Performance evaluation of routing protocols in Zigbee network: DSR vs AODV

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***Abstract*— Wireless sensor networks (WSN) are becoming popular now among network experts and researchers because of increasing demand in WSN applications in the field of sensor networks. Also, the research in routing protocols of WSN has grown tremendously to make sure that WSN applications in WSN is performing at its full potential. This paper focuses on analyzing the performance evaluation of routing protocols in Zigbee network (a form of WSN), particularly DSR and AODV routing protocols in Zigbee network. Zigbee has become a widely used application with different routing protocol options in the Personal Area Network (PAN), Wireless Sensor Network (WSN) and in Internet of Things (IoT) applications due to its ease of use and accessibility. The metrics that are used to analyze the performance of these routing protocols are the throughput, delay and the number of packets received. The simulation results using eight nodes showed that AODV routing protocol is more efficient network to be applied in Zigbee when compared to DSR routing protocol as it recorded a higher number of packets received, throughput and lower delay than DSR. Overall, the findings are found to be consistent with previous studies and proved that AODV is the preferred routing protocol for Zigbee networks.**

Keywords*— Zigbee, DSR, AODV, WSN, throughput, delay

I. INTRODUCTION

Wireless Sensor Networks (WSN) has become an increasingly important topic among network design researchers as there is an increasing need in the application of this technology [1]. WSN is widely used in many different areas of technology due to the ease of the ad hoc network, and the application to sensor nodes such as light sensors, smell and vibrations [1]. Wireless sensor networks are efficient and reliable network with a high adaptability to be used in areas such as home area network and personal area network [2]. Wireless sensor network contains a set of systematic sensor nodes which are small devices that assesses different parameters including sounds, vibrations and pressure points [3].

Moreover, WSNs have expanded into different areas such as medical field, agricultural and even at home primarily due to the fact that WSNs are effective communication networks since these networks often require low cost and sensor technologies, while offering multiple sensor options such as using humidity, pressure and even temperature [4]. Similarly, according to [5], the wireless LAN is widely popular as there is a higher throughput and data transfer rate. Therefore, wireless networks especially wireless sensor networks are more widely being used for network and applications. Moreover, according to [6], wireless sensor networks are increasingly being used due to its ease of application and the ability to connect to more nodes. Placement of nodes is vital in order to ensure higher network efficiency that only requires low energy consumption while still maintaining a low cost [6].

Zigbee network is a form of WSN as it operates in personal area network (PAN) and is accessible to almost any organization or individual as it is widely flexible to be used [2]. Zigbee has become a popular communication protocol in the wireless sensor network, Internet of Things (IoT) and ad-hoc network application [7]. Zigbee is a widely used network that is primarily used in wireless technologies since it is able to connect to networks and is deemed to be one of the most popular communication standards in recent times [2]. Zigbee can use up to sixty-four thousand devices on a network, making it a viable network especially for wireless sensor networks [2].

II. LITERATURE REVIEW

About Zigbee Network

Zigbee can be defined as a low-cost network that uses wireless connection and application through a very reliable transfer of data meant for short-range operations. The primary objective of Zigbee is to ensure that it is easy to install, low cost and has a good battery life, while having flexible routing protocols [8]. ZigBee network is an efficient and widely used network that consumes low power and low cost [9]. There are standardized protocols that are primarily used in the Personal Area Network (PAN) and Wireless Sensor Networks (WSN). Zigbee follows a standardized 802.15.4 protocol which enables Multiple Access Control (MAC) layer and Personal Area Network (PAN) layers to be accessed [6] [10]. This creates an ad hoc network that allows flexibility in designing networks for different wireless sensor network applications [6] [10]. ZigBee is widely used in home network applications, smart lightings and even smart energy applications due to its ease of use [9] [11] [2].

Zigbee operates primarily in personal area network and the main node is setup in the network as a coordinator node. The coordinator then chooses an identified, also known as a PAN ID which is mainly a unique ID used for each network and its own channel [2]. This ID must be the same as it will be used by different devices that are present in the network, allowing for communication between these devices. Parameters set allows the coordinators to then join the network and transfer data between nodes, which means that there is a security requirement for Zigbee network. Zigbee often uses 128-bit encryption that protects the devices and the network itself from any cyber-attacks [2].

