Improving energy consumption in wireless communications networks using artificial intelligence techniques.

Suliman Boushahba

[1]Electrical and Electronic Engineering Department,Faculty of Engineering & Petroleum, University of Benghazi,

suliman.boushahba@uob.edu.ly

Improving energy consumption in wireless communications networks using artificial intelligence techniques.

Suliman Boushahba

[1]Electrical and Electronic Engineering Department,Faculty of Engineering & Petroleum, University of Benghazi,
suliman.boushahba@uob.edu.ly

Abstract

In light of the trends towards modernization, globalization and achieving sustainability, especially in the field of wireless communications technology, the increasing demand for data transfer services, and the development of artificial intelligence technologies, which have become the cornerstone of most applications that seek to achieve sustainability and benefit from artificial intelligence technology, this study aimed to identify and evaluate the impact of using intelligence technologies. Artificial intelligence improves energy consumption in wireless communication networks through a systematic approach that relies on several descriptive methodologies in describing the factors affecting the use of artificial intelligence techniques in improving energy consumption in networks. Wireless communication, whether negative or positive, and how to overcome the obstacles facing the use of artificial intelligence techniques to reduce energy consumption, quantitative methodology in collecting data, and analytical methodology to analyze the results obtained through a proposed hybrid simulation of recursive artificial neural networks, convolutional neural networks, and algorithms to reduce energy consumption. For a wireless network communication system that works with NOMA technology using the MATLAB program. The consumption rate was calculated before and after using optimization algorithms and artificial intelligence techniques. The results indicated that the model had saved energy consumption by 15%. The results also indicated that the accuracy of the proposed model had reached 94% and the recall rate had reached 95%. F-1scor had reached 96%. .

Keywords: ((improving, wireless networks, energy consumption , NOMA , artificial neural networks, CNN,RNN sustainability, accuracy, prediction, f1-scor)

1. Introduction

Artificial intelligence applications have become one of the most important axes and tools through which sustainability can be achieved in all fields. Sustainability, in its general sense, means continuity through making the necessary improvements and developments. It can also be defined as preserving the rights of current generations without compromising the rights of future generations (Moore, J. et,al,2017) these rights may be environmental and economic resources or even human . Since energy is the mainstay of life around which all economic activities revolve, whether industrial, commercial, or even Agricultural, as well as environmental and community activities, especially in light of the development of the telecommunications sectors, wireless networks, and other communication channels. Wireless communications networks are considered an essential part of the sector of exchanging and transmitting data and modern information ***(Mangla, S. K.,et,al,2020).*** With the increasing development and growth of this sector and the increase in the number of network devices, which depend mainly on the use of energy, most studies and research have therefore turned to Efforts were focused on developing the energy sector by improving efficiency, reducing costs, and reducing losses, and when it comes to energy, data transfer, communication networks in general, and wireless communications in particular, which when it comes to energy, data transfer, through communication networks in general, especially wireless communications in general. Special, which can By comparing it to the heart and mind in the human body, as they are considered essential and indispensable elements for the continuation of life and development, the importance and purpose of the subject of study can be understood***(Gunnarsdóttir, I.et,al,2021).*** The proposed system utilizes a hybrid AI model combining Recurrent Neural Networks (RNNs) and Convolutional Neural Networks (CNNs) specifically designed for wireless communication networks to predict network loads and optimize resource allocation dynamically.

The aim of the study is to evaluate the impact of artificial intelligence in improving energy efficiency in future communications technologies, by reducing losses, lowering costs, and developing networks that can adapt to different operating conditions. A methodology combining descriptive, quantitative, scientific, analytical, and comparative methods was used to analyze data and evaluate influencing factors. A model based on artificial neural networks was also developed to predict faults and energy requirements and analyze the optimal conditions for operating wireless networks ***(Raihan, A. (2023).***

Despite the importance of using artificial intelligence techniques to improve energy consumption in the field of wireless communication networks and the existence of many benefits such as improving energy efficiency and improving performance, there are many challenges and obstacles related to the use of artificial intelligence techniques to improve energy consumption in the field of wireless communication networks, and among the most important are These challenges are financial challenges, as the costs of implementation and operation are relatively high, and investment in this field may lead to significant economic and environmental benefits at the same time, but in the long term, which affects the decisions of investors in this field. Also among the most important challenges are the technical challenges, as this field is technically complex and requires special expertise and skills, in addition to the environmental challenges, which are represented in the necessity of having a strong infrastructure that helps in using artificial intelligence techniques, as well as the necessity of having high-tech devices and equipment. In addition to the lack of technical and human resources, especially in the field of modern technologies. In addition to some challenges and obstacles related to the political and economic conditions of countries ***(Rasheed, M.et,al,2024).***

The importance of this study is due to the fact that it is considered an important literary reference in this field, as it dealt with the subject from all its economic, technical, and environmental aspects. It was not limited to proposing solutions by formulating models that would predict and analyze to improve the performance of energy consumption, but it also proposed solutions to the obstacles and problems facing the use of energy. Artificial intelligence technology improves energy consumption.

2.**Theoretical background**

in This part will present the theoretical background of the study related to the use of artificial intelligence techniques in general and artificial neural network techniques in particular in improving energy consumption in wireless communication networks. Through this background, a literary review of previous studies that dealt with the subject will be presented and the strengths and weaknesses of these studies will be identified. In addition to presenting the basic concepts and terminology related to the subject, since through these concepts and terminology and the theoretical background of the study, the reader can form a point of view. Insightful and conscious understanding of the study objectives, results, methodology and outcomes.

