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CRITICAL DATA TRANSMISSION USING PTR SCHEME FOR WIRELESS BODY AREA NETWORK

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ABSTRACT

Wireless Body Area Network (WBAN) is an exigent research field in recent times, to continuously monitor and transfer the lifecare or critical data over wireless medium for next level analysis. In such a network, channel access techniques play an essential role to solve the collision, delay and energy consumption problems. Many research works either used contention based or contention free channel access schemes for resolving the aforementioned issues. In contention based, whenever a node needs to transmit a data packet and it senses the channel to be busy, then node defers its transmission until it becomes idle. Since access to the network cannot be guaranteed in advance and the possibility collisions will be more when two or more nodes try to reserve time slots at the same time across the network. In contention free, the time frame is divided into fixed number of time slots and then assigned a time slot to a particular node for data transmission, thus it completely eliminates the collision issue. This fixed slot assignment is not suitable in the emergency cases. Since, if nodes have data to transmit, but cannot get a slot in that time frame. In other case, some time slots may be sent empty. Therefore, each channel access scheme has its own merits and demerits. To overcome such issues, this paper introduces a Priority based Time slot Reservation (PTR) scheme using IEEE 802.15.4 for time critical data transmission. Initially, node listens to an idle channel, then notify other nodes from attempting to reserve the current slot and also provide a way to other nodes to reserve the time slot by piggybacking the Criticality Index Value (CIV). To minimize the future control packets collisions, a novel Reservation Counter Algorithm (RCA) is introduced. Therefore, it significantly avoids the collision and allocate the time slot for time critical node by deferring non-critical node's transmission during the reservation phase. Simulation results show that proposed technique reduces the collisions of data packets, subsequently minimized the delay and also compared with existing methods.

Keywords: Collision, Delay, Power Consumption, Time-slot Reservation, Wireless body area network

I. INTRODUCTION

Wireless Body Area Network is a propitious technology to periodically monitor and report the vital signs of the human body. This type of network contains low power sensor nodes attached in and around the human body for gathering the vital parameters and transfer the collected data to the network coordinator. The coordinator or network aggregator node is responsible to collect and transfer the aggregated data to the base station for next level analysis [1]. Fig.1 represents the overall schematic representation of WBAN system. The IEEE 802.15.4

Medium Access Control protocol or ZigBee [2] is the standard specially designed for Low-Rate Wireless Personal Area Networks (LR-WPAN) and also used in many testbeds scenarios for WBAN. It supports only the low data rates, not adequate to support high data rates (>250 Kbps) and does not differentiate the data traffic based on the degree of importance. IEEE 802.15.4 is challenging, when sensor node reports the time critical data. Since, it cannot provide any preferential access to emergency or critical nodes while accessing the shared wireless medium [3].

To solve such issues, several MAC Protocols are developed to efficiently utilize the channel, avoid the collision, packet delay and energy consumption. Generally, contention or random based and contention free or schedule based access methods are the two major channel access methods in WBAN. Contention based techniques use random backoff procedure for data frame transmission. Each and every node in the network heeds the channel before making an attempt to transmit. If the channel is idle, then nodes start transmission otherwise it defers the data transmission until the channel becomes idle in order to avoid collisions among the neighboring nodes [4]. The nodes randomly reserve the first available time slots to successfully complete their intended transmission. Therefore, access to the wireless channel cannot be guaranteed in advance and also the possibility of collisions will be more while two or more nodes try to reserve time slots at the same time.

