A New Backoff algorithm considering Hop Count for the IEEE 802.11 Distributed Coordination Function

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Abstract—The IEEE 802.11 is a MAC protocol which has been standardized by IEEE for Wireless Local Area Networks (WLANs). In the IEEE 802.11 WLANs, network nodes experiencing collisions on the shared channel need to backoff for a random period of time, which is uniformly selected from the Contention Window (CW). This contention window is dynamically controlled by the Binary Exponential Backoff (BEB) algorithm. However, the BEB scheme suffers from a fairness problem; some nodes can achieve significantly larger throughput than others. This paper proposes a new backoff algorithm for the IEEE 802.11 DCF scheme. This algorithm uses the hop count for considering fairness. It causes flows with high hop count to generate short backoff interval than those with low hop count, thus getting high priority. Therefore, when a collision occurs, the modified IEEE 802.11 DCF assigns higher priority to flow to be close to a destination.

Index Terms—IEEE 802.11 DCF, backoff algorithm, hop count, Wireless Local Area Networks (WLANs)

I. INTRODUCTION

As the technology for wireless communications advances and the cost of manufacturing a sensor node continues to decrease, a low-cost but yet powerful sensor network may be deployed for various applications that can be envisioned for daily life. Although each sensor node may seem to be much less capable than a traditional stationary sensor, a collective effort of the sensor nodes may provide sensing capabilities in space and time that surpass the stationary sensor.

A typical wireless sensor network (WSN) may contain hundreds to thousands of microsensor nodes, which are connected by a wireless medium. These sensor nodes are capable of capturing various physical properties, such as temperature, humidity, or pressure [1].

Energy consumption of a WSN occurs in three domains; sensing; data processing; and communications; among these, radio communication is the major consumer of energy [2].

In all wireless networks, nodes must share a single medium for communication. Network performance largely depends upon how efficiently and fairly the nodes can share this common medium. Note that the packet transmission is directly handled by the MAC layer. Compared to a wired medium, a significant portion of the node's energy is spent on radio transmissions and on listening to the medium for anticipated packet reception. On the other hand, wireless networks always have restricted power sources. Thus, careful design of the MAC scheme is necessary for the optimal performance and extended lifetime of the network. Nodes of a WSN carry extremely low energy resources and remain unattended after deployment. Therefore, the node lifetime depends entirely on how energy is conserved during communication. Although some exhausted nodes could be compensated using redundant neighboring nodes, certain situations may arise rendering a part of the network inaccessible and isolated from the other parts. Such scenarios could be averted by avoiding unnecessary transmissions and longer listening periods.

In WSNs, all nodes are capable of transmitting data through the same broadcast channel. As a tiny communication device, each sensor node may have only one receiving antenna. Therefore, if two or more transmissions from multiple sources arrive at the same time, a collision will happen, and none of transmitted packets can be received correctly. To ensure reliable transmission, after source nodes detect data collision, they must retransmit, which causes extra energy expenditure.

This paper proposes a new backoff algorithm for the IEEE 802.11 DCF scheme. This algorithm uses the hop count for considering fairness. It causes flows with high hop count to generate short backoff interval than those with low hop count, thus getting high priority.

The paper is organized as follows. Section II briefly reviews related works. The details of the standardized IEEE 802.11 DCF are presented in Section III. In this section, I also present a new backoff algorithm for the IEEE 802.11 DCF scheme. Section IV discusses the simulation results. Section V concludes the work.

II. RELATED WORKS

The MAC schemes for WSNs should be carefully designed to achieve the optimum performance toward the intended application. Previous surveys discuss some issues related to medium access in WSN [1]. The closest types of networks rendering a similar behavior to WSNs are wireless ad hoc networks (WAHNs).

Currently available MAC protocols for wireless ad hoc networks are of two major types : contention based

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(CSMA) and scheduling based (TDMA, FDMA, or CDMA). In contention-based MAC schemes, the nodes compete among each other for channel access, whereas in scheduling-based methods, a specific schedule of channel access is used in time, frequency, or code domains. This section will briefly discuss several important medium access schemes belonging to both categories, including IEEE 802.11, Bluetooth, energy-conserving MAC (EC-MAC), and the power aware multiple access (PAMAS) [3, 4, 5].

IEEE 802.11 is a standard developed for wireless LAN (WLAN) applications intended to replace conventional wired LANs [3]. Nodes in such networks would be mostly laptops and other typical equipment connected to a LAN. The distributed coordination function (DCF) in IEEE 802.11 is the access method used to support asynchronous data transfer on a best-effort basis when the network functions in an ad hoc mode. DCF can also coexist with an infrastructure network. This is a contention-based protocol based on MACA and MACAW schemes [6, 7]. It uses carrier sense multiple access with collision avoidance (CSMA/CA). However, the energy consumption using IEEE 802.11 MAC protocol is significantly high because the nodes are listening to the channel most of the time. Although the 802.11 standard defines the power saving (PS) mode, it provides very limited policy about when nodes should go to sleep. Also, requirements for clock synchronization and the suboptimal power saving makes this scheme an improper candidate for medium access in WSNs.

