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Zigbee based Indoor Location Tracking and Monitoring System

Athira K.R, Anju Babu

Abstract*: Indoor positioning systems (IPS) are used to locate objects or moving persons in indoor environments based on sensors and different wireless communication technologies. Nowadays IPS are very attractive because it finds applications in several areas. GPS and cellular systems have a very wide range of applications in location tracking and monitoring, but it gives poor performance in indoor environment. This project presents a low-cost approach for location tracking and monitoring system using ZigBee Technology in indoor environment. ZigBee is a low cost, low power wireless communication technology. This is an ideal communication technology for indoor positioning in terms of its unique characteristics. System uses location fingerprinting method for position estimation. Fingerprinting is an effective technique for indoor localization. In this method the location-related fingerprints will be formed by collecting signals from different access points. when it receives an instruction to locate a position of a person or object, it will execute RSSI based location monitoring algorithm to obtain the matched record within the database. After that it will return the corresponding locations to the user. The system makes use of IoT Technology to view the location of a specific person in indoor environment through a webpage. System consists of ATMEGA2560 microcontroller, ZigBee modules, ATMEGA328 microcontroller, Raspberry pi 3, LCD, laptop/PC, etc.

***Index Terms*: Indoor Positioning System (IPS), IoT, Received Signal Strength Indicator (RSSI), XCTU, Zigbee.**

I. INTRODUCTION

An indoor positioning system (IPS) is a system used to locate objects or people inside a building using various kinds of technologies. There are several commercial systems available for indoor localization on the market, but there is no standard for an indoor positioning system. IPS use different technologies such as distance measurement to nearby reference nodes (nodes with a predefined positions). Still the research is going on to find a better technology for indoor localization. This indicates the importance and popularity or demand of indoor positioning systems over worldwide.

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***** Correspondence Author
Athira K.R*, Department of Electronics and Communication Engineering, Sahrdaya College of Engineering and Technology, Kodakara, India.
Anju Babu, Department of Electronics and Communication Engineering, Sahrdaya College of Engineering and Technology, Kodakara, India.

Location detection and tracking has been very successfully implemented at outdoor environments using satellite-based Global Positioning System (GPS) technology. GPS is having various kinds of applications in guidance, mapping, and so forth.In indoor environment, the exact location identification is not practical using GPS.

GPS signal is facing attenuation due to walls and other physical parameters and it leads to significant power loss. GPS receivers should have a view to at least four satellites to locate the position of an object. This will be restricted in indoor areas. Apart from that multiple reflections at surfaces cause multi-path propagation and that will lead to uncontrollable errors. Thus, the need for specialized methods and technologies for indoor location systems has been widely accepted. The aim of this project is to develop a low cost, low energy and scalable indoor location positioning system which can be used to locate the position of moving object or person in indoor environment. Zigbee is used in this project because it has a flexible network structure. It supports all kinds of network topologies. Here, mesh network topology is considered. Zigbee is having low cost and is power effective. It is less complex than Bluetooth. ZigBee network comprises of mainly three components, ZigBee Coordinator (gateway node), ZigBee Router (static node/ reference node) and ZigBee End Device (mobile node).

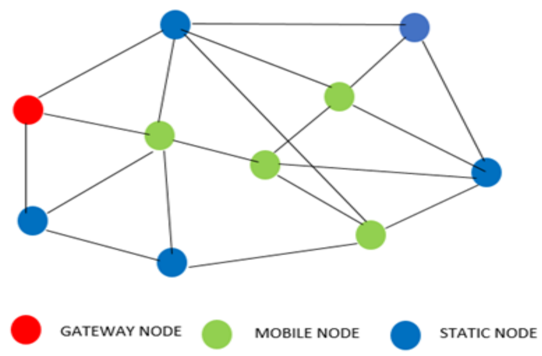


Fig.1. Zigbee Mesh Network

Location fingerprinting method is used for position estimation. It consists of two phases. First phase is training phase. In this phase, it uses a moving ZigBee device to collect signals from different fixed nodes, RSSI from each node is sampled to establish a database. The second phase is positioning phase. In this phase, a mobile node with unknown position will be estimated by comparing the run time RSSI value with the values already stored in the database with the help of RSSI based location monitoring Algorithm. Each location of a target environment has distinguishable characteristics of the wireless signal i.e., Received signal strength indicator values. Fingerprint identification method make use of this concept. We can associate the RSSI value with the location coordinates of a specific point.

