Amelioration of Five Phase Reservation Protocol on Contention Probability Calculation

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***Abstract*—the original FPRP (Five Phase Reservation Protocol) uses only one bit to exchange reservation message and uses pseudo-Bayesian algorithm to approach the contention probability. To enhance the realizability of the protocol, this paper expanded the reservation bit to several bytes to carry more information, and inserted a notification slot among volumes to help gathering neighbor information quickly. Based on such improvements we provided an ameliorated queue-length-based algorithm to calculate the contention probability instead of pseudo-Bayesian algorithm. The simulation result shows that when network load is heavy, the ameliorated FPRP performs better than DRAND, original FPRP and 802.11 DCF in end to end throughput, and average packet delay.**

Keywords-MANETs; FPRP; realizability; comtention probability; data flow

I. INTRODUCTION

MANETs have been rapidly developed these years, due to its characteristics of infrastructure independent, fast deployment, low cost and high survivability. The MANETs has taken an important place in military communication, emergency communication, sensor networks, and personal digital devices. Because of the mobility and distribute characteristics, the MAC layer protocol design becomes a challenge.

According to the control strategy, MAC layer protocols could be divided into centralized and distributed control. Most TDMA protocols are centralized because a global time provider is needed to synchronize the clock. However, the cost of a central node and the inconvenient of deploying limited the development of TDMA MAC protocols. When global positioning and timing systems such as GPS becomes popular, distributed TDMA MAC protocols attract more attention, since the TDMA protocols are free of conflict.

FPRP [1] is the first proposed TDMA protocol in distributed packet radio networks. It solved the problem of potential handshake collision in R-CSMA[2], DARE[3] and RTMAC[4], which is mentioned in [5]. However, FPRP assumes that the link between two nodes is a noiseless, symmetric channel, and it advises that a packet needs only consist of a single logic bit, to minimize the time of handshaking procedure. These assumptions are too ideal to implement.

DRAND [6] is another distributed TDMA protocol, which does not need any time synchronization. DRAND is the first distribution implementation of RAND, which is a centralized and heuristic solution of time slot assignment. Paper [7] introduced a traffic-adaptive, flow-specific mechanism to MAC, which outperformed the traditional contention, non-contention, and hybrid MAC mechanisms. The novel mechanism uses queue size as an indicator of flow-specific traffic demand. [8] provided a data flow oriented MAC protocol. The protocol is a slotted protocol and introduced a new concept of data flow, instead of single packet, to drive distributed resource reservation.

The contribution of this paper is 2-fold. First, the frame structure of FPRP is redesigned to make the protocol realizable. A single synchronizing slot is inserted for fast neighbor discovery and competition probability initializing. Second, an ameliorated competition probability calculation algorithm is provided to improve the throughput and QoS performance.

The rest of this paper is organized as follows: Section 2 describes the main improvement of the ameliorated FPRP. In Sect. 3 the simulation result is given and performance analysis is presented. Section 4 concludes and suggests future work.

II. AMELIORATION DESCRIPTION

A. frame structure description

The frame structure of original FPRP is shown if Fig.1.

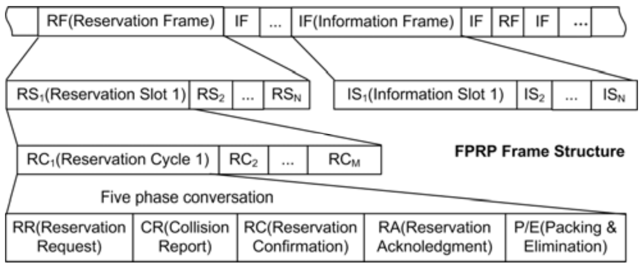

Figure 1. Frame structure of original five phase reservation protocol.

The Ameliorated FPRP has made two major improvements on frame structure of the original FPRP:
1. Assembles an RF and the following IF's to a "volume", and inserts some "notification slot" between adjacent volumes.
2. Expanded the packet of five phases, described the packet structure to carry more important information.

