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PERFORMANCE ANALYSIS OF IEEE802.15.4 IN TERMS OF ENERGY EFFICIENT PARAMETERS WITHIN WSN

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ABSTRACT

IEEE 802.15.4 standard has been proposed to support low power, low-cost wireless communication. It provides support to various WSN applications at minimum energy cost. In this paper, we have performed intensive simulation analysis on GTS nodes with different Energy control parameters. Our simulation analysis parameters are based on Battery module i.e. TelosB and Micaz, node density, distance, 100% and 25% duty cycles at different Interarrival applications i.e 0.1,0.2,1.0 & 2.0 and different modulation techniques namely QAM-64, QAM-16 and MSK. Star topology is implemented to investigate all these parameters with beacon enabled mode. Our Analysis results have shown that TelosB mote is more energy efficient than Micaz mote due to its low idle and receive mode i.e. 26.1µA and 24.8 mA, 25% sleep mode at (7, 5) offers less energy consumption and minimum E2E delay for 2.0 Interarrival rate, PAN-coordinator must consist of less node density within one cluster, the distance between end nodes from its PAN node must be small and QAM-64 is best choice at PAN node in case of less energy consumption. Results have shown efficient control over these parameters, to prolong the lifetime of sensor nodes.
KEYWORDS: OPNET Modeler 14.5, WSN, battery, Modulation, duty cycle

1. INTRODUCTION

Sensors network are entities which are deployed in specific area for collecting specific information. Wireless Sensor Network (WSN) has low-power and low cost. It is used in many fields due to its multifunctioning ability. WSN are used in military applications, civilian areas, health monitoring System, Habitat monitoring system and many others areas (Gilbert 2012).These applications offer real time data, which are supported by IEEE 802.15.4 based standard GTS node. GTS node offers GTS allocation mechanism for real time communication at network coordinator. Main features of IEEE 802.15.4 standard are low power consumption, low transmission of data rate and low complexity (Buratti et al., 2009).In 802.15 working group establish with particular objective of developing standards for short wireless network which is called WPAN. IEEE802.15 has four major working groups i.e. 802.15.1, 802.15.2, 802.15.3 and 802.15.4. IEEE 802.15.4 standard is responsible to develop standard for PHY and MAC layers, small flow of data and very complex solution to extend the life time of sensor nodes for a year (http:\\www.ieee802.org/15/pub/TG4.html,retrived on 12-12-2013).

The purpose of this study is to reduce Energy consumption of sensor node to achieve long life span of Wireless sensor nodes. To conserve Sensor node energy is the popular issue now days. There is need to bring improvement in sensor node parameters to conserve its energy and expand its lifetime, our aim to get energy efficient network with long lifetime of sensor node. In our research, we take consideration on Energy efficient parameters. If we control over on these parameters we can get long battery lifespan.

Rest of the paper covers the following sections; section 2 covers related works of researchers, Section 3 covers working and structure of Mac layer protocol, section 4 describes Performance analysis scenarios and results which are obtained from simulations. Finally, section 5 covers conclusion of this paper.

2. RELATED WORK.

Clustering is considered best approach to increase the lifetime of sensor network and to conserve its energy. Many clustering algorithms have been proposed for Wireless Sensor Nodes to increase the scalability, throughput and lifetime of the network. To deploy clustering scheme with appropriate energy efficient parameters and also to increase life time of sensor nodes, different researchers have done different works in their respective area. Some works of these researchers are as following:

In (Pal et al., 2012) clustering scheme, Sensor nodes are grouped in to independent clusters. Each cluster has at least one CH, which has the ability to collect data from its join sensor nodes and to transfers it to the base station

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(BS) through single hop or multiple hops path. Clustering algorithms extend the lifetime of sensor networks by avoiding long distance communication from sensor nodes to base station.

(Fan et al., 2010) performed analysis of GTS traffic performance in high data arrival rate of IEEE 802.15.4 protocol on OPNET Modeler. Results show that GTS allocation throughput is largely affected by arrival rate of data, buffer capacity and SO in term of low data arrival, low buffer capacity and high value of SO are not good choice for efficient use of GTS for data throughput.

(Part et al., 2009) analysis the GTS allocation mechanism of IEEE 802.15.4 protocol by proposes Markov chain for detailed analysis of stability, delay and throughput of GTS allocation. Results reveal that theoretical analysis is precise to improve the performance of GTS allocation.

