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Optimization of Wi-Fi Throughput for IoT Livestock Monitoring Using Machine Learning

***Adimora K. C.* [a]*, *Aru O. E.* [b], *Ilo F. S.* [b], *and Ezeh C. M-E.* [c]**
[a,b,c,d]Department of Computer Engineering, College of Engineering and Engineering Technology, Michael Okpara University of Agriculture Umudike, Umuahia Abia State, Nigeria.
*[1]adimora.kyrian@mouau.edu.ng; Tel: +2348060479425

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ABSTRACT

The Internet of Things (IoT) has revolutionized agricultural activities, especially in the area of remote monitoring. Although, it has some limitations in terms of network instability and data security. The issue of Wi-Fi network instability and data security have impacted negatively on the IoT technology for monitoring livestock. In this study, a Logistic Regression (LR) algorithm of the Machine Learning (ML) technique was deployed for the optimization of the Wi-Fi network throughput function. Data security and privacy for a secured network were implemented using cryptography and steganography encryption methods. A graphical user interface and a database in form of a web application were created for viewing real-time livestock activities. The significant results of the study showed a positive impact of both machine learning and encryption on IoT technology. The paper, results were tested with MATLAB software application.

1. Introduction

In the last two years, the total volume of agricultural yield across the globe has increased unprecedentedly with a notable decrease in the cost of farm produce, due to the application of Unmanned Aerial Vehicles (UAV) to agriculture [1]. Although, Unmanned Aerial Vehicle (UAV) can be exploited in a variety of applications related to agriculture management but has a major drawback (absence of a standardized workflow) that keeps it from being widely used in commercial precision in agriculture applications Tsouros *et al*. [2]. Internet of Things (IoT) can significantly provide potential precision in agriculture and smart farming, enabling a long- term increase in productivity [3]. Predicting the signal strength from a drone over IoT devices in smart cities for effective network coverage and connection with desired quality of service (QoS) using artificial neural network was optimal based on drone flying path and altitude without consideration of its none standardized workflow attribute that affects its optimal performance and none usage in the commercial precision of agriculture Saeed *et al.* [4]. Drone flying path, most times have issues with erected trees and structures found at the smart farm solely meant for cattle rearing Saeed *et al.* [4]. Yaohua *et al.* [5] carried out a comprehensive research survey on the latest advances of machine learning in wireless communication. Halim [6] carried out a study that employed the application of linear algebra in linear regression and support vector machine of machine learning in a wireless communication network. The exploration of how domain knowledge in networking can inform the different aspects of Machine Learning techniques in problem formulation of internet technology in wireless communication networks [7]. A review work on IoT and Machine Learning that is based on healthcare issues related to remote monitoring [8]. The need for integration of Machine Learning in wireless communication with the main focus on the fifth generation and millimeter-wave technologies [9].

Alessio *et al.* [10] executed research on a wireless network design that deals with the use of deep learning techniques in future wireless communication networks. Kulin *et al.* [11] present a systematic and comprehensive survey that reviews the latest study focused on machine learning-based performance improvement of wireless networks while considering all layers of the protocol stack. A comprehensive framework of optimizing wireless communication systems with the main focus on optimal decision schemes based on supervised learning modeling and reinforcement learning algorithm Oshima *et al*. [12]. Muhammed [13] conducted a research study on a routing protocol for the Internet of Things (IoT) that supports multiple gateways in the same network with the main focus on reducing memory requirements for storing a forwarding table. Khushbu *et al.* [14] carried out a research study on the importance of IoT technology for farmers to increase productivity. The research mainly focused on the importance of IoT technology in smart farming without any consideration to the network through which the real-time information would be transmitted and received. The Internet of Things can also be considered as a global network that allows the communication between human-to-human, human-to-things, and things-to-things, which is anything in the world by providing a unique identity to each and every object [15].

