Journal of Computer Science, Information Technology and Telecommunication Engineering (JCoSITTE)
Vol. 5, No. 2, September 2024, pp. 581~588
ISSN: 2721-3838, DOI: 10.30596/jcositte.v5i2.20002

Implementation of a Wireless Sensor Network with Mesh Topology with XBee for Centralized Building Room Monitoring

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ABSTRACT

Room monitoring in office buildings or campuses such as POLMED, especially the use of lights and indoor activities after working hours, is very necessary. In this research, a wireless sensor network with a mesh topology was implemented. A network with a mesh topology allows each node to establish communication with surrounding nodes and send information through intermediary nodes. This implementation is able to provide benefits by increasing the network area, number of sensor nodes and network reliability. The monitoring system is designed to consist of sensor nodes and server nodes. Each server node consists of a light sensor, motion sensor and XBee RF module for communication placed in each room, so that each node can communicate and send information to the monitoring center. The server node as a monitoring center receives data from sensor nodes which can be displayed in room mapping. In testing the sensor node network, it can successfully send a message to the server node if there is at least one intermediate node that can forward the message to the destination. From the test results, it was found that sending one frame with 17 bytes was 0.09 s, 0.11 s, and 0.12 s for 1 hop, 2 hops and 3 hops respectively.

Keywords: network, sensor, mesh, wireless

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Article history:
Received Jun 14, 2024
Revised Jul 20, 2024
Accepted Aug 11, 2024

1. INTRODUCTION

Technological advances encourage the increasing importance of practicality in monitoring rooms, especially lecture classrooms, this will make it easier for staff to monitor the use of classrooms and the facilities in them. Monitoring classrooms to determine air quality such as carbon monoxide is needed to determine air pollution in classrooms(DARA et al., 2021) Sensor nodes equipped with PIR sensors and light sensors can be used to detect the presence or absence of movement activity and the conditions of light use in the room where the sensor node is placed. The detection results of this sensor node can provide information on space usage. The use of a room can be indicated if there is movement in a dark room at night which may have occurred. A radio transmitting device can be added to the sensor so that room conditions can be sent wirelessly to a monitoring center. Wireless sensor networks (WSN) with a mesh topology can be used to build connections between sensor nodes. A surveillance system with the ease of increasing the number of sensor nodes is needed to accelerate the expansion of the sensor network.

Applying a mesh topology to a monitoring node network system can reduce data transmission failures from sensor nodes to the monitoring center or server nodes due to problematic nodes. Nodes that experience failure to forward data due to inactive intermediate nodes will search for/form new routes to the destination node. It is hoped that the implementation of WSN with a mesh topology in centralized room monitoring can increase the reliability of the sensor network, so that the number of rooms that are not monitored due to network failure can be reduced.

This research can solve the problem of how to place sensors in separate rooms in buildings. How does a wireless sensor network perform in transmitting information from sensors. Will a mesh topology in centralized sensor monitoring reduce data collection failures caused by data transmission failures due to faulty sensor nodes? How does mesh topology perform in forwarding passed information.

The implementation of the sensor network in this research is limited to the application of the Mesh network and its performance. The sensors used are motion sensors to detect whether there is activity in the room, light detection sensors determine whether there is lighting in the room. The network tested is a network consisting of 4 (four) sensor nodes with 2 (two) sensors each and a central monitoring node.

The research produced a centralized building space monitoring system. The sensor is able to detect room conditions which are transmitted via a wireless network. The applied network has the ability to repair itself if the network is disconnected when a sensor node fails or a sensor node malfunctions resulting in a failure to connect to the network. Implementation of this system provides convenience and reliability in monitoring rooms in the building and adding nodes without the need to reconfigure.

2. RESEARCH METHOD

The implementation of technology in research begins with a study of literature related to documents and publications related to research so that a better picture of the results of the implementation that will be carried out is obtained. System modeling is carried out to obtain the criteria to be achieved in the system that will be produced. Based on the predetermined criteria, each component to be implemented is then designed.

System implementation is carried out according to predetermined system modeling and performance testing is carried out. Based on the test results, an evaluation is carried out regarding system performance.

A. *System Model*

This research is an implementation of a mesh network topology in a sensor network. The sensor network is used to carry out centralized monitoring of the room. In this research, a monitoring system was built consisting of sensor nodes as sources of information and sink nodes as observation centers where all information is collected. The system model is built to be able to meet the design criteria for sensor nodes and sink nodes which are carried out to fulfill the research that will be carried out. OnFig. **1**The model of the proposed room surveillance system is shown. The research model designed a system consisting of sensor nodes and server nodes as a monitoring center.