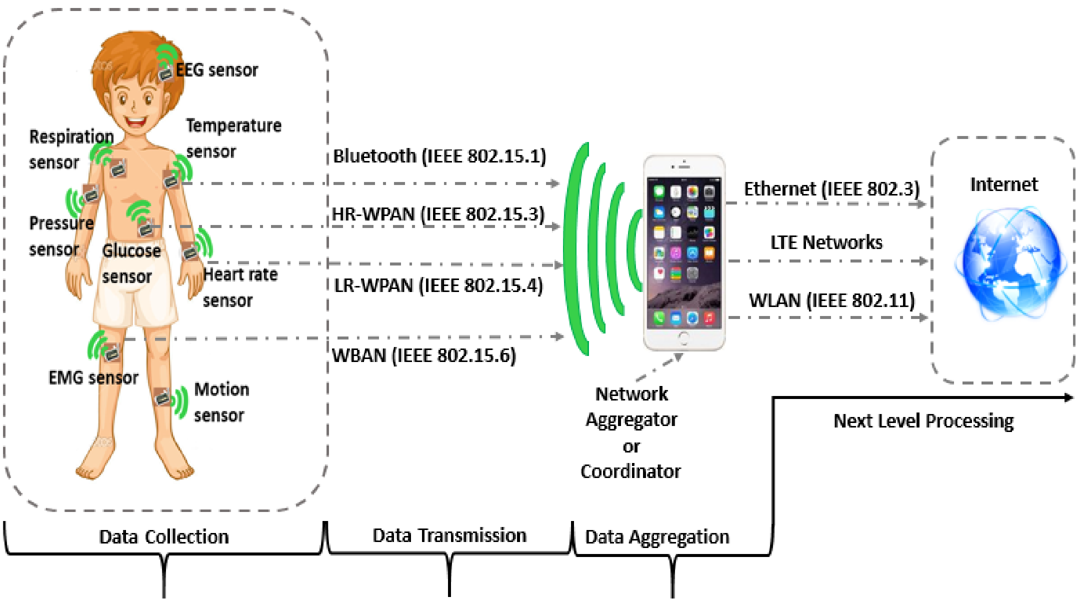


Fig.1 Overall schematic representation of WBAN system.

Due to network impairment of CSMA/CA, the critical or emergency data of the patients could not be transmitted to the network aggregator node. In another type, the shared channels are divided into fixed number of time slots and then assigned the time slot to a particular node for data transmission, thus it completely eliminates the collision issue. Sometimes, there is a situation when nodeshave data to transmit, but did not get a slot in that time frame [5]. Similarly, some time slots were sent empty. Since, this fixed slot assignment for sensor nodes are not suitable in the emergency cases. To address such drawbacks, this paper introduces a novel Priority based Time slot Reservation Medium Access Control (PTR-MAC) mechanism to handle the Time

Critical (TC) and Non-Time Critical (NTC) data transmission based on the Criticality Index Value (CIV). In this method, node listens to an idle channel, send control packets to neighboring nodes from attempting to reserve time slot in the current time frame and allow other nodes to reserve the time slot by piggybacking the updated CIV to the coordinator. Therefore, this proposed method eliminates the packet collisions and reduce the delay of time critical data by preventing other node's transmission during the reservation phase. Table.1 illustrates the data range values of the vital parameters.

The rest of this paper is drafted as follows. Section II briefly describes the related works of contention over reservation mechanisms. Section III examines the proposed technique. Results and the discussion is presented in section IV. Finally, Section V gives a conclusion of the paper.

II. RELATED WORKS

This section reviews the issues related to the contention over reservation problems for WBAN with neat focus on energy consumption, collision and delay. Authors implemented Collison Avoidance Time Allocation (CATA) technique for wireless networks to reserve the time slots by using distributed reservation and handshake mechanism. CATA supports all type of communication like unicast, multicast and broadcast simultaneously based on the dynamic service time. Nodes transmit its data packets in the reserved time slots after successful reservation in the subsequent frames without any collisions, until the reservation gets terminated. This CATA supports real-time applications. The length of the control packets and backoff duration for non-prioritization of nodes will increase the packet overhead as well backoff delay [6].

Contention over Reservation MAC (CoR-MAC) supports dual reservation process. In this, if any reserved time slots are empty, it permits other nodes to reserve the time slots. It makes the reservation according to the data traffic such as urgent, time-critical and non-time critical data. Node transmits urgent data in the Contention Free Phase (CFP). The urgent data can be transmitted in the unused CFP time slots and the non-time critical data also used the same CFP time slots. Since, it supports dual reservation policy in the same phase that may increase the collision when multiple nodes transmit more than two urgent data at the same time [7]. Authors developed a novel Token based Two Round Reservation MAC [8] to assign the time slots to nodes according to the arrival rate of data traffic. A token is used to indicate the health severity index of sensor nodes with burst data traffic. It offers two kinds of reservation modes for burst data and periodic, which minimizes the energy consumption and delay simultaneously.