Shah *et al.* [16] proposed an IoT livestock monitoring system that was microcontroller based and sensors supported for transmitting and receiving data through a Subscriber Identity Module (SIM) to the cloud but without the description on how data transmitted to the cloud is protected from the hackers. [17] Conducted research on machine learning in complex wireless communication technology that allows real-time data to be analyzed and modeled in agricultural IoT systems. Anneketh *et al.* [18] executed research on machine learning farm automation that is based on the Internet of Things (IoT), capable of solving irrigation problems, achieved with wireless sensor network and common server. In this paper, a Wi-Fi network throughput is optimized through the application of Machine Learning algorithm to overcome the issue of network instability.

2. Methodology

The details of the materials and method used in the optimization of the Wi-Fi throughput function and data security is described here. Machine Learning technique was the method used in the implementation of the new system for the optimization of the Wi-Fi throughput. While the secured communication channel was achieved through the application of cryptography and steganography encryption standards.

These are materials used.

I. Visual Studio IDE for coding
II. Sensors, NFC tags, and Network Access Points (Gateways)
III. Python script, JavaScript, HTML, CSS, PHP, and MySQL
IV. Microcontroller 8051 and Raspberry pi

The new system consists of several datasets from various machine learning repository, a web application for viewing real-time livestock information, micro-chip robot as a hardware. The web application back end was designed using PHP and MySQL programming technologies while the front end was created using HTML, CSS, JavaScript, and Bootstrap. The hardware (Microchip robot) is comprised of several hardware components integrated as one. The service unit otherwise known as the system software runs the web application program code. The database is the information repository. The Python script running in the raspberry pi checks for the various conditions defined in the microcontroller unit (MCU) of the micro-chip robot. The data to the cloud is encrypted using Rivest Shamir Adleman (RSA) algorithms which is a public key cryptosystem

that is widely used for secure data transmission. The encrypted data will be hidden in the image files of the (.bmp) extension. The encryption model is shown in Figure 1.
According to [19; 20], cryptography is the method of writing using secrete styles or codes. The plaintext in this context will be converted to cipher text using secret keys. The process of converting the plaintext to cipher text is known as encryption. Decryption is the opposite of encryption and it is the process of converting from cipher-text to original texts. The decryption needs secret keys to extract the original texts. RSA is considered an asymmetric cryptography method [21]. Thus, the encryption and decryption processes need independent keys based on RSA. The RSA algorithm can be used for both key exchange and digital signatures. Steganography is the art of hiding information in other information. This encryption algorithm conceals a message in a cover without leaving a remarkable track on the original message [22; 23; 24]. Jassim *et al.* (2019) executed research that improved the cryptography securing level using a supportive method which is steganography. Figure 2 shows the new system architecture.

