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CONSTANT –TIME CONTENTION RESOLUTION MAC SCHEME FOR MULTI-RATE AD-HOC NETWORK

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KeyWords

Ad-hoc wireless network, DCF, collision, constant-time.

ABSTRACT

In ad-hoc wireless network, the nodes share a common broadcast radio channel and it may be possible that multiple nodes access the channel at the same time, resulting in collision. Thus a medium access control (MAC) protocol is needed which can efficiently distribute the use of the shared medium among the nodes. IEEE 802.11 standard uses DCF (Distributed Coordinated Function) as the MAC scheme. The DCF scheme is based on carrier sense multiple access with collision avoidance (CSMA/CA), which is a random access scheme with carrier sense and collision avoidance through random backoff. It's main limitation is that, the number of collisions increases with number of stations. This affects other performance parameters such as decreased throughput. Thus after DCF many other MAC protocols have been proposed. These MAC schemes proved to result in less number of collisions but their other side is that they are taking variable number of time slots to resolve the contention. One MAC scheme known as CONTI considers both points that is resolving the contention with less number of collisions as well as in constant time. This paper uses the concept of CONTI and extends the scheme to work for multi-rate ad-hoc networks.

I. INTRODUCTION

In recent years the ad-hoc wireless network has gained a lot of popularity. An ad-hoc wireless network is a decentralized wireless network. It is a collection of independent nodes or stations which communicate with each other by creating a multihop radio network. The decentralized nature of such networks makes them suitable for a variety of applications which are not supported by infrastructure-based networks. Infrastructure-less nature and quick deployment make ad-hoc networks suitable for emergency situations like natural disasters or military conflicts.

In ad-hoc wireless networks a single medium of transmission is shared by multiple nodes. Due to this sharing, there occurs the problem of resolving the contention between stations' chance of sending data to other station or receiving data from other station. This contention resolution is the work of the MAC protocol. The characteristics of the wireless medium are completely different from those of the wired medium. Since ad hoc wireless networks need to address unique issues such as node mobility, limited bandwidth, hidden and exposed terminal problems which are not applicable to wired networks. Hence a different set of MAC protocols are required for accessing the shared medium in such networks. While designing any MAC scheme many issues are considered like risk of collisions, throughput, delay, fairness etc. DCF is the most widely used MAC scheme for IEEE 802.11 standard.

The DCF mechanism is based on CSMA/CA protocol. The stations trying to access the medium defer their access for a random period of time, so as to avoid collisions. The stations make use of contention window (CW) to randomize their access to the medium. The stations chose any random number from the CW and then defers for that number of time slots. After their wait is over, they try to access the medium. DCF scheme proved to be unstable for large size networks. Hence many other MAC protocols have been proposed by various researchers such as PREMA [1] and K-EC [2]. These MAC schemes also have certain drawbacks like if at one side they try to resolve the contention with reduced number of collisions, then at the other side time they take to do this is not constant. Another MAC scheme known as CONTI is proposed in [3] which has solved both the problems that is resolving the contention among the stations with lower number of collisions and in constant number of time slots. It eliminates some of the contending stations after the elapse of one contention slot. This elimination is based on a randomly chosen value of a local Boolean variable as one or zero. The value of the Boolean variable is then reset and the process is repeated several times until one station remains in the set of contending stations. According to this method, the collision rate is directly dependent on the number of contention slots.

In the above scheme, values of two parameters are optimally chosen, which are, the number of contention slots and the probability of choosing the value of local Boolean variable as one or zero in every slot. These optimal values allow resolving the contention among the stations in constant-time with lesser number of collisions. In the proposed work, the above mentioned concept of resolving the contention in constant-time, is used and extended to work for four different data rates: 1 Mbps, 2 Mbps, 5.5 Mbps and 11 Mbps, which are supported by IEEE 802.11b. The simulation is done on NCTUns-5.0 by using multiple data rates.

The rest of the paper is organized as follows. Section II briefly describes the IEEE 802.11 standard DCF protocol. Section III presents the various other MAC schemes. Section IV discusses the proposed system in detail. Section V evaluates the performance of DCF and the proposed MAC scheme and Section V concludes this paper.

II. EXISTING SYSTEM

The DCF mechanism is based on carrier sense multiple access with collision avoidance (CSMA/CA), which is a random access scheme with carrier sense and collision avoidance through random backoff.

