers aimed at mimicking human modes of thinking and behaviour in an environment. This helps the machine solve problems and optimize the output of the system. AI has been used in network systems for radio access technology (RAT) selection by employing the parallel fuzzy system (PFS) to determine network selection probability (Datta and Kaushal, 2015). By automatically classifying the KPIs, a neural network was used to correlate key performance indicators (KPIs) with quality of experience (QoE) in mobile operators (Banupriya, et al., 2018). Sangeetha and Aruldoss, (2016), employed reinforcement learning algorithms in wireless communication to self-organize and self-heal cell outages.

Two design case studies are shown here to show the potential of AI technology in wireless communications as reported by the National Instruments (2022), they are as follows:

First, users can train signal detection and classification sensors using the OmniSIG software development kit (SDK) from DeepSig Inc. This kit is based on deep learning technology and uses real-time signal processing.

The passive Wi-Fi sensing system for monitoring health, activity, and well-being in nursing homes is another design case study demonstrating how AI technologies like deep learning can influence future hardware architectures and designs (Figure 3). A thorough analysis of the Wi-Fi signals that reflect off a patient is performed by the continuous surveillance system developed at Coventry University using gesture recognition libraries and machine learning systems for signal classification. This analysis reveals patterns of body movement and vital signs (National Instruments, 2022).

A passive Wi-Fi sensing system is a receive-only device that tracks changes in the dynamic Wi-Fi signal brought on by moving interior targets traveling along different paths. Here, engineers can use frequency to calculate the rate at which the phase will change over the course of the measurement as well as Doppler shift to detect movements thanks to AI technologies like machine learning (National Instruments, 2022).

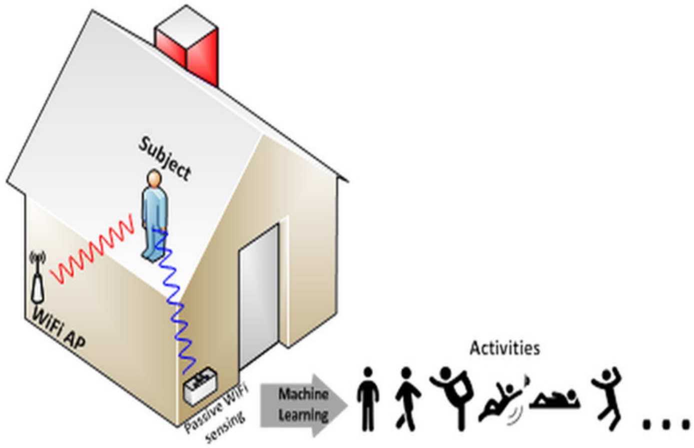

Figure 3: Using the Doppler-time spectral map, machine learning enables designers to categorize radio signals for identifying daily activities (National Instruments, 2022)

The relationship between physical activity and the Doppler-time spectral map connected to movements like picking something up or sitting down can be established by machine learning techniques. The data batches' phase is precise enough to detect the minute motions of the body brought on by breathing. LabVIEW software was used by Coventry University to record, process, and decode the raw RF signal samples in order to construct a prototype of a passive Wi-Fi sensing system. Engineers can manage complicated system setups and fine-tune signal processing parameters with LabVIEW, an intuitive graphical programming environment for both processors and FPGAs. By tackling a wide range of RF design domains and developing new wireless use cases, the aforementioned design examples demonstrate how AI technologies like machine learning and deep learning have the potential to change the RF design industry (National Instruments, 2022).

5. THE NIGERIAN PERSPECTIVE ON THE IMPLEMENTATION OF ARTIFICIAL INTELLIGENCE IN RADIO COMMUNICATION

In developing nations like Nigeria, there is a deficiency in data acquisition in terms of the number of network users, location, transit time, quality of service delivery, power supply, access to the internet, etc (Tyokighir et al., 2023). The unavailability of these parameters can and will certainly limit the implementation of AI in radio communication. Inadequate power supply is one of the biggest challenges facing the telecommunications sector in Nigeria (Lawal, et al., 2016; Ukhurebor and Nwankwo, 2019). To successfully implement AI in radio communication, there has to be a steady supply of electricity. In Nigeria, achieving or implementing AI in radio communication requires the efforts and synergy of experts in various fields of software development. Hence, there is a need for AI specialists to organize and train human capital on the implementation of AI in radio communication. The future of AI applications in radio communication in Nigeria is bright considering the nation’s large population. As a result, policymakers must make resources available to stakeholders for a proper and comprehensive implementation of AI in radio communication.

Radio communication advancements have always been assertive at the frontier of radio machineries. Presently, radio communication networks can offer very high data rates, ultra-low expectancy, and high dependability to serve the essence and purpose of the communication sector. However, radio communication technologies have become extremely multifaceted, and this calls for innovative solutions. The current advances in AI, together with data mining, machine learning, and big data analytics, bring substantial capacities and potential for addressing some of the difficulties in radio communication networks (Nwankwo and Ukhurebor, 2021; Chen, et al., 2020). It has been one of the fastest growing trends in moving intelligence beyond the spectrum access that intellectual radio is primarily aimed at, addressing several challenges in radio communication networks such as modulation, channel modelling, radio resource allocation, beam forming, network management, and so on (Chen, et al., 2020; Nwankwo and Ukhurebor, 2019; Ukhurebor and Azi, 2019).

Evidently, there are few or limited studies that discuss the development, implementation, and advancement of AI in radio communication in Nigeria. Consequently, it is recommended that researchers and all other pertinent stakeholders in the communication domain focus on this evolving intelligence of radio communication networks (intelligent radio), in which AI algorithms and frameworks are utilized.

6. CONCLUSION

Radio communication network technologies are the means of evolving the intelligence of radio communication networks (intelligent radio), in which AI algorithms and frameworks are employed in learning from their surroundings (environments) and exploring the concealed characteristics of radio communication networks for innovative capacities, performances, and potentials as well as services. As previously mentioned, there are few or no studies that discuss the development, implementation, and advancement of AI in radio communication in Nigeria. Hence, it is suggested that researchers and all other relevant shareholders in the communication domain should key into this evolving intelligence of radio communication networks (intelligent radio), in which AI algorithms and frameworks are utilized. It is alleged that the intelligence of radio communication networks will be one of the most prominent features of subsequent-generation wireless radio communication networks. The use of AI in wireless networks is still in its infancy. However, the presence of commercial technologies like USRP indicates that the AI revolution has begun to impact wireless. Therefore, it is pertinent that interdisciplinary research that will integrate the advances in AI, radio communications, cloud technologies, and computing be conducted. Both applied and theoretical innovations are anticipated in this new-fangled aspect.

7. ACKNOWLEDGMENT

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8. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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