IEEE 802.11
Wireless Access Method and Physical Layer Specifications

Title: Fair Control in Contention-Based MAC for Wireless LANs

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Abstract

We proposed a wireless access method called the Bandwidth-request Labeled-slot Multiple Access (BLMA) at the Minneapolis meeting(1992)[1]. This access method is a request-grant-type method and employs a slotted ALOHA for an access method in a request region. In IEEE 802.11, many protocols using contention-based access methods such as a slotted ALOHA and CSMA have been proposed [1-3].

This paper points out that unfair access happens on contention-based access methods due to the near-far problem and proposes the Request Cycle Method to solve the unfair access. The evaluation results for proposed method combined with the BLMA are also described.

I. Summary of BLMA

In the BLMA, a wireless station requests an assignment of an access right to the base station during a request field in a frame, using a slotted ALOHA. The base station grants an access right to the wireless station at the top of each fragment and controls the retransmission. Figure 1 shows the basic frame format and the proposed communication procedure is shown in Fig. 2. An outline of the BLMA procedure is as follows:

1. A station needing to send fragments requests fragment slots needed for transmission from the base station using the request region.
2. When the base station acknowledges the request, it stores it in a queue.
3. The base station replies as to whether the request has been acknowledged in the reply region.
4. In that frame, or in the following frames, the base station assigns fragment slots to the station one by one by transmitting the station identifier at the top of the fragment.
5. The designated station transmits a fragment in the assigned fragment slot.
6. The transmitted fragment is received by both the base station and the destination station.
7. The destination station replies as to whether the transmitted fragment has been successfully received.
8. If the destination station cannot receive the fragment, the base station retransmits the fragment for the source station. If the base station also fails to receive the fragment, the base station assigns a fragment slot for retransmission to the source station and the source station retransmits the fragment.

The BLMA has the following attractive features:

1. Mitigation performance penalty due to hidden stations using a request-grant-type multiple access
2. Provision for peer-to-peer communication and furthermore, for automatic translation from peer-to-peer communication mode to store-and-forward communication mode using retransmission by the base station
3. Realization of the Stop and Wait ARQ protocol using slot-by-slot bandwidth allocation by the base station
4. Provision for easy buffer control for receiving and transmitting due to the Stop and Wait ARQ protocol
5. Prevention of overlap-reception in the retransmission stage using the Stop and Wait ARQ protocol and selective-reception mechanism of each station
6. Provision for easy control of multimedia communications using slot-by-slot bandwidth allocation by a base station

II. Unfairness on Contention-based Access Method

The transmitted power is attenuated according to the inverse square of the distance. This causes the near-far problem. This problem leads to unfairness on a contention-based access for wireless LANs, that is, when several stations transmit requests or data at the same time, a station giving the strongest received power to a receiving station may succeed in transmission. Generally, the surviving station is a station next to the receiving station without shadowing. In the request region of the request-grant-type multiple access, the receiving station is a base station.

Figure 3 shows a model for unfair access estimation. When both stations, Sa and Sb, transmit 100-bit packets using QPSK at the same time, Sa may be a surviving station if the following formula is satisfied.

$$Pa / (Pb+N) > SNR \text{ (at BER=1E-2)} \qquad (1)$$

where Pa, Pb is the received power level at the base station and N is the noise power level.
Pa is given by Pa=r*r*Pb, and N/Pb<1 and SNR=9 dB when BER=1E-2.
Then

$$20 \log r > 9$$

$$r > 2.8$$

Since the radius of microcell for wireless LANs is from several tens of meters to several hundreds of meters, unfair access will often occur.

Unfairness is fatal for MAC. In IEEE Std 802.6, Distributed Queue Dual Bus, the discussion focused on its unfairness and standardization was delayed. The traditional contention-based MAC is an ALOHA and a Slotted ALOHA. And many protocols using these methods have been proposed in IEEE 802.11.

III. Request Cycle Method

A solution to this problem is power control. However, power control is not the best solution because it is a method based on a failing together policy and it is not easy to control transmission power in environments with intermittent signal fading. To solve the unfair access problem, we propose the Request Cycle Method which allows a surviving station. The basic concept of the Request Cycle Method is already employed in some ring-LANs such as ATMR [4] to prevent unfair access 'hogging'.

The Request Cycle Method can be carried out by the following procedure.

1. The base station defines the request cycle and indicates it in the frame control field (see Fig.4).
2. Each station can reserve bandwidth up to window size (WD) in each request cycle.
3. The base station judges whether an active station exists during the request cycle. The active station is a station which has messages to transmit and has a right to reserve bandwidth during the request cycle.

