1. INTRODUCTION

Real-time monitoring is one of the prime necessities for a weapon flight test that is required for the efficient and timely collection of large amounts of high-rate sampled data acquired by an event-trigger. The wireless sensor network is a good candidate to resolve this requirement, especially considering the inhospitable environment of a weapon flight test. In this paper, we propose a priority based multi-channel MAC protocol with CSMA/CA over a single radio for a real-time monitoring of a weapon flight test. Multi-channel transmissions of nodes can improve the network performance in wireless sensor networks. Our proposed MAC protocol has two operation modes: Normal mode and Priority Mode. In the normal mode, the node exploits the normal CSMA/CA mechanism. In the priority mode, the node has one of three grades - Class A, B, and C. The node uses a different CSMA/CA mechanism according to its grade that is determined by a signal level. High grade nodes can exploit more channels and lower backoff exponents than low ones, which allow high grade nodes to obtain more transmission opportunities. In addition, it can guarantee successful transmission of important data generated by high grade nodes. Simulation results show that the proposed MAC exhibits excellent performance in an event-triggered real-time application.

Keywords : Wireless sensor networks, Real-time monitoring, Weapon flight test, Multi-channel MAC

Abstract

Real-time monitoring is one of the prime necessities of the test and evaluation (T&E) of a weapon flight test for test command and control as well as the safety of people and property. The flight test of weapon systems such as missiles, rockets and artillery is very dangerous and occurs within short spans of time. The monitoring system of the weapon system for detection of submunitions or debris falling on land or sea can be used in a virtually wide and inhospitable environment, even those where wired connections are not possible, or where physical placement may be difficult.

A Wireless Sensor Network (WSN) [1-3] is a good candidate to monitor the test environment of land or sea by the wireless ad-hoc network which connects deeply embedded sensors, actuators, and processors. WSNs are used over a wide range such as military application, environmental monitoring, medical care, smart buildings and other industries. Recent WSNs are considered to support more complex operations which require high throughput, timeliness, and energy-efficiency.

Energy efficiency is a main objective in most Medium Access Control (MAC) protocols for WSNs [4-7]. Other parameters such as bandwidth utilization, low-latency and scalability are dealt with as secondary objectives. However, bandwidth and low-latency are as important as saving energy in some applications requiring real-time monitoring.

The flight test is an event-triggered application [8] in which sensor nodes do not transmit any data unless an actual relevant event occurs, i.e. an explosion and/or a crash. When sensor nodes detect an event, they send a sensed data to the sink at the same time. It can generate a traffic burst in a network. Since an event typically triggers many sensor nodes concurrently, the occurrence of traffic bursts produced by different nodes is highly correlated in time domain. Bursty or heavy wireless communication in one location may lead to contention for channel access by the nearby sensor nodes. WSNs for the weapon flight test require the efficient and timely collection of large amounts
data with high resolution. However, WSN using a single channel or the 802.15.4 wireless network cannot provide these requirements because of radio collisions and limited bandwidth.

The 802.15.4 standard defines a protocol for Low Rate Wireless Personal Area Networks (LR-WPAN) and has been generally used for many applications in WSNs. Its network bandwidth is limited and the MAC layer packet is small with a typical size of 30-50 bytes compared to 512 bytes in the 802.11 wireless networks. WSN using the 802.15.4 standard is not suitable for our situation because of its constraints. The media access method of the 802.11 is Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA). It is a contention-based protocol which concentrates on the collisions of transmitted data and was developed mainly for wireless networks. Multi-channel is used to assign different nodes to different frequency bands in wireless networks. Multi-channel exploits bandwidth better and thus may exhibit good performance in case of applications requiring a high data rate. The 802.11 standard has up to three non-overlapped channels (channel 1, 6, and 11). Applying the multi-channel assignment to the 802.11 scheme would help to decrease contention for a single medium, congestion and collision. Recently, there have been many proposed MAC protocols so as to improve network performance in WSN.

Existing MAC protocols are not well-suited for the real-time monitoring of such event triggered applications with large amounts of data. Characteristics of events in the weapon flight test are different from ordinary environments. We may not know the exact location of an event point in a wide test zone, and an event occurrence time is very short. Therefore, schedule based multi-channel protocols are inappropriate to a real-time monitoring of the weapon flight test. The scheduled multi-channel schemes are needed to negotiate time and procedure before data packet transmission between the sender and the receiver node. Data of an event area is the interesting information which is more reliably and timely transmitted to the base station than other areas.

