PERFORMANCE ANALYSIS OF MEDIUM ACCESS CONTROL SOLUTION BASED ON PRIORITY TRAFFIC PROPORTION IN MULTI-EVENT WIRELESS SENSOR NETWORKS

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***Abstract*— **High quality of service (QoS) requirements in multi-priority wireless sensor networks pose new challenges to the Internet of Things (IoT). In a multi-event wireless sensor network (MWSN), nodes generate different types of data packets with different priority such as urgent (high priority) or normal (low priority), with different traffic proportion. High-priority packets require faster transmission and higher reliability in the network. In many recent research works, the existing media access control (MAC) protocol for MWSN has been modified to increase transmission efficiency and priority but has not yet taken into account different priority traffic proportion. Therefore, the we propose an energy-efficient MAC algorithm that combines multiple priorities of data packets to match the traffic proportion, called PT-MAC. PT-MAC supports multi-events by considering four different packet priorities and employs a new approach to adaptively adjusting contention windows. The mathematical estimation with different priority traffic rates is also done in combination with the simulation in the paper, showing that PT-MAC ensures better performance, especially energy saving up to nearly 40 % when compared to the predecessor protocol TMPQ-MAC.

Keywords — IoT wireless sensor network, medium access control, energy efficiency, priority traffic proportion.

I. INTRODUCTION

Recently, Internet of Things (IoT) and related technologies have been rapidly developed and deployed worldwide. IoT allows connecting not only people with each other, but also connecting physical devices based on low-cost sensors or smart objects, which can observe and interact with their surroundings [1-3]. Despite the Covid-19 pandemic, the IoT market is still growing rapidly. It is predicted that by 2025, there will be more than 30 billion IoT connections and on average each person has nearly 4 IoT devices [4]. Thanks to the sensing, collecting, processing and exchanging capabilities of sensor nodes (SNs) or smart devices, IoT has attracted considerable attention and is deployed in various applications such as smart wearable devices, forest fire monitoring, weather forecast… [5- 8]. The rapid growth of IoT applications has increased the need to support multi-priority sensor data in multi-event wireless sensor networks (MWSNs). This has posed a number of challenges and network performance problems due to the computational and power limitations of smart sensors/devices [1, 5]. Data from multiple sensor sources is expected to be transmitted simultaneously and instantaneously to selected receivers with different quality of service (QoS) and reliability requirements [9]. For example, data events such as warning (emergency) messages need to be delivered instantaneously with high reliability to satisfy QoS requirements while other data packets such as information and maintenance messages (normal) does not require immediate transmission. To deal with such new challenges, providing flexible, instantaneous, and reliable QoS-assured communications becomes essential for IoTs to efficiently serve high-priority data [1, 5, 9].

Many research works have been developed to address the flexible requirements of QoS [10-12] and different priority data transmission requirements, while ensuring certain energy efficiency in WSN [12-14]. These studies have taken into account the priority and requirement of energy consumption separately or simultaneously and can be classified into three main groups based on their approach: application layer, defining priority route/queue and MAC layer. Each approach has its own advantages and disadvantages. For example, routing/queuing and application-layer priority-based approaches may yield better end-to-end performance in terms of reliability, but these studies may encounter many difficulties in achieving high energy efficiency [15-17]. In contrast, the MAC layer-based approach can reduce power consumption while maintaining communication quality [10, 18, 19]. This is because the MAC protocol has direct control over transceivers that consume most of the power, thus having

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a significant impact on network life. Therefore, it is necessary to develop MAC protocols in the direction of considering data prioritization and saving energy. These protocols should be able to support emergency situations where multiple sensor nodes must transmit the appropriate data simultaneously and with the lowest possible delay to the receiver, for the receiver to assess the severity. of the situation [18,20]. The works of [13, 20] use multi-priority, but [20] assigns priority based on remaining energy, rather than data priority, and also does not guarantee the latency of terminal packet. In addition, the study [13] considers a limited number of data priorities and does not consider different traffic rates. Therefore, it is necessary to develop an energy-efficient MAC protocol that efficiently adapts with different packet priorities to ensure QoS in the network.