Authors introduced [9] a novel Backoff Counter Reservation (BCR) scheme to predict the future data frame transmission by adding the next backoff value to the MAC payload of each transmitted data frame. If the data frame does not arrive at the predicted transmission slot, then the Guaranteed Time Slot (GTS) is allocated to the node in the next superframe. The coordinator predicts the next backoff durations of sensor nodes, so it could manage the next backoff which reduces the collision and delay problems. This method did not consider the priority of the data traffic to calculate the next backoff duration. If any node detects critical data that also needs to wait for next time frame. Since, it will maximize the collision as well as the delay of the critical data. Most of the above techniques use contention over reservation strategy to resolve the collisions, delay and increase channel utilization. Still, there are many issues to be considered to solve the reservation problems for critical data and non-critical data.

Table 1: Data Range Values of Vital Parameters

Vital Parameters	Data Range			
	Non-Time Critical		Critical	
	Normal	Moderate	Warning	Dangerous
Heart Rate (bpm)	80-120	90-140	95-160	100-190
Respiration Rate (bpm)	14-20	20-24	25-29	30-60
Blood Pressure (mmHg)	80-120	90-140	100-160	100-180
Body Temperature (°F)	97.7 - 99.5	99.5-106	106-110	106-114
Glucose (mg/dl)	60-100	100-120	120-140	140-310

III. PTR TECHNIQUE FOR WBAN

3.1 Network Model and Basic Assumptions

This method assumes the sensor nodes are fixed so there is no mobility in the network. The sensor nodes periodically monitor and report the vital parameters to the coordinator. The basic formation of WBAN is a star topology. There are number of nodes in the network, and assume some nodes that can generate normal or urgent data depending on their range mentioned in Table 2. Data traffic is divided into two priority levels: Time Critical (TC) and Non-Time-Critical (NTC) data. It is possible that all nodes can possible to generate TC and NTC data. The generic superframe format of contention over reservation is shown in Fig.2. In this network, times are slotted by the coordinator, so that the sensor nodes can be synchronized. The entire operation is based on the following two principles:

- Data from a critical sensor node must flow without interference from other body sensor nodes over a reserved slot. So, the coordinator must send the piggybacked control packet to the potential sensor nodes in order to defer its data transmission.
- The sensor node must send the control packet to the receiver, if there exists high CIV than the received piggybacked CIV in the current packet. Thus, effectively reduces the delay of time critical data and collision problem.

The modified superframe structure of PTR-MAC is shown in Fig.3. The CFP is divided into time slots S_t= (S_1, S_2., S_N), and TC is allocated to Si. Initially (N = 0), there is no CFP, and the CAP durations from the end of the BP to the beginning of the IP. The time slot reservation request for TC is transmitted over the CAP. N is the maximum allowable number of time slots in the CFP and it is selected based on the number of nodes that generate TC data. The CIV for each node may vary according to the severity of data traffic collected from the human body, as shown in Table.2.