In the ameliorated FPRP (as shown in Fig. 2), A volume contains a reservation frame and L information frames. A notification slot, whose structure is the same as the reservation slot, is inserted between adjacent volumes, to help gathering neighbor topology information rapidly. The difference between a notification slot and a reservation slot is that, in a reservation slot, only nodes which have some data to send shall take part in the competition, while in a notification slot, all nodes shall participate in the competition to announce its existence. During the notification slot, a node shall know its 2-hop-neighborhood

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information, which will help deciding the initial probability in the reservation slot of the next reservation frame.

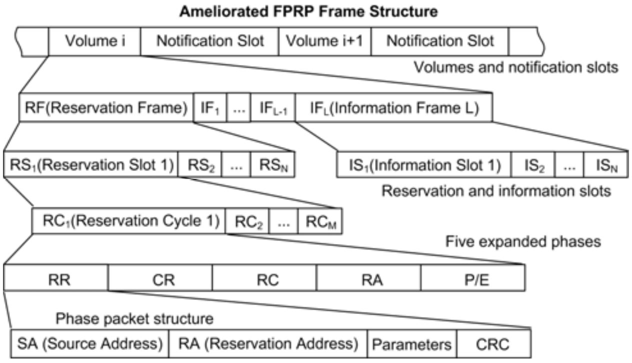

Figure 2. Frame structure of Ameliorated five phase reservation protocol

The original FPRP indicate that in the five phases, a single bit is enough for the message exchange, as the meaning of the packet could be implicitly conveyed in the context of the protocol. Such a design makes a reservation cycle very compact. However, it could not be implemented in an authentic wireless network. First, the propagation delay (distance/light-speed) might be longer than transmitting such a single-bit-packet (packet-length/transmit-rate). To guarantee that the transmitting and receiving of a packet are always in the same phase, the phase duration must be larger than $D_{max}/c+L_{pkt}/r$, where D_{max} is the maximum distance of adjacent nodes, c is the speed of light, L_{pkt} is length of a reservation packet in bits, and r is transmit rate in bps. As the propagation delay is the main part of the phase duration, reducing the length of a packet is meaningless.

We expanded the 1-bit-packet to several bytes. The expanded packet consists of four parts: the source address field, the reservation address field, the parameters field, and CRC field. "Source address" is filled with the address of the packet sender. "Reservation address" refers to the initiator of the current reservation cycle (The node who sends the RR packet is called a initiator). The field of parameters is often filled with 2 numbers which respectively indicate how many packets are pending in the reservation node's send queue, and how much is the current contention probability of the reservation node. Such parameters aim to help calculating the competition probability in the next reservation cycle. With proper competition probabilities, the time slot schedule would be more efficient, and could improve the throughput of the whole network. CRC is filled with the checksum of this packet.

B. Algorithm Description

The original FPRP suggests a multi-hop pseudo-Bayesian algorithm to determine at which probability the node shall broadcast an RR packet when it has some data to send. The algorithm is a heuristic algorithm. A node adjusts the number of contenders in its 2-hop neighborhood *n*, and sets the probability of competition $p = 1/n$. The information of contenders is gathered in the reservation cycle. The multi-hop pseudo-Bayesian algorithm gives a series of equations to reckon the contender number (n_c), and lets the probability of broadcasting an RR be reciprocal of n_c.

The multi-hop pseudo-Bayesian algorithm did not take the pending packet number into consideration. We assume that there are *N* nodes in node *i*'s 2-hop neighborhood and the competition probability of node *k* is p_k, $(1<=k<=N)$, then the success probability of node *i* shall be:

$$p_{success}(i) = p_i \prod_{k=1,k\neq i}^{N} (1-p_k) \qquad (1)$$

Consider a simple cross topology as shown in Fig 3. In the graph, node A and B are sending data packet to C and D respectively at an identical constant rate *r (bps)*. Node M is the intermediate node. In this scene, M shall forward the packets at the rate of *2r (bps)*. We assume that the competition probability in the phase of RR of both node A and B is *p*, then the probability of M should be *2p/(1+p)*, so according to equation (1), node M's successful reserving probability $p_{success}(M) = (1-p)*(1-p)*2p/(1+p)$, twice as much as the probability $p_{success}(A) = p*(1-p)*(1-2p/(1+p))$. However, according to the original multi-hop pseudo-Bayesian algorithm, as the 2-hop neighbor number of A, B and M are all the same, the probability will converge into the same value. As a result, when the network load is heavy, half of the packets will be dropped at M.

