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RSSI study of wireless Internet of Things technologies

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Abstract. The Internet of Things (IoT) idea now entails a dispersed collection of different sensor networks with several functions that collect data, which is then analysed and used in applications such as smart cities. These networks are capable of transmitting massive volumes of data in a relatively efficient, yet unsecure wireless environment. These applications will only succeed if is developed a dependable a low-cost real-time method for pinpointing accurate location. Power consumption is another consideration for indoor localisation. Recent wireless technologies like ZigBee, Bluetooth Low Energy (BLE) and Long Range (LoRa), use less resources, making them ideal for interior positioning. When IoT devices are utilised, these technologies are compared in terms of precision of localisation and power consumption. Tracking the Received Signal Strength Indicator (RSSI) values can be used to locate mobile sensor nodes for low-power IoT networks. The RSSI values of sensor nodes in the BLE, ZigBee and LoRa networks for IoT were explore in this study.

1. Introduction

Globally, 4.4 billion 5G subscriptions are expected by 2027, accounting for 49 percent of all mobile subscriptions. In terms of subscriptions, 5G will overtake 4G as the most popular mobile access technology in 2027. During the third quarter of 2021, 4G subscriptions climbed by nearly 48 million, bringing the total number of 4G subscriptions to more than 4.6 billion. As users shift to 5G, 4G subscriptions are peaked to 4.7 billion, then fall to roughly 3.3 billion by the end of 2027 [1]. The different types of Internet of Things (IoT) technologies are growing and integrating more and more as the coverage and capabilities of new generation networks (4G, 5G) expand, which provide a high-speed environment for transmitting different types of data [2].

IoT networks play variety of roles like to monitor parameters of the world around us like as temperature, pressure, humidity, illumination, and so on. In today's world, remote monitoring of many parameters is becoming more common, and the need for it is especially apparent during emergencies. Modern IoT sensor networks let for the periodically monitoring of metrics from static and moving sensor devices. These parameters can be used to monitor the state of the environment or the health of patients. On rare occasions, it might be essential to locate the network's sensor nodes. Tracking figures for Received Signal Strength Indicator (RSSI) is one method for accomplishing this with the help of a system of low-power sensor nodes.

The goal of this study is to compare the RSSI of several wireless technologies, including ZigBee, LoRa, and BLE. The wireless technologies under consideration chosen based on aspects like as popularity, public availability, and use in IoT. ZigBee is a prominent low-power technology that is frequently utilised in IoT applications. BLE is widely used in modern life. Most devices can communicate with at least one or both of these, allowing for the formation of a network of devices. LoRa is a revolutionary technology that is not as widely used as the preceding technologies. Because of their low cost and low power consumption, these technologies have become widely used in industrial applications. To achieve the linking of networks of sensing devices with communication LoRa and BLE in order to imitate an intelligent campus, comparative relations of performance characteristics. Each network has its own sniffer for collecting and analysing packets exchanged between nodes, as well as connectivity between LoRa devices via a gateway.

2. Related work

The present IoT revolution, which aims to create a universal link between things, is regarded as a component of the Internet of the Future. In the last few years, various methodologies have been used to develop an effective indoor localisation network. A perfect IoT network would function well in a variety of situations and be able to monitor a large number of targets with minimum errors. To determine the best inside location, a comparative analysis of the most common wireless technology like BLE, ZigBee and LoRa is required. Tracking the values for the RSSI is one approach to do this with a network of low-power sensor nodes.

The research in [3] compares BLE and Wi-Fi. In the experiments for outside and inside contexts trilateration used. Experiments carried out for both line of sight (LoS) and non-line of sight (NLoS) situations, and the distance between nodes calculated using RSSI measurements and the lognormal attenuation model. When utilised for localisation, the results show that BLE is more accurate than WiFi. When compared, the BLE was found to be more capable of relating RSSI values to distances, resulting in a more accurate system.

