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End-To-End Fully-Informed Network Nodes Associated with 433 MHz Outdoor Propagation Environment

Adamu Abubakar[1], Mohamed Tarek El-Gammal[2] and Ala Abdusalam Alarood[3]

[1,2]Department, of Computer Sciences International Islamic University Malaysia, Kuala Lumpur, Malaysia
[3]Collage e of Computer Science and Engineering, University of Jeddah, 29159, Jeddah, Saudi Arabia

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Abstract: This paper focuses on an end-to-end fully-informed network in a 433 MHz outdoor propagation environment with the intention of studying data flow in a network. This is motivated by the fact that, in a transmission where minimizing delay is critical, maintaining transmission time is influenced by a dataflow. As a result, 433 MHz propagation transmitter is used to analyzed the dataflow within its transmission session. This is meant to answer two questions: "how does transmission delay affect early detection of network failure within this antenna?" and "how quickly is it necessary to recover from a network failure within this antenna?" As a result, a fully informed end-to-end network was designed and built. An experimental analysis of data transmission over a network was carried out. The experimental results show that the antenna height and distance between transmitter and receiver have the greatest impact on transmission success. Furthermore, above 50 metres, high rate bandwidths have a negative effect on data integrity and total dysfunctionality. The finding can be concluded that in an end-to-end fully-informed network with this specific antenna, data flow greater than 8 KB (at both 57600 bps and 115200 bps) has a disadvantage in the network. However, transmission over 80 metres is the most stable and maintains network data integrity at (9600 bps).

Keywords: Communicating session, Transmission session, Delay detection, Informed network

1. Introduction

Communication is essential for the development of anything, and it is one of the most important aspects of human existence. In today's world, the use of networks allows humans and machines to communicate and collaborate in ways that were previously impossible. However, when it comes to research, the term "network" or "communication network" is overly broad. Therefore, the "transmission session" in this current study was operationally defined as "data actively in transit within end-to-end fully-informed network nodes," during which data was actively in transit within end-to-end nodes that were fully informed. The terms "fault tolerance," "scalability," "quality of service (QoS)," and "security" are used interchangeably in this active network scenario [1-2]. When it comes to "fault tolerance," it refers to the ability of a network to adapt in the event of an unexpected failure. That is how to keep a network operational in the event of a failure or how to quickly recover from a failed network. "Delay" is the most important controlling variable in this situation. According to the findings of this current study, two claims were established: "if a network fails, it should be known sooner," and "if a network fails, it should recover faster." As a result of these assumptions, an end-to-end, fully informed network was built from the ground up. It was investigated whether it was possible to reduce packet transmission delays in an efficient manner. According to the research assumptions, the network type that is best suited for it is the Internet of Things, which consists of a diverse range of devices that are all connected to the Internet. This supports the main focus of this paper, which is end-to-end Fully-Informed network nodes from beginning to end. It means that devices at different ends of the spectrum communicate with one another using their own pre-configured intelligence. For the most part, there are four basic categories of communication involved: Human-to-machine communication, Machine-to-machine communication, Machine-to-human communication, and finally Human-to-Human communication. The scenarios of machine-to-machine communication are taken into consideration for this study.

In the field of civil technology, the Internet of Things (IoT) paradigm is considered to be one of the most disruptive. It has had a significant impact on the global economy as well as on devices that are connected to the Internet. According to estimates, the expected global

E-mail: adamu@iium.edu.my, mohammed.elgammal@gmail.com, alaa.alarood@gmail.com

economic impact of the Internet of Things will be worth more than USD 11 trillion by 2025 [3]. Now we are in a new era, one in which everything will be connected to the Internet in some way. Nonetheless, the stakeholders have a variety of interests and backgrounds, which influence their approach to understanding and defining this new paradigm and its implications. It is possible to describe the Internet of Things in simple terms as a convergence point or conjunction that connects both everyday life devices and software applications that extract meaningful information from those devices, in order to facilitate optimised human activities [4]. The Internet of Things (IoT) has a bright future, but it is also unpredictable. In order to contribute and assist in decision-making, it transforms physical objects into speaker and listener objects that are capable of communicating with one another and exchanging information. The Internet of Things is supported by a number of different factors. On the other hand, the development of interactive sensors, communication technologies, and protocols, on the other hand, are the most important factors. According to [5], the revolutionary shift in current Internet technologies, mobile communications, and machine-to-machine (M2M) communication is the first stage in the evolution of the Internet of Things.

The Machine-to-Machine (M2M) paradigm refers to the autonomous communication and interaction between any number of homogeneous or heterogeneous connected devices without the need for human intervention, regardless of the method of communication used [6]. The successful integration of the M2M paradigm with the mobility concept to create M2M Wireless Communication Networks is a significant accomplishment that benefits human beings in many ways. Wireless machine-to-machine (M2M) communication is currently used in many aspects of life, including smart homes, industrial factory automation, and the healthcare industry. Wireless M2M networks are made up of a number of Wireless Sensor Network (WSN) nodes that are connected and run on batteries that can be carried around with them. Normally, WSN nodes rely on a limited amount of power to function. An important part of research right now is finding a balance between how much energy each node uses and how well it works.

A task-oriented data packet transmission network is associated with an end-to-end fully-informed network from start to finish. In this case, it is specifically concerned with the behavior of the packet during the transmission session while also taking the content of the transmitted packet into consideration. The same approach is used in wireless sensor networks, where each node among the sensors has predefined tasks that it performs when it receives a task-oriented packet that corresponds to a specific operation. A description of how the receiver node's operation should be interpreted most of the time. On the receiving node, the task associated with a packet in order to initiate a desired operation is determined by the wishes of the transmitting node and the contents of the packet. When compared to other environments, the transmission propagation's performance and behaviour in certain environments are significantly different. During data transmission, one of the most important variables to control is the transmitting device's capacity. On the other hand, low-rate transmitters achieve low power consumption in wireless M2M communication and are therefore effective for the majority of end-to-end fully-informed networks, especially in urban areas. Because of the following factors [3, 7], the 2.4 GHz band was the most commonly used frequency when constructing a networked environment (wireless) in the first place: First and foremost, it is freely available throughout the world without any restrictions or license requirements. It is also designated as a Low-Rate Wireless Personal Area Network (LR-WPAN) band in the IEEE 802.15.4 standard, which is the industry standard. As a result, manufacturers created a variety of wireless transceivers based on this frequency band in order to comply with the standards [7]. Despite this, it has been observed that the 2.4 GHz band suffers from significant attenuation in concrete and metal environments.