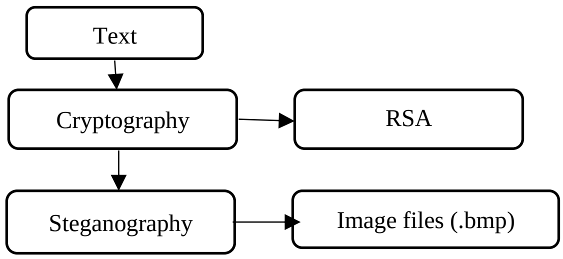

Figure 1: Secured channel encryption model

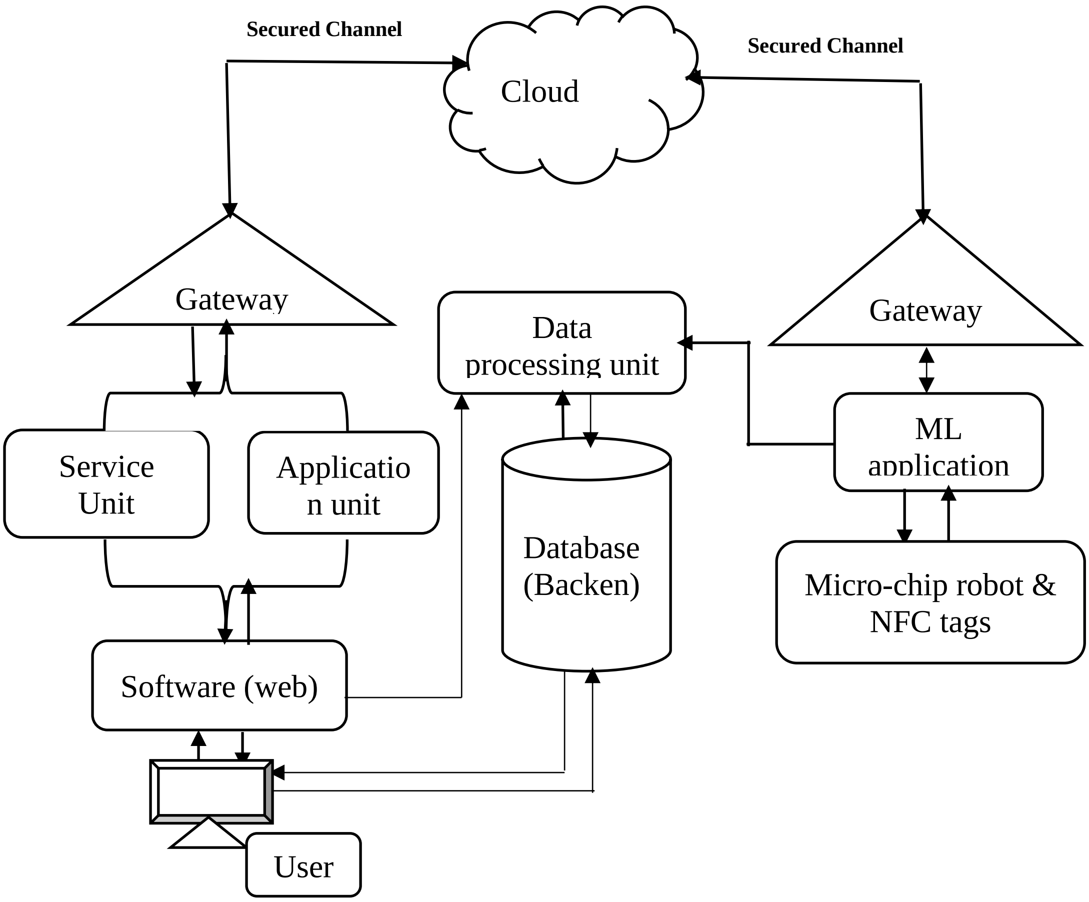

Figure 2: New System's Architectural Framework

In Figure 2, is composed of a secured cloud channel implemented with a hybrid of the cryptography and steganography encryption standards developed in Python code. The application unit is the graphical user interface of the web application that allows the user to access the livestock real-time information remotely and seamlessly. The microchip robot is the hardware unit of the system that provides information about the livestock from the remote environment. It is interfaced with several sensors and tags.

2.1.1 ML Approach

The ML approach defines the optimized Wi-Fi throughput logistic regression entropy value as 1 for success (s) and as 0 for failure (f). Then following a Bernoulli distribution in equation stated in equation (1), the sigmoid function of the logistic regression algorithm is formulated as follows:

$$Y \sim Ber(P) \tag{1}$$

Where P is our sigmoid function.

$$P[Y = y|X = x] = \sigma(\theta^T x^i)^y (1 - \sigma(\theta^T x^i)^{1-y} \tag{2}$$

Where $\sigma(\theta^{\wedge T} x^{\wedge i})$ is the sigmoid function and for n observations we have

$$L(\theta) = \prod_1^n \sigma(\theta^T x^i)^y (1 - \sigma(\theta^T x^i)^{1-y} \tag{3}$$

This is because we need a value for theta (θ) which will optimize the Wi-Fi throughput function. Multiplying log on both sides we get the Wi-Fi throughput function stated in equation (4).

$$Log\ (L(\theta) = \sum_1^n y * \log\left[\sigma(\theta^T x^i)\right] + (1 - y) * \log\left[\ (1 - \sigma\left(\theta^T x^i\right)\right] \tag{4}$$

In Machine Learning (ML) with reference to equation (4), it is conventional to minimize a loss (error) function via gradient descent, rather than maximize an objective function via gradient ascent. Therefore, if we maximize equation (4) then we will have to deal with gradient ascent to avoid this we take negative of this log which is our cost function as shown in equation (5). It is common practice to minimize a cost function for optimization problems and that is what the machine learning application is performing on our Wi-Fi throughput function of this study.

$$-Log\ (L(\theta) = -\sum_1^n y * \log\left[\sigma(\theta^T x^i)\right] + (1 - y) * \log\left[\ (1 - \sigma\left(\theta^T x^i\right)\right] \tag{5}$$

Here y represents the actual class of Wi-Fi throughput function and $\sigma(\theta^{\wedge T} x^{\wedge i})$ is the probability of that class.