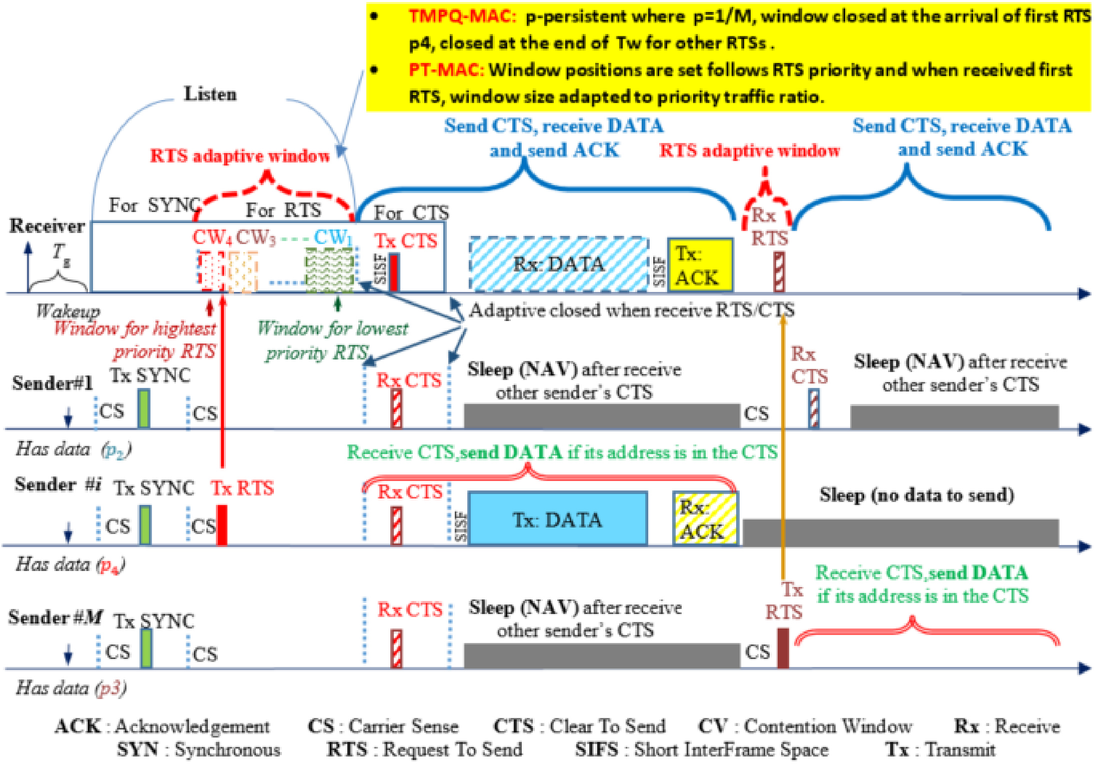

Figure 1: The operation of PT-MAC

In this study, we propose an algorithm in MAC that supports multi-priority in multi-event WSNs and computes traffic-based contention window, named PT-MAC. The proposed protocol improves wireless sensor network performance in terms of end-to-end latency, packet success rate, and power consumption. Furthermore, PT-MAC uses adaptive congestion windows based on the priority and traffic ratio of different priority data to ensure end-to-end packet delay. It exploits a combination of collision avoidance and event priority-based servicing with four priority levels. The preliminary idea of this paper was presented at an international conference [21]. In which, the initial idea of an adaptive collision avoidance scheduling scheme using both data prioritization and traffic adaptation and its performance is briefly introduced. To clarify the efficiency of the developed PT-MAC, we add a mathematical estimate for energy consumption. The obtained simulation results demonstrate that our developed solution outperforms its predecessor, TMPQ-MAC [22].

The rest of the paper is structured as follows. Part II describes the proposed PT-MAC scheme. Part III is a mathematical estimate of energy consumption. Part IV presents the results of matching simulation with TMPQ-MAC protocol, and the final part is the conclusion.

II. PROPOSED SOLUTION

The proposed PT-MAC protocol uses a fixed duty cycle that describes the awake and sleep periods of the node. However, wake and sleep times can be adjusted according to application requirements. To deal with collisions or hidden endpoints, RTS/CTS handshakes are used. If a sending node needs to send a packet, it generates and transmits an RTS message to the receiver (sink) at random during the contention window. The RTS message includes the required data transmission time, expressed in NAV. After receiving the RTS successfully, other sending nodes will go to sleep during the NAV period to avoid power consumption for the node to stay awake and for the entire network. Then, the receiving node selects the sender node, generates and sends the corresponding CTS message to the selected sending node to notify the node which has the data to send. As soon as the appropriate CTS packet is received, the selected sender can start transmitting its data. On successful data reception, a corresponding ACK packet will be sent from the receiving node to the sending node. The S-MAC protocol mentioned in [23] also effectively saves network power and ensures relatively low latency due to small competition window by sending CTS as soon as first RTS is received. However, S-MAC does not incorporate packet prioritization and treats all packets equally, resulting in all packets with the same latency and reliability. Therefore, to meet different data transmission requirements, a data discriminating mechanism is needed to support low latency and high reliability for high priority data. Therefore, in PT-MAC protocol, we inherit the idea of prioritizing data of MPQ-MAC and TMPQ-MAC protocols [22, 24]. We differentiate priorities based on sending traffic. Assume that the network supports N traffic types, in other words, up to N priority levels will be applied and a higher priority value is assigned to the more important data type. For example, in a network with four types of traffic (N = 4), urgent traffic has priority of 4, most important, important, and normal traffic has priority 3, 2 and 1 respectively. Furthermore, the collision window will be divided into four sections according to traffic types. Figure 1 shows the operation of the PT-MAC for two consecutive cycles, during which the priority information of data packets generated at the application layer is passed down to the MAC layer.

PT-MAC uses receiver-initiated approach, after waking up, the receiving node senses the shared media for a guaranteed time T_{g} and broadcasts Wake-up Beacon to all potential sending nodes ability to announce it is ready to receive data. A sender node can adjust its contention window size and position according to its own data priority and traffic rate. As illustrated in Figure 1, the contention window is adaptive because the window will be closed as soon as the receiving node successfully receives the RTS (no collision). Then, the receiving node starts sending a CTS and waits to receive data from the selected node. Assume the network consists of M competing senders as shown in Figure 1. Then, sender i can immediately send its data while the other senders go to sleep during that data transmission. When the data transmission is complete, sender i goes to sleep while the other senders 1 and M wake up. Then, sender M sends its RTS in the contension window earlier than sender i because M ‘s RTS has higher priority ($3 > 2$). Such operations will continue until all senders have successfully send their data. In PT-MAC, RTS is sent from the sending node with a collision window that varies with data priority and traffic ratio. In this scheme, if a sending node has data to send, it first listens to the channel to check if the channel is free and sends its RTS frame randomly in the its resized contention window. If the sender sense the channel and finds the channel is in busy state, it will re-sense that channel until it finds the channel in idle state. The starting time for sending RTS is randomised to avoid collision of RTSs with the same priority from other senders.

