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Optimization of QAM-64 Modulation Technique Within WSN

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ABSTRACT

This paper analysis energy consumption within existing modulation schemes and ponders over efficient methods using OPNET Modeler 14.5 for wireless Sensor Network. We have investigated IEEE 802.15.4 physical layer for modulation schemes namely Quadrature amplitude modulation-64 (QAM-64), Quadrature amplitude modulation-16 (QAM-16), Binary Phase Shift Key (BPSK), Minimum Shift Key (MSK), Frequency Shift Key-2 (FSK-2) and Phase Shift Key (PSK-8) at different duty cycles i-e 25%,50% and 100% in order to figure out that particular modulation scheme , which can show best energy efficiency results for PAN Granted Time Slot (GTS) node. Our Analysis results are based on Bit Error rate (BER), packet loss ratio, Signal to Noise (S\N) ratio, received power and consumed energy parameters at different duty cycles. Derived results have shown efficiency of Quadrature amplitude modulation-64(QAM-64) modulation scheme over Minimum Shift Key (MSK), Quadrature amplitude modulation-16 (QAM-16), Frequency Shift Key-2 (FSK-2) and Phase Shift Key (PSK8) for energy consumption within wireless sensor networks using star topology at GTS nodes.
KEYWORDS*:* Modulation techniques; Personal Area Network node; Granted Time Slot node; duty cycle

1. INTRODUCTION

WSN follows industrial standard IEEE 802.15.4 to communicate with sensor nodes. Basically, Sensor Network consists of two types of sensor nodes. Sensor Node which is deployed to sense the environment is called normal node and the other which is deployed to provide interface between sensor network and external world is called gateway node.

WSN consists of tiny nodes that are able to communicate with each other either in homogeneous or heterogeneous network. Sensor nodes are deployed in surveillance area where human access is inaccessible, so lifetime of sensor nodes must be increased. Some characteristics of WSN are as follows [1]

- WSN has weak connection and communicate with other nodes through wireless media.
- Wireless sensor node supports dynamic and self-organizing topology.
- Sensor node communicates directly with physical environment.
- WSN gives support to multihop or single hop communication.

OPNET Modeler provides by default support of two types of battery (MICAZ & TelosB) with different modes to control and manage battery consumption, detail analysis is discussed [2].

IPPP Hurray Research Group.[3] design WPAN node model that support two node model with by default support of 250kbps data rate , 2.4 GHZ frequency and QPSK modulation . MAC layer give support to IEEE 802.15.4 protocol for both beacon enabled and non-beacon enabled mode. This model gives support during runtime simulation on OPNET Modeler 14.5.

In **[4]**, MAC layer protocol give support two equipped modes: Beacon enabled mode and Non_beacon enabled mode. When PAN_C selects beacon enabled mode, it manage to use super frame structure. The active portion of super frame is divided into 16 equally size time slots called Super frame Duration (SD), during which data transmission occur. Each active portion is divided into two periods. Contention Access period (CAP) and Contention Free period (CFP).The distance between two consecutive beacon slot is called Beacon Interval (BI) and CSMA/CA mechanism is used within Contention Access period (CAP). Peer to peer network which is used slotted CSMA/CA for transmission of data. There is no superframe structure, all nodes are 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. Node is operated in non_beacon enabled mode by using CSMA/CA during Contention Access period (CAP).

