A Hidden Node Aware Network Allocation Vector Management System for Multi-hop Wireless Ad hoc Networks

M. Najimi[1] and Mohammad Sayad Haghighi[2]

Khaje Nasir Toosi University of Technology,

1: maryam_najimi1361@yahoo.com, 2: sayad@ee.kntu.ac.ir

Abstract— **Many performance evaluations for IEEE 802.11 distributed coordination function (DCF) have been previously reported in the literature. Some of them have clearly indicated that 802.11 MAC protocol has poor performance in multi-hop wireless ad hoc networks due to exposed and hidden node problems. Although RTS/CTS transmission scheme mitigates these phenomena, it has not been successful in thoroughly omitting these drawbacks. We argue that when eliminating hidden node effect with a given protocol is not feasible, one may sometimes earn more throughput by controlling or even wisely creating this phenomenon. In this paper we propose a novel solution to improve the performance of IEEE 802.11 MAC protocol in multi-hop networks through modifying NAV timer. We may call this method Dynamic NAV (DNAV) since the NAV timer operation changes dynamically with the change of environment variables. Simulation results show that our approach noticeably increases the throughput in multi-hop wireless ad-hoc networks.**

Index Terms— **Multi-hop ad hoc networks, Hidden node effect, Medium Access Control Protocol, IEEE 802.11 standard**

I. INTRODUCTION & RELATED WORK

Wireless ad hoc networks consists of some nodes that are interconnected by wireless-multi-hop communication paths. These ad hoc wireless networks are self -creating, self-organizing, and self -administering [1].

The hidden node problem deals with a configuration of three nodes, like figure 1, whereby B is located in the transmission range of A from node C. C will not be able to understand the transmission and C, and A is hidden from A to B by carrier sensing, and, so, its transmission can collide with the data B is receiving from A [2].

In wireless networks, the hidden node problem can occur frequently. Removing hidden node problem is one of the most important aspects of a MAC protocol design.

To eliminate the hidden node problem, Karn proposed a way involving short packets whose exchange should precede the actual transmission [3]. The sender sends a RTS (Request To Send) packet prior to sending the main data.

When the destination of packet receives RTS, it sends CTS (Clear To Send) packet back to the sender. Both packets contain the length of time needed to transmit the data packet in their payloads. Any other nodes receiving these packets set their NAVs to the length of time specified in RTS or CTS. So, these nodes will refrain from transmission to avoid interfering with exchange in progress. In Karn's scheme, the complete exchange is composed of four messages: RTS, CTS, DATA and ACK. The first pairs are to take care of the hidden nodes, and ACK provides a reliable delivery acknowledgment.

RTS/CTS exchange (which later adopted by IEEE 802.11 designing group) can be effective when all of the hidden nodes are in transmission range of the receiver. But when the transmitter-receiver distance is a large value, this assumption does not hold and collisions may occur. In multi-hop ad hoc networks, this becomes a serious problem since the nodes are scattered in the area and the above-mentioned scenario can be frequently repeated [4][5][6].

To eliminate the hidden node problem in [7] a receiver-initiated busy-tone multiple access protocol for packet-radio networks has been proposed. In this scheme, a sender transmits a RTS to the receiver prior to sending a data packet. When the receiver captures the RTS, it separately transmits a busy-tone to alert other nodes nearby to back-off. The corresponding source is notified that it can proceed with transmission of the data packet.

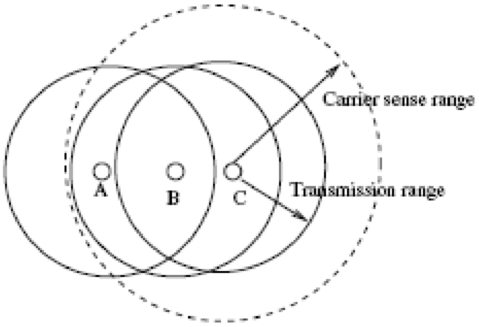

Fig. 1, Topology of the hidden node scenario. Node C does not sense the ongoing transmission from A to B and hence its signal collides with that of A on node B.

This work was supported in part by Iran Telecommunication Research Center (ITRC) under grant T-500/9119.

