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Performance Evaluation of Beacon-Enabled Mode for IEEE 802.15.4 Wireless Sensor Network

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Abstract

IEEE 802.15.5 standard support structure of star and peer-to-peer network formation. Strating from these, the cluster tree network can be built as a special case of peer-to-peer network to increse coverage area. In this paper, we provide an performance evaluation of beacon-enabled mode for IEEE 802.15.4 wireless sensor network on star and cluster topology in order to get the maximum result to apply the appropriate topology model as needed. We conduct analysis on each topology model by using the numbers of nodes from 10 nodes to 100 nodes to analyze throughput, delay, energy consumption, and probability success packet by using NS2 simulator. The simulation results show that the throughput and the probability of success packet of cluster topology are higher than that of star topology, and the energy consumption of cluster topology is lesser than that of star topology. However, cluster topology increases the delay more than star topology.

Keywords: IEEE 802.15.4, wireless sensor network, beacon-enabled mode, topology, csma/ca

1. INTRODUCTION

Zigbee is specification for a suite of high level communication protocol used to create personal area network built from low-power and small digital radio. The technology defined by zigbee specification is intended to be simpler and less expensive than other wireless personal area network (WPAN). Network architecture on WPAN is designed for simple network concept such as home automation system with short operating system. IEEE 802.15.4 is standard for WPAN that focuses on two layers bottom protocol, physical (PHY) and medium access control (MAC) layer. MAC layer is defined by standard IEEE 802.15.4 as the access channel with two mechanism access, beacon-enabled and non beacon-enabled [1-4].

Nowadays, researchers describe on the performance of IEEE 802.15.4 standard with different topology and use many techniques. Yet, for comparing the performance between two topologies by purpose to get better result in its utilization is still rare to be conducted. In paper [5], the authors conduct performance analysis of WPAN network on mesh topology by using routing protocol AODV and DSR to get the result of throughput, delay, and packet loss. The final result of the analysis is thatthe throughput of AODV is always bigger than throughput of DSR value, packet loss routing of AODV is always bigger than that of DSR, delay for routing AODV is bigger than that of DSR. In paper [6], the authors analyze the performance of routing FSR on WPAN network by using numbers of nodes and average distance of area in each node is 10 meter. Parameters from the analysis are throughput, data delay, and packets delivery ratio (PDR). In paper [7], the authors conduct development of simulator NS2 for IEEE 802.15.4 and conduct such sets of experiment to learn many features. In the experiment, they compare the new standard of IEEE 802.15.4 with standard of IEEE 802.11 and obtained the result that IEEE 802.15.4 is more efficient in overhead cost and energy resource consumption than that of IEEE 802.11. In paper [8], the authors conduct saturation analysis on throughput system with assumed that every sensor has unlimited packet backlog. The authors validate the model with NS2 simulation and find that by backoff parameter of saturation standard, the throughput shortly decreasing by the increment of nodes number. In paper [9], the authors present the specific scenario where all nodes have simultaneously transmission that is the most dangerous cases for CSMA/CA protocol. They models the CSMA/CA algorithm on IEEE 802.15.4 and conduct non stationary analysis for synchronization experiment of transmission.

In paper [10], the authors analyze the mechanism of performance limit of slotted CSMA/CA for IEEE 802.15.4 in mode beacon enabled for broadcast transmission in wireless sensor network (WSN). They conduct evaluation of beacon-enabled mode because of the flexibility for WSN application than by mode non beacon-enabled. The performance of slotted CSMA/CA is evaluated and is analyzed for different network systematization to know the effect from protocol attribute such as superframe order (SO), signal and backoff exponents, toward network performance. In paper [11], simulation model of algorithm CSMA/CA for IEEE 802.15.4 by using OPNET Modeler is developed to analyze the delay effect toward WSN performance. They present that delay packet to the new superframe is very influencing throughput, success probability and delay average of WSN for short superframe, but it is not influencing WSN performance for superframe with long duration. The result of simulation shows that short delay influencing the long duration superframe, meanwhile for short duration frame specified the backoff period on the initial superframe that increase algorithm performance of CSMA/CA. Delay average for packet delivery increase because of more time has been spent in backoff period, overall, it increase success probability of package delivery.

Finally, the purpose of this paper is analyze network simulation of WPAN by using NS2 and compare the performance from star and cluster topology with throughput, delay, energy consumption and success packet probability parameters.

2. DESIGN AND SYSTEM

Figure 1 shows the system design for comparing the performance of star and cluster tree topology. It is knowledgeable that system design in general is illustrated with performance comparison of beacon enable IEEE 802.15.4 WSN by using topology star and cluster tree through two processes of compile and filtering that result data output of performance between topology star and cluster tree.

