

# Quality of Service Control in Wireless Sensor Network with Priority Access

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## ABSTRACT

In recent years, wireless sensor networks have been widely used in many types of monitoring applications. Conventionally, all sensor nodes are treated equally when they try to gain access to the air channel for packet transmission. For some applications such as in wild fire monitoring, sensor nodes which are in close proximity to a petrol station or residential area should be granted immediate access to the air channel when required to report a fire outbreak. Sensor networks are always built by using low cost and low specification hardware components. In our research, we begin by looking into the feasibility of developing a priority medium access scheme on top of this low spec hardware platform. Tinyos and Crossbow MICAz were used in prototyping and experiments. In this paper, a summary of experimental programme and test results for a CSMA/CA priority scheme are provided.

## KEY WORDS

Priority medium access control, priority queue, wireless sensor networks. TinyOS, MICAz.

## 1. Introduction

The key attributes of wireless sensor networks (WSN) low cost, minimal maintenance requirement and flexibility [1] have dramatically increased the range of application where such networks are considered. Environmental monitoring, surveillance, and asset management and tracking are a few of the common applications where this technology offers significant operational benefits.

Boosted by a growing demand for sensor networks, the development of WSN has improved steadily in term of integration, survivability, and functionality. Recently, a number of medium access control (MAC) protocols have been proposed [2, 3]. The main advantages of these protocols are improved power conservation and scalability where sensor nodes are able to operate in low power consumption with lengthy sleep period and form an autonomous network for data gathering. The primary objectives of these protocols are always focused on energy conservation, scalability, and self-configuration, whereas priority access and temporal delay are often

secondary and sometimes might not even being considered.

In [4], sensor network traffic has been defined as event-based considering the traffic pattern is mainly correlated to phenomena which have been observed in a sensor network. The amount of transmissions carried out by the sensor nodes generally increase in response to an external event. The network might be overloaded with traffic as the number of sensors transmissions increases. This situation has been outlined as one of the potential problems [5] since some of the strategically important sensor nodes might not be able to communicate an event to the sink quickly. To understand this problem further, an experiment has been conducted to evaluate a network performance in a fire outbreak event where 13 sensor nodes are configured to simulate the detection of a fire alert and begin competing access to the shared channel.

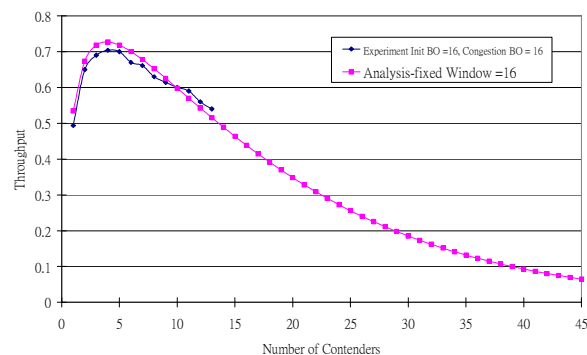


Figure 1. Network throughput versus number of contenders.

Figure 1 shows the result of network throughput which degrades as the number of sensor nodes increases resulting in greater competition for access to the air channel. According to the analysis, the network throughput is projected come to a halt where network throughput below is 10% when the number of contenders increases to 40.

This paper looks into the possibility to use a priority based medium access control allowing some of the strategically important sensor nodes get their data through the congested network with minimum delay and loss. The paper is organized as in the following. In section 2, the CSMA/CA based priority scheme is described.

Experiments and results are presented in section 3 and the paper is concluded in section 4.

## 2. Priority Medium Access Control

The priority MAC is based on the well known carrier sense multiple access/collision avoidance (CSMA/CA) [3] function which works on listen-before-talk principle. There are a few standardised CSMA/CA based priority protocols such as IEEE 802.11 DCF which are commonly used in high speed computer networks and Internet Protocol (IP) applications. However these protocols are complicated and are generally not applicable to WSN due to the limitation of sensor node’s hardware. Here we evaluate a class of service priority scheme developed by simplifying 802.11 DCF [6], and we refer this scheme as P-MAC.

