ECTI Transactions on Computer and Information Technology
Journal homepage: https://ph01.tci-thaijo.org/index.php/ecticit/
Published by the ECTI Association, Thailand, ISSN: 2286-9131

An Experimental Study of Wireless Network Configuration for a Device-free Human Detection System using RSSI Signals

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ABSTRACT

In recent years, device-free localization (DFL) has been an interesting technique that can detect humans in both indoor and outdoor environments without attaching any devices to them. Since the DFL is integrated with wireless networks, it can be applied in several applications. In this paper, we propose the network configuration protocol for the device-free human detection system using a received signal strength indicator (RSSI) with wireless nodes based on the IEEE 802.15.4 standard. The contribution and novelty of this proposed system are that it assigns a coordinator node for setting important parameters, including sampling rate, transmit power, filter algorithm, and window size, to adapt the network behavior for efficient human detection. The packet delivery ratio (PDR) has been studied for the network performance of this system. Experimental results show that the packet success rate is higher than 90% when the sampling rate is less than 100 samplings per second. Additionally, to increase human detection accuracy, a weighted moving average (WMA) filter is employed to smooth the RSSI data. Appropriate window size has also been studied for this process. Finally, the experimental results demonstrate that the proposed system with a zone-based detection method obtains high accuracy regarding the correct detection.

Article information:
Keywords: Device-free Localization, WSNs, Sampling Rate, RSSI, Filter Algorithm

Article history:
Received: July 22, 2022
Revised: August 13, 2022
Accepted: January 21, 2023
Published: March 11, 2023 (Online)

DOI: 10.37936/ecti-cit.2023171.249021

1. INTRODUCTION

DFL technology operates radio frequencies with wireless communication devices for real-time human detection [1–3]. This technique can work with the most well-known wireless network standard, the IEEE 802.11 standard for Wi-Fi in general use. There is also the IEEE 802.15.4 standard, a low-power wireless communication standard for sensor networks [4-8].

The DFL systems with the radio frequency were proposed in [1–3] using the RSSI information. They used a combination of RSSI properties as a condition for detecting people by processing RSSI data at a given time or window. The network structure was developed for a one-array full mesh topology. This network infrastructure was arranged to communicate between devices on the same plane and had no joint communication with a network on another plane. Since our goal in this work is to detect only humans, it is different from [4], which developed a fall detection system that required RSSI data with many dimensions and volumes of the communication network.

The process of data cleaning for communication signals received from a wireless network was described in [9]. It was necessary to go through a data cleaning method to eliminate the noise caused by environments. The WMA filter algorithm, a data cleaning algorithm, was presented in such a paper. However, DFL-related articles have been reviewed, and most of the signals were not filtered before being analyzed to enter the next detection process. After filtering, the process could detect more accurately. Based on this information, this work also presents a filtering signal process that can respond to change quickly with low and uncomplicated processing.

Our work develops to study the inspection floor size of 4 m × 4 m due to the size of an operating room approximately. It is easy to provide a place

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for daily experimentation with the number of devices in the network. A minimum network of four devices is sufficient for the RSSI data to be used to detect people covering the interest area.

2. PROPOSED NETWORK

2.1 Network System

The proposed network provides a packet structure that designs a node's network operation, BSN, and network operation settings through the user interface on a computer (PC). The packet structure applies to communication through TinyOS, which supports commands to set the data in the metadata section of the software and be able to design and develop independently with a size not exceeding 28 bytes.

There are six types of packets that have been designed and used in our proposed network. It consists of three types of data, as follows: PC-Mote packet, Mote-Mote packet as well as Mote-Mote response packet (see Fig. 1), and three kinds without metadata as follows: Mote-Mote join request packet, Mote-Mote join response packet, and Mote-Mote query packet. They use it to verify node communication and initiate communication only.

PC-Mote packet

Name	Size (bytes)	Description
txPower	2	Transmission power of the communication.
queryRate	2	Query-rate is the query interval that represents to sampling-rate configuration for start the communication.

Mote-Mote packet

Name	Size (bytes)	Description
txPower	2	Transmission power of the communication.

Mote-Mote response packet

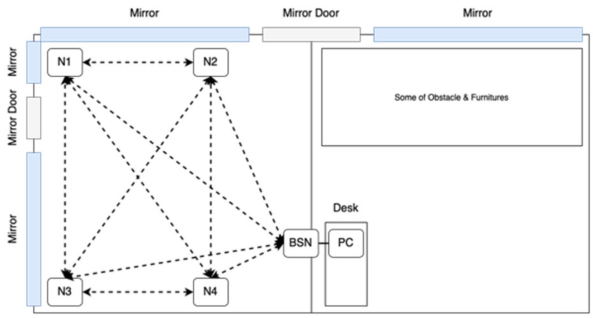
Name	Size (bytes)	Description
a	8	RSSI storage A
B	8	RSSI storage B
c	8	RSSI storage C

Fig.1: *Data structures in each packet.*

Four nodes and one BSN connected to a PC's serial port make up our communication network, operating in a full mesh topology, as seen in Fig. 2. These four nodes measure each other's RSSI values and send the RSSI data back to the BSN. Every node's communication takes place in a certain setting. A wall is made of concrete, while the other two walls have glass tops on them. Additionally, there are several obstacles behind them. Due to the impact of various reflection indications from the surrounding environment, the RSSI of each communication route has varying signal levels.