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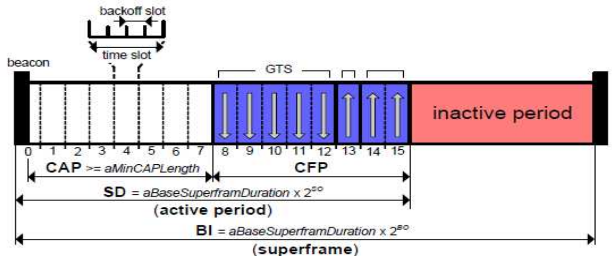

Figure 1. Superframe Model of IEEE 802.15.4 standard [3]

Figure 1. illustrates IEEE 802.15.4 superframe model, which consists of two major parts : Active and inactive period. Active period which prevails communication phase and inactive period shows sleep mode. Active period is further divided into Contention Access period (CAP) and Contention Free period (CFP). To get control over lifetime of sensor nodes, many parameters are under consideration. Digital Modulation technique affects the physical characteristics of wireless sensor node. As we talking about digital modulation technique, it concern with ASK, QAM and BPSk and others. The lifetime of sensor node also depends on the performance of Transreceiver, coding scheme and modulation techniques. So, here we are going to analyses different modulation techniques.

Rest of the paper is described as follow: Section 2 covers Related work that has been done by other researchers, Section 3 covers Methodology: Simulation Environment Description, section 4 covers result and discussion and section 5 represents conclusion and future work.

2. RELATED WORK

Wireless Sensor Networks (WSNs) have become the cynosure for the researchers due to its sensing competence. Wireless sensor nodes are deployed in those areas, where human access is impossible. So, researchers have showed their interest to extend the lifetime of sensor network and preserved its energy through modulation schemes.

Costa et al.[5] presents the energy optimization modulation coding scheme, they made comparison between three modulation techniques MPSK,MQAM and MFSK. Two energy consumption limitations are discussed in this modulation comparison. One situation deal with energy limitation of transmitter and receiver and other situation deal with energy limitation at receiver side only. Three modulation techniques performance are compared with node distance, results conclude that MPSK and MQAM show same results for near and far distance of node from its PAN but MFSK show poor performance for short distance. **Shrotriya.A and Nitnawwre.D [6]** analyzes different modulation techniques on different existing Wireless Sensor Network models MICAZ and MICA motes. It has been found that MICAZ is more energy efficient than MICA mote .Two node models (MICA and MICAZ mote) are compared for idle mode; receive mode and transmit mode with different modulation techniques Ask, BPSK and O-QPSK. ASK modulation technique consume less energy as compared to other modulation scheme for both models. Similarly, energy consumption in receive mode is minimum in case of O-QPSK for both models as compared to others modulation. In ideal mode, most efficient modulation technique is ASK which is followed by O-QPSK in case of both energy models. **Soltan. M et al. [7]** presents location aware choice of modulation schemes for sensors, it shows that how modulation selection can balance spatial distribution of energy consumption over coverage area in Wireless Sensor Network (WSN). Three modulation techniques are compared in three different ways. First scheme concern with homogeneous modulation DQPSK, second scheme homogeneous modulation with location aware modulation scaling (DQPSK) and third one relate with location aware heterogeneous modulation with DQPSK,DBPSK and BPSK are compared with each other and result show that heterogeneous modulation has long lifetime as compared to other two scheme. **Dawood ,M.S et al. [8]** survey different performance of modulation and analysis of its coding technique and apply it on different condition of channels to improve the lifetime of wireless sensor network.

Home automation scenario is designed on Qualnet using optimize modulation technique among ASK, BPSK and OQPSK with less consumption of energy. Results reveal that OQPSK is energy efficient modulation scheme as compared to ASK, even ASK has less energy consumption but ASK modulation has probability of high Bit Error Rate (BER). As we concern with less BER, QAM is suitable for less BER and low noise interface.[9]

Bamber and Sharma [10] analyze the performance of 802.15.4 WSN with different modulation techniques i.e.(Sharma, Sachan, & Imam, 2012) QAM-64, MSK and BPSK. It is concluded that if queue size of PAN node under consideration then QAM-64 modulation technique is preferred. If queue size is demanded at end node then BPSK modulation technique is recommended.

3. METHODOLOGY: SIMULATION ENVIRONMENT DESCRIPTION.

We have used OPNET Modeler 14.5 in our research work, which support IEEE 802.15.4 2003 specified model. The OPNET Modeler is used due to its accuracy and ease use of graphical Environment.

