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EVALUATION OF BACK-OFF ALGORITHM PERFORMANCE OF MAC LAYER IEEE 802.11 WLAN

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ABSTRACT
The medium access control (MAC) protocol is the main element which determines the system throughput in wireless local area networks. The MAC technique of the IEEE 802.11 protocol is called Distributed Coordination Function (DCF). However, in the DCF access procedure, the system throughput decreases when the number of stations is large. This paper proposes a simple and effective contention window-resetting scheme, named Double Increment Double Decrement (DIDD), to improve the performance of IEEE 802.11 Binary Exponential Backoff (BEB) under an error-prone environment. Our work becomes important and meaningful in the sense that it predicts both IEEE 802.11 BEB and DIDD performance very accurately considering transmission errors. We explore the effect of transmission errors; packet size, data rate and network size on the performance of BEB and DIDD, in terms of throughput efficiency, average packet delay, packet drop probability and packet inter arrival time.

KEYWORDS: MAC, BEB, DIDD, WLAN.

INTRODUCTION

Wireless Local Area Networks (WLANs) are becoming more and more popular attracting the interest of researchers, system integrators and manufacturers of wireless devices. The IEEE 802.11 protocol [1] is the dominant standard for WLANs and is turning into increasingly prevalent for offices, public places, and homes. IEEE 802.11 WLANs are widely deployed in hotspots such as airports, hotels and other areas in which people can have public access to Internet and wireless high-speed data services.

The IEEE 802.11 standard [1] includes detailed specifications for both the Medium Access Control (MAC) and the Physical Layer (PHY). The MAC incorporates two different medium access methods; the compulsory Distributed Coordination Function (DCF) and the optional Point Coordination Function (PCF). The contention-based DCF supports asynchronous data transfer on a best effort basis that best suits delay insensitive data (e.g. email, ftp). On the other hand, the polling-based PCF is built on top of DCF and is utilized for delay sensitive data transmissions (e.g. real-time audio or video). Most of today's IEEE 802.11 devices operate in the DCF mode only, since PCF is barely implemented in current products due its complexity and inefficiency in common data transmissions.

IEEE 802.11 DCF is based on a Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) technique and employs a contention resolution method, namely Binary Exponential Backoff (BEB), in order to minimize the probability of collisions due to multiple simultaneous transmissions. DCF defines two access mechanisms to employ packet transmission. The default scheme is called the basic access mechanism, in which stations transmit data packets after deferring when the medium is busy. DCF also provides an optional way of transmitting data packets, namely the Request-To-Send/Clear-To-Send (RTS/CTS) reservation scheme. This scheme uses small RTS/CTS packets to reserve the medium before large packets are transmitted in order to reduce the duration of a collision. Moreover, the RTS/CTS reservation scheme is utilized to combat the hidden station problem.

This paper a simple and effective contention window-resetting scheme, named Double Increment Double Decrement (DIDD), to improve the performance of the contention based IEEE 802.11 Distributed Coordination Function (DCF). An alternative mathematical analysis for the proposed scheme is developed based on elementary conditional probability arguments rather than bi-dimensional Markov chains. Performance results are presented to identify the improvement of DIDD in terms of throughput and packet drop comparing to the Binary Exponential Backoff (BEB) utilized in the legacy IEEE 802.11 DCF.

802.11 MAC COORDINATION METHODs

The 802.11 Medium Access Control (MAC) layer is concerned with controlling access to the wireless medium. It specifies two mechanisms for accessing the wireless medium: DCF and PCF. This section gives a description of the two mechanisms.

Distributed Coordination Function (DCF)

The mandatory distributed coordination function is the primary access protocol for the automatic sharing of the wireless medium between stations and access points having compatible physical layers (PHYs). Similar to the MAC coordination of the 802.3 Ethernet wired line standard, 802.11 networks use a carrier sense multiple access/collision avoidance (CSMA/CA) protocol for sharing the wireless medium. A wireless station wanting to transmit senses the wireless medium. If the medium has been sensed idle for a distributed inter frame space (DIFS) period, the station can transmit immediately. If the transmission was successful, the receiver station sends an acknowledgement to the sender after a short inter frame space period (SIFS) period. If the medium is found to be busy, the transmission is deferred till the end of the current transmission. At the end of the current transmission, if there is no collision, the station waits for another DIFS, but if there is a collision (frame is received in error), then the station defers its transmission by extended interframe space (EIFS) period. After the deferral period, the station begins a random back-off. The back-off is in the range 0 to CW (contention window). The value of CW depends on the PHY characteristics of the medium. The back-off time is calculated as

Back-off time = Random () * slot_time

Where Random () generates a pseudorandom integer in the range [0, CW] and slot _time equals a constant value found in the station's Management Information Base (MIB). Back-off timer decrements the back-off time if the medium is idle for one-slot.