A portion of the Industrial, Scientific, and Medical (ISM) radio spectrum, the 433 MHz band, is available worldwide in the same way that the 2.4 GHz band is available. But when it comes to propagation characteristics, the 433 MHz band outperforms the 2.4 GHz band by a wide margin. This is true in terms of path loss, coverage distance, and even power consumption. On the other hand, the optimal antenna size in the 433 MHz band is larger than the optimal antenna size in the 2.4 GHz band. Furthermore, despite the fact that the 433 MHz band is widely available throughout the world, it is subject to a variety of regulatory regimes in different countries [7-8]. Because of this, the 433 MHz band was used in this paper for experiments with a fully informed network from end to end, which is associated with task-oriented data packet transmission and was tested end to end. Specifically, the paper focused on the outdoor propagation capabilities of the HC-12 wireless transceiver, which is a member of the IEEE 802.15.4g standard operating at 433 MHz. The experiment was developed in conjunction with the M2M infrastructure. For this reason, two nodes are constructed and equipped with an HC-12 transceiver. Implementation of task-oriented data packet transmission is accomplished through the use of a base station software programme that was created specifically for the purpose of conducting the experiment analysis.

The remaining parts of this paper are organised as follows: After this section is section 2, which presents the related works. Section 3 discusses and presents the research methodology. Section 4 presents the experimental analysis. Section 5 is for the presentation of the results and discussion. Section 6 presents the conclusion of the paper.

2. RELATED WORK

It is both humans and objects that are involved in the next generation of network paradigms. Machine-to-machine (M2M) communication is a new paradigm that enables widespread fully automated communications [9], and it is becoming increasingly popular. This results in an environment in which a large number of intelligent devices are linked together to interact and make collaborative decisions autonomously [10], creating a network of intelligent devices. As a result, the Wireless Sensor Network (WSN), which is based on the M2M concept [11], was developed. A wireless sensor network (WSN) is a network made up of multiple wireless nodes that have limited hardware resources and abilities [12]. Due to the sensor nodes' limited processing and power resources, a new protocol must be developed that is easier to use than TCP/IP and works with the sensor nodes' limited hardware.

M2M communication is typically carried out via low-power wireless frequencies or cellular technology [14]. With regard to low-power wireless technology, the 433 MHz band has gained popularity over other available frequencies due to its propagation characteristics, which are expected to be beneficial for machine-to-machine communication (M2M) [15]. Both the DASH7 Mod 2 and the IEEE 802.15.4f standards include a reference to the 433 MHz band in their physical layer specifications. As a result, there are numerous products available on the market that operate at this frequency [8]. The behaviour of packets within an end-to-end fully-informed network communication protocol has been the subject of numerous previous research studies [16–27]. Empirical studies of how 433 MHz propagation works in different environments make up the majority of the work that people write about.

Abubakar et al. [16] investigated wireless transmission sessions between three automated guided vehicles (AGVs) using the Arduino platform and the APC wireless transceiver as the transmission medium. The entire experiment was conducted in an indoor environment with direct line-of-sight communication between participants. While transmitting, different distances between the transmitter and receiver were tested, ranging from 0.5 to 970 metres between the transmitter and receiver. In their findings, they discovered that the most efficient frequency was 434MHz, with a 19200 bit per second baud rate and a 25 millisecond delay between data packets with a 56-byte size each. The researchers also found that factors like the distance between transceivers, the baud rate, and the frequency used can have a big impact on the quality of the transmission.

If the transmission sessions are taking place in the open air, it is important to consider the impact of environmental conditions on the radio frequency. This was demonstrated many years ago when researchers used the Mica2Dot platform in conjunction with a four-channel Chipcon CC1000 433 MHz transceiver to investigate the reliability of wireless sensor network propagation in a potato field [17]. The distance coverage range between a transmitter and a receiver is affected by the propagation of radio waves in high-humidity environments, at night, and when it rains. As previously stated, the effect of foliage on wireless propagation in a tropical forest environment is also a disadvantage for data transmission propagation [18]. In the 433 MHz band, this was most commonly seen in the RFM95W Lora-based transceiver and other devices. According to the findings, foliage has a negative impact on the performance of transmission systems. A similar comparison was made in a peach orchard by Zhang et al. [19], who compared the transmission ranges of both bands (2.4 GHz and 433 MHz), as well as path loss, data loss rate, and channel fading, while taking into account the antenna height of the transceiver. Transmission over 2.4 GHz and 433 MHz frequencies was accomplished with the help of the CC2430 and RF1100SE modules. Antenna heights of 1.5, 2.5, 3.5, and 4.5 metres were tested, as were different antenna configurations. The findings revealed that the effect of antenna height has a greater impact on the 433 MHz frequency than the 2.4 GHz frequency. The path loss at 2.4 GHz, on the other hand, is significantly higher. Finally, the best antenna height was found to be 3.5 metres, which was the highest of the heights that were tested.

Using measurements of wireless communication range for both the 2.4 GHz and 433 MHz bands, Pere and colleagues [7] developed a propagation model that took the antenna height into account. The model was developed by Pere et al. They discovered that, despite the fact that the 433 MHz band has a larger Fresnel Zone, it still has a longer range in both indoor and outdoor environments than the 2.4 GHz band, which they compared to the 2.4 GHz band. It doesn't make the communication system more durable to change the transmission channel from 2.4 GHz to 433 MHz.

Even though tracking wild animals in their natural habitats is a difficult task, a coordinated network environment comprised of wireless radio transceivers with low power consumption and long-range coverage makes it possible to conduct efficient wildlife monitoring. Wotherspoon et al. [20] conducted an evaluation of five different wireless transceivers in order to determine which was the most appropriate in terms of power consumption and communication range in wildlife terrain. Two nodes are constructed, one to represent the transmitter and the other to represent the receiver. The transmitter node was installed at a fixed height of 0.1 metre above the ground because it will be worn around the ankles of wild animals to provide them with information. The receiver node, on the other hand, has an adjustable height that was changed throughout the experiment in order to find the most appropriate height during the transmission phase. Results showed that the LoRa transceiver outperformed the other four modules in terms of performance, with less data loss and power consumption.

Underwater communication systems are an additional aspect of wireless transmission that is worth exploring. Abdou et al. [21] investigated the feasibility of constructing a WSN node that operates underwater and uses free ISM radio frequencies to communicate with the network. The study included three bands (6.7 MHz, 433 MHz, and 2.4 GHz), with the amplitude of the signal over different distances underwater being taken into consideration for each band. Furthermore, for each particular frequency, the study included a comparison between air propagation and underwater propagation. According to the findings of the study, the 6.7 MHz frequency band had the greatest signal amplitude compared to the other two bands, with the 433 MHz band coming in second.

Vershinin and colleagues [22] emphasised the importance of studying the characteristics of radio interference in their research. because it is advantageous in the design of a high-performance radio communication system. As a result, an experimental measurement of narrowband interference at the frequency of 433 MHz was performed. The experiment took place in four different urban districts in the Russian city of Tomsk. The results of the experiment revealed that the observed interference probability is approximately 6 percent, with an average duration of 1.6 seconds and a maximum duration of 14 seconds in the frequency range of 430 MHz to 435 MHz bands, according to the analysis of the results.