The network architecture can be divided into two types according to a node's functionality.

- *Mote* is a wireless communication device. The functions of the wireless nodes in Fig. 2 are N1, N2, N3, and N4, respectively. They all have to wait for the Mote-Mote packet from the BSN to initiate the Mote-Mote response packet that stores the RSSI data for sending to the BSN.
- *Base station (BSN)* serves to send commands to initiate communication of each mote, including setting the network's transmitting power and setting the data collection speed of the network at the BSN from the PC. Network radio signal strength reports data to the PC for storage and analysis.



(a) Proposed network

(b) Web interface

Fig.2: *Our proposed network and web interface.*

Where as the PC receives communication settings from users through the web interface, as seen in Fig. 2 (b), to set up the network system, process data, and display it to users. The components of the web interface are as follows:

1. *System setting:* the user can configure sampling rates, transmit powers, filter algorithms, and window sizes of the radio signal strength averaging process, as well as start and stop the system, which includes all network functions. Signal data will be saved on the computer after processing for the developer's convenience in analyzing the data continuously.
2. *Network communication path display:* When the system detects humans in the communication path, the path's color will change to reflect the detection.
3. *Data display:* a section of the communication path that detects the human shows three routes for each mote, with the first line being the most clearly detected path and the less clearly detected path, respectively.
4. *Received signal strength graph display:* RSSI

signals from all communication routes will be displayed.

5. *Latest RSSI data display:* All communication routes, including the selected communication path, will be reported.

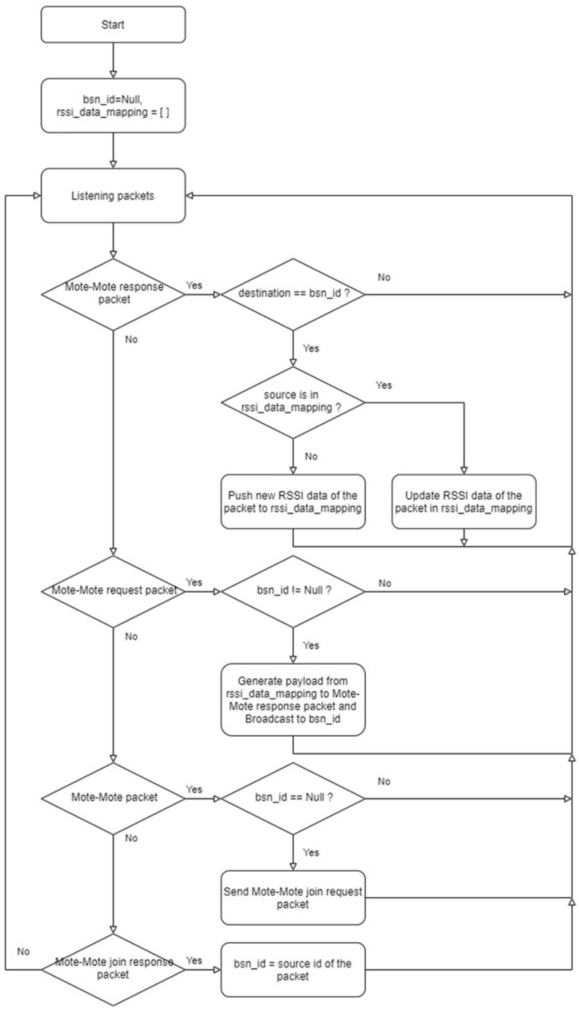


Fig.3: *Mote operation.*

2.2 Network Operation

As illustrated in Fig. 3, before the motes initiate communication with the BSN to transmit the radio signal, it is necessary to communicate with the BSN to join the communication network, where the mote listens to the Mote-Mote packet from the BSN. This message modifies the mote's configuration and is used for nodes joining the network. When the node has not joined the network, it receives the Mote-Mote message. The packet then sends the Mote-Mote join request packet back to the BSN, requesting to join the network. If the node receives the Mote-Mote join response packet, it will recognize the BSN requesting to join and wait for the Mote-Mote query packet to send RSSI data to the BSN. After the node joins the network, the node operates in two ways.