Taking P(y) to be the probability of 1 (ie Wi-Fi throughput success) and 1-P(y) to be the probability of 0 (ie Wi-Fi throughput failure). Then the Hessian matrix is applied as stated in equation (8) to simplify the machine learning algorithm of Wi-Fi throughput function in terms of data transmission (Tx) and reception (Rx). The data signal speed for (Tx) and (Rx) are denoted by (S_t) and (S_r) respectively.

$$S_t = f_s(L_t, M, P)\frac{K_E}{d} * \sigma = \frac{E_p}{S_A}\int_a^z f(N)dn \tag{6}$$

$$S_r = C_r \sum_a^z \frac{(L_r * M * \beta)}{K_E} * H \tag{7}$$

Here, K_E is the Kinetic Energy
L_t is the signal transmission location
S_A is the signal amplitude
d is the allowable signal duration over the IoT technology
E_p is the wireless network coverage area
$f(N)$ is the wireless communication network
M is the modulation
f_s is the signal frequency
$z\ and\ \alpha$ are the upper and lower boundary of the gradient descent.
P is the signal phase
σ is the standard deviation that computes the amount of variability in Wi-Fi throughput and bandwidth. In fact, it is the metric measurement of the signal strength and weakness. When the data

points are clustered together it demotes an excellent Wi-Fi throughput. On the other hand, the spread out of the data points denotes a weak Wi-Fi throughput.

$$H = \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \quad (8)$$

Where H is Hessian matrix.

Here, we have a function with variables success (1) as the content of Hessian matrix demonstrating successful optimization of the Wi-Fi throughput function that takes care of the identified network instability.

The logistic regression algorithm for computing the Wi-Fi throughput using entropy algorithm is presented as follows:

Algorithm: Logistic Regression algorithm for Wi-Fi throughput Optimization

1: **Input:** Wi-Fi throughput dataset
2: Compute entropy for dataset
3: **while** condition **do**
4: **for** every attribute
5: calculate entropy for categorical values
6: trained, test, and evaluate each categorical value of the entropy
7: take average information entropy for the current and every attribute
8: calculate gain in decibel for the current Wi-Fi attribute
9: pick the highest gain (dB) attribute
10: **end for**
11: **end while**
12: return final Wi-Fi throughput optimization classification
13: **end**

2.1.2 System Flowchart

The flowchart of the Wi-Fi throughput optimization system is shown in Figure 3.