Trasvia-Moreno et al. [23] used the Lora-based wireless transceiver RN2483 to compare the performance of two different frequencies, 433 MHz and 868 MHz, in an outdoor environment under line of sight communication. During the empirical experiment, the transmitter and receiver were located at a distance of 7 kilometres from one another. The receiver node, on the other hand, was located at ground level, while the transmitter node was located 300 metres above ground level. When comparing the 433 and 868 MHz bands, they discovered that the received signal strength indicator (RSSI) is significantly higher in the 433 band. As a result, it is expected that the 433 MHz frequency, which has a higher RSSI, will achieve a greater transmission distance than the 868 MHz frequency. Gaelens et al. [24] conducted a comparative analysis of signal-to-noise ratio and data packet loss for 433 MHz and 868 MHz in the Antarctic using Lora technology transceivers, and they found that the results were similar. In the experiments, two nodes are used: one fixed node equipped with directional antennas and another node mounted on the back of a 4x4 Toyota Hilux vehicle in order to be movable. The line-of-sight transmission tests were successful, with distances of up to 30 kilometres covered for both frequencies with nearly the same performance.

Extra-vehicular activity (EVA) is a term that refers to any spacewalk that an astronaut undertakes outside of the spacecraft's confines. A special spacesuit is required for this type of activity, so be prepared. This suit is capable of collecting astronaut biomedical data using conventional wired sensors [25], which are integrated into the suit. Taj-eldin et al. [26] investigated the wireless propagation performance inside a spacesuit in terms of channel path loss at three different frequency bands (315 MHz, 433 MHz, and 916 MHz) in order to determine whether the spacesuit is suitable for the construction of intra-spacesuit wireless body area networks (WBAN). They concluded that the spacesuit is generally conducive to radio frequencies. However, there are significant differences in path loss between the different frequency bands. Meanwhile, in 2014, Taj-eldin et al. [25] added one more band to their previous study, which is represented by the letter "2.4 GHz." According to the findings of the study, lower frequencies took advantage of the low path loss that was created during the transmission. A WSN system was proposed by Minhas et al. [27] to monitor underground mining activities, including the location of miners, in order to reduce human life losses and the frequency of common mining industry disasters. The proposed design addressed the radio propagation of WSNs, the energy consumption of communication protocols, and the algorithm for detecting critical events in WSNs. When it comes to wireless propagation, they compared the performance of 433 MHz and 868 MHz during underground wireless transmission in order to determine which frequency band would be the most appropriate for this particular situation. The proportion of received signal strength (RSS) and the packet error rate (PER) for both bands were taken into consideration in the comparison. As demonstrated by the results of the RF propagation performance tests conducted in this manner, the 433 MHz band has significantly better performance than the 868 MHz band.

A wireless underground sensor network (WUSN) was used to conduct an empirical underground-to-aboveground (UG2AG) wireless transmission experiment, which was carried out by Du et al. [19] in order to obtain the communication characteristics of the underground-to-aboveground environment. The experiment included a comparison of two different wireless transceivers (NRF905 and CC2530) that operate in different frequency bands (433 MHz and 2.4 GHz, respectively). The effect of the RSSI on the height of the receiver above the ground and the depth of the transmitter underground has been investigated for both frequencies in terms of height and depth. The results revealed that the 433 MHz frequency is more suitable for UG2AG communication than the 2.4 GHz frequency. Furthermore, there is an inverse relationship between the underground depth of the transmitter and the aboveground RMS (radio frequency) [28].

3. RESEARCH METHODOLOGY

This current study developed an end-to-end network and performed an experimental evaluation of two identical remotely controlled nodes. The nodes are constructed and networked for experimental purposes and are equipped with several features in order to facilitate the research experiments. Furthermore, a graphical user interface, windows-based software application has been developed using the C # programming language for the purpose of sink node functionality. The developed software is capable of managing the resources of both nodes simultaneously. The connection between the software and nodes is a Bluetooth connection. On the other hand, the dedicated connection between the nodes is based on 433 MHz radio frequency (RF), using the HC-12 transceiver. Figure 1 shows the main layers of the proposed system architecture that has been developed and the way of interaction and communication between each layer. Figure 2 shows the network topology of the proposed system.

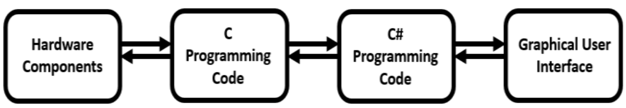

Figure 1. Main layers of the proposed system

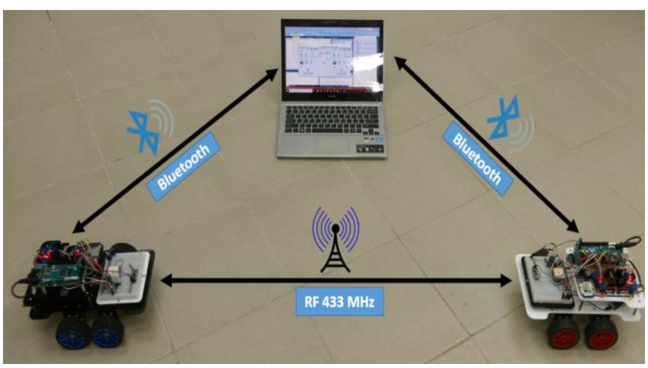

Figure 2. Network topology of the proposed system.

The hardware architecture is depicted in block diagram form in Figure 3. The direction of the arrows in each block represents the way in which information is exchanged between the hardware components.

With the communication module, the entire process of remotely establishing connections among the nodes, managing wireless data transmissions, configuring the hardware chips, and fully monitoring their behaviour is made much simpler and more convenient. The Microsoft Visual Studio 2017 Integrated Development Environment has been used in conjunction with C# (IDE). In accordance with Figure 4, the main interface of the application is divided into three primary sections. In the middle of the diagram is the section that is responsible for both data transmission modes, which are as follows: Instant Transmission mode attempts to start a transmission session based on the data size selected by the user; Analyzer mode attempts to start multiple transmission sessions at the same time for the purpose of data collection. The Instant Transmission menu (as shown in Figure 5) and the Analyzer menu (as shown in Figure 6) are accessed by pressing the buttons 13 and 14 on the Figure 4 keyboard, respectively.

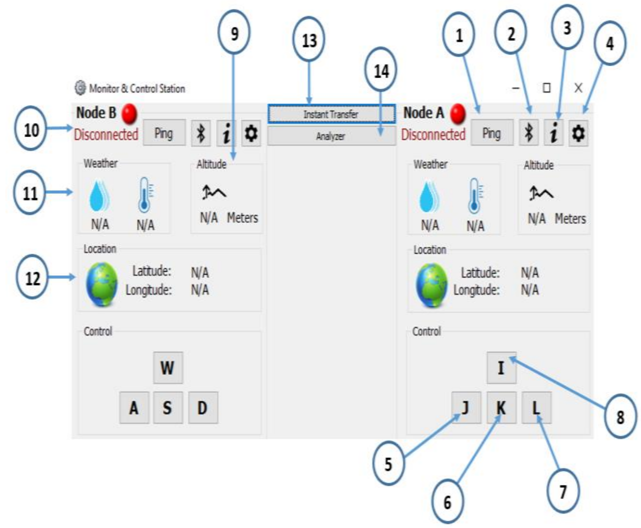

Figure 4. The monitor and control station software interface

Because each part of the software interface controls a single node, the right and left parts of the software interface are identical. Humidity, temperature, latitude, longitude, altitude, and even the connectivity status between the two nodes can be obtained by the software from the sensors on the nodes. Other information obtained by the software includes: As shown in the configuration menu in Figure 7, the software is capable of configuring the HC-12 module parameters such as power, Baud Rate, and channel.