The collection of information can be considered as a unique fingerprint information, and then we can establish a fingerprint database.

Indoor location positioning system can be deployed in various places, in schools to keep a track of children within school premises, in hospital to identify the location of staff or patient, in automatic guided vehicle system, in shopping malls, in airports, etc.

II. RELATED WORKS

Earlier similar systems were developed using technologies like RFID, WLAN and GPS, Bluetooth, Camera, etc. Still research is going on to find a better technology. RFID and Bluetooth technology has limited range coverage. WLAN based location positioning system consumes high power and cost is high for high range coverage. GPS system works fine in outdoor environment but gives poor performance in indoor environment. If camera is used, measurement of Angle of arrival, individual's mobility pattern is difficult and is very costly, power consuming and needs huge data storage space.

Paolo et.al. describes an Indoor positioning using Ultra-Wide Band (UWB) technologies: positioning accuracies and sensors performances [1]**.** This system consists of a network of RF Emitter/Receiver modules. The network consists of one tag, that transmit the packet of data, and some reference nodes with previously defined position. Another tag can be added to this network to set a coordinator to control and coordinate this network. The tags can be connected to any computational external device. This is not preferable method for indoor localization because accuracy of this technique is within 30 cm range.

Ming et.al. describes a VLC-based 3-D Indoor Positioning System Using Fingerprinting and K-Nearest Neighbor [2]**.** In this system, a controller is there to control the configuration of the whole system. Another important component is a gateway which accepts both controlling commands and positioning beacon signals from the controller. Then gateway will transmit the signals to another gateway or to the light emitting diode. Transmitter section consists of this light emitting diode and its driving circuit. At the receiver side, there will be a photo diode and an analog-to-digital converter. An analyzer is another important part of the proposed system in this paper. It will run a positioning algorithm and output the positioning result.

III. PROPOSED METHOD

ZigBee has some unique capabilities that make it the best option to implement an ad hoc, on-demand, low-cost and low-power location tracking and monitoring system. Zigbee supports large number of nodes i.e., around 65000 nodes. Replacing battery in a WSN (wireless sensor networks) is very crucial task. Zigbee is having Very long battery life so that the battery replacement is not an issue here. Location fingerprinting method is used for position estimation. It consists of two phases. First phase is Training Phase or Calibration Phase. In this phase, indoor area where position system is to be deployed is calibrated. Following steps are performed in this phase.

1. Divide the entire area where location of an object is to be tracked into the grid. Note down the (xi, yi) coordinates of the grid point.
2. At each grid point, measure the RSSI (Received Signal Strength Indicator) value of Reference Nodes (RN) of Zigbee.
3. RSSI at same location fluctuates with respect to time. So, we need to take multiple samples for averaging the RSSI value.
4. Store the normalized RSSI values received from multiple reference nodes into the fingerprint database with respect to each grid point.

Second phase is Estimation phase. In this phase, run time mobile node's signal strength is tracked. Then it is compared with the values stored in fingerprint database as in [5], [6] and will update the position inside a webpage.

Zigbee mesh network comprises of mainly three components. Zigbee Coordinator, Zigbee Router and Zigbee End Device, Zigbee coordinator and router device requires continuous power, Zigbee end device can be a battery powered device.

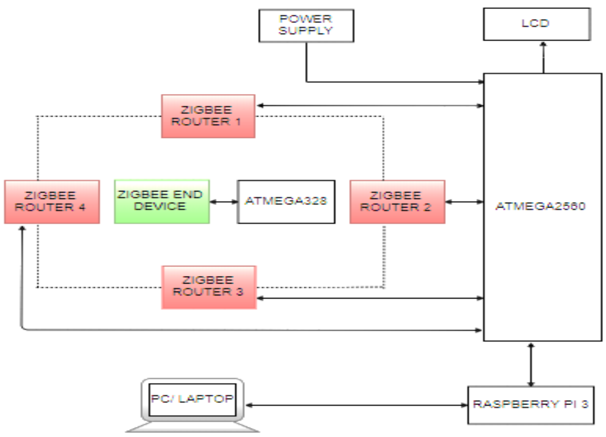


Fig. 2. Block Diagram

Zigbee coordinator is connected to the PC or laptop over UART where one can track the location of the object. Zigbee routers are the stationary nodes which are placed at predefined locations on the floor and is connected to microcontroller ATMEGA2560 over UART interface. Four Zigbee routers are placed at predefined locations and we need to calculate and record the signal strength from each of the Zigbee routers to the Zigbee end device. The received signal strength value is displayed in an LCD. Zigbee Coordinator is interfaced with microcontroller ATMEGA2560 to give instructions to the Zigbee routers to locate the position of Zigbee End device.

