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Packet Normalized based PEH-QoS Energy Management in WBAN Network Powered by Human Energy Harvesting

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ABSTRACT

Energy scavenging from the human environment is the new innovative idea to feed the sensors and to provide uninterrupted service in wireless body area network. The functioning of the body node highly depends upon the available power to detect events and to transmit them over a wireless network. The system performance depends upon the available energy and calculated in terms of its quality of service, delay, and throughput and packet loss. Moreover the available energy further reckons on the harvesting source accessibility. This concludes a condition where the system has to attain its performance with the available energy. Hence we propose a power management scheme in this paper which includes three algorithms. These algorithms provide a guarantee to the system performance under critical energy conditions for differentiating the data into normal, critical and highly critical categories in the queue. It emphasis to transmit the highly critical data as the first priority and considering the normal information at least priority or even discard the normal information under critical energy conditions to remove duplicity to give space to the highly critical data in the queue. Considerable simulations are carried out to interpret the performance of the system under these algorithms for different human activities such as relaxing, walking, running and cycling. This proposed system assures the quality of service (QoS) in ECG node performance.

Keywords: WBAN; Energy Harvesting; Quality of Servic ; E-Health

I. INTRODUCTION

A. Motivation

This WBAN network comprises of body nodes which perform distinctive tasks depend upon the need. Prior to final execution of WBAN, it faces a number of challenges which should be determined to achieve utmost performance of the system. The system performance is defined in terms of QoS, packet loss, delay and throughput. As BN performs different task and its QoS requirement may vary depending upon the task performed. In WBAN, the critical information is analyzed for the human health. Hence the BN performance is also highly crucial factor.

Moreover, the BNs are associated with human bodies so it faces the space constraints hence restrict the size and the number of nodes in the network. The bulkiness of the node is proportional to the size and the weight of the node which further defines the battery storage capacity. BN is driven by battery power so the operation of BN is directly affected by the available power of the battery. The battery is a limited power source hence the BN operation may be halted at last which may raise serious problems for the health of the patient as it may jeopardize the patient or it may be fatal. To recommence the operation of BN, it is inevitable to restore the battery or replace it. However, battery substitution is always not reasonable as in the case of implantable nodes it involves a surgical operation [1]. The capacity of the battery should be increased to upsurge the battery life which in turn increases the weight and makes battery bulky in size.

Scavenging energy from available resources [2] can provide uninterrupted power supply to the node. This solution can overcome the energy related problem in the nodes. A special device called a harvester is used to extract energy from surrounding. Since number of harvesting sources is available in the form of motion, heat, vibrations [3] etc and energy harvester extracts energy from these sources and convert them into electrical form to provide energy to node. Further two systems are used to utilize the harvested power which is harvest use architecture and harvest store use architecture. Since the harvesting source availability cannot be predicted so harvest store use architecture is more acceptable. In this a storage device such a battery, capacitor or super capacitor is used to store energy which is extracted by harvesting source to utilize it later when required. Energy harvesters provide very limited amount of power hence to avail the smooth operation of BN is required to manage the available power intelligently. Kansal et. al. proposed a concept of ENO state in BN, it is energy neutral operation which involves that a node always consumes less or equal amount of energy than the available harvested energy i.e. the node always has sufficient energy to perform its operation [4].

A concept of human energy harvesting is proposed in [5] which depicts that the energy can be extracted from human body movements, motion, body heat and biochemical reactions i.e. from mechanic, kinetic, thermal and biochemical sources. Since very less amount of energy is collected from these sources and this makes the condition worse for the operation of the node. This can be overcome by the use of piezoelectric harvester which extracts energy from vibrations produced by the human body into electrical energy [6]. These harvesters continuously collect a small amount of energy for a long period of time using human movements [7] and collect enough energy and provide these energy using power management circuits to the node. Piezoelectric harvester can be joined with other harvesters such as electromagnetic harvester to enhance the power output [8]. BN is used to carry out vital body signals hence its utmost requires providing quality of service in the system. Hence number of researchers devoted their attention to improve the quality of service of WBAN system to overcome the challenges in terms of delay, packet loss and throughput of the system.

B. Contribution

We purpose a priority based power QoS control scheme modeled for BN derived by human energy harvesting. This paper aimed to introduce a procedure to achieve ENO state in the system by managing the available power intelligently. The proposed scheme particularly put attention on these:

- It promotes ENO state in the system by managing power efficiently and hence improves detection ability of the BN.
- It avoids the saturation of the data queue and stores only useful and valid data in the data queue.
- It facilitates the node to transmit data in the aggregation for the optimal use of energy.

We have executed simulations for four distinct activities relaxing, walking, running and cycling in accordance to the different rates of EH in order to analyze the functioning of our algorithms in the rational environment.

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II. RELATED WORK

WBAN provide a variety of applications with distinct specifications, and it essential to propose MAC protocols that support QoS of the system. Some alterations are carried out in IEEE802.15.4 to support on demand MAC protocol such as assured time slots for real time transmission, collision avoidance and adapt the duration of super frame to support energy efficiency.