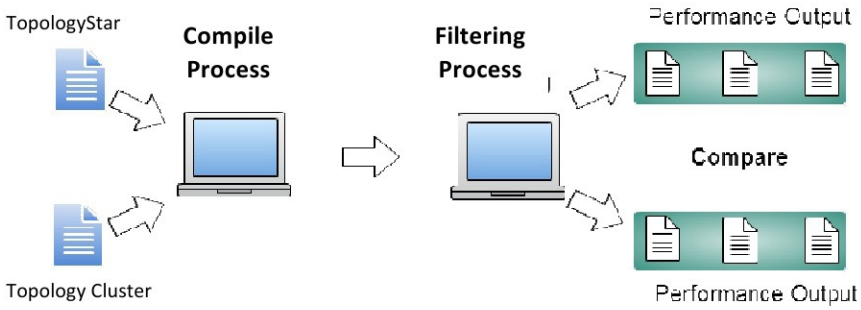

Figure 1. Design and system for WSN performance

The more detailed process is illustrated as follow in Figure 2.

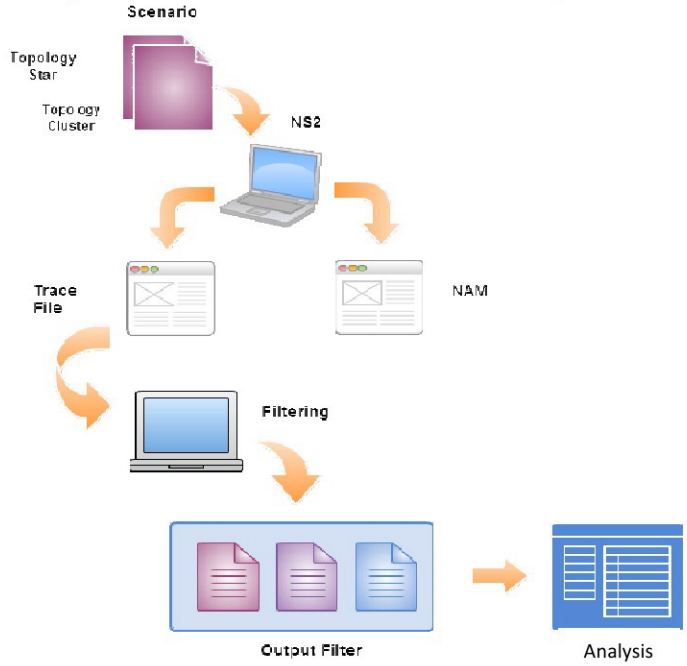

Figure 2. Scenario process on star and cluster topology

Figure 2 shows scenario for star and cluster topology which consists of .scn and .tcl files. File .scn contains coordinate spots, which arrange every node to be a topology as a topology scenario. File .tcl contains WPAN scenario that consist of helping variable to change network scenario and to control simulation process. We conduct simulation by using NS2 simulator. NS2 is widely used to learn dynamic structure from communication network. The advantages to use NS2 are NS2 equipped with validation tool so that the making of simulation by using NS2 is far easier than by using developer software like Delphi or C++. NS2 can be used on windows operation system and linux operation system linux [12].

The output of NS2 simulation process are network animator (NAM) and trace file. NAM presents simulation with animation display and is illustrated in the Figure 3.