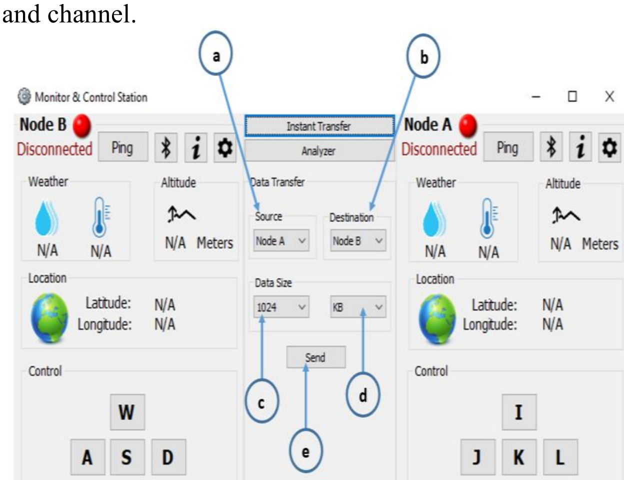

Figure 5. Instant transmission menu

The “Informed Network Nodes programme” assigns tasks to the nodes by transmitting a specific signal to each one. Therefore, the nodes begin the task in accordance with the information they have received, and they send a feedback notification to the “Informed Network Nodes programme” software after each action they take. In order to provide more specifics, Table 1 outlines the functionality of each button in the “Informed Network Nodes programme” software.

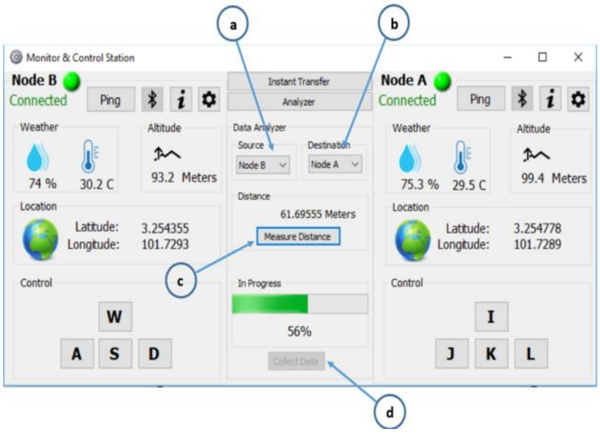

Figure 6. Data collection menu

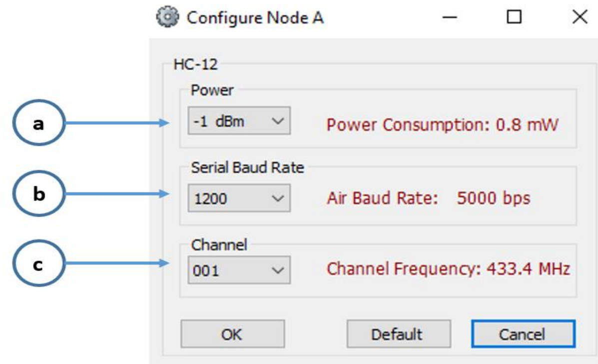

Figure 7. HC-12 Transceiver configuration menu

TABLE 1. THE FUNCTIONALITY OF THE SOFTWARE GUI INTERFACE

Event	Action
1	Checks the connectivity between the two nodes.
2	Start Bluetooth connection between each node and the sink node (Laptop)
3	Gets all sensor nodes information (Location, temperature, and humidity) and show them in the
4	Opens the HC-12 transceiver configuration menu
	a. Configure the HC-12 transmission power.
	b. Configure the serial baud rate of the communication between the Arduino microcontroller
	c. Configure the HC-12 transmission channel
5	Moves the node wheels to left direction
6	Moves the node wheels to the backward direction
7	Moves the node wheels to right direction
8	Moves the node wheels to forward direction
9	Shows the node altitude based on GPS reading data
10	Shows the connectivity status between the node and laptop
11	Shows the temperature and the humidity readings
12	Shows the latitude and the longitude readings
13	Opens the Instant Transmission menu
	a. Choose the transmitter node
	b. Choose the receiver node
	c. Select the data size that will be transmitted
	d. Choose between the available data units
	e. Start the transmission session between nodes
14	Opens Data collection menu to automatically start transmission different test cases with different data
	a. Select the transmitter node
	b. Select the receiver node
	c. Measure the distance between nodes
	d. Start data collection progress

4. EXPERIMENTAL ANALYSIS

The fundamental premise of the experiment is to initiate various transmission scenarios based on specific parameters (control variables), and then to measure the behaviour of the transmission session (outcome variables) in each scenario. It is possible to divide the parameters of the study into two categories. To begin, there are three control parameters to consider: distance, bandwidth, and data size. Second, there are the outcome parameters, which include transmission time, throughput, and data loss (among others).

The distance between the transmitter and receiver nodes is measured in metres between the two nodes. In general, the distance between wireless nodes and the height of their antennas have an impact on their connectivity. It is expected that the connection between nodes will be lost at some points during the experiment because the sensor nodes are only nine centimetres (9 cm) above the ground during the experiment. In this case, nodes should be placed at a higher elevation in order to increase the antenna height in order to re-establish connectivity between them.

The HC-12 transceiver can be configured for a variety of serial baud rates, which refer to the speed or data rate at which data is transferred between the RF transceiver and the Arduino microcontroller unit during communication (MCU). The transceiver then broadcasts this serial communication data into the air at the speed that has been configured for the transceiver. In order for communication to be successful, the baud rate must be the same in both the transceiver and the MCU. The default baud rate for the transceiver is 9600 bits per second. As shown in Table 2, the results of the overall simulation for the configurable baud rates are presented in detail.

TABLE 2 HC-12 AVAILABLE CONFIGURABLE SERIAL BAUD RATE [SOURCE: (ROZEE, 2016)]

Serial Port Baud Rate	1200 bps	2400 bps	4800 bps	9600 bps	19200 bps	38400 bps	57600 bps	115200 bps
On Air Baud Rate	5000 bps		15000 bps		58000 bps		236000 bps	
	625 Bps		1875 Bps		7250 Bps		29500 Bps	

In the experiment, the states of the data size are evaluated in terms of their significance. It was decided to use a default packet composed of 64 unique bytes in order to make the transmission scenarios more realistic (as depicted in Figure 8). The transmitted data is a replication of this default data packet, which allows for the generation of a variety of transmission scenarios with varying data sizes. The entire packet will be dropped and will be considered to have been lost if any byte of a particular packet is lost during the transmission session.