Presently, the trend in WBAN network is to improve the quality of service of the system which can be achieved by the efficient power consumption and battery management. The major challenge is to propose protocols that access BN according to its priorities with accounts of the current energy conditions. Z.A. EU et. al. in [9,10] discussed about the functioning and relative examination of MAC scheme for WSN-HEAP. This protocol is designed for both single and multiple hop networks and also known as probabilistic polling. The factors such as change in the number of nodes and the harvesting rate of the harvester are easily adapted by the protocol. Some parameters such as throughput and fairness can be improved with the dynamic behaviour of protocol.

In WBAN, it is very much important to detect the vital signals first, as this reveals the health of the patient. In WSN data loss may be compensated by other nodes but this is not possible in WBAN network as limited nodes are available in WBAN with specified task.

Hortus [11, 12] proposed that the solar energy and wind energy harvesting techniques affect the quality of service at a sensor node of real time WSN systems. The lifetime of the network may be increased at the cost of quality of service of the system. Prashanth [13] conducted studies about the steadiness measurements of the nodes powered by indoor solar system in the data queue. Due to the energy variation in the harvesting system, the throughput of the system also suffered degradation due to waiting time of data in queue. The data appearance rate, examination time and waiting time concludes the stability of the queue. Some other facts are concluded such as: (i) the energy per byte is higher for low data rates as compared to higher data rates. (ii) the stability of the queue is maximum when data and energy follow an exponential distribution. The proposal of sleep-wake policies for energy harvesting sensor nodes results in the increased throughput and stabilization of queue [14]. Yang and Ulukus [15] designed a scheme to lessen the time interval to transmit the packets to the sink by adapting varying transmission rate according to the varying traffic load and available energy. Khairnar and Mehta [16] developed a transmission scheme to achieve a throughput close to the maximum achievable throughput for energy harvesting nodes. Depending upon the energy level and channel gain node adjusts its power by switching between only pre specified data rates. Murthy [17] proposed transmission schemes that transmit data by availing pre set modulation scheme for a specified data rate to achieve specific throughput and hence manage the data and power efficiently. Ozel et. al. in [18] developed adjusting transmission scheme in order to improve the throughput of the node. Energy is efficiently managed by varying the behaviour of the transmitter according to the available energy. In above cited papers reveal the problems faced by energy harvesting system in WSN. As compared to the traditional WSN system, the quality of service is a more critical factor in WBAN system [19]. The author in [20] developed a scheme based on data classification and prioritization of data to provide quality of service assurance in WBAN. A data centric and multi objective QoS routing protocol based on modular design architecture and which focused on increasing delay and reliability is introduced by Razzaque in [21]. Liang and Balasingham [22] developed a user specific protocol that provides QoS and priority routing according to the requirement. To improve the delay and reliability of collected data in WBAN system a genetic algorithm is proposed in [23] by Hassanpour. Tsouri et. al. developed a scheme in order to enhance the network lifetime through a global routing protocol based on least cost function to balance the energy utilization in WBAN.

Seyedi and Sikandar in [24] proposed a model to evaluate BN powered by WBAN. And emphasis on the analysis of loss events due to lack of harvested energy. A relationship among the average harvested energy, maximum battery capacity and the average traffic rate is analyzed in the result and HEH-WBAN, energy efficient transmission protocols are introduced. The author evaluates the current difficulty and assigned a transmission technique based on Markov decision process and also considers the current battery level and recharging state of the body node. Optimization schemes are proposed in [25] to provide quality of service in order to reduce the delay and packet loss. All these cited papers depict the process mortification at the nodes in packet transmission and event detection because of energy harvesting. Energy is required to detect an event and transmit data, whereas both events require a specific amount of energy which is collected for some time. Hence the major challenge in energy harvesting BN is to keep both detector and transmitter in working state by providing the correct amount of energy at the correct time.

III. SYSTEM MODEL

A. BNs architecture and WBAN topology

In figure 4.1, the BN structure and WBAN topology are illustrated. We assume a single BN which use Harvest-Store-Use architecture and where WBAN is configured in star topology. Based on the latest trend in technology the specifications of ultra low power [26] and low power [27] wireless nodes are considered in WBAN network in order to realize a realistic model design. Super capacitors have been selected as a storage device in our system as the super capacitors can charge and discharge at a faster rate as compared to batteries. The proper utilization of the stored energy is the key strategy for the efficient operation of a node. This motivates the author in [28] to design energy management architecture in biomedical field which utilize super capacitor as a storage device. The energy management integrated circuit (EMIC) is composed of switched capacitor DC-DC transformer which transfers a source of direct current from one voltage level to another, a 4nW band gap voltage reference; switch matrix and voltage control circuit [28].