The base station has two means for the judgement, the Request Indication Field (RI) (see Fig.4 (a)) and the RS field (see Fig.4 (b)). Using the RI field, active stations must transmit any pattern in the RI field. The base station detects the carrier in the RI field or the RS field (this has been previously proposed as the Carrier Detecting Method [1]).

4. If an active station exists, the request cycle continues. On the other hand, if no active station exists, a new request cycle begin.

Using the Request Cycle Method, although unfair access may occur in one request cycle, unfairness can be locked in the request cycle. The length of one request cycle is several tens of msec or several hundreds of msec depending on the value of WD and the number of stations in the microcell. Therefore, there are no problems about fairness.

IV. Performance Evaluation

We now describe the evaluations of the Request Cycle Method obtained by computer simulation. The simulation model is shown in Fig. 5. In this simulation, messages to be transmitted are generated with random interarrival times, and are distributed to randomly selected stations. The total number of stations is 100.

Each station is categorized into high, middle, and low, priority groups. When contention of transmission occurs, only the highest priority station succeeds in the request if the highest priority station is only one. This model simulates the near-far problem.

Figure 6 shows characteristics of the average arrival rate vs. the access delay. The horizontal axis represents the arrival rate normalized by the total number of request slots and the vertical axis represents the request access delay normalized by the length of the frame. Case A shows characteristics on condition of unfair access due to the near-far problem, case B shows characteristics employing the Request Cycle Method, and case C shows characteristics employing the ideal power control. In case A, unfair access occurs. As shown in Fig. 7, when Am=0.9, many messages in lower priority stations are discarded at the message buffer. Figure 6 shows that the Request Cycle Method is promising for overcoming unfair access from the viewpoint of performance and controllability.

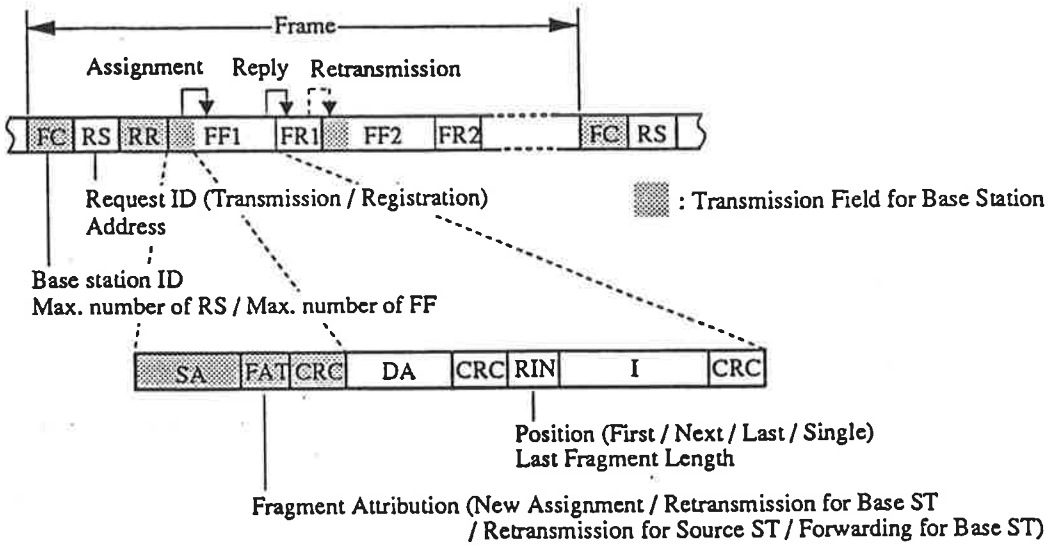
References

[1] Y. Takiyasu,"High Performance Access Control Method for Base-Station-Controlled Systems," IEEE Documentation P802.11/92-71.

[2] K.S. Natarajan et al., "Medium Access Control for Radio LANs," IEEE Documentation P802.11/91-74.

[3] J. Cheah, "A Proposed Architecture and Access Protocol Outline for the IEEE 802.11 Radio LAN Standards, Part II," IEEE Documentation P802.11/91-54.

[4] H. Ohnishi et al., "ATM Ring Protocol and Performance," ICC'89, June 1989.