According to [9], ZigBee has four primary routing protocols which are hierarchical tree routing (HTR), on-

demand routing protocol, many-to-one routing protocol with a combination to source routing and multicast routing. These routing protocols can be changed according to the requirement which is based on the anticipated patterns of behavior and traffic. Zigbee standard has three types of nodes which is the coordinator, router and end device. A coordinator can be defined as the primary device that is used in the network, such as personal area network (PAN) which stores and manages information on the network [8]. Zigbee network connected nodes to routers, while are able to increase or decrease their signal strength based on the proximity to a location [13]. Furthermore, Zigbee is also found to be able to optimize algorithms to cater for automation and to optimize on demand. However, Zigbee is primarily more apt for low-cost and low-power hardware devices that are easily available and can be used as solutions in Wi-Fi settings [13]. Furthermore, Zigbee chips are also sold as microcontrollers and often has a range of between 60kb to about 250kb, making it easy to access and use for any application [3].

Routing messages are also sent through a coordinator as it can send any message to any device on the network including start, mesh and tree topologies [8]. A router on the other hand, would be able to connect with other routers and devices using only batteries or direct power supply. Star topologies do not need routers while tree and mesh topologies would require a router that allows messages to be passed up and down the network [8]. Moreover, according to [5], a wireless ad hoc network has no centralized node and it is widely distributed. This type of network often does not have an existing infrastructure and all nodes can communicate with one another freely.

III. ZIGBEE ROUTING PROTOCOLS: DSR & AODV

Routing protocols are really important, especially when it comes to maximizing network resources. A good routing protocol system will ensure that the network is adaptable to different sizes, increase in traffic as well as in network partitioning [5]. The Ad-Hoc routing protocol is also known as On-Demand Distance Vector (AODV) in Zigbee. One of the primary problems found in AODV networks is that in mesh networks there are reportedly higher packet collisions that cause higher packet and data loss [5]. It also consumes high amount of data. AODV is generally incompetent in fast environments.

Zigbee routing protocols operates under three main modes which are proactive, reactive and hybrid mode which are more commonly known as DSR, AODV, OLSR and ZRP routing protocols [3]. Most researchers in this field often assess the four types of routing protocols against different Zigbee network design, however according to [8], there are two main types of routing protocols in Zigbee network which is Ad Hoc On Demand Distance Vector (AODV) and TBR which is tree-based routing [8]. On the other hand, the performance of routing protocols has been measured using different metrics such as packet delivery, throughput and routing load using AODV and ZRP protocols [7].

DSR can be defined as Dynamic Source Routing Protocol (DSR) which is a wireless mesh network that takes a on-demand node that transmits nodes upon requests [3]. DSR also uses source routing that varies according to routing table that is aligned between the different devices. Furthermore, this is also a better approach in Zigbee as linking is easily done between different data packets that are sent and received. Zigbee also saves and follows the same route caches which contains node routes [3]. On the other hand, ad hoc on demand distance vector routing protocol is more of a reactive protocol. This protocol was developed by a group of mobile company researchers who combined wireless and ad hoc networks to create a new protocol (3017). AODV works by identifying and communicating with nearby nodes. A study conducted by [4] found that the baud rate or data transfer rate between the different network points in Zigbee has a low latency rate using Zigbee protocol. The coordinator node is spaced out at 3m from the sensor node and using a hundred and twenty data packets sent, there was a 1 second interval between transmissions. The study recorded a throughput rate of 19.2kbps using 115200 bps with a packet size of 80 bytes. Therefore, this study will focus on using throughput and latency rate to assess the different routing protocols.

IV. ZIGBEE NETWORK PERFORMANCE METRICS

Zigbee network can be measured using performance metrics which includes throughput data, latency, energy consumption and packet delivery ratio [5] [6]. The following metrics are described in detail below.

i. Throughput - successful data packets to be transferred from the source node to the destination node within a time frame. Throughput basically measures how fast the data can pass through a network. Usually this is counted in bits per second, and is calculated by Zigbee application during simulation. The packets are known as 'Tps, TIps and Tfps'.

ii. Packet Delivery Ratio - The number of packets received at the destination node from the source node ratio. This is also defined as the number of packets successfully received in the MAC layer [5].

iii. Latency - Delay time of packets to get from the source to the destination. This includes route discovery, queuing and transfer time. This is a fundamental aspect of wireless sensor networks as the applications often require an input for time sensitive data.

iv. Energy consumption - energy efficiency is a primary consideration since nodes are powered by batteries and often require more time to charge, and a higher cost to recharge batteries after deployment. There are four energy consumption modes which are transmit (TX), receiving (RX), idle and sleep mode. A nearby node that is in idle mode may require unused energy to search and report different networks, while nodes that are in sleep mode may decrease energy as there is no packets to be sent or received. Upon being activated, the nodes consume a higher amount of energy to receive and send nodes.

v. Packet loss (%) - The percentage ratio of lost packets during transmission in the MAC layer.