Our research is focusing on the design of the priority based multi-channel MAC protocol with CSMA/CA over a single radio for the real-time monitoring WSN in the weapon flight test. The proposed scheme can improve network throughput and provide reliable and timely communication services for our purpose.

Our proposed MAC protocol adds a specialized priority factor at the normal slotted CSMA/CA mechanism considering the weapon flight test environment. This MAC protocol gives high transmission priority to the inner nodes of the event area than the outer nodes. Furthermore, this MAC protocol can obtain not only the collision reduction effect between nodes in the whole sensing area but also guarantee data transmission of high grade nodes. Our proposed MAC protocol has two operation modes. One is ‘Normal’ mode and the other is ‘Priority’ mode. In the normal mode, nodes are operated on normal CSMA/CA. Also, nodes have different priority depending on a sensed signal level in the priority mode. High grade nodes can use more channels for data transmission than low grade nodes. The grade of nodes is determined by its own sensed data in the priority mode. Nodes have one of 3 grades - Class A, Class B and Class C. When sensed data at each node exceed a specific threshold value, each node has a specific grade. High grade nodes have low backoff exponents and can obtain more transmission opportunities than those of low grade node. These mechanisms guarantee successful transmission of important data generated by high grade nodes.

This paper is a revised and extended version of a paper that was presented at SENSORCOMM 2012 [19].

The rest of this paper is organized as follows. Section-II reviews the related works. Section-III presents the proposed priority based multi-channel MAC protocol scheme in detail. Then, in section-IV we show performance evaluation through simulations. Finally, section-V concludes this paper with summary and directions for future work.

2. RELATED WORKS

Researchers have proposed multi-channel MAC protocols [10-15] that exploit multiple channels to increase the network throughput by eliminating the contention and interference on a single-channel in WSNs. WSNs have some limitation such as limited computation, low bandwidth, small MAC layer packet size, battery-operated power, and so on. Therefore, the multi-channel MAC protocol for WSNs should consider the minimum control overhead possible in channel negotiation. Channel negotiation packets cannot be ignored as small overhead.

Multi-channel MAC protocols can be classified into three categories [9]: scheduled protocols [10-12], contention protocols [13, 14], and hybrid protocols [15].
2.1 Scheduled multi-channel MAC protocols

In this scheme, a time slot in the TDMA frame for data transmission is allotted to every node which is unique in its 2-hop neighborhood. This guarantees collision-free medium access, and the protocol does not waste energy and bandwidth on competition and collisions.

MC-LMAC [10] proposed a multi-channel scheme based on LMAC which allows the node to utilize new frequency channels on-demand, if the network reaches a density limit. This method is composed of two phases, one where the nodes attempt to select timeslots according to the single channel in the LMAC rule and the other involves nodes which are unable to grab a timeslot in the first phase invite the neighbor nodes which are free to listen to them on an agreed channel or time slot.

TMCP [11] is a tree-based multi-channel protocol for data collection applications. The goal is to partition the network into multiple subtrees with minimizing the intra-tree interference. The protocol partitions the network into subtrees and assigns different channels to the nodes residing on different trees. TMCP is designed to support convergecast traffic and it is difficult to have successful broadcasts due to the partitions. Contention inside the branches is not resolved since the nodes communicate on the same channel.

In TFMAC [12], a channel scheduling mechanism is used to manage and decide when a node should switch channels to support the current communication requirements. TFMAC requires time synchronization and it uses a single half duplex transceiver. This protocol divides each channel into time slots and the slot scheduling has been done for the medium access. The frame has been divided into a contention access period where the slot scheduling and channel allocation have been done and the contention free period where the data transfer has been done.

2.2 Contention-based multi-channel MAC protocols

Contention-based multi-channel MAC protocols use neither a predetermined transmission schedule nor the frame which is divided into time slots. Instead, the contention procedure is conducted at the beginning of each frame, beforehand every transmission, in order to avoid collisions. Contention-based MAC protocols allow a small delay and high throughput in cases of low traffic.

MMSN [13] and TMMAC [14] have attempted to make use of multiple channels by assigning different channels to different nodes in a two-hop neighborhood to avoid potential interference. They use a different channel from its downstream and upstream nodes. Time slots are used to coordinate transmissions in these protocols. In addition, they also require precise time synchronization at nodes with frequent channel switching delays and scheduling overheads especially for high data traffic. In the multi-hop flow, nodes have to switch channels in order to receive and forward packets. This causes frequent channel switching and potential packet losses. In order to prevent packet loss, these protocols use some negotiation or scheduling schemes to coordinate channel switching and transmission among nodes with different channels. They require many orthogonal channels for channel assignment in dense networks.

