Volume 5, Issue 5, May 2015 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Performance Evaluation of IEEE 802.15.4/ZigBee WSN for Large Scale Deployment in Mesh Topology

Dr. Ziyad Khalaf Farej, Ali Maher Abdul-Hameed
Computer Engineering Department
Northern Technical University
Technical Engineering College,
Mosul, Iraq

Abstract: In this paper the performance of IEEE 802.15.4 standard Wireless Sensor Network (WSN) in mesh topology for large scale applications is evaluated. The OPNET simulator (version 14.5) is used to simulate and analyze the performance of the network in terms of number of nodes, packet size and packet interval time (PIT). Starting with a packet size of 1408 bit and PIT of 1 sec, a deep comparison among different network has been made and the simulation result shows that the optimum network performance is obtained at 50 nodes number with a packet size of 1408 bits and PIT equals 3 sec.

Keywords: - Wireless Sensor Network; IEEE 802.15.4; Optimum performance; mesh topology; OPNET.

I. INTRODUCTION

Wireless Sensor Networks (WSN) have emerged as one of the most exciting fields in Computer Science research over the past 15 years. Processors with on-board sensors are said to be nearing the size of a dust. Applications of WSN include military surveillance, habitat monitoring, structural monitoring and cargo tracking [1]. WSN is composed of sensor nodes with special function that exchange information by self-organizing wireless communication and do certain function together. IEEE 802.15.4 agreement with low rate is intended for low power and low cost in the industrial automation, intelligent households, medical applications…etc. Therefore, the study of its performance is necessary for its design [2]. IEEE 802.15.4 standard is a very reliable protocol for wireless connection among inexpensive devices either fixed or portable such as sensor networks, home networks and Wireless Body Area Network (WBAN) [3].

In [4], the study tries to assess the influence of the configuration of MAC parameters on the behavior of beaconless IEEE 802.15.4 networks under different traffic loads and levels of interference. In [5], evaluation and comparison of IEEE 802.15.4 standard performance using Omnet++ simulator is performed, focusing on single sink scenario in terms of data delivery rate, goodput, throughput and error rate metrics. In [6], the effect of (CSMA/CA) random access mechanism, network devices number, sampling rate and cycle of the transmission are studied. Also the performance metrics, which consist of packet delivery rate, end to end latency and transmission delay are analyzed.

In this paper, the best performance of the IEEE 802.15.4 based WSN mesh topology is evaluated by changing a number of different parameters such as, number of nodes, packet size and packet interval time. This is done by: first, increasing number of nodes and choosing the best performance, second, increasing packet size for the best performance, third, changing packet interval time in order to reach the optimum performance for the WSN at which the throughput is at its maximum value.

This paper is organized as follows; Section 2, gives a brief overview about the IEEE 802.15.4. Section 3, includes the modeled network and parameter setting that are used in the simulation. In section 4, the simulation results and graphs are given. Finally, section 5 presents the conclusion.

II. BRIEF OVERVIEW OF IEEE 802.15.4

IEEE 802.15.4 standard defines physical (PHY) and Medium Access Control (MAC) sub-layers. The structure includes the physical layer, the network layer and the application layer. The physical layer is used for data transmission and reception; channel sensing, channel selection, link quality determination and node state setting. It interacts with wireless channel and supply information to and from the upper layer. The MAC layer of the standard provides an interface between upper layer and physical layer and also it handles link management, security, channel access, frame validation and nodes synchronization. IEEE 802.15.4 support two types of topologies, star topology and peer to peer topology (see Figure 1). The Zigbee standard is based, at the first two layers of the ISO/OSI stack, on the IEEE 802.15.4 standard [7], which employs a non-persistent Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), Medium Access Control (MAC) protocol can operates in the 2.4 GHz band. In addition, the IEEE 802.15.4 standard provides an optional ACK message to confirm the correct delivery of a packet. Medium access mechanism in Zigbee wireless networks makes use of a back-off algorithm to reduce the number of packet collisions. A node, before transmitting a new packet, waits for a period randomly chosen in an interval defined during the network start-up phase. After this period has elapsed, the node tries to send its packet: if it detects a collision, it doubles the previously chosen interval and waits; if, instead, the channel is free, it transmits its packet. This procedure is repeated for five times, after which the waiting interval is maintained fixed to its maximum value. This back-off algorithm makes it likely, in the considered scenarios with low traffic loads that a node will eventually succeed in transmitting its packet [8].