The first operation is receiving the Mote-Mote query packet and beginning to send the RSSI data to the BSN with the Mote-Mote response packet. The next step is receiving the Mote-Mote response packet from another node in the network. It collects the source node and the RSSI to wait for data to be sent during the receiving own Mote-Mote query packet. The Mote-Mote response packet can store all network communication paths in a single packet. It can make data communication efficient in terms of speed increase and adaptability to data changes.

The crucial communication in each cycle of communications from mote to the BSN with the Mote-Mote response packet can store all communication paths in a single packet. This method makes communication more efficient and increases response time to data changes. We designed the Mote-Mote response packet structured in Fig. 1 with three variables. The characters a, b, and c are 8 bytes for a total of 24 bytes. Every 2 bytes of data for each variable contain the first 4 bits as the source node number and the last 12 bits for the RSSI, as shown in Fig. 4 (a). For example, mote stores four node numbers and RSSI data in 2-byte variables, consisting of the first 4 bits as node numbers and the last 12 bits as the RSSI.

In Fig. 4 (b), mote stores the previously created 2-byte path data for the Mote-Mote response packet. Firstly, it checks if the last 2 bytes of variable a in the Mote-Mote response packet equals 0x00. If so, this means that variables can store additional data. The node stores the newly created 2 bytes after variable a and shifts bits to 2 bytes. If the last 2 bytes of variable a are not equal to 0x00, then the entire data cannot be stored. The node will continue to use variables b and c.

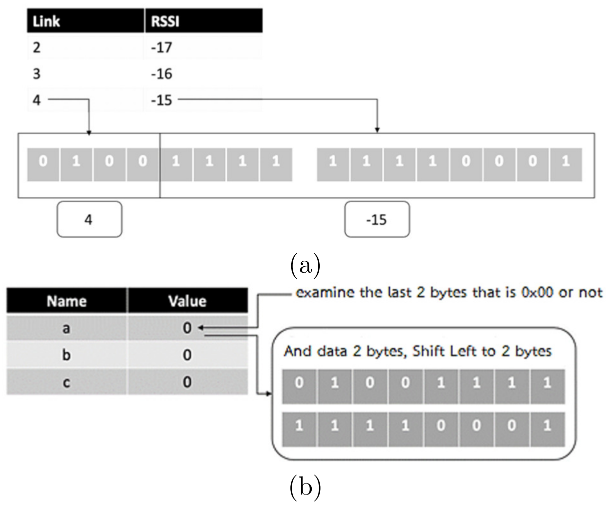


Fig.4: *(a) Generating route data combined with RSSI data, and (b) Storing RSSI data into the Mote-Mote response packet.*

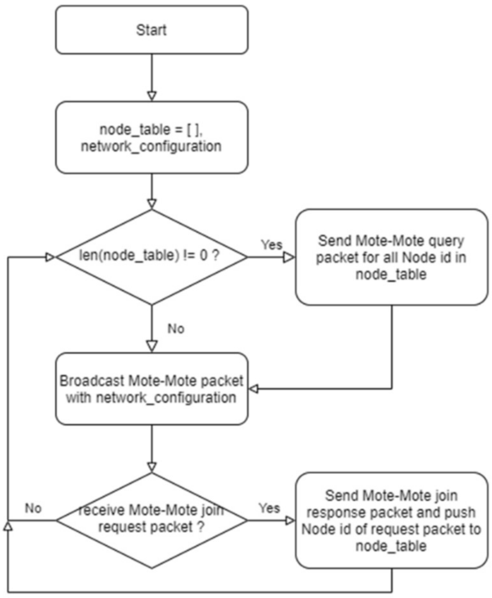


Fig.5: *Base station operation.*

The BSN starts first to check whether there is any node in the network. If so, the BSN will begin to send the Mote-Mote query packet to every node in the network to request the RSSI information and end the communication cycle by sending the Mote-Mote packet to update the network settings based on the settings from the user. Then, the operation begins to continue the node's communication. The BSN operation, as seen in Fig. 5, shows that the network is directed by the respective network's BSN, which ensures the occurrence of a collision event. Communication is minimal because the communication is organized in a clear sequence.

The BSN startup creates a variable node_table = [...] for storing the number of communication nodes in the network among communications. Mote creates a variable BSN equal to null for storing the number of the BSN that is communicating, and the variable rssi_table = [...] for storing RSSI data of communication paths. Since the BSN does not contain node number information, the first transmission of the message is the Mote-Mote packet, which is the message that updates network behavior and network join permissions as seen in step (2) of Fig. 6. When the variable of the BSN is null, it receives the Mote-Mote join request packet for BSN requesting to join the network, after which BSN will recognize and respond with this message, as illustrated in step (3) of Fig. 6.