The DCF protocol is used for channel arbitration in IEEE 802.11 based ad-hoc network. In DCF protocol, the stations use Contention Window (CW) to randomize their access and try to avoid collisions. Initially, a station waits for DIFS and transmits if the channel is idle, as shown in fig.1. However if the channel is busy, the CW is used. The CW is initially assigned to a preset value, CW_{min}, which depends on the physical layer. Then a station sets a backoff counter to random value chosen from a uniform distribution from [0, CW]. The station decreases the backoff counter by one for every time slot the channel is idle. If a busy channel is detected, the backoff counter freezes and the countdown resumes from the freeze value after the channel is idle for duration of DIFS. The station transmits when its backoff counter reaches zero. If two or more stations reach zero at the same time, there will be collision and the transmitted frames won't be received correctly. The colliding stations will not receive an ACK frame and they will double their CW, until it reaches CW_{max}. On the other hand, when a station transmits a data frame successfully, its CW is reset to the initial value CW_{min}.

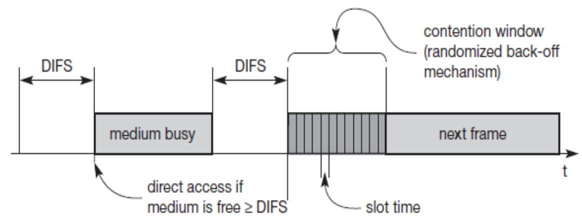

Fig. 1: Medium Access in DCF

The existing MAC scheme, IEEE 802.11 DCF for ad-hoc wireless networks has some drawbacks. The DCF scheme performs reasonably well for transmitting best-effort packets in small-size networks. But, as the number of serviced stations grows high, the performance starts degrading. Initially when network was small, the DCF protocol worked efficiently. At present with the increase in network size the performance of DCF protocol decreases. The main reason for performance degradation of DCF protocol is increased collision rate due to increase in number of stations. Large number of collisions cause decrease in network throughput and increase in access delay. For large networks the DCF protocol cannot resolve the contention efficiently.

III. RELATED WORK

Numerous MAC schemes for contention resolution among the nodes of ad-hoc networks have been proposed in the past. Some well known schemes are studied for the proposed work.

One of the MAC scheme is Prioritized Repeated Eliminations Multiple Access (PREMA) [1]. It has several rounds of elimination and work as follows. Contending stations transmit a jam, whose length in slots is drawn from a geometric distribution with parameter q. After the last jam slot, the stations do one slot of carrier sense. If they hear another ongoing slot, they're out of this contention. If not, it means they passed this elimination. The stations with the longest burst will survive the elimination. Following to this they do another elimination by choosing another random number from the same distribution and jamming and then one slot of carrier sense. The number of eliminations is a parameter called h. The authors of PREMA use the parameters h = 4 and q = 0.5. PREMA suffers from two limitations. One is when increasing the load on network; the number of contenders is increasing causing more interference and lower throughput. And the second limitation is number of time slots spent in contention resolution increases with number of stations.

Another scheme is k-Round Elimination Contention (k-EC) [2], which, like PREMA, is a jamming-based scheme. It also has several rounds of eliminations in a contention. There are k rounds of elimination, where k is a parameter. A round of k-EC consists of at most m slots. The contending stations choose a random number uniformly from [0, m – 1] and transmit only one jam in the slot number. For example, if a station chooses 0, then it is the first slot. If the station is not jamming, then it should be listening by carrier sense. When a station hears a jam while it's listening, it drops out of the contention and the round is finished for it. The other stations survive and move to the next round. Since the jam can happen in any slot, a round of k-EC is at most m slots long. The authors of k-EC use k = 7 and m = 3 as the best parameters. As a result, a contention of k-EC with these parameters takes anywhere from 7 slots to 21 slots. The limitation of k-EC is that the number of time slots spent in contention resolution is more for less number of stations whereas it keeps on decreasing as the number of stations grow.

Third contention based MAC scheme studied is CONTI [3, 4]. It is a constant-time contention resolution MAC scheme for WLAN. It is based on binary countdown mechanism. For the wired networks access this mechanism works as follows. To access the medium, stations participate in a contention which runs for a period of length (in time slots) equal to the number of bits representing the stations' address. Each time slot corresponds to a bit position, with the earliest time slot corresponding to the most significant bit. During each slot, a station that has a value of one in the corresponding bit jams the medium. Stations having a value of zero for that bit sense the medium. If the medium has been jammed, the listening stations retire from the current contention. The main limitation of this mechanism is letting the station with the highest address win. On the other hand, the main advantage of this mechanism is collision-free communication since addresses are unique identifiers. This paper has re-discovered this mechanism and found two critical parameters which will obtain the best of this mechanism. These two critical parameters are: the number of slots for which the contention should be run and the probability with which the stations will chose whether to jam or sense the medium during a time slot.

