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Temperature Aware MAC Protocol for CSMA/CA Networks in Fire Sites

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Abstract—**In this paper, we present the issue of exploiting the temperature aware frame scheduling and transmissions especially in high temperature environments such as fire and disaster sites. Since the highly tempered atmosphere by the fire makes it difficult to provide reliable frame transmissions, we propose a novel MAC protocol, called HTAM (High Temperature Aware MAC), which monitors the current temperature of each node to identify the unreliability symptom according to the predefined threshold value, and dynamically adjusts its backoff value and frame retransmission parameter. This new protocol is highly compatible with any conventional CSMA/CA based wireless networks. We also expect that the proposed protocol is suitable for mitigating the wireless link failures in fire sites thanks to the reliable channel access.**

Keywords—CSMA/CA Network; High Temperature; Backoff Scheme; MAC Protocol

I. INTRODUCTION

WLAN (Wireless Local Area Network) [1] and wireless sensor network [2] are the most representative growing technologies to access network resources easily, any time, anywhere, in a timely way through the wireless channels. In these wireless networks, wireless nodes are randomly scattered and their positions are not strictly predetermined. This means that each wireless node can freely access the shared wireless medium with a fair channel competition method among the neighboring nodes. Thus, such convenient network service is applicable to various purposes such as telemedicine, disaster monitoring, remote device control and etc. However, when we consider the deployment of wireless network service, a number of unresolved problems remain. The most representative among these are as follows. Firstly, the wireless devices such as mobile phone and laptop computers use a bandwidth limited wireless channel that is significantly error prone compared with existing wired network systems. Hence, this unreliable feature is extremely critical to process emergent data especially in disaster areas. Second, the air temperature is rapidly increased when the wireless device is used in fire sites. Since, in general, the tiny electrical devices are significantly vulnerable to high temperature, these wireless nodes may suffer from hardware failures. Moreover, the previous work [3] revealed that the high temperature also results in CCA (Clear to Channel Assessment) failures. This is because the signal strength is significantly decreased by the highly tempered atmosphere. Finally, the wireless node transmit its data frame even through the channel is not idle, which results in severe packet collisions with other packets from neighboring nodes. Furthermore, such packet losses is very critical to emergency activity of fire fighters who carry with mobile device with CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) schemes [4]. Figure 1 shows the simplified CSMA/CA algorithm of IEEE 802.11 standard [5].

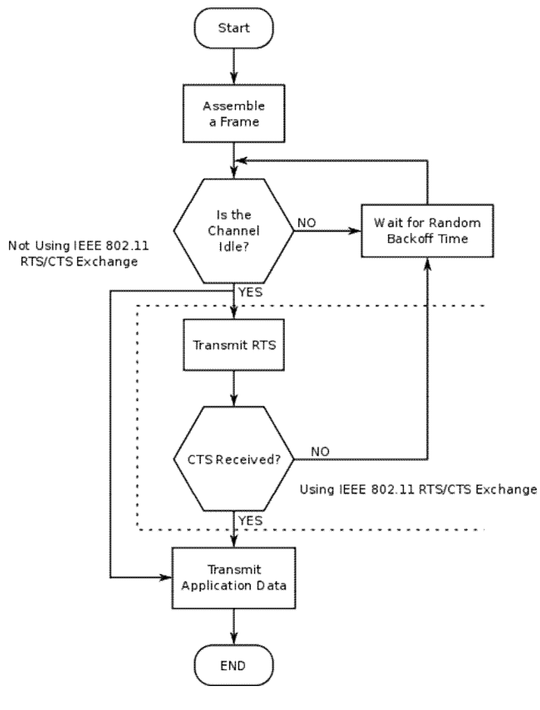

Fig. 1. Simplified CSMA/CA scheme in IEEE802.11

In figure 1, once the wireless node identifies that the channel is idle via the CCA mechanism, it starts to transmit RTS frame or data frame into the wireless medium. However, when the temperature of atmosphere is high (e.g. more than 70-80 degree), the CCA may report wrong decisions. Since the node cannot identify this problem, the performance degradation is inevitable. In order to tackle this transmission failure problem, we propose a novel MAC protocol which provides temperature aware channel access algorithm especially in high temperature environments.

The rest of this paper is organized as follows. In section II, we describes the proposed protocol in detail and Section III presents the expected service scenario and application. Finally, concluding remarks are given in section IV.

II. PROPOSED SCHEME

In this section, we introduce the detailed operations of the proposed scheme, named HTAM, to support reliable frame transmission services over CSMA/CA networks. Thus, HTAM mainly focuses on channel contention based access approaches without TDMA (Time Division Multiple Access) based channel synchronization. Although TDMA is also efficient for providing channel fairness by using the Contention Free Period (CFP) mechanism, the scheduling overhead is nothing to sneeze at. That is, the proposed protocol basically assumes that all wireless nodes adopts the CSMA/CA mechanism and uses the identical wireless channel frequency. In addition, the proposed protocol also assumes that all participating nodes are equipped with temperature sensors on their hardware platforms in order to measure current temperature of the atmosphere. Finally, all nodes are supposed that they adopt identical add-on abilities such as RTS (Ready to Send)/CTS (Clear to Send) exchange.