When BSN detects that node number information is available in the node_table variable, it sends the mote-Mote query packet to every node in the node_table variable, respectively, as seen in step (4). The BSN sends a message to N1. After N1 receives the Mote-Mote query packet, it takes the data from the rssi_table variable and stores it in the Mote-Mote response packet, as seen in step (5). N1 also sends the message back to the BSN in broadcast format, thus enabling another node. Any node on the network can receive this message for further processing. When the BSN receives the Mote-Mote response packet, the RSSI data is sent to the PC, but for other nodes, when the Mote-Mote response packet is received, it reads The RSSI of this message stores the message's source ID along with the readable RSSI into the rssi_table variable, as seen in step (6). Based on the BSN behavior described here, the BSN will continue to send the Mote-Mote query packet to the remaining nodes based on the node number in the node_table variable, from N2, N3, N4, and so on.

2.3 Network Application

A fundamental human detection tool frequently employed and used as an evaluation methodology in DFL research is the link-based or zone-based method [7, 10, 11]. This method detects human movements in each zone (or each area in the wireless networks) by comparing the measured RSSI level with the threshold, representing the human presence situation. The different RSSI levels between cases with and without humans in the zone are explored for threshold determination.

In this work, we create a new algorithm that can increase human detection accuracy based on the link-based or zone-based method. Moreover, it speeds up the presentation of information to users through the web interface.

The proposed method has three main functions, see Fig. 7:

1. *Filter algorithm:* This is an essential solution that can reduce RSSI noise from raw RSSI data and leads to the next step.
2. *Normalization:* This function can first adjust the signal level to the same level to make detection easier. The method subtracts the average RSSI of the communication path from the current RSSI data.
3. *Sorting:* The data also has a small amount of noise, a signal level of ± 1 dBm. This is a range of data to be ignored. Signal information that is less than -1 dBm is considered and sorted ascendingly in the form of the RSSI array of communication channels. The RSSI of the most affected communication path to the least affected way is represented in this sorted data. The earliest position information in the array can then be used to determine humans.

As mentioned above, our proposed human detection method uses the filter algorithm. In this work, the weighted moving average or WMA filter is applied, as calculated in (1).

$$\bar{x}_i^t = \frac{w_{i,t-kk+1} x_{i,t-k+1} + \cdots + w_{i,t} x_{i,t}}{w_{i,t-kk+1} + \cdots + w_{i,t}} \quad (1)$$

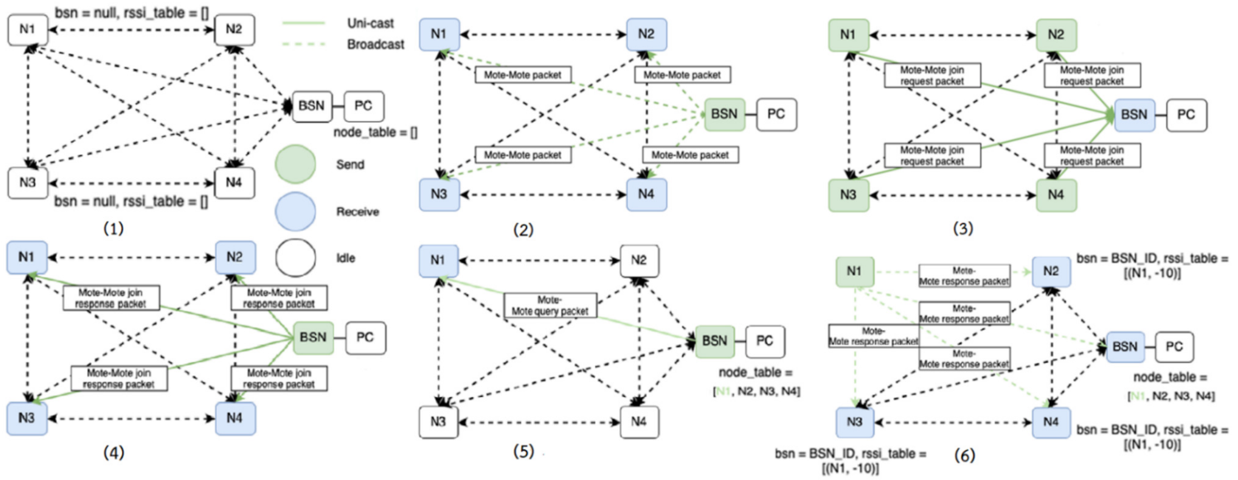


Fig.6: *Network configuration.*

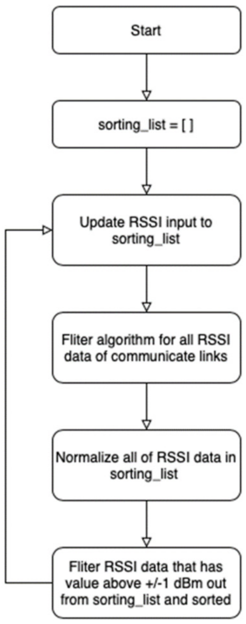


Fig.7: *The operation of the proposed human detection method.*

Where $w_{i,t}$ is the weight of $x_{i,t}$ (i.e. the RSSI value) at the sensor i and time t.