In P-MAC, a classifier and a set of priority queues are integrated into CSMA/CA MAC core module. CSMA/CA defines two unique procedures to allow sensor nodes access to the air channel with fairness and also reduces collision probability. The first procedure is the CSMA, which has defined a sequence of actions to regulate transmissions of individual sensor nodes. Before initiating a transmission, each node is required to sense the shared air channel and perform an initial binary backoff. The second procedure is referred as the CA mechanism, which is only performed by the sensor node when a collision takes place. The CA procedure will generate a new backoff time (BT) randomly from a contention window (CW) size:

$$BT = random [CW_{min}, CW_{max}] \times slot\ time \quad (1)$$

P-MAC defines strategic important sensors as high priority nodes allowing them to gain access to air channel before other low priority nodes. Without introducing extra complexity the high priority sensor nodes operate in fundamentally the same way as the lower priority sensor nodes except that P-MAC defines a shorter initial binary backoff and a smaller CW for the high priority nodes. Figure 1 shows the flow diagram of P-MAC protocol.

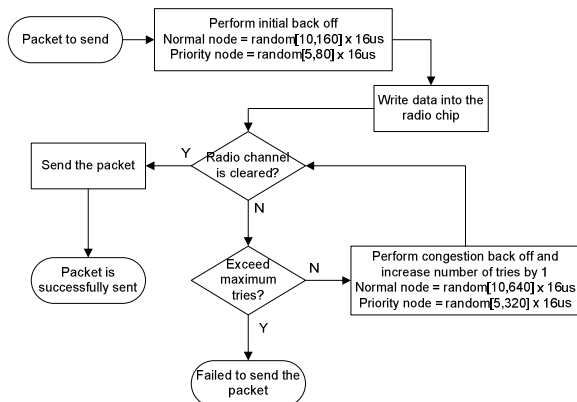


Figure 2. P-MAC flow diagram

An experiment has been setup to verify that the priority node has indeed given privilege in access the air channel. In the experiment, 25 normal nodes were placed together with 5 priority nodes. All of these nodes are set to transmit packets with 0.16s interval and generating 150 kbps of traffic. Figure 2 contrasts the packet delay and loss between priority node (ID 26 ~ 30) and normal nodes (ID 1~25).

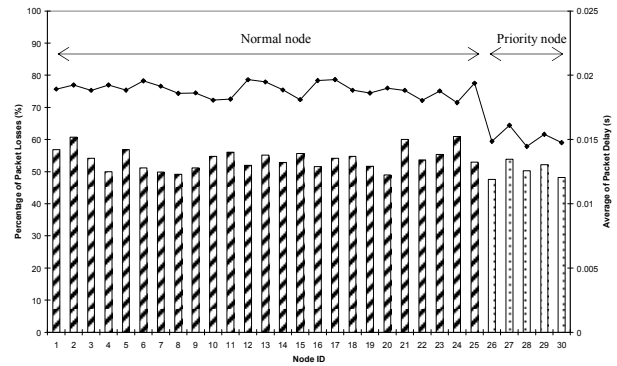


Figure 3. Comparison between priority node and normal node.

The figure shows that on average priority nodes have 4% fewer packet loss than normal nodes and packet delay of priority nodes has significantly outperformed that of normal nodes. The above experiment has clearly shown that a minor alteration of the initial backoff and CW lengths priority nodes are favoured to access to air channel before other nodes. Although, priority nodes have outperformed normal nodes in winning the access right to air channel but this does not guarantee that the packet released by the priority node can reach its destination promptly unless the following relay nodes process this packet with a special procedure.

In this P-MAC scheme, relay node instead of using conventional first-in-first-out packet relay scheme. It will give privileged treatment to the priority packets and allow them to be forwarded before other packets. Therefore, in a hop-by-hop basis, the priority packets are relayed before any other packets and thus can arrive to the destination in a timely manner. To achieve this, a multiple queuing structure is required for the relay nodes. In this paper, two different queues are applied in the relay nodes. The first queue is used to buffer priority packets and the second queue is for accommodating other packets. Packets in the priority queue are given special treatment and allowed to be forwarded before others. Figure 4 shows a forwarding flow diagram of a relay node.

