Optimum Distance Planning of Wireless Sensor Network Using Linear Regression Method

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Abstract. This research is very important to know the performance and capability of ESP-01 as a sensor node in network planning using Wireless Sensor Network (WSN). The optimal distance between nodes is obtained from the recording using the wireshark application. The linear regression method is used to build distance forecasting systems with packet loss and delay metrics. Observation is done by simulation using Network Simulator and direct measurement using wireshark. The results showed that the recommended optimal distance is 34 meters with a good category network quality.

Key words: Optimum distance planning, WSN, Linear Regression

1. Introduction

WSN is a wireless network that consists of several sensor nodes spread over a certain area that can be used to monitor the condition of an environment [1]. Each sensor node has the ability to collect data and information which is then sent to the webservice / base station. So, researchers can obtain a complete information about a condition without having to be around the sensor area. Information can be accessed remotely via devices such as laptops, smartphones, remote controls and others [2]. Some of the advantages of WSN technology are that it is practical and in certain geographical conditions more profitable than Wired Sensors [3] [4]. Some disadvantages of WSN compared to wired network are, network security issues, lower data transfer speeds, more complicated configurations, easily interrupted by external factors such as weather, physical barriers, distance and signal attenuation [5].

There are many researches in WSN. Some of them proposed concept in energy in WSN [6] [7]. Other research developed secure routing protocols in WSN [8]. But, optimization is needed to maximize the advantages of WSN and reduce its weaknesses. There are many researches that develop optimization of network QoS. Research [9] optimizes energy consumption by mapping the deployment of nodes to maintain excess power usage so that connectivity remains stable. Research [10] optimizes QoS by efficient multipath routing.

In this study, ESP8266-01 is set as a sensor node by testing the distance change to find out the optimum distance. Observations were made on each addition of 10 meters until the connection is lost.
QoS metrics in this observation are packet loss, delay and throughput. The observation results are then processed using linear regression to find the optimal distance in accordance with the recommended QoS standard.

2. Literature Review

2.1. Wireless Sensor Network

WSN is a wireless network that consists of a node in the form of a router and sensor devices. Each node that is spread is connected in one network wirelessly. WSN has been widely used in daily life in many monitoring applications such as environment, health, military needs and others [11]. WSN consists of two components, namely Sensor Node and Sink. Sensor Node is a unit of several devices consisting of processors for data processing, memory for storing data, sensors for event detection, ADC (Analog Digital Converter) to convert readings from analog to digital, tranceiver as a sender and receiver of radio signals to and from other nodes and batteries as an energy source. While the sink is a unit that collects information on environmental conditions that are monitored from the sensor node so that information can be processed further [12].

![Figure 1. The design of WSN [11]](image_url)

WSN must be planned well so that the data transmission in the form of sensor readings to the monitoring PC can be sent properly. One optimization that can be done is by setting the distance between nodes based on the ability of the device used [13].

2.2. ESP 8266-01

ESP 8266-01 module is a microcontroller board based on wireless communication that can be programmed according to the required application. It acts as an SOC with integrated TC /IP so that the microcontroller can access the WiFi network (802.11). The ESP8266-01 board can connect to all WiFi networks. Therefore, ESP8266-01 is more suitable as a sensor node that sends data to the server wirelessly [14].
2.3. Network Performance

Network performance or Quality of Service (QoS) is an important component in various communication systems. QoS shows the consistency and success rate of sending data so that it is used as a measure of the reliability of the network. Some metrics used to measure QoS in this study are packet loss, delay and throughput.

Packet Loss is the value of the ratio of packets lost in the process of transmission from sender to receiver. Packet loss is calculated using the following formula (1) [15]. The packet loss standard is shown in table 1.

\[
Packet \ loss \ rate = \left( \frac{Total \ packet \ loss}{Total \ packet \ sent} \right) \times 100\% \quad (1)
\]

| Category   | Packet loss |
|------------|-------------|
| Very good  | < 3%        |
| Good       | 3% - 15%    |
| Average    | 15% - 25%   |
| Poor       | > 25%       |

Table 1. Packet loss categories

Delay is defined as the time difference in sending a packet from the sender to the receiver. There are several types of delay, namely transmission delay, propagation delay process delay [16]. The delay categories is shown in table 2.

| Category | Delay  |
|----------|--------|
| Very good| < 150 ms |
| Good     | 150 ms - 300 ms |
| Average  | 300 ms - 450 ms |
| Poor     | > 450 ms   |

Table 2. Delay categories according to ETSI 1999

Throughput is the actual data rate per unit time (Bytes per second). Throughput Usually associated with bandwidth and can be called bandwidth under certain conditions. Bandwidth is more rigid while throughput is dynamic depending on traffic conditions [17]. The formula for calculating throughput is formula (2).