Wireless technologies such as ISM868 and Zigbee compared using a similar RSSI-based trilateration model in [4]. Studies conducted utilising RSSI values to establish the range in-between nodes in both outdoor and indoor settings. Both technologies are not suited for indoor localisation, according to the data, but Zigbee is the superior of the two. The experiment's hardware could have resulted in a high error rate; a fall detector was utilised as the transmitter to test ISM868, although this fall detector is not recommended for localisation and might have contributed to the significant error rate.

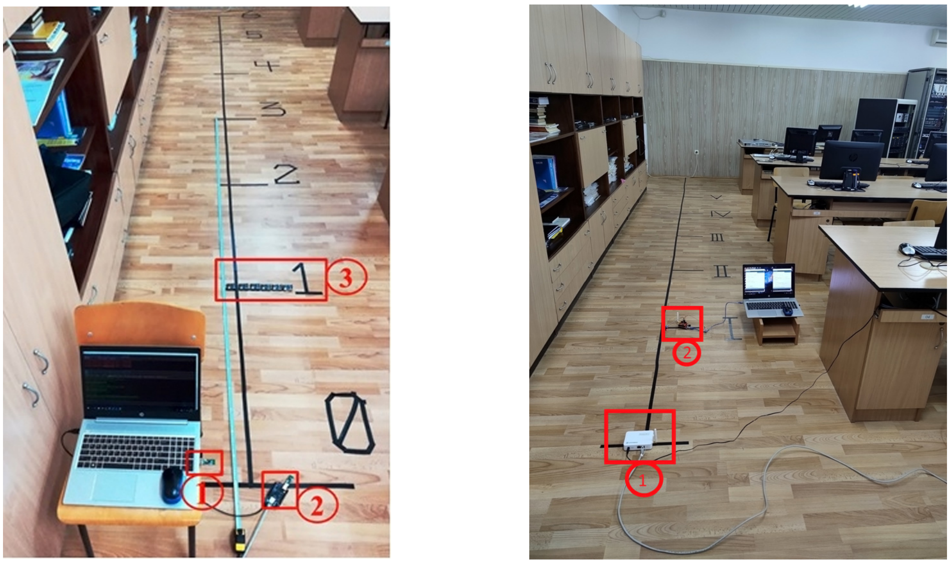
Based on a functional research and full utilisation of multi-channel RSSI in BLE technology, the work in [5] proposes a new high-precision approach of vehicle localisation. The goal of the study is to precisely locate the occupant in the car.

A comparison of IoT standards is made in [6]. The characteristics taken into account here are the accuracy and RSSI to compare wireless technologies. To approximate the location, several devices are employed as transmitter nodes, while the last device used as a receiver node. Wi-Fi was discovered to be the most precise of all examined technologies, with a low rate of errors, followed by BLE and LoRaWAN, which uses a low frequency of 915MHz to transmit and has a large departure from its transmission distance.

According to an analysis of those research, RSSI is critical in establishing the position of end devices while building IoT networks. This requires the study of RSSI in appropriate IoT technologies. The RSSI values of the sensor nodes in the BLE, ZigBee, and LoRa indoor networks for IoT were studied in this paper.

3. Experimental scenario, results, and physical deployment of LoRa, ZigBee and BLE

Experiments with the devices carried out with various numbers of static end nodes linked in the networks (1, 2, 3, 4, 5 and 6). The end nodes in each experiment placed at various distances from the main device. For the experiments, the connection topologies are shown on figure 1. The studies include calculating the values of the RSSI parameters, at distances of 1m, 2m, 3m, 4m, and 5m between the serving device and the sensor nodes when sending 20 packets.



a) b)

Figure 1. Experimental topologies: ZigBee and BLE physical topologies (a); LoRa physical topology (b).

A physical ZigBee network (figure 1 – a) is built using a BeagleBone Black (BBB) - BBB01-SC-505 [7] board with the operating system Bone-Debian-9.9. To interact successfully with the sensor nodes, a Texas Instruments (TI) transceiver - CC2531EMK [8] is put on the BBB board. The transceiver can be set up to use ZigBee or BLE technology (figure 1, a – 2).

