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Performance Analysis of Wireless Sensor Network

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Abstract- **This project presents the performance analysis of Wireless Sensor Network (WSN) used in the high-end applications such as weapons sensor ship, biomedical applications, habitat sensing and seismic monitoring. Recently WSN also focuses on national security applications and consumer applications. This project shall demonstrate the performance of WSN models, which are created and simulated using QualNet Developer software simulator. Several sensor nodes were uniformly deployed in the networks to create sensing phenomena. The simulation results recorded were the amount of data packets sent and received by each node, the throughput and the delay. All these graphical simulation results from several WSN models will be compared and analyzed separately. Therefore, the important factors and issues pertaining to the WSN performance will also be determined and describe briefly.**

I. INTRODUCTION

Wireless Sensor Network (WSN) are a trend of the last few years due to the advances made in wireless communication, information technologies and electronics filed. The development of low-cost, low-power, a multifunctional sensor has received increasing attention from various industries [1]. WSN is a wireless network composed of autonomous and compact devices called sensor nodes or *motes*. A sensor network is designed to detect phenomena, collect and process data and transmit sensed information to users. Sensor nodes or *motes* in WSNs, are small sized and are capable of sensing, gathering and processing data while communicating with other connected nodes in the network, via radio frequency (RF) channel.

Fig.1 represents the system architecture of a sensor node. A sensor node consists of a radio transceiver or optical as the communication unit, sensor as the sensing unit, a microcontroller for the processing unit and battery as the power unit.

The hardware device in the sensing unit may consist up to several sensors. This device produces measurable response to change which acts as an interface between *motes* to the environment. Measurable changes are, vibration, temperature, sound, motion, pollutants or pressure in environmental conditions.

There are two kinds of sensor used in the network. One is the normal sensor node deployed to sense the phenomena. The other is a gateway node that interfaces sensor network to the external world. Many types of sensor exist such as magnetometer, accelerometer, light and others but the types of sensor being used in a sensor node will depend on the application.

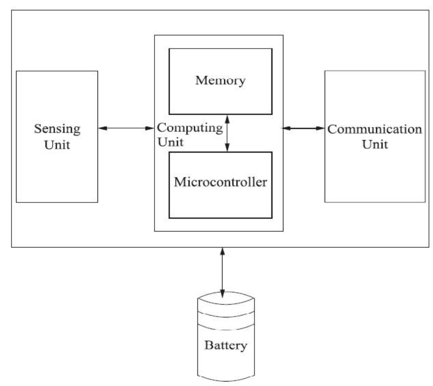

Fig. 1. Sensor Node System Architecture [2]

The processing unit is responsible for the collecting and processing of the captured signal from the sensor unit. These signals are then transmitted to the network. It determines both energy consumption as well as computational capabilities of the sensor node.

The power unit consisting of battery supplies power to the sensor node. It is important to choose the battery type since durability will affect the design of sensor node.

The Wireless Sensor Networks are being used in many ways. Traditionally, it has been used in the high-end application such as radiation and nuclear-threat detection systems, weapons sensors for ships, biomedical applications, habitat sensing and seismic monitoring. Recently, Wireless Sensor Networks are focusing on national security applications and consumer applications such as [3]:

1. Military applications
   - Monitoring, tracking and surveillance of borders
   - Nuclear, biological and chemical attack detection
   - Battle damage assessment
2. Environmental applications
   - Flood and oceans detection
   - Forest fire detection

- Precision agriculture
3. Health applications
   - Drug administration
   - Remote monitoring of physiological data
   - Tracking and monitoring doctors and patients inside a hospital
4. Home applications
   - Automated meter reading
   - Home automation
   - Instrumented environment
5. Commercial applications
   - Monitoring vibration that could damage the buildings structures
   - Monitoring traffic flow and road condition
   - Vehicle tracking and detection

II. METHODOLOGY

Fig.2 represents the processes carried out in produce a performance output before the WSN model can analyze. Three major process involved in analyzing the performance of WSN are, creating a scenario model, simulating and analysis, as shown in Fig.3. All these processes were done by the QualNet Developer Graphical User Interface (GUI). The QualNet Developer GUI consists of Scenario Designer, Animator and Analyzer.