2.3 Hybrid multi-channel MAC protocols

These protocols combine principles from the previous two methods. The frame is divided into time slots, but slots are assigned to receivers instead of transmitters. In the absence of traffic, hybrid protocols are more energy efficient than scheduled protocols, since each node needs to be awakened to receive data only once per frame. Although hybrid protocols require contention of the potential transmitters at the beginning of each slot, the contention mechanism is simpler and wastes less energy than contention-based protocols since there is always only one receiver.

Y-MAC [15] is a hybrid multi-channel MAC protocol and divides time into frames and slots, where each frame contains a broadcast period and a unicast period. Every node must wake up at the beginning of a broadcast period and nodes contend to access the medium during this period. If there are no incoming broadcast messages, each node turns off its radio awaiting its first assigned slot in the unicast period. Each slot in the unicast period is assigned to only one node for receiving data. This receiver-driven model can be more energy-efficient under light traffic conditions, because each node samples the medium only in its own receive time slots.

3. PROTOCOL DESCRIPTION

Our approach uses priority based multi-channel assignments in the 802.11 network over a single radio for
the specific WSN application which is real-time monitoring for the weapon flight test. Our proposed MAC protocol distributes the nodes in a network to multiple channels, so this method can reduce collisions between nodes in a network and improve network transmission efficiency [16, 17]. Our MAC protocol has two operation modes. The first is 'Normal' mode and the second is 'Priority' mode. Change of the operation mode is controlled by an external command. Two modes also exploit the normal slotted CSMA/CA mechanism. Furthermore, nodes have a different transmission opportunity according to their priority in the priority mode. High grade nodes can use more transmission channels and lower Backoff Exponents (BE) than low grade nodes. This can guarantee the successful transmission of important data generated by high grade nodes.

### 3.1 Normal Mode

In a general situation, the proposed MAC protocol operates a normal CSMA/CA. But, nodes in a network can use multiple channels, and perform not only time backoff but also channel backoff [18]. This twin backoff mechanism is more efficient to avoid collisions between nodes in a network. All nodes have the same Contention Window (CE) and Backoff Exponents (BE), and can use three channels.

When nodes need to transmit sensed data, they first generate a backoff value, select a random transmit channel, and perform Channel Clearance Assessment (CCA) in the selected channel on time. If the selected channel is idle, the node transmits their data. Otherwise, nodes perform a new time and channel backoff using a new CW and increased BE value. Detailed description about this procedure is represented in Fig. 1. The first sequence is a variable initialization. The number of Backoff (NB) is 0 and the CW value of the node is 0. The BE value of the node is pre-defined. After this initialization sequence, each node selects its own data channel and waits for the end of the backoff period. At the backoff period boundary each node checks the channel situation. If the selected channel situation is clear, the node decreases the CW value and checks the CW value. If the CW value is 0, the node executes data transmission. Otherwise, the node performs CCA on the next backoff period and repeats the above sequence. If the channel situation is busy on the backoff period boundary, each node increases the NB value, resets the CW value and reselects the BE value. After this sequence, the node compares MaxBackoffs with the NB value. If the NB value of the node is bigger than the MaxBackoffs value, the node drops its data packet and attempts to send the next data packet in order to transmit a next packet. If the NB value is smaller than MaxBackoffs, each node repeats channel selection to check the channel situation.

![](image)

**Fig. 1. Procedure flow chart of normal mode.**

### 3.2 Priority Mode

In priority mode, each node has one of three degrees - Class A, Class B, and Class C. Fig. 2 represents the procedure of the priority mode. The grade of nodes is determined by a sensed signal level at the sensor node. Two threshold values - THR1 and THR2 (THR1 > THR2) are defined preliminary before the flight test of the weapon systems. If the node detects the sensed value larger than THR1 during the specific period, its degree is determined as Class A. Class B node has a sensed value between THR1 and THR2. Also, Class C node has a sensed value below THR2. Each node is worked by a different CSMA/CA mechanism according to its grade, respectively. High grade node has low Backoff Exponents and can use
more transmission channels. This mechanism allows that the high grade node has more transmission opportunity and guarantees transmission of important data generated by high grade nodes.

Fig. 2. Procedure flow chart of priority mode.