The pseudo code for RTS sending procedure in its specified contention window is shown in Figure 2. Thus, in PT-MAC, the RTS with the highest priority will have a chance to appear earlier than other packets with lower priority, so the delay of the highest priority packet will be lower than the lower priority packet. By doing so, the PT-MAC protocol will shorten the sending node's waiting time to receive CTS, compared to the T_w of the MPQ-MAC and TMPQ-MAC protocols. In MPQ-MAC and TMPQ-MAC, the contention window closes when the receiving node receives the highest priority Tx Beacon (or RTS) (adaptation window only applied for priority 4) or when T_w expires. The window size is fixed with lower priority 1, 2 and 3. So all sending node expends energy to stay awake and send its RTS in fixed window T_w which can lead to RTS collision and wasted energy.

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1:  procedure POSITIONING WINDOWS AND SENDING RTS IN PT-MAC
    input: $j$, traffic rate, channel status
    ouput: $j$-priority window location and size, RTS is randomly sent in the window in free channel status
2:  for sender $i$
3:      Determine the corresponding priority $j$ and the corresponding traffic rate
4:      Locate the window and assign the $j$-priority window to the priority position, the highest-priority window to be placed first, and the lower-priority window to follow.
5:      Estimate the proportional priority window size according to the corresponding traffic ratio.
6:      while sensing the channel do
7:          if the channel is free then
8:              At the assigned time, the sending node sends its RTS randomly in the collision window assigned in steps 4 and 5.
9:          else
10:             Go back to step 6
11:         endif
12:     endwhile
13: endfor
```

Figure 2. Pseudo code for positioning windows and sending RTS in PT-MAC

III. MATHEMATICAL EVALUATION

A. Assumption

In this paper, we study an IoT wireless sensor network consisting of a receiver node at the network center (sink) and a predefined total number of sending nodes randomly and uniformly distributed. For computational simplicity, the network model considers only single-hop communication with the sending and receiving nodes being considered within each other's wireless transmission range. The network is targeted to apply to IoT and industrial applications, therefore, limited to small standalone IoT networks such as smart home, smart garden, and industrial factory. Furthermore, the main assumptions and notation are given as follows:

1) M is the number of contension nodes.

2) The maximum number of priorities applied is N, where the probability of a frame having priority L_j ($1 \leq j \leq N$) is p_j. In the TMPQ-MAC protocol, all priority frame types are assumed to have equal probability, that is, $p_j = 1/N$ with j=1,2,...,N. For PT-MAC, p_j can be changed adaptively according to different traffic rates.

3) With PT-MAC protocol, all sending nodes use CSMA/CA mechanism with a contention window to send RTS packets. The matching protocol, TMPQ-MAC, applies

CSMA p-persisitet to send RTS. Therefore, the i^{th} *sender node (*G_i *where* $i \in [1 \ldots M]$*) accesses the channel in the idle state with probability 1 for PT-MAC or probability* p_i *for TMPQ-MAC with* $\sum_i^M p_i = 1$*.*

4) The receiver contention window size of the PT-MAC is denoted by CW and is the same as T_w *in TMPQ-MAC.*

5) The PT-MAC sender contention window size is denoted CW_j $(CW = \sum_1^j CW_j)$ *with different priorities according to data priority and retention rate. quantity of each node. As for the send node in TMPQ-MAC, the window size depends on the number of contention nodes and the data priority.*