Bluetooth is a short-range wireless networking for electronic consumer devices [8]. It uses a TDMA and CDMA hybrid scheduling based MAC scheme. The topology is a star network in which several slave nodes are attached to and synchronized with a master node to from a piconet. Along with the basic TDMA scheme, Bluetooth uses frequency hopping code division multiple access (FH-CDMA), which uses a large number of pseudorandom hopping sequences.

Compared to contention-based MAC schemes, TDMA schemes have a natural advantage of energy conservation because the duty cycle of the radio is reduced and there are no contention-introduced overheads or collisions. But, use of a TDMA protocol usually requires the nodes to form real communication clusters such as the piconets. Managing intercluster communication and interference is not an easy task. Moreover, when the number of nodes within a cluster changes, it is not easy for a TDMA protocol to change its frame length and time slot assignment dynamically.

III. THE MODIFIED IEEE 802.11 DCF

The 802.11 WLAN MAC/PHY specifications is one of the recommended international standards for WLANs. Two coordination functions are defined in the IEEE 802.11 MAC/PHY standard: the Point Coordination Function (PCF) and the Distributed Coordination Function (DCF)[3]. In the PCF mechanism, a polling technique is employed by the access points or base stations to query network nodes for any traffic they may have to send. In the DCF medium access mode, active nodes compete for the use of the channel in a distributed manner via the use of the Carrier Sensing Multiple Access with Collision Avoidance (CSMA/CA) scheme.

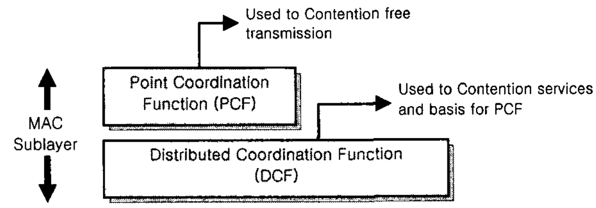

Fig. 1 MAC Architecture of 802.11

The CSMA/CA scheme uses both physical and virtual carrier sensing with the help of the optional Request-To-Send/Clear-To-Send (RTS/CTS) dialogue. The RTS/CTS dialogue was designed to mitigate the so-called hidden-terminal and exposed-terminal problems for WLANs.

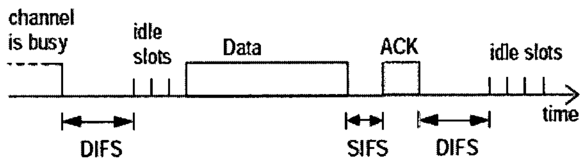

Fig. 2 The IEEE 802.11 access method

Contention for the channel access between two nodes, N1 and N2, is illustrated in Figure 3. Initially N1 is transmitting frame 1 followed by ACK reception. After waiting for the DIFS period, it starts decrementing the backoff counter in an attempt to transfer another packet. Because the backoff counter of N2 reaches zero first, it captures the medium and transmits a frame while N1 senses the medium is busy. Following the transmission of N2, N1 recaptures the medium for transmission of its second frame.

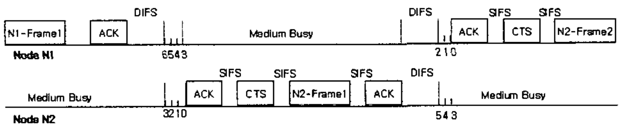

Fig. 3 Contention between nodes N1 and N2 in the IEEE 802.11 DCF

Packet collisions are not completely eliminated in the IEEE 802.11 MAC/PHY standard due to the distributed nature of the competing nodes and the bursty traffic arrival at the nodes. In the IEEE 802.11 DCF scheme, the senders of the colliding packets need to refrain from immediate retransmissions in order to avoid repeated collisions. Thus, each competing node sets up a backoff timer according to a randomly selected backoff time period and enters the backoff state. This backoff time period is selected uniformly between 0 and the Contention Window (CW). In the IEEE 802.11 DCF scheme, the CW is dynamically controlled by the backoff algorithm; the Binary Exponential Backoff (BEB)[10].

In the BEB algorithm, the contention window is doubled every time a node experiences a packet collision. If a node is successful in its packet transmission, the contention window is reset to the minimum value.

$$Backoff\_time = \lfloor 2^{2+i} \times rand(\ ) \rfloor \times Slot\_time \qquad (1)$$

where *Slot_time* is a function of the physical layer and *rand()* is a function with a uniform distribution in [0,1].

However, the BEB scheme suffers from a fairness problem; some nodes can achieve significantly larger throughput than others [9]. The fairness problem occurs due to the fact that the scheme resets the contention window of a successful sender to CW_{min}, while other nodes continue to maintain larger contention windows, thus reducing their chances of seizing the channel and resulting in channel domination by the successful nodes.

