Enhancement of the Performance of the Medium Access Control (MAC) Protocol by using Modified New Approach

Shefali Soni, Sandeep Sahu

Abstract— Wireless networks are the widely used networks for communication now days. Hence it is very necessary to improve the performance of the Medium Access Control (MAC) layer by preventing the communication from collisions. In this work a new scheme is explained, for efficient channel access, which is based on the sequencing. The proposed method minimizes the number of collisions as well as the delays that occur during the backoff periods. When collision occurs in a MAC layer in the network, it may result in decreased throughput in the data transfer. In this way the bandwidth is wasted. Here an analytical study on MAC-layer issues is presented, which are very important when accessing a channel over wireless networks. The main function of Medium Access Control (MAC) is to share the channel efficiently between all nodes. The new approch is used in order to prevent collisions during multiple channel access in MAC Layer. This scheme uses fair distributed mechanisms for channel access. In this method, a counter is introduced at each node to maintain the discipline of the nodes. It is based on the concept of sequencing technique. As the routing protocol, AODV is used in this method and NS-2 is used for simulation environment. The proposed method minimizes the number of collisions in data transfer and increases the throughput along the network. The performance of the proposed method is evaluated under various conditions, and the obtained results are very promising. Also the proposed scheme shows that the energy requirements are minimum due to the limitation on the number of transmissions while reducing collisions in the MAC layer.

Index Terms— Channel access, distributed coordination function (DCF), meddium access control (MAC), backoff, ad-hoc on demand distance vecctor (AODV), sequencing technique, network simulator – 2 (NS-2).

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1 Introduction

IN the last few years, wireless technology has become very popular for communication. As a result, wireless local area network (WLAN) is rising as a potent means of wireless communications and the Internet access [6]. IEEE 802.11 is the most popular WLAN technology, which supports high-speed communications up to 54 Mbps in the unlicensed bands such as those in 2.4 GHz and 5 GHz [5]. The Medium Access Control (MAC) layer is mainly used for the effective sharing of the channel. The MAC protocol of wireless networks should support various flows with fairness by providing effective channel access and bandwidth. It is very difficult and challenging while implementing the MAC protocol due to the increasing number of nodes and changing network condition [1].

For this study, we are focused on the DCF method. If the number of stations contending for channel access increases, the probability of occurring collisions also increases. The performance of the wireless network depends also on the backoff methods of the DCF protocol which are used during channel access.

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It should be noted very well that an efficient backoff algorithm would increase the performance of wireless network. In this paper, a procedure is explained to minimize number of collisions and to increase the throughput of the system. The basic concept of this new approach is to limit the number of transmissions of a node based on a sequence number. It produces a solution to MAC by proposing an alternate method to backoff algorithms.

IEEE 802.11 is a set of standards for wireless local area network (WLAN) communication operating in the 2.4, 3.6 and 5 GHz frequency bands. Like other 802.x protocols, the 802.11 protocol describes the MAC and PHYSICAL layer. The first and lowest layer is the PHYSICAL layer in the OSI model of computer networking which has seven layer architecture. It is often termed as PHY in the implementation of this layer. It consists of the basic transmission technologies and hardware of a network. It is a basic layer below the logical data structures of the higher level functions in a network. It interfaces with the medium access control (MAC) sublayer of the data link layer.

Medium Access Control (MAC) is the sub layer of Data Link Layer specified in the seven-layer of OSI model. It provides addressing and channel access mechanism to communicate with several stations in a network. The MAC protocol of the IEEE 802.11 is a major protocol that is used for efficient channel access with contention based and contention-free access in wireless networks [5]-[8]. We have two schemes for effective sharing of the channel specified in the IEEE 802.11 wireless LAN standard, namely, the Distributed Coordination Function (DCF) which is mandatory, and the Point Coordination Function (PCF) which is optional [7], [8]. The DCF provides the channel access in a distributed manner, but the PCF provides centralized access to the channel using a coordinator. We know this coordinator as the Access Point (AP).