The above paper thus proposes a scheme which involves the use of a local Boolean variable known as try-bit. Each station chooses a value for its try-bit and either jams (try-bit = 1) or senses the medium (try-bit = 1). A station retires only if its try-bit is equal to zero and the medium was jammed. After the elapse of one time slot, the stations that were not eliminated refresh their try-bit variables and repeat the same process. This process is repeated for a specified number of slots, until one station remains in the set of contending stations. Therefore this station will initiate a transmission. This paper has also demonstrated the mathematical analysis for finding the two optimal parameters: the number of time slots for which to contend and the probability with which the station chooses the value of the Boolean variable as 1 or 0 in every slot. The optimal parameters are found to be $k = 7$ and $p = \{0.18, 0.31, 0.40, 0.48, 0.48, 0.49, 0.49\}$, where k is number of time slots and p is probability vector containing probability corresponding to each of the 7 slots.

In the proposed scheme the idea of contention resolution among the stations in constant-time as given in [3] is utilized and extended to work in multiple data rate environment.

IV. PROPOSED SYSTEM

The existing DCF mechanism of IEEE 802.11 standard which is used as MAC scheme for contention resolution in ad-hoc wireless networks suffers from large number of collisions as the number of contending station increases. This limitation also affects the throughput and access delay of the network. Thus it is proposed to develop a MAC scheme for multi-rate ad-hoc networks which resolves the contention in constant-time with reduced number of collisions, higher throughput and lower access delay.

The proposed system runs a certain number of contention slots so as to resolve the contention among the stations before a transmission can be initiated. At the end of each contention slot a number of contending stations is eliminated. The stations eliminated will stop their contention to the medium during this transmission trial and can again participate in the contention in the next attempt to transmit. At the end of last slot only one station is expected to be left which wins this transmission attempt.

There will be a probability vector p which will be used by all the stations. The contention of n stations is resolved over k contention time slots. One value corresponding to every time slot is there in p. A local Boolean variable named as *signal* is used to decide whether to remain in the contention or to retire from the contention. Before a slot s_i, all the stations either choose the value of *signal* as 1 with probability p_i or *signal* as 0 with probability $(1-p_i)$. Based on the value of *signal* stations are logically divided into two groups: active group (stations with *signal* as 1) and the passive group (stations with *signal* as 0). During the contention slot, station with *signal* as 1 makes the channel busy by transmitting a pulse. On the other hand stations with *signal* as 0 will listen to the channel. The pulse that is transmitted doesn't need to contain any information. Rather, its presence on the channel signals to other stations that one or more stations have chosen *signal* as 1. The station listening to the channel, if senses the presence of a pulse, will leave the contention. Thus the station is said to be preempted, and this station doesn't contend anymore in this transmission attempt. But if a station with *signal* as 0 doesn't sense any pulse, it stays in the contention. It means no station has chosen the *signal* as 1. The stations which remain, after the end of the current slot, moves to the next contention slot and same procedure as above is repeated. At the end of the k^{th} slot, a station that has not been preempted transmits its data.

It may be possible that during a contention slot all the stations choose *signal* as 1. Then, no stations are eliminated. It also happens if all the stations choose *signal* as 0. If this happens, then the subsequent slots will continue the contention. But if it happens in the last slot and there are more than one station remaining, there will be a collision. Thus for an efficient contention resolution, the probability choices should be optimized to minimize the collision rate. The number of slots should also be minimized so that the time spent in the contention is reduced. The optimal parameters used are $k = 7$ and $p = \{0.18, 0.31, 0.40, 0.48, 0.48, 0.49, 0.49\}$.

Multi-Rate Environment

The various wireless standards are IEEE's 802.11a, 802.11b, 802.11g and 802.11n. IEEE 802.11b is the standard considered for multi-rate environment. The data rates supported by IEEE 802.11b are 1 Mbps, 2 Mbps, 5.5 Mbps and 11 Mbps. The simulations are done at these four data rates for measuring the performance parameters like number of collisions, throughput and access delay. The results obtained after the simulation are used to find out the optimal data rates for the best performance of the network.

V. PERFORMANCE EVALUATION

For performance evaluation the comparison is done between proposed scheme and IEEE 802.11. For both the schemes, the average number of collisions, the average throughput and the average access delay is measured. The topology used for observing the performance of both the schemes is as shown in fig.2 below.