OPNET Modeler 14.5 gives support to Wireless Personal Area Network (WPAN) node v2.0 which can easily add within OPNET Modeler 14.5. It gives support to star topology only. WPAN model further divided into two nodes: one is sensor node and second is Analyzer node. Star topology is built by taking one Personal Area Network (PAN) Coordinator node which lie at the center of the end nodes and all the end nodes send and receive traffic from its central device i.e. Personal area Network (PAN) Coordinator node. IEEE 802.15.4 model consists of 4 major functional parts [3]

1. **Physical layer.** It consists of radio transmitter **(tx)** and receiver **(rx)** module, which is operated at the speed of 2.4 GHZ frequency band with data rate up to 250 kbps. By default it gives support to QPSK modulation technique.
2. **MAC Layer.** MAC layer give support to slotted CSMA\CA and GTS mechanism. The GTS traffic incoming from the application layer and stored into MAC bounded capacity buffer and send into the network when GTS is active. In case of non-critical data traffic, it is stored into unbounded buffer and transferred traffic into the network by slotted CSMA\CA when CAP is active. This layer also gives support to generate beacon frame and synchronization among nodes when node acts as PAN Coordinator.
3. **Application Layer.** Application layer is responsible to generate two types of traffic i.e. traffic source and GTS traffic source and other is traffic sink. Traffic source generate UNACK and ACK data frames which is transmitted during CAP. The GTS traffic source can also generate ACK and UNACK data frames. The traffic sink module accept frame from lower layer and perform some useful statistics.
4. **Battery Module.** This module calculated the level of energy consuming and remaining energy after run simulation. By default it gives support to Micaz battery module.

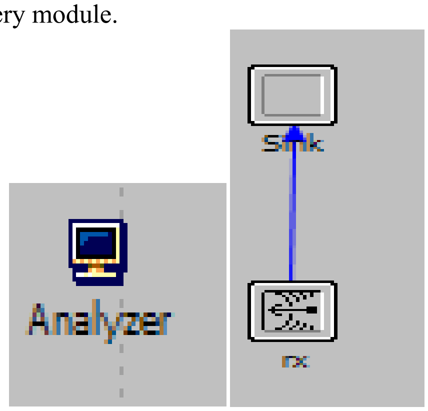

Figure 2. Analyzer node and its node model

Analyzer node collects all the global statistics data from the network. It also provides support to attach with another network. WPAN v2.0 introduces two model analyzer and end node, End node model consists of traffic sink, traffic source, GTS traffic source, WPAN-Mac and battery module.