When the back-off timer expires the station can transmit. If the transmission is not successful this time (if there is another collision), then the size of the contention window is doubled and a new back-off timer is started. The station with the smallest back-off wins the contention for the medium and transmits. After a successful transmission a station is required to perform another backoff prior to transmitting additional packets.

Though DCF is easy to implement, it does not provide prioritized access, as it suffers from the serious drawback of service differentiation. DCF does not support explicit specification of delay, jitter and bandwidth requirements by higher layer data applications and hence cannot guarantee QoS performance. All stations and data traffic are given the same priority to access the wireless medium. Time periods when DCF is in operation are called Contention Periods (CP).

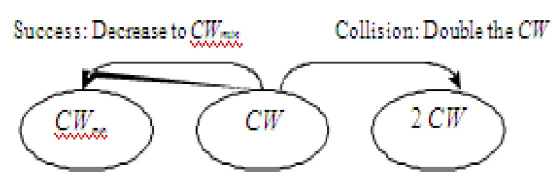
Point Coordination Function (PCF)

The optional point coordination function provides contention-free frame transfer for processing time-critical information transfers. PCF uses the point coordinator (PC) as the polling master. The PC resides in the AP of the wireless network. At the beginning of the contention-free period (CFP), the point coordinator has an opportunity to gain control of the medium. The PC first senses the medium. If the medium is idle for a point coordination function interframe space (PIFS) period, the PC sends a polling packet to the wireless station asking it for data packets during the contention free period. The polled station then sends the packet to the AP after a SIFS period upon which the AP sends an ACK to the polled station after a SIFS period. If the medium is found to be busy, the AP (and hence the PC) defers access till the end of the current transmission. The AP then waits a PIFS period and sends out a polling packet to the station requesting the data packet. The polled station sends out the data packet and receives an ACK after the expiration of a SIFS period. In general back-off is not used for PCF as it operates in a contention-free mode unlike DCF. Both DCF and PCF can be combined within a BSS, with CFP and CP alternating over time. During the CFP, PCF is used as the access mechanism and during the CP, DCF is used as the access mechanism. In most cases DCF would suffice. However, for time-bounded applications such as audio and video PCF would be needed. The PCF, though, would impose greater overhead and complexity due to the transmission of the polling packets and the additional protocols required.

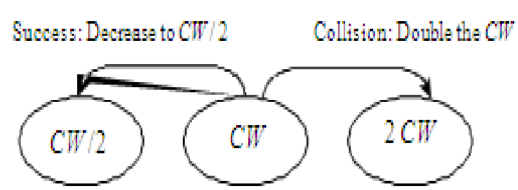
THE BACKOFF SCHEME

As it has been shown earlier, BEB "forgets" about the collision experience it had and resets the contention window after a successful packet transmission regardless of network conditions such as the congestion level. At first glance, BEB tends to work well when there are only a few competing stations. When the number of contending stations increases, the sudden reduction of the contention window can lead to significant performance degradation since, it encourages more collisions after every successful transmission.

Since congestion level is not likely to drop rapidly, we propose a "smooth" decrease of the contention window, referred as Double Increment Double Decrement (DIDD). The main concept of DIDD is that CW decreases gently and gradually after a successful packet transmission. More specifically, if a packet collides, then similar to the operations of BEB, DIDD will double the contention window in order to reduce the probability of a packet collision (the case of two or more stations transmitting simultaneously). However, in the case of a successful packet transmission, DIDD will halve the CW (will not go back to CWmin) in order to avoid potential future packet collisions. Figure 1 clearly illustrates the difference between DIDD and BEB schemes in resolving packet collisions and after a successful transmission.



(a) Legacy binary exponential backoff (BEB) scheme



(b) Double Increment Double Decrement (DIDD) backoff scheme

Fig. 1 Comparison of the CW process in the two backoff schemes

The mathematical modeling and performance analysis of the proposed DIDD backoff scheme can be developed by utilizing three different approaches as shown in [6]. We can either employ a 2-dimensional Markov chain model like in [2][3][10], a 1-dimensional Markov chain model used in [4] or elementary conditional probability arguments as in [5].

OPNET WIRELESS MODELER

OPNET Modeler is the industry's leading network simulation commercial software. Modeler supports all major network types and technologies. The application areas include:

1. Network planning (both LAN and/or WAN) and analysis of performance and problems prior to actual implementation
2. Wireless and Satellite communication schemes and protocols
3. Microwave and Fiber-optic based Network Management
4. Protocol Development and management
5. Routing algorithm evaluation for routers, switches, and other connecting devices.

