PERFORMANCE TRADE OFF WITH MODULATION IN 802.15.4 WPAN FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

The main objective of this paper is to investigate the performance trade off with MSK, BPSK and QAM_64 modulation techniques. Investigations have been reported to compare the performance and tradeoffs of MSK, BPSK and QAM_64 modulation schemes. Here modulation schemes have been identified which gives significant performance improvement over the other based on energy consumption and power reception at the WPAN devices. The results have been presented Pan Coordinator (FFD) and GTS & Non GTS End Device (RFD) of Wireless Sensor Network (WSN). It has been concluded that the energy consumption is minimum if QAM_64 modulation scheme is used while it is maximum in rest of the cases for MSK and moderate for BPSK. Further, it has been shown that the radio power received is maximum for all kind of WPAN devices with MSK. On the other hand there is variation of received power in case of BPSK and QAM_64. Overall it has been revealed that there is trade off for using various modulation schemes.

KEYWORDS

Wireless Sensor Networks, WPAN, BPSK, MSK, QAM_64.

1. INTRODUCTION

The rapid growth experienced by the wireless sensor communication sector in the recent years is conspicuous. Wireless sensor network kind of technologies have followed suit owing to the adoption of services where data is shared and exchanged with requirements for such technologies driven by the need for larger data throughput, lower BER, higher SNR, minimum end to end delay etc. This, however, has left a number of high-rate, low power sensing and monitoring applications including those in the industrial, public safety, residential, vehicular and related sectors underserved by proliferation of wireless sensor technology that is expensive, protocol rich and power hungry.

The choice of the digital modulation scheme will significantly affect the characteristics, performance and resulting physical realization of wireless sensor communication system. There is no universal 'best' choice of the modulation scheme, but depending on the physical characteristics of the channel, parametric optimizations and required level of performance some will prove better fit than the others. The 802.15.4 is an IEEE standard, targeting a set of applications that require simple wireless connectivity, high throughput, very low power consumption and lower module cost. Its objective is to provide low complexity, cost and power for wireless sensor connectivity among inexpensive, fixed, portable and moving devices.

A lot of work on 802.15.4 has been reported by the various researchers [1-18]. Some have investigated various performance issues like: Delay; Throughput evaluation of GTS mechanism [1]. While some have investigated distributed active control technique for IEEE 802.15.4 wireless sensor network [4]. Few others have worked on power efficient radio configuration in

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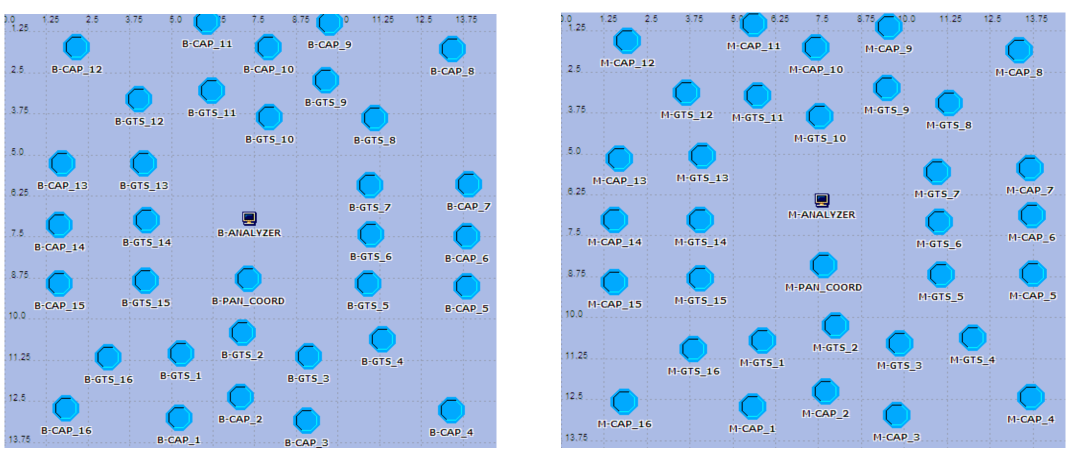
fixed broadband wireless networks [5]. Researchers have also studied adaptive algorithm for mapping channel quality information to modulation and coding schemes [8]. Researchers have also tried to study performance tradeoff with adaptive frame length and modulation in wireless network [10]. Some researchers have studied suboptimum receivers for DS-CDMA with BPSK modulation [13]. Researchers have also investigated voice and data transmission technique using adaptive modulation [14]. Few have tried to study efficient non-coherent demodulation scheme for IEEE 802.15.4 LR – WPAN systems [18]. But none of the researchers have so far compared the modulation schemes in 802.15.4 for energy consumption and power reception for WPAN devices based on modulation formats MSK, BPSK and QAM_64. This paper proposes the comparison of different modulation schemes (MSK, BPSK & QAM_64) to determine the suitability of the scheme according to the type of the device Fully Functional Device / Reduced Functional Device (FFD / RFD). Here the performance metrics like: energy consumption and power reception at the radio receiver have been considered for their comparative study.