Each grade has its own basic channel which is one of three non-overlapped channels on the 802.11 wireless network. A basic channel of Class A, B, and C is named the first channel (CH-1), the second channel (CH-2), and the third channel (CH-3), respectively.

Fig. 3 represents the state diagram for the priority operation mode. We can divide it into 4 states which are the initial state, selection state, check state and decision state. Firstly, in the initial state, each node initializes their parameter such as CW, BE and NB. After initialization, the nodes change their state to selection state. In this state, each node decides their grade. Each node selects a data channel and backoff slots according to its own grade. On the boundary of the backoff slot, the node performs the CCA mechanism and evaluates the channel situation. If the channel is clear, the node changes its own state to a decision state. Otherwise, the nodes state becomes a selection state, and the node performs a channel and backoff selection procedure again. In the decision state, the node checks the CW value. If the CW value equals 0, the node performs data transmission. Otherwise, the node returns its own state to the previous check state.

Class A nodes can access all channels. Thus, these nodes can access media easier than other grade nodes. Class B nodes can use 2 of 3 channels and Class C nodes only use one data channel. Each node decides its own transmission priority when sending data generated by a pre-determined threshold value. Following its own transmission priority, each node selects the BE and TX channel. After the selection of the BE and TX value, each node perform CCA on the backoff period boundary. If the channel is clear, the nodes perform the data sending sequence. But, if the channel is busy, the nodes perform the backoff sequence. In the backoff sequence, a node only reselects the TX channel.

All nodes can access the CH-1 where many collisions may occur between all nodes. We also propose a channel selection weight factor for reducing this collision at the common channel. Each node has a weight factor to select a channel. Class A and Class B nodes select their own basic channel more frequently due to this weight factor. The weight factors of nodes in Class A and Class B are expressed as 1:1: \(w_A\) and 1: \(w_B\), respectively, where the default value of \(w_A\) and \(w_B\) are 1. The channel selection probabilities after the grade decision of nodes are expressed as:

Fig. 3. State diagram of priority mode.
The probabilities $P(CH_1)$, $P(CH_2)$ and $P(CH_3)$ are that nodes select the CH-1, CH-2 and CH-3 in three grades, respectively, and are given by:

$$P(CH_1) = \frac{pa}{2 + w_A} + \frac{pb}{1 + w_B} + pc$$  \hspace{1cm} (8)

$$P(CH_2) = \frac{pa}{2 + w_A} + \frac{pb \cdot w_B}{1 + w_B}$$  \hspace{1cm} (9)

$$P(CH_3) = \frac{pa \cdot w_A}{2 + w_A}$$  \hspace{1cm} (10)

Where $P(A)$, $P(B)$ and $P(C)$ are the grade decision probability of nodes, and are denoted by $P(A) = pa$, $P(B) = pb$ and $P(C) = pc$.

We examine the effect of the weight factor on the channel selection in each grade through the simple example whose result is shown in Table 1. All nodes can access the CH-1 which is predicted to be busy. Only part of Class A nodes can access the CH-3 which is relatively idle in comparison with CH-1. We assume that all classes have the same nodes. Hence, $pa$, $pb$ and $pc$ are 1/3. Default weight factors are applied to Case-1. The weight factors of Class A and Class B are 1:1:3 and 1:1:2, respectively, in Case-2. As shown in Table 1, Case-2 achieves lower $P(CH_1)$ and higher $P(CH_3)$ than Case-1 being approximately 10.0% lower and 8.9% higher, respectively. Namely, selecting the probability of a busy channel is decreased and that of a relatively idle channel is increased. This result shows that applying the weight factors in the channel selection would help to raise the availability of overall channels.

Table 1. Channel selection probability according to the weight factors

<table>
<thead>
<tr>
<th>Channel Selection Probability</th>
<th>Case-1</th>
<th>Case-2</th>
<th>Variation Rate [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$w_A=1, w_B=1$</td>
<td>61.1%</td>
<td>51.1%</td>
<td>-10.0</td>
</tr>
<tr>
<td>$w_A=3, w_B=2$</td>
<td>27.8%</td>
<td>28.9%</td>
<td>+ 1.1</td>
</tr>
<tr>
<td>$w_C=3$</td>
<td>11.1%</td>
<td>20.0%</td>
<td>+ 8.9</td>
</tr>
</tbody>
</table>

**4. SIMULATION RESULTS**

The proposed multi-channel MAC protocol is evaluated by simulation. As previously mentioned, when sensing an event, all nodes will be made aware of their priority and the number of available channels. When a node needs to transmit data, the CSMA mechanism is invoked in order to determine the availability of the channel. If the number of backoffs is smaller than MaxBackoffs, each node repeats the channel selection to check the channel situation during the backoff period. Otherwise, the node drops this data packet and attempts to send the next data packet.