The fundamental MAC technology of the IEEE 802.11 standard for wireless LAN is DCF (Distributed Coordination Function). The DCF works on the concept of CSMA/CA (Carrier Sense Multiple Access – Collision Avoidance) protocol. In this protocol, a station senses the medium and then transmits its frame only when the medium is idle to avoid the collisions. In CSMA/CA, the collision avoidance mechanism makes use of the random backoff period to each attempt of the frame transmission. This kind of transmission is referred as basic access. In case of hidden nodes, collisions can still occur. The RTS/CTS handshake is proposed by the standard to reduce this problem. The use of the random backoff period decreases the probability of collisions, but it cannot remove them completely since more than one station can finish their backoff times simultaneously. A random back-off eliminates the probability of collisions of the same nodes again, even if they use the same back-off algorithm. We can also prevent collisions which are repeating by increasing the back-off period after each collision, especially when the network is heavily loaded. DCF makes use of CSMA/CA protocol with Slotted Binary Exponential (SBE) [6], [10], and Binary exponential backoff (BEB) [1], [2], [6], algorithms. There are a number of time slots in the SBE backoff mechanism, [6], [10], which are divided into idle DIFS periods. These DIFS periods are to be used for transmitting the data by any station. Whereas in BEB [1], [2], [6], if a station wants to transmit a frame, it requires first listening for the status of the transmission medium for a DIFS interval. If the medium is busy during the DIFS time period, the station will defer its frame transmission. But if the medium is idle at least for a DIFS period, the node randomly selects a backoff counter value, which is a random value selected from a uniform distribution interval [0, CW]. Here CW stands for Contention Window and its value is an integer within the range $CW_{min} \leq CW \leq CW_{max}$. The main objective of the BEB procedure is to distribute the idle time slots between the nodes by giving them random backoff values. The backoff value is a number of idle slots a node must wait before transmitting the frame. It is well noted that an efficient backoff algorithm would increase the performance of wireless networks.

In a network, for transmission over a wireless channel there are a number of stations contend for the access. If more than one station sense the channel and get it busy, they will defer their access. They also find the channel free virtually simultaneously and then try to occupy the channel. It may result in occurrences of collisions. For preventing such collisions, DCF also explains random backoff, which pushes a node to defer its access to the medium for a further period. The equation for determining the length of the backoff period is as follows:

$$\textbf{Backoff Time} = \textbf{random}\ (CW_{min}, CW_{max}) * \textbf{Slot Time}$$

In the real-time scenario, there will be certain amount of wastage in bandwidth due to back-off periods. More bandwidth will be wasted in idle state if the back-off period is very high and collision may occur if the back-off period is small. So, an optimization is needed for this problem. The main objective of the work is to reduce delay due to back-off period thereby reducing collision and increasing throughput. Here a new method is used to optimize the back-off period and thereby it increases throughput and reduces collisions. The main idea is to optimize the number of transmission for every node. A counter is introduced at each node to implement this idea. Here counter value represents the sequence number.

The capability to reduce the communication overhead of the medium is the most important benefit of the new method, because the sequencing technique does not allow to share the information among the stations. Thus, this new approach can be used as replacement of the legacy DCF [2], [7], ECA [3], EBA [9], and BCR-CS [11]. The performance of the proposed scheme is better than the research done previously such as the legacy DCF, ECA, EBA and BCR-CS methods. Simulation is done in NS-2 environment. The results obtained are found to be promising.

2 Background

In a single channel contention based medium access control (MAC) protocols, whenever more than one station try to access the medium at the same instant of time, it may have collisions. If the collided station tries to access the channel again, the packets will collide as the nodes are synchronized in time. So the nodes need to be displaced in time. To displace them temporally, a backoff algorithm is used. Backoff algorithms are used in order to improve throughput in a wireless network by avoiding collision among different nodes.

In Binary Exponential Backoff (BEB) algorithm, [1], [2], [6], when a station wants to transmit a data packet, then it must first carrier sense the medium. If the channel is idle for at least the DIFS duration, the node randomly picks a backoff counter value, which is randomly selected from a uniform distribution interval [0, CW], where CW is the integer within the range $CWmin \leq CW \leq CWmax$. If the medium is sensed to be busy, the node must defer its transmission until the medium is idle for at least the DIFS duration before selecting a backoff value. BEB aims to distribute the idle slots by giving random backoff values. The backoff value represents the number of idle slots a node has to wait before it can transmit the data. It is well noted that an efficient backoff algorithm would increase the performance of wireless networks. The disadvantage of this method is that, it suffers from collisions. The chosen range of the random backoff period is critical to the performance of the MAC protocol. If the range of the backoff period is too large, then much bandwidth will be wasted in the idle state. If the range of the backoff period is too small, then collisions are likely to happen, and it will lead to the wastage of bandwidth as well.

R.O Baldwin [3] introduced a real time MAC protocol for Ad-Hoc network. Here two methods are used they are Transmission Control procedure (TC) and Enhanced Collision Avoidance procedure (ECA). TC is used check the deadlines of packets. If the dead line of the packet is expired then transmission will be varied. Here ECA is used to compare the current back-off value with the back-off value of other stations. A station whose back-off value is low can access the channel.

J.Choi[9] used a method called Early Back-off Announcement (EBA) to reduce the collision and simultaneously increase the throughput of the network. The main idea of this method is to announce the back-off intervals before the transmission of data. Here a station announces its future back-off information via MAC header. But, this method requires many updates for back-off periods due to the change in network condition and also it fails to number of collision when network size gets increased.