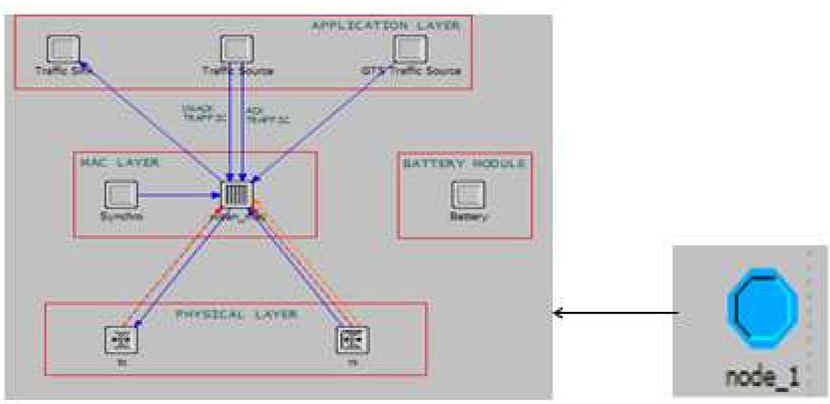

Figure 3. WPAN v2.0 Node Model

3.1 Modulation technique and related parameters. Different modulation scheme is supported by WPAN node which is designed by IPP HURRAY i.e. BPSK with 20 or 40 Kbit rates of data parameters, ASK with 250 Kbit rate, O-QPSK with 100 bit rate and O_QPSK supported 250 Kbit rates of data parameters. [3] Digital modulation techniques are built on keying: FSK, PSK, ASK and QAM. PSK consists of finite number of phases, FSK consists of finite number of frequencies, ASK consists of Amplitude and QAM is combination of at least two phases and amplitudes. All of these phases, frequencies and amplitudes are allocated a pattern of unique binary bits. This binary bit contains the symbols which represent frequency, phase or amplitude. Representation: $M= 2^N$ Where, Alphabet M consists of 2^N alternative symbols. It represent each symbol contains message of N bits. [11]
In our research, we analyze different modulation techniques to check the impact of modulation on energy consumption of sensor nodes. Here, we analyze six modulation techniques QAM-64 which is using M=64 symbols, BPSK consists of M= 2 symbols, PSK8 using M=8 symbols, FSK 8 using M=8 symbols QAM-16 using M= 16 symbols and MSK.
A. Radio Receiver Signal to noise (S\N) ratio. Signal to noise ratio mean to measure the level of signal with amount of noise, it is measured in dB, Higher the value of S\N ratio higher will be specification signal result and offer less noise distortion in signal as compared to small value [12].
B. Received power (W). This statistic represents the average power of a packet arriving at a receiver channel. RSSI is used to measure the power of received radio signal in wireless network. Received signal strength establishes a link between wireless devices; higher received power mean stronger will be the connection between devices. [13]
C. Bit Error Rate (BER). This statistic represents bit error rate among the bits of the packet, which is completely arrival at the receiver channel. BER mean no. of bit errors in the No. of received bits of packet over a channel that is changed due to distortion, noise or interference [14]. We choose this parameter to check which modulation scheme provide less Bit Error Rate (BER) and fit for Personal Area Network (PAN) node.
D. Packet loss ratio. This statistics represent the acceptance or rejection of a packet at receiver node respectively. Packet loss occurs due to signal degradation, Bit Error RATE (BER) in packet, channel congestion and many other factors. This metric cause not only poor receive or transmission performance of the node but also provide high consumption of energy. To calculate the packet loss ratio value by using formula [15].
No. of Packet lost / No. of packet received (At receiver side)
No. of Packet lost / No. of packet sent (At sender side)
E. Consumed Energy. This parametric metric in wireless sensor network is under consideration of researchers. To get control over energy consumption, sensor nodes lifetime can be enhanced. We have analyzed this metric over different modulation techniques by using star topology, to check which modulation provides efficient support to sensor.
3.2 OPNET SCENARIO. Scenarios are designed with suitable parameters to check the efficiency of Wireless Sensor Network (WSN). These parameters are as follows: low distance, heterogeneous network on the basis initial energy to prevent PAN node to drain out its energy quickly, Modulation Schemes (QAM_64, QAM_16, MSK, BPSK, PSK8 and FSK2) and different duty cycle which show sleep mode is enabled or disabled during inactive or active mode to conserve node energy. These EE parameters are implemented in our WSN model. Running time of simulation is 2200seconds and the Network size is 100 x 100 meter. Five sub scenarios are designed to compare the result of EE model scenarios with other Modulation scheme to check the best Energy Efficient cluster model with suitable modulation scheme.

Table 1. Parameters for Scenarios

Simulation Parameters	Corresponding values
Energy Model	TelosB Mote
Radio Type	IEEE 802.15.4
Transmission mode	-5dBm
Initial energy of the PAN's battery	2AA batteries,2300mAh
Initial energy of End nodes	2AA batteries,1600mAh
Modulation scheme	QAM_64, QAM_16, MSK, BPSK, PSK8 and FSK2
No. of devices	1 PAN node and 7 End nodes
MAC layer	Beacon mode Active
Duty cycle	100% , 50% and 25%