Raspberry pi 3 is used to provide Wi- Fi access. Position of the Zigbee end device will be shown in a webpage by make use of IoT Technology.

IV. EXPERIMENTAL SETUP

Zigbee is widely used because of its quick applicability for building WSN with low transmission rate, up to 250 Kbit/s. ZigBee PRO and ZigBee Remote Control (RF4CE) are other available ZigBee profiles, based on the IEEE 802.15.4 protocol. This is operating at 2.4GHz suitable for applications that require relatively infrequent data transfers at low data-rates within a 100m range such as in a home or inside a building. Now ZigBee with range up to 300m are also available in the market. The XBee module used in this project is shown in Fig. 3. Six XBee modules are used in this project to conduct the experiment.

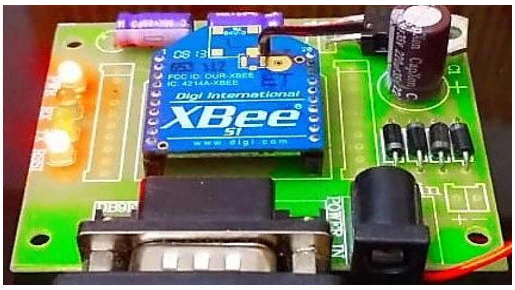


Fig. 3. XBee module used in the experiment

The primary stage of this project is to determine the communication range of XBee wireless modules for indoor communication as in [7]. To conduct an experiment to find the communication range between XBee modules we need Two XBee modules, two adaptors to connect two XBee modules into the laptop and one PC/laptop with XCTU installed. XCTU is an open source software, it can be directly downloaded and installed from internet.

ZigBee network is easy to setup and run. First, we need to connect the mini USB cable to the adaptor module. To interface between the modem and a PC/Laptop, two drivers must be installed in our system. One is a USB driver and other is a virtual COM port driver. After the modem is detected, a wizard for installing the USB driver is appear on the screen. After that we can select the communication port or USB Serial port accordingly and configure serial characteristics like baud rate, data bits, and stop bits, etc.

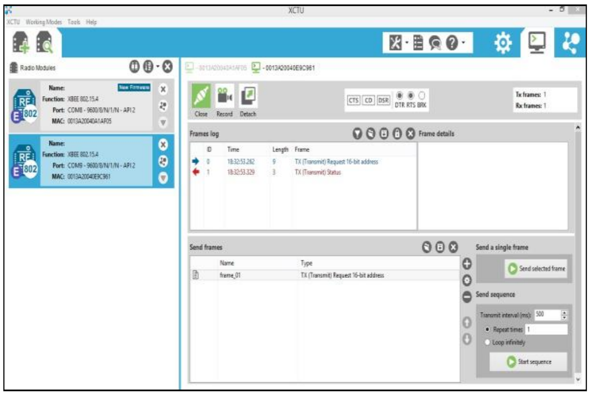


Fig. 4. Frame sent in XCTU

To add XBee modules, click on the Add device tab in XCTU menu. Then click on one of the module and wait for a few seconds as XCTU reads the configuration settings of the XBee.The right half of the XCTU software will contain the entire configuration details of the XBee. Next, create a frame in one of the XBee and add data on it and send it to the other XBee.

If we click on the Receiver XBee, we can see the data which is received and the RSSI value. After that we can use that RSSI value to estimate the distance.

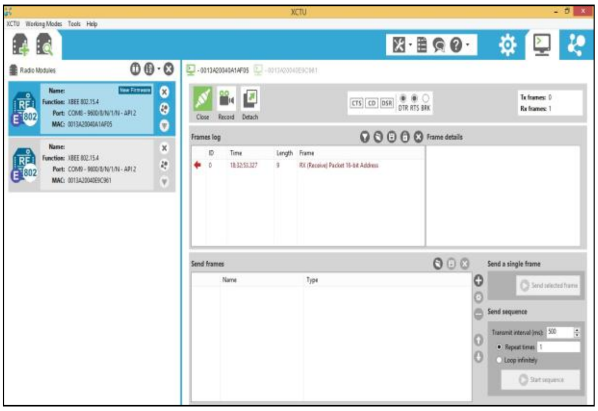


Fig. 5. Frame received in XCTU

Communication architecture of this system is shown in Fig. 6. as in [8]. The gateway collects packets from every reference node, which contain source and destination addresses, transmitted power and RSSI. The gateway sends these values to the server. Server will process all incoming information to estimate distances between mobile and reference (fixed) nodes.