A Scenario Designer is a network design tool to create the WSN model on the canvas which allows the creation of a scenario model using components such as devices, links, applications and network components. All elements in the scenario such as mobility, radio type, energy model, battery model parameters, and network, transport and application layer protocols can be configured.

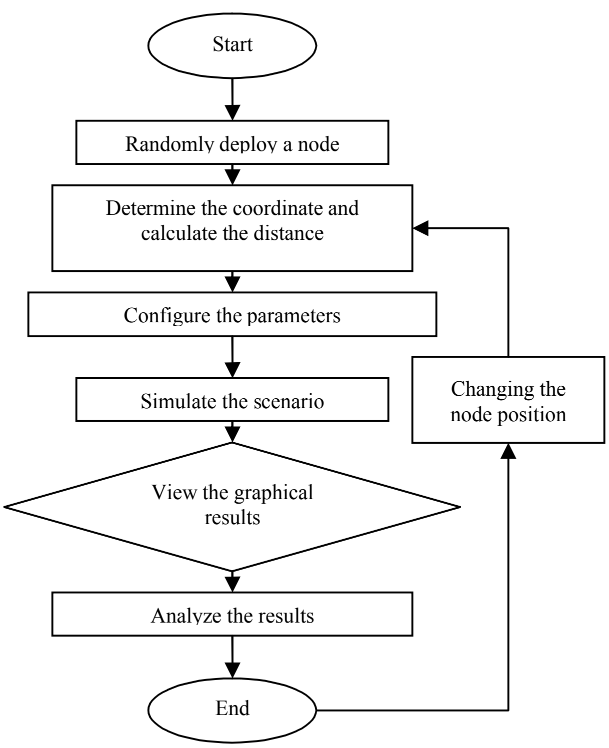

Fig. 2. Flow chart of project implementation

An Animator offers an in-depth visualization and analysis of the scenario designed in the Scenario Designer. While simulation is running, we can see packets being animated at various layers, flow through the network. We can also speed up or slow down the speed of the simulation to clearly observe and analyze the network scenario.

Once the simulation has been done, the graphical metrics results collected during simulation of a network scenario and the results can be view in term of bar chart or histogram using the Analyzer [4].

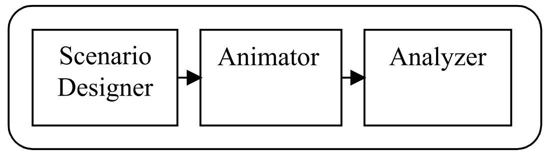

Fig.3. Block Diagram of QualNet Developer GUI

Two WSN models have been created in the Qualnet identified as WSN Model 1 and WSN Model 2.

A. *WSN Model 1*

Fig.4 shows the WSN Model 1 that has been created with the Scenario Designer.