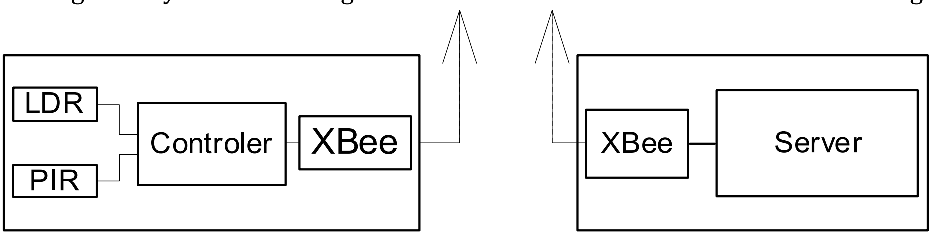

Fig. 1 Sensor Node (a) and Server Node (b) Design

1. Sensor Nodes
   The sensor node is designed to collect information on room conditions. The sensor node will consist of 2 (two) LDR sensors as indoor light detectors and Passive Infra-Red (PIR) as human activity detectors in the room. The LDR sensor as a light detector in the classroom is connected as shown inFig. **2**to connect to the controller.

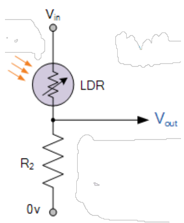

Fig. 2 Sensor Circuit

The sensor node uses an Arduino Uno microcontroller to control the sensor node. Arduino Uno detects light intensity by reading the analog value from the voltage divider circuit onFig. **2.** The microcontroller which already has information obtained from the sensor will forward the data to the monitoring center. As a forwarder of information from nodes, XBee is used to transmit signals to other nodes.

Each sensor node in this research is configured to be able to send information to the sink node either directly or peer to peer or through another node as an intermediary. So we get a network that is able to build a new route to the nose sink if a certain route cannot be passed.Fig. 1a depicts the sensor node design.

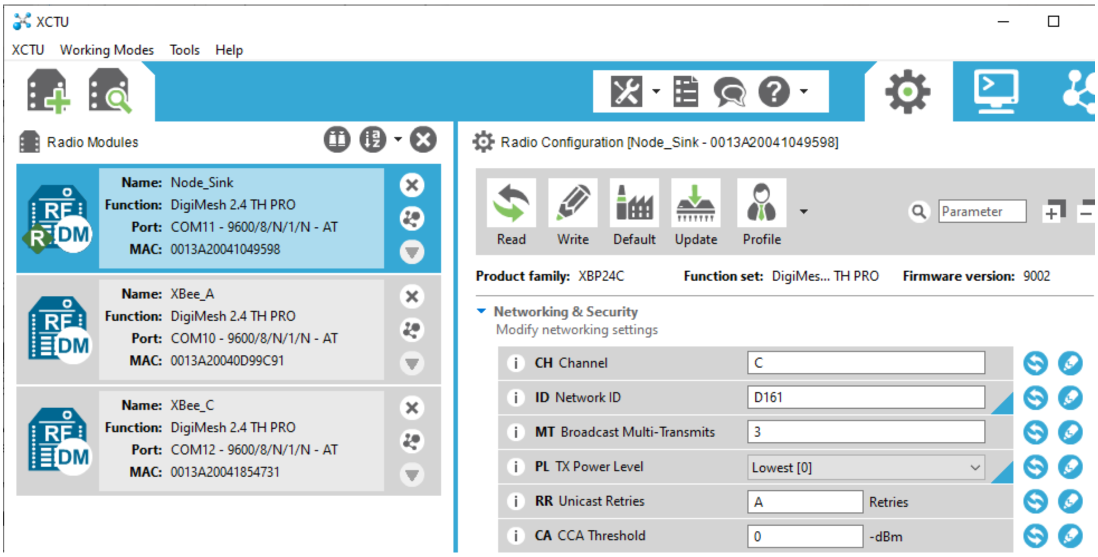

Fig. 3 XCTU software

The XBee module on the sensor node is configured using XCTU software as shown in

Fig. **3**. Each XBee on the network is set with the same Channel (CH) and Network ID (ID), where in this research Channel (CH) is set: C and Network ID (ID): D161. With these settings, each XBee module will be on the same network.

