SELECTIVE SUSPENSION OF TRANSMISSION FOR AVOIDING PRIORITY REVERSAL IN MOBILE AD HOC NETWORKS

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ABSTRACT
Ad hoc wireless networks are a very potential field offering lot of scope for research. In these networks, the Medium Access Control (MAC) protocols are responsible for coordinating the access from active nodes. These protocols assume greater significance since the wireless communication channel is inherently prone to such problems as hidden terminal, exposed terminal and fading effects .The scheme proposed here is used to perform priority scheduling in nodes resolving any contention scenario that can arise for the channel in the best possible manner. Alert transmission packets are used as a means of notification whenever a high priority node wants to transmit data. Suspend transmission packets are used to avoid priority reversal issue and a retry count is implemented to avoid starvation among the nodes.

Keywords: Ad Hoc Networks, Alert Transmission, Suspend Transmission, Priority, Retry Count

1 INTRODUCTION

Contention for channel among the nodes is resolved using Contention based protocols. In a heterogeneous network like ad-hoc several problems like hidden terminal and exposed terminal problem can arise. The popular Carrier Sense Multiple Access MAC scheme and its variations such as CSMA [1] with Collision Detection (CSMA/CD) developed for wired networks, cannot be used for wireless networks. Priority scheduling is a means to avoid channel contention among the various nodes in the network. The scheme here proposes a new protocol for effective priority scheduling. Two new packets have been designed namely Alert Transmission and Suspend Transmission packets which form the crux of the new scheme. A retry count is implemented to avoid priority starvation.

The rest of this paper is organized as follows. Section 2 presents the related work. The proposed Priority Scheduling scheme with a Suspend Transmission mechanism is explained in Section 3. Simulation results are given in section 4.

2 RELATED WORK

2.1 Classic CSMA problems

In fig 1 Node B is within the range of A and C but nodes A and C are not visible to each other Let us consider the case where A is transmitting to B. Node C, unaware of the transmission at B can transmit data to B thus causing collision at B. This is referred to as the hidden-terminal problem, as nodes

A and C are hidden from each other. Now consider another case where B is transmitting to A. Since C is within B's range it receives the transmission too and can eventually defer its own transmission which is unnecessary as C's transmission is in no way going to affect A receiving the packets from B. This is known as the exposed terminal problem i.e. C is exposed to B.

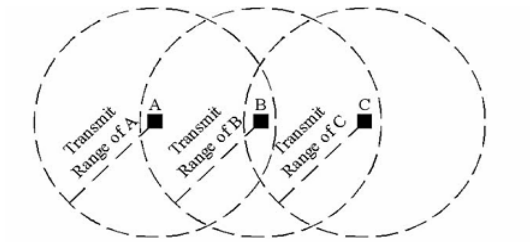

Figure 1: Hidden Terminal Problem

Different flows in multi-hop networks have different degree of contention. Here, the contention degree for a flow is defined as the number of flows with which it is competing for the channel. Two types of MAC schemes are prominently used. Reservation and contention based schemes. Reservation based schemes usually make some assumptions about high priority traffic. Flow scheduling is done locally while contention resolving probabilistically. Black-burst dealt in [8] is a typical example where a high priority node transmits this black-burst signal as a notification for its transmission. Reference [9] generalizes this for wireless ad-hoc network. That is each station can sense the transmission of the other nodes in the network. Reference [6] explains a dynamic priority scheduling with a CAN MAC protocol.

2.2 IEEE MAC 802.11 DCF

The 802.11 DCF function [5] is subjected to several research modifications, which is giving a back-off counter to each node such a way that every node can choose a random number between 0 to maximum contention window size. After sensing the channel to be idle for an inter-frame space the nodes start counting their back-off counters to zero, and if the channel is found to be busy they freeze the back-off counters. The value of Contention Window is constrained to be between CWmin and CWmax. A source station sends an RTS for which it receives back CTS following which it transmits data and gets an ACK packet back. In the event of CTS or ACK not received the source is led to believe that collision has occurred, so it is imperative that there is adequate waiting time for the source before it arrives at some decision. There are two waiting stages in