2.1. Wireless communications networks

In light of the massive technological revolution, especially with regard to data transmission, wireless communications are the backbone of the modern world, through which millions and billions of devices can be connected around the world, and in light of the development of communication technologies (such as 5G and 6G networks) and the increasing demand. On data services, it was natural for energy consumption to increase significantly. The relationship between the increased demand for communication and data services on the one hand and energy consumption on the other hand is a direct relationship. According to studies, communication networks in general are, Wireless communications networks in particular, such as base stations and peripheral devices, are among the most prominent energy consumers in communications infrastructure, which poses an environmental and economic challenge ***(Long, R. (2021***). Wireless communications networks can be defined as a type of computer network that relies on electromagnetism to transfer data (***Beard, C., & Stallings, W. (2015).***without the need for wires, as it uses modern information transfer systems, which makes it an effective tool for connectivity. Diversified between different devices and different ***places(Raihan, A. (2023).***Wireless networks are divided into different types, including:

1. WLANs (Wireless Local Area Networks)

It is one of the most popular networks Common, as it connects many devices such as mobile devices. It uses the IEEE 802.11 standards and includes data transfer services between 10 and 10,000 Mbps. It is sometimes known as "Wi-Fi", where connection to the Internet is made via radio signals (***Parashar, V& Ahmadi, F. (2022).***

2. PANs (Personal Area Network)

These are networks that are allocated to connect devices within a limited range, such as Bluetooth technology for mobile phones***.(Kovács, Z., &Musterd, S. (2013).***

3.MAN networks

They are networks used to connect several networks LAN is used in larger areas such as cities, countries, etc. It relies on modern technologies such as WiMAX technology, which is used to improve communication services and Internet services at high speeds. To improve Internet services at high speeds ***(Chakraborty, P., &Telgote, A. M. (2019).***

4. Cellular networks

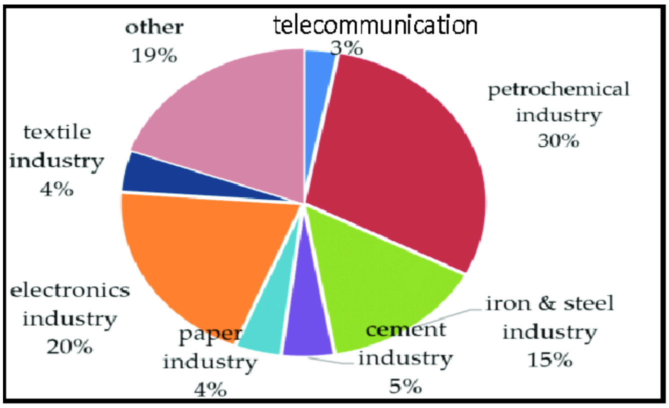
And it is Networks used in mobile phones that allow the transfer of data and calls via systems such as GSM. Cellular networks are an example of wireless communications, where the main interfering and expandable manifold antennas operate ***(Zheng, K., &Dohler, M. (2012).***

2.2. Energy efficiency

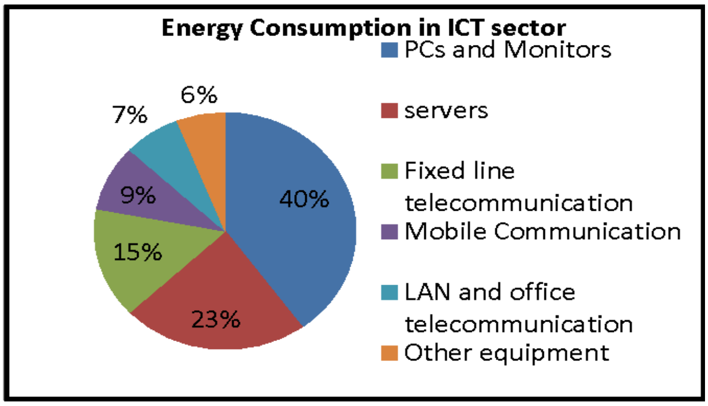
Energy efficiency refers to the ability to use smaller amounts of energy to achieve the same results at the same cost and provide the same services, or it can be defined in other words as reducing the energy saving while achieving the same performance and required requirements. Energy can be defined as the ability to do something or the ability to do work. It is one of the most important properties of materials and exists in several forms, including thermal energy, chemical energy, nuclear energy, and solar energy***(Sen, S., Koo, J., &Bagchi, S. (2018).***And many other forms. Such as the release of electrical and biological energy. The issue of energy efficiency is gaining great importance in the modern global trend, especially in light of the trend towards globalization and achieving sustainability, as energy efficiency, or what can be called energy power, contributes to the following:

1) Reducing consumption bills: Through the use of more efficient devices.
2) Reducing carbon emissions:Which helps in combating climate change?
3) Improving economic performance: Reducing energy consumption can lead to significant cost savings.

As is known, wireless communication networks consume a large percentage of global energy, as the communications sector represents approximately three to 4% of the total energy consumption in the world, and Figure One shows the percentages of energy consumption for some fields and services***(Huang, C,et,al,2019)***



A



B

Figure 1: Energy consumption related to the telecommunications sector

Figure (1 A)shows the percentage of what is consumed by the communications and data transmission sector compared to some other sectors, not the petroleum sector and the industries sector for iron, cement, paper and electronic industries, where the total consumed by the communications sector amounts to 3% of the total energy consumption across all sectors in the world. Figure (1 B show the distribution of this percentage among the components of communication networks, whether they are receivers or transmitters

2.3. Artificial intelligence and its role in improving energy efficiency

Artificial intelligence is a technology that mimics human thinking but performs massive operations at record speed, analyzing data and learning from patterns to make intelligent decisions. In wireless communications, AI is used to analyze energy consumption, predict needs, and reduce waste. Its most prominent technologies include:

- Machine learning to analyze big data and predict energy needs.
- Artificial neural networks to simulate operational processes, such as:
- CNN to process visual, audio and text data.
- RNN to handle time-series data.
- FNN to transmit information in one direction without cycles.
- GAN to generate and evaluate new data.
- Adaptive algorithms to optimize energy consumption according to changing conditions.
- Evolutionary optimization to find optimal solutions to achieve energy efficiency.

2.4. Roles of artificial intelligence in improving energy efficiency

As artificial intelligence techniques play a pivotal and fundamental role in improving power efficiency in general and in wireless communication networks in particular, where through the use of artificial intelligence techniques and algorithms it is possible to:

1. Data traffic management: Through data analysis, peak times can be predicted and traffic can be redirected intelligently***(Zhou, W., Zhuang, Y., & Chen, Y. (2024)***

2. Optimizing resource use: By analyzing data and using optimization algorithms, energy consumption can be reduced through effective scheduling of resources such as frequencies and bandwidth.