Y.Xiao [11] introduced a method called Back-off Counter Reservation and Classifying Stations (BCR-CS). This method announces the Back-off counter in advance and avoids possible collisions among reserved stations. But there is communication delay while transmitting back-off counter value and hence it will cause collision and it should maintain the state information of all the nodes.

The main idea of this new approach is to limit the total number of transmission of a node to a sequence number named ‘k’. So that every node can transmit equal number of times in a given period ‘T’. The idea behind this algorithm is sequencing technique mentioned in [12] and [13].

3 THE ALGORITHM

The proposed sequencing technique can be applied with and without RTS/CTS scenarios. Here two variants of the new method are presented. The performance of the algorithm depends on the discipline of the nodes on idle slots distribution. But it is common that most of the nodes will try to access the medium throughout their slots, which will cause collisions and the performance of the system is reduced. The algorithm can be implemented in two ways – with or without sharing the counters, based on the sequencing technique [12], [13]. The steps for both of them are summarized as follows:

*A. **Algorithm 1:** With Counter Sharing*

Step 1: Declare the number of nodes.

Step 2: Set the sequence number, K.

Step 3: Initialize the counter value, counter[i] = 0.

Step 4: Consider a node and check the counter, counter[i] ≤ K.

Step 5: Check, the channel is idle.

Step 6: Check, the node maintains correct discipline by sharing the counter information, if so, access the channel, else defer.

Step 7: Increment counter, counter[i]++.

Step 8: Repeat Step 4 to 7 until counter[i] > K.

Step 9: Consider next node and precede the steps from 3 to 8.

*B. **Algorithm 2** With No Counter Sharing*

Step 1: Declare the number of nodes.

Step 2: Set the sequence number, K.

Step 3: Initialize the counter value, counter[i] = 0.

Step 4: Consider a node and check the counter, counter[i] ≤ K.

Step 5: Check, the channel is idle, if so, access the channel.

Step 6: Increment counter, counter[i]++.

Step 7: Repeat Step 4 to 7 until counter[i] > K.

Step 8: Consider next node and precede the steps from 3 to 8.

In the proposed method, each node is allowed to access the medium for a limited number of times, which is equal to the factor, sequence number. It means the number of attempts made by a node will be limited to a value known as sequence number, K. after distribution of idle slots, each node is entitled to access the channel after their slot time. The major problem arises when more than one node attempt to access the channel in the same slot time. If a node wants to access the channel and it senses the channel busy then access of the channel is denied to that node, otherwise it can access the channel provided that the counter of the node is less than the sequence number, K.

4 PERFORMANCE ANALYSIS

In this section, the simulation results of new method are presented. The simulation is performed using NS-2. The performance is measured by calculating the MAC efficiency and by estimating the number of collisions during transmission. I have set up a discrete event simulator using the features of NS-2 and investigated the performance of the proposed scheme. I have estimated its total power, energy consumed, packet delivery ratio and throughput. All simulations are performed on a Windows platform using NS-2 with a simulation time of 0.05 s. My simulation setup includes 15 wireless LAN nodes trying to access the channel. The simulation parameters are listed in Table I. The advantage of the proposed scheme is it produces better MAC performance, although the counter information is not being shared among other stations, whereas in the case of the EBA and BCR-CS schemes, the performance depends on its backoff value announcement and sharing.

It is observed that the performance of the new algorithm greatly depends on the sequence number *K*. As in Fig. 1, we can see the collisions are very few as compared with the Legacy DCF. It is clear from the figure if the number of nodes increases, the number of collisions also increases. But in this new approach it is very small increment in comparison with the Legacy DCF. The average end-to-end delay and the average throughput when different number of nodes transmits data can be observed in Fig.2 and Fig. 3. From Fig. 2, it is seen that the average end-to-end delay is low when compared to the legacy DCF backoff algorithm. From Fig. 3, it is clear that the average throughput increases as the number of nodes increases. The throughput performance of the proposed system for different numbers of nodes can be observed in Fig.4. From Fig. 4, it is seen that the performance of the network decreases as the number of nodes increases and the performance of the proposed method is greater than the legacy DCF. The strength of the proposed method is significantly reducing the number of collisions and, therefore, increasing the quality of service for wireless networks.