With the proposed system, three tests, as shown in Fig. 8, have been created for the walking pattern scenarios, which are arranged in order of the complexity of the experimental pattern as follows:

1. Pattern A: The communication network is traversed by a person who then makes their way back.
2. Pattern B: A person walks through all routes of the communication network, as seen in the figure.
3. Pattern C: A person traverses each path of an intermediary communication network.

3. RESULTS AND DISCUSSION

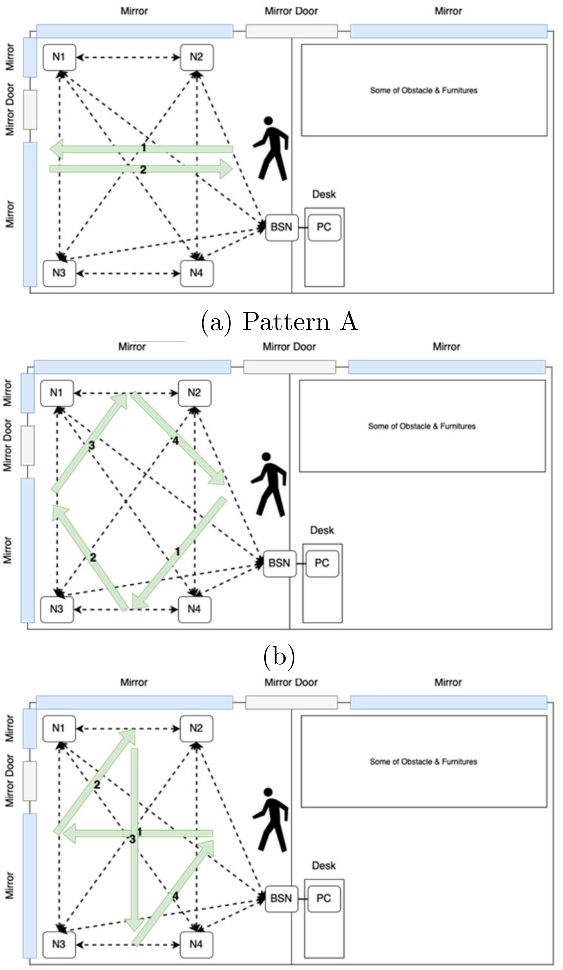
3.1 Network Performance

In the experimental results regarding the proposed network, we used the real hardware wireless node, Zolertia Z1 Motes, for our network system and studied the packet delivery ratio (PDR). The PDR is the ratio of the total number of packets received by the destination node to the total number of packets sent by the source node. The calculation of the PDR has been expressed in (2).

$$PDR(\%) = \frac{receive\_packet}{send\_packet} \times 100 \qquad (2)$$

The implementation has been divided into two tests. The first experiment is the study of the PDR in one-to-one communication. The test has been desired to measure the network performance in the actual hardware with five different time intervals from 5 ms to 25 ms, as demonstrated in Fig. 9. This measurement can find the suitable timeslot for communication with maximum packet payload between nodes. For the tests, the packet success rate while sending the data obtains almost 100%. The smallest interval, 5 ms, can make communication successful with an 88.10% PDR. As a result, when increasing the time intervals, the PDR value will increase accordingly. From a time interval of 5 ms to 10 ms, the PDR result increases significantly to 95.91%. However, at higher intervals after 10 ms, the PDR increases slightly in the range of 95 - 99%. Therefore, the selected time interval for our proposed network is 10 ms.

For the second experiment, we set the time slot per packet at 10 ms, as the PDR is greater than 95%. When we deployed on the existing network, as seen in Fig. 8, the result represented the PDR at 93%, with a slight decrease of 2.91%. Nevertheless, it still gives more than 90% of the PDR, which can be considered reliable to be used in the actual environment



(a) Pattern A

(b)

(c)

Fig. 8: *Walking pattern scenarios; Pattern A, B, and C.*

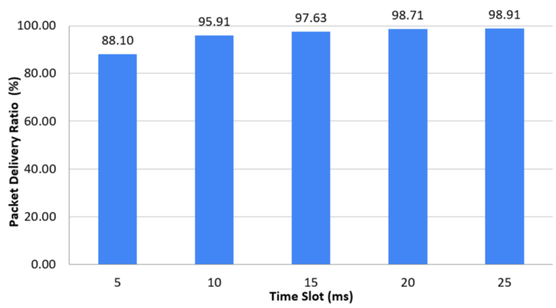


Fig. 9: *PDR in one-to-one communication.*

for future work.