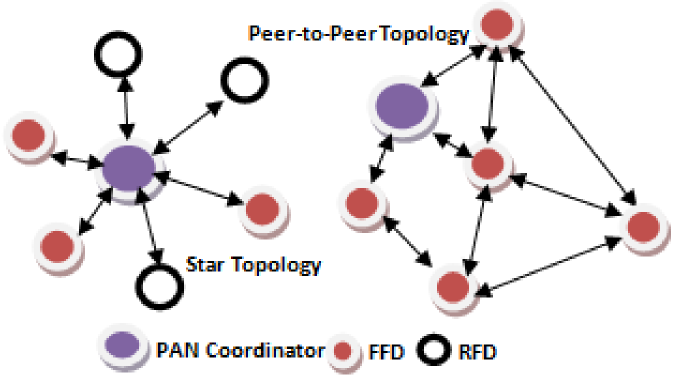

Fig.1 Star and peer-to-peer topology

III. MODELED NETWORK PARAMETER

The parameters which are set in our OPNET models during the simulation process are shown in Table1.

Table 1 Parameters setting

Parameters	**Values**
	Mesh
Payload (bits)	Variable (1024,1408,2048,3072,4096,8192)
Max. children	260
Max. routers	10
Max. depth	10
Mesh routing	Enabled
Packet Interval Time –PIT(sec)	Variable (1 - 8)
Transmit Power (watt)	0.1
Channel Sensing duration (sec)	0.2
Packets reception power threshold (dbm)	-90
Simulation time	10 minutes

The modeled networks are simulated under the following assumption:-

1- All system nodes distributed over 100X100 m^2 area.
2- ACK mechanism is not used.
3- Slotted CSMA/CA is not used.
4- All nodes are fixed.
5- Beacon-enabled mode is not used.
6- The addressing mechanism used in PANID is only 16bit.
7- The destination is randomly chosen from their neighbors.

IV. SIMULATION RESULTS

The best performance of the IEEE 802.15.4 based WSN mesh topology is evaluated by changing the following performance parameters: number of nodes (starting from 30 up to 260 nodes), packet size and PIT. As a start a packet size of 1408 bit with PIT of 1 sec is chosen.

A. Number of nodes

It is found that the highest (~440 Kbit/sec) steady state throughput is acquired at 50 nodes as shown in Figure 2. It is worth to mention that, for the same configuration parameters, the throughput in this network topology is higher than that of the tree (maximum throughput 280 Kbit/sec at 90 node number) and star (maximum throughput 220 Kbit/sec at 230 node number) topologies. The reason is that the mesh network topology uses mesh routing where routers inside network communicate together to update their routing tables, so the best (either shorter or faster) rout can be chosen depending on the used mesh routing algorithm. In a mesh topology data can take different routes through global network and its throughput adds up to high values.