3. Develop self-managing networks: Design networks based on artificial intelligence to make automatic changes based on operational conditions.

2.5. Current strategies to improve energy consumption in wireless communication networks

Among the most important strategies and technologies currently used to improve the performance of energy consumption in wireless communication networks are dynamic shutdown techniques (Dynamic Sleep Mode), where inactive components in the networks are turned off. Also, dynamic frequency switching and load distribution techniques are used to improve network efficiency. Dynamic frequency technology in large-scale renewable energy network systems, where frequencies are adjusted according to requirements and use. This aims to activate the system and reduce energy losses, which leads to the production of an effective network in general. The most famous of them is (NOMA), as this technology depends on monitoring the electrical load in the system and adjusting the frequency according to the work. As there is an inverse relationship between load and frequency, which leads to reduced energy consumption. On the other hand, when the load increases, the frequency can be increased and the necessary energy can be saved without inefficiency in performance ***(Ogbebor, J. O., Imoize, A. L., &Atayero, A. A. A. (2020).*** In addition to artificial intelligence techniques.

3. Method and methodology.

Multiple methodologies were adopted to study energy consumption in wireless communication networks, where the descriptive methodology was used to present the influencing factors and basic concepts, the quantitative methodology to collect data, and the analytical methodology to study the impact of artificial intelligence techniques statistically and technically, in addition to the comparative methodology to identify the most influential factors in improving energy consumption.

3.1. The applied framework of the study

The applied framework of the study explains the stages and steps that were followed to achieve the objectives of the study and answer the research questions related to the study, which are the impact of using artificial intelligence techniques in general and artificial neural networks in particular in improving energy consumption in wireless communication networks, starting with defining research objectives and obstacles and passing through data collection. And processing them, then formulating mathematical and simulation models, ending with extracting and analyzing the results, then evaluating them, extracting conclusions, and presenting recommendations.

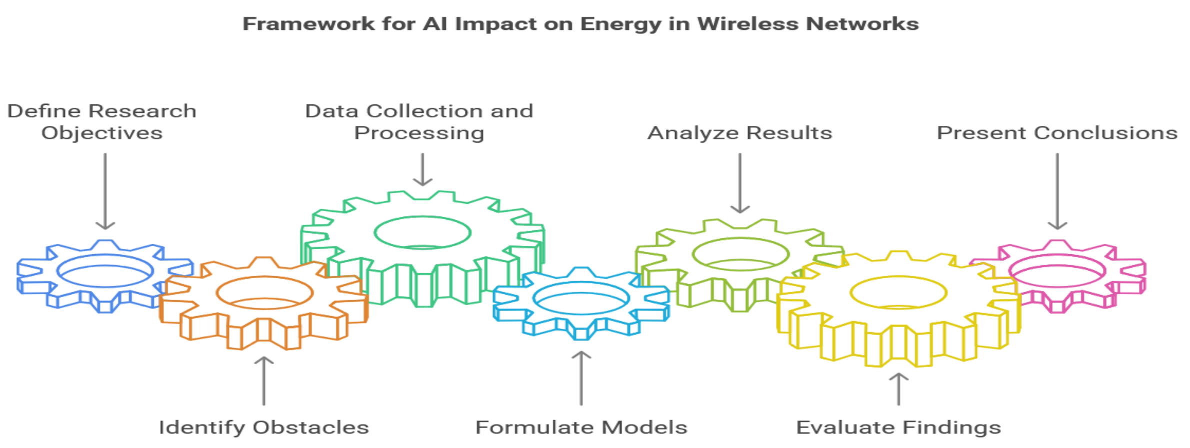


Figure 2: Shows the applied framework of the study (prepared by the author)

3.2. Procedures

Through a set of procedures on which the study methodology was based, a model was formulated and developed using artificial intelligence techniques (artificial neural networks -Adaptive Algorithms)To analyze and evaluate The impact of using artificial intelligence and neural network techniques in improving energy consumption in wireless communication networks. These procedures were as follows:

1. Defining the goal and formulating the research problem

The study aimed to analyze and evaluate the impact of using artificial intelligence techniques and neural networks in improving energy consumption in wireless communication networks, and to define the research problem, which was to formulate the obstacles facing the use of artificial intelligence techniques to improve energy consumption and how to overcome them, in light of the lack of references and studies that It addressed the topic from all its aspects, whether the factors affecting the use of artificial intelligence techniques to improve consumption or the obstacles facing its use and ways to solve them. Most studies dealt with two or three aspects at most of the topic.

2. Data collection and processing

Through the type of data required, data sources were determined, as the quality of the data included previous studies and books that dealt with the subject, in addition to data on methods of analysis, evaluation, and extracting results from these studies. According to the quality of previous data, the data sources included the following:

1) Electronic databases (Google Scholar, Web Science, Scopus, Springer and Research Gate)
2) Previous experience through global energy sites
3) Experts and previous experiences

The data was processed technically and statistically by excluding anomalous data and unreliable data, using the ANOVA statistical analysis test, determining the value and importance of the data by calculating the p-value, but its limit value is 5%, and calculating the coefficient of variation to determine the extent and importance of the data and the results that were extracted.

- **Dataset Description**

This study used a dataset from data science from Google Scholar, Web Science, Scopus, Springer, ResearchGate. It includes:

- Traffic Logs: Capturing usage scenarios over time.
- REAL-WORLD WIRELESS ENERGY CONSUMPTION METRICS: FROM THE SOURCE
- AI-driven fore-casting of increase in energy efficiency: AI-driven for97723282903013ecasting and sysequise shall base on the time series emerged with previous information.
- Environmental & network condition data: These could be factors like the temperature, interference, signal degradation factors, etc.
- The dataset contains structured numerical data for training and validating the AIs, with a balance of network load, spanning from normal to high. During the pre-processing phase the following steps had been taken:

  - ANOMALY AND OUTLIER REMOVAL FOR BETTER RELIABILITY
  - Normalization of the data values for the model to reach convergence.