Table 1. Shows basic parameters that are used all over scenarios, TelosB mote is used which is more energy efficient. Transmission mode set to -5dBm that cover larger transmission area. In experimental models, duty cycles are induced. 100% mean there is no sleep mode, 50% represents 50% active mode and 50% sleep mode of PAN node and 25% show 25% active mode and 75% sleep mode. Scenarios are based on 8 nodes, one is coordinator node and others are end nodes, all these nodes enabled in beacon phase.
Figure 4. shows six different scenarios: QAM_64, QAM_16, MSK, BPSK, PSK8 and FSK2, which contain Analyzer node, one PAN node and 7 end node devices. PAN node act as Full Functional device and 7 end nodes act as GTS devices.

Here, we have included GTS node to see the impact of energy consumption with different duty cycle on modulation schemes. In our scenario, PAN node in receive mode and remaining end devices are in transmit mode. GTS node's data approaching from the application layer to a buffer, where it is stored with a certain buffer capacity and transmitted to the network when GTS is active.

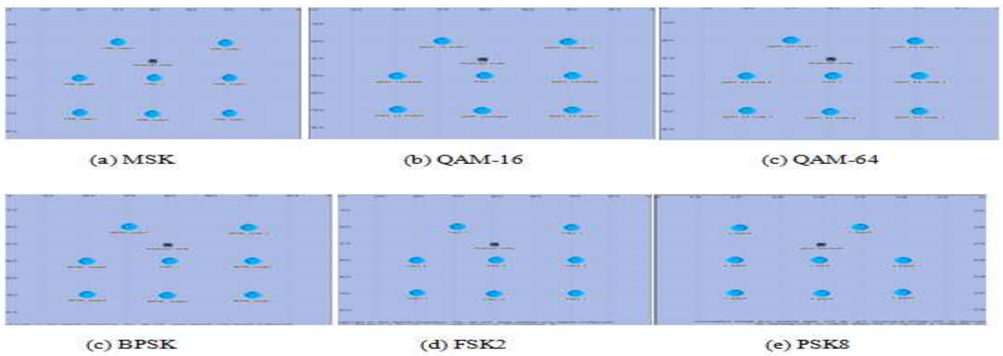

Figure 4. Wireless Sensor Network Modulation Scenarios

Scenarios are checked with different duty cycles for different modulation schemes, our aim to check which modulation scheme show less energy consumption and efficient transfer of traffic within network. Three duty cycles parameters are set as: 100 % duty cycle has Beacon Order (BO) =5 and Super Frame Order (SO) =5, 50% duty cycle is set as Beacon Order Beacon Order (BO)=5 and Super Frame Order (SO) = 4 and in case of 25% duty cycle set to Beacon Order (BO) = 5 and Super Frame Order (SO) = 3.

4. RESULT & DISCUSSION

Results of our scenarios that are built on modulation scheme with different duty cycle in wireless sensor network are as follows:

4.1 Results of Bit Error Rate at Different Modulation Scheme. In **Figure 5**: we have checked BER result in case of different modulation scheme, which one modulation has less error rate at PAN node .our aim to conserve PAN node energy which act as management node for other end nodes.