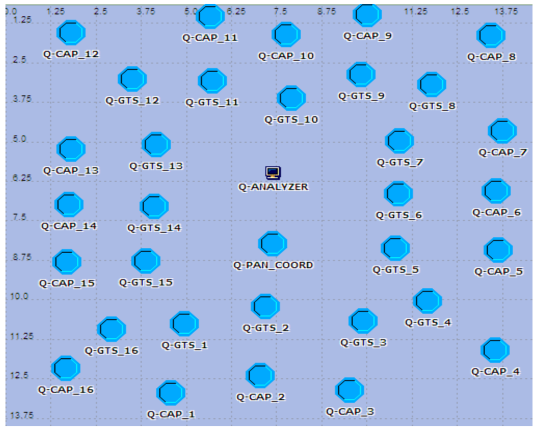
The paper is outlined as: Section [I] consists of the Abstract. Section [II] gives the brief introduction of the model and simulation. Section [III] constitutes the system description which contains node model, process model, and parametric tables of the model. Section [IV] shows the results and discussions derived from the experiments carried out on 802.15.4 for different modulation schemes. Finally Section [V] concludes the paper.

2. SYSTEM DESCRIPTION

The simulation model implements physical and medium access layers defined in IEEE 802.15.4 standard. The OPNET® Modeler 14.5 is used for developing 802.15.4 wireless sensor network.



(a) (b)

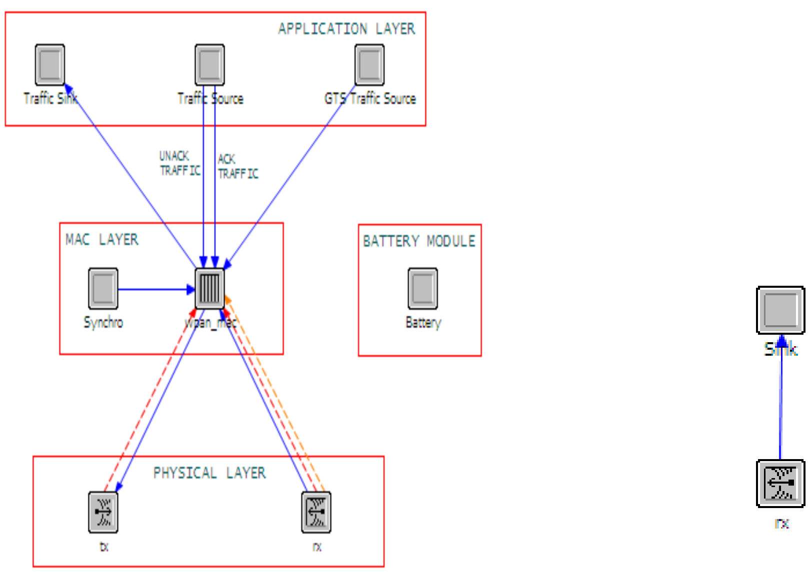


(c)

Figure 1. Network Scenarios (a) BPSK (b) MSK (c) Quadrature (QAM_64)

Figure 1 shows three different Scenarios: BPSK, MSK and QAM_64. BPSK Scenario as shown in Figure 1(a) contains one PAN Coordinator, one analyzer and thirty two end devices out of which sixteen are Guaranteed Time Slots (GTS) enabled and rest are non GTS devices. PAN Coordinator is a fully functional device which manages whole functioning of the network. Analyzer is a routing device which routes the data between PAN coordinator and the End Devices. End Devices are the fixed stations that communicate with the PAN Coordinator in Peer to Peer mode, support GTS and non GTS traffic respectively. Similar Scenarios have been created for MSK and QAM_64 as shown in figure 1 (b & c).