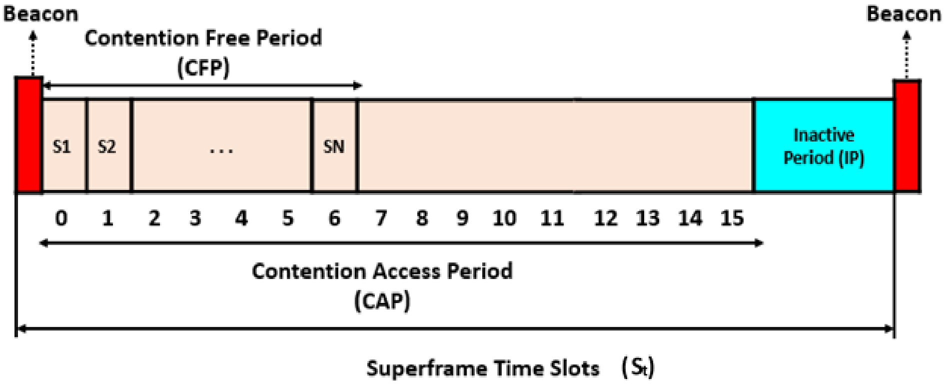


Fig.2 Generic format of contention over reservation

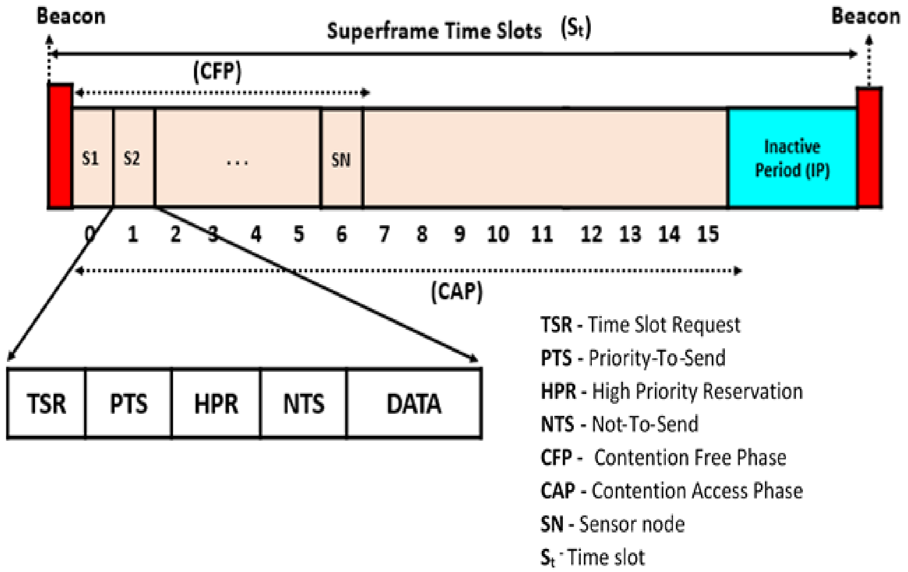


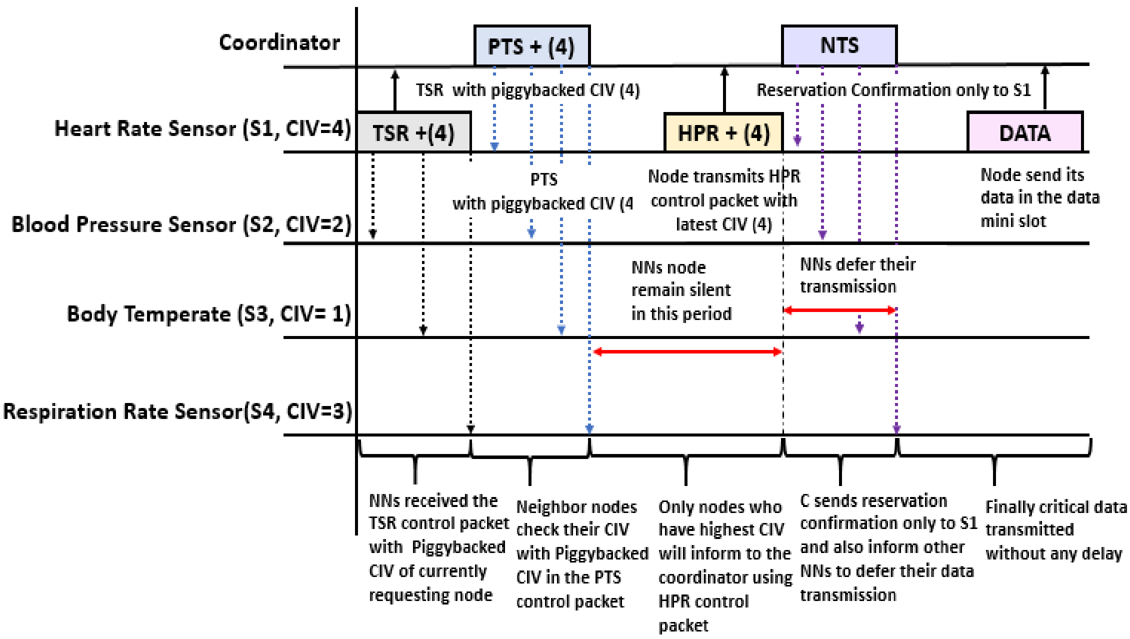
Fig.3Layout of modified superframe of PTR-MAC

