A Wireless Network Configuration for Device-free Human Detection System using RSSI Signals

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Abstract: In many recent years, Device free localization (DFL) is an interesting technique which can detect human in both indoor and outdoor environments without attaching any devices on the person. Since the DFL is integrated with a wireless communication network, it can be applied in several applications. In this paper, we propose the network configuration protocol for the device-free human detection system using received signal strength indicator with wireless nodes, Zolertia Z1 Motes based on IEEE802.15.4 standard. This system needs a coordinator node for setting the important parameters such as sampling rate, transmit power, filter algorithm and window size to adapt the network behavior for the human detection system appropriately. Packet delivery ratio has been studied the network performance for this scheme. The experimental results show that the packet success rate is higher than 90% when sampling rate has less than 100 samplings per second.

Keywords: Device free localization, WSNs, sampling rate

1. Introduction

DFL technology operates radio frequency with wireless communication devices for real-time human detection. This technique can work with the most well-known wireless network standard, the IEEE 802.11 for Wi-Fi in general application. There is also a standard IEEE 802.15.4 which is a low-power wireless communication standard for small sensor networks.

The DFL systems with the radio frequency have been proposed in [1–3] using the received signal strength (RSSI) properties. They take a combination of those properties as a condition for detecting people with processing RSSI data at a time (window). The network structure developed for one-Array full mesh topology. This network infrastructure is arranged to communicate between devices on the same plane and no joint communication with a network on another plane. This is because our goal is to detect only the person. This is different from [4] that has developed a fall detection system that require RSSI data with many dimensions and volume of the communication network

Our work develops to study on the inspection floor size 4 m x 4 m due to the size of a working room approximately. It is easy to provide a place 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 interested area.

2. Proposed Network

2.1 Network System

This proposed communication network simplifies the process of storing the average of RSSI based on environmental impact with low complexity. It consists of a packet structure that designed the node's network operation, base station's network management settings through the user interface on a computer (PC). The packet structure applies to communicate through TinyOS which support 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 packages have been designed and used in our network. It consists of three types with data as follows: PC-Mote packet, Mote-Mote packet as well as Mote-Mote response packet as seen in Figure 1 and three types without metadata as following: Mote-Mote join request packet, Mote-Mote join response packet and Mote-Mote query packet. They use 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

Figure 1. Data Structures of messages with the data.

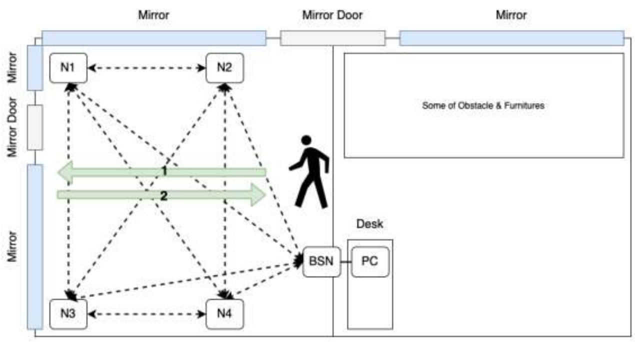

Figure 2. Our proposed network system

The architecture of network can be divided the nodes into

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two categories according to the functionality.

Mote is a wireless communication device. The functions of the wireless nodes from Figure 2 are: N1, N2, N3, and N4 they all have to wait for a Mote-Mote packet from the base station to initiate a Mote-Mote response packet that stores the radio signal strength data for sending to the base station

Base station (BSN) serves to send commands to initiate communication of each Mote, including setting the network's transmitting power and the data collection speed of the network at the BSN from the PC. Network radio signal strength has been reported to PC for storage and analysis. Whereas a computer (PC) serves to receive communication settings from the user through the web interface to set up the network system, process data and display to the user.

2.2 Network Operation

Before Motes initiate communication with BSN to transmit the radio signal strength. It is necessary to communicate with BSN in order to join the communication network, where the Mote listens to the Mote-Mote packet from BSN. This message modifies the Mote's configuration and is used for node's joining in the network. When a node has not joined the network received a Mote-Mote message. The packet then sends a Mote-Mote join request packet back to the BSN requesting to join the network. If the Mote receives a Mote-Mote join response packet, it will recognize the BSN requesting to join and wait for the Mote-Mote query packet to send radio signal strength data to BSN. After a node joins the network, the node operates in two ways.

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

BSN starts first to check whether there is any node in the network. If so, BSN will begin to send a Mote-Mote query packet to every node in the network for requesting the RSSI information and end the communication cycle by sending a Mote-Mote packet to update the network settings based on the settings from the user. After that, the operation begins to continue the node's communication. The network is managed by the network's BSN which ensures the occurrence of a collision event.

3. Results and discussion

In the experiment, we use the real hardware wireless node, Zolertia Z1 Motes, for our network system and study the Packet delivery ratio (PDR). PDR is the ratio of the total number of packets received by the destination node to the number of source packets sent as expressed in equation (1).

$$\mathrm{PDR}(\%) = \frac{\mathrm{received\_packet}}{\mathrm{sent\_packet}} \times 100 \qquad (1)$$

The implementation has been divided into two tests. The first experiment is the study of PDR in one-to-one communication. This test has been desired to measure the network performance in the real hardware with five different time intervals from 5 to 25 ms. This measurement can find the suitable time slot for the communication with maximum packet payload between nodes. For the tests, the mostly packet success rate when sending the data obtains almost 100% as seen in Figure 3.

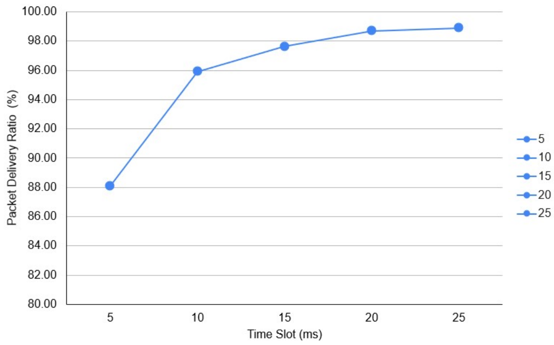

Figure 3. The packet delivery ratio for the first experiment

The smallest time interval, 5 ms, can make communication successful with 88.10% PDR. As a result, when increase the time intervals, the PDR value will increase accordingly. From a time interval of 5 ms to 10 ms, PDR result increases significantly with 95.91%. However, higher time intervals after 10 ms, the PDR increases slightly in the range 95 - 99%. Therefore, the selected time interval for our proposed network is at 10 ms.

For the second experiment, we use the time slot per packet at 10 ms as the PDR is more than 95%. When we deploy on the actual network as seen in the Figure 2, the result represents the PDR at 93% with a slight decrease at 2.91%. Nevertheless, it still gives more than 90% of the PDR which can be considered reliable to be used in the actual environment for the future work.

4. Conclusion

From the experiment performed using the sensor node Z1, the results show that packet time interval in the network is important factors for the certain value affecting the communication reliability identified by the packet delivery ratio. In the future work, we will study the other network performance for this proposed network such as the convergence time.

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," vol. 131, 12, pp 435-446, 2013.

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