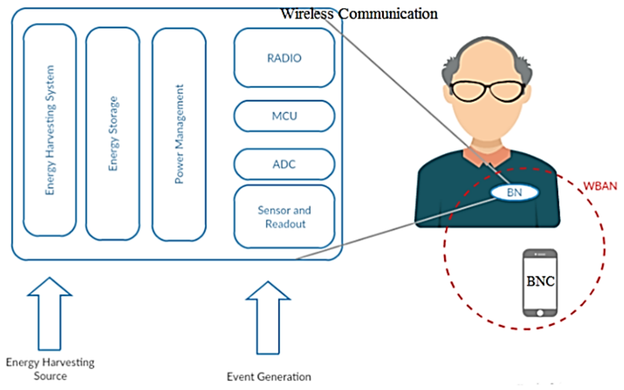

Figure 1. System model: BN architecture and WBAN topology

Most of the energy, even more than 98% of the collected power will be accessible to use with the aid of EMIC. For personal body area network, the transceiver is designed as a 1.9nJ/b 2.4 GHz multi standard transceiver [29] and based on a 30 µW analog signal the sensor and reader are designed on processor integrated circuit for biomedical signal monitoring [29]. Due to low power intake and better reliability, above components are used in WBAN.

In our model, BNC body node coordinator is a smart phone which is a kind of sink and has high processing capabilities as compared to BN. It forms the major part of the WBAN which gathers the information sent by BN. It is considered that the BNC provided with an external power source and BN collects energy from the energy harvester source which scavenges energy at a steady rate K_{EH} from the human environment. ID-polling access mode of HEH-BMAC is responsible for communication between BNC and BN. For event generation, we accept the same packet size I_{pkt} as in [30] i.e. of 12 bits, in order to design a more rational state. BN power consumption is divided into two sections: the event detection P_{det} power and packet transmission power $P_{tx.}$ As P_{det} comprise of the power used by BN to detect an event and is consumed by MCU, ADC, and sensor and read out units. On the other side, the term P_{tx} includes the power consumed in the data communication process account to the transceiver duty cycle.

IV. PEH-QOS AWARE MANAGEMENT ALGORITHMS

In WBAN, the PEH-QoS algorithm is implemented at every node. The main motive of our proposal is to achieve the BN functioning reflecting its specific characteristics i.e. power supply and QoS requirements. Our system is comprised of three sub-sections: i) the Power EH-Management (PHAM) ii) the Priority based Data Queue Aware control (PDQAC) iii) the Packet Aggregator/Scheduling System (PASS). Figure 4.2 depicts the interconnection of these sub-algorithms in the BN's process. It is clear that the BNs operation is adjusted with respect to the specifications and constraints of each node and with regard to medical application.

In the PEH-QoS regulation scheme, the PHAM sub-section exploits estimates and control the energy demand to perform the specific required task in order to keep check over the whole energy utilization and to maintain the ENO state in the node. DQAC sub-unit utilizes the knowledge regarding delay; reliability specifications and power status of the node to avoid the transmission of stale data packets that lost their clinical validity and transmit only effective data strings based on their defined priority in case of energy scarcity. Lastly, the PASS sub-unit utilizes the information regarding the number of packets in the queue and the available power in order to transmit maximum number of packets for each data communication cycle. The detail of each sub-section is elaborated below with their specific operation:

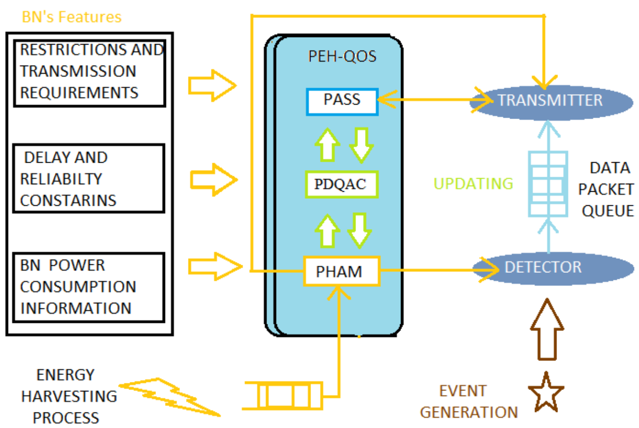

Figure 2. Priority based PEH-QoS module

A. PHAM Power-EH Aware Management

This module allocates the power intelligently to assure the best utilization of harvested energy from the human environment. To manage the power wisely is the key to training the system under current energy harvesting situation. Utilizing the BN power expenditure PHAM execute the power management. Since event detection and transmission are two major tasks performed by BN. Power consumed by BN radio part is much more than the power consumed by the detector section i.e. $E_{Tx} >> E_{det.}$ The node obligates to scavenge enough energy to perform it's both tasks (detection and transmission) efficiently. The BNs operation to detect event is as critical as transmission of packets. Event detection is also necessary to check over the criticality of the event that whether it is critical or stale event. To hold the noble detection ability, the node utilizes the PHAM module which aims to ensure the node in ENO state. The detection efficiency D_{eff} is defined as:

$$\mathrm{Deff} = \frac{\text{Total number of events detected}}{\text{Total number of events occurred}}$$

Based on the energy harvesting situation the power management control is conducted by the PHAM scheme. In this module, the main function of PHAM module is to maintain ENO state to ensure the quality performance of the node.