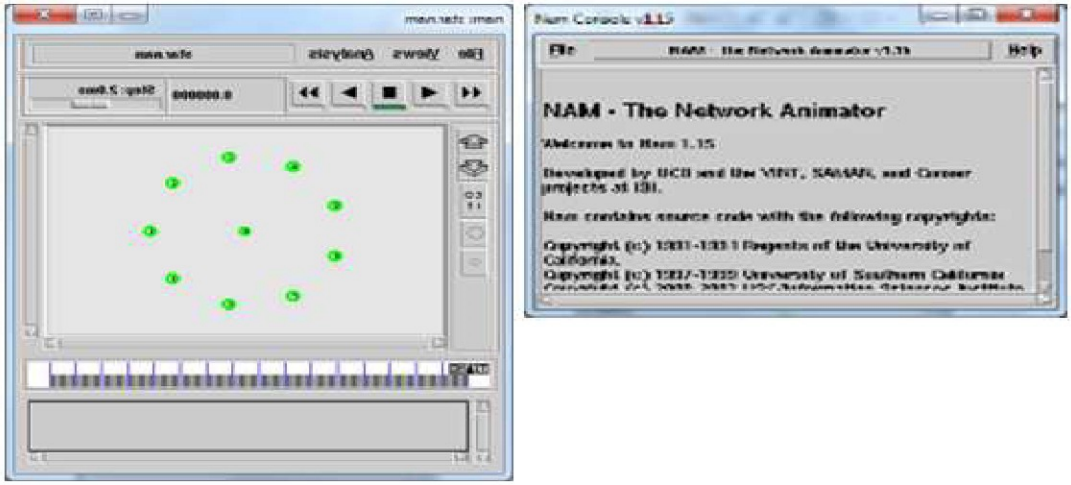

Figure3. NAM display

Trace file or file .tr contains data from the result of simulation start from the beginning up to the final that would be used for numerical analysis. From trace file, we do filtering process by using AWK file in order to get the output results, that are throughput.txt, delay.txt, and energy_consumption.txt to analyze throughput, delay, and energy consumption, respectively. The final step is comparing the performance from both topology with throughput, delay, energy consumption, and success package probability as parameters.

In simulation program of WPAN, there is influencing parameter for the result of simulation. Parameter used in simulation is classified into two parts; parameter defined by NS2 and parameter defined by the designer. Tabel 1 shows the simulation parameter of WPAN.

In this research, we compare star and cluster topology by the maximum number of node is 100 nodes for each topology. Figure 4 shows simulation model example of star and cluster topology for star and cluster tree with 60 nodes.

Table 1. Simulation parameter of WPAN network

Parameter	Value
Type line interface	Drop Tail
Antenna model	Omni antenna
Topography dimension	50 x 50 points
Total of maximum node	100 node
Simulation time	2500 second

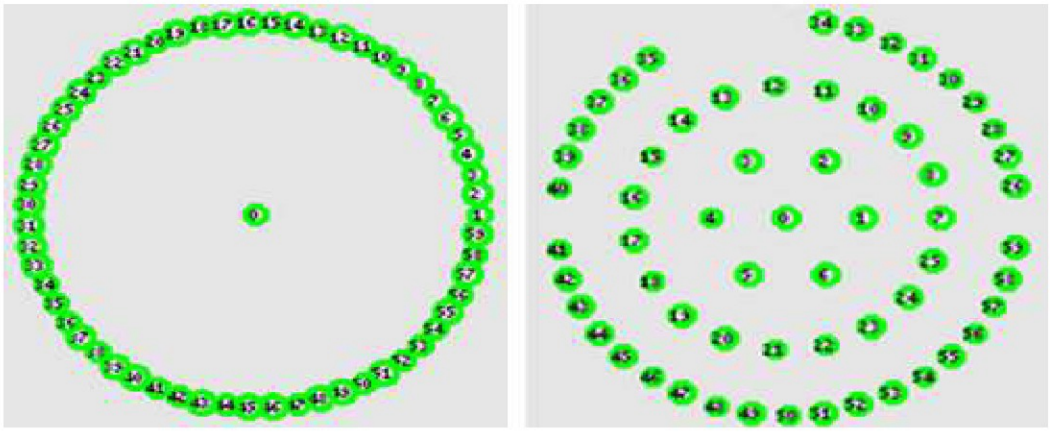

Figure 4. Simulation model of star and clustertopology

On topology star, node is in perfectly circle form with the same degree based on the number of node and the distance between PAN coordinator and end device as far as 20 points. For topology cluster tree, the location of independent node and the distance between PAN coordinator, coordinator, and end device is as far as 8 points.

Then we make scenario by determining the number of node, the number of lines, simulation time, and simulation area range. After getting the setting, device can be activated and scenario can be started, yet there is no traffic between nodes. In WSN, there are several kinds of traffic models. One of it is poison traffic. Poison traffic resulted traffic based on exponential On/Off distribution. Simulation program of this WPAN network is made in 6 scenarios as shown in the Table 2.

Table 2. Scenario table in simulation

Scenario	The number of Node
1	10
2	20
3	40
4	60
5	80
6	100

3. EXPERIMENT AND ANALYSIS

In performace analysis section, we conduct analysis on the comparison of star and cluster tree topology performance. The following are comparison graphic from the result of simulation between star and cluster tree topology in term of throughput, delay, energy consumption, and packet delivery probability.