Figure 2 shows the node models for three types of WPAN devices used for modeling 802.15.4 scenarios. PAN Coordinator, GTS and Non GTS end device have the same node model as shown in Figure 2 (a) while the node model for analyzer is depicted in Figure 2 (b).

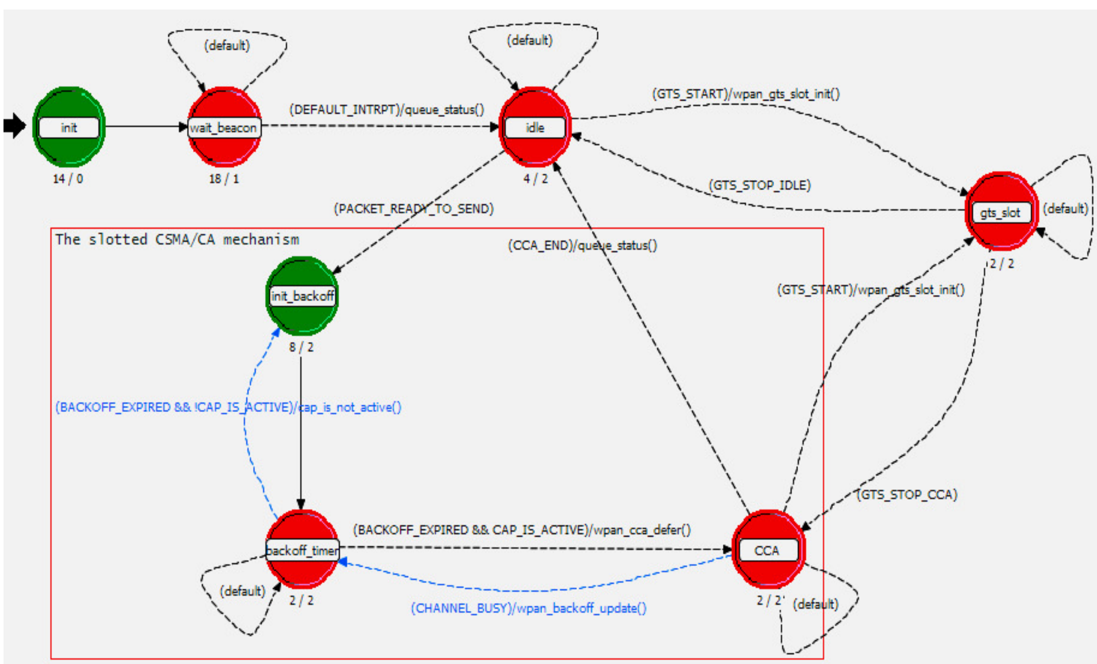


(a) (b)

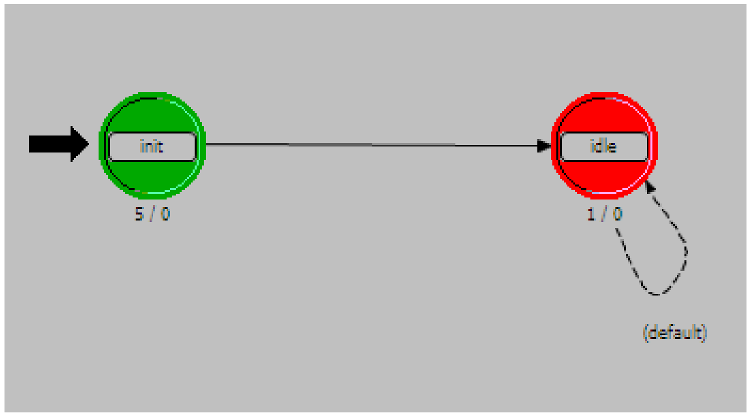
Figure 2. Node Model (a) PAN Coordinator, GTS and Non GTS end device (b) Analyzer