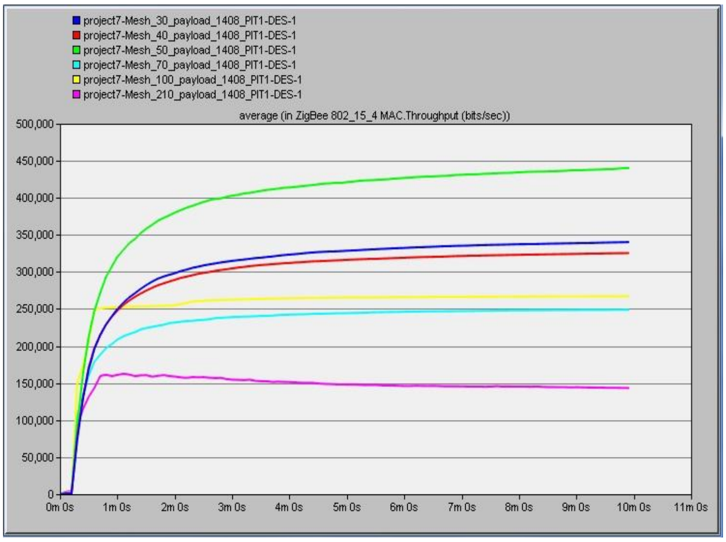

Fig.2 Global throughput variation for different number of nodes at 1408 packet size and PIT=1

Figure 3 shows that the packet dropping increases as the number of nodes increase. Also it is seen that there is a very high packet drop (65 packets) in the case of 210 nodes, while there is a little drop (24 packets) in case of 50 nodes. The reason for high packet dropping is mainly the congestion and packet collision which occurs at the routers as well as the coordinator, while for low packet dropping is the additional load by the mesh routing algorithm on the different paths as well as frequent loss of some packets.

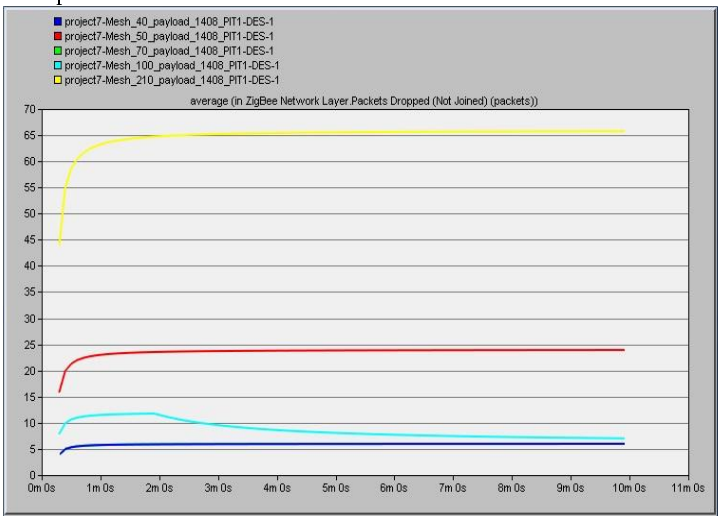

Fig.3 Packet drop variation for different number of nodes at 1408 packet size and PIT=1

Figure 4 shows the average end to end delay where it is seen that the delay is high at 50 nodes, the reason is the high number of nodes which are taking part in the transmission of their data and also the delay is normally added over multiple hops to reach the coordinator.

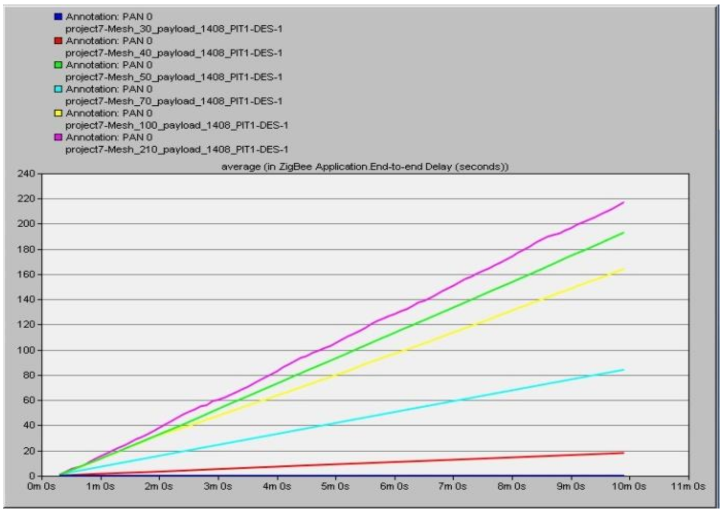

Fig.4 End to end delay variation for different number of nodes at 1408 packet size and PIT=1

Figure 5 shows average number of hops where it is seen that the highest average number of hops (6 hops) is at 50 nodes.