V. METHDOLOGY

NetSim simulation software will be used to design Zigbee network and to assess the performance of the routing protocols. NetSim platform allows for ad hoc network design as well as Personal Area Network (PAN) design using wireless simulation [14]. Netsim is often used to simulate a network design and to perform research activities related to network designs [3]. It has many features and can easily be

used for many purposes such as WSN, LAN, TCP and so on. In terms of simulation for Zigbee, often 100 by 100 meters are used and nodes are places according to the required number of the user. For the purpose of this study, a total of eight nodes would be used and placed according to an ad hoc network setting, using wireless link [3].

VI. FINDINGS

Two routing protocols were used to identify the faster routing protocol. This was done between DSR and AODV. The simulation design was done using 8 nodes as depicted below in figure 1 with one ad hoc link and one pan coordinator.

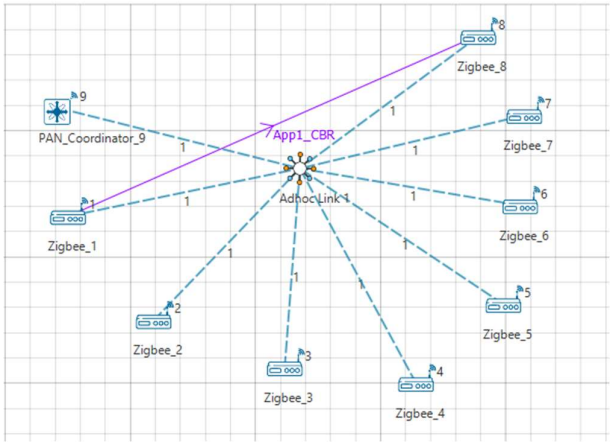

Fig. 1. Zigbee network simulation

Simulation parameters used are described as below.

TABLE I. SIMULATION PARAMETERS

Simulator	NetSim
Protocols	DSR & AODV
Application Metrics	Throughput (Mbps) Delay (Microsecs)
Network Metrics	Number of packets transmitted & received
Number of Nodes	Eight (8) nodes

The simulation was done using Netsim application and two primary protocols were used, which was DSR and AODV. The application and network metrics were throughput (measured through Mbps), delay (measured through microseconds) and the number of packets that were transmitted and received. There were eight nodes used in the simulation, as depicted in Figure 2 above. Throughput is the measurement for the performance of changes in data packets transmission, using a specific time frame in a network. A single transmission in a personal area network can be recorded at 115 kbps. Throughput measurement can be calculated using the number of packets delivered by the total duration of the simulation. Delay is a performance metric that analyses the time frame for data packets to move from the source to the destination node in the simulation. This is measured in milliseconds and can be an important indicator in network simulation and design. Therefore, the lesser the number of delays, it means that the network is fast and efficient. Besides that, the number of packets transmitted is also an important performance metric to be considered. A packet of data may contain important information and user data. Therefore, the higher the number of packets that were transmitted and received, the better the quality of the network.

The DSR routing protocol was set in the physical layer as shown in Figure 2 below.

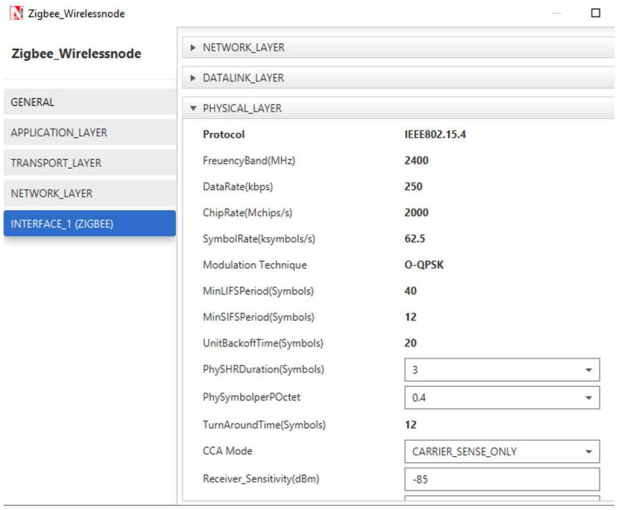

Fig. 2. DSR physical layer

As shown above, the Zigbee protocol used was IEEE 802.15.4 with a frequency of 2400 and with a data rate of 250. Figure 3 below shows the link layer acknowledgement for DSR routing protocol.