As it has been observed from the Figure 2 (a), a node model for PAN Coordinator, GTS end device and Non GTS end device has three layers: physical, MAC and application layers. Physical layer consists of a transmitter and a receiver compliant to the IEEE 802.15.4 specification, operating at 2.4 GHz frequency band and data rate equal to 250 kbps. MAC layer implements slotted CSMA/CA and GTS mechanisms. The GTS data traffic coming from the application layer is stored in a buffer with a specified capacity and dispatched to the network when the corresponding GTS is active. The non time-critical data frames are stored in an unbounded buffer and based on slotted CSMA/CA algorithm are transmitted to the network during the active Contention Access Period (CAP). This layer is also responsible for the generation of beacon frames and synchronizing the network when a given node acts as a PAN Coordinator. Finally is the topmost application layer which is responsible for generation and reception of traffic consists of two data traffic generators (i.e. Traffic Source and GTS Traffic Source) and one traffic sink. The traffic source generates acknowledged and unacknowledged data frames transmitted during CAP. GTS traffic source can produce acknowledged and unacknowledged time-critical data frames using GTS mechanism. The traffic sink module receives frames forwarded from lower layers. Figure 2 (b) shows the node model for the analyzer which consists of sink and a radio receiver.

Corresponding process models for PAN Coordinator, GTS end device, Non GTS end device and analyzer that deals with each and every operation on the data are depicted in Figure 3:



(a)



(b)

Figure 3. Process model (a) PAN Coordinator, GTS and Non GTS end device (b) Analyzer

Figure 3 (a) shows the process model for the PAN Coordinator, GTS and Non GTS end device. It consists of the various states: Init whose function is to initialize MAC and GTS scheduling; Wait_beacon which is responsible for synchronizing the traffic of the node with rest of the WPAN in order to minimize the collisions; Idle which is responsible for introducing delays in order to make the maximum use of the resources; gts_slot which is responsible for generation, reception and management of GTS traffic; Backoff_timer used for sensing the medium and transfer of data, CCA - for interrupt processing. Similarly figure 3 (b) shows the process model for analyzer which consists of init and idle states. Basically the process model explains how the data is sent from the generating node to the PAN Coordinator, taking into consideration the availability of PAN Coordinator as it has to communicate with the other similar nodes.

Here three different Scenarios have been created with three different modulation formats like: BPSK, MSK and QAM_64. Following parameters as shown in the table 1 have been set for the said scenarios:

Table 1. Parametric values for PAN Coordinator, GTS and Non GTS End Device in BPSK, MSK and QAM_64 Scenarios

Parameter \ Scenario	**PAN Coordinator**			**GTS Enabled End Device**			**Non GTS End Device**		
Modulation	BPSK	MSK	QAM_64	BPSK	MSK	QAM_64	BPSK	MSK	QAM_64
Acknowledged Traffic Source									
Destination MAC Address	Broadcast			PAN Coordinator					
MSDU Interarrival Time (sec)	Exponential(1.0)			Constant (1.0)			Exponential(1.0)		
MSDU Size (bits)	Exponential(912)			Constant (0.0)			Exponential(912)		
Start Time (sec)	0.0			Infinity			1.0		
Stop Time (sec)	Infinity								
Unacknowledged Traffic Source									
MSDU Interarrival Time (sec)	Exponential(1.0)			Constant (1.0)			Exponential(1.0)		
MSDU Size (bits)	Exponential(912)			Constant (0.0)			Exponential(912)		

Start Time (sec)	0.1	Infinity	1.1
Stop Time (sec)	Infinity		
CSMA/CA Parameters			
Maximum Back-off Number	4		
Minimum Back-off Exponent	3		
IEEE 802.15.4			
Device Mode	PAN coordinator	End Device	
MAC Address	Auto Assigned		
WPAN Settings			
Beacon Order	14	7	
Superframe Order	6		
PAN ID	0		
Logging			
Enable Logging	Enabled		
GTS Settings			
GTS Permit	Enabled		
Start Time	0.0	0.1	Infinity
Stop Time	Infinity		
Length (slots)	1		0
Direction	Receive	Transmit	
Buffer Capacity (bits)	10,000	1000	
GTS Traffic Parameters			
MSDU Interarrival Time (sec)	Exponential(1.0)		Constant (1.0)
MSDU Size (bits)	Exponential(912)		Constant (0.0)
Acknowledgement	Enabled		Disabled

3. RESULTS AND DISCUSSION

Simulation has been carried out for the three different scenarios of WPAN: Quadrature (QAM_64), MSK and BPSK. In this section results for energy consumption by the battery and power reception of the radio receiver have been presented and discussed for different types of devices in wireless sensor networks like: FFD – those devices that controls the network and manages the routing tables, RFD – those devices which can communicate to the FFD but not to the other RFD's with different modulation schemes.