Energy collected in the battery (B_{level}) depends on the energy scavenged (E_{EH}) from the human environment. So it is given by:

Algorithm 1 Power-EH Aware Management

if ($E_{stored} \geq E_{det} + E_{tx}$) **then**

Set detector module to **ON** state

if ($N_Q \geq N_{tx}$) **then**

Set transceiver module to **ON** state

Proceed to transmission of N_{tx} packets

else

Set transceiver module to **SLEEP** state

end if

else if ($E_{stored} < E_{det} + E_{tx}$) **then if** ($E_{stored} \geq E_{det}$) **then**

Set detector module to **ON** state

Set transceiver module to **OFF** state

else

Set detector module to **OFF** state

Set transceiver module to **OFF** state

else

Set detector module to **OFF** state

Set transceiver module to **OFF** state

end if

end if

$$B_{level}(t) = B_{level}(t-1) + E_{EH}$$

On the other side E_{EH} is depends on the K_{EH} and the time T_{EH} which is elaborated as:

$$E_{EH} = \int_0^{TEH} K_{EH} = K_{EH} * T_{EH} \qquad ¥\ T_{EH} € [0, \infty)$$

B. PDQAC Priority Based Data Queue Aware Control

The quantity of scavenging energy is based upon the energy of harvesting source accessibility. Prior to transmission, packets can be stored for the time being to collect enough energy for their transmission. Two issues arise, as the node posses limited storage capacity so it can store finite number of packets and after that the queue will be saturated hence no more events can be stored by queue i.e. queue is overflowed. The second case is raised when the packet is stored for a longer time in the queue. It may lose their clinical validity, i.e. the packet is no more contain valuable information. Hence PDQAC is executed to perform two functions i) it avoids the queue from overflowing with insignificant data. ii) it permits all detected events to be saved.

Algorithm 2 Priority based Data Queue Aware Control

if ($N_Q > 0$) **then**

for ($i = 0 : N_Q$) **do**

if ($D_Q(i) \geq D_{Qmax}$ **&&** packet Priority <=1) **then**

Delete data packet i

else if ($D_Q(i) < D_{Qmax}$ **&&** packet Priority <=0)

Delete data packet i

end if

end for

end if

if Event is detected **then if** ($N_Q < SC_{max}$) **then**

Store data packet in the queue

Set priority of data on Event Type

else if ($N_Q == SC_{max}$) **then**

Delete oldest data packet with packet Priority <=1

Store new data packet in the queue

Set priority of data on Event Type

end if

end if

Availing the information regarding the maximum queue capacity (SC_{max}) and utmost end to end delay (Dly_{max}) the queue will be updated and unimportant packets are rejected. SC_{max} defines the physical constraint over the capacity of the queue and Dly_{max} rely on BN specifications. PDQAC continuously supervise the delay period of each packet (T_{pkt}) and the stored packets (DQ_{level}). The value of T_{pkt} should be less than maximum waiting time in the queue to keep the packet in the queue. Otherwise it will be dropped to clear the space from queue. Packets are dropped to make space for new arrived packets and to remove the stale packets. T_{Qmax} is computed as,

$$T_{Qmax} = Dly_{max} - T_{tx}$$

T_{tx} = time required for processing of data communication and it is evaluated in PASS module.

In case of scare energy we define three types of packets through priorities; normal packets, critical packets and highly critical packets. Normal packets are those packets which carry normal medical events which explore the normal status of the patient. Highly critical packets define the events which carry the patient's critical health status information whereas the critical packets carry information regarding the changing condition of the patient from normal to critical. To utilize the power efficiently we reject the packets which carry normal information. On the basis of available energy the critical packets and highly critical packets are handled. Highly critical packets are definitely transmitted to the BNC whereas the critical packets are transmitted only if the node has enough energy to transmit the packets.

C. PASS: Packet Aggregator Sub-module

When the BN operation is monitored by battery, the packets are transmitted as soon as they are generated. But in case of BN monitored by energy harvesters, the BN waits to collect specific amount of energy to transmit the packets. PASS module has been introduced to make the system efficient with current energy conditions. The main purpose of PASS module is to transmit maximum number of data packets for each transmission. PASS utilize the MAC protocol data for the estimation of E_{TX}.