The BLE network is built on the RaspberryPi 4 Model B [9] development environment. A built-in BLE transceiver on the RaspberryPi 4 board is used to communicate with the end sensor nodes.

The studies are carried out using TI sensor nodes which have variety standards - CC2650STK [10]. These sensor nodes could possibly be set up to function with ZigBee or BLE. The sensor nodes were configured with a TI CC-DEVPACK-DEBUG board [11]. Interception of ZigBee packets was done with the software ZBOSS sniffer. Wireshark requires a preliminary configuration to decode ZigBee packets, and the software provides a ZigBee stream for Wireshark, where intercepted packets are shown. The BLE packets can be intercepted using Wireshark too, which is installed on the RaspberryPi 4 board. The Bluetooth interface used to capture packets.

The LoRa network (figure 1 – b) is built with Dragino LG01-S - Single Channel LoRa IoT Gateway (figure 1, b – 1). It consists of a LoRa wireless module with a microcontroller and a Linux module for the Internet connection and the USB Host interface. The LoRa module is embedded by an RFM9xW 868MHz transceiver radio module with the SX1276 chipset, which is controlled by an Atmega 328P microcontroller loaded with an Arduino Uno bootloader [12].

For transmitting data a Dragino LoRa Shield with Arduino UNO is used (figure 1, b – 2). Lora Shield allows Arduino microcontroller boards to wirelessly transmit data over long distances with low power consumption. It is built from LoRa transceiver radio module RFM9xW 868MHz, which works with SPI interface via ICSP connector or digital D11-D13 ports of Arduino - configurable with jumpers. Several sensors can be connected to the LoRa Shield. For the purposes of the experiments are used flame sensor and DHT11 (Temperature & Humidity sensors). A Mosquitto server configuration using MQTT Broker on Windows was used to read the packages received from the LoRa gateway (figure 2). The topic whose messages will be listened to must first be selected (figure 2 – 1) and visualisation of captured packets and RSSI value through MQTT Broker on Windows can be seen (figure 2 – 2).

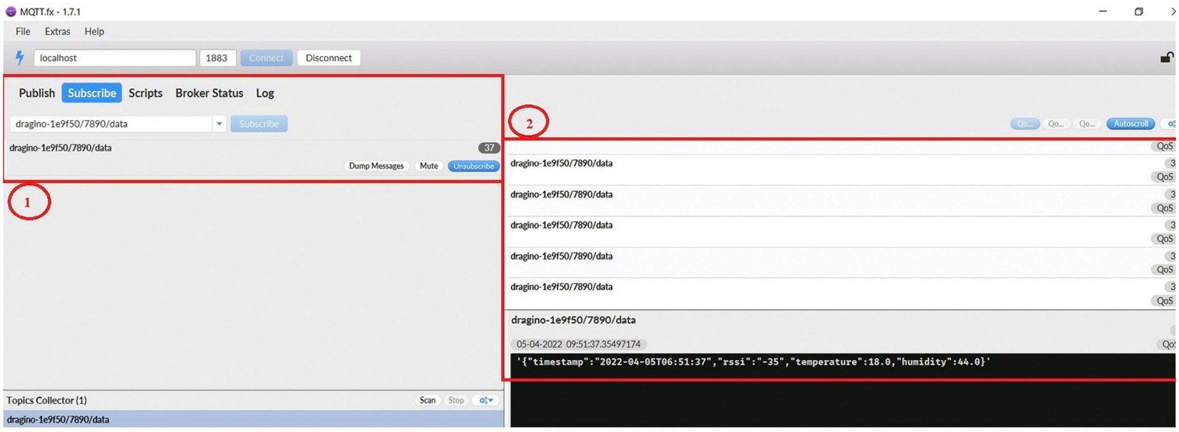


Figure 2. Captured packets and RSSI value through MQTT Broker on Windows

4. Experimental results

The RSSI values in the LoRa network are not always the same. Table 1 shows the outcomes of all of the trials that were conducted. The results for one node show that when the length between sensor and the gateway device grows, the RSSI indices acquired got worse. According to the results for two sensor nodes, the received values for one of the devices are pretty close to the results in the testing with only one LoRa end node. The reported RSSI values drop as the range between the gateway and the number of end devices in the system is growing. The communication channel's load, as well as the concurrent transmission of the end nodes in it, produces a disturbance, lowering the quality and strength of the signal.

