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Improving the Performance of Medium Access Control (MAC) Layer Using Virtual Backoff Algorithm (VBA)

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Abstract: Nowadays, there is a wide range of communication over wireless networks. As the need for communication increases, there is a need to prevent wireless communication from collision. This paper presents a scheme, called the Virtual Backoff Algorithm (VBA) for efficient Medium Access Control (MAC) layer. The proposed method minimizes the number of collisions as well as the delays that occur during the backoff periods. The VBA method uses fair distributed mechanism to access the channel. When collision occurs in a MAC layer, it may result in decreased throughput, hence leads to lower bandwidth utilization. Virtual Backoff Algorithm (VBA) is used inorder to prevent collision during multiple channel access in MAC Layer. In this method, we introduce a counter at each node to maintain the discipline of the nodes. AODV is used as the routing protocol in this method. The proposed method minimizes the number of collisions and increases the throughput along the network. Also the proposed scheme shows that the energy requirements are minimum while reducing collisions in the MAC layer.

Keyword: Channel access, IEEE 802.11 protocol, CSMA/CA, distributed coordination function (DCF), Medium-access control (MAC), ad hoc on-demand distance vector (AODV).

I. INTRODUCTION

Wireless communication technology has gained widespread acceptance in recent years. As a result, wireless local area network (WLAN) is emerging as a dominant means of wireless communications and the Internet access [1]. 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 [2], [5]. The IEEE 802.11 standard specifies two Medium Access Control (MAC) schemes, namely, a mandatory Distributed Coordination Function (DCF), and an optional Point Coordination Function (PCF) [3], [4]. Most of today's WLAN devices implement DCF only due to its simplicity and the efficient best-effort service provisioning. DCF is based on carrier sense multiple access with collision avoidance (CSMA/CA), in which a station transmits its frame only if the medium is determined to be empty, i.e., not occupied by other station(s). The collision avoidance mechanism utilizes the random backoff period to each frame transmission attempt. While the random backoff can reduce the collision probability, it cannot completely eliminate the collisions since two or more stations can finish their backoff procedures simultaneously. As the number of contending stations increases, the number of collisions is also likely to increase.

It is well noted that an efficient backoff algorithm would increase the performance of wireless network. In this paper, we propose a procedure called as Virtual Backoff Algorithm (VBA) to minimize number of collisions and to increase the throughput of the system. The basic principle of VBA is to limit the number of transmissions of a node based on a sequence number. The VBA gives a solution to MAC by proposing an alternate method to backoff algorithms.

Medium Access Control **(MAC) is the s**ub layer of Data Link Layer specified in the seven-layer of OSI model provides addressing and channel access mechanism to communicate with several network nodes.

The IEEE 802.11 standard specifies two Medium Access Control (MAC) schemes, namely, a mandatory Distributed Coordination Function (DCF), and an optional Point Coordination Function (PCF). The DCF provides distributed channel access, whereas the PCF provides centralized channel access using a coordinator. The PCF uses polling to provide channel access for the nodes. Most of today's WLAN devices implement DCF only

due to its simplicity and the efficient best-effort service provisioning.

Distributed coordination function (**DCF**) is the fundamental MAC technique of the IEEE 802.11 based WLAN standard. DCF employs a CSMA/CA with Binary exponential backoff algorithm. DCF requires a station wishing to transmit to listen for the channel status for a DIFS interval. If the channel is found busy during the DIFS interval, the station defers its transmission. In a network, a number of stations contend for the wireless medium. If multiple stations sense the channel busy and defer their access, they will also virtually simultaneously find that the channel is released and then try to seize the channel. As a result, collisions may occur. In order to avoid such collisions, DCF also specifies random backoff, which forces a station to defer its access to the channel for an extra period. The length of the backoff period is determined by the following equation:

Backoff Time= random (CWmin, CWmax) *** Slot Time**

DCF also has an optional virtual carrier sense mechanism that exchanges short Request-to-send (RTS) and Clear-to-send (CTS) frames between source and destination stations during the intervals between the data frame transmissions. DCF includes a positive acknowledge scheme, which means that if a frame is successfully received by the destination it is addressed to, the destination needs to send an ACK frame to notify the source of the successful reception. The performance of the proposed VBA scheme is good when compared with the previous works such as the legacy DCF, ECA, BCR-CS, and EBA methods.