The OPNET Modeler Wireless Suite provides high fidelity modeling, simulation, and analysis of a broad range of wireless networks. Modeler Wireless Suite supports any network with mobile devices, including cellular (GSM, CDMA, UMTS, IEEE802.16 WiMAX, LTE, etc.), mobile ad hoc, wireless LAN (IEEE 802.11), personal area networks (Bluetooth, ZigBee, etc.) and satellite.

The OPNET WLAN model provide high-fidelity modeling, simulation, and analysis of wireless LAN networks, including the RF environment, interference, transmitter/receiver characteristics, and full protocol stack, including MAC, routing, higher layer protocols and applications. Furthermore, the ability to incorporate node mobility and interconnection with wire-line transport networks provide a rich and realistic modeling environment.

IMPLEMENTATION AND SIMULATION

We will evaluate two different back-off algorithms under different traffic to understand better of their advantages and disadvantages. One algorithm is the default algorithm of 802.11 MAC layer - BEB (Binary Exponential Back-off). Another algorithm comes from Chatzimisios' paper [7], called DIDD (Double Increment Double Decrement).

As WLAN document stated, the station will wait for a period before next retrial if it detects a collision. But how much time the station should wait is determined by back-off algorithm. BEB method is very simple. Each station has a minimum congestion window at the beginning. If the collision is detected, the congestion window is doubled until it reaches a maximum value. If the packet is successfully delivered, then the congestion window is reset to minimum value. When the station has to wait for a period before next deliver, it chooses a random value from the 1 to the value of the congestion window. The algorithm works very well, but there are some situations the algorithm haven't concern yet. First it causes unfair. The station's congestion window is reset to minimum value when it sends packet successfully, so its waiting time is shorter than others. It is more possible that the same station can access media again because it can wake up soon from shorter waiting status. Second resetting congestion window ignore the recent change of network situation; the successful deliver doesn't mean the congestion is gone. So the station will encounter another collision soon.

DIDD algorithm uses a very simple method to resolve the problems. Instead resetting congestion window it halves congestion window when successfully deliver. On one hand the successfully deliver maybe mean the worse situation of network is changing better, on other hand we don't know how much the network recover. So the new method shortens the congestion window but not reset it to minimum value.

In order to test functionality of the two algorithms, we use 20, 40 and 60 nodes to build ad hoc network. All nodes are set to same parameter except the Back-off method. So the different nodes number can create different traffic. For adding the DIDD algorithm, we have changed some code in the "back-off need" module.

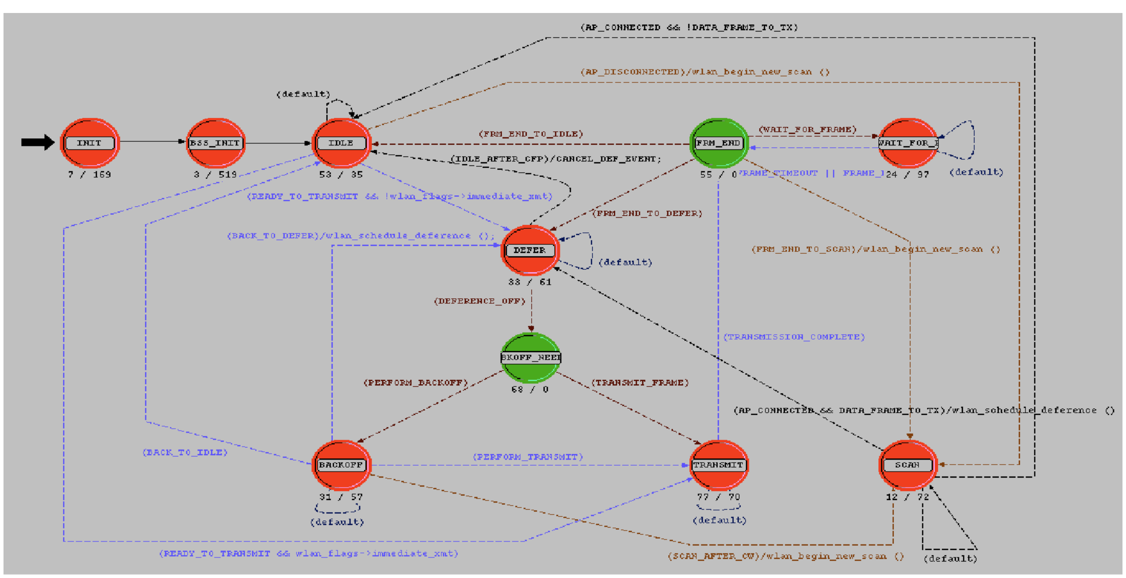


Figure2: The changed process module in the state machine (the circled module)

One new parameter “Back-off Method” is added in the node attribute. It controls which back-off method is used in current scenario.