3.1. Energy Consumed

3.1.1. Fully Functional Device – PAN Coordinator

Figure 4 below indicates that the energy consumed by the PAN Coordinator is 30.7947, 29.1781 and 26.8718 joules for the MSK, BPSK and QAM_64 respectively. It is observed that battery energy consumption is minimum in case of QAM_64 due to its non-linear modulation scheme having a constant envelope which makes the use of power efficient non-linear amplifiers [19, 20]. While it has been observed that battery energy consumption is maximum in case of MSK as it has to convert the modulating pulse to symmetrical or '0' otherwise, also it has to have a constant envelope in order to be spectrally efficient [21, 22]. From the figure 4 it is concluded that for FFD PAN Coordinator the energy consumption is minimum in case of QAM_64 on the other hand it is highest in case of MSK therefore it is proposed to use QAM_64 for FFD.

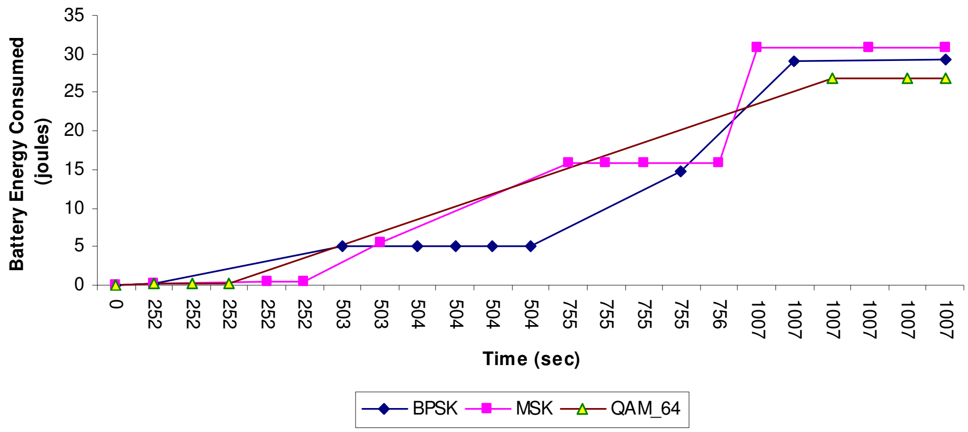


Figure 4. Battery Energy Consumed by the PAN Coordinator

3.1.2. Reduced Functional Device – GTS End Device

Figure 5 shows energy consumed by the GTS End Device. It has been observed that it is 24.2138, 23.8187 and 22.4551 joules for MSK, BPSK and QAM_64 respectively. It has been experimentally proved that energy consumed is minimum in case of QAM_64 while it is maximum in case of MSK. From the above results it is concluded that if battery energy consumed is to be taken into consideration at the RFD that is GTS enabled in wireless sensor networks then QAM_64 is a better option.

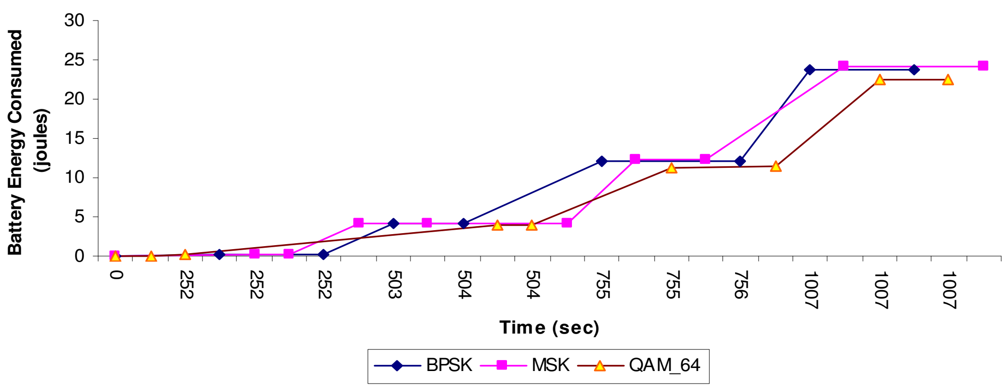


Figure 5. Battery Energy Consumed by the GTS End Device

3.1.3. Reduced Functional Device – Non GTS End Device

Figure 6 reveals that battery energy consumed by the Non GTS End Device is 26.7983, 26.0876 and 25.0293 joules respectively for MSK, BPSK and QAM_64. It is observed that energy consumed is minimum in case of QAM_64, on the other hand it maximum in case of MSK.