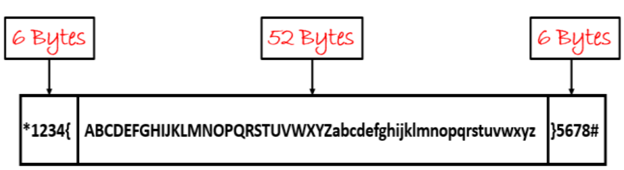

Figure 8. The content of the default data packet

Transmission time refers to the amount of time that the receiver records in milliseconds during a transmission session in the context of that session. During transmission, it began when the first byte of the first packet was received in the transmitted data and continued until the last byte of the last packet was received in the transmitted data. In the context of data transmission over the air, the term "throughput" refers to the actual data rate transmitted over the air during transmission, which is not always the same as the theoretical baud rate (bandwidth). Throughput is calculated for each transmission scenario by dividing the size of the transmitted data by the amount of time it takes for the data to be transmitted to be transmitted. Instead of the default overhead of one extra bit for every eight bits of data, the HC-12 transceiver has one extra bit for every byte of data. In the context of wireless transmission, this term refers to the percentage of packets that have been sent by the transmitter node but have not been received by the receiver node during the transmission process. The following is a formula for calculating data loss:

The experimental test cases for each scenario were laid out in accordance with the experimental test cases that had been previously defined. Specific values for each control parameter have been specified in order to ensure that the experiment will be viable at the end of it. The values that have been assigned to each parameter are listed in Table 3, which can be found below. In order to transmit all data size values for each distance value, they have been transmitted in each of the five different bandwidths that are available to the system (Speed).

The maximum and default transmission power of the transmitter is set to 20 dBm, which is the highest level of power that is capable of being transmitted. Furthermore, the transmission channel has been set to the default, which is channel 001, which operates at a frequency of 433.4 MHz and is the most commonly encountered. These two variables are maintained constant throughout the experiment and are therefore excluded from the analysis of the data.

TABLE 3. SPECIFIED VALUES FOR THE EXPERIMENT CONTROL VARIABLES

Distance	Value (Meters)	Speed	Value (bps)	Data Size	Value (Packets)
1 2 3	25 50 100	1 2 3 4 5	9600 19200 38400 57600 115200	1 2 3 4 5 6 7 8 9 10 11 12	1 2 4 8 16 32 64 128 256 512 1024 2048

5. PRESENTATION THE RESULTS

In this section, you will learn how to build an end-to-end network, how to transmit data over connections, and how to collect all of the information about transmission session operation operations. Other than distance, the major performance parameters are Serial Baud Rate (the transceiver configurable bandwidth), Data Size (the amount of transmitted data), Transmission Time (the duration of each transmission session), Throughput (the actual wireless data rate during transmission for the only successful transmission attempts), and Data Loss (the amount of data lost during transmission) (the percentage of lost packets during transmission).

A. Transmission Over 20 Meters Distance

The physical distance between the transmitter and receiver in the first experimental scenario is 20 metres. The Data Collection Method (also known as the "Informed Network Nodes programme") is invoked to begin the transmission session. An M2M communication is initiated by the "Informed Network Nodes programme," which sends a signal to the transmitter node to initiate the communication and then continuously transmits data in various sizes. Each time a transmission occurs, the transmitter sends a request first and then waits for the receiver node response before continuing. Following receipt of the response, it begins the transmission of the data. A record of that transmission session is then stored in the SD card attached memory, and it contains information such as the number of packets sent (Data Size) and the status of that transmission session (either success or failure). The receiver, on the other hand, accepts the sending request and then sends a response to the transmitter while waiting for the data to arrive. Meanwhile, the receiver maintains a record of the transmission duration and the number of packets it has successfully received.

The transmission over a distance of 20 metres at the default bandwidth of 9600 bits per second. The average throughput of wireless propagation is degrading by nearly 9.5 percent of the configured bandwidth on a monthly average basis. Furthermore, it has been observed that transmitting data of varying sizes within the same bandwidth has a minor impact on the throughput performance. As a result, the greater the data size, the lower the throughput. Conclusion: When transmitting from end-to-end within a distance of 20 metres, the inverse relationship between packet size and throughput is observed.

The transmission scenario at 19200 bps bandwidth for this scenario is similar to the previous experiment in terms of set up and configuration. The serial baud rate, on the other hand, is doubled in this experiment. According to the findings, the average wireless propagation throughput among all successful transmission attempts is degrading at a rate of approximately 9.4 percent of the theoretical throughput on an annual basis. Furthermore, as the size of the transmitted data increases, there is a slight decrease in the throughput performance of the connection.

The bandwidth that has been configured is 38400 bits per second. According to the findings of this study, the wireless throughput performance is 9.5 percent less than the theoretical bandwidth capacity. Throughput performance is still slightly degraded when the data size is increased, but the effect is less noticeable. Transmission sessions at a bandwidth of 57600 bits per second (bps); this baud rate exhibits the first instances of data loss among the previous data rates. The transmission was successful until the total number of packets reached 128. (8 KB). Nevertheless, for all transmission attempts with a packet size greater than 128 packets, there has been no successful transmission. The throughput of the successful transmission attempts is 8.9 percent lower than the bandwidth that was configured for the transmission attempts. Furthermore, decreasing the data size results in a slight increase in the throughput. Table 4 shows the most recent transmission sessions conducted at this distance using the highest available bandwidth. When transmitting 256 packets and forward, data began to be lost as a result of the transmission. Between the successful transmission cases, the measured throughput was 8.5 percent less than the configured bandwidth.

The transmission sessions over a distance of 20 metres using the first three baud rates (9600, 19200, and 38400) bps demonstrated acceptable performance, with high accuracy data transmission during the first three transmission sessions (0 percent data loss). However, as illustrated in Figure 9, using the last two baud rates (57600 and 115200) resulted in transmission failure due to the increase in data size, as indicated by the dotted line. As a result, when the data size is greater than 8 KB, high speed baud rates (57600 bps and 115200 bps) are unable to achieve successful transmissions.