(Shah et al., 2013) carry out work on Opnet modeler simulation and soft computing (ANN) for the purpose of evaluation of IEEE 802.15.4 performance. Results show that value of SO>7 are not maintained by WPAN and GTS allocation performance can be enhanced by applying fuzzy logarithm.

(C.Shu and Z.Mir et al., 2007) proposed new enhanced IEEE 802.15.4 beacon enabled mode. In this paper, C.Shu show to using the information of available traffic which depends on his traffic indication technique to utilize IEEE 802.15.4 CCA function which help to adjust the active duration in such way to save extra energy consumption and to get high throughput.

(M. Salayama and W. Mardini et al.,2013) performed simulation of IEEE802.15.4 based protocol on Qualnet 5.2 simulator, to check the behavior of beacon enabled mode by adjusting the value of BO and SO at suitable level for different duty cycle and arrival rate. Simulation performed on star topology by increasing end nodes to examine the parameters of Energy consumption, delay and throughput. They compare it with their new adaptive MAC algorithm. Results show that new adaptive MAC algorithm reduces energy consumption, 26%, E2E delay and increases 16% of its throughput. (Bamber and Sharma 2010) investigated the performance of IEEE 802.15.4 WSN in terms of different modulation Schemes; QAM-64, MSK and BPSK to check the impact of queue size with different modulation scheme. Results reveal that if queue size of PAN node under consideration then QAM-64 modulation is preferred. If queue size at end node is concerned then BPSK modulation scheme is suggested for end nodes. (Sharma et al., 2012) perform analytical research with different modulation technique at wireless sensor node to check energy consumption for each modulation it is concluded that OQPSK is best choice for sensor node due to less consumption of energy.

(Kim et al., 2006) proposed Sequential clustering Based Beacon Scheduling (SCBS), Which assigns the beacon slot efficiently among the sensor nodes through arbitrary choose the cluster head at each time and then hierarchal extend the WSN. The minimum numbers of beacon slot are uniquely assigned to each of Cluster Head and Gateway by single hop frequency.(Kawano et al., 2008) proposed an algorithm to reduce the multihop route from sensors node to base station in multiple sink sensor network by using graph coloring algorithm.

(Pal et al., 2012) proposed Energy-efficient cluster head election scheme for surveillance area, this scheme divides the network into two parts: inner region and boarder region.CH election always occur in inner region in each round, while boarder node always acts as member node. This scheme minimizes the distance of intra-cluster communication to achieve longevity of the network.

(N.Golmie et al., 2005) performed performance analysis on LR-WSN technologies in medical field. They focus on scalability issue of wireless sensor nodes by applying 10 sensor nodes in patient room. CSMA\CA mechanism can limit the medium utilization by change the Back off parameters may improve CSMA\CA performance. To reduce the interference mechanism of WPAN node, each WPAN node share same channel.

(Lee et al., 2006) proposed CODA algorithm which selects CH randomly based on their residual energy.CH migrates properly itself to reduce the communication cost in WSN. Cluster balance the energy through merging and partition the no. of nodes in cluster. (Shin et al., 2011) proposed Balanced Clustering Algorithm (BCA) for non_uniformly deployed WSNs. In this algorithm, each node calculates the probability of itself to become the cluster Head (CH) on the basis of node density .It distributes the coverage area of each cluster node uniformly by calculating the node's density to conserve node energy.

(M.salayma et al., 2013) carry out simulation by using different no. of nodes in network scenario. These scenarios are analysis in order to check the energy consumption, E2E delay and throughput with different arrival rate and duty cycle (50% and 100%). Results show that to increase in duty cycle which brings improvement in E2E delay and throughput.(F.Zafar & Maryam 2014) presents detail simulation analysis between Micaz and TelosB mote for energy efficiency, TelosB has shown energy efficient results for different values of modes. Result has shown that TelosB mote is energy efficient due to its sleep and idle mode.