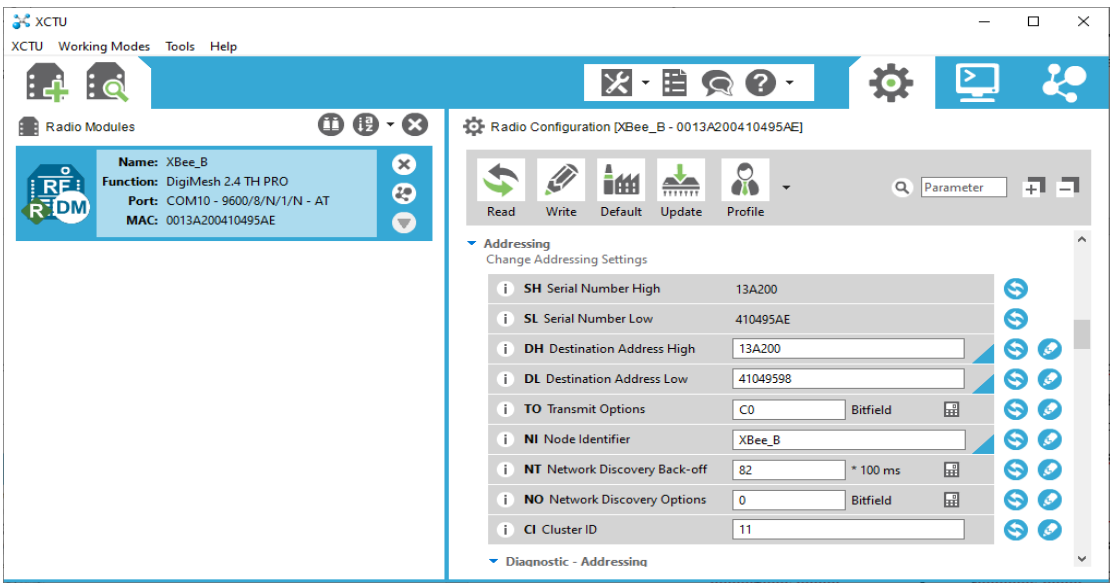

Fig. 4 Configure the destination address on the XBee_B sensor node

Apart from setting the Channel (CH) and Network ID (ID), each sensor node needs to set the address to which data will be sent. This data sending address is the MAC address of the XBee module on the sink node. Destination address settings are shown inFig. **4**. Destination Address High (DH) is filled with the first 32-bits of the destination node's MAC and Destination Address Low (DL) is filled with the final 32-bits of the destination node's MAC. This setting will direct XBee to always send data to the sink node either directly or through an intermediary.

The microcontroller on the sensor node is embedded with a program so that it can carry out the given tasks. The software works like a flowchart on**Error! Reference source not found.**. In the initial stage, serial communication with the Xbee will be initialized, then the PIR and LDR sensor pins will be initialized. In the program loop, what will be carried out continuously is reading data from each sensor. After the data from the sensor is obtained, a data packet is formed which will be sent. The data package consists of a preamble for data markers, 2 data slots for sensor values. The data packet ends with a node marker and a packet cap. The following illustrates the data packets formed and sent by the Data controller: data1&data2Xbee_A. #data: is a data packet preamble as the beginning of the message sent, data1 and data2 are the contents of the information obtained from the sensor, while the "&" sign marks the boundary between data. For Xbee01, it is a sensor node identifier that ends with "#" as the end of the packet.

The delay given to the program regulates how often information data is sent from the sensor node to the sink node. A small delay value can be given for more routine information updates. Meanwhile, a larger delay value provides longer information updates.

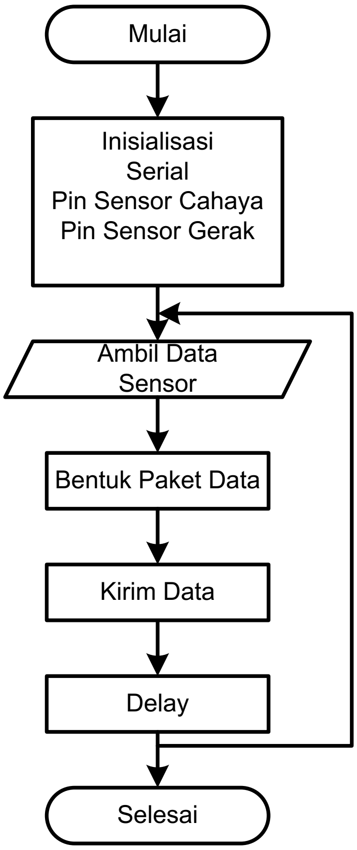

Fig. 7 Controller Program Flowchart

2. Server nodes
   The server node in this research is designed to collect information from each sensor node. The server node is equipped with an XBee RF module as a channel for communication with sensor nodes. The sensor node design is shown inFig. **1**(b). The sensor node consists of an XBee module and a server containing software to translate data received from the XBee Module. Data packets from each sensor node are sent to the XBee module on the server node by designating its MAC address on delivery. The XBee module will receive data sent to the XBee MAC address on the server

node. The XBee module will forward the received data packets to the COM-serial port on the server. To make it easier for users to understand the information received, an interface was designed to display monitoring information obtained from sensor nodes.