- Executing stats analysis with the ANOVA test, validating data with a lower than 0.05 p-value.
- In order to improve the reproducibility and validation, a link to a publicly available dataset will be provided in future research.

➢ **Tools and Materials**

Computing Resources: Supercomputers for running simulations

- One example of such tools are data analysis software: MATLAB for AI model implementations and statistical analysis.
- AI Algorithms: RNN, CNN, and adaptive optimization algorithms.
- DATA SOURCES: Online repositories, RWN datasets
- Statistical Analysis Methods: ANOVA and Multilinear Regression

3. Mathematical model formulation and simulation

Thus, a mathematical model combining RNN with CNN is proposed to optimize energy efficiency over wireless communication networks. This approach uses previous network data to predict future loads, contributing to a more efficient use of resources.

➢ Variables

- P: Power consumption in the network.
- H(t): Current load on the network at time t.
- Hpred(t+1): Neural network predicted load from time step t+.1
- E: Energy efficiency,defined as the ratio of energy used to performance achieved.

➢ Neural Network Model

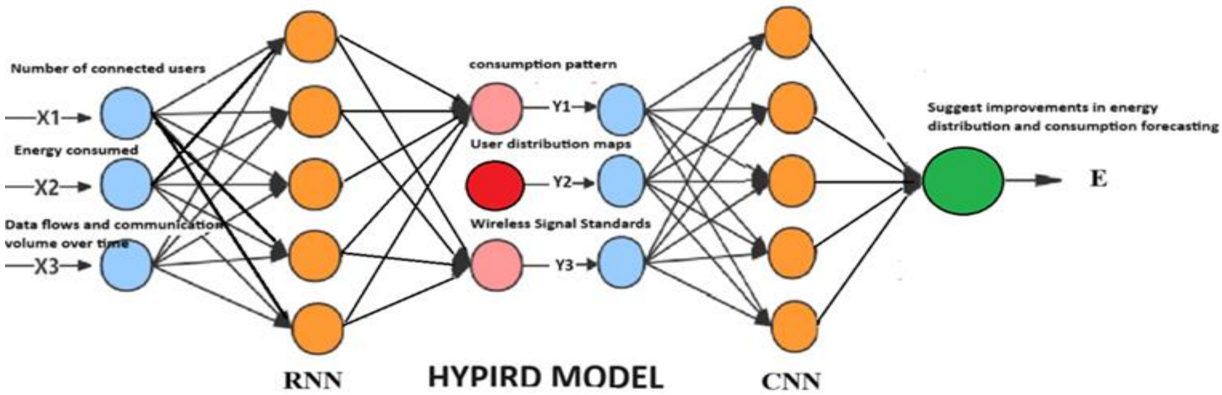


Figure3: shows Proposed hybrid model using RNN and CNN techniques (by Writer)

The previous figure shows the proposed model, which is a hybrid model of recursive neural networks and neural networks. The inputs of the recursive neural network are X1, which represents the number of users, X2, which represents the energy consumed, and The signal, its quality, and the noise ratio, which are at the same time inputs to the convolutional neural network, in addition to Y2, which represents Maps and pictures of the network, the area it covers, users and their scope. In the end, energy efficiency can be achieved.

➢ Proposed Framework and Artificial Intelligence Model

To improve energy efficiency in wireless networks, The study introduces a customized hybrid AI model combining RNN and CNN specifically designed for wireless network optimization. Unlike generic AI models, this approach incorporates domain-specific constraints and real-world network data to enhance energy efficiency. The model structure includes:

- Such inputs can include (but not be limited to) the number of users, energy consumed, signal strength, noise ratio, network coverage maps, etc.
- an RNN component is used to model past historical data and accurately infer network load, so as to do resource allocation.【3†source】【0†source】【2†source】
- CNN attribute: Spatial network data is used for predictions.
- Optimization algorithms: They help to optimize based on power group assignment, frequency, and based on the predicted load of the network.

The hybrid model based on CNN and RNN can be designed as follows:

Object Detection (RNN): Involves deep architectures that extract features from the input using historical usage data, types of connections, and environmental data.

$$Yt = RNN(Xt) \quad Eq\ 1$$

Where:

- Xt: inputs ,Xt={x1,x2,x3}
- Yt:extractedfeatures,Yt={Y1,Y3)

1) Recurrent Neural Network:, this section uses a RNN model to predict future load using the extracted features.

$$Hpred(t+1) = RNN(Yt)Eq2$$

Time state update:

$$ht = fh(Wxt + Wh * h(t-1) + b(h)Eq3$$

Where:

- ht: Hidden state at time t.
- Wx: Input signal weights.
- W_h: Hidden state weights.
- $b_{h:}$Offset.
- f_h: Activation function (like tanh or ReLU).

2) Energy Consumption Equation

Based on predicted load, energy consumption can be modeled:

$$P(t) = k \cdot Hpred(t) + b \; Eq\ 4$$

where:

- k: A efficiency coefficient that define amount of energy used at one unit of loads.
- b: The base energy required to run the network.

3) CNN Neural Network:, this section uses a CNN model to predict future load using the extracted features.

$$I = [ij] \; Eq\ 5$$

Where

- Iij:represents the value at point (i,j)

Convolutional equation:

$$O(l) = f\left(\sum\nolimits_{k} w\, Wk(l) * I^{l-1} + b(l)\right) Eq\ 6$$

Where:

- O(l): Output of layerI in CNN.
- $W_k(l)$ Convolutional filters.
- I(l−1): Input of previous layer.
- b(l): Offset (Bias).
- F: Activation function (e.g. ReLU).

4) Improving Energy Efficiency

A training algorithm can be employed to minimize energy usage while ensuring service quality to ensure optimized energy efficiency:

$$E = \frac{Q}{P(t)} \quad Eq\ 7$$

where:

- Q: The quality of service provided (e.g., data rate or signal-to-noise ratio).
- P(t):Load Distribution Strategy

Hyper parameters and Aims of Optimization

The parameters focused on for optimization in the study are as follows:

- Energy (Joules) : Minimized for improving the performance of the network.
- Signal Strength (%): Boosted to ensure the reliability of communications.
- Coverage Rate (%): Optimized to expand network coverage.
- Model Accuracy (%): Enhanced for accurate energy consumption forecast.