3. WORKING AND STRUCTURE OF MAC LAYER PROTOCOL.

IPPP Hurray Groups (Petr 2007) define IEEE 802.15.4 physical and MAC layer for WPAN node. IEEE 802.15.4 physical layer is responsible for transmission and reception of low rate data at different unlicensed bands of frequencies: 250 kbps data rate at 2.4 GHz for worldwide, 40 kbps data rate at 915 MHz for North America and20 kbps data rate at 866 MHZ for Europe. IEEE 802.15.4 MAC layer controls two operational modes: Beacon enabled mode and Non Beacon enabled mode. These operational modes are controlled by PAN node.

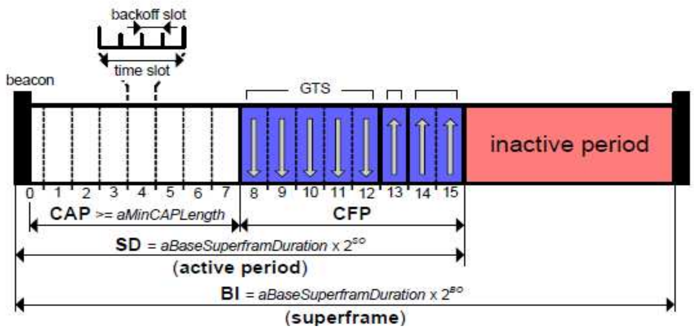


Figure 1. Superframe structure [19]

During Enabled mode also called active portion, PAN-C uses Superframe structure. The Superframe structure which is divided into 16 equally part called Superframe Duration. Superframe Duration is further divided into two periods: Contention Access period (CAP) and Contention Free period(CFP). The distance between two beacon slots is called Beacon Interval (BI).After transmission of beacon frame at the start of slot 0, the CAP active period is started immediately. During CAP, all nodes and PAN_C access channel by using CSMA/CA. The CAP is optionally which is followed by CFP, in which all the individual nodes granted access to the medium. If the GTS communication is setup then device send request to PAN_C to allot GTS slot. During inactive period of superframe structure, all end nodes and PAN_C starts to consume its energy because there is no transfer of data. It is better to turn off switches or send these nodes into low power consumption node called sleep mode.BI and active portion of superframe is controlled by BO and SO parameters that are adjusted by PAN_C. So that 0<=SO<=BO<=14 this formula is valid only for within 0 to 14 range. During inactive period or Non GTS node, there is no superframe structure is used, each node is self-organized, it means that if node wants to save its energy by simply disabling its receiver for longtime and it inform all nearby Transreceiver and PAN node set as BO=SO=15(Misic 2008).

4. PERFORMANCE EVALUATION.

Optimization Network Evaluation Tool (OPNET) simulation 14.5 is used throughout this research due to its convenient analysis. OPNET simulation results provide high reliability and efficiency as compared to other network simulation. OPNET Modeler provides GUI based support with drop down menu to its end user. In order to analyze the performance of IEEE 802.15.4 parameters to check the efficiency of wireless sensor node, we use OPNET Modeler 14.5 simulator. First set basic network topology model and then simulate different IEEE802.15.4 parameters.

4.1 Network model. Network topology model implemented in our work are as follows:

a. Sensor Nodes “N” are dispersed within square field area “A”. The Cluster Head (CH) is positioned at the centered of sensor area “A” to follow star topology.
b. All sensor nodes and CH or PAN node are fixed after placement.
c. MAC layer protocol IEEE 802.15.4 is implemented with beacon enable mode.
d. TelosB battery is supported for all sensor nodes.
e. All Sensor nodes follow heterogeneous network, PAN node has high energy level as compared to PAN coordinator.
f. By default modulation scheme is used throughout simulation setup except scenario 5.

4.2 Scenario Setup:

4.2.1 Scenario 1: Comparison between MICAZ and TelosB mote. It is designed to check the battery efficiency of two different Wireless sensor nodes vendors**.** Here, comparisons between MICZ and TelosB motes are made on the basis of node density to check which one consumes less energy.