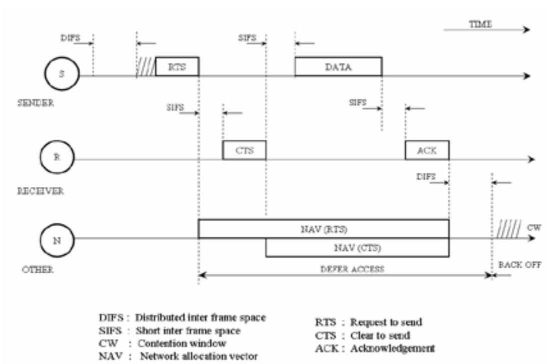

Figure 2: Distributed Coordination Function (DCF)

ad hoc network, the inter frame space (IFS) stage and the back off stage. The back off counter is a random value between zero and the Contention Window. For example high priority source stations randomly choose the back off interval from [0, 2i+1 -1] and low priority source stations choose from [2i+1, 2i+2 -1], where i is the number of consecutive times a station attempts to send a packet. Two different values of CWmin and CWmax are set for different priority classes. It proposes an exponential increase by a factor of 2 in the event of collision.

2.3 Existing Scheme

In order to effectively perform a priority scheduling among these nodes in the network, a priority scheduling scheme was proposed. Whenever a high priority packet is backlogged at some high priority node 0, it will send a primary busy tone signal every M slots before it acquires the channel, where M is a parameter of the proposed scheme. When another node1 of lower priority hears this primary busy tone signal (BT1), it will send a secondary busy tone signal (BT2). All nodes with low priority packets that hear either BT1 or BT2 will defer their transmissions for some duration. In this way, channel access priority of a high priority node can be ensured. Certainly, if there is no high priority packet backlogged at a high priority node, a low priority node will not receive any busy tone.

3 PROPOSED SCHEME

In this scheme priority scheduling in wireless ad-hoc networks, using alert transmission mechanism is implemented. This way contention for channel access between nodes is resolved. This is also seen to eliminate the hidden terminal and exposed terminal problems occurring frequently in ad-hoc networks. Individual nodes are assigned priority ‘Low and High’ based on the back off counter value. It is computed using the formula shown in Eq. (1)

Back Off = (1%cw)*priority*slot time …..(1)

where cw is the size of the contention window for each node. And, priority is a user defined integer value. For each node slot-time is 20µs, and CWmin < CW < CWmax, where CWmin is the minimum CW, and it is usually set to 32 and CWmax is the maximum CW and often set to 1024.

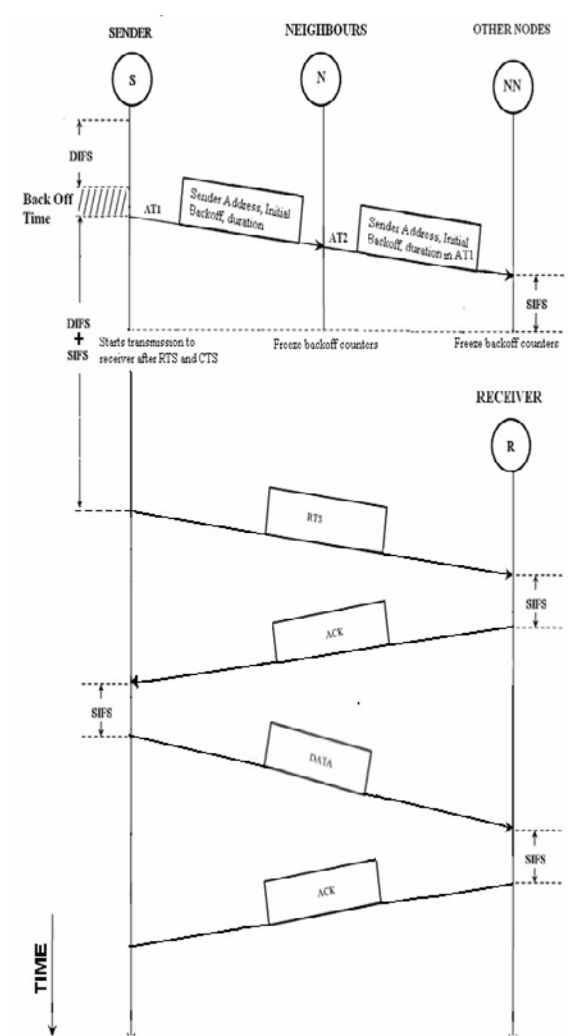

Figure 3: Transmission of AT1 and AT2 packets and Data between the sender, receiver and neighbors.