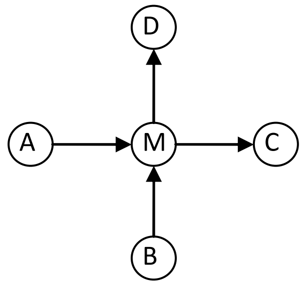

Fig. 3 A Cross Topology

The ameliorated algorithm takes pending packet number into consideration. If a node knows how many pending packets there are in its neighbor nodes, it could judge the probability of competition, to optimize the chance of successful reservation.

In the ameliorated FPRP frame structure, the RR packet contains a field "parameters", which consists of two numbers: the pending packet number in the queue of the source node, and the competition probability of the source node. With these parameters, the node could solve its competition probability with *(2)*:

$$\frac{p_{success}(i)}{\sum_{k=1}^{N} p_{success}(k)} = \frac{L_i}{\sum_{k=1}^{N} L_k} \qquad (2)$$

Where L_k denotes the number of pending packets in the link layer queue of node *k*. Solve (2), we get a formula for generating $p_{i,m+1}$:

$$p_{i,m+1} = \frac{L_i \sum_{\substack{j=1\\ j\neq i}}^{N} \left[p_{j,m} \prod_{\substack{k=1\\ k\neq i,j}}^{N} (1-p_{k,m}) \right]}{\prod_{\substack{k=1\\ k\neq i}}^{N} (1-p_{k,m}) . \sum_{\substack{k=1\\ k\neq i}}^{N} L_k + L_i \sum_{\substack{j=1\\ j\neq i}}^{N} \left[p_{j,m} \prod_{\substack{k=1\\ k\neq i,j}}^{N} (1-p_{k,m}) \right]} \qquad (3)$$

Where *N* indicates the number of 2-hop neighbors of node *i*, *m* is the reservation cycle number $(1\leq m\leq M)$, $p_{k,m}$ stands for the competition probability of node *k* in cycle *m*.

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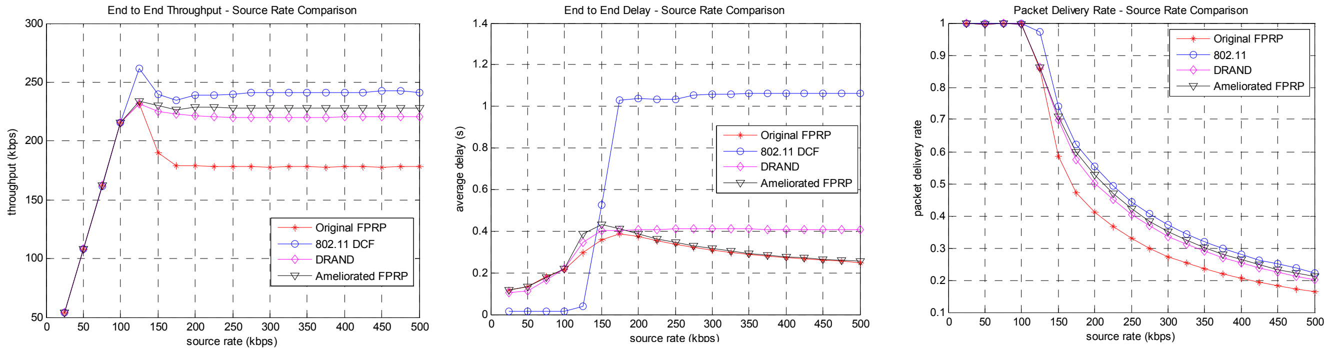

Figure 4. End to end throughput, delay and packet-delivery-rate comparison among original FPRP, ameliorated FPRP, DRAND and 802.11 DCF

In the ameliorated FPRP implementation, a node shall maintain a table of its 2-hop-neighbors. Every entry of this table shall contain a neighbor's MAC address, the contention probability of that neighbor, and the pending packet number of that neighbor. At the beginning of the notification slot, a node shall count the pending packet number of the link-layer transmission queue, and write this number to its own 2-hop-neighbor table. At the same time, a predefined probability is also written to the table, which stands for the initial contention probability of this node. Then the notification slot begins and every node broadcasts an RR at its own initial probability in the first cycle. Equation (3) is used at the end of this cycle when some neighbor's information is gathered, and the probability is renewed. The procedure shall be executed iteratively in each cycle of the notification slot. Then at the beginning of next volume, a proper contention probability is formed and shall be used in the reservation frame. At the end of each reservation slot, each success reservation shall be subtracted in the 2-hop-neighbor table. The contention probability should be refreshed at the head of next reservation slot.