Table 2:Data Range Values of Vital Parameters

Data Traffic Conditions	Criticality Index Value
Dangerous	4
Warning	3
Moderate	2
Normal	1

3.2 Data Transmission Procedure

To accomplish slot reservations according to the above principles, PTR-MAC divides a slot into five mini-slots. The first four mini-slots are decided for control packets. The last mini-slot is intended for data transmission. The data mini-slot should be much longer than any control mini-slots to reduce the protocol overhead. Fig.4 demonstrates how slots are identified as reserved and how TC data are sent without any collision over reserved time slots. Initially, each node listens the channel whether it is busy or idle. If the channel is idle, then all nodes attempt to reserve the slots. Whenever node detects the data that transmits Time-Slot-Request (TSR) with its current CIV to the coordinator node during the control mini slot 1. This serves to inform other neighboring sensor nodes about the currently active reservation and prevent them from attempting to reserve the current slot. Next, coordinator node



piggybacks the received CIV with Priority-To-Send (PTS) control packet to the requested and other waiting sensor nodes during the control mini slot 2.

Fig.4 Data transmission procedure of PTR-MAC

On receiving this packet, the requested sensor node understands the channel is idle and does not transmit anything until it receives reservation confirmation reply from the coordinator. Similarly, all nodes check their own CIV value with received CIV. The sensor node who has higher CIV compared with piggybacked CIV only that node transmits the Higher Priority Reservation (HPR) control packet to coordinator node. Both the sensor nodes and coordinator node remain silent during the control mini slot 3. After received this HPR control packet, coordinator transmits with Not-To-Send (NTS) packet to other sensor nodes during the control mini slot 4, so that all nodes receive this packet will defer their data transmission and the requested node understands the reservation was successful, then it starts transmit the data during the data mini slot 5. This PTR-MAC completely reduces the delay of TC data and avoid the collision by deferring other node's transmission using piggybacked CIV and control packets transmission.

3.3 Reservation Counter Algorithm

Most of the reservation mechanism in WBAN fails to handle control packet's collisions. In order to minimize the probability of future control packets collisions and increase the channel utilization, this paper also introduces a novel Reservation Counter Algorithm and it works as follows:

- Initially, each and every node has a Reservation Counter (RC) that sets the value to zero (RC=0), if its data queue is empty.
- If a new data packet arrives, the node sets its slot reservation attempt probability to one ($SP_{reservation}=1$) and tries to make a reservation in the next available slot.
- If the channel is busy with ongoing transmission, then node increases its RC value by one (RC=RC+1) and sets its slot reservation attempt probability to $SP_{reservation} = (1/2)^{RC}$.
- If anyone of its neighbor nodes makes a successful reservation, then it decreases its RC by one (RC=RC-1), but it does not modify its slot reservation attempt probability. The slot reservation attempt probability is reformed only during the node's reservation attempt and not by neighbor's node successful reservation. The overall procedure for RC algorithm is figured out in the Fig.5.

Algorithm 1 Reservation Backoff Counter algorithm

1. **Input:** S_i-Sensor node, P_i-Packet, *DQ*-Data Queue, $SP_{reservation}$, *C- Channel*, CIV_{min}, CIV_{max}.
2. **Initialization:** *DQ=RC= 0*
3. **If** *DQ == empty*
4. $S_i \rightarrow RC=0$
5. **Else** $P_i \rightarrow DQ$ **then** *RC=1*
6. $SP_{Reservation} == 1$
7. **End if**
8. **End else**
9. **If** *C* → *Busy with ongoing transmission*
10. **Increment** the value of $RC = RC + 1$ *&&* **Modify** $SP_{Reservation} = (1/2)^{RC}$
11. **Else Minimize** the value of $RC = RC - 1$ *&&* $SP_{Reservation} = 0$
12. **If** $CIV_{max} \geq CIV_{min}$
13. **Check** with latest piggybacked *CIV*
14. **Allocate** a *GTS Slot*
15. $SP_{Reservation} \rightarrow$ *Success*
16. **Again, go to** Step 1
17. **End if**
18. **End Else**
19. **End if**