6) In the considered network, the propagation delay is expected to be significantly smaller than the idle time and thus, for simplicity, can be neglected [25].

7) The maximum RTS/TxBeacon retransmission value is restricted to avoid delay exceeding the acceptance threshold.

B. Energy consumption

The problem of computing power dissipation is a difficult problem to calculate specifically, especially in real situations because there are many parameters, so it can only be estimated through the differences in the operation of the network.

1) Transceiver energy model

The energy consumption in a wireless sensor network has three main components: sensing, communication (receiving, transmitting) and data processing. In which, energy for communication is the main part [26]. The node energy for data transmission is based on the first-order radio model [27]. In Figure 3, ε_{elec} is the energy required to transmit or receive one bit of data, and ε_{amp} is the energy to amplify one bit of transmitter data, d is the distance between the transmitter and receiver.

Then, the energy consumed to send a message/frame of length S to a node in a distance d can be calculated according to the following formula [27]:

$$E(S,d) = 2 \times \varepsilon_{elec} \times S + \varepsilon_{amp} \times S \times d^2 \qquad (1)$$

For communication networks, energy efficiency can be defined as the inverse ratio of the average energy consumed for the successful transmission of a data unit. Thus, the average energy consumption for the transmission of a data unit is less, the higher the efficiency is [24]. If a message has to be retransmitted many times due to dropping during transmission, the energy efficiency will be reduced because now it can be considered that the size S in formula (1) will be multiplied by the number of resends.

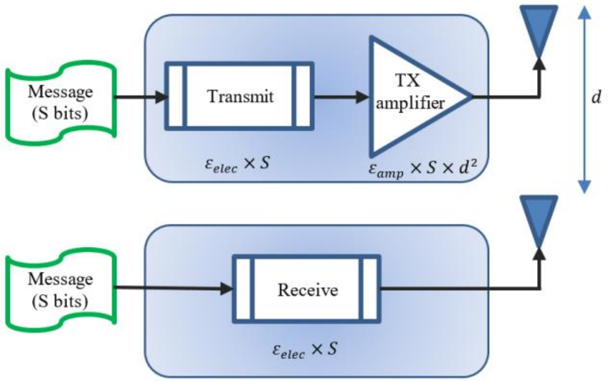
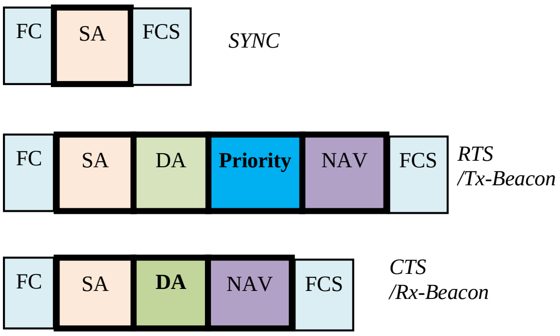


Figure 3: The transceiver energy model of the sensor node.

With the two protocols considered PT-MAC and TMPQ-MAC, data is delivered from the sensor to the destination through the SYN, RTS/CTS and ACK mechanism, so the assumption power for communication is not only the transmission and reception of data packets but also for SYN, RTS/CTS frames (Figure 4). In each of those frames/packets, there are many header bits for the whole physical layer instead of just information for the MAC layer or above.



DA: Destination Address FC: Frame Control
FCS: Frame Check Sequence NAV: Network Allocation Vector
SA: Source Address

Figure 4: Structure of MAC frames in PT-MAC and TMPQ-MAC.

From the mechanism of data sending and receiving operation in the Figure 1, it can be seen that the basic difference in power consumption will depend on the contention phase of sending RTS (the more RTS sent and re-sent due to the collision, the more power consumption) and the duration the node has to stay awake, listening, waiting to decide whether to send the frame or not (the longer this duration, the more power will be consumed) but the consuming power of the data packet and acknowledgment is the same because there is no longer a conflict due to the application of RTS/CTS scheme. Therefore, in the analysis of energy consumption, this research only focuses on these two basic differences of the two protocols.

2) One sender case