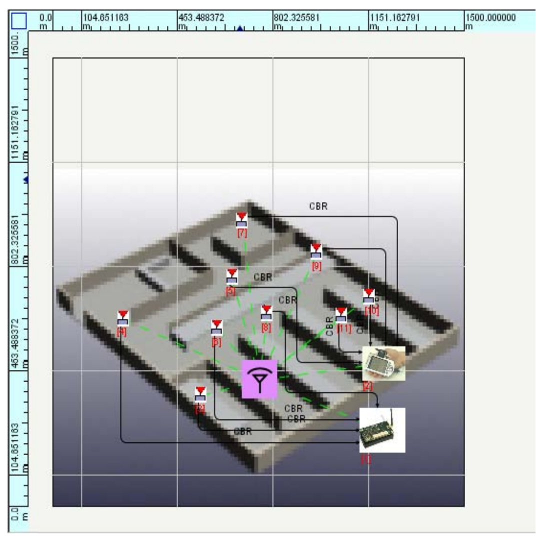

Fig.4. WSN Model 1

Eleven sensor nodes have been randomly deployed onto the Scenario Designer, each individual node identified as node1 until node11. Node1 acting as a sink node or base station, consumes the data or the node that sends out a data to the external network. Meanwhile, node2 which acts as a router passes data from the sensor nodes to the base station. The subsequent nodes, node3 until node11 are the sensor nodes that sensed and sent the data message to the sink node. The events sensed by the sensor channel are propagated across the network through the wireless channel. Wireless subnet connecting all sensor nodes to each other has also been deployed into the network scenario. In addition, parameters of each sensor nodes have been configured before the simulation started.

B. *WSN Model 2*

Fig.5 shows the second model, WSN Model 2 also created using the Scenario Designer. Similar to the WSN Model 1, this model also deployed similar number of nodes with similar function configured before the commencing of the simulation. The difference between WSN Model 1 and WSN Model 2 is the position of the sensor nodes. In WSN Model 1, the sensor nodes are randomly deployed on the Scenario Designer but in WSN Model 2, node3, node4, node6 and node8 were deployed closer to the sink node. Meanwhile, node5, node7, node9, node10 and node11 were deployed farthest away from the sink node. The configured parameters for both models will be shown in the next section below.

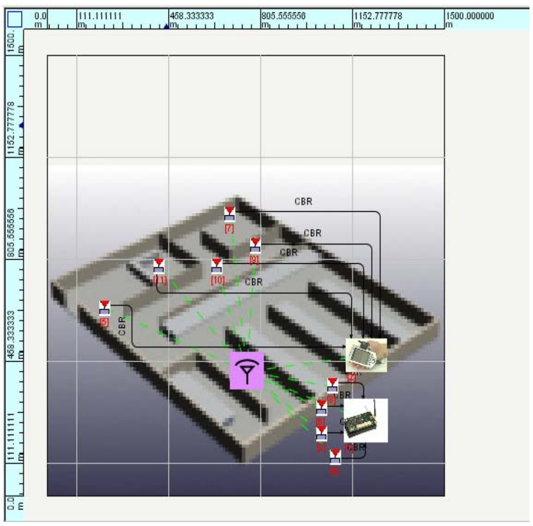

Fig.5. WSN Model 2

C. *Configured Parameter*

The configured parameters for both models are as below:

1) Radio/Physical layer
   - Energy Model specification: **MicaZ**
   - Battery Model: **Service Life Accurate**
   - Radio Type: **IEEE 802.15.4 radio**
   - Modulation Scheme: **O-QPSK**
   - Packet Reception Model: **PHY802.15.4**
   - CCA Mode: **Carrier-Sense**
2) MAC Protocol
   - MAC Protocol: **IEEE 802.15.4**
   - Device Type:

     node1:
     Device Type: FFD
     FFD Mode: PAN Coordinator

     node2:
     Device Type: FFD
     FFD Mode: Coordinator

     node3 to node11:
     Device Type: RFD
3) Network Protocol
   - Network Protocol: **IPv4**
   - Routing Protocol for IPv4: **AODV**

Table I and II tabulates the coordinate of each node and the distance between each sensor node to the sink node for both WSN model created. The location of each sensor node are determined and defined in terms of coordinate (Xn , Yn). The distance, D between each sensor node from sink node had been determined using (1),

$$D = \sqrt{Xn^2 + Yn^2} \tag{1}$$

where;