20. **End goto Statement**

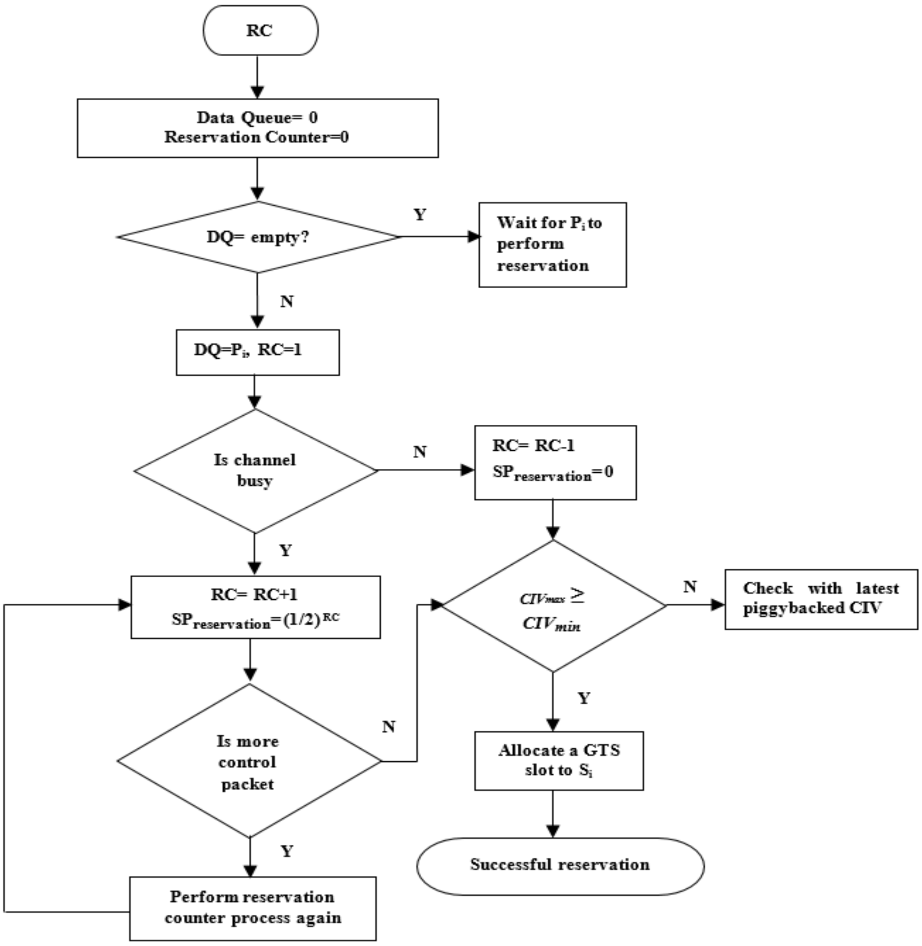


Fig.5 Overall procedure of RC algorithm

IV. RESULTS AND DISCUSSIONS

The performance of the proposed PTR-MAC is evaluated and compared with existing method [9] using Network Simulator 3 (NS3). The network parameters used in the simulation are summarized in Table.3.

Table 3: Simulation Parameters

Parameter	Values
Topology size	4m *0.8m
Number of sensor nodes	25
No of Coordinator node	1
Time Critical Data	2 per node
Non-time Critical Data	3 per node

Superframe Duration	30ms
CFP time Slot Length	932.3 µs
Beacon Period	350 µs
Beacon Frame Size	128-400 bits
TSR Frame Size	24 bits
PTS Frame Size	24 bits
HPR Frame Size	24 bits
NTS Frame Size	24 bits
Data Frame Size	192 bits
Power Supply	6.0 V

4.1 Delay

Fig [6]shows the average TC data and NTC data packet's delay versus the packet size in bytes. The delay is increased gradually when the packet size increases as well PTR-MAC achieves better result when compared with existing method. The existing method is used only for predicting the next packet transmission, but cannot process TC and NTC effectively. Because, if the data frame does not arrive at predicted transmission slot, a Guaranteed Time Slot (GTS) is allocated to the requested sensor node in the next superframe. At this situation, if any node detects emergency or critical data that can get a fixed time slot only in the next time frame, since the waiting period to get a slot extremely increases the delay in [9]. But, PTR-MAC processes the TC and NTC, and allows other nodes to access the channel using CIV during the entire superframe.