FC : Frame Control Field
RS : Request Slot Field
RR : Request Reply Field
FF : Fragment Field
FR : Fragment Reply Field

SA : Source Address
FAT : Fragment Attribution
CRC : Cycle Redundancy Code

DA : Destination Address
RIN : Reassemble Information
I : Information

Fig. 1. Frame and Fragment Structure

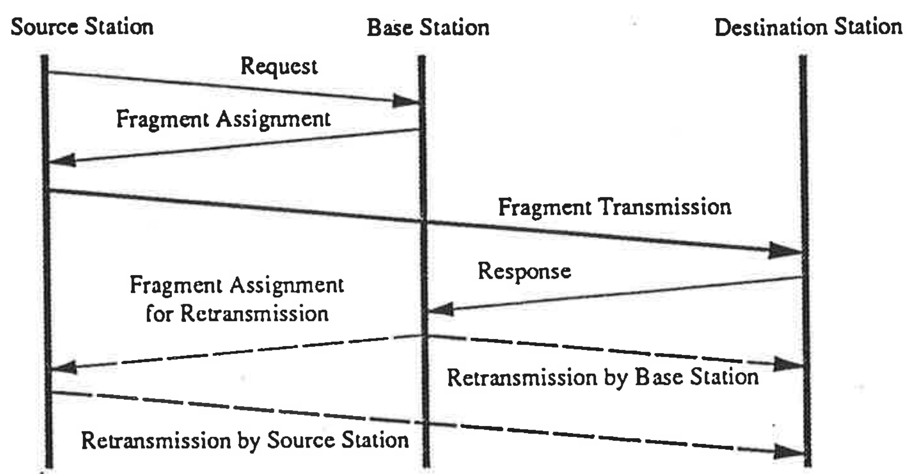


Fig. 2. Communication Procedures