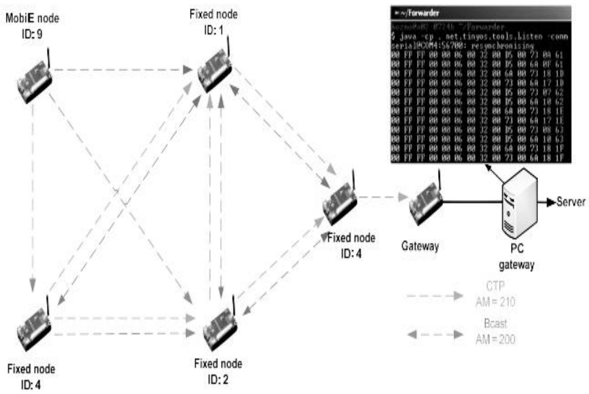


Fig. 6. Scheme of communication

For communication the CTP (Collection Tree) protocol is used which is implemented in TinyOS (kind of operating system used in wireless sensor network). This network can consist of multiple gateways that are the roots of the communication tree. CTP protocol is suited for low data rate Wireless Personal Area Networks. This type of communication is characteristic for WSN.

Fig. 7 shows the relationship of RSSI over distance. RSSI will inversely vary with distance.

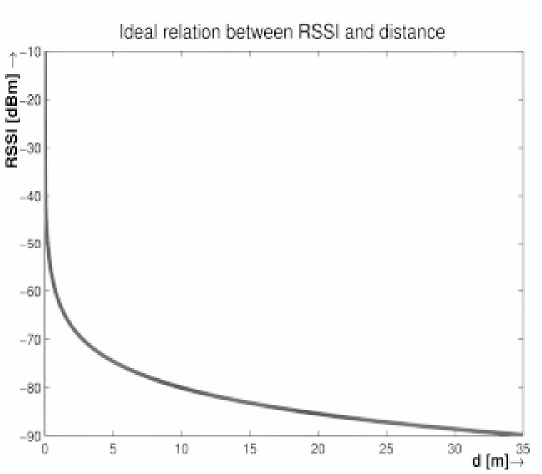


Fig. 7. RSSI over distance

This project can be implemented inside any indoor environments. A schematic way of placing different nodes inside a school building and in the playground is shown in Fig.8.as in [9]

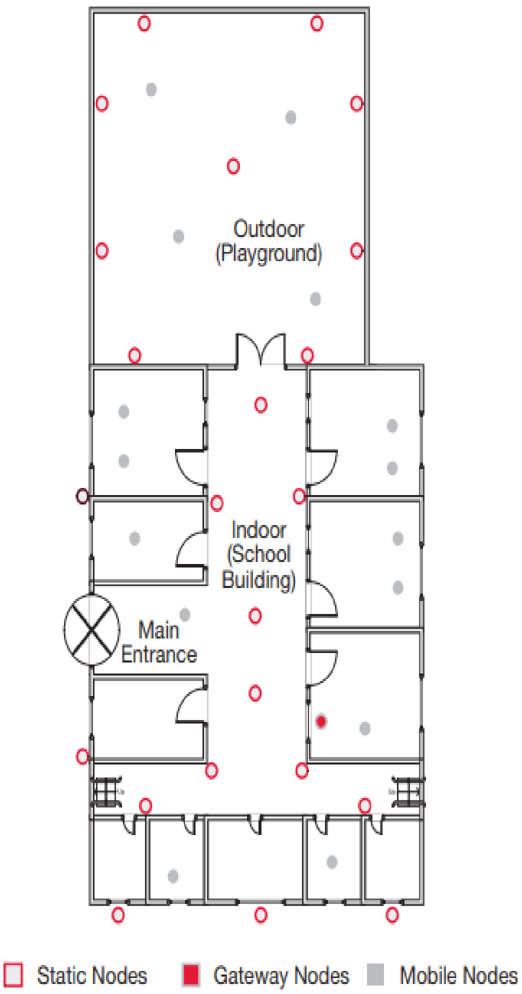


Fig. 8. Placing nodes on school premises

V. RESULTS AND DISCUSSIONS

Hardware setup for the project is as shown in fig.9. Four ZigBee each with 9V battery are connected to ATMEGA2560 and the moving Zigbee with 12V battery is connected to ATMEGA328. 5V power supply is provided to ATMEGA2560. An LCD display is interfaced with ATMEGA2560 to show the RSSI values.