After DIFS idle time, the station senses the medium to determine whether or not it is idle. If it is idle, then the station decrements its back off value by a slot time, otherwise the back off value stays the same. When the back off value of a station reaches 0, the station sends an alert transmission packet AT1 to its immediate neighbors, which again sends secondary AT2 packet to its neighbors and so on such that the hidden terminal problem is effectively overcome. The transmission of AT1 and AT2 packets is shown in Fig 3. All the nodes in the network are thus conveyed of the node's intention to transmit data. A typical Alert transmission packet shown in Fig 4 will contain the following information: Sender Address, Initial Back Off counter of the original sender node, Receiver Addresses, and The time of transmission.

The frame format of the Alert Transmission Packet (AT) is as follows:

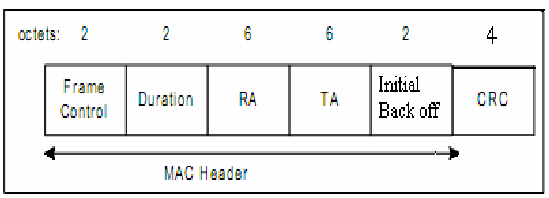

Figure 4: Frame Format of Alert Transmission Packet (AT1 or AT2)

Duration represents the time of sending and TA is the sender address while RA is the receiver address. Other lower priority nodes sensing the transmission immediately freeze their back off counters and defer their transmission to a later period.

3.1 Priority Reversal

A priority reversal occurs when a low priority node has its back off at zero when nodes at a higher priority are in contention. This can lead to a situation where the lower priority node grabbing the channel before the Higher priority nodes.

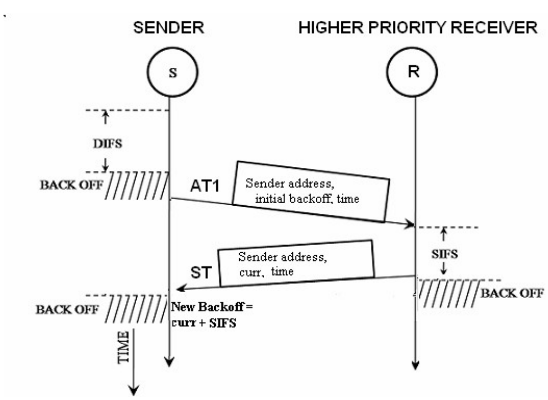

Figure 5: Suspend Transmission Packet during Priority Reversal

Therefore in order to eliminate such a scenario, whenever a high priority node receives a Alert transmission packet either directly or via indirect means it can compare the initial back off value in the Alert transmission packet to check if the source node is of higher priority or lower than its own. The high priority node will immediately send a SUSPEND TRANSMISSION (ST) packet for suspending the transmission this will be directed at the source node.

However not all high priority nodes can transmit the ST packet. This transmission of ST is decided based on the following criteria: original priority of the node, priority threshold determined through average packet transmission time. Only if a high priority node satisfies these conditions it can transmit the ST packet. The ST packet contains the following fields: Sender Address, Receiver Address, and Initial Back off counter, Time sent.

The frame format of the Suspend Transmission Packet (ST) is as follows:

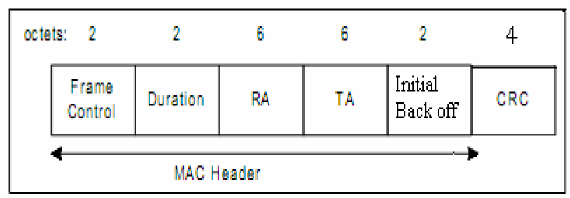

Figure 6: Frame Format of Suspend Transmission Packet

Duration represents the time of sending and TA is the sender address while RA is the receiver address. The right to send an ST packet for nodes will not remain constant it can be subjected to changes based on network characteristics.

An example scenario is depicted in Fig 7. Nodes 1, 4 are high priority nodes and nodes 3, 5 are of low priority. At t1, the initial back off values of nodes 1, 3, 5 are 10, 17 and 18.