Algorithm 3 Packet Aggregator/Scheduling System

Calculate E_{tx} for single packet transmission

Check E_{stored} and data queue status

if ($N_Q = 1$) and ($E_{stored} \geq E_{det} + E_{tx}$) **then**

Make $N_Q = 1$

Initiate data communication process **else if** ($N_Q > 1$) **then**

if ($E_{stored} \geq E_{det} + E_{tx}$) **then**

Determine N_{tx}

Calculate E_{tx} to send N_{tx} **if** ($N_Q \geq N_{tx}$) **then**

Remove duplicate packets;

Make aggregated packet of size N_{tx}

Initiate data communication process

else if ($N_Q < N_{tx}$) **then**

Recalculate N_{tx}

Calculate E_{tx} to send N_{tx}

Make aggregated packet of size N_{tx}

Initiate data communication process

end if

end if

end if

The format of the IEEE 802.15.6 standard data frame is shown in the figure 3. The maximum number of packets can be transmitted by utilizing the identical control frames based on the implemented protocol. D_{Load} which is the number of packets collected may be varied depending upon the size of the queue D_{QLevel} and the available energy E_{TX}, the aggregation of packets to be transmitted is varied. Hence the value of K_{EH} and data arrival time is directed by D_{Load}.

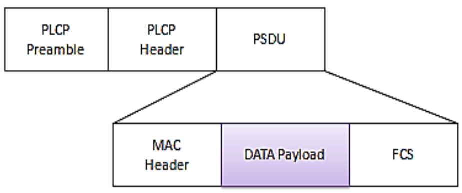

Figure 3. Data frame structure of IEEE802.15.6

V. PEFORMANCE EVALUATION

A. Simulation Consideration and Setup:

We have accomplished an event driven MATLAB simulator that achieves our algorithms in a simple HEH-WBAN. The system is comprised of one BNC and one BN. We consider that BNC is powered with external power supply so we assume that BNC does not face any power shortage problem in its operation. Whereas the BN is powered by the energy harvester source which scavenges energy from the human environment and provide for the node at fixed rate $K_{EH.}$

Table 1 ECG BN Characteristics

Data and traffic features	Data arrival time		2 ms
	Buffer size		200 packets
	Packet size		12 bits
Power consumption distribution	Sensor, read – out and ADC		30 µW
	MCU		19.25 µW
	Transceiver	Reception	3.8 mW
		Transmission	4.6 mW
		Sleep	4 µW
		Idle	0.712mW
QoS Requirements	Delay constraint		250ms
	Packet loss constraint		10 %

Super capacitor is used as a storage device to collect the harvested energy. ECG node is selected for the simulation and events identified by ECG are reformed into packets which are further stored in the data buffer. The ECG specification and QoS needs are summarized in table 1.We consider the interaction between the ECG and BNC is carried out without any obstruction. Medium access is carried out through the ID-polling access of the HEH-BMAC. IEEE 802.15.6 PHY-MAC is responsible for the selection of network parameters. Network specifications are chosen as stated in the IEEE 802.15.6 PHY-MAC specifications. System specifications adopted in the simulation is encapsulated in table 2 [30].

To analyze our scheme, we examine the working of ECG with priority based PEH-QoS and without priority based PEH-QoS respectively. In our simulation scheme, we suppose that the packets lost only because of the overflowing of the buffer. We consider the average packet end to end delay of all the transmitted packets for delay evaluation. The delay is calculated as the time between the packets is generated and the packet is received by the BNC. Moreover we also consider the data storage efficiency, the normalized throughput and the energy efficiency of BN. The measure of the proficiency of the data storage as the ratio of the total number of events stored to the total number of events detected. We calculate the energy efficiency as the ratio of the total number of useful data transmitted to the total power consumption. And the normalized throughput is calculated as the ratio of number of bits successfully delivered to the total number of generated bits, within a specific period of time. Specifications for the energy scavenging source in each activity are summarized in table 3.

Table 2 ECG-BN System Parameters

Parameter	Value	Parameter	Value
Simulation time	60000 ms	MAC Header	56 bits
Psifs	0.05 ms	FCS	16 bits
pCSMA slot	0.125 ms	PLCP preamble	90 bits
PLCP Tx rate	91.9 kbps	PLCP header	31 bits
Data Tx rate	485.7 kbps	ACK	72 bits
Control Tx rate	121.4 kbps	T.POLL	88 bits

Table 3 EH Source Parameters

Activity	P_{EHmin}	P_{EHmax}	μ_{ON}
Relaxing	1 µW	4.8µW	0.9µW
Walking	128.6µW	186µW	0.1µW
Running	724.2µW	910µW	0.1-0.2µW
Cycling	37.4µW	72.3µW	0.9µW

