Performance Analysis on Wireless Sensor Network Based on Zigbee Wireless Communication Protocol

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Abstract

This journal discusses the performance analysis of a Wireless Sensor Network (WSN) system based on the Zigbee Wireless Communication protocol. Zigbee in this system is used for sensor communications that do not require high data transmission speeds, such as sensor applications, such as temperature, humidity, light, pressure, and other sensors. The analysis carried out is to examine the QoS of a network system based on the topology used in the Zigbee protocol-based WSN system. The results of the study show that the use of topology is very influential on the availability, stable speed, and accuracy of the data transmitted between these sensors.

Keywords--- Wireless Sensor Network (WSN), IoT, IEEE 802.15.4, Zigbee, QoS, topology, mesh, star, tree

INTRODUCTION

Today WSN have increasingly widespread applications and have the potential to revolutionize many aspects in human life, from environmental monitoring and control, manufacturing and business asset management, to automation in transportation and healthcare industries. A lot of research has been done on the actual implementation and deployment of sensor networks that are tailored to the existing needs, especially in sensing and monitoring applications. To form a WSN application that has high performance, a reliable and efficient communication protocol is needed. Especially with the proliferation of IoT-based applications, the WSN applications and communication protocols are designed to provide high energy efficiency.

IEEE 802.15.4

The IEEE 802.15.4 protocol standard embedded in the physical and data link layer (DLL), which is used for low-power wireless network communications and was defined as the IEEE 802.15.4 standard defined in 2003. Devices communicate in small networks called Private Area Networks (PANs).

IEEE 802.15.4 defines two sublayers of DLLs – Logical Link Control (LLC) and Media Access Control (MAC). The MAC sublayer defines simultaneous access from multiple devices to the transmission medium using the appropriate protocol (e.g. Carrier Sense Multiple Access / Collision Avoidance (CSMA/CA)), whereas the LLC coordinates the distribution of data packets to the appropriate services at the Network Layer.

Zigbee-Based Wireless Sensor Network

Zigbee is a wireless technology that was developed as an open global standard to meet the needs of wireless IoT networks that can consume low power and can be built at an affordable cost. The Zigbee standard operates on the IEEE 802.15.4 physical radio specification and operates in the 2.4 GHz, 900 MHz, and 868 MHz free frequency bands. ZigBee is also able to provide integrated and complete solutions for general purposes, especially for sensor network-based applications. ZigBee provides services such as security, discovery, filtering, and so on.

Due to the limited transmission power, the maximum reachable point is 400 meters, which is defined as T, so the network coverage diameter of a single device is $2\rho T$. Thus the overall maximum network diameter, defined as $R_{max}$ can be calculated using the formula (1), where $d$ is the furthest distance between two devices (but still in one network and connected by routing nodes (RD)).
The maximum range can also be calculated using the formula (2) where nRD is the number of RDs connected to the network

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R_{\text{max}} = (n_{\text{RD}} + 1) \cdot \rho_T
\]  

By using formula 2 it can be calculated the minimum amount of RD needed to achieve R\(_{\text{max}}\) as shown in Figure 1.

Fig 1. Transmission distance based on the addition of RD

Table 1 shows the maximum bit rate and symbol rate data from IEEE 802.15.4 where the bit rate at the 2.4 GHz frequency is 250 kBit/s, this limits the amount of data that can be transmitted by ZigBee.

| PHY (MHz) | Frequency band (MHz) | Spreading parameters Modulation | Data parameters Bit rate (kb/s) Symbol rate (kymbol/s) Symbols |
|----------|-----------------------|---------------------------------|----------------------|----------------------|----------------------|
| 868/915  | 868-868.6             | 300 BPSK                        | 20                   | 20                   | Binary               |
|          | 902-928               | 600 BPSK                        | 40                   | 40                   | Binary               |
| 2450     | 2400-2483.5           | 2000 O-QPSK                     | 250                  | 62.5                 | 16-ary Orthogonal    |

Network Topology

The most important thing that affects the performance of this Zigbee-based network is the physical network topology. The IEEE 802.15.4 protocol standard specifies the topology used is the star (figure 2) and peer-to-peer, while the topology specification for Zigbee added 2 more topologies, namely tree (figure 3) and mesh (figure 4).
IMPLEMENTATION OF ZIGBEE TOPOLOGY IN SIMULATOR

The data collection method is carried out on the simulator, by implementing mesh, tree, and star topologies. From the experiment result, the suitable topology can be determined to be implemented on a WSN based on the Zigbee protocol, based on the QoS data obtained during the observation.

Throughput (bit/s), Load (bit/s), and end-to-end delay (second) are the parameters chosen because they are the global statistical data standards that best describe the ZigBee network in terms of performance. The following picture is a scenario of star topology (figure 5), tree (figure 6), and mesh (figure 7) that has been made on the simulator. The simulation of each scenario is run for 90 minutes to get optimal results.
Fig 5. Star topology scenario

Fig 6. Tree topology scenario

Fig 7. Mesh topology scenario
RESULT AND ANALYSIS

The data generated from the simulator in the form of network performance looks very different from one topology to another. The network parameters used are throughput (bits/s), load (bits/s), and end-to-end delay (second), all of these parameters are carried out for all topological scenarios.

Load (bit/s) refers to the load that occurs in the MAC layer of the Zigbee network, throughput (bit/s) is the traffic at a certain moment range while the end-to-end delay (second) is the time span between the sending end node and the end node. Consignee's end for the manufacture and delivery of the package.

The MAC Load measurement results as shown in Figure 8 show that the average MAC Load value for the tree topology is 30131 bits/s, while the average MAC Load values for star and mesh topologies are 23148 bits/s and 25119 bits/s, respectively. So from this value, it can be seen that the tree topology has a higher MAC Load value than the other 2 topologies.

Likewise with the MAC throughput measurement as shown in the graph in Figure 9. The average value of MAC throughput for tree topology is 30131 bit/s, this value is better than the average value for star topology which is 23148 bit/s and mesh (25119 bit/s), this is due to tree routing, where each end device can only communicate with coordinators and routers, while in a mesh topology, routing is formed from communication from one device to another.
As shown in Figure 10, the lowest average end to end delay value is obtained from the start topology with a value of 0.014673684 seconds, while the mesh topology is slightly higher in value, namely 0.015968421 seconds, and the highest value is obtained from the mesh topology with a value of 0.015968421 seconds. Based on these results, the star topology is considered more efficient because in any condition every device connected to the network and wants to communicate with other devices must first send data to the coordinator.

CONCLUSION

In this study, determining the appropriate topology is an important step in determining the success of the test or in designing a WSN based on this Zigbee protocol. From the results obtained from testing the system through the simulator, a WSN with a tree topology is the most suitable topology because it has the highest MAC Load value among the other 2 topologies, and has an acceptable end-to-end delay number based on the TIPHON reference.

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