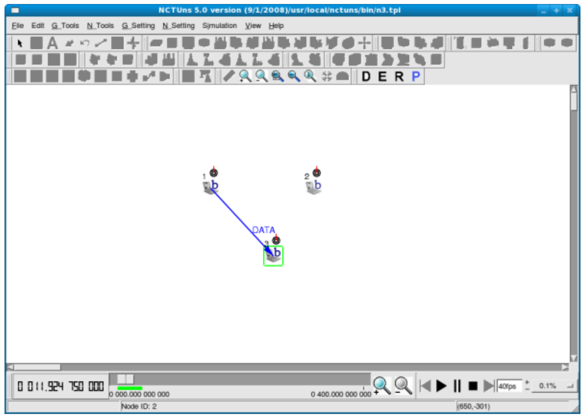

Fig.2: Topology Used for Simulation

The above topology consists of three nodes, where node 1 and node 2 acts as senders while node 3 acts as a receiver. When node 1 and node 2 simultaneously send the data to node 3, it causes a collision. The proposed protocol resolves the contention between node 1 and node 2 in such a way that lesser number of collisions occur at node 3.

Simulation of MAC schemes is done using NCTUns 5.0 network simulator and the network is simulated under 1, 2, 5.5 and 11 Mbps data rates. The NCTUns network simulator is a high-fidelity and extensible network simulator capable of simulating various devices and protocols used in both wired and wireless networks. It uses an open-system architecture to enable protocol modules to be easily added to the simulator. In addition, it has a highly-integrated GUI environment for editing a network topology, specifying network traffic, plotting performance curves, configuring the protocol stack used inside a network node, and playing back animations of logged packet transfers. Following two sub-sections illustrate the two cases of performance comparison.

1) Performance Parameters vs. Data Rates

In this sub-section the performance of the existing and proposed scheme is compared at multiple data rates keeping the frame size constant. The simulation parameters taken are as follows:

TABLE 1

Simulation Parameters	Value
No. of contention slots	7
Slot time	20 Microseconds
Data rates	*1 Mbps, 2 Mbps, 5.5 Mbps, 11 Mbps*
Data packet size	1400 Bytes
Duration	40 Seconds

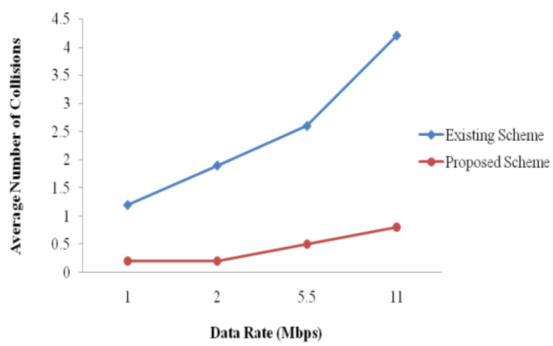

Fig.3: Average Number of Collisions vs. Data Rate

From fig. 3 it can be interpreted that as the data rate increases, number of collisions also increases. It is extremely low at 1 Mbps data rate, and very high at 11 Mbps. The average number of collisions of the proposed scheme is found to be much lower than the existing scheme. There is a vast difference seen at the highest data rate i.e., 11 Mbps. In existing scheme, the average number of collisions have suddenly increased from 2.6 at 5.5 Mbps to 4.2 at 11 Mbps and due to this high collision rate performance of the network degrades. On the other hand, in case of proposed scheme, it has increased from 0.5 at 5.5 Mbps to just 0.8 at 11 Mbps.

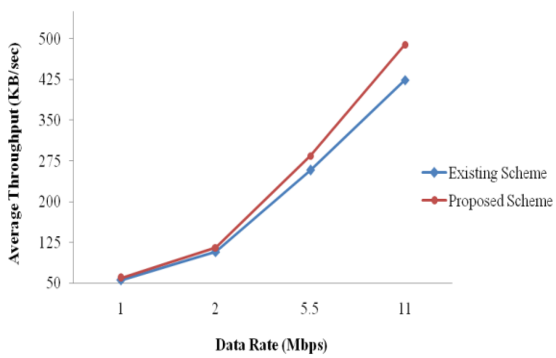

Fig.4: Average Throughput vs. Data Rate

From fig. 4 it is observed that at every bandwidth, proposed scheme results in higher throughput as compared to the existing scheme of IEEE 802.11. At 1 Mbps and 2 Mbps there is not much difference between the average throughputs of both the schemes. At 5.5 Mbps, this difference is increased from 258 KBps in existing scheme to 284 KBps in proposed scheme. And, finally at 11 Mbps proposed scheme with 489 KBps has outperformed the existing scheme with 423 KBps, a difference of 66 KBps. This improvement in the average throughput has resulted from the much lesser number of collisions in the proposed scheme.