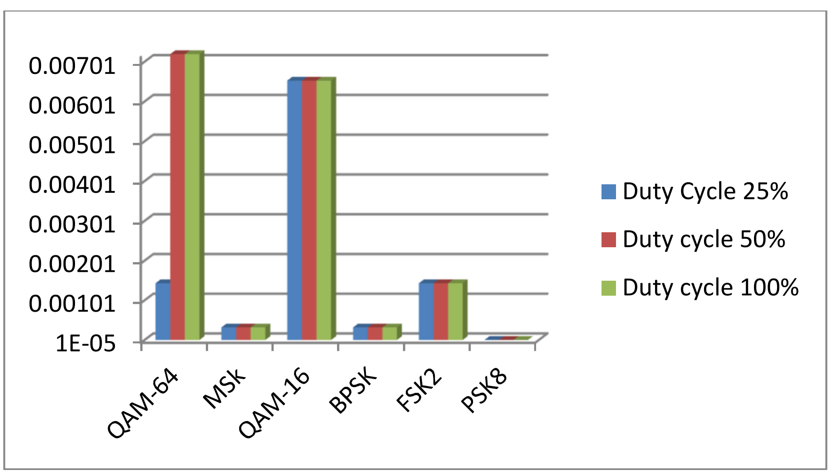

Figure 5. Result of Bit Error Rate (BER) at PAN node

PSK8 shows less bit error rate as compare to other modulation techniques, QAM-64 shows best result at 25% duty cycle but at 50% and 100% duty cycle BER is high.

4.2 Results of Packet Loss Ratio at Different Modulation Scheme. Results reveals that QAM-64 modulation scheme shows high packet loss ratio at 50% and 100% duty cycle but it is less in case of PSK8 modulation scheme at same duty cycle. QAM-64 again shows best result at 25% duty cycle.

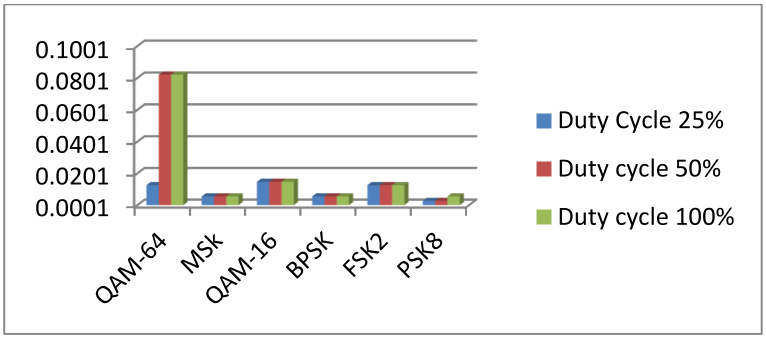

Figure 6. Result of Packet loss ratio at PAN node

4.3 Results of Received Power at Different Modulation Scheme. Greater the received power of packet at PAN node receiver channel reveals that stronger will be communication link between sensor end devices. Here, results reveal that QAM-64 show stronger communication link at 50% and 100% duty cycle as compared to other modulation scheme.

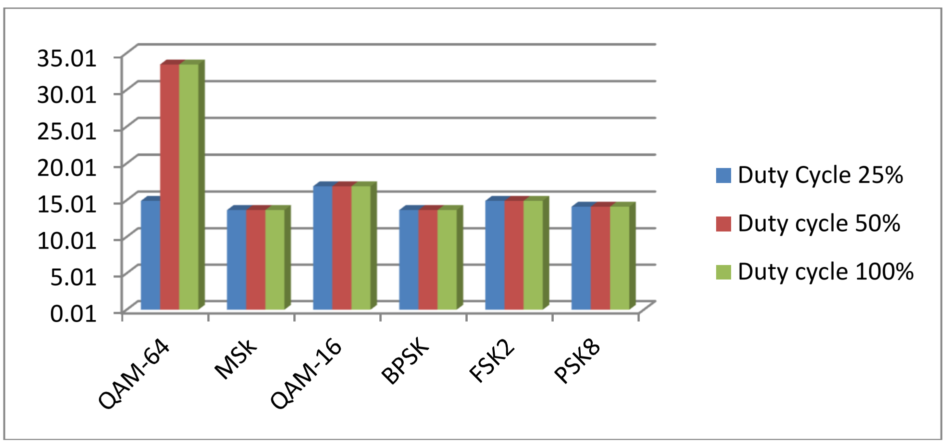

Figure 7. Result of Received power at PAN node

4.4 Results of S\N at Different Modulation Scheme. Signal to noise ratio represent the strength of the signal with amount of noise, higher the S\N ratio mean high the strength of the signal. **Figure 7:** reveals that QAM-64 shows high S\N ratio at 50% and 100% duty cycle, High the signal strength, less energy consumption will be occurred. While, other modulation scheme at different duty cycle show the same results that are not preferable as compared to QAM-64 values.