III. SIMULATION RESULTS

We use NS2 to compare the performance of the original FPRP and ameliorated FPRP, and the simulation result of DRAND and 802.11 DCF are provided for reference. The scene is the cross-topological structure as shown in Fig 3.

The link-layer data rate is set to 1Mbps. The simulation result of throughput, average delay and packet-delivery-rate is showed in fig.4. In the figure we could see that when the network load is light (source rate is less than 100kbps), the four protocols have the same performance. When the source data rate increases, the buffer of node M is full filled and some packets have to be dropped. In such condition the throughput and delay trend to a fixed value.

802.11 is a contention based protocol. When network load is light, every packet could be transmitted immediately when it arrive the MAC layer. On the contrast, FPRP has a reservation process, which delays the transmission of packets. So as shown in the average delay figure, the performance of 802.11 is better than both FPRPs and DRAND when source rate is less than 150kbps. However when network load becomes heavy, collision of 802.11 RTS becomes more frequently, and the pending queue grows rapidly. As a result, the average delay of 802.11 increases terribly. The advantage of FPRP is that when N (number of slots per frame) and L (number of information frame per volume) is given, the capacity of the network is fixed. Then we could always send the latest packet, and drop the oldest packet. Such strategy could guarantee that the average delay is limited to a low level.

IV. CONCLUSION

This paper developed an ameliorated FPRP protocol. We improved the frame structure of the original FPRP to carry more information and to enhance the information exchange procedure between wireless nodes. The improved frame structure is more realizable and reasonable than original FPRP. Based on the frame structure improvement we also ameliorated the contention probability generating algorithm to acquire a better performance on the throughput and average delay when network load is heavy. Simulations based on NS2 verified the mentioned amelioration.

REFERENCES

[1] Chenxi Zhu, M.S. Corson. "A Five-Phase Reservation Protocol (FPRP) for Mobile Ad Hoc Networks", Wireless Networks, vol. 7, pp. 371-384, Apr. 2001.

[2] Inwhee Joe, "QoS-aware MAC with reservation for mobile ad-hoc networks", IEEE 60th Vehicular Technology Conference, 2004, pp. 1108-1112 Vol. 2, Sep. 2004

[3] Carlson, E., Prehofer, C., et al, "A Distributed End-to-End Reservation Protocol for IEEE 802.11-Based Wireless Mesh Networks", IEEE Journal on Selected Areas in Communications, vol 24, issue 11, pp. 2018-2027, Nov. 2006.

[4] Reddy, T.B., Manoj, B.S. and Murthy, C.S.R, "Multimedia traffic support for asynchronous ad hoc wireless networks", First International Conference on Broadband Networks, 2004, pp 569-578, Oct. 2004.

[5] Ghalem Boudour, Cedric Teyssie, Zoubir Mammeri, "A Robust reservation protocol for wireless ad-hoc networks", Proceedings of the 2009 International Conference on Wireless Communications and Mobile Computing, Leipzig, Germany, pp. 687-692, Jun 2009.

[6] Rhee, I.; Warrier, A. et al, "DRAND: Distributed Randomized TDMA Scheduling for Wireless Ad Hoc Networks", IEEE Transactions on Mobile Computing, volume 8, issue 10, pp 1384-1396, 2009.

[7] T. Owens Walker, Murali Tummala, and John McEachen, "Traffic-adaptive, Flow-specific Medium Access Control for Wireless Networks", Proceedings of the IEEE Wireless Communications & Networking Conference, Budapest, Hungary, pp. 1926-1931, Apr. 2009.

[8] Hai W., Shiying T., et. al, "FD-MAC : a flow-driven MAC protocol for mobile ad hoc networks", 28th IEEE conference on Global telecommunications, Honolulu, Hawaii, pp. 2902-2906, Nov.-Dec. 2009.