Xn – difference between coordinate X of the sensor nodes and the sink node

Yn – difference between coordinate Y of the sensor nodes and the sink node

TABLE I
COORDINATE AND DISTANCE FOR WSN MODEL 1

Coordinate (X_n , Y_n) Sink Node	Node	Distance, D (meters)
[1] (1206.00 , 252.00)	[3] (541.72 , 368.88)	674.48
	[4] (257.81 , 625.67)	1019.16
	[5] (654.98 , 764.46)	752.49
	[6] (601.29 , 593.25)	694.35
	[7] (692.38 , 953.67)	869.57
	[8] (782.00 , 642.00)	576.09
	[9] (964.98 , 847.07)	642.03
	[10] (1056.00 , 636.00)	412.26
	[11] (1156.00 , 698.00)	448.79

TABLE II
COORDINATE AND DISTANCE FOR WSN MODEL 2

Coordinate (X_n , Y_n) Sink Node	Node	Distance, D (meters)
[1] (1206.00 , 252.00)	[3] (1038.25 , 209.16)	173.13
	[4] (1091.14 , 129.14)	168.19
	[5] (220.95 , 635.99)	1057.25
	[6] (1038.79 , 294.64)	172.56
	[7] (692.38 , 953.67)	869.57
	[8] (1080.61 , 371.17)	172.99
	[9] (787.90 , 847.07)	727.27
	[10] (642.11 , 777.86)	771.04
	[11] (424.06 , 778.36)	942.59

D. *QualNet Animator*

Upon completion of configuration for each node in the Scenario Designer, click the **Run** icon in the runtime controls toolbar to begin execution of the scenario. The speed of simulation can be slowed-down to clearly observe the node broadcasts and communications flow.

E. QualNet Analyzer

Lastly, the graphical metrics result collected during the simulation can be view by clicking on **Analyze** icon.

III. RESULT AND DISCUSSION

The results collected during the simulation were shown in a 2D bar graph for all nodes. Fig.6 exhibit the total packets sent from the client to the server. The result shows that node10 transmit more packets to node1 because this node located closer to the node1 compared to the node4. Least packets are transmits by node4 because this node located far away from node1 where node4 may miss the opportunities to transmit the packets to the node1.

Fig. 7 shows the total packets sent by each node for WSN Model 2. Observing Fig.5, shows that node3, node4, node6 and node8 were located closer to the node1 while other nodes were located far away from node1. Therefore, we can see that sensor nodes which are located closer to the node1 will sent more packets of data compared to the sensor nodes which are located far away from node1.

Therefore, from the result in Fig.6 and Fig.7, sensor nodes which were located closer to the server node may receive more opportunities to transmit data packets the server node. Meanwhile, the farthest sensor nodes from server node may experience disconnection between the sensor nodes and server node, which resulted packet loss due to link error.

Fig.8 and Fig.9 above shows the total packet received by each server node for WSN Model 1 and Model 2. We can see that node2 received more packets of data than node1 because all sensor nodes tend to transmit data packets to the node1 which may cause the occurrence of congestion at node1. This affects the number of packets received by server node. As shown the number of packets received also decreased from the number of packets transmitted due to packet loss and congestion during the receiving of packets from all nodes at the same time.