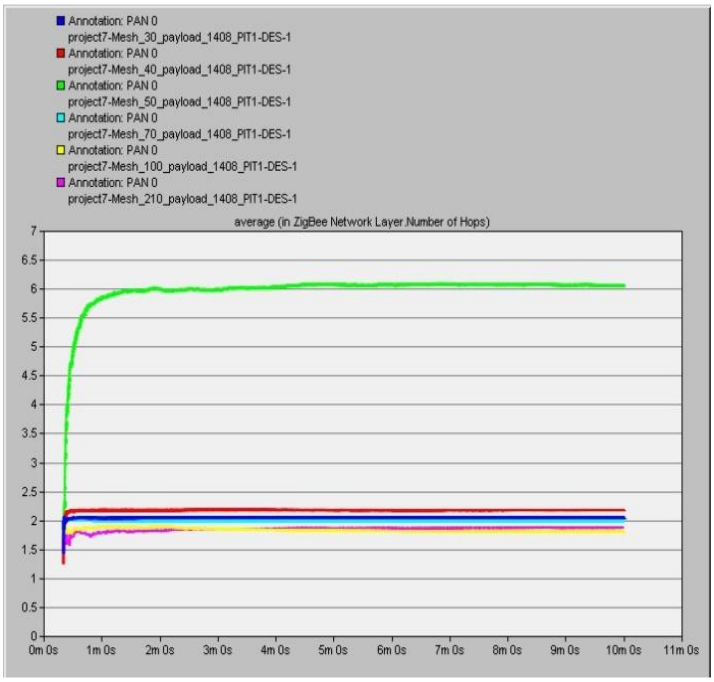

Fig.5 Average numbers of hops variation for different number of nodes at 1408 packet size and PIT=1

Referring to Figure 2, where it is seen that the 50 nodes network topology has the highest throughput, this result contradicts with the results shown in Figure 4 where the end to end delay at this node number is also high. The reason is the high number of nodes which successfully taking part and transmitting their data to destination over high number of hops which make the delay high as well as the throughput which is gathered by the routers over the network different routes.

B. Packet size

Figure 6 shows different network packet sizes. It is seen that the best network performance is at 50 nodes network topology with 1408 bits packet size where there is a good stability in network performance.

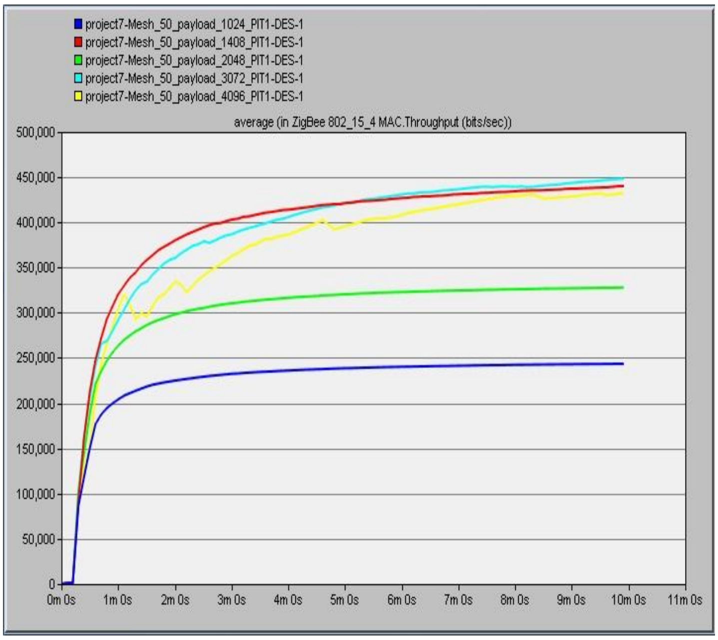

Fig.6 Throughput variation for different packet sizes at PIT of one

C. Packet Interval Time (PIT)

The PIT for the best network performance (i.e. 50 nodes with 1408 bits packet size) is changed from 1 to 5. It is found that the throughput clearly increases when the PIT is increased up to 3, but it begins to decrease when the PIT is increased more than that; therefore the best performance for the 50 nodes 1408 bits packet size mesh network topology is when the PIT equals 3 as shown in Figure 7.