1. The author is with the Department of Electrical Engineering, K.N.Toosi university of technology, P.O.B. 16315-1355, Tehran, Iran (email: najimi1361@yahoo.com)

The limitation of this scheme is using a separate channel for busy-tone messages transmission.

Jiang et al. states a set of sufficient conditions to remove the hidden nodes [8]. The suggested method in this paper is called HFD which includes a signal-reception mechanism called the restart mode and two constraints on the power budget of the links.

In reference [9] the authors tried to eliminate the problems in performance of wireless networks through “offered load control” at data sources without major changes in MAC protocol. They argue that controlling the data rate in sources can mitigate some of the problems may emerge along the path.

Gupta et al. [10] argues that the per-node throughput falls as the number of nodes grows. But he has assumed a saturated network in which the nodes always have data to send and are ready to transmit as fast as their wireless connection allows.

In reference [11] the initial design of MACA-P is presented that enables simultaneous transmissions in multi-hop Ad-hoc networks. MACA-P avoids collisions and improves the system throughput through delaying the data transmissions by a control phase interval which allows multiple sender-receiver pairs to synchronize their data transfers.

In the next section we introduce an adaptive NAV timer called DNAV which deals with the hidden node problem in a different manner. In section IV we will evaluate the proposed NAV by simulations.

II. THE PROPOSED NETWORK ALLOCATION VECTOR MANAGEMENT SYSTEM (DNAV)

Any node in a wireless network has a number of neighbors according to its transmission range and its receiver sensitivity. In IEEE 802.11 transmission scheduling is done through exchanging of RTS/CTS control packets.

The main idea behind DNAV is to increase the throughput of the network through preventing overflow of packets in the queue of the intermediate nodes along the data stream path.

To start, consider the string topology in figure 2. As it is shown, B is in the transmission range of node C. In IEEE 802.11 protocol, when node C sends a RTS to node D, NAV timer in node B is set to be expired at the end of C-D transmission and hence, B can not schedule any transmission in this period. In DNAV, when node B has a packet (RTS, CTS or DATA) to transmit, it can conditionally send them in NAV interval if its transmission does not drop other nodes packets toward the destination.

Unlike the IEEE 802.11 NAV, DNAV gathers the information of all local transmissions by listening to the channel continuously and also monitors the queue level. It saves a temporal history of incoming/outgoing packet sources/destinations to later determine which node is feeding it and which node it feeds. We shall call these two, “previous” and “next” nodes respectively while we may call the rest of the neighbors “the other nodes”. Depending on this information, it decides whether to allow a packet to be transmitted or not.

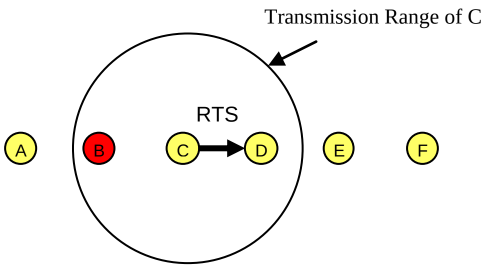

Fig. 2, Hearing the RTS packet, node B sets its Network Allocation Vector (NAV) to the duration of C-D transmission.

In DNAV, there are two thresholds which specify the fullness level of a node queue: Queue_Th_high and Queue_Th_low. If the queue level is higher than Queue_Th_high, it is considered to be nearly full, and if the queue level is less than Queue_Th_low, we assume the queue to be almost empty.

It is worth to mention that DNAV is designed with the notion of multi-streams in mind. It somehow adds more priority to the current node packets if the queue level is critical. For example a node having enough packets in its queue to deliver, does not need further packets in its queue. So it may even intentionally override the rules and create intentional hidden node effects since the benefit of pushing a packet one hop forward toward the destination is higher than that of receiving a packet which would be dropped due to queue fullness.