3.2 Network Settings

We continue to employ the same wireless sensor nodes in this experimental result concerning the suggested network. Five window sizes are used to test the WMA: 5, 10, 15, 20, and 25. The N2-N4 communication link used in this test is depicted with a person walking over it. The experimental result demonstrates that the signal attenuation is also two times. When using the WMA, it is compared to the graph of the N2-N4 communication link. The outcome considers the peak delay, which represents the period when the RSSI's lowest value passed through the filter algorithm at a slower rate than the period when the RSSI's actual minimum signal occurred. The final result considers the peak loss, which represents the minimum difference of RSSI through the filter algorithm with the lowest value of RSSI from the real signal. WMA results are summarized for peak delay and peak loss in Table 1. As the window size increases, the value of peak delay and peak loss increases, respectively.

Table 1: *Parameters studied in the WMA experiments.*

Window size	**Peak delay (milliseconds)**	**Peak loss (dBm)**
5	400	-2
10	900	-3
15	1200	-5
20	1700	-6
25	2200	-6

According to Table 1, when considering the development of systems requiring faster response speeds, choosing a window size of 5 seems to be the most appropriate. However, it cannot conclude the results of this experiment immediately because the higher the window size, the lower the signal noise. In some cases, the compromise of reducing response times in exchange for higher accuracy in human detection seems to be an option worth exploring.

The following experimental results demonstrate the origin of the standard deviations (STD) used in our proposed method of detecting the mean change of the RSSI with the RSSI processing at regular intervals. The RSSI approaches are constant and unaffected by the environment or people. Our selection uses RSSI from six communication routes for testing, namely N1-N2, N1-N3, N1-N4, N2-N3, N2-N4, and N3-N4. One thousand data points for each route have been collected during ten iterations to calculate the variance's average over all paths.

Table 2: *The STD of RSSI means changing the detection method.*

Communication Links	**STD**
N1-N2	0.495
N1-N3	0.367
N1-N4	0.216
N2-N3	0.385
N2-N4	0.583
N3-N4	0.586
Average STD	0.439

As seen in Table 2, represents the values of the STD of the RSSI mean change detection method for each communication route. We conclude that the mean STD for all communication routes is 0.439. The RSSI suggests change detection method's criteria are for calculating STD values. The way of capturing the average change in RSSI is a step forward for future work. Other variables that affect RSSI averages can lead to errors in the process of identifying people using detection methods. However, we do not always want to restart the offline phase process, so the RSSI mean change detection method is developed to detect the change and keep improving the original stored RSSI mean for the correct operation at all times.

$$Average_{rssi} = \begin{cases} Mean(rssi\_window), Std(rssi\_window) < 0.439 \\ Do\ nothing, otherwise \end{cases} \quad (3)$$

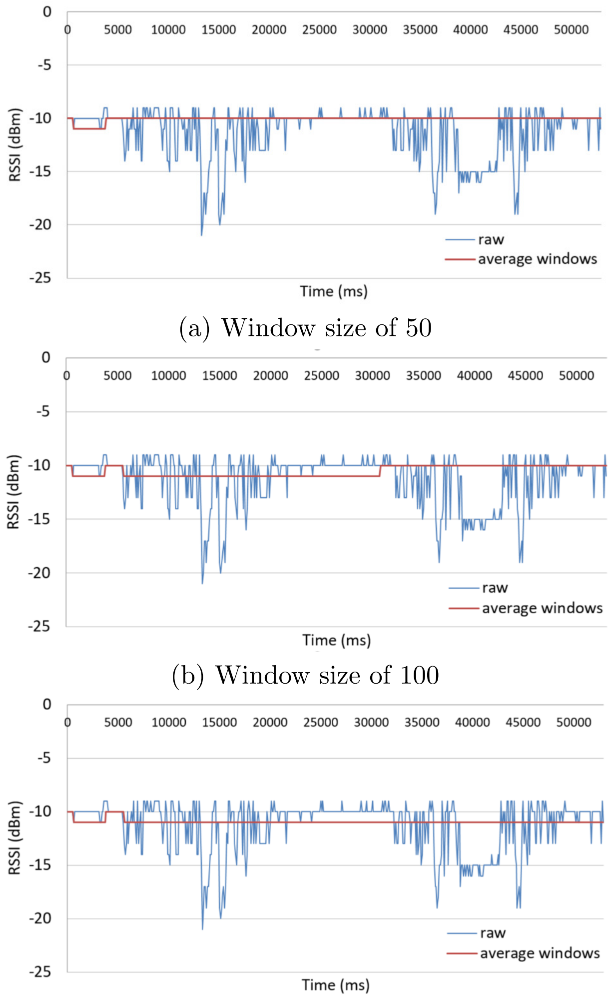
Where $rssi\_window$ is the RSSI dataset stored at the beginning of the process in the averaging range.