\[
Throughput = \frac{Total \ packet \ sent}{Time} \quad (2)
\]

2.4. Linear Regression

Linear regression analysis is a linear relationship between the independent variable \(X\) and the dependent variable \(Y\). This analysis is to determine the direction of the relationship between the independent variable with the dependent variable whether positive or negative and to predict the value of the dependent variable if the value of the independent variable has increased or decreased [18]. The linear regression formula is as follows:

\[
Y = a + bX \quad (3)
\]

\(Y\) : Dependent variable (predicted value)
\(X\) : Independent variable
\(a\) : Constant (Y value if \(X = 0\))
\(b\) : Regression coefficient (value of increase or decrease)
Values a and b, can be found using the Least Square method.

\[
a = \bar{y} - b\bar{x}
\]

\[
b = \frac{n \sum xy - (\sum x)(\sum y)}{n \sum x^2 - (\sum x)^2}
\]

(4) 

(5)

The relationship between variables \(X\) and \(Y\) can be either perfectly dependent or perfectly independent. This method is used to predict the value of the independent variable after knowing the value of the independent variable.

3. Research Methods

Distance has an influence on the quality of communication on wireless networks. The farther the distance between the nodes, the worse the quality of the network. Conversely the closer the distance between nodes, the better the quality of the network. So testing with distance change is essential to know the optimal distance between nodes [19].

In this study, testing is carried out to determine the optimal distance of ESP 8266-01 in context as a WSN device using linear regression method. Observation is done by simulation using Network Simulator and direct measurement using wireshark [20].

4. Results and Discussion

Simulation results about the relationship between throughput to changes in distance are shown in table 3. Table 3 shows the throughput values of the test with a distance of 30, 70, 100 and 110 meters.

| Distance | Throughput (Bps) |
|----------|------------------|
| 30       | 19806.5          |
| 70       | 19804.1          |
| 100      | 19184.8          |
| 110      | 0.00177778       |

The throughput value of the distance of 30 and 70 meters is almost the same and has a difference of 2.4 Bps. Then at a distance of 100 meters the throughput value rises to 19184.8 Bps. Throughput decreases with increasing testing distance. At a distance of 110 meters the value of throughput decreases to 0.00177778 bps. This is because many packets are not sent compared to distances of 30 and 70 meters. The farther the distance between nodes results in the lower signal coverage, so the value of throughput is smaller.

The next observation is direct measurement with delay, packet loss and throughput as metrics. The graph of the transmission delay to the change in distance is shown in Figure 2.
From the graph above, increasing the distance results in higher delay. In other words the longer the distance between sender and receiver, the worse the quality of the network.

The next observed metric is packet loss. Observation results are shown in Figure 3. Figure 3 shows that the packet loss value tends to increase linearly with distance. The value of packet loss is higher when the distance is farther away. The highest percentage loss package in this experiment is 60% at a distance of 120 meters. The next observed metric is throughput. Observation results are shown in Figure 4.
Figure 4 shows that the farther the distance, the lower the value of throughput. At 10 meters, the throughput is 1571 Bps. The value of throughput is around 1500 Bps at a distance of 20 and 30 meters. But after 40 meters, the value of throughput drops to 275 Bps. And throughput is 220 Bps - 275 Bps at a distance of more than 40 meters.

The next step is analysis using the linear regression method. This analysis is intended to predict the value of the distance between nodes based on delay and packet loss metrics. By using equations (3), (4) and (5), equation (6) for delay metrics and equation (7) for packet loss metrics are obtained.

\[
Y_d = 175.61 + 3.63X \tag{6}
\]

\[
Y_{pl} = -10.98 + 0.41X \tag{7}
\]

\(Y_d\) : Prediction equation of delay
\(Y_{pl}\) : Prediction equation of packet loss
\(X\) : Distance

By using both categories in table 1 and table 2, and with equations (6) and (7) an optimal distance between nodes is obtained. The recommended optimal distance is about 34 meters.

5. Conclusion

Based on the results of research and analysis, it can be concluded that the change in distance affects the QoS of the ESP8266-01 module. The farther the distance between nodes, the smaller the throughput, the greater delay, and the greater packet loss. Conversely, the closer the distance between nodes, the higher the throughput, the smaller the delay and the smaller packet loss. In addition, the recommended distance to produce QoS at a good level is about 34 meters.

References

[1] Vipin Sharma, "Limitation Associated with Wireless Sensor Network," *International Journal of Computer Science and Technology*, vol. 1, no. 1, pp. 110-112, 2014.