Assume there is only one sender and so there is no conflict in sending RTS. Thus the sending probability in this case is always 100% because th bere is no contention. Figure 5 illustrates the window position and RTS sending delay time when there is only one send node, the start time of the collision window is t_b. The packet delay is t_p, is calculated as the time from the beginning of the collision window/start of the sending cycle (excluding synchronization issues) to the moment the data is accepted by the receiving node (see Figure 1). Consider the duration from the moment the sender sends the RTS to the moment when the node has received the data and the sender receives the ACK as t_r where

$$t_r = t_{\mathrm{RTS}} + t_{\mathrm{CTS}} + t_{\mathrm{DATA}} + t_{\mathrm{ACK}} + 4 \times t_{\mathrm{SISF}} \qquad (1)$$

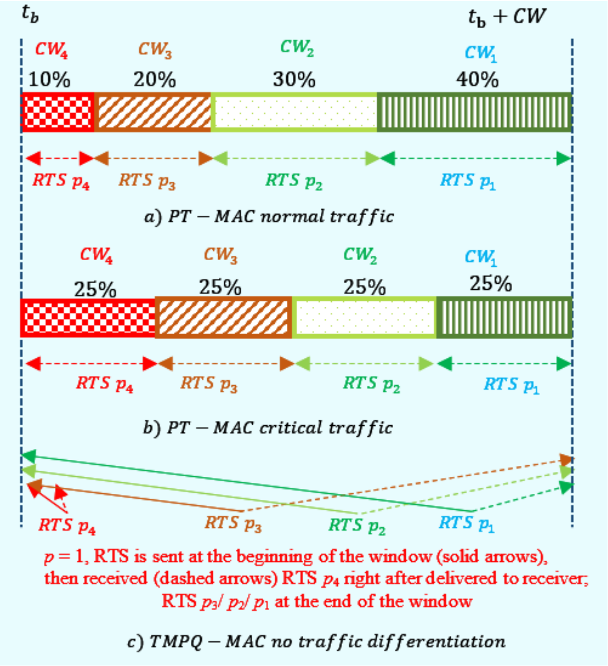


Figure 5: The arrival and reception moments of RTS in PT-MAC and TMPQ-MAC in case of one sender.

In PT-MAC, priority windows will be ordered from highest to lowest priority from left to right, i.e. if the RTS with the highest priority will appear in the first random window on the left side CW_4. Thus, the average packet sending delay is

$$t^{j}_{\mathrm{pPT}} = t_{\mathrm{b}} + \left\lfloor CW - \textstyle\sum_1^j CW_j + CW_j\,/2 \right\rfloor + t_r \quad (2)$$

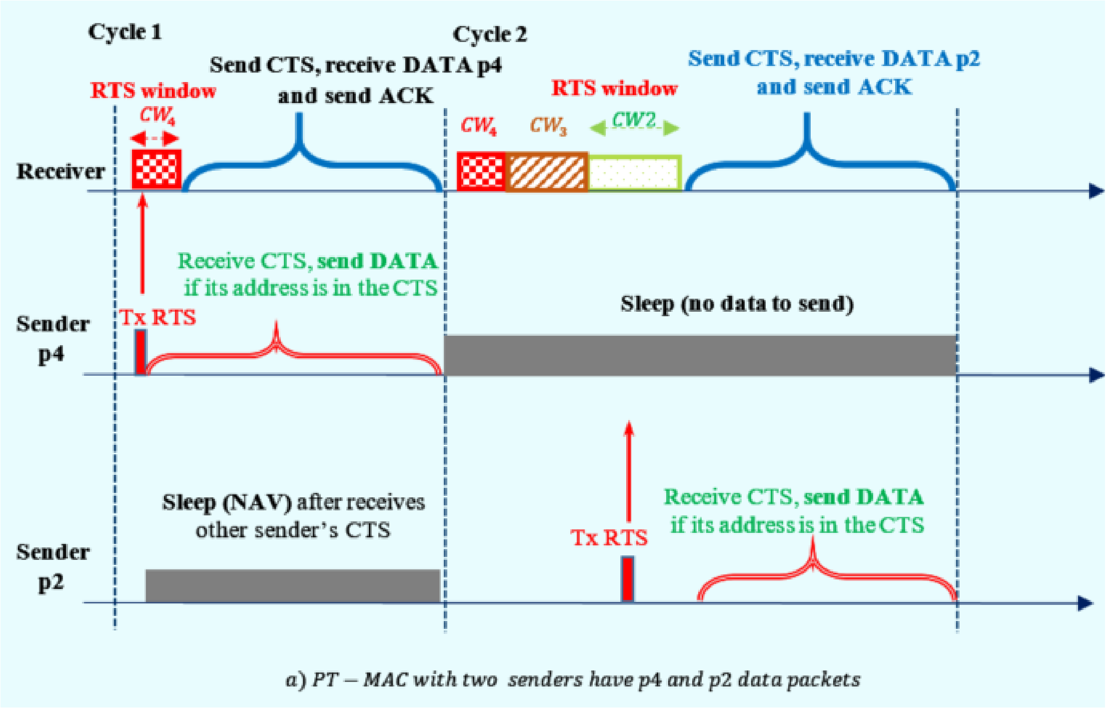
In TMPQ-MAC, RTS delay is

$$t_{\mathrm{pTMPQ}} = \begin{cases} t_{\mathrm{b}} + t_r & for\ priority\ level\ 4 \\ t_{\mathrm{b}} + CW + t_r & for\ other\ priority\ level \end{cases} \quad (3)$$

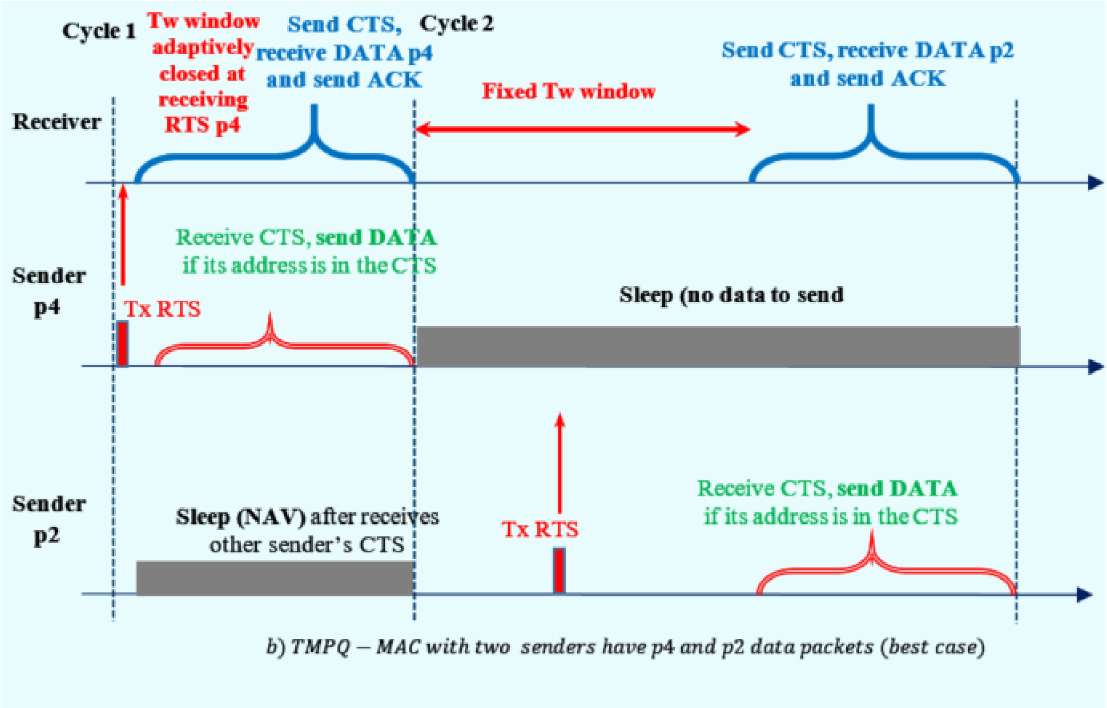
The difference in power consumption in this case is mainly due to the average extra time the sensor waits to send the RTS during the collision window period, which is approximately $\left\lfloor CW - \sum_1^j CW_j + CW_j\,/2 \right\rfloor$ with PT-MAC and [0] or [CW] with TMPQ-MAC. Assume there are 2 different types of traffic in the normal case (the proportion of urgent priority traffic is small) and the critical case (the proportion of the urgent priority traffic is large) with the respective percentage of priority traffic (p_1: p_2: p_3: p_4 = 10: 20: 30: 40) and (p_1: p_2: p_3: p_4 = 25: 25: 25: 25) that is, the total amount remains constant at 100%; then the average extra delay can be calculated in Table I. Thus, the longer the waiting delay to send RTS, the higher the power consumption will be. From the analysis, it can be seen that the average extra delay or the average extra power consumption of PT-MAC is lower than that of TMPQ-MAC, corresponding to a value of 0.5CW compared to 0.90CW/ 0.75CW.

TABLE I. ANALYSIS OF ADDED TIME WHEN THERE IS A SENDER IS A CAUSE OF DIFFERENCE IN ENERGY CONSUMPTION

Protocol		p_1	p_2	p_3	p_4	*Average*
PT-MAC	*Normal*	$0.050CW$	$0.200CW$	$0.450CW$	$0.800CW$	$0.500CW$
	Critical	$0.125CW$	$0.375CW$	$0.625CW$	$0.875CW$	
TMPQ-MAC	*Normal*	0	CW	CW	CW	$0.900CW$
	Critical					$0.750CW$



a) PT – MAC with two senders have p4 and p2 data packets



b) TMPQ – MAC with two senders have p4 and p2 data packets (best case)

Figure 6: Time to send and receive RTS for PT-MAC and TMPQ-MAC in case of 2 senders with RTS p4 and p2.

3) Two sender case

When there are two senders, if there is no collision, there will be one node sending data in each cycle, so the average delay will increase because the next sender is delayed by one cycle and that node will have to stay awake longer and the consumed energy increases. In case of a collision because two senders can send at the same time, the sending nodes will have to resend the RTS, which will consume more power for the extra RTS transmission and the time it takes to resend increased, leading to an increase in energy consumption during the additional waiting time.