The values will be adjusted at the start of the averaging. When the STD of the stored RSSI dataset is in (3), the network operates under conditions where the environment has a slight impact on the RSSI and is relatively stable. No other changes will be made because the RSSI is severely compromised. Otherwise, a human is present in the communication network.

The following results demonstrate the origin of the RSSI window size value used in the RSSI means change detection method. We select to use RSSIs from communication paths N2-N4 from pattern A, as in Fig. 8. It is the signal data with a human walking through the path twice at a time, 10-20 s and 30-50 s, tested with different window size values. The window size values of 50, 100, 150, 200, and 250 have been tested. The blue line represents the signal data of link N2-N4, and the red line shows the current average RSSI.

As a result of the window size being set to 50, which is the lowest value, as seen in Fig. 10. The mean RSSI initially decreases slightly before returning to -10 dBm, with no individual response to the RSSI change. The window size of 100, the second set, shows that the average RSSI at the beginning was also slightly lower. However, the mean improvement to -10 dBm was significantly slower than the window size of 50.

As the window size increased until the maximum value, as seen in the result in Fig. 10 (c), the data and interval used to improve the mean back to -10 dBm was even greater. Thus, it is the origin of the window size that will be used in the experiment. Our proposed network has been selected to use a window size of 50.



(a) Window size of 50

(b) Window size of 100

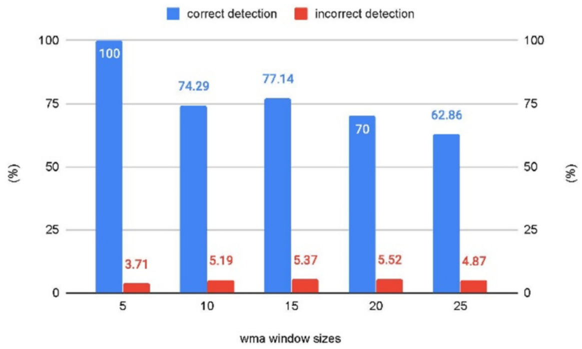
(c) Window size of 250

Fig.10: *The window size test result of the RSSI mean change detection method.*

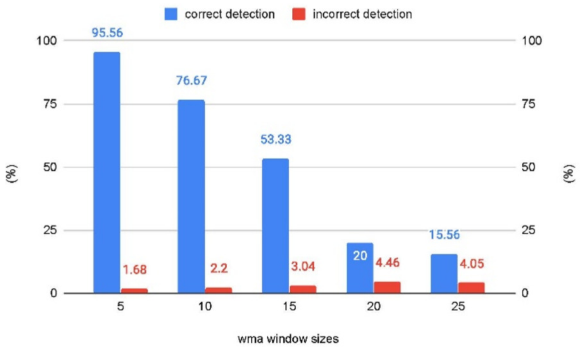
3.3 Human Detection System

For the first walking pattern, as in Fig. 8, the experiment on pattern A has been tested with ten iterations. Because the proposed detection method has not been modified by any additional variables, we can directly use the graph data similar to Fig. 10 to reproduce the experiment results. We know the exact number of patterns, and we can identify the correct person detections in percentage. Invalid person detections are summed up as an average of the number of times instead. According to the results, the proposed method achieves human detection with 100% accuracy, with an average number of invalid detections based on the pattern of only 3.17%. For these results of the individual detection experiment in pattern A using the WMA technique, we selected the experimental result with a window size of 5 because it is the most accurate person detection test result.

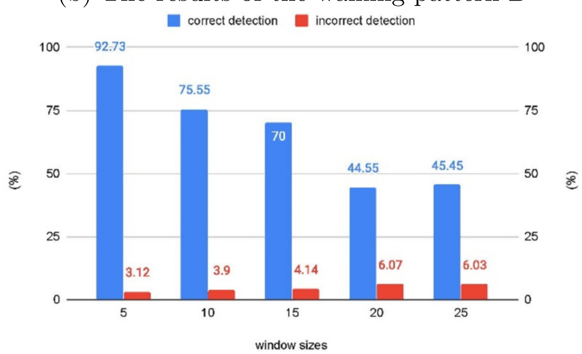
We also select the experimental result with a window size of 5 for the individual detection experiment for the walking pattern B because it is the most accu-



(a) The results of the walking pattern A



(b) The results of the walking pattern B



(c) The results of the walking pattern C

Fig.11: *The detection results of the walking patterns.*

rate person detection result (95.56%), and the results of individual detection experiments for the incorrect value have the lowest average (1.68%).

Finally, for the experimental results of person detection in the third pattern, we still choose the result of having the window size equal to 5. The development of the detection of the most accurate person is 92.73%, and the influence of invalid individual detection shows the value at the lowest average of 3.12%.

