

Collision-Free On-Demand Multiple Access Protocol for Mobile Ad Hoc Networks

Chenyu Zhang and Kai Liu

School of Electronics and Information Engineering
Beihang University, Beijing, 100191, China
E-mail: cyzhang@ee.buaa.edu.cn, liuk@buaa.edu.cn

Abstract—In this paper, a collision-free on-demand multiple access (CF-ODMA) protocol for mobile ad hoc networks is proposed. In the CF-ODMA protocol, every node obtains collision-free polling service by channel reservation. In addition, a collision resolution algorithm is presented to guarantee that in the present of reservation collisions the access nodes can successfully access channel in sequence, and resolve packet collisions during the contention access period. Simulation results show that the proposed protocol can achieve better performances than the IEEE 802.11 distributed coordination function (DCF) and point coordination function (PCF) mechanisms in terms of throughput, average packet dropping rate and delay.

Keywords— *medium access control (MAC); mobile ad hoc networks; reservation; collision resolution; polling*

I. INTRODUCTION

A mobile ad hoc network is a highly dynamic self-organizing network consisting of many mobile users or nodes with no predetermined topology and central control. One of its hotspots is multiple access, also known as medium access control (MAC) [1], which deals with efficient channel resource sharing for multiple nodes during communications. Many multiple access protocols have been presented to solve such common channel sharing of multiple nodes for mobile ad hoc networks. A typical example of pure random access protocols is request-to-send/clear-to-send (RTS/CTS) distribution mode of IEEE 802.11 MAC protocol, which employs RTS/CTS handshake mechanism to decrease transmission collisions from the transmission time of long data packet to that of RTS mini-packet mostly due to hidden terminal problem [2] caused by multihop architecture and the application of carrier sensing. Other typical protocols based on random multiple access techniques are IEEE 802.11 DCF [3], multiple access collision avoidance (MACA) [4] and distributed packet reservation multiple access (D-PRMA) [5] protocol, etc. The conflict-free protocols for MANET mostly use a central control point to flexibly assign channel resources for its neighbor nodes, such as 802.11 point coordination function (PCF) [3], virtual base station (VBS) [6], and Bluetooth. Random multiple access protocol can overcome the resource wastage problem existing in fixed assignment multiple access protocol. However, the probability of packet collisions increases with the increase of the number of active nodes or total offered load. These packet

collisions can be avoided by adopting polling mechanism. However, polling overhead and related packet delay will increase drastically when a large number of nodes have no packets to transmit.

Wang *et al* proposed a slotted MAC protocol called FD-MAC [7]. FD-MAC protocol combines random access and reservation-based access, and introduces the concept of “data flow” and a flow-driven mechanism for resource reservation. For short-duration data flows, it employs a random access protocol, while for the long-duration data flows it employs a flow-driven reservation-based access protocol. CSMAC proposed in [8] is based on the popular DCF mechanism. In the new mechanism, the AP controls the medium access by adjusting the randomly generated back-off number of the stations. In this way the AP prevents collisions in the system, and helps in the scheduling of transmissions of the stations by maintaining a list of the time-slots that have been reserved for their next transmissions.

By integrating the advantages of random access and reservation-based access, and combining collision prevention mechanism, a novel efficient multiple access protocol based on clustering architecture is proposed, i.e. collision-free on-demand multiple access (CF-ODMA) protocol, which employs the idea of reservation with random contention and perfect scheduling transmission with polling.

The rest of the paper is organized as follows. Firstly, node model and clustering architecture are described in Section II. Secondly, Section III presents the CF-ODMA protocol. In Section IV, performance evaluation is provided. Finally, some useful conclusions are given in Section V.

II. NETWORK MODEL

In MANET, we assume that each node has only one set of transceiver operating in half-duplex mode and a unique identifier (ID). In the CF-ODMA protocol, a local central control node (CCN) is needed to be responsible for scheduling packet transmissions of its neighbor nodes, which can be achieved according to some certain clustering algorithm (refer to the clustering algorithm in [9]). By this, it can be extended to multihop networks. The distance of any two nodes in this kind of cluster is at most two hops, and all the packets, whose source and destination are not in communication range, must be relayed by CCN or gateway. One or multiple gateways are selected by CCN to relay inter-cluster traffic. Different clusters

This work was supported by National Science Foundation for Innovative Research Groups of China under Grant 60921001, the National Outstanding Youth Science Foundation of China under Grant 60625102, the National 863 Program of China under Grant 2006AA12A103, and the “New Star in Blue Sky” Program of BUAA, China under Grant 221235.

reaches saturate, the networks with longer queue length have a higher delay because of the large number of waiting packets; whereas the networks with shorter queue length have higher dropping rate and lower delay, for the nodes directly drop the packets that newly generated.