The following fuzzy-like rules list, simplifies the DNAV operation explanation. We assume that the table of neighbor nodes RTS/CTS messages of current local transmissions has already been created.

```
ch_state=0 // default channel state is set to Busy
 if (Node has a pktCTS to send) then
 {
   if (Other nodes already sent pktCTS or  pktRTS) then
      if  (Queue level is low) then
         ch_state=1 // Assume channel is free
  }

 if (Node has a pktRTS to send) then
  {
    if (the previous node already sent pktCTS) then
      if (Queue level is high) then
        ch_state=1 //intentional hidden node effect

     if (other nodes already sent pktCTS or pktRTS) then
       if (Queue level is high) then ch_state=1
  }

 if (Node has a pktData to send) then
  {
    if (previous node already sent pktRTS) then  ch_state=1
    if (previous node already sent pktCTS ) then  ch_state=1
    if (other nodes already sent pktCTS or pktRTS) then
         if (Queue level is high) then  ch_state=1
   }

if (Node has a pktACK to send) then  ch_state=1

if (Node does not have a packet to send and previous and next nodes do
not have any packet to send) then  ch_state=1
```

As we mentioned in the earlier parts, IEEE 802.11 MAC does not work well in multi-hop networks. DNAV tries to keep a stream alive and avoid re-routings by balancing the traffic along the path. It even sometimes takes use of intentional hidden node effect to virtually block the feeding node from flooding the others with its packets. This way the overall performance of the network is increased.

III. SIMULATION RESULTS

Simulations were conducted under Linux platform using NS-2 (Network Simulator II). The network was composed of 100 nodes placed in a square area of 4000m×4000m. The mean distance between nodes set to 100m. The packets size was considered to be 512B and the traffic sources were assumed to be of CBR type. The mean number of intermediate nodes connecting source and destination was swept and the throughput measured in each case. The simulation results evidently show that DNAV has significantly increased the total throughput comparing to the IEEE 802.11 MAC protocol.

Figures 3, 4 and 5 plot the throughput of a single stream ad-hoc network. When the number of hops is small, DNAV and NAV has almost the same performance however when the number of hops increases, the difference reveals. In figure 3 the throughput is approximately increased 11%, in figure 4, 18% and in figure 5 we have an increase of 26%.
When the number hops increases, the throughput of the network is decreased as we expected

.

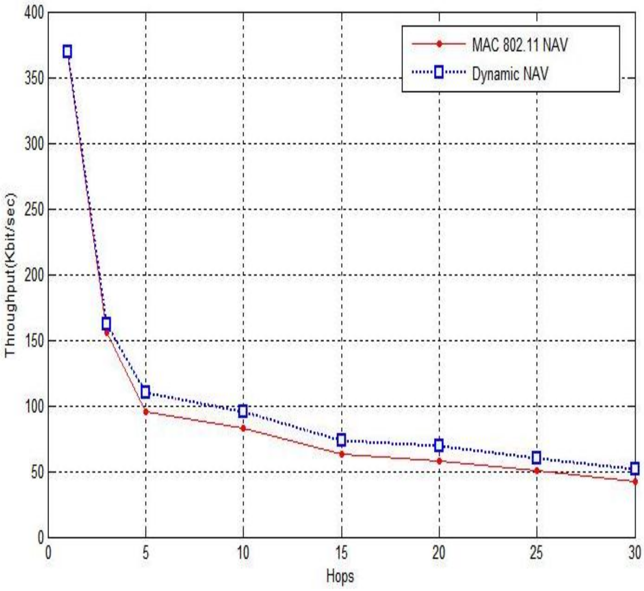

Fig. 3, Throughput versus different number of hops. Queue_Th_high=20, Queue_Th_low=5 in single-stream scenario

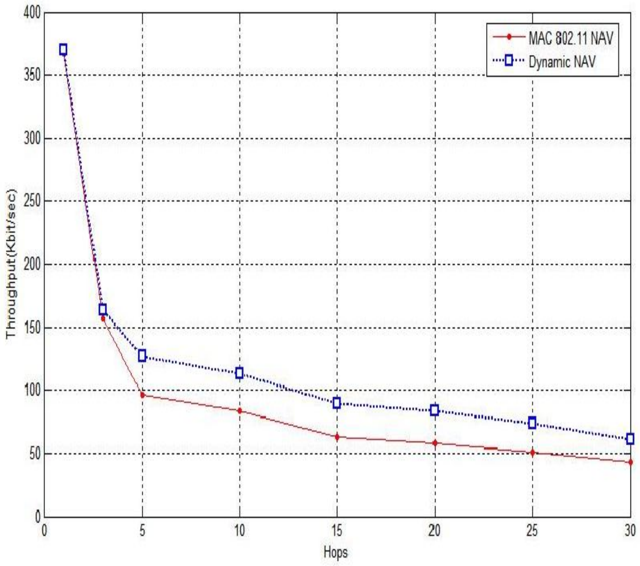

Fig. 4, Throughput versus different number of hops. Queue_Th_high=30,Queue_Th_low=3 in single-stream scenario