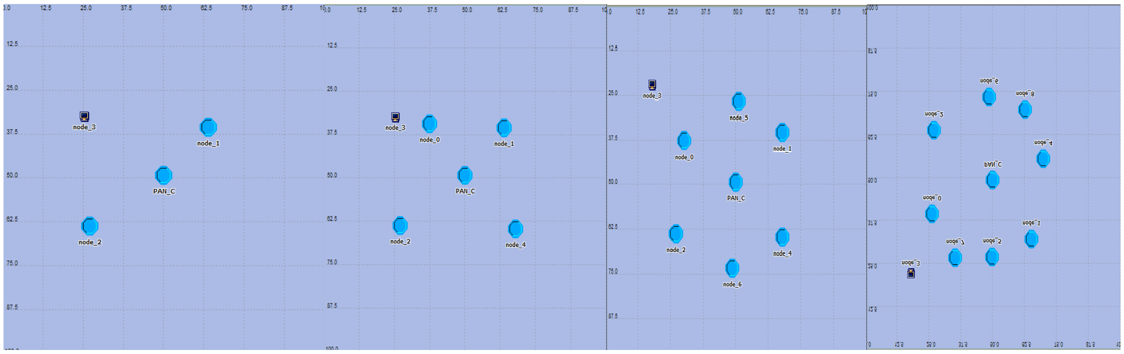


Figure 2. Energy Module selection scenerio for 2 , 4 ,6 and 8 nodes

The network size is 100x100 meter and Beacon enabled mode is implemented and simulation run time is 2200 seconds. Duty cycle is 100%, BO=SO=2.

4.2.2 .Scenario 2: Impact of Energy Consumption on Distance. This setup is designed to check the impact of energy consumption at PAN node, when distance of PAN node increases from its end nodes. Two sub scenarios are built on different network areas, one based on 100*100 meter network size and other 300*300 meters network size. Duty cycle 100% is implemented.

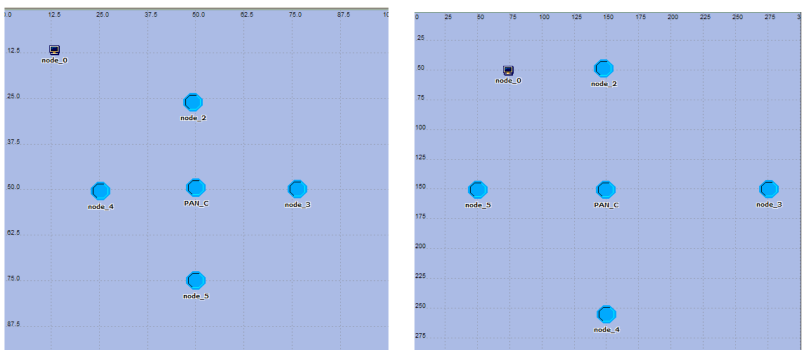


Figure 3. Analyzing Small distance and large distance

4.2.3 Scenario 3 (100% duty cycle). This scenario is designed to see the impact of Energy Consumption on WSN when the value of SO=BO are increased with 100% duty cycle. Fig 4 shows 2 end nodes and 9 possible changing of SO=BO are made at PAN_C node. Possible changes are as follows: SO=BO=1,SO=BO=2,SO=BO=3,SO=BO=4,SO=BO=5,SO=BO=6,SO=BO=7,SO=BO=8andSO=BO=9.AsSO=B=15 mean there is no superframe structure. All these changing made with MSDU=50 bit and TelosB battery.

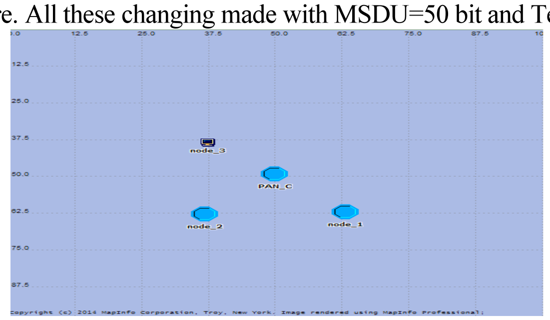


Figure 4. Analysis of sensor node with duty cycle

4.2.4. Scenario 4 (25% duty cycle). Scenario 4 is designed to check the behavior of 50% duty cycle on E2E delay and Throughput with different data arrival rate i.e. 0.2, 0.1, 1.0 and 2.0. For this purpose 7_GTS end nodes are implemented with one PAN. Here, IEEE 802.15.4 protocol setting is SO=BO by increase 1 value in both SO and BO, TelosB battery is used to check the result of Energy consumption. Network size is 100 x100 meter and each node is positioned 25 meter away from its PAN node.