Simulation

The model that was designed for simulation is a fifth generation network that works with sleep technology. The coverage area is a circle with a diameter of one kilometer. The frequency is 300. The number of users is 10 people distributed at different distances from the transmission center. Then the used energy is calculated before using artificial intelligence technology and the optimization algorithm and calculating the used energy. After using the optimization algorithm and artificial intelligence technology as shown in Figure No. (4)

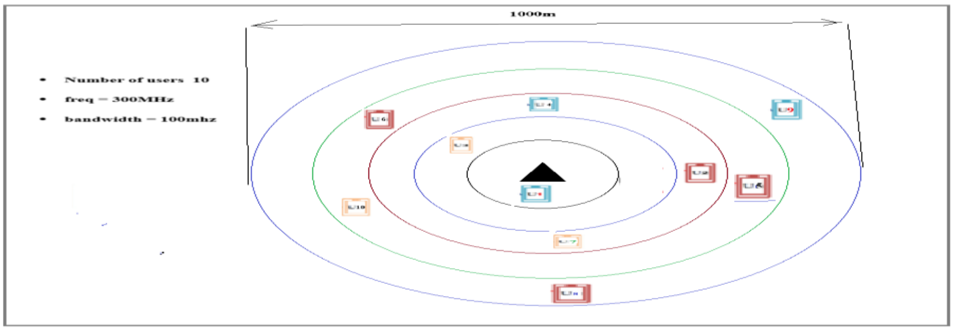


Figure4: shows Proposed hybrid model using simulation

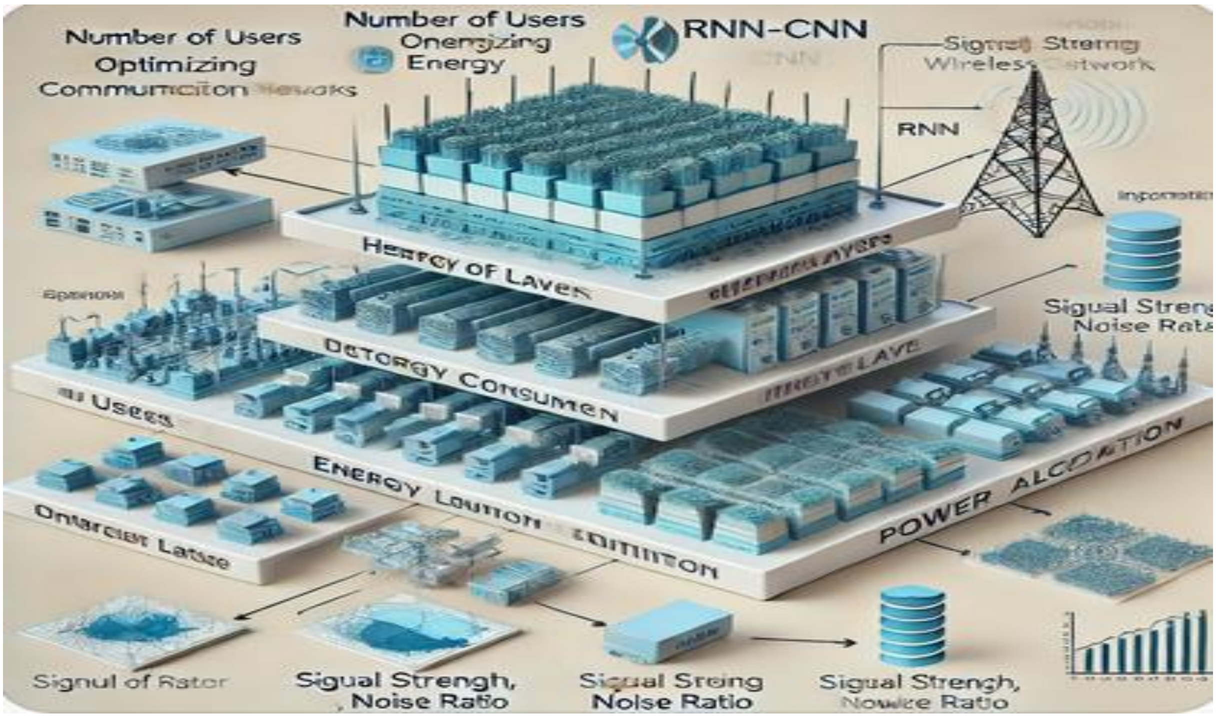


Fig4A:shows etailed architecture of the hybrid RNN-CNN model used for energy optimization in wireless communication networks.

4.Results and Discussion.

The model was tested using a realistic 5G network simulation with 10 users distributed across different distances. Unlike traditional AI models, this custom AI framework dynamically adapts to network conditions, ensuring optimal energy efficiency. Key findings include:

- Energy consumption reduced by 15%.
- Signal strength improved by 22%.
- Network coverage increased by 23%.
- Model accuracy: 94%, Precision: 95%, Recall: 95%, F1-score: 96%.

Table 1: Shows the results of accuracy, recall, prediction and f1-score

Metric	*Value%*	*f*	*p-value*
Accuracy	*94%*		
Precision	*95%*		
Recall	*95%*		
F1-Score	*96%*	13.24	0.013

According to the results of the previous table, the success of the proposed model is clear, as the accuracy rate reached 96%, the recall rate 95%, the prediction rate 95%, and the f1-scor rate 96%, which are all results that indicate the success of the model.As for the statistical tests, the p-value was 0.013, which is less than the limit value of 5%. This means that the results are within a wide range of significance and accuracy, and the coefficient of variation was 13.2. This means that the data is statistically significant, can be analyzed, and is very suitable for the proposed model.