TABLE 4 TRANSMISSION OVER 20 METERS AT 115200 BPS BANDWIDTH

Test Cases	Transmitted		Received		Transmission Statistics		
	Data Size (Packets)	Data Size (KB)	Data Size (Packets)	Data Loss (%)	Total Time (m/s)	Throughput (bps)	Status
1	1	0.0625	1	0%	5	115200.0	**Success**
2	2	0.125	2	0%	11	104727.2	**Success**
3	4	0.25	4	0%	22	104727.2	**Success**
4	8	0.5	8	0%	44	104727.2	**Success**
5	16	1	16	0%	90	102399.9	**Success**
6	32	2	32	0%	177	104135.5	**Success**
7	64	4	64	0%	356	103550.5	**Success**
8	128	8	128	0%	711	103696.1	**Success**
9	256	16	220	14%	-	-	**Failed**
10	512	32	401	21.6%	-	-	**Failed**
11	1024	64	863	15.7%	-	-	**Failed**
12	2048	128	1679	18%	-	-	**Failed**
Average Data Loss (%)			**16.5 %**		**Average Throughput** *(Successful Transmission only)*		**105396.0**

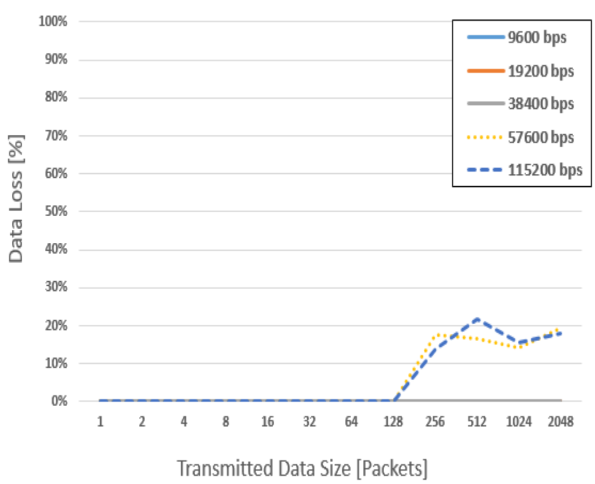

Figure 9. Transmission over 20 meters

B. *Transmission Over 50 Meters Distance*

Increasing the quality of communication when transmitting data over a distance of 50 metres

necessitated a significant improvement in the antenna height parameter, which could not be achieved without involving the antenna height parameter. Sensor nodes were mounted on a 56-centimeter object, as depicted in Figure 10, in order to raise the antennas' heights above the surrounding terrain. The increase in antenna height results in the establishment of a successful connection between the sensor node.

Transmission session tests cases were run at the default baud rate, and the results were presented. If you use the default baud rate, there is no statistically significant difference between this distance and 25 metres. In spite of this, the average throughput in 50 metres was a little bit higher than the average throughput in over 25 metres.

When the bandwidth is increased, the transmission sessions result in a baud rate of 19200 bits per second. The increase in data size results in a slight increase in throughput. However, when compared to the previous distance, the average throughput suffers a significant reduction in speed.

Figure 10. Increase the height of the sensor nodes

The transmissions have a baud rate of 38400 bits per second. By increasing the amount of data that is transmitted, it is possible to achieve significant gains in throughput. The overall average throughput, on the other hand, is lower than the first distance travelled. Transmission at a baud rate of 57600 bits per second has proven to be a resounding failure, with only two successful transmissions out of a total of 12 test cases. Furthermore, the data that was successfully transmitted was of a small size, consisting of only one packet and four packets. The total percentage of data loss was 92 percent of the total amount of data transmitted. Table 5 shows the results of the twelve test cases, with only one successful transmission occurring at the 115200 bps baud rate, which was the worst of the bunch. The average percentage of data loss was 93.6 percent across all transmitted packets on the day in question. More significantly still, the data size of the single successful transmission was two packets (0.125 KB), resulting in a throughput that was 9 percent lower than the configured bandwidth. When it comes to transmission over 50 metres, both baud rates (57600 bps and 115200 bps) showed an unexpectedly high percentage of data loss, which was unexpected (more than 90 percent). In contrast, as illustrated in Figure 11, the first three baud rates maintained the same level of performance as before.

TABLE 5 TRANSMISSION OVER 50 METERS AT 115200 BPS BANDWIDTH

Test Cases	Transmitted		Received		Transmission Statistics		
	Data Size (Packets)	**Data Size (KB)**	**Data Size (Packets)**	**Data Loss (%)**	**Total Time (m/s)**	**Throughput (bps)**	**Status**
1	1	0.0625	0	100%	-	-	Failed
2	2	0.125	2	0%	11	104727.2	Success
3	4	0.25	0	100%	-	-	Failed
4	8	0.5	0	100%	-	-	Failed
5	16	1	9	43.7%	-	-	Failed
6	32	2	6	81.2%	-	-	Failed
7	64	4	0	100%	-	-	Failed
8	128	8	81	36.7%	-	-	Failed
9	256	16	0	100%	-	-	Failed
10	512	32	162	68.3%	-	-	Failed
11	1024	64	0	100%	-	-	Failed
12	2048	128	0	100%	-	-	Failed
Average Data Loss (%)			**93.6 %**		**Average Throughput** *(Successful Transmission only)*		**104727**

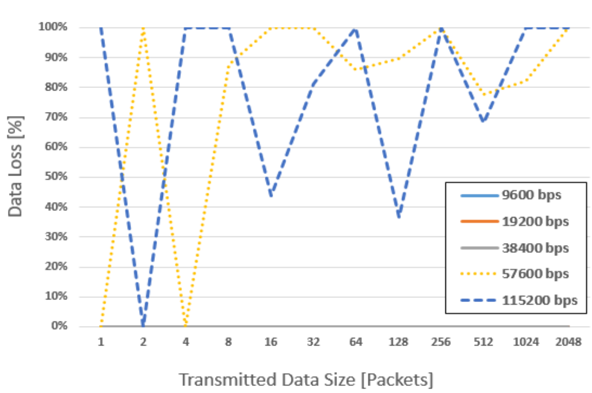

Figure 11. Transmission over 50 meters

C. Transmission Over 50 Meters Distance

The transmission over 100 meters required more antenna height. Thus, two dustbins are joined vertically and installed as shown in Figure 12 in order to double the height of the previous scenario. Increasing the distance up to 80 meters using this new height resulted same outcomes as the previous scenario. However, reaching 100 meters' distance brought extremely unexpected results. The first three bandwidths (9600, 19200 and 38400) have shown transmission failures for the first time. Furthermore, the last two bandwidths (57600 and 115200) have not achieved any successful communication at all.

Despite the failure of two transmission cases in Table 6, the default bandwidth has shown the best results over 100-meter distance. Furthermore, in the two failed cases the percentage of lost data was only 8.9 % and 7.0 % respectively with 1.4 % overall data loss. The overall throughput is slightly less than the previous two distances.

8.35 % packet loss among all transmission cases. The throughput keeps its slight increase due to data size increase as the previous distance. However, the average throughput performance is 10.3 % less than the configured baud rate.

Changing the baud rate from 19200 to 38400 over 100

Figure 12. Increase the antenna height to 112 cm approximately

Moving to the second baud rate (19200 bps) the accuracy was degraded dramatically. Half of the transmission attempts were failed with overall meters has affected the accuracy of the transmitted packets significantly. Almost 75 % of the transmitted packets were lost. Only five transmission test cases have completed successfully. The throughput performance has not been affected as it is steady in all test cases.