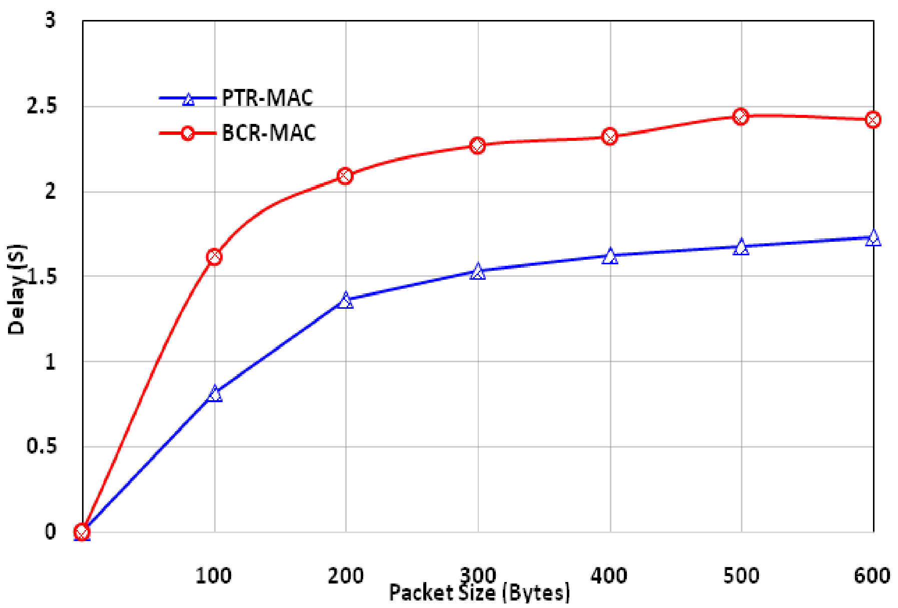


Fig. 6 Delay

4.2 Power Consumption

The estimation of the average power consumption is analyzed based on the inter arrival time as shown in Fig [7]. The packet collision, high contention or long period of listening the channel to transmit the data will increase the energy consumption. The data traffic prioritization reduces the contention problem, collision and packet retransmission. These issues are avoided by allowing nodes to reserve guaranteed time slots based on the priority of the data traffic, including the special control packet and CIV in order to avoid the collision and contention problems.

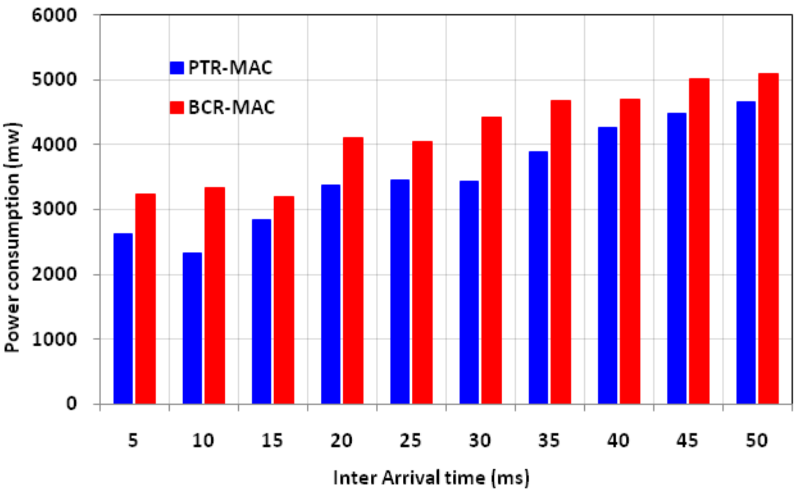


Fig. 7 Power consumption

4.3 Packet Collisions Rate

Fig [8] depicts the control packets collision rate of the overall traffic in a network in a specific period. The traditional contention over reservation mechanism with non-prioritization of data traffic could not solve the collision problem. The proposed PTR-MAC provides a low packets collision rate, even the packet size is increased as compared to the existing technique [9], by prioritizing the data traffic as well deferring another nodes transmission.