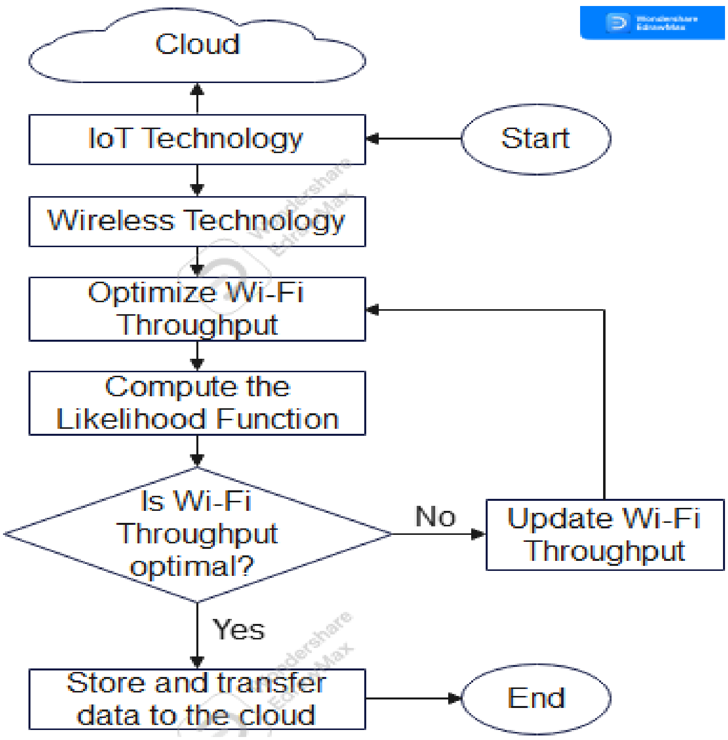

Figure 3: Flowchart of the proposed system

2.2 Microchip Robot Simulation Circuit

The microchip robot is the hardware part of the system with its microcontroller (MCU) programmed in such a way that it gets activated whenever either fire or water is sensed and automatically sends a coded email alert to the livestock owner via the developed web application. The microchip robot is a miniaturized hardware device worn by each of the livestock in the smart farm that is being monitored. The microchip robot is composed of a variety of sensors. Figure 4 depicts the micro-chip robot Proteus simulated circuit diagram.