This paper proposes a new backoff algorithm for the IEEE 802.11 DCF scheme. This algorithm uses the hop count for considering fairness. The modified backoff time equation is

$$Backoff\_time = \left\lfloor \frac{2^{2+i} \times rand(\ )}{hop\_count} \right\rfloor \times Slot\_time \qquad (2)$$

The operation of the modified backoff algorithm is based on a hop count. This paper adds one field, *called hop count*, into the IEEE 802.11 frame. This field keeps track of the number of hops that have been traversed between the sink node and the node currently occurring data collision.

In the standard IEEE 802.11 DCF, the backoff interval calculated is proportional to the size of the packet to send and inversely proportional to the weight of the flow. This causes stations with low weights to generate longer backoff interval than those with high weights, thus getting lower priority.

However, in the modified IEEE 802.11 DCF, the backoff interval calculated is proportional to the size of the packet to send and inversely proportional to the hop count. If a collision occurs, a new backoff interval is calculated using the equation (2). This causes flows with high hop count to generate short backoff interval than those with low hop count, thus getting high priority. Therefore, when a collision occurs, the modified IEEE 802.11 DCF assigns higher priority to flow to be close to a destination.

Figure 4 shows the 802.11 Frame Control field [3]. Type and Subtype fields define the Type and SubType of the frame as indicated in the Table 1.

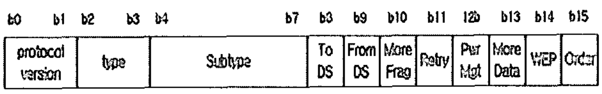

Fig. 4 IEEE 802.11 Frame Control Field

This algorithm uses **b3b2 = 11** in Type value to keep track of the number of hops that have been traversed between the sink node and the node currently occurring data collision.

Table 1 Type and Subtype of the IEEE 802.11 Frame

Type value b3 b2	Type Description	Subtype Value b7 b6 b5 b4	Subtype Description
00	Management	0000 ~ 1100	
01	Control	1010 ~ 1111	
10	Data	0000 ~ 0111	
11	Hop Count	0000 ~ 1111	# of hop count

IV. PERFORMANCE EVALUATION

To evaluate the performance of the proposed algorithm, this paper uses the *ns* simulator to simulate the IEEE 802.11 DCF functions. This paper modifies the IEEE 802.11 DCF module in the *ns* simulator into a modified IEEE 802.11 DCF by modifying the backoff_timer module and frame control field [11]. Figure 5 shows the modified backoff_timer module.

```
BackoffTimer::start(int cw, int idle)
{
        Scheduler &s = Scheduler::instance();
        stime = s.clock();

        rtime = ((Random::random() %cw) / hop_count) * mac->phymib_->SlotTime;

        #ifdef   USE_SLOT_TIME
                ROUND_TIME();
        #endif
                difs_wait = 0.0;

        if(idle == 0)
                paused_ = 1;
        else {
                assert(rtime >= 0.0);
                s.schedule(this, &intr, rtime);
        }
}
```

Fig. 5 The modified backoff_timer module

This paper simulates a WLAN consisting 10 stations. The performance measure used in the analysis is the average MAC delay that is the average delay experienced by a message from the time it reaches the head of the local queue up until the beginning of its successful transmission.

The system parameters for simulation environment are reported in Table 2. These values are specified in the IEEE 802.11 standard. Traffic related parameters are reported in Table 3.

Table 2 System Parameter Values

System Parameter	Parameter Value (μsec)
Slot-time	50
SIFS	28
DIFS	128 (SIFS + 2Slot-time)
Medium Capacity	1 Mbit/sec

Table 3 Traffic Parameter Values

Traffic Parameter	Parameter Value
Station Offered Load	30Kbits/sec
Average ON duration	3.3 sec
Average OFF duration	22.8sec

Figure 6 shows the average access delay versus the number of stations. As shown in Figure 6, the modified IEEE 802.11 DCF algorithm significantly influences the average access delay for the number of stations.

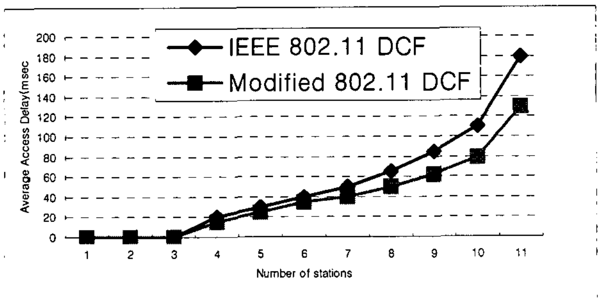

Fig. 6 Average access delay vs. the number of stations

V. CONCLUSIONS

This paper presents a modified IEEE 802.11 DCF algorithm for WLANs. It has a good performance comparing with the standard IEEE 802.11 DCF. The algorithm has been implemented on *ns* simulator, which shows its effectiveness.

The future work includes more analytical study on the energy consumption and the latency as well as how protocol parameters affect their trade-offs. More implementation work is needed for the case of various environments.

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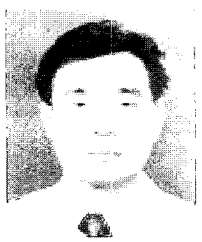

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