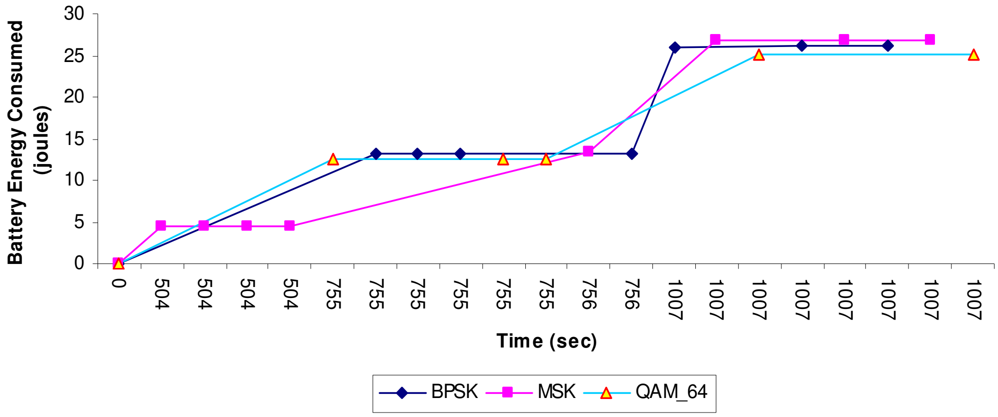


Figure 6. Battery Energy Consumed by the Non GTS End Device

From the results obtained in cases I to III for FFD, GTS and Non GTS RFD, it has been concluded that the energy consumption is minimum if QAM_64 modulation scheme is used while it is maximum in rest of the cases for MSK. Therefore it is recommended that QAM_64 may be preferred over rest of the modulation schemes for 802.15.4 WPAN wireless sensor networks.

3.2. Radio Receiver Power

3.2.1. Fully Functional Device – PAN Coordinator

Figure 7 below shows the power received by the radio receiver at the PAN Coordinator is 0.0149, 0.0143 and 0.0118 watts for MSK, BPSK and QAM_64 respectively. Here it is observed that power received is maximum in case of MSK while it is minimum for QAM_64. The results establish that the power received at the radio receiver of a FFD is maximum for MSK in comparison to BPSK and QAM_64. Hence it is recommended to prefer MSK modulation scheme over rest of the modulation formats.

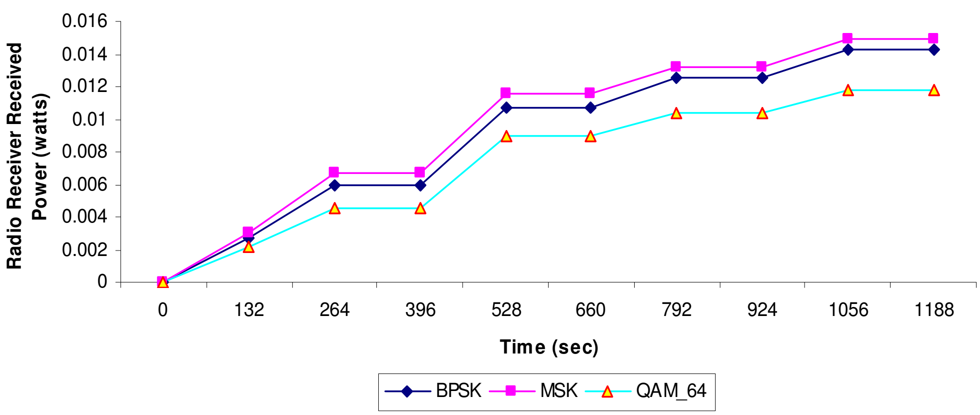


Figure 7. Radio Receiver Received Power at the PAN Coordinator

3.2.2. Reduced Functional Device – GTS End Device

Figure 8 indicates that the power received at GTS End Device is 0.0016, 0.0003 and 0.0002 watts for MSK, QAM_64 and BPSK respectively. It is observed that power received is maximum in case of MSK while it is minimum in case of BPSK because it receives power according to $A^2/4$ while the other two modulation schemes receives power according to the $A^2/2$ where A is amplitude [19].