With two sending nodes, there will be 16 pairs of RTS sent together on the contention window with TMPQ-MAC, but with PT-MAC, it will less appear because only one RTS comes first and is acknowledged when there is no collision. The window will be closed and the other node will wait after NAV time to be allowed to send RTS. RTS arrival times will vary due to the randomness at the MAC layer. Specifically, considering the event that RTS p4 and RTS p2 want to be sent at the same time, with PT-MAC, the windows of the two priority categories are separate, so there is no conflict (Figure 6a). High priority RTS p4 will be sent in the first cycle while RTS p2 will be sent in the second cycle. Then we have RTS delay p4 as follow

$$t^4_{\mathrm{pPT}} = t_{\mathrm{bd}} + CW_4/2 + t_r \qquad (4)$$

For the RTS p2, it is randomly sent in the CW2 window of cycle 2 (after cycle 1 for RTS p4 to be sent), so it is calculated by adding t^4_{pPT} delay in the formula (4) as follow

$$\begin{aligned} t^2_{\mathrm{pPT}} &= t^4_{\mathrm{pPT}} + CW_4 + CW_3 + CW_2/2 + t_r \\ &= t_{\mathrm{b}} + 2 \times t_r + CW_4 + CW_3 + CW_4/2 + CW_2/2 \quad (5) \end{aligned}$$

The average extra delay of sending packets will now be calculated as the ratio of the traffic times the average extra delay of priority packets p4 and p2, respectively.

Whereas with TMPQ-MAC when the number of nodes is 2, the sowing probability of each node is random and is halved (according to the p-persistent mechanism is p=1/2) to be allowed to send RTS. At this point there are many possible cases:

- One of the two RTS comes in the window T_{w}. Then if RTS p4 comes first and reaches the start of the window it is the most efficient in terms of delay and energy because then the RTS p2 sender will sleep during NAV and wake up to send in the next cycle without losing a single added RTS p2 (Figure 6b). RTS p4 will be sent in the first cycle even earlier than PT-MAC, but by the second cycle, RTS p2 even sent early at the beginning of the T_{w}window will only be received at the end of the collision window T_{w} (equivalent size $CW = CW_4 + CW_3 + CW_2 + CW_1$) so the average delay will be higher than PT-MAC.
- Two RTS come in the window T_{w}. Then there are two cases where RTS p4 comes first or RTS p2 comes first. The best case is that RTS p4 arriving at the beginning of the first cycle will ensure better priority for p4 and reduce the overall delay because when RTS p4 arrives the window will close, the node that sends RTS p2 will sleep for the NAV time and wake up to send on the next cycle. If RTS p2 comes first, the window stays open until RTS p4 arrives, and then it wastes energy for one RTS p2 to

send and the time RTS p2 sender has to stay awake in the first cycle also consumes more power.

- Both RTSs come later than T_{w}, then the window is closed and it takes energy for the two nodes to stay awake when the receiver opens the window again. The process repeats itself.
- Two RTSs collide (coming together within a certain period of time in T_{w}), then both sending nodes will have to resend the RTS, which consumes more energy, even the wake time is extended to the next cycle.

Thus, even in the best case, TMPQ-MAC is still not more efficient than PT-MAC in terms of delay, other cases are not as efficient both in terms of delay and additional RTS to resend, so overall the energy efficiency is lower. The quality of TMPQ-MAC will be less than that of PT-MAC.

4) *Multiple sender case*

When there are many senders, they will have to arrange to send in turn because there is only one receiver, so the average delay will increase in both cases of the MAC protocol. Furthermore, the potential for collision of the senders increases as the number of concurrent senders increases. Therefore, the higher the number of competing nodes, the lower the transmission success rate, leading to more resends, causing much more delay and resulting in more power consumption of the sensors.