TABLE I
SIMULATION PARAMETERS

Parameter	**Value**
DIFS	50 µs
SIFS	10 µs
MAC	802.11 DCF
Routing	AODV
Network Type	Single Hop
Number of Contending Stations	2-260
Network Size	260
Sequence Number, K	50, 100, 150, 200, 250, 300
CW_{min}	31
CW_{max}	1023
Traffic Type	CBR
PHY Data Rate	1 MBPS
PLCP Preamble	144 µs
PLCP Header	48 µs
Frame Size	2304 Octets
ACK Timeout	50 µs

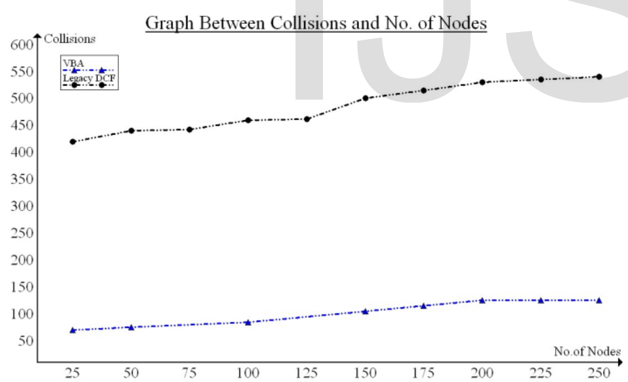

Fig. 1. Comparison of Collisions for Different No.of Nodes.

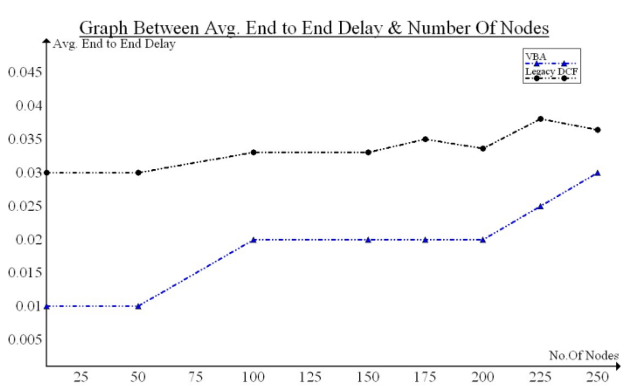

Fig. 2. Comparison of Average End-to-End Delay for Different No.of Nodes.

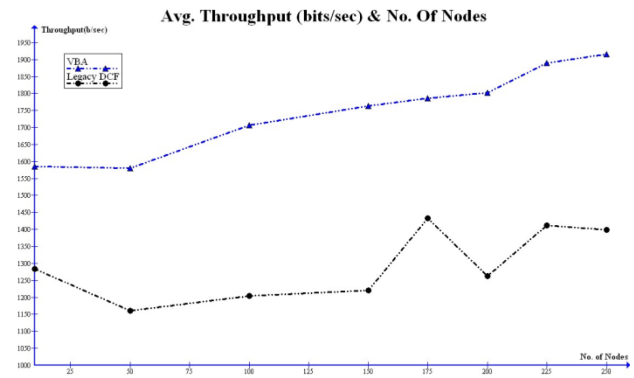

Fig. 3. Comparison of Average Throughput for Different No.of Nodes.

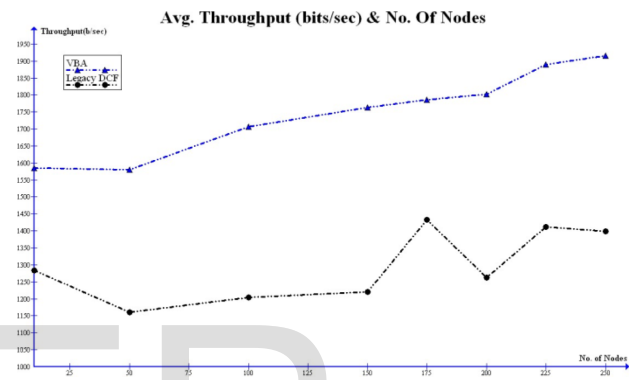

Fig. 4. Comparison of Performance for Different No. of Packets Sent.

5 CONCLUSION

Optimization of back-off period is done using a method based on sequencing technique. Two variants of this approach with Counter Sharing and with No Counter Sharing are compared. Here four parameters namely Collision, Average End-to-End Delay, Average Throughput and Performance Efficiency are considered to evaluate the performance of both of the approaches. The simulation results show that both the variants of the proposed method perform well for all the four parameters. The basic principle used in this method is limiting the number of transmission of a node based on sequence number. The proposed scheme uses fair distributed mechanisms to access a channel. A counter at each node is introduced to maintain the discipline of the nodes. Hence, by optimizing the back-off period it is noticed that a great reduction in the amount of collision and significant increase in throughput.

The sequence number used for simulation is constant for all the nodes. In the future work this approach can be made as adaptive, that is, to vary the value of the sequence number for each node according to the data availability of the node.

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