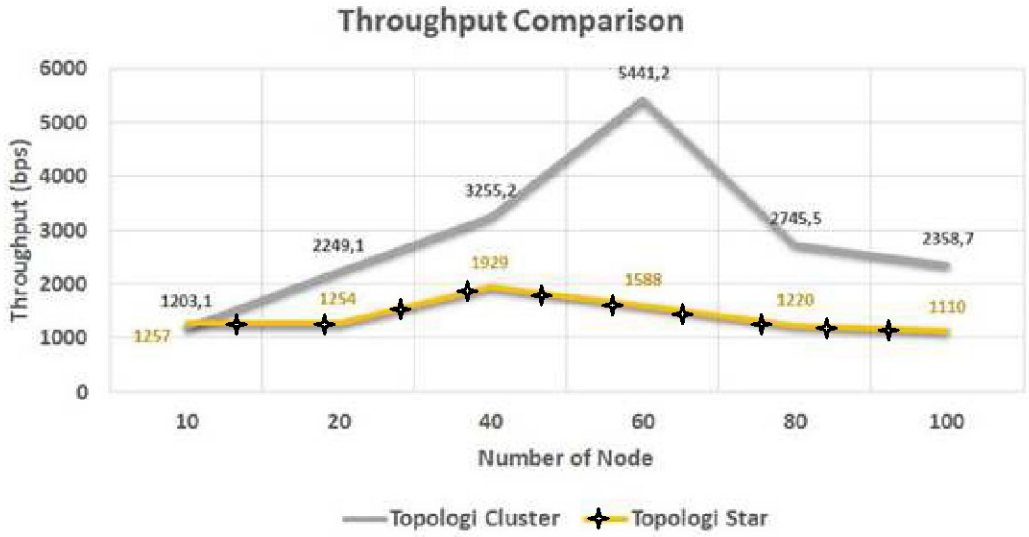

Figure 5. Throughput comparison between star and cluster

From Figure 5, we can see that the throughput of the cluster topology is more dominant than that of the star topology. In star topology, the data is sent directly to the personal area network (PAN) coordinator. If there are more number of node would like to send packet data, there will be more collision among packet data or packet data could not be send due to source node sense busy channel. In cluster tree topology, the source node will send packet data to its coordinator node, thenthe coordinator node will send packet data to PAN coordinator. Cluster tree topology decreases the probability of collision due to the packet data is not directly compete with all source node in the network. A node thet want send packet will only compete with other source node in the same coordinator node.

Figure 6 shows the comparison of average delay between star and cluster topology. In cluster topology, the average delay is irregular, because the cluster topology depends on how many nodes and how many layers we created. Since the model we made in several layers so that the delay at the time of delivery of data packets were not the same. Unlike the star topology which only has a single layer devices ranging from the number of 10 nodes to 100 nodes to measure the distance between the PAN coordinator to end device to hover around 20 points. So that the average delays time data transmission in star topology has the same delay time. The average delay in cluster topology is more than that of star topology because the source node

and the coordinator node need time twice to assess the channel and take backoff.

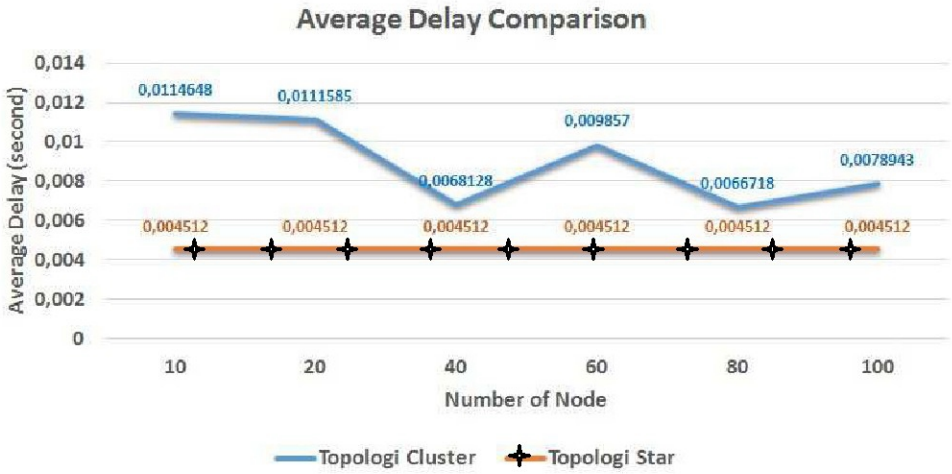

Figure 6. Average delay comparison between star and cluster

Figure 7 shows that the energy consumption of cluster topology is lesser than that of star topology. In star topology, all of end devices will send data directly to PAN coordinator. It will consume more energy if the distance between end devices and PAN coordinator increase. Beside that, if there more end devices want to transmit, the probability of collision will increase, then the end device need to retransmit its data and consume more energy. In the cluster topology, the end devices will not send its packet data directly to PAN coordinator. The end devices will send packet data through its coordinator node, due to the distance to transmit packet data to coordinator node is lesser than transmit packet data to PAN coordinator, the energy consumption of cluster topology is lesser than energy consumption of star topology. Moreover, not all of the cluster topology nodes. The coordinator node govern data transmission lines from end devices to the PAN coordinator.