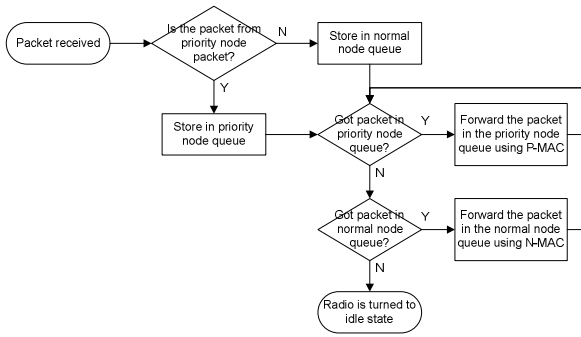


Figure 4. A forwarding flow diagram of relay node

### 3. Experiment and Result

In the experiments, the network is configured as in Figure 5 and is conducted using Crossbow MICAz module [7]. In the experiment, three radio zones are setup and in each of the radio zone, 10 nodes (9 normal nodes and 1 priority node) and a relay node presented. The relay node is responsible to forward all received packets to next relay node.

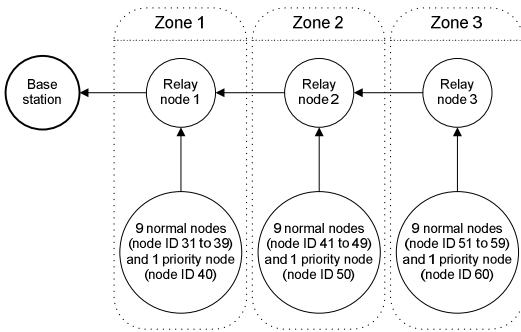


Figure 5. Network configuration used in experiment setup.

A Poisson traffic generator was used in each node and the total network load for the experiment is 150kbps. The parameters applied in the experiments are listed in Table 1.

Table 1. Experiment parameters.

Parameters	Normal node packet	Priority node packet
Initial back off	$random[10,160] \times 16 \mu s$	$random[5,80] \times 16 \mu s$
Congestion back off	$random[10,640] \times 16 \mu s$	$random[5,320] \times 16 \mu s$
Queue size to accommodate the packet	20	5

In the experiments, sensor nodes (including normal and priority nodes) compete with each other for packet transmissions. The relay node is positioned in an overlapped area where it not only can receive packets

from its own radio zone but it also can communicate with other relay nodes.

After successfully receiving a packet (from either sensor nodes or relay nodes) the relay node will place the packet in either priority queue or a normal queue according to marker inside the packet structure. The packets stored in these queues will be forwarder to next relay nodes according to the procedure defined in Figure 4.

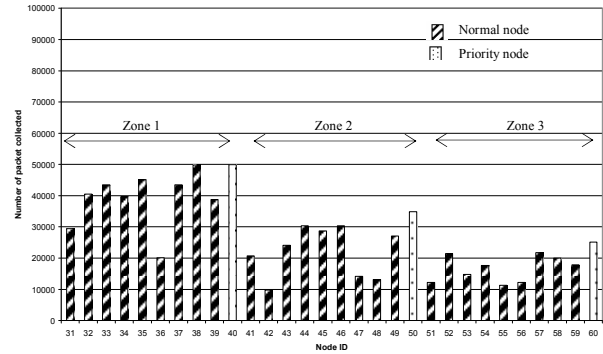


Figure 6. Amount of data collected at base station

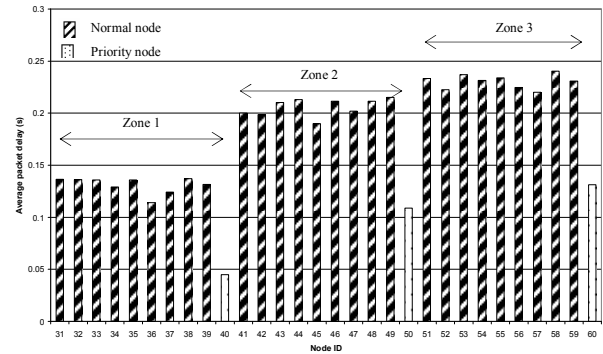


Figure 7. Average of end-to-end packet delay

Figure 6 shows the amount of data collected at the base station. The results show that the priority node in radio zone 3 has a 52% greater transmission of packets to the base station compared to the normal nodes. Further, the priority node's packets reach the destination 1.7 times faster than the packets released by normal nodes. Figure 7 illustrates packet average delay for various nodes. A summary of the results gathered during this experiment are listed in table below.

Table 2. Average delay and successful transmission rate.