3.4 Discussion

All experimental results have been divided into two parts: the performance of our proposed network and the efficiency of our proposed method for human detection. For the network performance test, we initially tested the optimal timing of one-to-one communication as the timeslot period of the network communication method. Based on the experimental results, the selected time interval was ten milliseconds, which yielded 95.91% network efficiency. When we used it in a real-world implementation with four nodes communicating with the BSN, the PDR results also showed a good value of 93%. However, the actual communication PDR is greater than 90%, thus ensuring that the RSSI data from our proposed network is reliable to use continuously in the field of human detection.

The results of testing the effectiveness of the human detection method take the RSSI data from the proposed network. An experiment with different variables using signal data from three walking patterns has been examined. The experimental results show that the human detection technique with the weighted moving average and a window size of 5 provides the following accurate detection results and the average number of invalid detection results for walking patterns: (100%, 3.71%), (95.56%, 1.68%), and (92.73%, 3.12%), respectively.

All results here indicate that both the proposed network and the proposed human detection method with the WMA filter and the window size of 5 can efficiently be used to detect a person in different human walking patterns with high communication reliability and detection accuracy.

4. CONCLUSIONS

From the experiment performed using the sensor node Z1 test results, there are two parts, which are the wireless communication network for DFL and the human detection technique. The packet format, joining procedures, and storage of all RSSI data are all part of the network system design. The packet inter-arrival time is short and is suitable for real-time development. It is a significant factor for the specific value influencing communication reliability as identified by the packet delivery ratio. Additionally, we also proposed a human detection technique by bringing the measured RSSI data to normalization using the RSSI mean-changing detection method. It also chooses a data cleaning method to reduce the noise of RSSI data by using a filter algorithm. Results from the weighted moving average with the smallest window size show high detection accuracy.

References

[1] S. Sigg, S. Shi, F. Büsching, Y. Ji, and L. Wolf, “Leveraging RF-channel fluctuation for activity recognition: Active and passive systems, continuous and RSSI-based signal features,” *ACM International Conference Proceeding Series*, pp. 43–52, 2013.

[2] S. Sigg, M. Hock, M. Scholz, L. Wolf, Y. Ji, M. Beigl, and G. Tröster, “Passive, device-free recognition on your mobile phone: Tools, features and a case study,” *International Confer-*

ence on Mobile and Ubiquitous Systems: Computing, Networking, and Services, vol. 131, 12, pp 435-446, 2013.

[3] S. Sigg, U. Blanke, and G. Tröster, "The telepathic phone: Frictionless activity recognition from WiFi-RSSI," *2014 IEEE International Conference on Pervasive Computing and Communications (PerCom)*, pp. 148-155, 2014.

[4] S. Kianoush, S. Savazzi, F. Vicentini, V. Rampa, and M. Giussani, "Device-free RF human body fall detection and localization in industrial workplaces," *IEEE Internet of Things Journal*, vol. 4, no. 2, pp. 351–362, 2017.

[5] S. Shukri and L. Kamarudin, "Device free localization technology for human detection and counting with RF sensor networks: A review," *Journal of Network and Computer Applications*, vol. 97, no. 1, pp.157-174, 2017.

[6] S. J. Sreeraj and R. Ramanathan, "Improved geometric filter algorithm for device free localization," *Proc. 2017 Int. Conf. Wirel. Commun. Signal Process. Networking, WiSPNET 2017*, vol. 2018-Janua, pp. 914–918, 2018.

[7] J. S. C. Turner et al., "The study of human movement effect on signal strength for indoor WSN deployment," *2013 2013 IEEE Conference on Wireless Sensor (ICWISE)*, pp. 30–35, 2013.

[8] Y. Chapre, P.mohapatra, S. Jha, and A. Seneviratne, "Received signal strength indicator and its analysis in a typical WLAN system (short paper)," *38th Annual IEEE Conference on Local Computer Networks*, pp. 304–307, 2013.

[9] Y. Zhuang, L. Chen, X. S. Wang, and J. Lian, "A weighted moving average-based approach for cleaning sensor data," *27th International Conference on Distributed Computing Systems (ICDCS '07)*, pp 38-38, 2007.

[10] F. Vicentini, S. Savazzi, S. Kianoush,m. Giussani, and V. Rampa, "Device-Free RF Human Body Fall Detection and Localization in Industrial Workplaces," *EEE Internet of Things Journal*, vol. 4, no. 2, pp. 351–362, 2016.

[11] A. Booranawong, N. Jindapetch and H. Saito, "Adaptive Filtering Methods for RSSI Signals in a Device-Free Human Detection and Tracking System," in *IEEE Systems Journal*, vol. 13, no. 3, pp. 2998-3009, Sept. 2019.

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