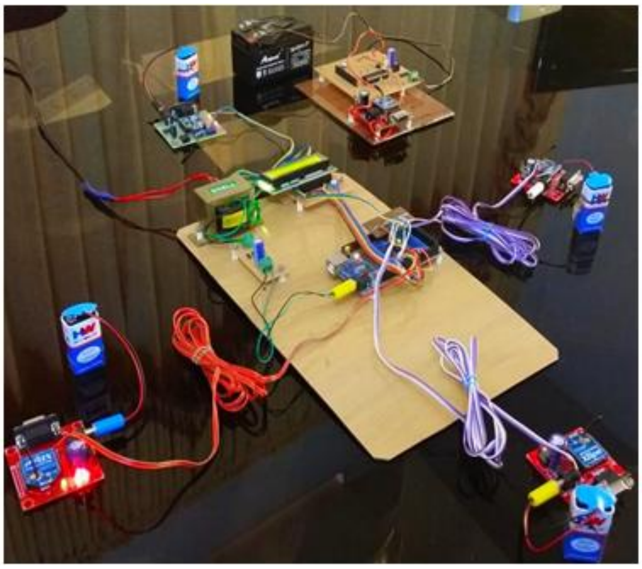
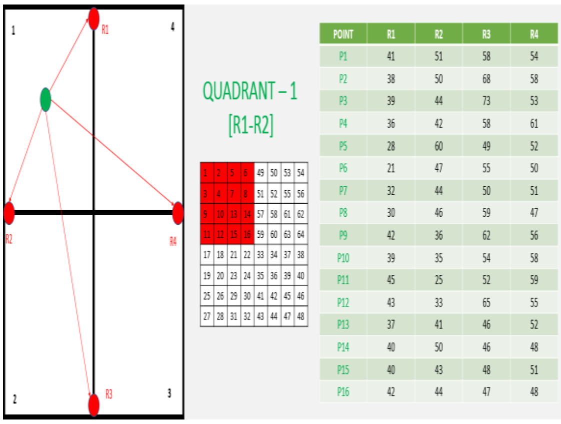


Fig. 9. Hardware

Experiment is conducted by dividing a 158 x 158 (cm) square area into 4 quadrants and each quadrant is further divided into 16 grid points and taken the RSSI value from each of the grid point. Red colored circles indicate Zigbee routers which are fixed in predefined locations. Green colored circle represents the moving node whose location we need to get. Fig. 10 shows the values got at the first quadrant. Fig. 10 shows the values got at the first quadrant. Fig. 11 shows the values got at the second quadrant. Fig. 12 shows the values got at the third quadrant. Fig. 13 shows the values got at the fourth quadrant.



POINT	R1	R2	R3	R4
P1	41	51	58	54
P2	38	50	68	58
P3	39	44	73	53
P4	36	42	58	61
P5	28	60	49	52
P6	21	47	55	50
P7	32	44	50	51
P8	30	46	59	47
P9	42	36	62	56
P10	39	35	54	58
P11	45	25	52	59
P12	43	33	65	55
P13	37	41	46	52
P14	40	50	46	48
P15	40	43	48	51
P16	42	44	47	48