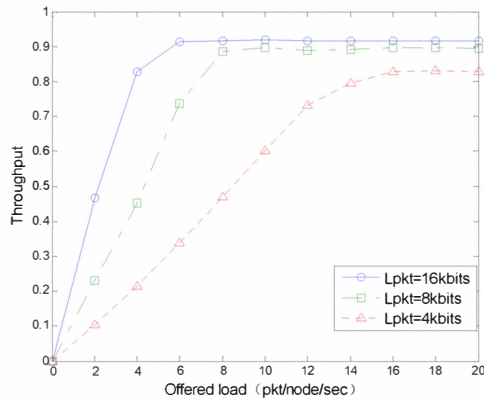


Fig. 6 Throughput of CF-ODMA protocol

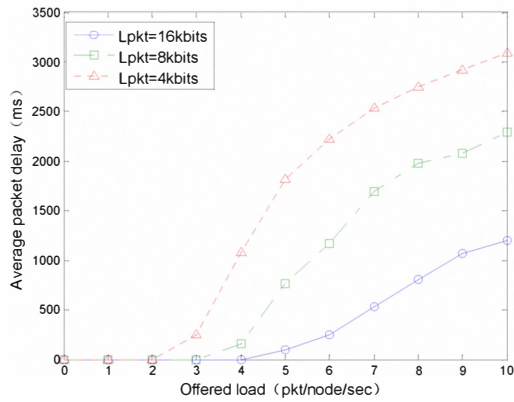


Fig. 7 Average packet delay of CF-ODMA protocol

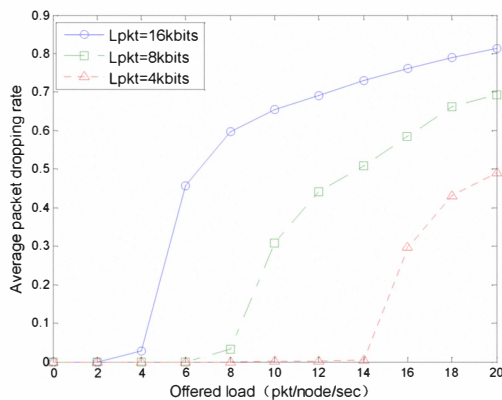


Fig. 8 Average packet dropping rate of CF-ODMA protocol

C. Performance Comparison

The performance comparison of CF-ODMA protocol with IEEE 802.11 DCF and PCF mechanism is shown in Fig. 9, 10 and 11. For CF-ODMA protocol, the number of network nodes is 30. For 802.11 PCF, CCN is considered as the AP to polls all the nodes in its cluster.

From the figures, we can see that at low offered load, the throughput of CF-ODMA, 802.11 DCF and PCF protocols increase lineally with the increase of offered load. The throughput of CF-ODMA and 802.11 PCF protocols are almost the same, and larger than that of 802.11 DCF protocol due to existing slight packet collisions and retransmissions in 802.11 DCF protocol. However, the average packet delay of 802.11 PCF protocol is much higher than that of CF-ODMA protocol because CCN polls many nodes, which do not have packets to send. Due to frequent packet collisions and retransmissions, the throughput of 802.11 DCF is much smaller than that of CF-ODMA protocol and its average packet dropping rate is higher than that of CF-ODMA protocol. When offered load is very high, the CF-ODMA protocol cancels the reservation access phase in the case of the full polling queue of CCN, thus its throughput is the same as that of 802.11 PCF polling mechanism. However, the average packet delay of 802.11 PCF protocol is much longer due to long interval of polling all the nodes at a time.