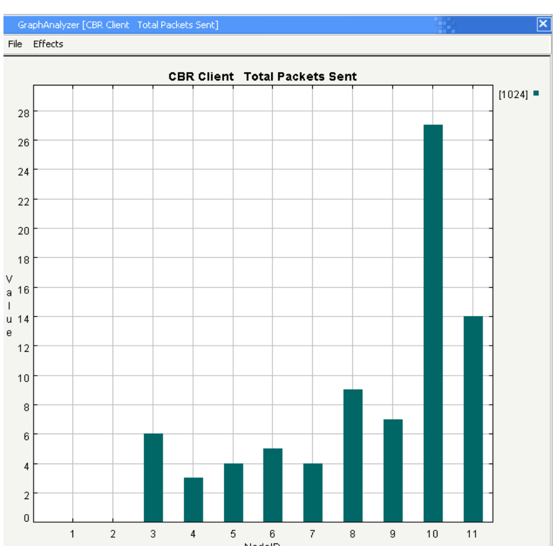

Fig.6. Total Packets Sent for WSN Model 1

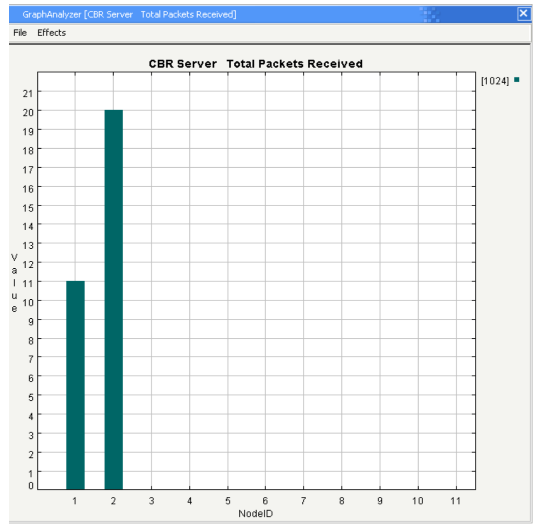

Fig.8. Total Packets Received for WSN Model 1

Fig.10 and Fig.11 shows the client-side throughput. Throughput is the data transmission rate at which channel capacity are used to transmit a data. From both figures, we can see that the throughput for node which is located closer to node1 has the highest throughput than other nodes which are located farthest away from node1. This is because throughput will increases as the packets transmission also increases. We already establish that node10 at WSN Model 1 and node4 at WSN Model 2 transmitted more packets than any of other nodes. Thus, high transmission rate occurred at these two nodes for each WSN model.

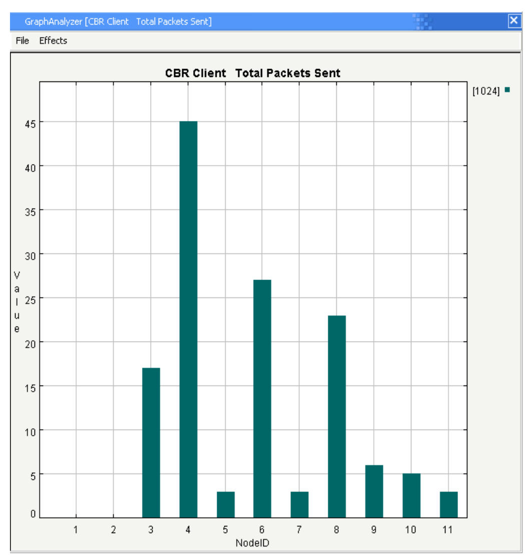

Fig.7. Total Packets Sent for WSN Model 2

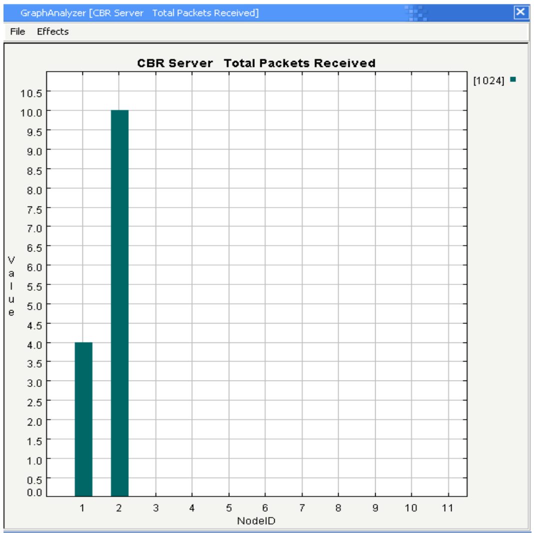

Fig.9. Total Packets Received for WSN Model 2

Fig.12 and Fig.13 shows the server-side throughput for both WSN Model 1 and Model 2. Both figures showed that the data transmission rate for node1 is lower than node2. We know that the throughput will increases in accordance to the increase in packets transmission. Due to the congestion and packets loss which occurred at node1 during transmission, node1 received fewer packets of data compared to data packets received by node2. Hence, the throughput for node1 will be less than the throughput for node2.