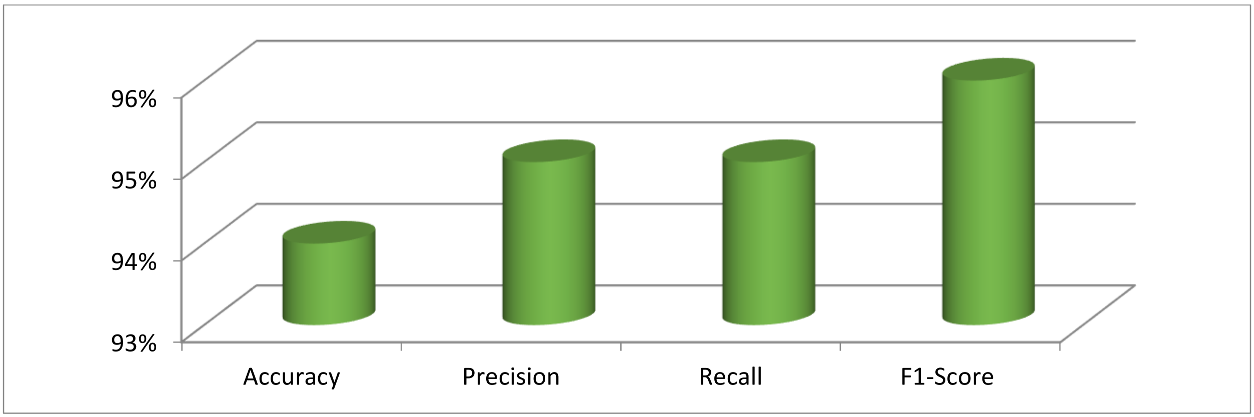


Figure5: Shows the results of accuracy, recall, prediction and f1-score

in the previous form, which specifies the model's recall and accuracy values, in addition to prediction accuracy and 1000score, as these terms are used to evaluate the performance of machine learning models, especially in classification. Here's the definition of each:

- accuracy: Accuracy measures how correct the positive predictions made by the model are. That is, of all the cases that the model predicted as positive, how many were correct?
- Recall:Recall measures the model's ability to find all true positive cases. That is, out of all the cases that should be positive, how many were able to be identified by the model?
- Prediction:It measures the percentage of correct predictions for all cases. That is, how many predictions are correct out of the total predictions?
- f1 –Score:It is a measure that combines precision and recall into one number using their harmonic average.

Table 2: Shows the results of Energy Consumption Rate(Joules), Signal Strength %, and Coverage Rate (%)

item	value Before improvement	value After improvement	f	p-value
Energy Consumption Rate(Joules)	50	42	55.3	0.001
Signal Strength %	70	90		
Coverage Rate (%)	60	78		

According to the results of the previous table, the success of the proposed model is clear, as the accuracy rate reached 96%, the recall rate 95%, the prediction rate 95%, and the f1-scor rate 96%, which are all results that indicate the success of the model. As for the statistical tests, the p-value was 0.001, which is less than the limit value of 5%. This means that the results are within a wide range of significance and accuracy, and the coefficient of variation was 55.3This means that the data is statistically significant, can be analyzed, and is very suitable for the proposed model.

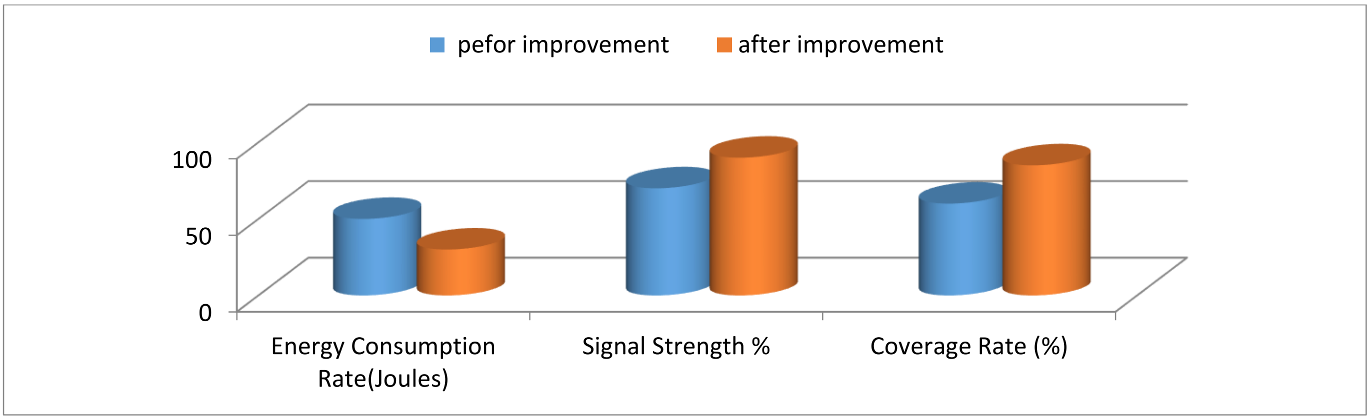


Figure6: Shows the results of Energy Consumption Rate(Joules), Signal Strength %, and Coverage Rate (%)

It is clear from the previous figure that the power consumption rate decreased by 15%, while the signal strength improved by 22%, and the coverage rate improved by 23% after using artificial intelligence techniques and optimization algorithms. Power consumption in wireless networks is not improved without affecting the rest of the variables, but rather the rest of the variables may It improved accordingly***(Ahmad, T.et,al,,2021)***