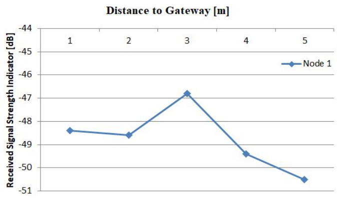
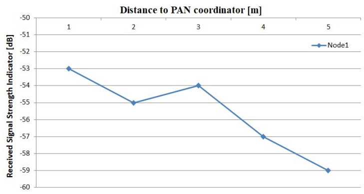
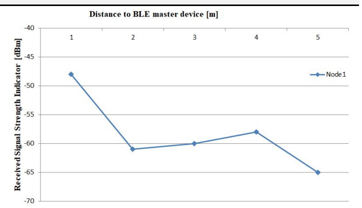
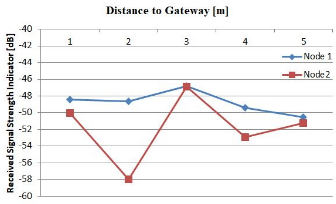
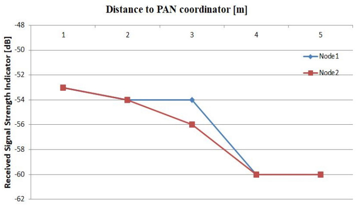
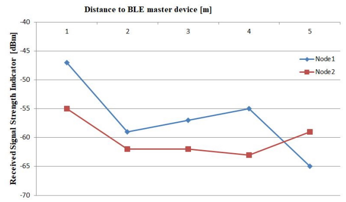
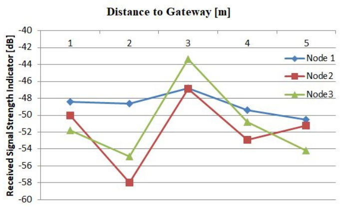
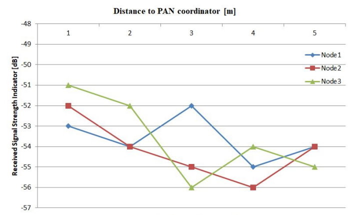
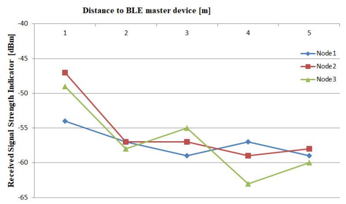
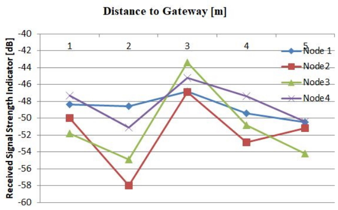
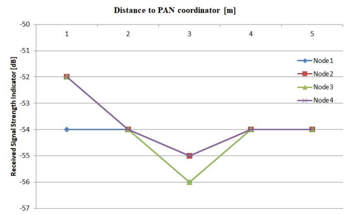
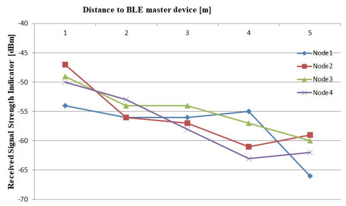
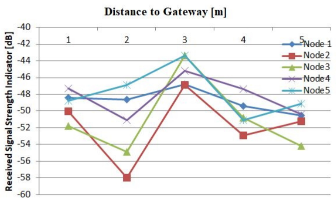
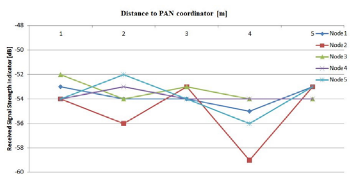
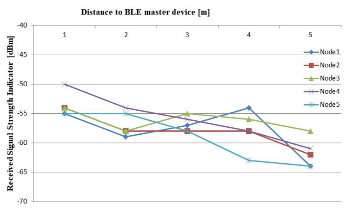
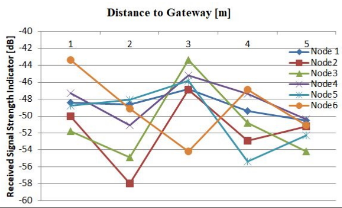
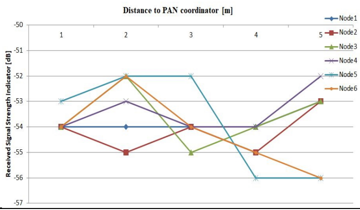
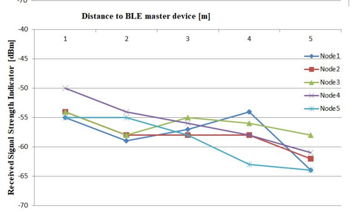
For BLE the RSSI values are not constant, as evidenced by the experimental data presented in table 1 for all experiments undertaken. The results for one node demonstrate that the obtained RSSI values worsen as the range between the sensors and the coordinator device grows. Although only one device is broadcasting in an unloaded communication environment, the prior values may have declined because of interference from outside sources. According to the results obtained from two sensor nodes, the measured RSSI values for one of the nodes are close to the results in a test with one node. The derived values for the second node may be seen to be much lower. The RSSI values worsen as the range from the main device rises. Other tests with up to 6 sensors support the pattern that the observed RSSI values are improved at closer distances to the service device.