		Normal node	Priority node
Zone 1	Average delay	0.131s	0.045s
	Successful Transmission	38.94%	49.93%
Zone 2	Average delay	0.206s	0.109s
	Successful Transmission	22.03%	34.87%

Zone 3	Average delay	0.230s	0.131s
	Successful Transmission	16.57%	25.18%

### 3.1 Relay node performance and analysis

When the priority nodes' packet relayed hop-by-hop enroute to the base station, relay nodes play a crucial part in ensuring that they are forwarded in as shortest time as possible. In the experiment, each relay node has two queues to accommodate priority nodes' packets and normal nodes' packets. The relay nodes will always process the packets in the priority queue and it will only process packets in normal queue when the priority queue is empty. The relay node, when required to transmit a priority packet, will use the initial and congestion backoffs defined for priority node in competing the air channel. Whereas, when it is required to transmit a normal packet it will switch back to the normal backoff values.

Figure 8 shows average waiting time for packets from normal and priority nodes in a relay node. For relay node 3, the waiting times for both priority node and normal node packets are shorter compared to those of relay node 2 and relay node 1. This is because relay node 3 is only responsible for relaying packets generated in radio zone 3. On the other hand, relay node 2 and relay node 3 not only require to process packets from their own radio zone but they also need to relay packets from other radio zones which have been forwarded to them.

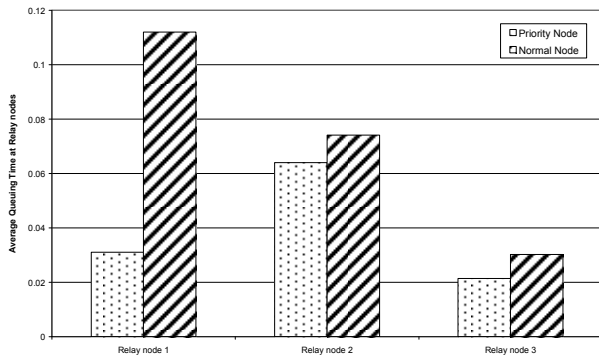


Figure 8. Average waiting for normal node and priority node packets stay in a relay node.

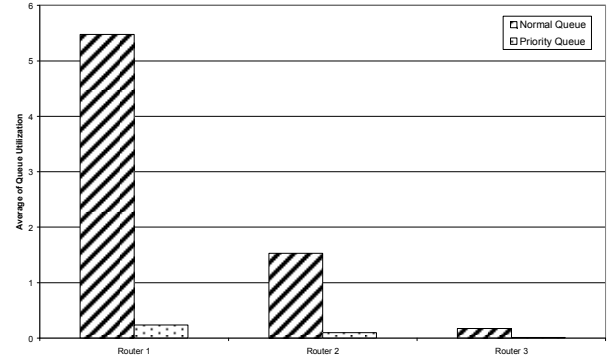


Figure 9. Average of queue utilization for normal queue and priority queue.

Figure 9 shows the average of queue utilization by the relay nodes. In this figure, the queue size for normal nodes' packets has grown exponentially when the relay nodes are closer to the base station. Conventionally, only single queue exists in the relay node and all packets are treated in first come first out manner. Given the exponential growth of the queue size, longer queuing delay and higher packet loss (due to overloaded queue) will occur in the relay node closer to the base station. This phenomenon is highly undesirable as for each hop a packet travels it not only consumes bandwidth but also consumes the limited amount of power resource. Also shown in this figure is the fact that more packets are lost when they are very close to the final destination – the base station.

In a typical sensor network, the traffic volume will sharply increase as traffic is correlated to an observation of an external event. It is unlikely that it will be possible to regulate the sensor node's traffic in an event driven environment. Therefore, instead of focusing on how to shape or on attempting to regulate the traffic, this paper applies a class of service approaches to ensure that crucial information is reaching the base station.

## 4. Conclusion

Consideration of various WSN has shown that packets suffer not only longer queuing delay but also suffered higher loss when they are within the final few hops away from the base station. This phenomenon is caused by the fact that a sudden burst of traffic generated by sensor nodes when a major event has been detected. This situation has delivered a common false sense that WSN is not reliable for large scale monitoring purposes where an event trend to escalate quickly. Consequently WSN are sometimes considered inappropriate for some industrial applications. Of course, the situation can be improved by changing the design space of wireless sensor network by adopting high end hardware. In this paper, an alternative solution is proposed where a simplified version of 802.11 DCF priority scheme have been used to deliver some of

the sensor node's packets which have been classified as strategic important information. Experimental results have shown that this important information can be promptly relayed back to base station even though the network is overloaded.

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