B. Simulation Result:

Simulation outcome for ECG detection proficiency with existing PEH-QoS algorithm and enhanced priority based PEH-QoS algorithm has been shown in figure 4. The figure illustrates that the priority based PEH-QoS enhances the system efficiency in terms of detection efficiency. We analyze that our system detects ECG events with very little value of K_{EH}. As the ECG node is conscious about the available energy and hence does not try to detect events when it does not have enough energy to detect event, hence saves its scavenged energy. In this, our system improves the efficiency by 5% in case of relaxing activity since very less amount of energy is scavenged i.e. about 1 μW ≤ K_{EH} ≤ 4.8 μW. In case of walking activity, since the availability of a node is only 10% but node scavenges more power as compared to relax activity i.e. to 128.6 μW ≤ K_{EH} ≤ 186 μW. In this, the baseline achieves 64% of detection efficiency whereas our scheme outperform with 68%. In case of running and cycling our system scavenges enough energy to allow almost 100% detection ability. As in the cycling activity the collected power range is 37.4 μW ≤ K_{EH} ≤ 72.3 μW which is less than the case of running activity which is 724.2 μW ≤ K_{EH} ≤ 910 μW but the accessibility of node is 90% which is quite high to achieve that much power level by which it detect events significantly. We can observe that both systems attain the 100% detection efficiency as the system achieves enough energy to detect all events.

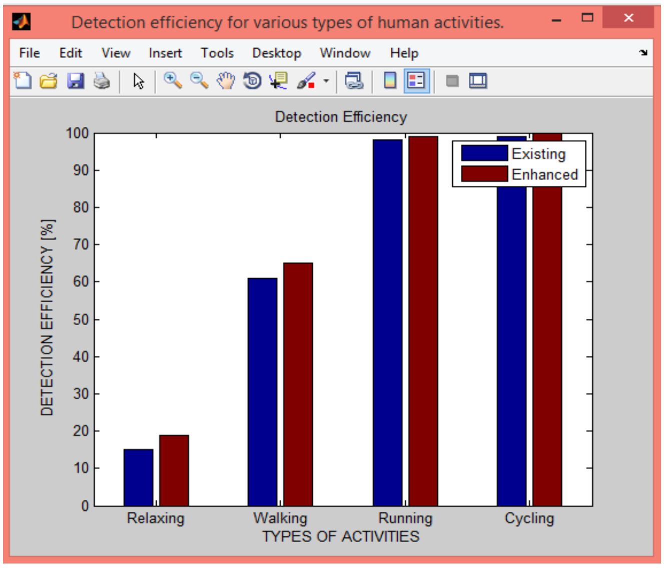

Figure 4. Detection efficiency for various types of human activities

Figure 5 illustrates the performance of data queue for two schemes. In this figure, we can analyze that the packets are gathered at the node does not accumulate enough energy to transmit that packets. In this condition our algorithm tries to store the maximum number of useful packets and tries to stabilize the queue. Moreover, we can observe from the figure that the queue becomes stable at 125 packets and stored data is 100% valid where PEH-QoS scheme queue is stabilized at 124 packets.

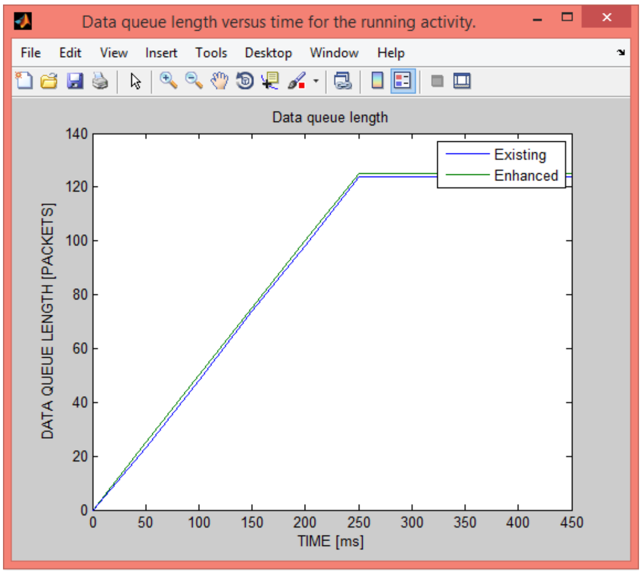

Figure 5. Data queues length versus time for running activity

In figure 6 shows that both PEH-QoS can attain 100% data storage capability. It let the node to store packets until it will be transmitted or became stale.

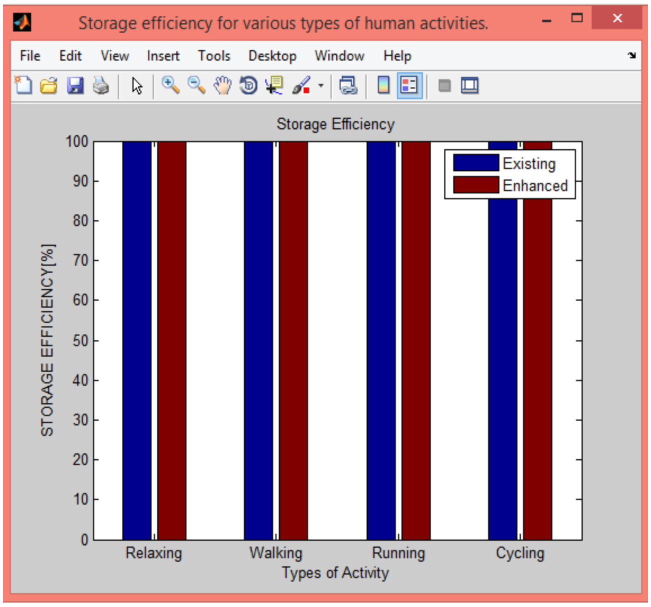

Figure 6. Storage efficiency for various types of human activities

Figure 7 depicts the setup throughput for both systems in running activity for distinct packet aggregation under two different cases. It involves two cases μ_{ON} =0.1 and μ_{ON} =0.2. In the figure 6(a) the availability of source