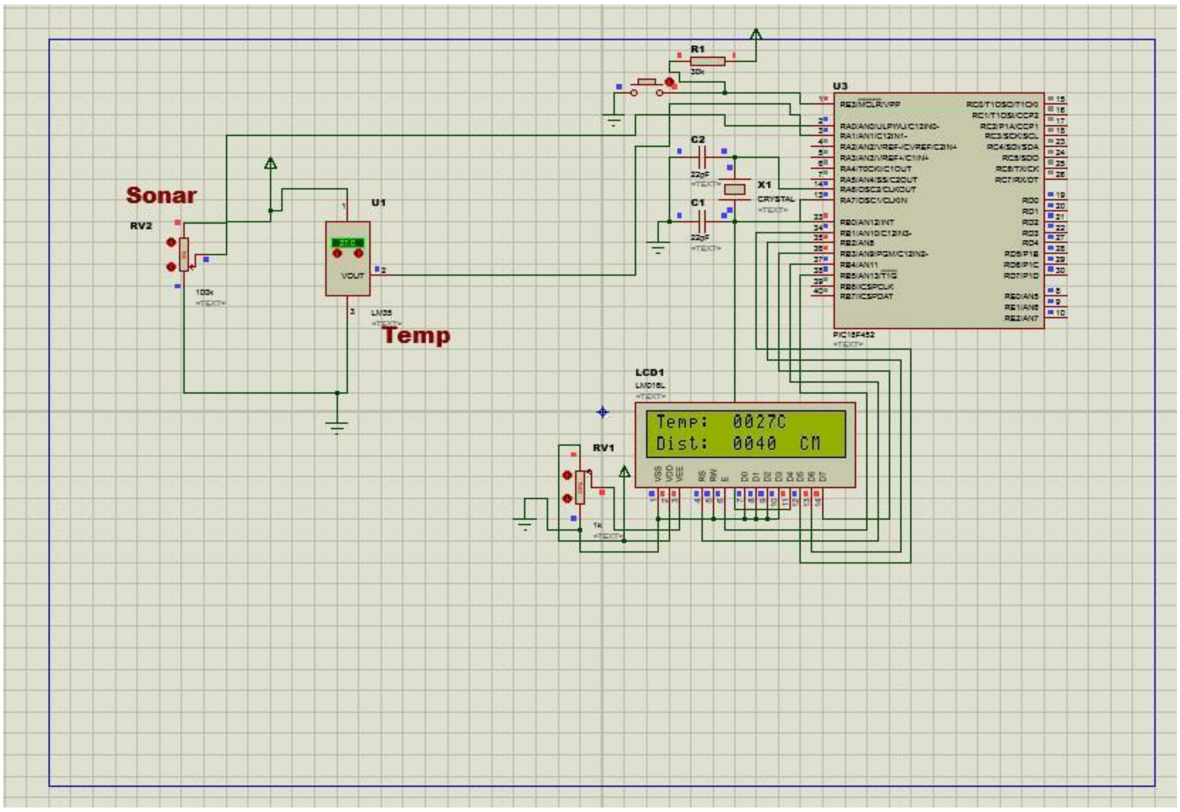

Figure 4: Micro-chip robot Proteus simulated circuit

3. Results and Discussion

In this paper, the logistic regression algorithm of machine learning algorithms was used in the optimization of the Wi-Fi throughput function and network bandwidth. The optimization of the Wi-Fi throughput was initiated with the initial configuration of the wireless facility (802.11) and the distribution of nodes in the MATLAB environment. The application of the LR algorithm for optimization reduces the value of the objective function in each of the trained and tested data that converged the optimal points for enhancing the Wi-Fi throughput function. In this study, the focus is to address the issue of network instability and data security through the optimization of the Wi-Fi throughput function using machine learning techniques that incorporate encryption for a secured network communication channel. Table 1 depicts the daily livestock real-time location that is captured through the secured network communication channel of optimized Wi-Fi throughput and bandwidth for the system evaluation and result from analysis.

Table 1: Daily livestock real-time location results

S/N	TAG NO	TEMP. ^{0}C	Throughput (Mbps)	LOCATION	CAPTURE TIME
1.	0100	35	21	Lat. (32, 18), Long. (45, 35)	2022-02-18 11:01:12
2.	0101	28	16	Lat. (50, 29), Long. (28,40)	2022-02-18 12:11:34
3.	0102	36	24	Lat. (11, 33), Long. (15, 42)	2022-02-19 01:45:22
4.	0103	30	18	Lat. (45, 09), Long. (55, 20)	2022-02-19 02: 18:01
5.	0104	37	20	Lat. (39, 04), Long (66, 12)	2022-02-19 03: 53:04
6.	0105	34	21	Lat. (21, 61), Long. (52, 17)	2022-02-20 04:16:23
7.	0106	29	22	Lat. (16, 22), Long. (32, 19)	2022-02-20 05:40:06

Table 1 is the record of the livestock real-time locations, temperature, and throughput that were captured on the 18th, 19th, and 20th February 2022 at different hours of the day for each experiment. The location was specified with compass calibration of latitude and longitude. The tag number represents a unique number for each livestock being monitored remotely. The Wi-Fi throughput in Mbps was excellent and it is evidence that the Wi-Fi throughput was successfully optimized by the application of the machine learning algorithm. Figure 5 depicts the optimization of Wi-Fi throughput using logistic regression (LR).

The clustering algorithm which happens to be an unsupervised learning algorithm is used in the analysis of Figure 5 that revealed the level of Wi-Fi throughput optimization using LR. The clustered region of trained data denotes a high level of wireless throughput with excellent signal strength at both transmission (Tx) and reception (Rx) ends. The network throughput optimization was achieved through the application of the logistic regression (LR) algorithm of machine learning. The white space represents the cloud or the secured network channel in which data is transmitted and received on the IoT technology. Figure 6 depicts the basic service set (BSS) of various wireless stations that communicate within an 802.11 network employed in the trained and tested data of this study. BSS wireless is the collection of stations that communicate within a network. In this paper, the 802.11 networks were used in training and testing the datasets for the machine learning application.