A matter of interest is the performance enhancement of Class A nodes because data of the Class A node is more important than that of Class B and C. We assume that the number of sensor nodes is 30, each class has ten nodes, and nodes are uniformly distributed in a test area. All nodes have a single radio transceiver and can communicate with each other within a single-hop range on three non-overlapped channels. The duration of time slots in each channel is 10,000.

Simulation scenarios include six cases according to the type of the operation mode and the weight factor value which are shown in Table 2. Also, we compare the performance of our proposed scheme according to the variation of the BE ranges. We use three performance metrics: (i) media access delay, (ii) the number of transmitted time slots by sources, and (iii) the number of transmission opportunities at sources.
Fig. 4. Comparison of number of delayed time slots according to BE range.

(a) BE range from 3 to 5  (b) BE range from 1 to 4

Fig. 5. Comparison of the number of delayed time slots according to grade and weight factors.

(a) Normal mode  (b) Priority mode  (c) Priority mode with weight factors

Fig. 6. Comparison of the number of transmission opportunities according to BE range.

(a) BE range from 3 to 5  (b) BE range from 1 to 4

Fig. 7. Comparison of the number of transmission opportunities according to grade and weight factors.

(a) Normal mode  (b) Priority mode  (c) Priority mode with weight factors

Fig. 8. Comparison of the number of transmitted time slots according to BE range.

(a) BE range from 3 to 5  (b) BE range from 1 to 4

Fig. 9. Comparison of the number of transmitted time slots according to grade and weight factors.
All nodes in scenario 1 and 2 can randomly access one of three channels in the normal mode. Nodes in Scenario 3, 4, 5 and 6 are operated as a priority mode and have different transmission opportunities according to their grade and weight factor. The BE range of nodes is 3 to 5 in Ref-1, Pri-A1 and Pri-B1. Nodes in Ref-2, Pri-A2 and Pri-B2 have another BE range from 1 to 4. The operation conditions of the 6 scenarios are shown in Table 2.

Performances of 6 scenarios are shown in Fig. 4 to Fig. 9. Fig. 5(a), Fig. 7(a) and Fig. 9(a) present the performances of nodes in Ref-1, Pri-A1 and Pri-B1 which are same BE range from 3 to 5 respectively. In case of BE range from 1 to 4 performances of nodes in Ref-2, Pri-A2 and Pri-B2 are shown in Fig 5(b), Fig. 7(b) and Fig. 9(b) respectively. Performances of cases which have same mode and same weight factors are shown in Fig. 5, Fig. 7 and Fig. 9.

Access delay of the 6 scenarios is shown in Fig. 4 and Fig. 5. Nodes of Ref-1 and Ref-2 are operated as a normal mode and have similar access delay regardless of their grades. Nodes of Pri-A1, Pri-A2, Pri-B1 and Pri-B2 are operated as a priority mode in which the number of available channels of nodes depends on the grade of the node.

The access delay bar graphs show a decrease in Class A nodes on the Priority mode. However, the access delay value of Class C nodes has increased because they have only one available channel. The access delay of Class B nodes has a similar value in both the normal mode and priority mode. Nodes of Class A have more transmission opportunity than those of other grades which means that the data of Class A nodes can be more quickly transmitted to sink than that of other classes. Fig. 5 represents the access delay according to the variation of BE range in specific scenarios which is the same mode with equal weight factors. The smaller BE range the nodes have, the smaller access delay the nodes have. However, the smaller access delay does not always lead to more successful transmission in nodes.

If nodes successfully transmit their data without collision, they should secure a sufficient bandwidth. In the priority mode, Class A nodes have three available channels so they can transmit their data to sink with less collision. However, the possibility of collision is increased in Class C nodes because they only have one available channel.

Fig. 6(a) presents the transmission opportunity of nodes in 3 scenarios which have a BE range of 3 to 5. Fig 6(b) represents performances of nodes in case of a BE range from 1 to 4.

Fig. 6 expresses that nodes have similar transmission opportunity in the normal mode. In addition, Class A nodes have greater transmission opportunities when they are operated as in Priority with the weight factors. Class B nodes have somewhat similar values in scenarios which have the same BE range. But the performance of Class C nodes is decreased in the priority mode.