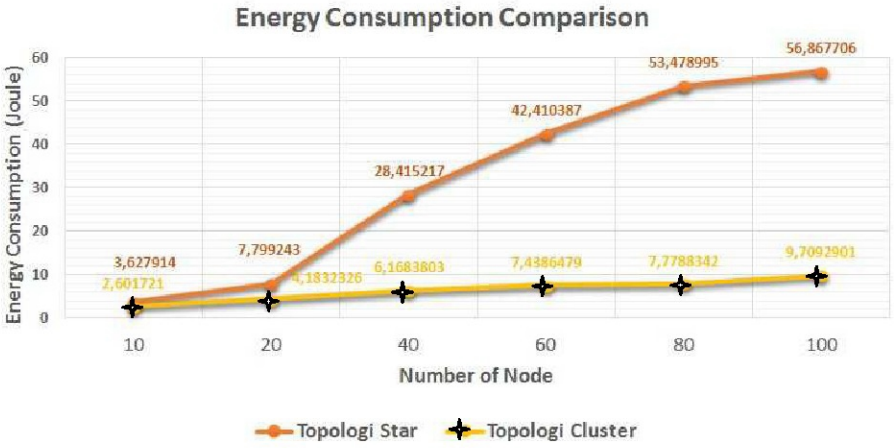

Figure 7. Energy consumption comparison between star and cluster

According to Figure 8, the probability of packet delivery success of cluster topology is higher than that of star topology. In star topology, more end devices want to transmit its packet data, more collision happen due to several end devices sense channel idle in the same time and send packet in the same time. Beside that, end devices could not send its packet due to always sense channel in busy condition, thus it could not send its packet. In cluster tree topology, the end device that want to transmit data only will compete with other end devices in the same group of its coordinator. So that the probabiligy of collision is lesser.

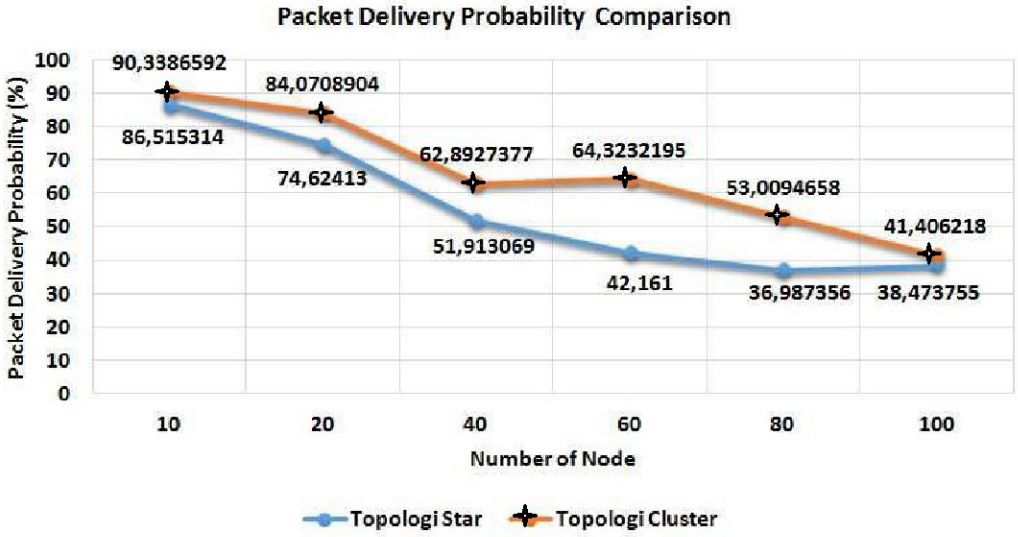

Figure 8. Packet delivery probability comparison between star and cluster

4. CONCLUSION

This paper conduct performance analysis on beacon-enabled mode of IEEE 802.15.4 wireless sensor network (WSN). We compare between start and cluster tree topology in term of throughput, average delay, energy consumption, and packet delivery probability. According to the simulation result, we found that the troughput of the cluster tree topology is greater than that of star topology. The average delay in the cluster is not the same and not uniform, because the cluster topology depends on how many nodes and how many layers we split the node to be the end device and coordinator. Star topology only has a single layer ranging from 10 nodes to 100 nodes. It results the average delay data only slightly adrift. In the comparison of energy consumption, the need for energy consumption on a star topology is greater than the energy consumption on the cluster topology. Finally, The chance of successful data sent on a cluster tree topology is larger than that of the star topology.

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