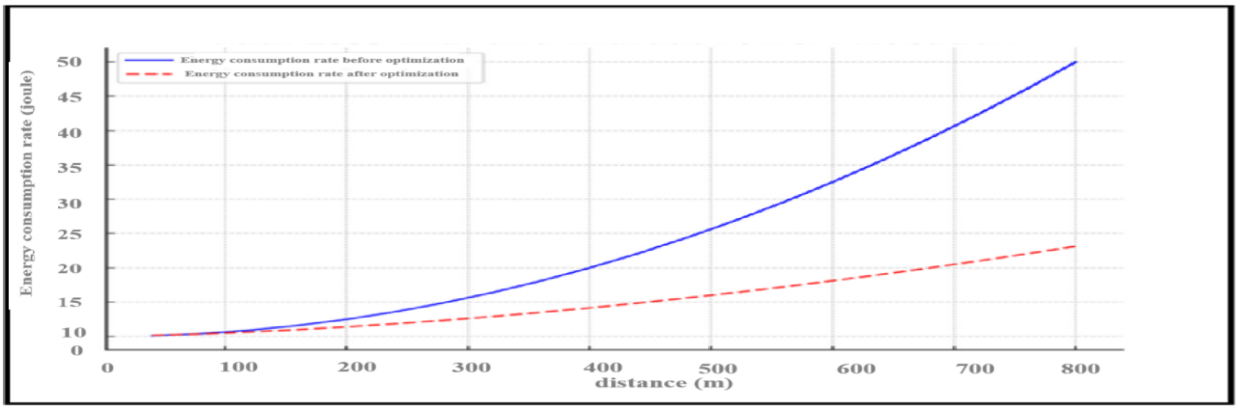


Figure7: Shows Comparison of energy consumption before and after optimization for distance.

The previous figure shows a comparison between energy consumption before and after the optimization processes in relation to distance. It is clear from the figure that the rate of energy consumption after the optimization process has decreased in relation to energy consumption before the optimization processes in relation to distance and distance from the network center.(***Alhammadi, A,et,al,2024)***

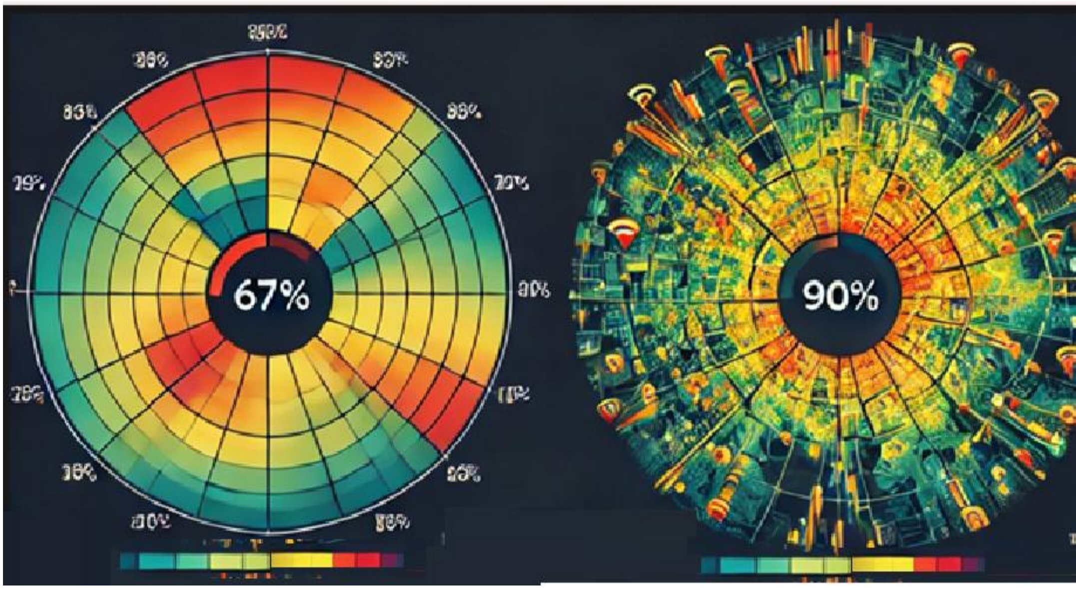


Figure7: Shows Improvement in coverage

The previous figure shows the coverage in the network, and from the figure it is clear that the coverage rate is good, as Figure A shows the coverage before improvement, and Figure B shows coverage after improvement. Whereas, after using the improvement, the coverage rate increased from 67% to 90%, meaning an average of 23% increase in coverage improvement. The figure also shows the gradation in colors, showing the gradation in coverage, starting with the red color, which expresses weak coverage, and ending with the blue color, which expresses good coverage.

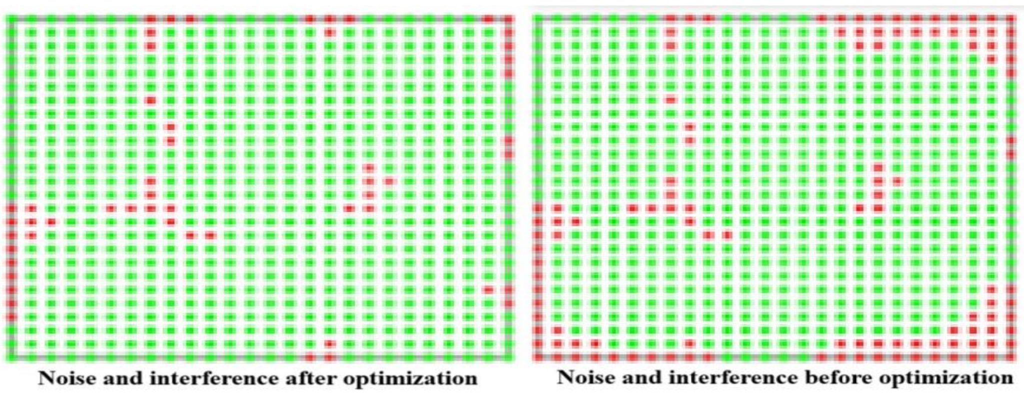


Figure 8: Comparison of noise and interference before and after improvement

According to the previous figure, which shows a comparison between the improvement in signal strength, which is represented by the green dots, and the interference and noise, which is represented by the red dot, we find that before the improvement, the signal strength was less and the interference was more, while after using the improvement algorithms, the signal strength was stronger and there was less interference.