With TMPQ-MAC, because there is a sending probability of each node according to the total number of participating senders, it is not possible to send RTS immediately, but it can be sent after many rounds of sowing, so the RTS will have to be delayed, moreover the p-value is fixed whether it is in the first sending cycle or in later sending cycles (when there is a previously sendable node). This will lead to an extended delay. What is more, the window is always open for multiple nodes that can send RTS after a node has sent RTS leading to a higher probability of RTS collision than with PT-MAC, resulting in more power consumption of TMPQ-MAC than PT-MAC as the number of nodes increases.

TABLE II: SIMULATION PARAMETERS

Parameters	Value
Number of senders	1-14
ε_{elec}	50nJ/bit
ε_{amp}	100pJ/bit/m^2
Number of RTS retransmission (TxRetries)	7
Number of priority	4
Bandwidth	250kb/s
MAC header size	11 byte
Application header size	5 byte
Packet length	28 byte
ACK size	11 byte
CCA	0.128ms
Physical frame header	6 byte
T_q	6,7ms
$CW\ /T_{\mathrm{w}}$	10ms

IV. SIMULATION RESULTS AND DISCUSSION

This section presents the results of evaluating and comparing multi-event WSN IoT performance using PT-MAC with TMPQ- MAC simulations based on Castalia 3.3 [28] and OMNeT++ 4.6 [29] using CC2420 [30].

A. *Simulation Parameters*

Table II presents the main parameters in the simulation. The node (receiver sink) is placed in the center of the 10m x 10m sensor area with the sensor nodes (senders) randomly scattered. Each sender sends packets of events at a rate of 1 event per second (that is, one packet per second), with a different priority packet traffic rate and four priority levels. The RTS/Tx-Beacon and CTS/Rx-Beacon frame/packet sizes are 14 bytes and 13 bytes, respectively.

The performance parameters evaluated in the simulation are:

- *Packet Loss Rate (PLR):* It is the ratio of the total number of packets that do not reach the receiving node to the total number of packets generated from all sensor nodes.
- *Energy Efficiency:* Evaluated by the inverse ratio of the average power consumption to successfully transmit one data bit (*mj*/bit). Thus, the less energy consumed, the higher the efficiency.

B. *Simulation Resutls*

1) *Delay and packet loss rate*

Figure 7 shows the delay and packet loss rate of different priority packets in wireless sensor networks using PT-MAC and TMPQ-MAC with the different number of concurrently senders.

As can be seen, PT-MAC makes the network more efficient with lower latency and very low packet loss rate (from 0% to less than 0.004%) with all packet types. The immediate acceptance of the first incoming RTS in the PT-MAC helps to avoid unnecessary collisions since the first-to-end RTS reception of the T_{w} collision window like TMPQ-MAC. As the number of senders simultaneously increases, the frequency of collisions increases, resulting in higher packet loss rates and increased delays.

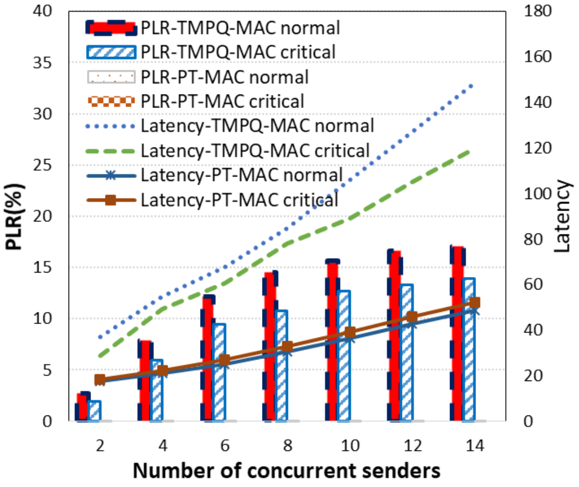


Figure 7. Latency and PLR of data packets with PT-MAC and TMPQ-MAC.

TMPQ-MAC has a high packet loss rate, which increases from over 2% to about 17% as the number of concurrent senders increases. With TMPQ-MAC, the collision window will open until the end of T_{w} in case the sending node does not have the highest priority, during which T_w multiple nodes can send RTS. When the window closes, the receiver chooses the received highest priority RTS for response. When the number of retransmissions is limited, many RTSs are not sent successfully, resulting in many packets not being sent to the receiver.

2) Efficient energy consumption