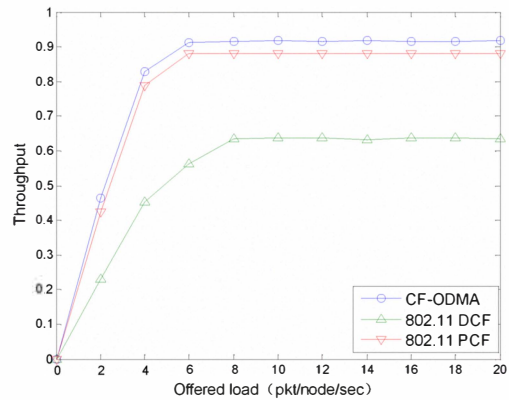


Fig. 9 Throughput of CF-ODMA, 802.11 DCF and PCF protocols

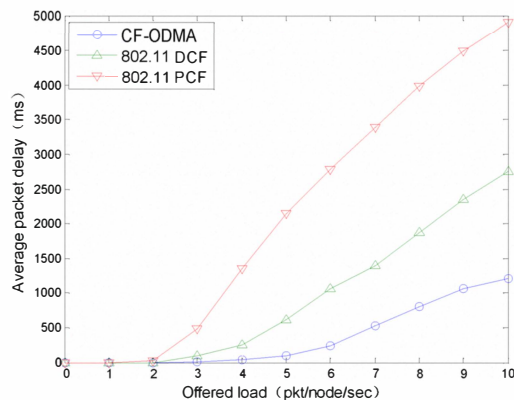


Fig. 10 Average delay of CF-ODMA, 802.11 DCF and PCF protocols

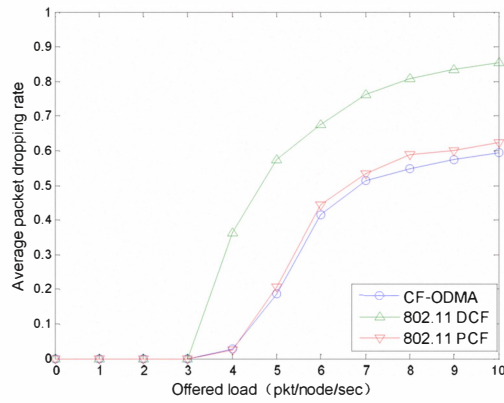


Fig. 11 Average packet dropping rate of CF-ODMA, 802.11 DCF and PCF protocols

V. CONCLUSION

An efficient and dynamic CF-ODMA protocol is proposed for MANET, which integrates the concepts of fair contention, collision-free reservation access and on-demand polling service. It supports continuous transmission and cancels reservation access phase at high offer load to improve channel usage efficiency. Therefore, it overcomes the disadvantages of 802.11 DCF and PCF protocols, avoids packet collisions, decreases unnecessary overhead, and greatly improves throughput and the access efficiency of nodes with data packets

to send. In addition, the proposed collision resolution algorithm completely resolves the unfairness problem. Simulation results show that the proposed protocol can provide efficient channel sharing.

REFERENCES

- [1] R. Jurdak, C. Videira Lopes and P. Baldi, "A survey, classification and comparative analysis of medium access control protocols for ad hoc networks", *IEEE Communications Surveys & Tutorials*, vol. 6, no. 1, First Quarter 2004, pp. 2-16.
- [2] S. Kumar, et al. "Medium Access Control protocols for ad hoc wireless networks: A survey", *Ad Hoc Networks*, 2006, vol 4:326-358.
- [3] Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, IEEE 802.11 Standard, 2007 Edition.
- [4] P. Karn. "MACA—A new channel access method for packet radio", *Proc ARRL/CRRL Amateur Radio 9th Computer Networking Conference*, ARRL, 1990. 134-140.
- [5] S. Jiang et al., "A simple distributed PRMA for MANETs", *IEEE Trans. Vehic. Tech.*, 2002, pp. 293–305
- [6] H. Hassanein and A. Safwat. "Virtual base stations for wireless mobile ad hoc communications: an Infrastructure for the infrastrucless", *Int. J. Commun. Sys.* 2001, 763-782
- [7] H. Wang, S.Y Tan and J. Zheng, "FD-MAC: A Flow-Driven MAC Protocol for Mobile Ad Hoc Networks", *Proc IEEE GLOBECOM 2009*. Honolulu, USA, 2009:1-5.
- [8] S. Ye, T. Korakis and S. Panwar, "CSMAC: A New Centralized Scheduling-based MAC Protocol for Wireless LAN", *Proc IEEE WCNC 2009*. Sydney, Australia, 2009:1-6.
- [9] J.Y Yu, P.H. J Chong, "A Survey of Clustering Schemes for Mobile Ad hoc Networks", *IEEE Communications Surveys and Tutorials*. 2005, vol.7(1):32-48.