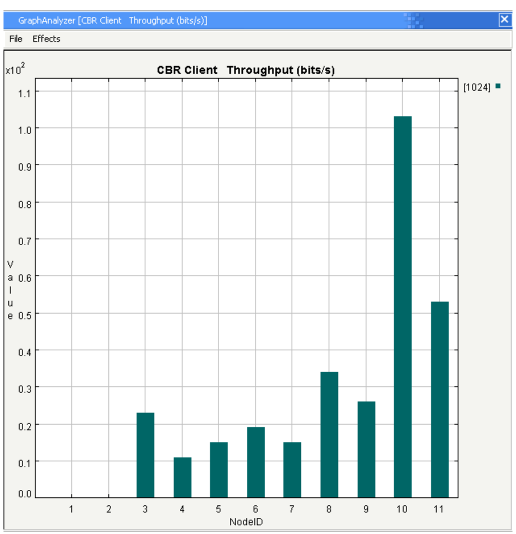

Fig.10. Client Throughput for WSN Model 1

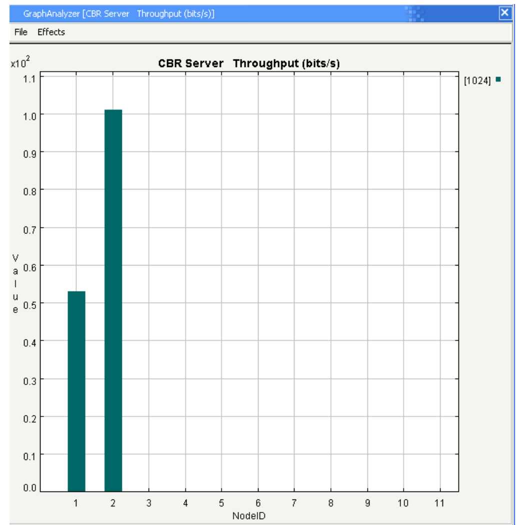

Fig.12.CBR Server Throughput for WSN Model 1

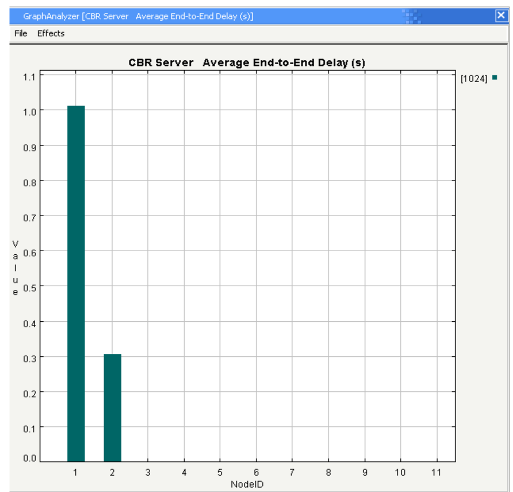

Fig.14. Average End - To - End Delay for WSN Model 1

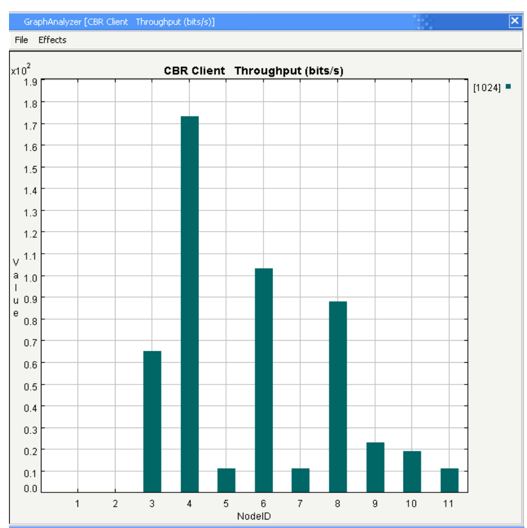

Fig.11. Client Throughput for WSN Model 2

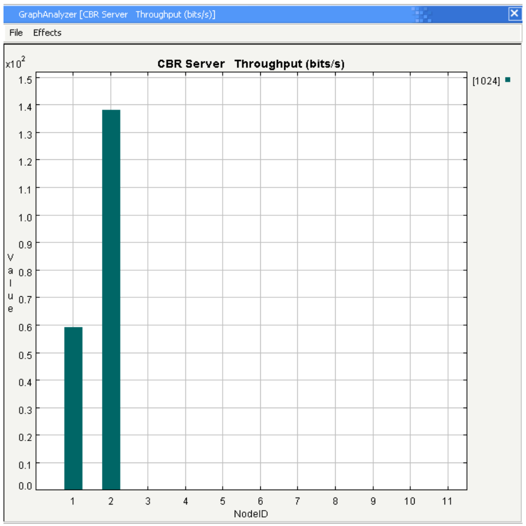

Fig.13.CBR Server Throughput for WSN Model 2

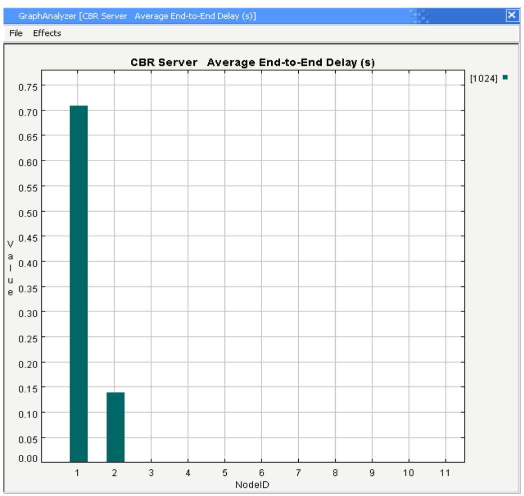

Fig.15. Average End - To - End Delay for WSN Model 2

Fig.14 and Fig.15 shows the average delay for packet transmission between client and server. Delay refers to the amount of time spent by a data packet before it is successfully transmitted which is determined by the network traffic load. Both figures pointed to the fact that node1 has higher delay time compared to node2. This is due to more traffic load received at node1 compared to node2. Since node1 had been assigned as the sink node, all sensor nodes tend to send the packets of data to node1. Hence, low channel throughput occurred during transmission which affect the data transmission time between client and server.

IV. Conclusion

Through this project, it can be concluded that the important issues contributing to the performance of WSNs are the location of the sensors, power consumptions, sensing capability, operating environment and connectivity with the PAN Coordinator.

For example, from the simulation for WSN Model 1, we can see that a lot of beacons had been dropped in node4 which was due to failure in the sensor to associate with PAN Coordinator of the network. Therefore, this factor will cause node4 to drop the data packets during the transmission. The location of node4 not suitable as it is too far away from the server node. Moreover, node4 also needs to compete with other sensor nodes which were located closer to the server node while transmitting the data.

Other factors to be considered are the fact that if the transmitted packets were to arrived at the same time at server node, it would create congestion at server node and may cause lower server throughput and longer delay in transmission time. This in return will result in energy consumption and packets loss at the sensor nodes.

V. Future Development

This project only focuses on performance of Wireless Sensor Network in QualNet Developer software simulator. Therefore, for the future development, the real Building Automation System can be integrated with the Wireless Sensor Network to control and improve indoor building condition and both installation and maintenance costs significantly reduced. This project can be continued for other Sensor Network application such as battle field monitoring by utilizing moving sensor nodes.

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