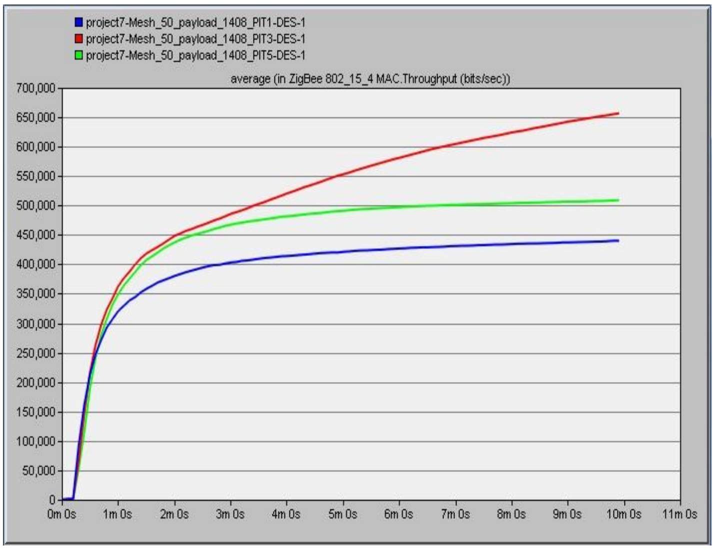

Fig.7 Throughput variation for different PIT at packet size of 1408 bits

V. CONCLUSION

The performance of IEEE 802.15.4 based WSN mesh topology is evaluated by changing the performance parameters: number of nodes, packet size and PIT. It is found that the highest throughput is obtained at 50 nodes. The network performance is optimized and it is concluded that the best throughput performance (~650 Kbit/sec) for mesh topology can be acquired at 50 node number with packet size of 1408 bits and PIT of 3 sec.

REFERENCE

[1] Marco G. et. al.; "Analysis of IEEE 802.15.4 Sensor Networks for Event Detection", IEEE "GLOBECOM", 2009.

[2] Boris M. and Mitko B.; "Overview and Analysis of the Performances of ZigBeebased Wireless Sensor Networks", International Journal of Computer Applications, Vol. 29, No.12, 2011.

[3] Y. Xiao and Y. Pan; Emerging Wireless LANs, Wireless PANs and Wireless MANs, New Jersey: John Wiley & Sons, 2009.

[4] Rohm, D. et. al.; "A simulation based analysis of the impact of IEEE 802.15.4 MAC parameters on the performance under different traffic loads", Mob. Info. Syst. , Vol. 5, pp. 81-99, 2009.

[5] L. Chaari and L. Kamoun; "Performance analysis of IEEE 802.15.4/ Zigbee standard under real time constraints", International Journal of Computer Networks and Communication (IJCNC), Vol.3, No.5, pp. 235-251, 2011.

[6] Liang, X. and balasingham, I.; "Performance Analysis of IEEE 802.15.4 Based ECG Monitoring Network", Proceeding of the seventh IATED International Conferences Wireless and Optical Communications, pp. 99-104, 2007.

[7] M. Kohvakka et. al.; "Performance analysis of IEEE 802.15.4 and ZigBee for large-scale wireless sensor network applications", In Proceedings of the 3rd ACM International Workshop on Performance Evaluation Of Wireless Ad Hoc, Sensor and Ubiquitous Networks (PE-WASUN'2006), pp. 48-57, 2006.

[8] Chiara B. and Roberto V.; "Performance Analysis of IEEE 802.15.4 Non Beacon-Enabled Mode", IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, vol. 58, no. 7, 2009.