5.Conclusions

The most important conclusions that were drawn from the study:

- The use of artificial intelligence techniques, especially artificial neural networks, to improve effective tools in reducing energy consumption in wireless communication networks(***Ren, H. &Grebogi, C. (2021).*** The model that was proposed reduced energy consumption by 15%, and the model's accuracy rate was 94%, the recall rate was 95%, and the f-1 score was 96%.
- Power allocation techniques through frequency control of wireless signals are effective and useful techniques in improving the performance of wireless networks, especially in light of the knowledge that the relationship between the power consumed and the signal frequency is a direct relationship. The higher the frequencies, the greater the power consumed*(Farzaneh, **H,et,al,2021).***
- Combining more than one technology achieves more accurate results, as the advantage of each technology is taken advantage of separately, but it is necessary to take into account the selection of the appropriate technologies for the appropriate applications***(Alahi, M,et,al,2023)).***
- The most important obstacles facing the use of artificial intelligence technology to reduce energy consumption in wireless communication networks are the cost, technical investigations, and the necessity of having a strong infrastructure that supports the use of artificial intelligence technologies***(Obaideen, K., & Mir, H. (2024).***

➢ Conflicts of interest

There is no conflict of interest.

➢ Future Work:

- Expanding the dataset to include real-time traffic data.
- Implementing reinforcement learning for dynamic power allocation.
- Evaluating the model in large-scale 6G network environments.

References

1. *Ahmad, T., Zhang, D., Huang, C., Zhang, H., Dai, N., Song, Y., & Chen, H. (2021). Artificial intelligence in sustainable energy industry: Status Quo, challenges and opportunities. Journal of Cleaner Production, 289, 125834.*
2. *Alahi, M. E. E., Sukkuea, A., Tina, F. W., Nag, A., Kurdthongmee, W., Suwannarat, K., &Mukhopadhyay, S. C. (2023). Integration of IoT-enabled technologies and artificial intelligence (AI) for smart city scenario: recent advancements and future trends. Sensors, 23(11), 5206.*
3. *Alhammadi, A., Shayea, I., El-Saleh, A. A., Azmi, M. H., Ismail, Z. H., Kouhalvandi, L., &Saad, S. A. (2024). Artificial Intelligence in 6G Wireless Networks: Opportunities, Applications, and Challenges. International Journal of Intelligent Systems, 2024(1), 8845070.*
4. *Beard, C., & Stallings, W. (2015). Wireless communication networks and systems. Pearson.*
5. *Chakraborty, P., &Telgote, A. M. (2019). Performance analysis of LAN, MAN, WAN, and WLAN topologies for VoIP services using OPNET modeler. In Computing, Communication and Signal Processing: Proceedings of ICCASP 2018 (pp. 185-196). Springer Singapore.*
6. *Farzaneh, H., Malehmirchegini, L., Bejan, A., Afolabi, T., Mulumba, A., &Daka, P. P. (2021). Artificial intelligence evolution in smart buildings for energy efficiency. Applied Sciences, 11(2), 763.*
7. *Gunnarsdóttir, I., Davidsdottir, B., Worrell, E., &Sigurgeirsdóttir, S. (2021). Sustainable energy development: History of the concept and emerging themes. Renewable and Sustainable Energy Reviews, 141, 110770.*
8. *Huang, C., Zappone, A., Alexandropoulos, G. C., Debbah, M., & Yuen, C. (2019). Reconfigurable intelligent surfaces for energy efficiency in wireless communication. IEEE Transactions on Wireless Communications, 18(8), 4157-4170.*
9. *Kovács, Z., &Musterd, S. (2013). Personal networks. Place‐making and Policies for Competitive Cities, 211-218.*
10. *Liu, J., Qian, Y., Yang, Y., & Yang, Z. (2022). Can artificial intelligence improve the energy efficiency of manufacturing companies? Evidence from China. International Journal of Environmental Research and Public Health, 19(4), 2091.*
11. *Long, R. (2021). Wireless Communications: Networks and Systems.*
12. *Mangla, S. K., Luthra, S., Jakhar, S., Gandhi, S., Muduli, K., & Kumar, A. (2020). A step to clean energy-Sustainability in energy system management in an emerging economy context. Journal of Cleaner Production, 242, 118462.*
13. *Moore, J. E., Mascarenhas, A., Bain, J., & Straus, S. E. (2017). Developing a comprehensive definition of sustainability. Implementation Science, 12, 1-8.*
14. *Obaideen, K., Albasha, L., Iqbal, U., & Mir, H. (2024). Wireless power transfer: Applications, challenges, barriers, and the role of AI in achieving sustainable development goals-A bibliometric analysis. Energy Strategy Reviews, 53, 101376.*
15. *Parashar, V., Kashyap, R., Rizwan, A., Karras, D. A., Altamirano, G. C., Dixit, E., & Ahmadi, F. (2022). Aggregation‐Based Dynamic Channel Bonding to Maximise the Performance of Wireless Local Area Networks (WLAN). Wireless Communications and Mobile Computing, 2022(1), 4464447.*
16. *Raihan, A. (2023). An overview of the implications of artificial intelligence (AI) in sixth generation (6G) communication network. Research Briefs on Information and Communication Technology Evolution, 9, 120-146.*
17. *Rasheed, M. Q., Yuhuan, Z., Ahmed, Z., Haseeb, A., & Saud, S. (2024). Information communication technology, economic growth, natural resources, and renewable energy production:*

Evaluating the asymmetric and symmetric impacts of artificial intelligence in robotics and innovative economies. Journal of Cleaner Production, 447, 141466.

18. Sen, S., Koo, J., &Bagchi, S. (2018). TRIFECTA: Security, energy efficiency, and communication capacity comparison for wireless IoT devices. IEEE Internet Computing, 22(1), 74-81.

19. Truong, N. S., Ngo, N. T., & Pham, A. D. (2021). Forecasting Time-Series Energy Data in Buildings Using an Additive Artificial Intelligence Model for Improving Energy Efficiency. Computational Intelligence and Neuroscience, 2021(1), 6028573.

20. Zheng, K., Hu, F., Wang, W., Xiang, W., &Dohler, M. (2012). Radio resource allocation in LTE-advanced cellular networks with M2M communications. IEEE Communications Magazine, 50(7), 184-192.

21. Zhou, W., Zhuang, Y., & Chen, Y. (2024). How does artificial intelligence affect pollutant emissions by improving energy efficiency and developing green technology. Energy Economics, 131, 107355.