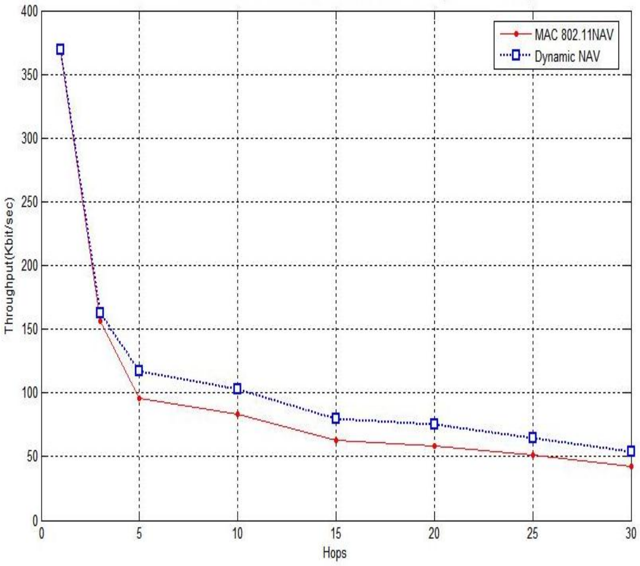

Fig. 5, Throughput versus different number of hops. Queue_Th_high=25,Queue_Th_low=3 in single-stream scenario

The two thresholds do effectively change the DNAV behavior. Setting Queue_Th_high to 20 and Queue_Th_low to 5, increases the probability of collisions while with the selection of 30 for Queue_Th_high, DNAV and NAV almost perform the same.

In figures 6, 7 and 8, the throughput has been depicted for the multi-stream case. As we expected DNAV performed better in this case showing its superiority by an increase of 35% in throughput.

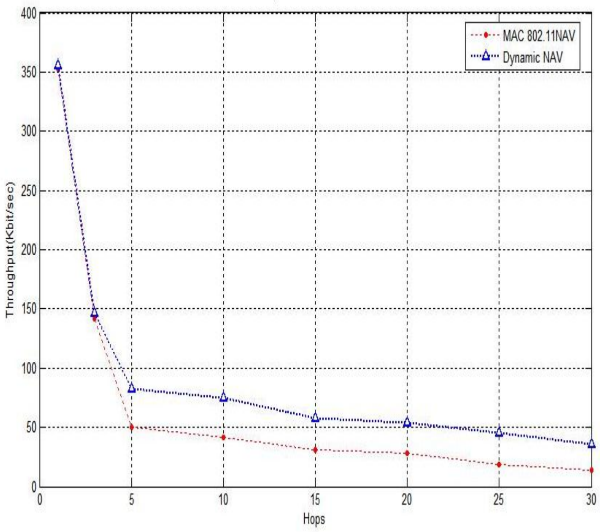

Fig. 6, Throughput versus different number of hops. Queue_Th_high=20, Queue_Th_low=5 multi-stream scenario

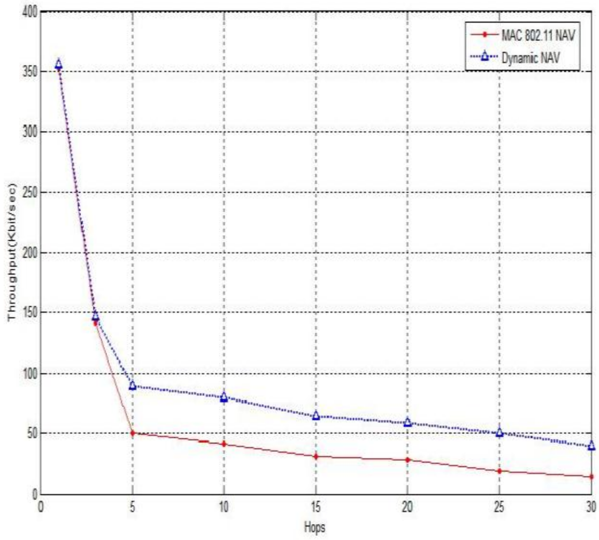

Fig. 7, Throughput versus different number of hops. Queue_Th_high=30, Queue_Th_low=3 in multi-stream scenario