The advantage of the VBA scheme is the ability to lower communication overhead because the sequencing scheme does not require information sharing among the neighboring nodes.
Hence, the VBA can be applied as an alternate method instead of using the legacy DCF [3], [6], ECA [9], [10], BCR-CS [11] and EBA [12]. The performance of the method is estimated using the NS-2 simulator, and the results show promising performance of the VBA.

II. VIRTUAL BACKOFF ALGORITHM

The proposed sequencing technique can be applied with RTS/CTS and without RTS/CTS scenarios. The performance of the Virtual Backoff Algorithm depends on the disciple of nodes on idle slots distribution. But it is often that most of the nodes will try to access the channel during their slots which will cause collisions and the performance of the system is reduced. VBA can be implemented in ways- with or without counter sharing based on sequencing technique [7], [8]. The steps of the algorithm describing VBA-CS and VBA-NCS can be summarized as shown in Algorithm 1 and 2.

Algorithm 1: Virtual Backoff with Counter Sharing (VBA-CS)
INPUT: STA_1, STA_2, STA_3, . . . , STA_n
//requests from various stations for channel access
Shared Variables:
for every i, 1 ≤ i ≤ n
counter[i] € {0, 1, 2, . . . ,N} initially 0, updated by stations
Sequence Number, K € {0, 1, 2, . . . ,N}, initially 0, will be set to a positive integer
Procedure:

```
//Initialization
Set sequence number K = m; //Fixing the Sequence Number
for (i = 1 to n)
counter[i] = 0;
for (i = 1 to n)
{
while (channel access[i])
if (counter[i]! = K)
{
if (channel == idle)
{
if (counter[i]<min(counter[i+1], counter[i+2], . . . ,
counter[i + n]))
access channel;
else
defer access;
}
counter[i] + +;
}
else
}
defer access;
}
```

Algorithm 2: Virtual Backoff with No Counter Sharing (VBA-NCS)
INPUT: STA_1, STA_2, STA_3 . . . , STA_n
//requests from various stations for channel access
Shared Variables:
for every i, 1 ≤ i ≤ n
counter[i] € {0, 1, 2, . . . ,N} initially 0, updated by stations
Sequence Number, K € {0, 1, 2, . . .N}, initially 0, will be set to a positive integer
Procedure:

```
//Initialization
Set sequence number K = m; //Fixing the Sequence Number
for (i = 1 to n)
counter[i] = 0;
for (i = 1 to n)
{
while (channel access[i])
if (counter[i]! = K)
{
if (channel == idle)
{
access channel;
else
defer access;
}
counter[i] + +;
}
else
defer access;
}
```

The proposed VBA will allow each node to access the channel to limited number of times, which is equal to factor sequence number i.e., the number of attempts made by a node will be restricted to a value known as sequence number K. After distribution of ideal slots, each node is entitled to access the channel after their slot time. The main problem arises when more than one node attempts to access the channel in the same slot time. If a node wants to access channel and it senses the channel is busy then access of 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.

III. ROUTING PROTOCOL

Ad hoc On-Demand Distance Vector **(AODV)** Routing is a routing protocol for mobile ad hoc networks (MANETs) and other wireless ad-hoc networks. It is a reactive routing protocol, meaning that it establishes a route to a destination only on demand. In contrast, the most common routing protocols of the Internet are proactive, meaning they find routing paths independently of the usage of the paths. AODV is, as the name indicates is a distance-vector routing protocol. AODV avoids the counting-to-infinity problem of other distance-vector protocols by using sequence numbers on route updates, a technique pioneered by DSDV. AODV is capable of both unicast and multicast routing.

The main advantage of this protocol is that routes are established on-demand and destination sequence numbers are used to find the latest route to the destination. The connection setup delay is lower.

In AODV, the path discovery process is initiated whenever a source node needs to communicate with another node for which it has no routing information in its table. Every node maintains two separate counters: a node sequence number and a broadcast id. The source node initiates path discovery by broadcasting a route request (RREQ) packet to its neighbors. RREQ will arrive at a node that possesses a current route to the destination or the destination itself. The receiving node first checks that the RREQ was received over a bi-directional link. If an intermediate node has a route entry for the desired destination, it determines whether the route is current by comparing the destination sequence number in its own route entry to the destination sequence number in the RREQ.