Fig. 10. First Quadrant Results

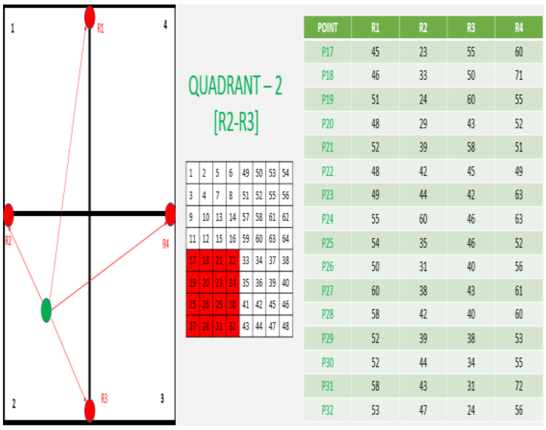


Fig. 11. Second Quadrant Results

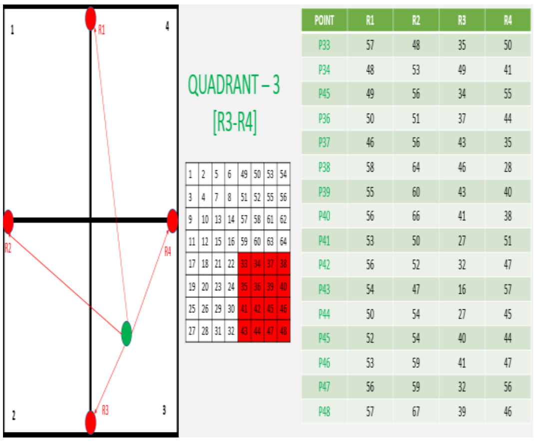


Fig. 12. Third Quadrant Results

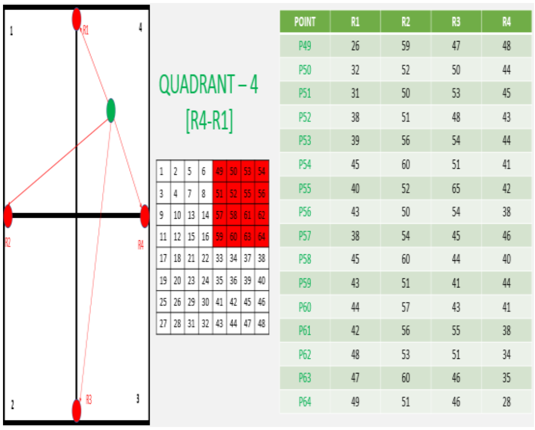


Fig. 13. Fourth Quadrant Results

Average of RSSI values got from the experiment is shown in Fig.14. We can easily find in which quadrant the moving node is being located from the above results and, we can update the position of the node inside a webpage.

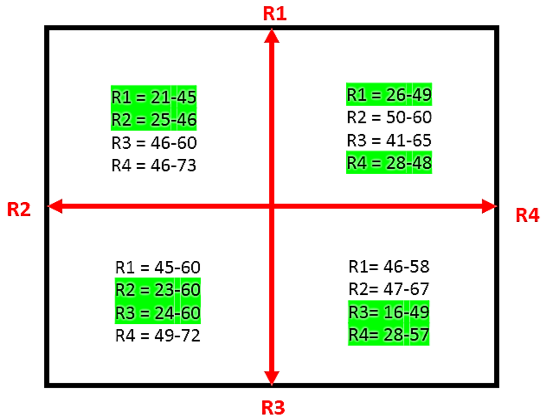


Fig. 14. Average RSSI Values

VI. CONCLUSION

By analyzing various existing technologies, it is understood that the Zigbee is more better technology for indoor localization in terms of coverage, power, battery life and number of nodes. From different theoretical and practical experiments, it can be concluded that the recommended distance between the units indoors is a distance not exceeding 30 meters. As a future work, this system can be extended to outdoor environment by including GPS. This can be done along with the implementation of an android app as in [10]. Whenever the person goes beyond the range of Zigbee network (outdoor environment), the control is automatically passed to GPS. Further location tracking can be done using GPS.

TABLE I. COMPARISON

	Zigbee	Bluetooth	UWB	Wi-Fi
Range	10-300m	10m	4-20m	10-100m
Power	Very low	Low	low	High
Network topology	All	Star	Star	Medium dependent
Data rate	250 Kbps	723 Kbps	110 Mbps-1.6Gbps	10-105Mbps
Battery life	Months to years	Hours to days	Hours	NA
Maximum nodes	65000	8	128	32

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AUTHORS PROFILE

Athira K.R Presently Pursuing M Tech in Embedded Systems at Sahrdaya College of Engineering and Technology, Kodakara under KTU. Completed B Tech in Computer Science and Engineering under Calicut University.

Anju Babu Presently working as Assistant Professor in Electronics and Communication Engineering Department at Sahrdaya College of Engineering and Technology, Kodakara. University topper in M Tech Embedded Systems at University of Kerala in 2012.