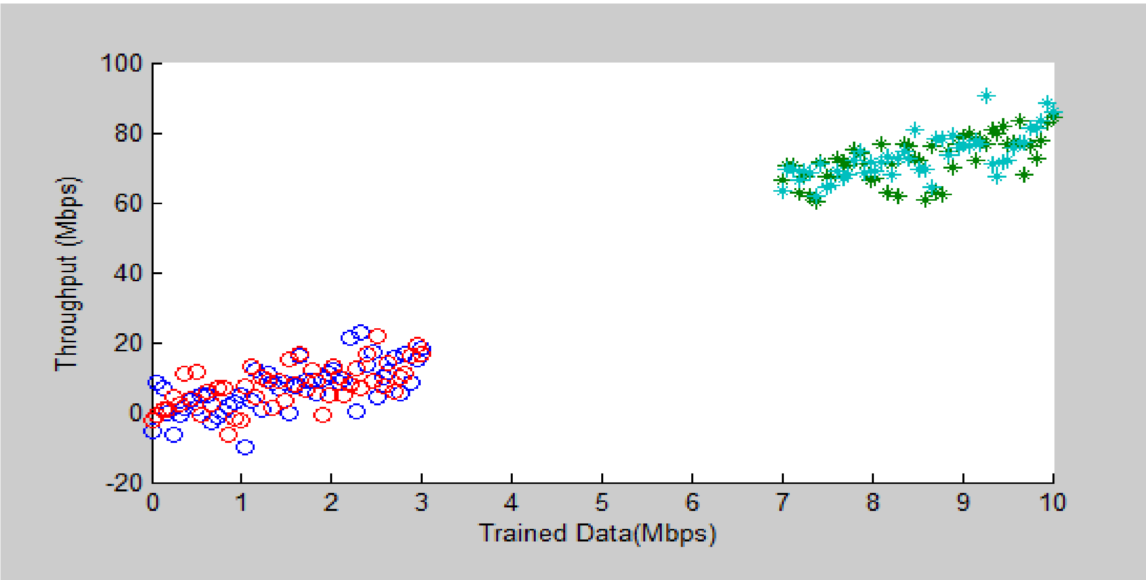

Figure 5: Wi-Fi throughput optimization using LR

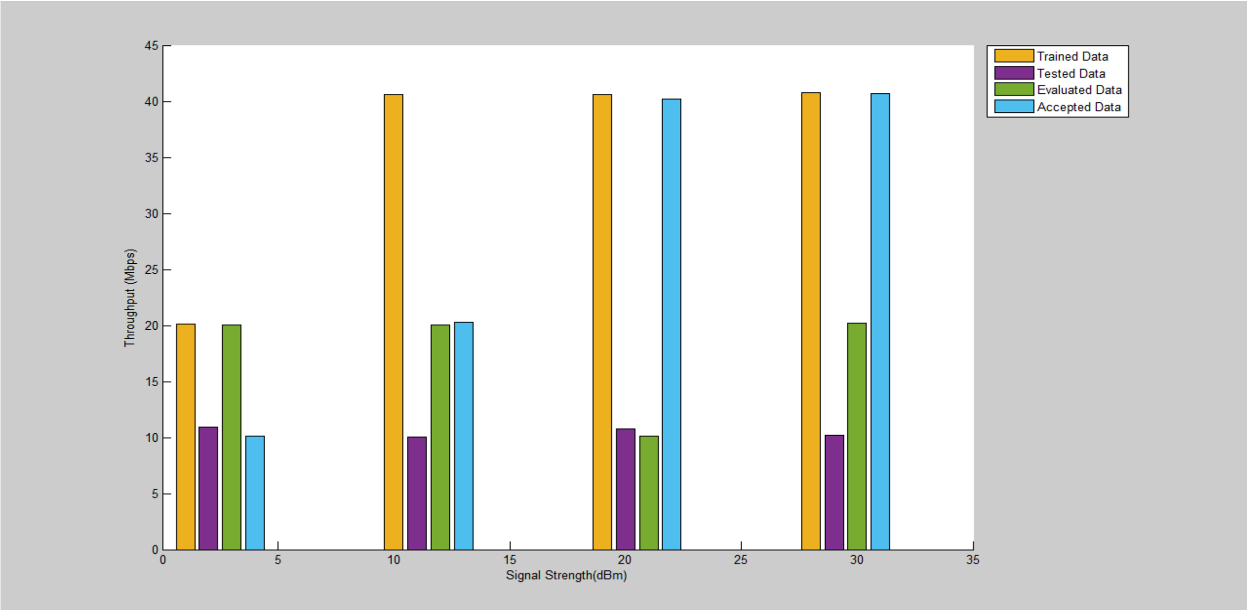

Figure 6: Impact of ML on Wi-Fi network throughput

Figure 6 explained how the logistic regression algorithm of machine learning has enhanced the Wi-Fi throughput by training, testing, and analyzing datasets of each base station communicating within the 802.11 networks onto which our IoT is implemented. In Figure 6, Wi-Fi throughput optimizes with the application of machine learning from (0-5) decibel of signal strength through (30 – 35) decibel of signal strength. Figure 6 shows that an increase in the signal strength is proportional to an increase in the Wi-Fi throughput which resulted from the application LR algorithm of ML.