The RSSI values acquired from the built ZigBee network are inconsistent in testing for 1 to 6 sensor nodes (table 1). The results of one and two sensors show that as the length between the main unit increases, so do the obtained RSSI results. In the testing with three and more sensor devices, there is no evidence of this trend. With increasing distance from the coordinator, the obtained RSSI values for some of the nodes are identical or better, while for others they are worse. This is due to the presence of external noise impacts and sensor node interference, which can become more prevalent as the number of devices in the network grows.

The following summary can be made from the results. RSSI has non-constant acquisition values for all three technologies considered in the specific conditions. There is a tendency in which the increased distance over the communication medium between the end devices and the main does not strongly affect the measured RSSI. The same goes for increasing the number of end devices on the network.

However, these changes are not drastic. LoRa technologies maintain values in the intervals -40dB and -60dB during experiments. The RSSI value of the ZigBee gain is between -50dB and -60dB, which proves there are no huge changes in all the experiments. BLE technology supports the degradation model according to the distance between the end devices and the main, maintaining values in the range between -46dB and -68dB. Although the value of all three technologies are close readings when a strong signal is needed when communicating over long distances for IoT, it would be good to use LoRa technology to give better RSSI values.

Table 1. Results for RSSI values from experiments for LoRa, ZigBee and BLE networks

Node №	LoRa	ZigBee	BLE
1 Device			
2 Devices			
3 Devices			
4 Devices			
5 Devices			
6 Devices			

5. Conclusion

This paper presents a comparative evaluation of RSSI of various wireless technologies. It can be used for indoor localisation systems for estimating the sensor node's location in BLE, LoRa and ZigBee sensor networks. RSSI results showed for BLE, LoRa and ZigBee sensor networks. The comparison based on measurements taken under identical conditions. The results demonstrate that LoRa has better RSSI values in the provided conditions but has a longer range, making it an ideal contender without exposing extra hardware, followed by ZigBee and BLE. The poorest of all was BLE, which had lower values than ZigBee and LoRa but could be the greatest answer in circumstances where systems-must work on batteries due to its lower power consumption.

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