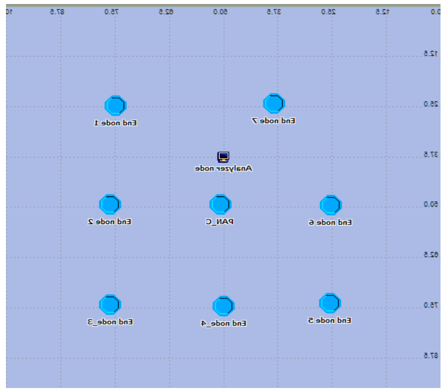


Figure 5. Analysis of SO and BO by using 7 GTS nodes

4.2.5. Scenario 5 (Modulation Scheme comparison). This scenario is designed to check the EE parameters of WSN by changing modulation scheme and check the impact of modulation scheme with energy efficiency. Modulation Schemes (QAM_64, QAM_16 and MSK) and SO=3 & BO=5 which mean sleep mode is enabled during inactive mode to conserve node energy and low density of node within cluster not more than 7. Simulation running time is set to 2200 seconds.

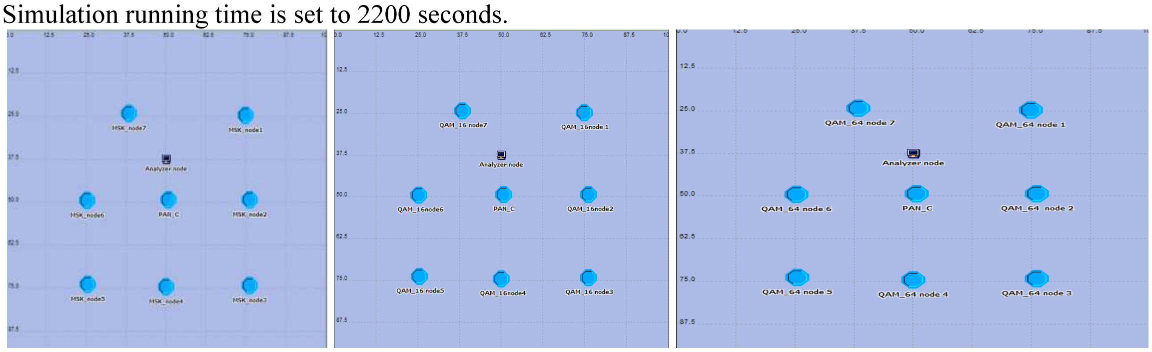


Figure 6. Analysis of different modulation schemes

5. RESULTS AND DISCUSSION

The result of our scenarios that are built on different parameters i.e. Battery module, node density, distance, SO and BO changes etc. in wireless sensor network. Our aims to get Energy Efficient Parameters that can control over Wireless sensor energy. The results of our scenarios are as follows:

5.1.Results of scenario 1:Comparison between MICAZ and TelosB mote to increase Node density. MICAZ consume overall energy 6.70504, 11.7233, 17.64448 and 23.3794 with addition of 2^n nodes in the network. Similarly, TelosB motes consume 5.94877, 10.34169, 15.54281 and 20.57025 global energy. Our simulation results show that TelosB motes consume less energy when the no. of nodes increases in the network. Both motes have same initial energy and same 2AA batteries but Idle and sleep mode made its distinction. TelosB is more efficient than Micaz.

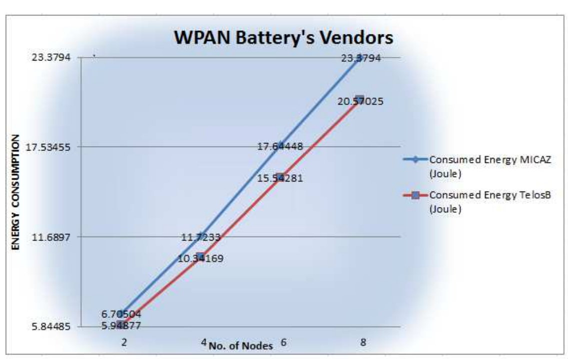


Figure 7. Global Energy Consumption

5.2. Results of scenario 2: Impact of Energy Consumption on Distance. Results reveal that distance of end nodes from PAN-C increase then energy consumption will also increase. Fig 8 show global statistic of network in case of two scenarios with small and large distance. When one end node wants to communicate to PAN-C it has to send data at large distance then huge amount of energy will be required to send and receive packet from large distance. At node 4 large amount of energy is consumed to send traffic to PAN-C in case of large distance.