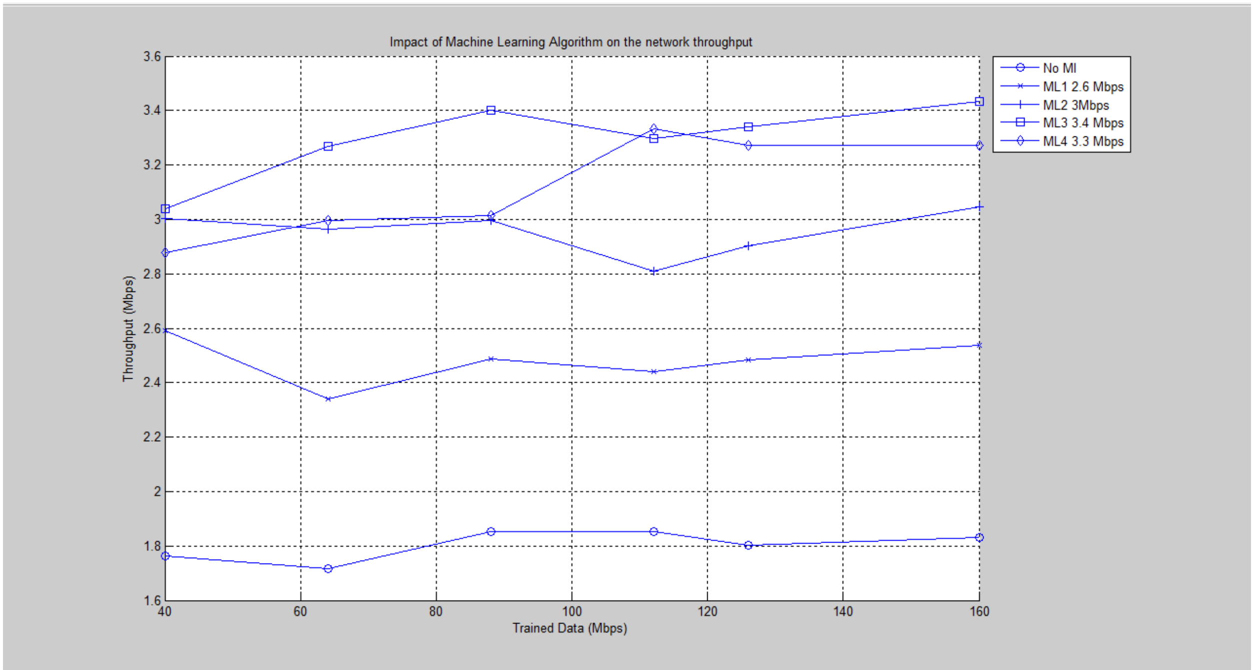

Figure 7: ML Wi-Fi throughput optimization using LR

Figure 7 demonstrates the efficacy of machine learning on Wi-Fi throughput optimization. The Wi-Fi throughput without machine learning application is 1.8 Mbps whereas the Wi-Fi throughput with machine learning application increases from 2.4 Mbps to 3.4 Mbps.

4. Conclusion

Internet of Things has revolutionized agricultural activities, especially in the area of remote monitoring with notable limitations in terms of network instability and data security. In this paper, the issue of network instability was addressed by optimizing the Wi-Fi throughput and bandwidth using logistic regression of the machine learning algorithm. Also, the issue of data security was solved with the application of cryptography and steganography encryption algorithms. The study results explicitly demonstrated the positive impact of the machine learning algorithm on the Wi-Fi throughput.
The future study will be focused on improving Wi-Fi scalability and load balancing using a hybrid of Machine Learning and Deep Learning techniques.

Conflict of Interest
The authors declare no conflict of interest

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