If the RREQ's sequence number for the destination is greater than that recorded by the intermediate node, the intermediate node must not use its recorded route to respond to the RREQ. Instead the intermediate node rebroadcasts the RREQ. The intermediate node can reply only when it has a route with a sequence number that is greater than or equal to that contained in the RREQ. If it does have a current route to the destination and if the RREQ has not been processed previously, the node then unicasts a route reply packet (RREP) back to its neighbor from which it received the RREQ.

IV PERFORMANCE ANALYSIS

In this section, I present the simulation results of VBA. 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 Linux platform using NS-2 with a simulation time of 0.05 s. My simulation setup includes 24 wireless LAN nodes trying to access the channel.

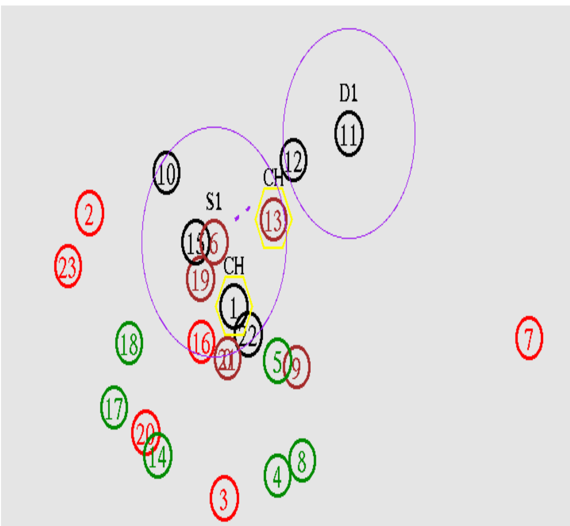

Figure.1 Transmission of packets based on AODV routing protocol

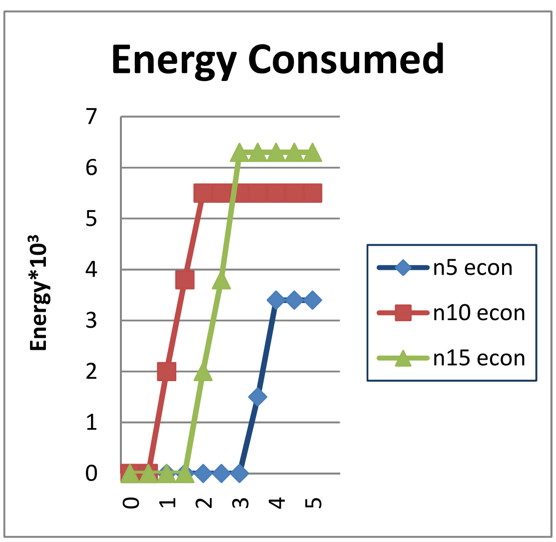

Figure.2 Energy consumed while different nodes are transmitting packets

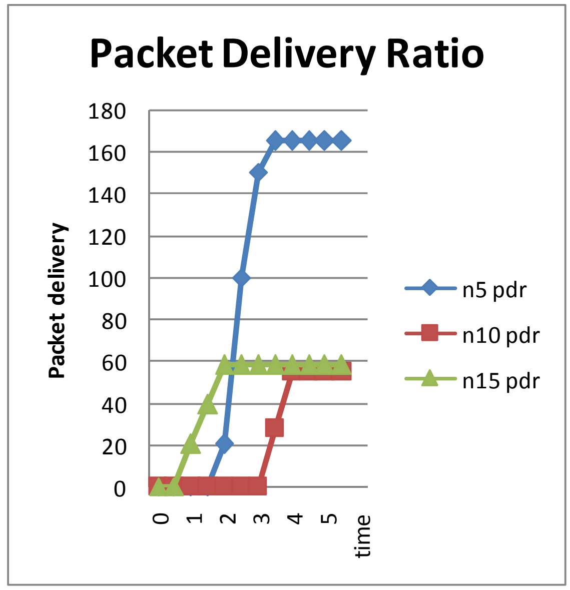

Figure.3 Cluster packet delivery ratio

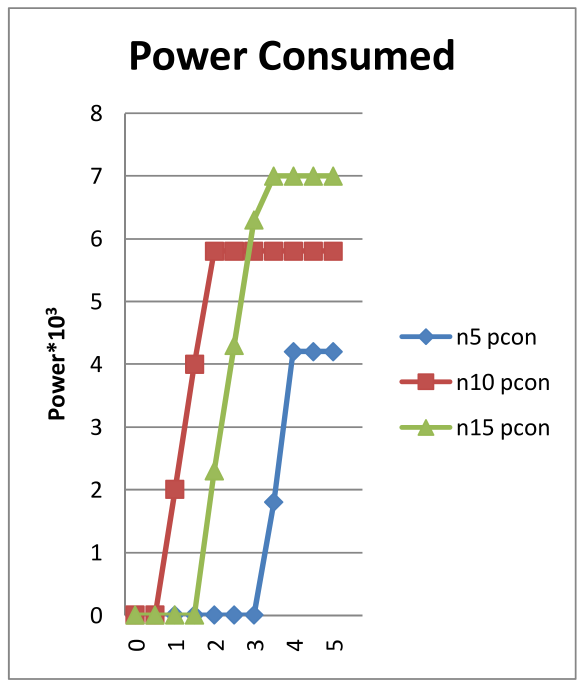

Figure.4 Total power consumed

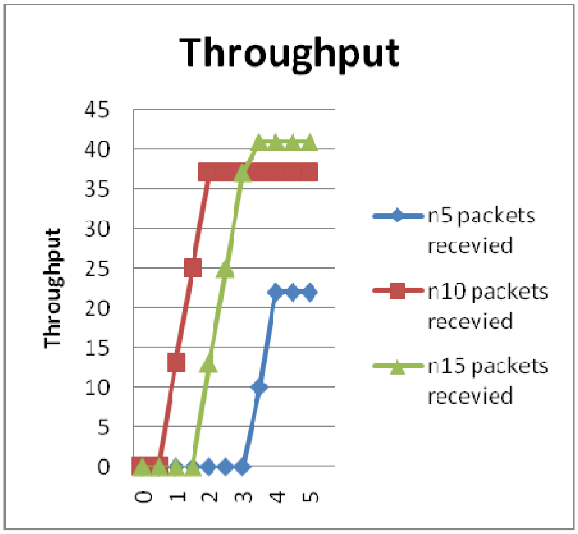

Figure.5 Cluster throughput

It can be observed in Fig. 1 that different nodes can transmit their data without any collision by assigning a proper route from the source node to the destination node. 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 VBA greatly depends on the sequence number *K*. Total power consumption as the number of nodes increases is plotted in Fig. 2. The packet delivery ratio and the total energy consumed when different number of nodes transmits data, can be observed in Fig.3 and Fig. 4. The throughput of the system increases