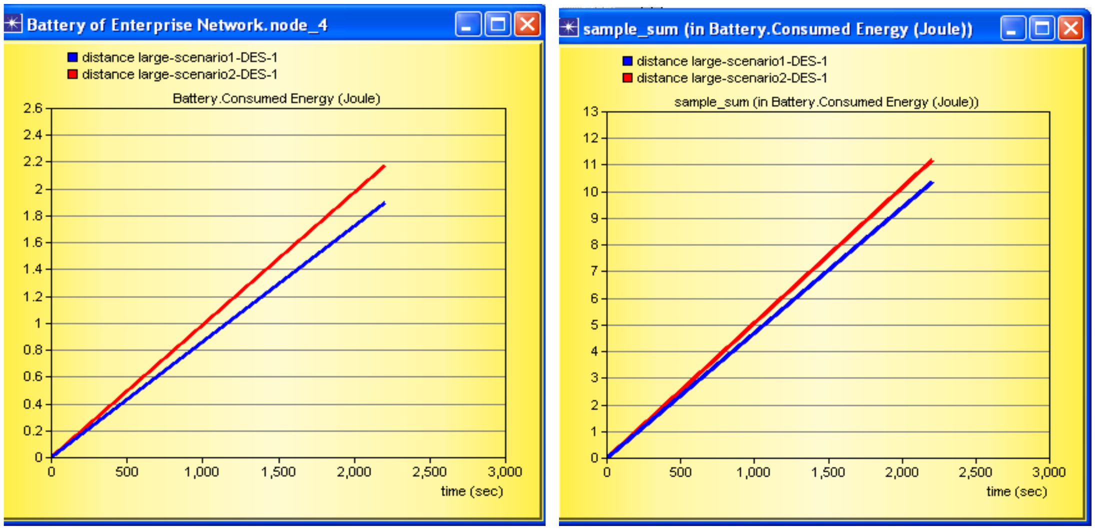


Figure 8. Energy consumption at End node 4 for distance

5.3.Results of Scenario 3 (100% duty cycle). Results Reveals that SO and BO parameters values are not suitable above SO=BO=8 in case of 100% duty cycle, energy consumption at the start SO=BO=1 >SO=BO=2< SO=BO= 3 > SO=BO=4 and so on .when SO=BO=9 then high energy consumption occur which is not suitable for sensor nodes. As BO values increase then BI will also increase, so end nodes will have to wait for Beacon increase and energy consumption of node will also increase.

Table 1. Energy consumption rate with change of SO and BO values

Duty cycle 100%	Energy Consumption	
	Minimum	Maximum
SO=BO=1	0.0	10.98
SO=BO=2	0.0	5.2
SO=BO=3	0.0	10.98
SO=BO=4	0.0	2.2
SO=BO=5	0.0	1.7
SO=BO=6	0.0	1.2
SO=BO=7	0.0	1.13
SO=BO=8	0.0	1.4
SO=BO=9	0.0	37

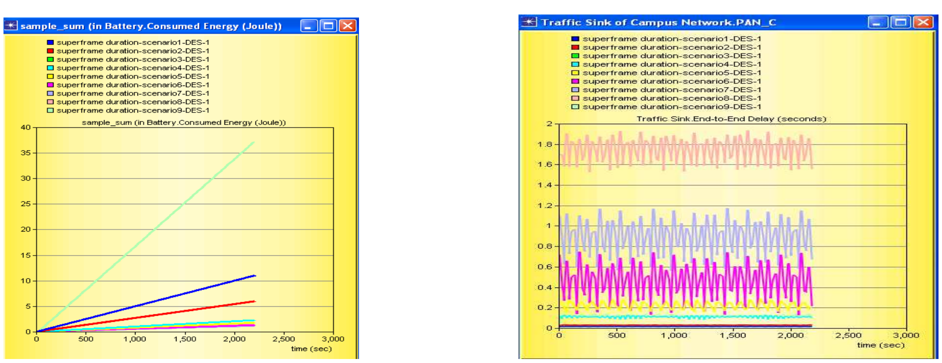


Figure 9. Analysis of Energy Consumption and E2E delay at 100% duty cycle

SO=BO=7 gives less energy consumption, it is best for WSN applications, but E2E delay is high. As we concern to E2E delay SO=BO=1 show less delay but energy consumption is high.