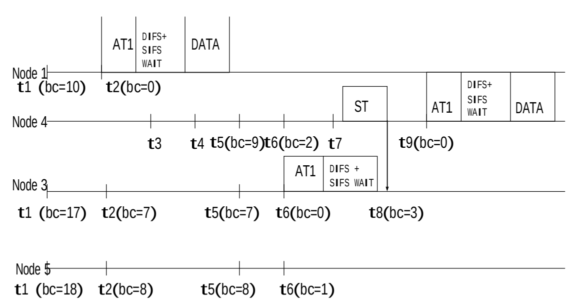

Figure 7: Scenario explaining the Priority Reversal

issue with 5 nodes.

At t1, nodes 1, 3, 5 compete for the channel access while 4 stays away from contention. Once the DIFS time expires, the back off time of node 1 counts to zero and then, it sends an alert transmission packet AT1 to all its neighbors. The nodes which receive AT1 send AT2 packet to its neighbors. After the SIFS period expires, nodes freeze their back off counters. Nodes 3, 5 have their back off counters frozen at 7, 8 respectively and their retry counts are increased by 1.

Node 1 after sending AT1 waits for a DIFS+SIFS period and then takes control of the channel for data transmission. At t4, nodes 4 (BC =9), node 3, 5 contend for the channel access with 3 beating 4 leading to a priority reversal. To overcome this, once the AT1 packet of 3 reaches node 4, it realizes that it has high priority than node 3. Hence, it disregards the AT1 packet and transmits a SUSPEND TRANSMISSION packet ST to node 3 for suspending the transmission. The ST packet contains the current back off value, curr of the sender node i.e., node 4 in our case. Once node 3 receives the ST packet from node 4, it resets it back off value according to the formula.

New Back off = curr + slot time (2)

Where, curr is the current back off value of the node sending ST. After sending ST, node 4 waits for an SIFS period and then starts counting its back off timer to zero. Once a node receives ST it is necessary to do the following apart from resetting its back off value. Firstly, there is a variable backpri initialized with the value of initial back off counter of the node. From the ST packet received, the current back off value of the high priority sender is obtained. This value is compared with the existing value in backpri and the smaller value is stored in backpri. Simultaneously, the back off counter is frozen.

If current back off time of sender < backpri, then
Overwrite backpri as follows
  Backpri=current back off time of sender
Else
  Do Nothing

Similarly, when this low priority node gets into contention in the next idle phase and if it loses contention again by receiving an ST from a high priority node, it will compare the backpri value with the current back off value of the sender and store the smaller value into backpri. Thus, the priority reversal issue is dealt with using Suspend Transmission packets.

3.2 Starvation Avoidance

A Retry Count (RC) is used to prevent the excessive starvation of a low priority node. This can be fixed based on the number of nodes in the network and network characteristics. The number of times the back off counter is frozen is the retry count. The backpri value of the low priority node comes in handy whenever its RC value reaches a threshold. Once a node's retry count reaches this threshold the following occurs. The initial back off counter value is replaced now with backpri value and a slot time is added to it. But before overwriting the initial back off value it is imperative that a copy of it is stored as backup in initial backup variable defined. Now the backpri value is used to overwrite the new back off value which denotes the current or active back off value of the low priority node. That is once RC threshold is reached do the following

Initial backup=Initial back off (3)

Initial back off=backpri+ slot time (4)

New back off= backpri (5)

The backpri value denotes the lowest current back off value of the high priority nodes that have beaten the current node to access the channel. This means the low priority node is promoted to a high priority status temporarily, this is only fair because it has starved so long a period defined by RC threshold to transmit the current packets, and it is necessary that some means are done to promote its priority status, to minimize the further backlogging of these packets. The low priority node will now enter contention as a high priority node since it has its initial back off value reset. Now the initial back off value will remain as backpri + slot-time only till the node transmits the current packets backlogged. The RC value is reset to zero as shown in Eq. (6) and initial back off value is set to the initial backup in Eq. (7) after current packets are transmitted.

RC=0 (6)

Initial back off= initial backup (7)

This means after the nodes are transmitted the node's priority is reverted back to its original status, which is only agreeable as it cannot be promoted all the time. This scheme would thus be helpful in avoiding starvation of low priority nodes for the channel access.