Fig. 7 represents the transmission opportunity according to the variation of BE range in the same mode and same weight factors. Nodes have larger transmission opportunities in case of the smaller BE range.

If nodes do not have sufficient bandwidth, the real transmitted slot is not increased even though the transmission opportunity of nodes is increased. Thus, we compare the number of transmitted time slots in 6 scenarios whose results are shown in Fig. 9 and Fig. 10.

Fig. 8 shows the number of transmitted time slots of nodes in 6 scenarios. This shows that the transmitted time slots are of similar value regardless of their grade in the normal mode. Class B nodes have somewhat similar values in scenarios with the same BE range. The transmitted time slots have increased in Class A nodes of the priority mode with the weight factor. Namely, the performances of Pri-B1 and Pri-B2 are superior to those of Pri-A1 and Pri-A2.

Fig. 9 demonstrates the number of transmitted time slots of nodes in case of a BE range from 3 to 5 and 1 to 4. This shows that the transmitted time slots of Class A nodes in the priority mode are increased but those of other classes

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Operation Mode</th>
<th>Weight Factor</th>
<th>Available Channel</th>
<th>BE Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref-1</td>
<td>Normal Mode</td>
<td></td>
<td>Ch-1,2,3</td>
<td>3~5</td>
</tr>
<tr>
<td>Ref-2</td>
<td>Normal Mode</td>
<td></td>
<td>Ch-1,2,3</td>
<td>1~4</td>
</tr>
<tr>
<td>Pri-A1</td>
<td>Priority Mode</td>
<td>ClassA 1:1:1</td>
<td>Ch-1,2,3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ClassB 1:1</td>
<td>Ch-1,2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ClassC 1</td>
<td>Ch-1</td>
<td></td>
</tr>
<tr>
<td>Pri-A2</td>
<td>Priority Mode</td>
<td>ClassA 1:1:1</td>
<td>Ch-1,2,3</td>
<td>1~4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ClassB 1:1</td>
<td>Ch-1,2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ClassC 1</td>
<td>Ch-1</td>
<td></td>
</tr>
<tr>
<td>Pri-B1</td>
<td>Priority Mode</td>
<td>ClassA 1:1:3</td>
<td>Ch-1,2,3</td>
<td>3~5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ClassB 1:2</td>
<td>Ch-1,2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ClassC 1</td>
<td>Ch-1</td>
<td></td>
</tr>
<tr>
<td>Pri-B2</td>
<td>Priority Mode</td>
<td>ClassA 1:1:3</td>
<td>Ch-1,2,3</td>
<td>1~4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ClassB 1:2</td>
<td>Ch-1,2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ClassC 1</td>
<td>Ch-1</td>
<td></td>
</tr>
</tbody>
</table>
show opposite results.

As shown in Fig. 8 Pri-B1 and Pri-B2 achieve a much higher transmission ratio than Ref-1 and Ref-2 (about 34% higher) with a BE range from 3 to 5 and 82% with a BE range from 1 to 4 in Class A nodes. An increase of the transmitted slots in Class A is largely due to the increase of the transmission opportunity as well as sufficient bandwidth. When the BE range of nodes in Class B and Class C is decreased, the possibility of collision becomes larger in their transmission channels. One cause of increasing collision is the insufficient bandwidth compared with the number of nodes attempting to transmit data. Consequently the number of transmitted time slots of nodes is decreased in Class B and Class C.

In summary, we can achieve a greater number of time slots for Class A nodes in priority mode with weight factors.

5. CONCLUSIONS

In this paper we present a priority based multi-channel MAC protocol with the modified CSMA/CA over a single radio for the real time monitoring of a weapon flight test.

The Real-time monitoring is one of the prime necessities of the flight test for weapon systems. Data of an event area is the interesting information which is more reliably and timely transmitted to the base station than other areas.

Our proposed protocol has two operation modes: normal mode and priority mode. In normal mode, nodes are operated on normal CSMA/CA. Moreover, nodes have different priority with different weight factors according to the sensed signal level in priority mode. High grade nodes in the priority mode can have more available channels and lower backoff exponents for data transmission than low priority nodes.

We evaluate and verify the effectiveness of the proposed scheme by comparing the 6 scenarios. Simulation results show that more data in high grade nodes is quickly transmitted to sink than that in low grade nodes.

In the future, we plan to setup a test bed sensor network system and evaluate the performance of the proposed MAC.

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