5.3.1 Energy Consumption. Here, we implement 7 end nodes that show high density as compared to 100% duty cycle which is implemented with only two end nodes in our scenario. More energy will be saved if sleep time is increased to 25% duty cycle. 25% duty cycle mean data transfer to the end node during 25% active stage of Superframe, remaining 75% cycle go to sleep mode.

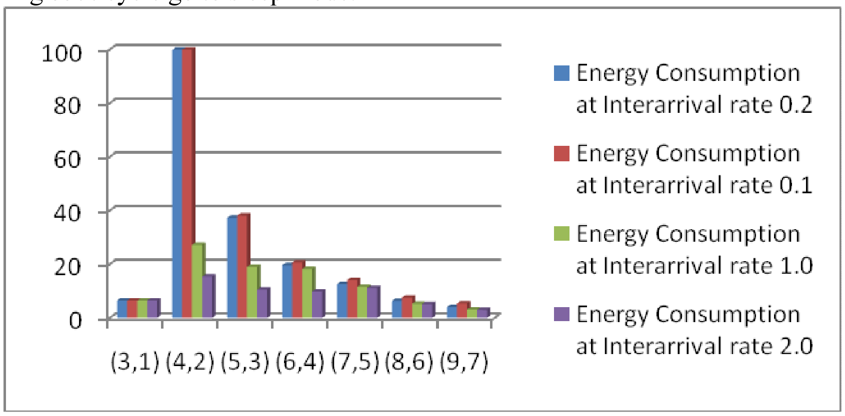


Figure 10. Global energy consumption at different Interarrival rate

Graph reveals that energy consumption decrease with increase in sleep time most of the time Sensor node go into sleep mode.

5.3.2. End to End delay. As we check individual (BO,SO) values result reveals that as Interarrival rates increase E2E delay minimum as compared to other Interarrival rates . Values of (BO, SO) from (4, 2) to (7, 5) reveals that E2E delay minimum at 2.0 as compared to other Interarrival rates. But at (3, 1) E2E delay same for all arrival rates due to minimum BI and at (9, 7) E2E delay high at 2.0 because of long BI node can use CAP for short period of time and sleep mode increases and delay also increases.

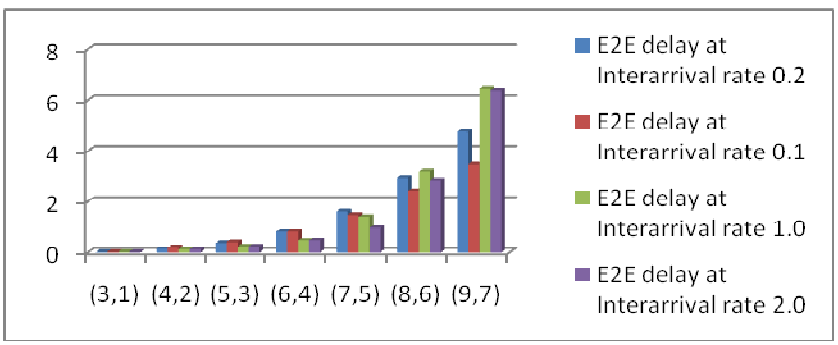
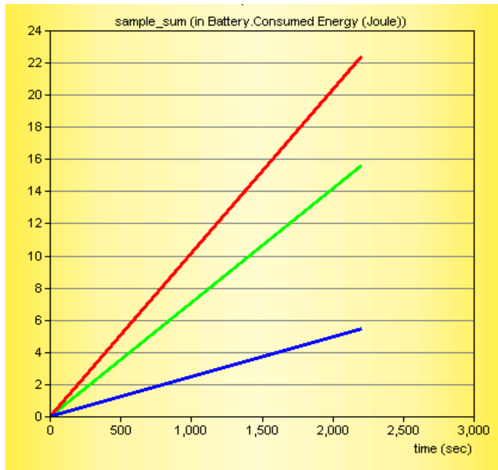