Figure 8 shows the average power consumption efficiency for PT-MAC and TMPQ-MAC data transmission. It can be noticed that as the number of senders increases from 2 to 14, the average power consumption when using TMPQ-MAC protocol in case of normal and emergency traffic increases rapidly from 0.28 mJ/bit to 1.40mJ/bit and 0.27 mJ/bit to 0.74 mJ/bit respectively. The packet loss rate increases when the number of concurrent nodes increases as shown in Figure 7. Meanwhile, with the PT-MAC protocol, this consumption only increases very slowly from 0.23 to 0.26mJ in both traffic cases, corresponding to a saving of 15% to 80% of energy compared to TMPQ-MAC, equivalent to over 40% of average power under simulated conditions, the more nodes increase, the better the comparative power efficiency. This result shows the advantage of the PT-MAC protocol over TMPQ-MAC in terms of energy efficiency and the adaptation of PT-MAC to the traffic ratio (when the traffic rate changes, the PT-MAC mechanism changes and keeps relative stability in average power efficiency).

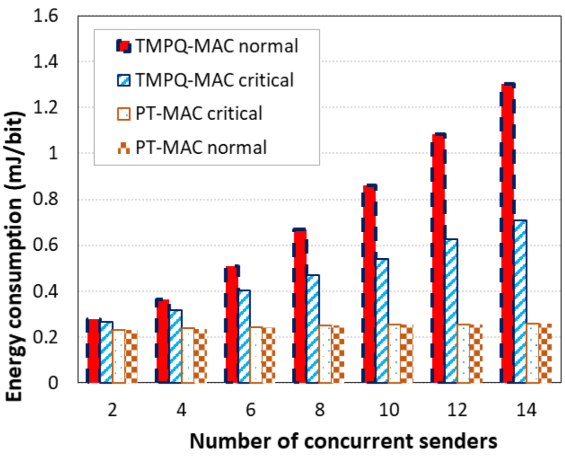


Figure 8. Energy consumption comparison of PT- MAC and TMPQ-MAC.

V. CONCLUSION

In this paper, we introduce a new MAC protocol that is based on data priority and adapts the traffic ratio of priority data types to improve multi-event IoT wireless sensor network performance. The proposed solution to apply priority processing on the collision window is called PT-MAC. This is a media access control solution that combines two mechanisms of SMAC and TMPQ MAC protocols to improve wireless sensor network performance: 1) CSMA/CA with earliest RTS acceptance mechanism and 2) priority on the contention window based on the data type and priority data traffic rate. The estimation results and performance evaluation of the multi-event IoT wireless sensor network using the PT-MAC access control solution are compared with the recent typical access control solution TMPQ-MAC. Our new solution is capable of significantly improving system performance with low packet loss rate and relatively stable and less average power consumption than TMPQ-MAC under different traffic rate conditions.

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PHÂN TÍCH HIỆU NĂNG GIẢI PHÁP MAC DỰA TRÊN TỶ LỆ LƯU LƯỢNG ƯU TIÊN TRONG MẠNG CẢM BIẾN KHÔNG DÂY ĐA SỰ KIỆN

Tóm tắt —Yêu cầu về chất lượng dịch vụ (QoS) cao trong các mạng cảm biến không dây đa ưu tiên đặt ra những thách thức mới lên Internet of Things (IoT). Trong mạng cảm biến không dây đa sự kiện (MWSN), các nút tạo ra các loại gói dữ liệu có mức ưu tiên khác nhau như khẩn cấp (ưu tiên cao) hoặc bình thường (ưu tiên thấp), với tỷ lệ lưu lượng khác nhau. Các gói có mức ưu tiên cao yêu cầu đảm bảo truyền nhanh hơn và độ tin cậy cao hơn trong mạng. Trong nhiều nghiên cứu gần đây, giao thức kiểm soát truy cập phương tiện (MAC) hiện có cho MWSN đã được điều chỉnh để tăng hiệu quả truyền tin và xét mức độ ưu tiên song vẫn chưa xét tới tỷ lệ lưu lượng ưu tiên khác nhau. Do đó, nhóm tác giả đề xuất một giải thuật MAC tiết kiệm năng lượng kết hợp đa ưu tiên của các gói dữ liệu sao cho phù hợp theo tỷ lệ lưu lượng, được gọi là PT-MAC. PT-MAC hỗ trợ đa sự kiện bằng cách xem xét bốn mức độ ưu tiên khác nhau của gói dữ liệu và sử dụng một cách tiếp cận mới để điều chỉnh cửa sổ tranh chấp một cách thích ứng. Việc ước lượng toán học với các tỷ lệ lưu lượng ưu tiên khác nhau cũng được thực hiện kết hợp với mô phỏng trong bài báo cho thấy rằng PT-MAC đảm bảo hiệu năng tốt hơn, đặc biệt là tiết kiệm năng lượng tới gần 40% khi so sánh với giao thức tiền nhiệm TMPQ-MAC.

Từ khóa — Mạng cảm biến không dây IoT, điều khiển truy nhập phương tiện, hiệu quả năng lượng, tỷ lệ lưu lượng ưu tiên.

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