Transmission over 100 meters showed transmission failure among all baud rates as shown in Figure 13. Nevertheless, using 9600 bps shoed the lowest data loss cases.

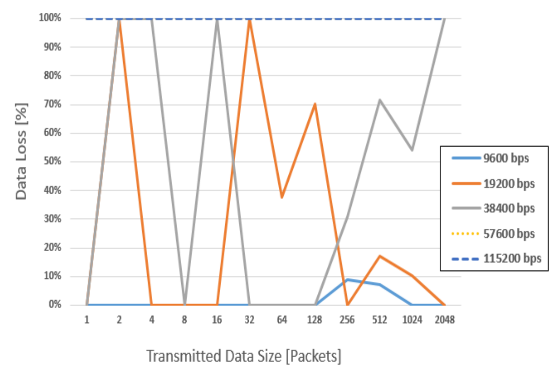

FIGURE 13. Transmission over 100 meters

TABLE 6 TRANSMISSION OVER 100 METERS AT 38400 BPS BANDWIDTH

Test Cases	Transmitted		Received		Transmission Statistics		
	Data Size (Packets)	**Data Size (KB)**	**Data Size (Packets)**	**Data Loss (%)**	**Total Time (m/s)**	**Throughput (bps)**	**Status**
1	1	0.0625	1	0%	17	33882.3	**Success**
2	2	0.125	0	100%	-	-	**Failed**
3	4	0.25	0	100%	-	-	**Failed**
4	8	0.5	8	0%	134	34388.0	**Success**
5	16	1	0	100%	-	-	**Failed**
6	32	2	32	0%	534	34516.8	**Success**
7	64	4	64	0%	1066	34581.6	**Success**
8	128	8	128	0%	2131	34597.8	**Success**
9	256	16	177	30.8%	-	-	**Failed**
10	512	32	146	71.4%	-	-	**Failed**
11	1024	64	471	54%	-	-	**Failed**
12	2048	128	0	100%	-	-	**Failed**
Average Data Loss (%)			**74.9 %**		**Average Throughput** *(Successful Transmission only)*		**34393.3**

6. INTERPRETATION OF THE FINDINGS

The principal finding of this study lies with the different types of task-oriented data packet transmission for the end-to-end Internet of Things (IoT) [29-32]. This dwells on autonomous communication and interaction between connected devices. Wireless Sensor Network (WSN) is

one of the M2M topologies where a various number of wireless sensing nodes are operating cooperatively or individually by interacting with one monitor and control station which is called the sink node. WSNs functionality relies on its wireless communication capabilities and performance. There are various technologies and products available to provide the WSN with a wireless connectivity. This paper studied the HC-12 transceiver as one of the available wireless modules on the market that used in M2M and IoT projects.

The main aim of this study is to achieve the proposed objectives. The first objective is to “examine the effect of data size associated with its given task” by performing different transmission scenarios over certain distances between the transmitter and the receiver nodes, with different data sizes and different data rates in order to observe the effect of the size among the transmitted data towards packet loss, and transmission throughput.

The experiment covered five different configurable bandwidths, for each bandwidth (Serial Baud Rate) 12 transmission test cases is performed based on specific data size. The transmitted data sizes varied from 1 packet (64

B) per transmission, until it reached to 2048 packet (128 KB) as a maximum test case size. The experiment results showed that the data size has a significant impact on the transmission success only at the high baud rates (57600 and 115200) only when the transmitted data size is greater than 128 Packets (8 KB). furthermore, data size has generally showed a slight impact on the transmission throughput. Nevertheless, the data size has a slight effect toward the transmission sessions among the other baud rates among all distances.

The main purpose of the designed software is to isolate the interface layer from the complication of the hardware configuration. Thus, the software provided the full functionality of configuring and controlling the hardware dynamically, just by few mouse clicks. Usually, in this type of projects, the configuration of the hardware components requires programming commands and sometimes hardware modifications which is inapplicable for the end-user. The designed software has successfully empowered anyone with a basic computer background to control the hardware and use it. Furthermore, the Graphical User Interface (GUI) software saved a long time during the data collection phase. Although the designed system provided multiple software and hardware features that facilitated the operations of the sensor nodes. However, extra hardware parts are used to provide optional features such as driving motors, Bluetooth connectivity, humidity and temperature sensor, and GPS chip, which are inessential for the operation of the wireless transmission. In other words, the proposed system consumes more power and more hardware resources from the main microcontroller unit. The question that arises is to what extent the proposed system might affect the HC-12 transceiver performance negatively. On the other hand, regardless the designed software, it is important to measure the performance of the HC-12 transceiver in order to realize how to utilize its capabilities.

The HC-12 evaluation concerned about three aspects. First, the evaluation of the transmission success based on the distance and the configured bandwidth. Second, the evaluation of the data transmission based on the distance regardless the configured bandwidth. Finally, the overall evaluation of the HC-12 transceiver.

The transmission success is significantly affected by both the distance between nodes and the configured bandwidth. Figure 14 shows the percentage of successful transmission over different distances using the available baud rates. It is observed that, baud rate and distance have an inverse correlation with the transmission success.

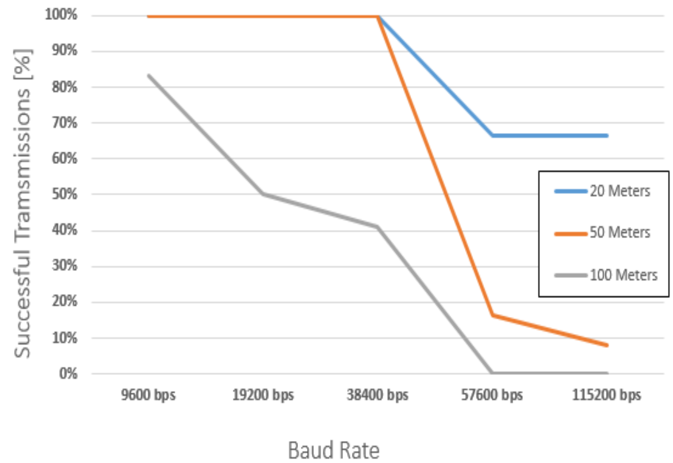

FIGURE 14. HC-12 baud-rate over distance evaluation

The distance evaluation of the HC-12 transceiver showed a significant inverse correlation between the distance and the transmission success regardless the configured band width and the transmitted data size as shown in Figure 15.