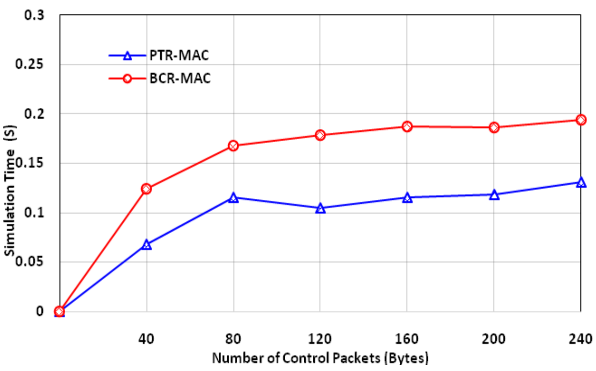


Fig. 8 Packet collisions rate

4.4 Throughput

The overall performance of the network throughput versus the simulation is illustrated in Fig [9]. The proposed PTR-MAC provides better performance compared to the existing method [9]. Due to random next backoff counter value, the collision rate increases sharply with the number of sensor nodes try to reserve time slot at the same time. This collision rate also increases the packet loss so it degrades the overall performance. The proposed PTR-MAC performs better result than the existing method, by reserving the channel for TC and NTC separately, and prioritization the data traffic using CIV.

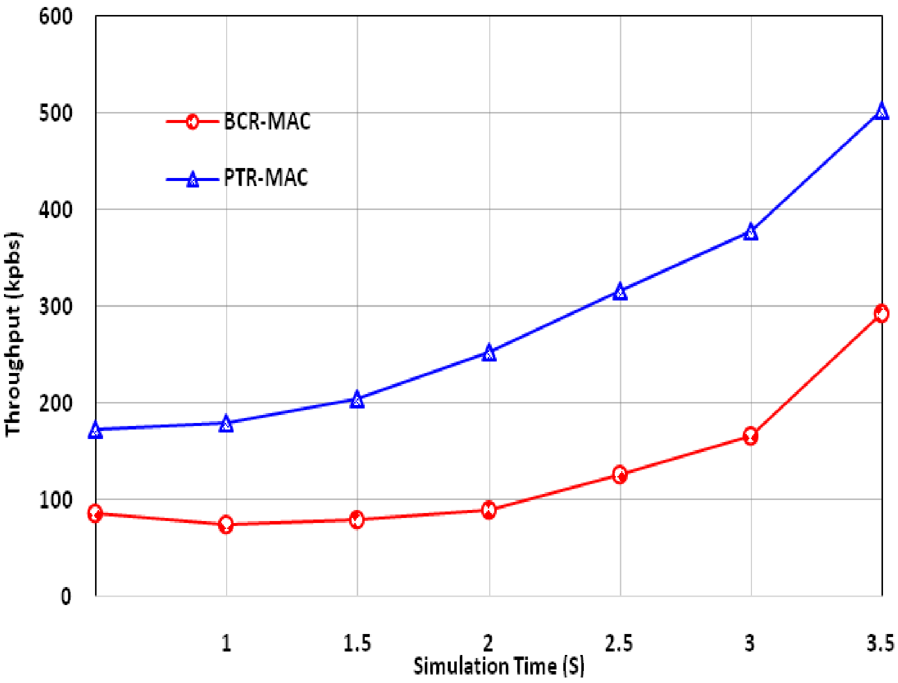


Fig. 9 Throughput

V.CONCLUSIONS

Existing reservation schemes cannot properly resolve the delay problem of critical data, collision among the sensor nodes and not considered any priority traffic classification, since they do not support TC data transmission. To solve the contention problem for sensor nodes and reduce the delay of critical data transmission, this paper introduced a new novel Priority based Channel Reservation MAC (PTR-MAC) using IEEE 802.15.4. In this method, the traffic is divided into TC and NTC using priority. This method allocates the time slots to the sensor nodes based on the piggybacked CIV that eliminates the collision, delay and utilize the available network bandwidth. The simulation results showed that the proposed scheme is very effective and provides significantly shorter delay compared with existing method by providing priority to the TC and NTC data transmission. This method provides better result when number of nodes are very less, if more than two nodes receive the same priority and CIV that will create major problem in emergency situation, this problem will be resolved in future.

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