[2] B.P. Sreeja, L. Jayakumar, and G. Devi Saratha, "Wireless Sensor Network Applications : A Study," *International Journal of Pure and Applied Mathematics*, vol. 118, no. 11, pp. 385-389, 2018.

[3] Hina Tandel and Rakesh Shah, "A Survey Paper on Wireless Sensor Network," *International Journal for Scientific Research and Development*, vol. 5, no. 10, pp. 907-909, 2017.

[4] Indu and Sunita Dixit, "Wireless Sensor Networks: Issues & Challenges," *International Journal of Computer Science and Mobile Computing*, vol. 3, no. 6, pp. 681-685, 2014.

[5] Prashant Tiwari, Varun Prakash Saxena, Raj Gaurav Mishra, and Devendra Bhavsar, "Wireless Sensor Networks: Introduction, Advantages, Applications and Research Challenges," *HTCL Open International Journal of Technology Innovations and Research*, vol. 14, 2015.

[6] U. Nandhini and Santhosh Kumar SVN., "Energy Efficient and Secure Data Dissemination in WSN," *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, no. 2, pp. 324-327, 2019.

[7] Rinkuben N. Patel and Nirav V. Bhatt, "Energy Efficient Quality Assurance MAC Protocols in WSN," *International Journal of Engineering and Advanced Technology*, vol. 9, no. 2, pp. 2090-2097, 2019.

[8] Somu Parande and Jayashree D. Mallapur, "Research Trends in Secure Routing Protocols and Communication System in WSNs," *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, no. 1, pp. 3413-3421, 2019.

[9] Adda Boualem, Youcef Dahmani, Abdelkader Maatoug, and Cyril De-Runz, "Area Coverage
Optimization in Wireless Sensor Network by Semi-random Deployment," in *International Conference on Sensor Networks*, 2018, pp. 85-90.

[10] Pradeep Karanje and Ravindra Eklarker, "Efficient Multipath Routing to Increase QoS by Link Estimation and Minimum Interference Path in MANET," *International Journal of Engineering and Advanced Technology*, vol. 9, no. 2, pp. 4806-4811, 2019.

[11] S. Prasanna and Srinivasa Rao, "An Overview of Wireless Sensor Networks Applicaations and Security," *International Journal of Soft Computing and Engineering*, vol. 2, no. 2, pp. 538-540, 2012.

[12] Mukhdeep Singh Manshahia, "Wireless Sensor Networks: A Survey," *International Journal of Scientific & Engineering Research*, vol. 7, no. 4, pp. 710-716, 2016.

[13] Li Zhu, Chunxiao Fa, Huarui Wu, and Zhingang Wen, "Coverage Optimization Algorithm of Wireless Sensor Network Based on Mobile Nodes," *International Journal of Online and Biomedical Engineering*, vol. 12, no. 8, pp. 45-50, 2016.

[14] Manan Mehta, "Esp 8266: A Breakthrough In Wireless Sensor Networks And Internet Of Things," *International Journal of Electronics and Communication Engineering & Technology*, vol. 6, no. 8, pp. 7-11, 2015.

[15] Winarno Sugeng, Jazi Eko Istiyanto, Khabib Mustofa, and Ahmad Ashari, "The Impact of QoS Changes towards Network Performance," *International Journal of Computer Networks and Communications Security*, vol. 3, no. 2, pp. 48-53, 2015.

[16] Dipika Jain, "The Simulation Effect of Packet Drop Ratio, Graph Throughput and End-2- End Delay in simple TORA and Black Hole Attack in AODV using NS-2.35," *International Journal of Software & Hardware Research in Engineering*, vol. 3, no. 12, pp. 6-11, 2015.

[17] Umeh O.A., Akpado K.A, Okechukwu G.N, and Ejiofor H.C, "Throughput and Delay Analysis in a Real Time," *International Journal of Engineering and Applied Sciences*, vol. 2, no. 12, pp. 27-34, 2015.

[18] Neelamadhab Padhy and Rasmita Panigrahi, "Data Mining: A prediction Technique for the workers in the PR Department of Orissa (Block and Panchayat)," *International Journal of Computer Science, Engineering and Information Technology*, vol. 2, no. 5, pp. 19-36, 2012.

[19] Mehajabeen Fatima and Ankita Tiwari, "Node Transmission Power Value Optimization in MANET," *International Journal of Innovative Research in Computer and Communication Engineering*, vol. 5, no. 8, 2017.

[20] Nedhal A. and Ben-Eid, "Ethical Network Monitoring Using Wireshark and Colasoft Capsa as Sniffing Tools," *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 4, no. 3, pp. 471-478, 2015.