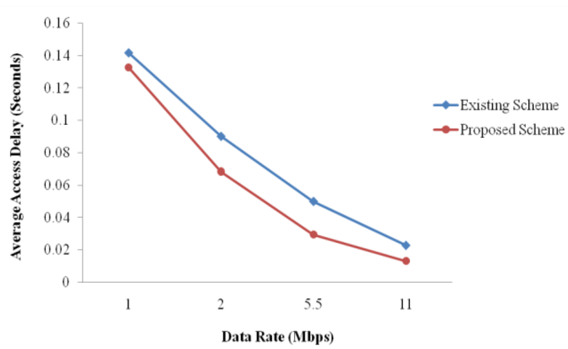

Fig.5: Average Access Delay vs. Data Rate

With the increase in the data rate, the access delay of the ad-hoc networks decreases. Lower the access delay better is the networks performance. It can be seen from fig. 5 that in all the four cases of data rates, proposed scheme has resulted in lower access delay as compared to the existing scheme.

2) Performance Parameters vs. Frame Sizes
In this sub-section the performance of the existing and proposed scheme is compared for different frame sizes keeping the data rate constant. Following are the simulation parameters taken:

TABLE 2

Simulation Parameters	Value
No. of contention slots	7
Slot time	20 Microseconds
Data rate	11 Mbps
Data packet size	600 Bytes, 800 Bytes, 1000 Bytes, 1200 Bytes, 1400 Bytes
Duration	40 Seconds

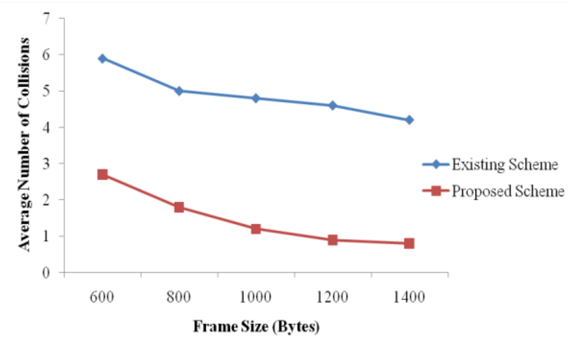

Fig. 6: Average Number of Collisions vs. Frame Size at 11 Mbps

At 11 Mbps data rate, with the increase in frame size, fig. 6 shows that the proposed scheme has resulted in a much lesser average number of collisions when compared to the existing scheme. Also, the average number of collisions is least for the maximum frame size.

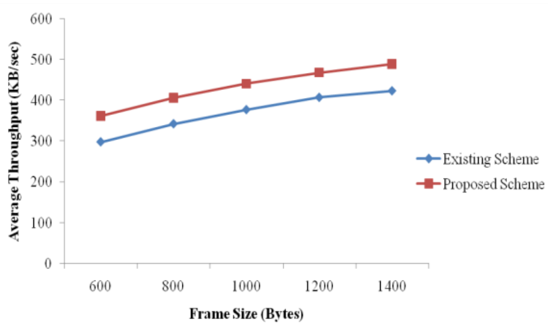

Fig. 7: Average Throughput vs. Frame Size at 11 Mbps

It is clear from the fig. 7 that for all the cases of frame size, proposed MAC scheme has resulted in higher average throughput than the existing one and this is due to lesser average number of collisions for every frame size in the proposed scheme.

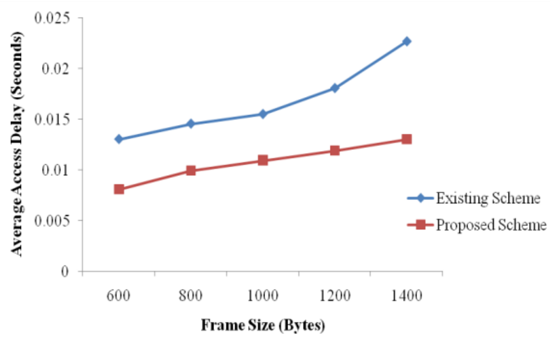

Fig. 8: Average Access Delay vs. Frame Size at 11 Mbps

Fig. 8 depicts that with every frame size, proposed scheme suffers from lower average access delay as compared to the existing scheme. The major difference between both the schemes is observed for the frame size 1400 Bytes.

Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Authors are strongly encouraged not to call out multiple figures or tables in the conclusion—these should be referenced in the body of the paper.

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