when the sequence number increases. The throughput performance of the proposed sequencing scheme for different numbers of nodes, can be observed in Fig.5. The strength of the proposed method is significantly reducing the number of collisions and, therefore, increasing the quality of service for wireless networks.

V CONCLUSION AND FUTURE WORK

The MAC-layer protocol DCF has been enhanced by proposing a new method, known as the VBA, which is based on the sequencing technique. The performance of the MAC layer is good while using the VBA when compared with other methods like legacy DCF, ECA, BCR-CS, and EBA.

To conclude, the proposed VBA method uses the concepts of sequencing. In the existing MAC layer, there is a certain amount of waste in the available bandwidth, which can be reduced by sequencing, whereby selected RTS/request packets are dropped in a controlled way in the new enhanced protocol. The enhanced protocol, which has been designed and implemented in this paper, improves the utilization of bandwidth by increasing the throughput. A significant increase in throughput is achieved with the modified version of MAC protocol. The power analysis on the proposed technique shows that it utilizes minimum energy. The results are validated by the simulation results generated by using NS-2.

In the future, the VBA scheme can be extended to ad hoc networks such as wireless sensor networks, and the performance of sensor networks needs to be analyzed. Self-discipline of the nodes while accessing a channel is important and the performance of any algorithm depends on this agreement. Presenting the VBA with a learning approach can be a future work extending this work. In addition, detecting the malicious nodes is potentially another future work using the VBA scheme.

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