μ_{ON}=0.1, our scheme attain the highest throughput at N_{tx} =124 with normalized throughput 62% whereas the baseline scheme attains normalized throughput of 59%. In the figure 6(b) as the availability of the source is increased i.e. μ_{ON} =0.2 our scheme attains the highest throughput at N_{tx} = 75,100 and 124 with normalized throughput 100% and also improves normalizes throughput at N_{tx} = 1, 25 and 50 marginally. We can analyze that our scheme performs better from the baseline scheme.

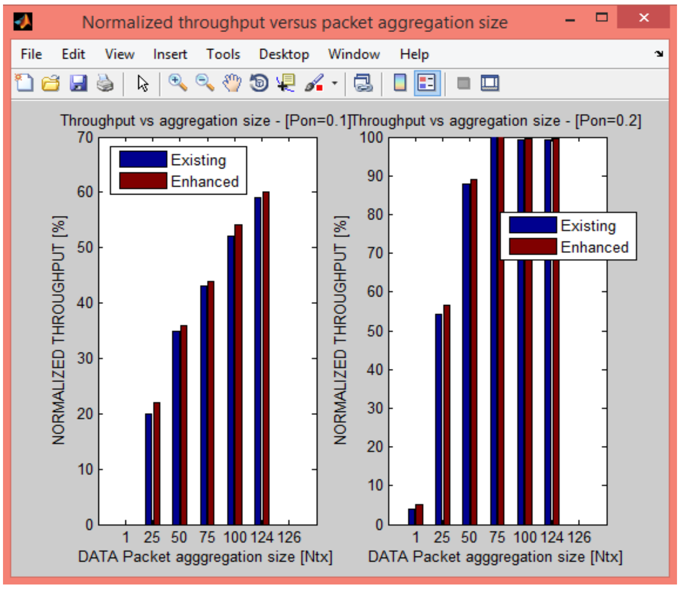

Figure 7. Normalized throughput versus packet aggregation size for the running activity (Case I= μ_{ON} =0.1 and Case II= μ_{ON} =0.2)

Under similar conditions, figure 8 and 9 illustrates the correlation between the N_{tx} with reliability restriction with respect to packet loss and packet end to end delay respectively. We can analyze that in figure 7(a) none of the N_{tx} attains reliability criteria in case of μ_{ON}=0.1 but the packets lost at different values of N_{tx} are marginally reduced as compared to the baseline system. In figure 7(b) in case of μ_{ON}=0.2, the values of N_{tx} for 75,100 and 125 achieve the reliability constraints i.e. keeping the packet loss at tolerated rate.

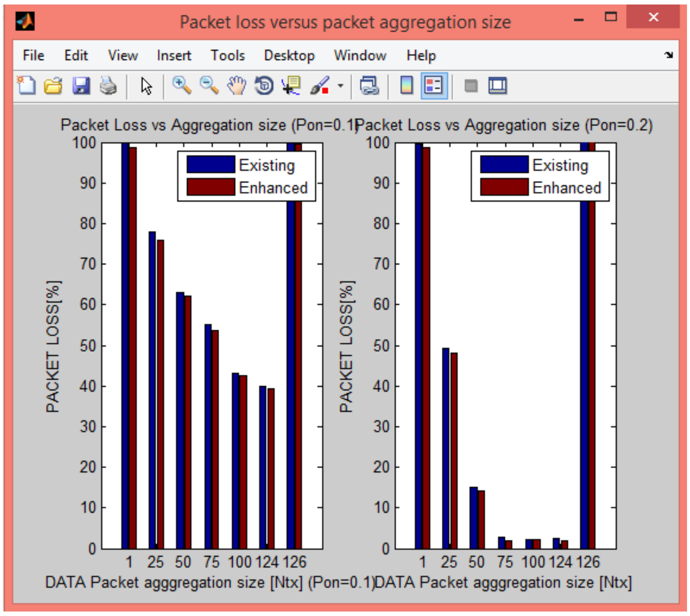

Figure 8. Packet loss versus packet aggregation size for running activity (Case I= μ_{ON} =0.1 and Case II= μ_{ON} =0.2)