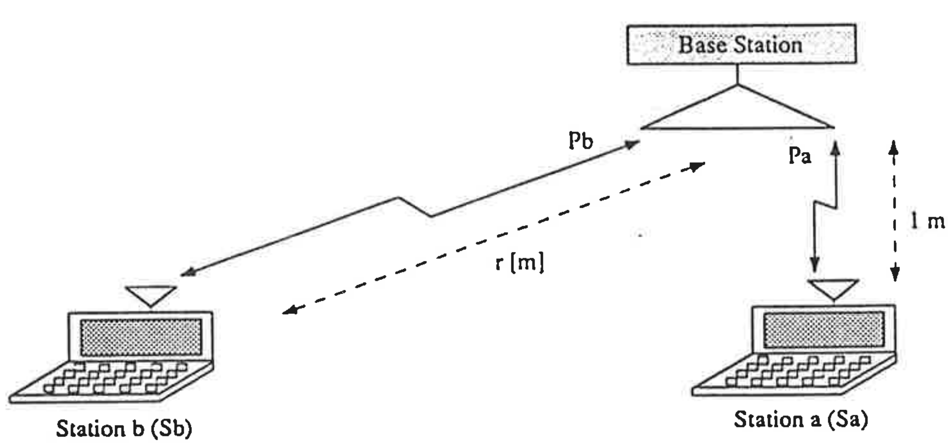


Fig. 3. System Model for Near-far Problem

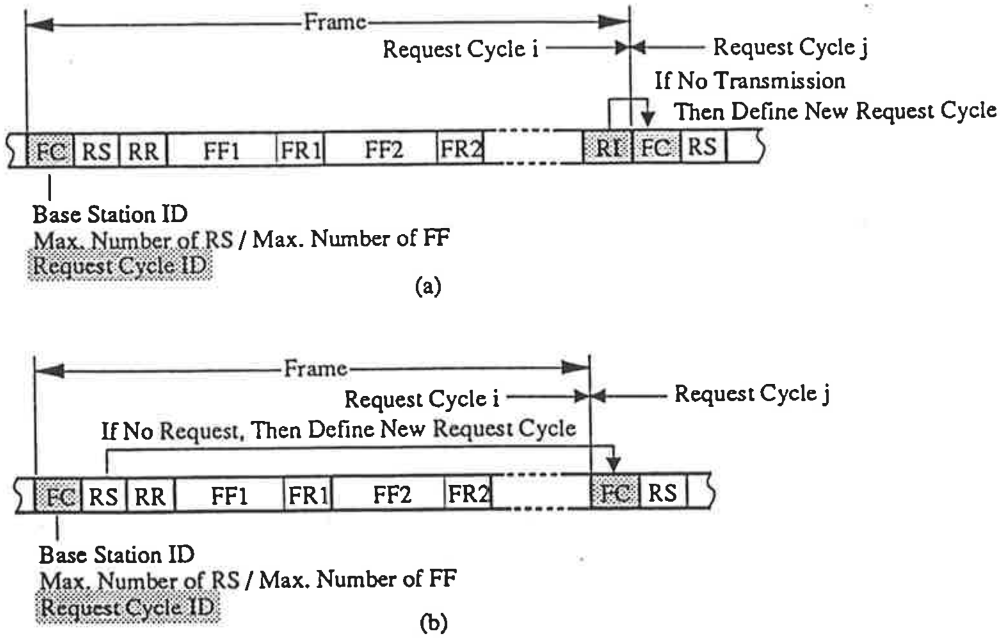


Fig. 4 Frame Structure for Request Cycle

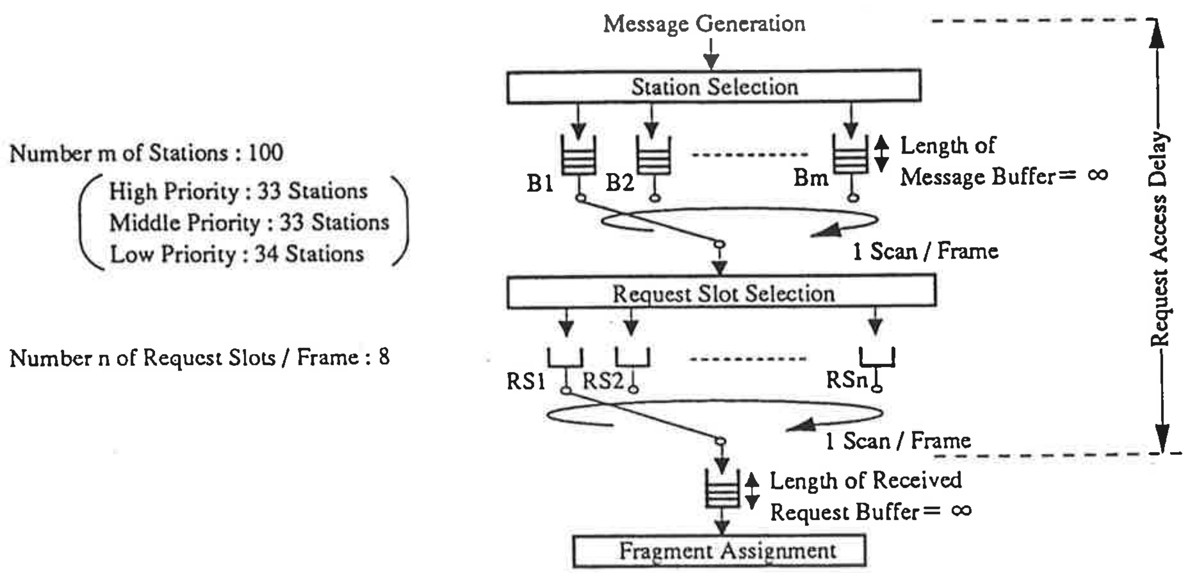


Fig. 5 Simulation Model

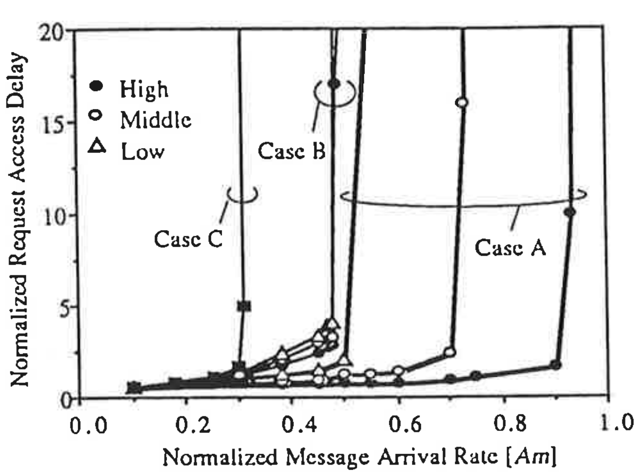


Fig. 6 Request Access Delay Characteristics

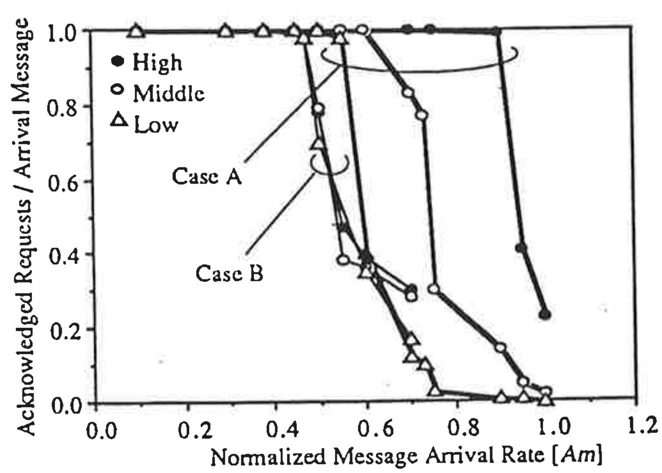


Fig. 7 Request Acknowledgment Characteristics