Figure11. E2E delay graph with 25% duty cycle

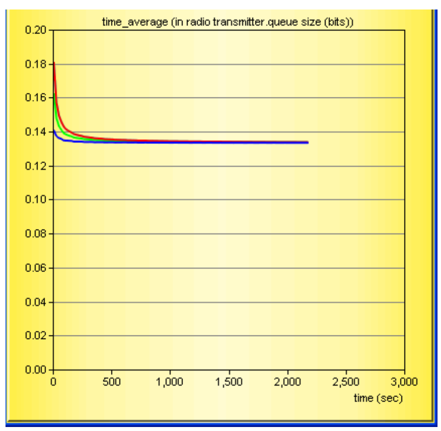
5.4. Result of Scenario 5 (Modulation Scheme comparison). Figure 12 reveal the results of three modulation techniques (QAM_64, QAM_16 and MSK) impact on energy consumption. Energy consumption values are: 5.431, 22.351 and 15.582 for QAM_64, MSK and QAM_16 modulation respectively. It is observed that MSK modulation consumes huge amount of energy over all network. Results reveals that QAM_64 is more efficient modulation technique than others because it is consumed less energy which is basic requirement in WSN.



MSK Modulation Technique
QAM_64 Modulation Technique
QAM_16 Modulation Technique

Figure 12. Results of Energy consumption at different Modulation scheme.

5.4.1. Results of Queue size at Radio Transmitter: Queue size of radio transmitter at PAN_C. Fig 13 reveals the analysis of queue size at PAN node. Results at PAN node are: 0.1410, 0.18019 and 0.1624 for QAM_64, MSK and QAM_16. It is observed that queue size at PAN node is increased at MSK while in case of other modulation techniques it is decreased and it will increase the efficiency of utilization of amplitude and phase shifts and minimize the delay.



QAM_64 Modulation Technique
QAM_16 Modulation Technique
MSK Modulation Technique

Figure 13. Analysis of transmitter Queue size at PAN node

5.4.2. Queue size of radio transmitter at End node: Fig 14 reveals the analysis of queue size at End node. Results at End node are: 0.000012, 0.002414 and 0.000014 for QAM_64, MSK and QAM_16. It is observed that queue size at End node is increased during MSK modulation while in case of other modulation techniques it is decreased and it will increase the efficiency of utilization of amplitude and phase shifts and minimize the delay. MSK is not good choice here.

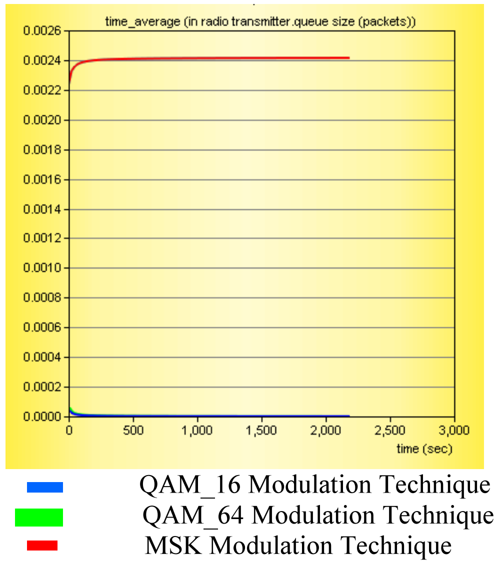


Figure 14 .Analysis of transmitter Queue size at End node

6. CONCLUSION

In this paper, we have studied different parameters of IEEE 802.15.4, to increase the lifetime of wireless sensor network. Many researchers are doing their work at network layer routing protocols to control the energy level of sensor node. Here, our focus to improve the efficiency of IEEE 802.15.4 protocol at MAC layer. In this research, analysis results have shown that low density of end nodes within cluster, small distance from PAN node, suitable sleep mode duty cycle and QAM-64 modulation scheme are more energy efficient milestone parameters that can help to reduce energy consumption in WSN. Derived results conclude that these milestones parameters will also show efficiency in tree topology.

It is recommended to design such Energy Efficient protocols that follows these above mentioned parameters for the purpose of prolong the network lifetime. To design such protocol in which Coordinator node selects appropriate duty cycle according to its node density , small distance of end nodes from PAN node with appropriate modulation scheme. OPNET Modeler 14.5 does not support WSN tree topology with energy module, so it is suggested that to test all these parameters for tree topology on higher version of OPNET Modeler i.e. 16 or 17 and compares result with star topology and these parameters are milestone to conserve sensor nodes energy within WSN.

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