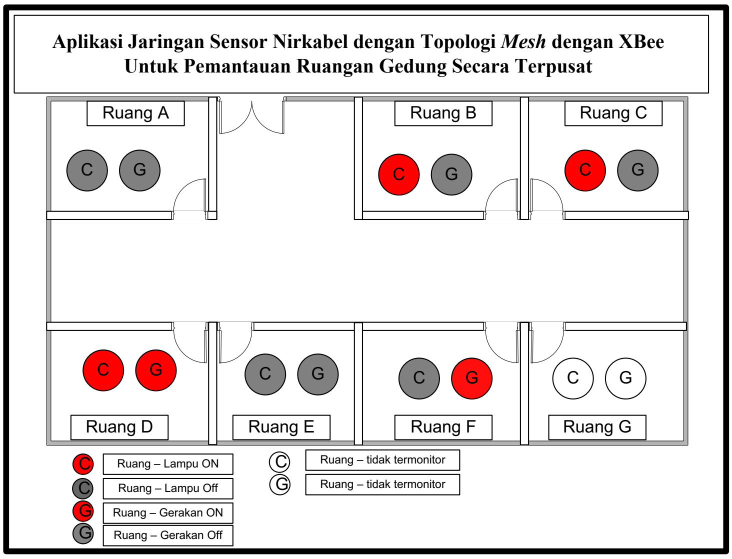

Fig. 5 Monitoring Plan View

The Software View is shown inFig. 5. The display shows a plan of the monitored room with two signs to indicate the condition of the room. Each indicator represents a type of sensor, in this case a motion and light sensor. Each indicator has 3 conditions displayed. If the indicator is red, it shows that there is motion detection on the PIR or light on the LDR. The indicator shows gray meaning the sensor did not detect movement or light, while white indicates data was not received for the specified period of time.

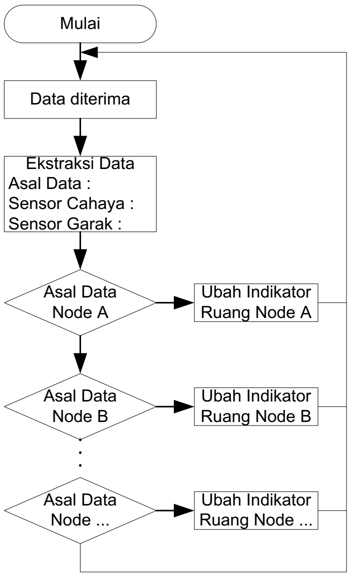

Fig. 6 Received Data Flowchart

The flow diagram of processing data received from sensor nodes is shown inFig. 6. In the flowchart image, it is shown that after the data sink node from the sensor node the data will be extracted to determine the information content. The information taken from the extraction results is the source of the data, the value of the light sensor and motion sensor. If the data source comes from node A, the indicators in room A will be adjusted according to room conditions. The sink node will change the space indicator display according to the data source sent.

B. Research Network simulation model

The design of the research network model is described inFig. **7.** Topology is used to simulate mesh networks for communication. In topology testing, all sensor nodes work normally and in conditions there are intermediate nodes that cannot forward information, so communication must be carried out via another route. The topology is considered to be able to simulate mesh topology. The simulation nodes are arranged so that the server node can only directly receive data from sensor node A. Sensor node A is only directly connected to Sink nodes, B and D. Sensor node C can be connected to sensors B and D.