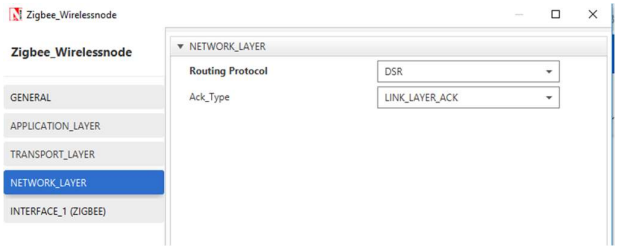

Fig. 3. DSR link layer

The results that were generated from DSR routing protocol are shown in Figure 4 and 5 below.

Application_Metrics_Table

Application_metrics Detailed View

Application Id	Application Name	Packet generated	Packet received	Throughput (Mbps)	Delay(microsec)
1	App1_CBR	75000	14910	0.116099	46232899.429577

Fig. 4. Application metric results for DSR

Network_Metrics_Table

Network_Metrics Detailed View

Link_id	Link_throughput_plot	Packet_transmit...		Packet_errored		Packet_collided	
		Data	Control	Data	Control	Data	Control
All	NA	14910	152	0	0	0	53
1	NA	14910	152	0	0	0	53

Fig. 5. Network metrics for DSR

As shown above, there were seventy-five thousand packets that were generated and 14,900 packets were received. The throughput rate was recorded at 0.116099 with a delay of 46 microseconds. This shows that the data packets had gone

through the routing protocol at a slight delay recorded at that rate through the DSR protocol. On the other hand, Figure 6 below shows the AODV routing protocol selection for the same Zigbee simulation.

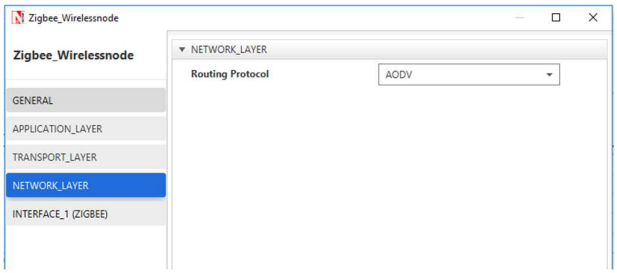

Fig. 6. AODV routing protocol

The application metrics and network metrics of the AODV routing protocols are shown in Figure 7 and 8 below.

Application_Metrics_Table

Application_metrics Detailed View

Application Id	Application Name	Packet generated	Packet received	Throughput (Mbps)	Delay(microsec)
1	App1_CBR	75000	15391	0.119848	39713040.256124

Fig. 7. Application metrics for AODV

Network_Metrics_Table

Network_Metrics Detailed View

Link_id	Link_throughput_plot	Packet_transmit...		Packet_errored		Packet_collided	
		Data	Control	Data	Control	Data	Control
All	NA	15391	4333	0	0	0	1532
1	NA	15391	4333	0	0	0	1532

Fig. 8. Network metrics for AODV

The results of the AODV shows that the same amount of packets were generated which was seventy-five thousand packets, however more packets were received via this routing protocol at 15, 931 packets which is an additional 481 packets. Furthermore, the throughput rate was also recorded to be at 0.119848 and AODV simulation recorded a delay of 39 microseconds which is much faster than DSR results. Overall, the results can conclude that AODV had recorded a much faster protocol, which would be more apt for Zigbee network since it is a simple and flexible network. This result is consistent with findings from previous researchers in this study [3]. Zigbee is apt for use in wireless sensor networks using lower rate of data applications since it impacts throughput and packet delays [4].

VII. CONCLUSION

In conclusion, Zigbee is a fast-growing application in the wireless sensor network and internet of things domain due to its flexibility, accessibility and ease of use. The Zigbee network has been applied primarily in personal area network and wireless sensor network settings. Many industries such as healthcare, fitness, and automation industry is using Zigbee and therefore this increases the need to find good routing protocols to increase the efficiency of the network performance. In this study, two routing protocols were used which was DSR and AODV. The results of the simulation depict that AODV is a faster and more efficient network for Zigbee network. AODV is a better routing protocol than DSR when the performance metrics such as throughput and delay is taken into consideration. This is consistent with findings from previous researchers in this area of study, making the study a definitive one.

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