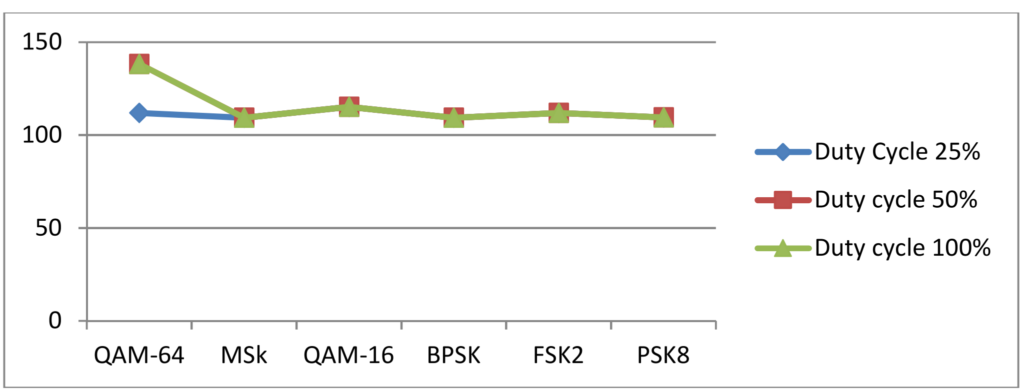

Figure 8. Result of Signal to noise ratio at PAN node

4.5 Results of Consumed Energy at Different Modulation Scheme. Our aims to prevent PAN node Energy to drain out quickly, Personal area Network (PAN) node acts as a Cluster head node which receive traffic from end node and manage it. Here, we have worked on physical layer to get control over energy consumption through modulation scheme at different duty cycle. In **Figure 8**: Results reveal that QAM-64 show best energy efficient result at 50% and 100% duty cycle as compared to others scheme. Quadrature Amplitude Modulation -16 (QAM-16) which is variant of QAM-64 also shows energy efficient values but not more than QAM-64.

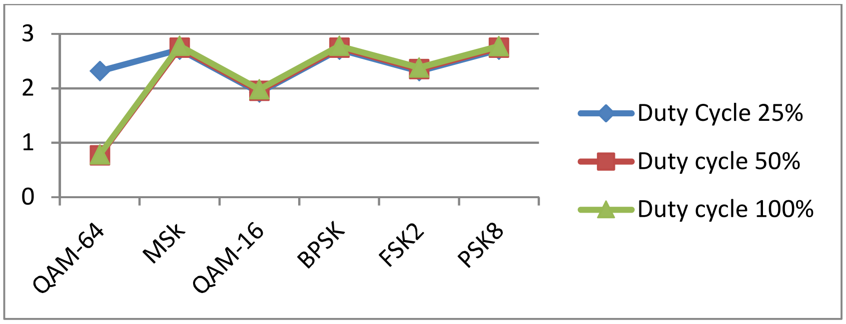

Figure 8. Result of consumed energy at PAN node

5. CONCLUSION AND FUTURE WORK

All simulation results are carried out on OPNET Modeler 14.5 by using TelosB mote which show energy efficient result. We have analyzed six modulation techniques namely QAM_64, QAM_16, MSK, BPSK, FSK2 and PSK8, on GTS node. Results reveal that QAM_64 is best choice for PAN node due to its high signal to Noise (S\N) ratio, high received power, less energy consumption at 50% and 100% duty cycle. BER and packet loss ratio is low in case of PSK8 and BPSK but it is high in QAM-64.

In addition QAM-64 has shown less BER and Packet loss ratio at 25% duty cycle which has resulted in satisfactory performance.

Future work is required to analyze these modulation techniques for tree topology by running clustering routing protocol to check the result of QAM-64 modulation techniques.

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