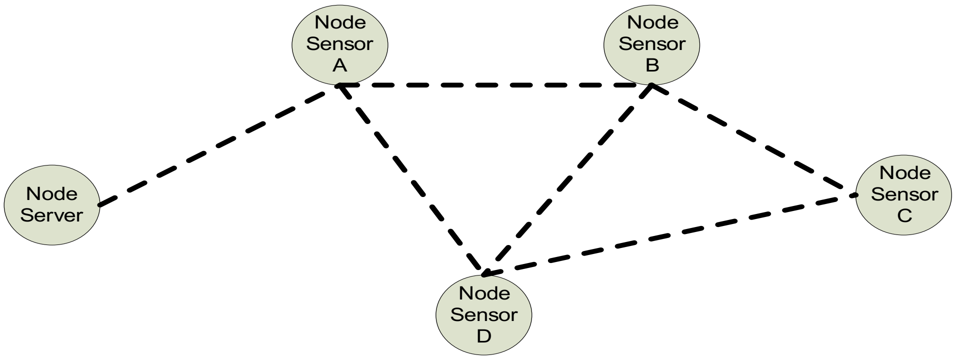

Fig. 7 Research Topology Design

3. RESULTS AND DISCUSSION

A. Data Delivery

Data transmission testing is carried out to determine the system's performance in transmitting information from the sensor node to the sensor node. Testing was carried out to determine the effect of the number of hops or intermediate nodes on data delivery delay and the amount of data sent within a certain time duration.Tabledisplays test results for sending data via 1 hop, 2 hop and 3 hop. Throughput and delay are obtained by sending data packets from the sensor node to the sink node. Ththroughput value is obtained by calculating the amount of data sent per unit time as in equation 1). The delay value in this research is the time required from when the packet is sent to the sink node and received again by the sensor node. The delay equation used is as in equation 2).

Throughput = (Number of sent bits / Sending time) 1)

Delay = Time of data received – Time of data sent

The test results show that the more frames sent, the average data delivery delay will increase. Throughput also affects the average time to send data. The increase in the amount of data sent is inversely proportional to throughput. The number of hops traversed by data affects data transmission time, where delay increases with increasing number of hops traversed.

Table.1.Data transmission performance

Frame No	Frame Size	1 Hop		2 Hops		3 Hops	
		Delay(s)	Throughput (bps)	Delay(s)	Throughput (bps)	Delay(s)	Throughput (bps)
1	17 Bytes	0.09	1511	0.11	1010	0.12	1097
5	17 Bytes	0.09	1501	0.12	974	0.15	902
10	17 Bytes	0.09	1472	0.129	1050	0.15	890

15	17 Bytes	0.11	1241	0.159	855	0.16	851
20	17 Bytes	0.11	1270	0.135	1014	0.16	964
30	17 Bytes	0.1	1376	0.18	728	0.18	758
40	17 Bytes	0.08	1636	0.1393	976	0.19	716
50	17 Bytes	0.11	1214	0.175	833	0.15	889
60	17 Bytes	0.11	1222	0.15	906	0.15	889
70	17 Bytes	0.12	1118	0.142	958	0.14	994
80	17 Bytes	0.13	1093	0.13086	1039	0.18	740
90	17 Bytes	0.14	1044	0.13247	1027	0.17	828
100	17 Bytes	0.16	911	0.14183	959	0.2	972

B. Network Formation

C. Observation of network formation is carried out by sending data from node C to the server node. With the scheme as explained previously inFig. **7**. OnTable. 1 Data Delivery **Path**the network test results are displayed. When all active nodes and node C send data the network is formed and the server node can receive data. When all intermediate nodes (nodes B, D, and A) are inactive, the sink node cannot receive data because the sink node is out of reach of node C without an intermediary. The sink node can again receive data when node A and node B or D are active because a network can be formed from node C to the sink node.

Table. 1 Data Delivery Path

No	Node C	Node B	Node D	Node A	Sink
1	Send	active	active	active	Data Received
2	Send	non-active	Non-active	Non-active	Data not Received
3	Send	active	Non-active	active	Data Received
4	Send	Non-active	Non-active	active	Data not Received
5	Send	Non-active	active	active	Data Received
6	Send	active	active	Non-active	Data not Received

4. CONCLUSION

From the results of trials implementing mesh topology in a centralized spatial surveillance network, it can be concluded that:

1. Network formation occurs when an intermediary node is available that can forward the data sent. When a node malfunctions and becomes inactive on the network, the node on the network will look for a replacement node to forward the information to be sent. So the placement of nodes in the room being monitored needs to be considered so that at least one node can be connected to be able to transmit information. For this, it is necessary to research a protocol that allows increasing the transmit power of the node to find the nearest node that can be used as an intermediary node.
2. From the test results, it was found that sending one frame with 17 bytes was 0.09 s, 0.11 s, and 0.12 s for 1 hop, 2 hops and 3 hops respectively.

3. Utilizing a mesh topology with Digi mesh provides convenience because new nodes can be added without the need to make changes to the existing network configuration.
4. The more hops the data goes through, the data delay will increase. There needs to be a study carried out to determine the optimal number of hopes for multi-hop communication.

Developments that might be carried out in future research include the need for a gateway to combine with different networks such as the internet. The use of other RF transmission media can also be considered for further development. Using mobile applications for monitoring can make monitoring easier at any time.

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