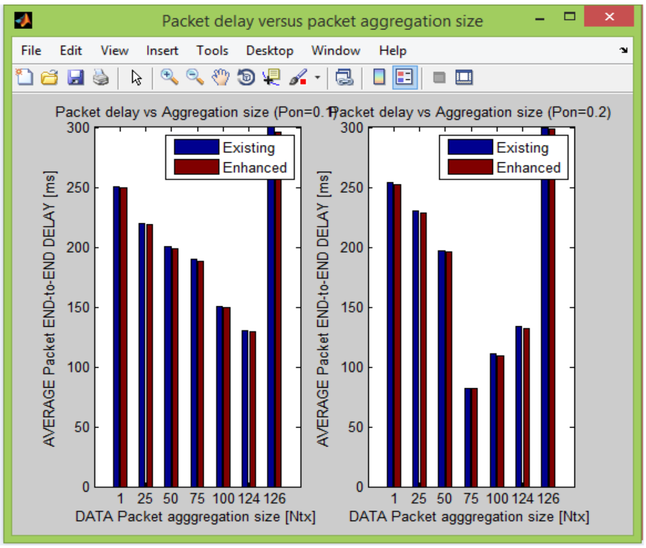

Figure 9. Packet delay versus packet aggregation size for running activity (Case I= μ_{ON} =0.1 and Case II= μ_{ON} =0.2)

In figure 9, in both the cases μ_{ON}=0.1 and 0.2 system achieves delay constraint i.e. that much delay can be tolerated in the system.

Figure 10 depicts the energy efficiency of the node using two distinct available probabilities of μ_{ON}=0.1 and 0.2 in the running mode under different packet aggregation values i.e. N_{tx} =75 and 124. It can observe from the figure that the energy efficiency is increased with the increase in packet aggregation. Our system achieves marginally higher efficiency about 1% as compared to baseline scheme in both cases μ_{ON}.

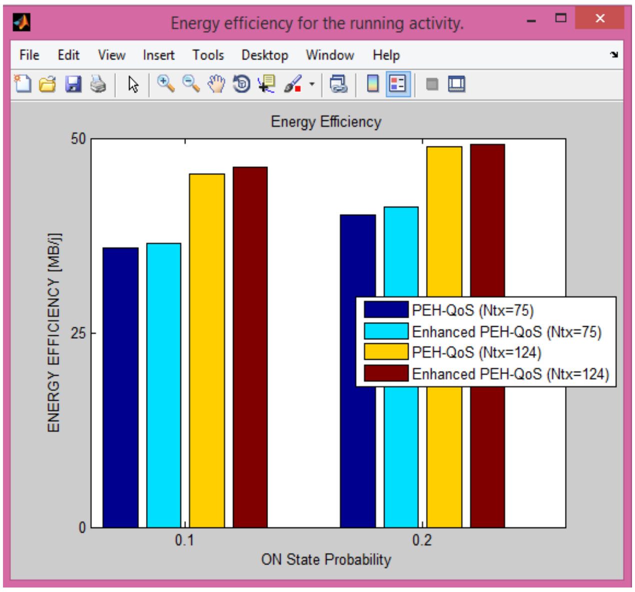

Figure 10. Energy efficiency of running activity

At last in figure 11, we analyze the packet loss under the same specifications. Since packet loss constrained is assumed at 10% and our system achieves this criterion in the case of μ_{ON}=0.2.

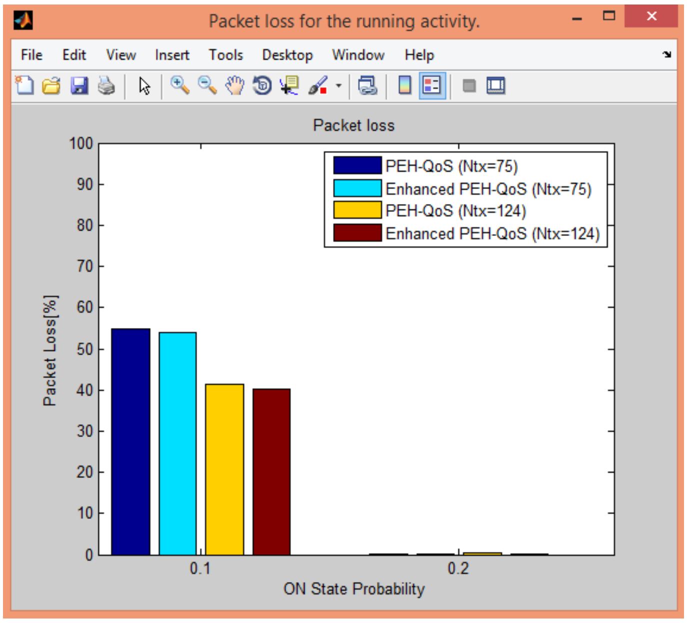

Figure 11. Packet loss for the running activity

VI. CONCLUSION

In this paper, we purpose a priority based PEH-QoS scheme which is to utilize the harvested power in human environment efficiently. This scheme exploits the harvested power very efficiently and improves the event detection and transmission in human environment hence enhances normalized throughput and energy efficiency; reduces delay and packet loss.

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