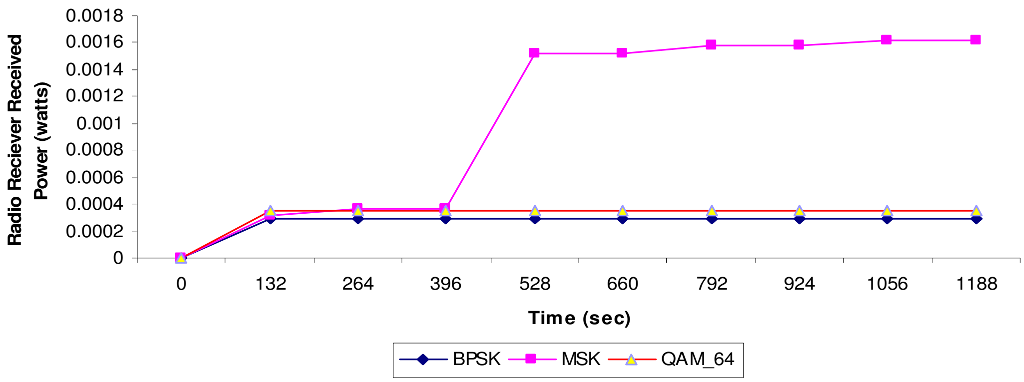


Figure 8. Radio Receiver Received Power at the GTS End Device

3.2.3. Reduced Functional Device – Non GTS End Device

Figure 9 indicates the power received at the Non GTS End Device. It has been observed that it is 0.0013, 0.0012 and 0.0010 watts for MSK, QAM_64 and BPSK respectively. It has been investigated that power received is maximum in case of MSK while it is minimum in case of BPSK.

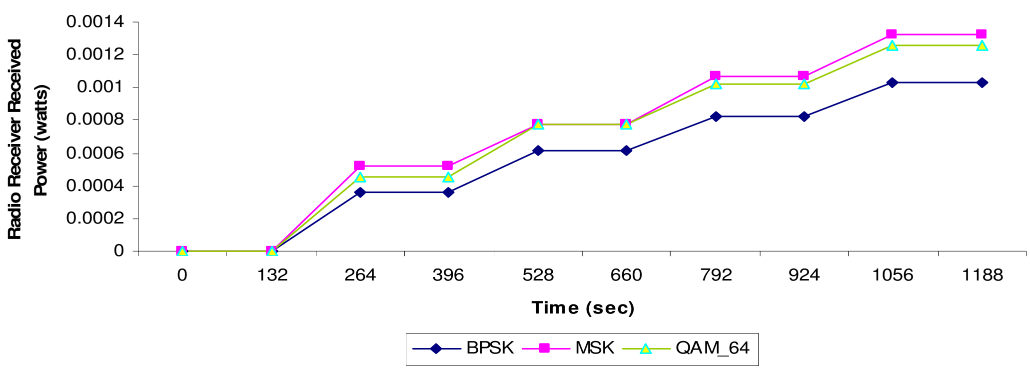


Figure 9. Radio Receiver Received Power at the Non GTS End Device

From the results obtained in cases I to III for FFD, GTS and Non GTS RFD respectively, it has been concluded that the radio power received is maximum for all cases with MSK. Therefore it is recommended that MSK may be preferred over rest of the modulation schemes for 802.15.4 wireless sensor networks.

4. CONCLUSIONS

This paper presents the energy consumption and power reception for a WPAN wireless sensor network using OPNET® Modeler 14.5. Here three different modulation scenarios for BPSK, MSK and QAM_64 have been considered. Results reveals that the energy consumed by the PAN Coordinator, GTS and Non GTS End Device is [30.7947, 29.1781, 26.8718], [24.2138, 23.8187, 22.4551] and [26.7983, 26.0876, 25.0293] joules for MSK, BPSK and QAM_64 respectively. Further the power received by the radio receiver at the PAN Coordinator, GTS and Non GTS End Device is [0.0149, 0.0143, 0.0118], [0.0016, 0.0002, 0.0003] and [0.0013, 0.0010, 0.0012] watts for MSK, BPSK and QAM_64 respectively. It is concluded that if energy consumption is to be considered then QAM_64 is recommended and if radio receiver power is to be accounted for then MSK is recommended for all types of devices in 802.15.4 wireless sensor networks.

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