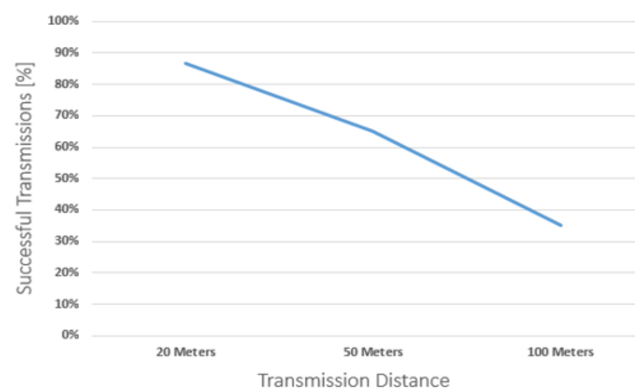

FIGURE 15. HC-12 distance evaluation

The overall collected data over all distances has been merged together to measure the percentage of successful transmitted data (accuracy) over each bandwidth, and the average throughput percentage (performance) at each bandwidth as shown in Table 7. The default bandwidth shows the most data integrity percentage over all transmissions. Then the accuracy gradually degrading in the next two baud rates. On the other hand, there is a dramatic change in accuracy in the last two baud rates. Although, the highest bandwidth has the best throughput, however, it has the worst data accuracy with 75 % data losses.

TABLE 7 HC-12 PERFORMANCE EVALUATION

Bandwidth (bps)	Accuracy (%)	Performance (%)
9600	94.4	90.43
19200	83.3	90.0
38400	80.5	89.7
57600	27.7	88.5
115200	25	91.1

HC-12 showed a steady throughput percentage during all transmissions. However, there is an accuracy gap between the first three baud rates and the last two as shown in Figure 16.

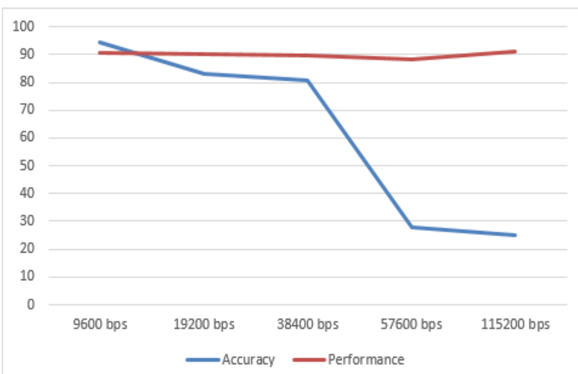

Figure 16. HC-12 Performance Evaluation

A hardware modification has been done to the sensor nodes and the topology in order to minimize the hardware components and software features to observe the performance of the transmission sessions with lower processing and power consumption as original legacy systems work. Thus, all extra hardware components are unplugged from the sensor nodes except the HC-12 transceiver and the buzzer (piezo speaker).

Each node has either receiving code or transmitting code. The communication between the laptop (sink node) and the transmitter was done using a USB wire cable. Then the communication between nodes was done through HC-12 as usual. However, there is no any direct connection between the sink node and the receiver node. Sink node configures the receiver node through the transmitter node. The sink node controls the nodes through Arduino studio command line interface only.

Meanwhile, two transmission sessions were performed, one by using the proposed system and the other by using the legacy system. Taking into consideration that both experiments were done under the same circumstance (Distance, transmission speed, data sizes, antenna height, and environmental circumstances). According to the results of the t-tests, the collected data showed insignificant performance differences in wireless transmission between the legacy system and the proposed system (P-value of the t-tests >0.05). Figure 17 shows the performance comparison between the legacy system and the proposed system.

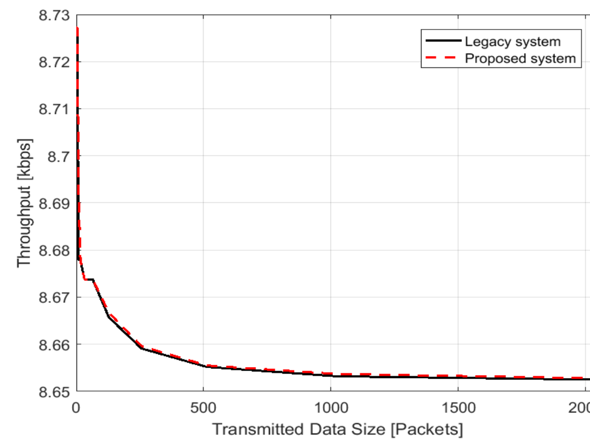

Figure 17. Transmission over the legacy system and proposed system.

7. CONCLUSION

The Internet of Things empowers the physical objects to communicate with the virtual online world without human intervention by using machine-to-machine communication. The emergence of mobility and portability concepts have enabled growth of scalability and extensibility of the IoT connected devices. Thus, the low power and low rate wireless sensors have become one of the most important IoT enabling technologies. However, the existence of tremendous wireless products on the market with various specifications, capabilities, and prices have raised many questions regarding their suitability and efficiency. The practical erudition of a certain wireless transceiver contributes to the industrial fields and market products. This study investigated HC-12 wireless transceiver in real-time outdoor experiments. The study found that HC-12 is more reliable and stable over short distances and with a proper height from the ground. The recommended bandwidth that showed the least data loss was (9600 bps). The recommended data size to be transmitted at a time when using the highest baud rate (115200 bps) is (8 KB) in order to avoid data loss. It has been observed that the proposed system could consume power more wisely if the hardware components have power saving features. For instance, the usage of GPS and DHT temperature sensor is very limited in the system and might be used in a few cases. However, because they don't have sleep capability, they waste the battery power as long as the nodes are switched on. Thus, it is highly recommended to use sleep mode enabled components, which can be switched on or off programmatically without extra hardware switches or transistors. Furthermore, the power source is one of the most important components that might malfunction the whole system if it has not selected properly. From the experience of this project, it is recommended to supply the Arduino with a dedicated power source between 7 – 9 voltages to provide adequate voltage and current. Finally, it is recommended to use DC buck converter instead of a linear regulator to provide low voltages to the system components. According to the findings of the data analysis, the HC-12 wireless transceiver is capable to perform efficiently in outdoor environments with up to 50 meters. However, to overcome this short distance coverage multiple nodes could be added in order to increase the transmission distance. Based on this study, the HC-12 can be used in real-life outdoor applications such as: precisions agriculture and climate monitor.

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Adamu Abubakar Ibrahim is currently an Assistant Professor in the department of Computer Science International Islamic University Malaysia (IIUM). He obtained his BSc (Hon) degree in Geography, PGD, MSc and PhD degrees in Computer Science and Information Technology from Bayero University, Kano, Nigeria and IIUM respectively. He received many awards in Invention and Innovation and published many papers in conferences, journals, and book chapters during his. He is a professional member of Association for Computing Machinery (ACM) and Institute of Electrical and Electronics Engineers (IEEE) since 2014.

Mohamed Tarek El-Gammal graduated from International Islamic University Malaysia where he obtained his Master in Information and Communication Technology at the Kulliyyah of Information and Communication Technology International Islamic University Malaysia (IIUM). His main area of research interest is on Artificial Intelligence.

Ala Abdusalam Alarood is currently an Assistant Professor of Computer Science in Faculty of Computer and Information Technology, University of Jeddah. He obtained his Bachelor, Masters and Phd in Computer Science from Yarmok University Jordan and Universiti Teknologi Malaysia respectively. His current research interest is in the area of Information Security, Networks Security, Steganalysis, Machine Learning, and Neural Network.