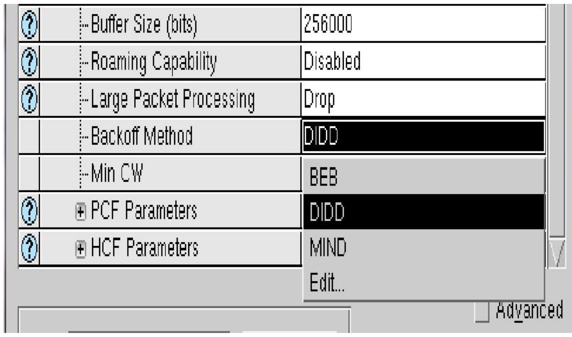


Figure3: The new back-off algorithm in the Node attributes

Simulation results

The important statistic parameters have been collected for our evaluation and analysis such as the average throughput, the average delay, and the packet collision at the receiver port, etc. 60 minute’s simulation data has been collected in our project. Random seeds were chosen to for simulation.

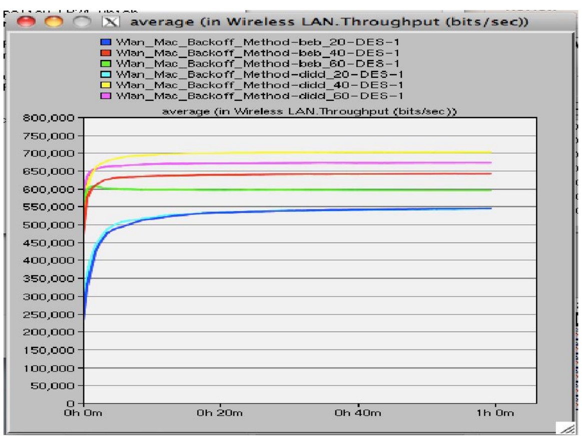


Figure4: Throughput

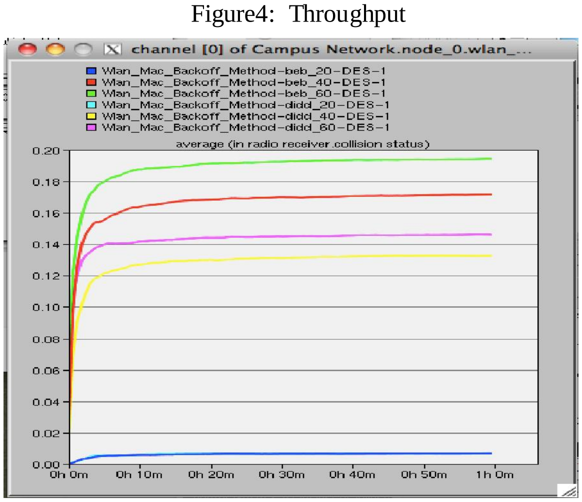


Figure5: Collision

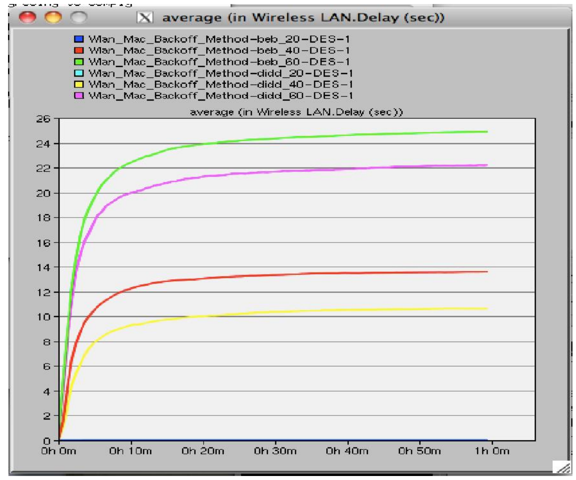


Figure6: Delay

Analysis

When nodes number is 20, the traffic doesn’t exceed the link bandwidth. So the throughput, delay and collision are close in two back-off algorithms. But when nodes number is greater than 40, the difference between two algorithms can be found. The DIDD can get better performance. The interesting thing is the performance doesn’t grow up with number of nodes; it is dropped on the contrary (red line and green line in throughput). Because more workstation causes more collision, so it affects the performance. But the new algorithm can compensate the drop. From the result we find the DIDD can reduce the performance drop (yellow line and pink line in throughput).

CONCLUSION

In this simulation Compared DIDD algorithm to the basic access BEB Back-off algorithm, we found that the DIDD is more efficient in a busy high traffic network and it has no performance drop in light traffic against BEB. BEB is a memory less algorithm; the feature makes it get worse performance when wireless stations are busy in sending or receiving packets like video conference. When more and more wireless devices appear in the small area like campus, airport, the network congestion is very easy to occur. Finding a more efficiency algorithm may be is an emergent requirement with WLAN growth. .

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