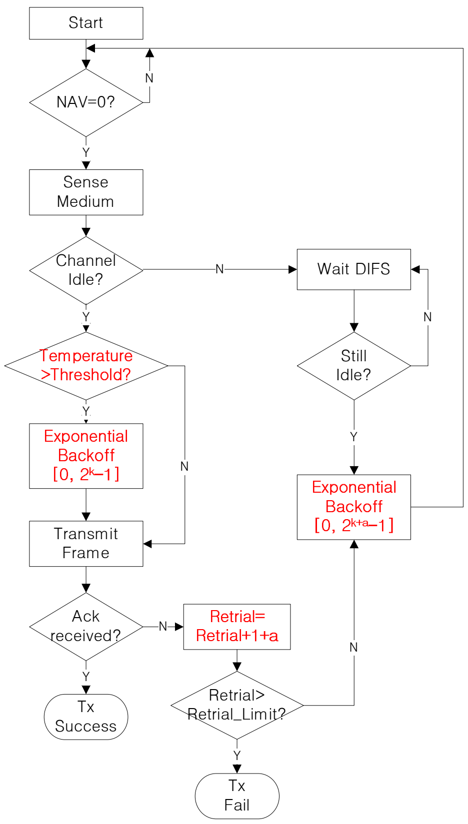

Fig. 2. Proposed MAC Protocol for CSMA/CA

Figure 3 illustrates the overall operations of the proposed protocol for the enhancement of conventional CSMA/CA networks. Firstly, when the node wish to transmit a frame, the node checks whether the NAV (Network Allocation Vector) value is still configured or not. If the NAV is not '0' value, it should wait until it become 0, which is the identical operation with conventional algorithm. However, after the node carried out the CCA function and it detect that the channel is idle, it compares its measured the temperature value with a predefined threshold value. If the measured temperature is larger than threshold, it defer to participate in the channel competition by performing additional backoff operation instead of trials for immediate transmissions. Although the threshold value can be configured according to application policy, we recommend more than 30 degree because the previous work [3] showed that the RSSI (Received Signal Strength Indicator) is decreased if the temperature of the atmosphere is larger than 30. When the node confirm that the channel is idle through the CCA procedure, it waits for DIFS (DCF Inter Frame Space) and then performs exponential backoff after additional confirmation of the channel idle. The backof function chooses a value between $[0, 2^{K}-1]$ and K is usually determined between 4 and 10. Finally, the backoff value is chosen between [15, 1023]. If the transmitted frame is collided or lost, the backoff value is doubled in order to prevent consequent packet collisions. This means that additional delay can avoid not only severe channel competition but also frame losses. However, when the temperature of atmosphere is increased, the node cannot fully identify whether the channel is idle or not through the CCA. To mitigate this problem, HTAM adds α value to K according to temperature increment. The expression for calculating α is shown in expression (1).

$$\alpha = \left\lfloor \frac{Temp_{CUR} - Temp_{TH}}{10} \right\rfloor \tag{1}$$

,where $Temp_{CUR}$ is the currently measured temperature value and *TempTH* is the threshold temperature value. For an example, when the current temperature is 52 degree and the threshold is 30, α is $\lfloor(52-30)/10\rfloor=2$. After all, the backoff value is doubled and the node has higher probability for successful transmissions. Meanwhile, when the channel is identified as busy, the node does not add α value to K. This is because the immoderate backoff increment leads to unnecessary transmission delay, which is a factor for performance degradation.

In the standard CSMA/CA algorithm, the sender identifies successful frame transmission by receiving the acknowledgement frame from the receiver. However, as mentioned above, the sender may not receive this acknowledgement due to high temperature atmosphere. Thus, HTAM performs additional retransmission trials by adding α to retrial value. In this paper, although we showed and compared with CSMA/CA algorithm of IEEE 802.11, the proposed protocol is fully compatible with any other protocols with Binary Exponential Backoff (BEB) (e.g. IEEE 802.15.4 [6] and ZigBee Solution [7]).

III. EXPECTED SCENARIO

In this section, we introduce a scenario example for the deployment of the proposed protocol in real fire sites. Figure 3 shows an indoor fire situation in the office building, where there are three access points (AP) and four mobile nodes which try to access the wireless link to communicate one another. When the fire is occurred near to AP1, the temperature of atmosphere will be gradually increased. At the specific moment [8], the nodes within the coverage of AP1 may suffer from CCA failures and packet collisions. To resolve this problem, the node B can adjust its backoff value when it wishes to communicate with node C. Then, node B can reliably report the emergent information to the remotely located nodes such as node D and AP3.

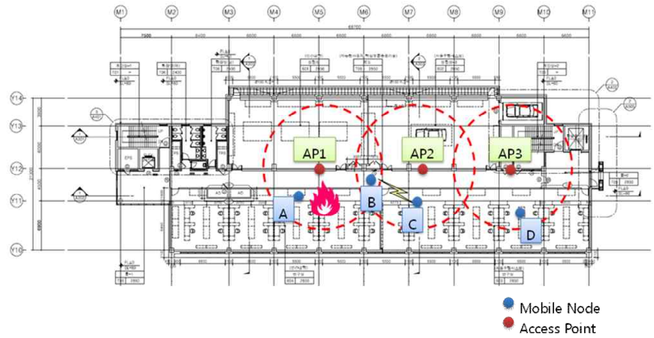

Fig. 3. Example scenario

IV. CONCLUSION

In this paper, we present a temperature aware MAC protocol called HTAM for CSMA/CA networks. Firstly in order to identify the levels for dangerous situation, HTAM periodically monitors its temperature and defines temperature threshold value. Then, if the node wishes to transmit a data frame, it dynamically adjust its backoff value according to current temperature of atmosphere. After all, the node can avoid unexpected packet collisions and achieves network reliability even though a fire is occurred.

In future works, we plan to develop a more reliable routing protocol for multi-hop based networks to cope with dynamic environments. In addition, we will study optimized cross-layer operations for improving delay and throughput.

ACKNOWLEDGMENT

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