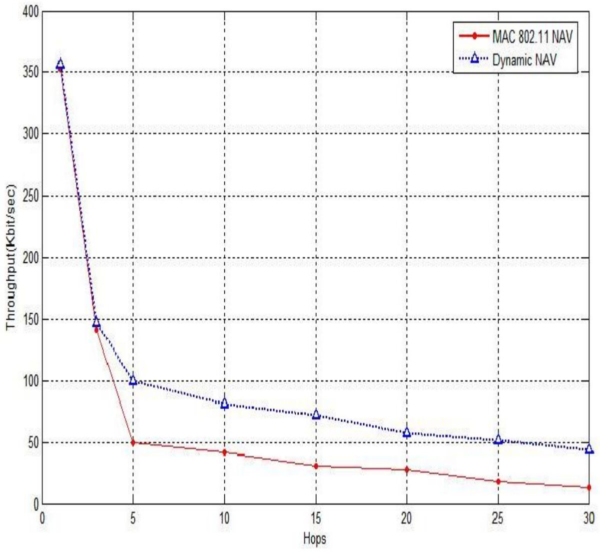

Fig. 8, Throughput versus different number of hops. Queue_Th_high=35,Queue_Th_low=3 multi-stream scenario

IV. CONCLUSION

Contrary to the previous beliefs of eradicating hidden node effect to increase the throughput, this paper showed that one can gain higher throughput by tolerating some potential collisions in the case elimination of the hidden node effect is costly. We introduced a new NAV management method called DNAV in which every node controls the packet transmission decision making according to its queue level and the environmental variables. The simulation results showed a noticeable improvement in throughput over the classic NAV handling method used in IEEE 802.11 standard.

REFERENCES

[1] S.Samal, "Mobility Pattern Aware routing in Mobile Ad Hoc Networks," M.S. thesis, Faculty of The Virginia Polythechnic Institue and State University, 2003.

[2] A.Rahman and P.Gburzynski,"Hidden Problems with the Hidden Node Problem", in *Proc. of 23rd Biennial Symposium on Communications*, Ontario, Canada, June 2006.

[3] P. Karn, " MACA- a new channel method for packet radio," in proc. of *the 9th Computer Networking Conference on ARRL/CRRL Amateur Radio*, pp. 134-140, Sep. 1990.

[4] K.Xu, M.Gerla, and S.Bae, " How Effective is the IEEE 802.11 RTS/CTS Handshake in AdHoc Networks?," *IEEE GlOBECOM*, vol. 1, pp. 17-21, Nov. 2002.

[5] S. Xu, T. Saadawi, "Does the IEEE 802.11 MAC protocol work well in multihop wireless adhoc networks?," *IEEE Communications Magazine*, vol. 39, june 2001.

[6] K. Kanth, S. Ansari, and M. Melikri, " Performance Enhancement of TCP on Multihop Ad hoc Wireless Network," in *proc. of IEEE Int. Conf. on Personal Wireless Communications (ICPWC)*, pp. 90-94, Dec. 2002.

[7] C.Wu and V. Li, "Receiver-initiated busy-tone multiple access in packet radio networks," *ACMSIGCOMM workshop of Frontiers in Computer Communicationa Technology*, Stowe, VT, USA, Aug. 1987.

[8] L.Jiang and S.Chang Liew, "Removing Hidden Nodes in IEEE 802.11Wireless Networks," in *proc. of IEEE Vehicular Technology Conference*, 2005.

[9] P. Chung and S. Chang Liew, "Offered Load Control in IEEE 802.11 Multi-hop Ad-hoc Networks," in *proc. IEEE Int. Conf. on Mobile Ad-hoc and Sensor Systems(MASS)*, Oct. 2004.

[10] P.Gupta, P.R.Kumar, "The Capacity of Wireless Networks," *IEEE Transactions on Information Theory*, vol. 2 ,Mar. 2000.

[11] A. Acharya, A. Mirsa, and S.Bansal, "MACA-P :A MAC for Concurrent transmission for multi-hop Wireless Networks," in *proc. IEEE Int. Conf. on Pervasive Computing and Communication*, 2003