4. SIMULATION

The proposed scheme is implemented with the help of ns2 and the results of the implementation analysis are illustrated in the following graphical representations. The Random Way Point model [10] is used in ns2 simulation. Figure 8 indicates the comparisons in aggregate throughput between the proposed Alert Transmission schemes to the existing IEEE MAC 802.11 scheme. The number of nodes is used as the measuring criteria. The simulation is carried out with 20, 40, 60, 80, 100 nodes. The results show that the proposed scheme produces better average throughput when the number of nodes increases.

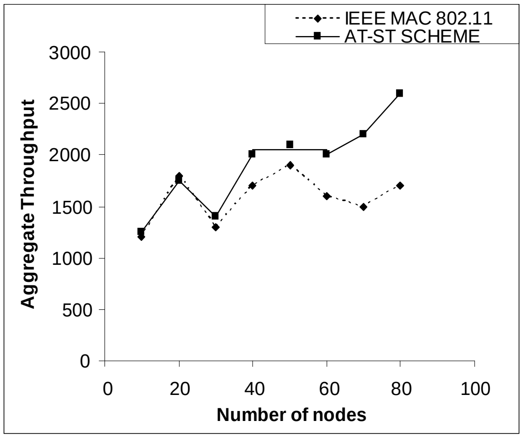

Figure 8: Comparisons in aggregate throughput between proposed Alert Transmission scheme and IEEE MAC 802.11 scheme.

Figure 9 shows the comparison results in the delivery ratio of high priority packets between the proposed scheme and the IEEE MAC 802.11 scheme. The results show that the high priority packets are delivered at a much better rate in the proposed scheme.

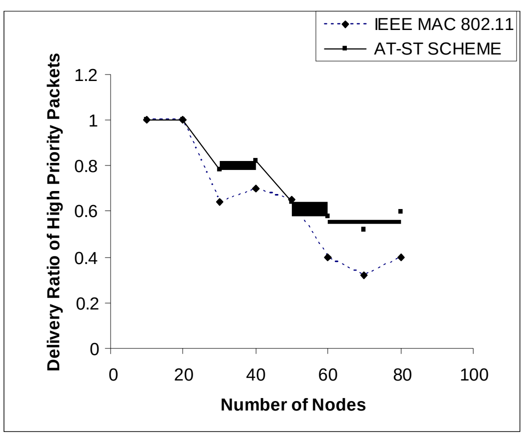

Figure 9: Comparison of delivery Ratio of High Priority Packets between the proposed Alert Transmission scheme and the IEEE MAC 802.11

Figure 10 shows the throughput as a function of delay in the arrival rate of packets, the number of nodes used here are 20, 40 and 60, 80, 100 and it is observed that with the increase in the number of nodes in the network, the throughput increases.

5. CONCLUSION

A new priority scheduling scheme (Alert Transmission Scheme) is proposed for ad hoc networks. With the use of AT1, AT2 the Alert Transmission Scheme ensures the channel access of high priority data packets. Priority reversal is also avoided by the use of Suspend Transmission ST packets. To avoid the starvation of lower priority packets and to ensure a fair scheduling, retry count is used.

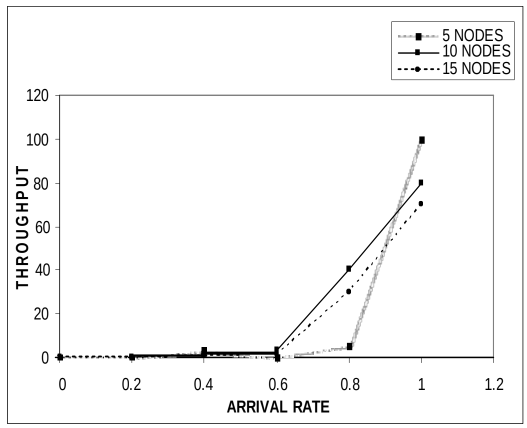

Figure 10: Throughput as a function of delay in the arrival of packets with different number of nodes in network

The average throughput is compared with the number of nodes in the network. The delivery ratio of high priority packets is also observed to be better in the proposed scheme, further the throughput is illustrated as a function of delay in arrival rate of packets for varying number of nodes in the networks. The simulation results ascertain that the overall average throughput, delivery of packets in the network implementing the proposed scheme is better than the IEEE MAC 802.11 scheme.

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