Performance Evaluation of a Packet Reservation Media Access (PRMA) Scheme for Broadband Fixed Wireless Access

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Abstract: This paper introduces a packet reservation based MAC layer for broadband fixed wireless access communications. The performance of a reservation based MAC scheme is compared with the performances of Pure-ALOHA and Slotted-ALOHA MAC schemes. A simulation using OPNET Modeler is performed to compare the performance of these MAC schemes in terms of channel throughput and average packet delay.

1. Introduction

Broadband Fixed Wireless Access (BFWA) is one of the solutions to the last mile problem in telecommunications. Typical BFWA network components are the Control Server (CS), the Access Point and the Subscriber Unit (SU) and they are arranged as shown in Figure 1. The SU is mounted on the subscriber's site and uses a directional antenna to communicate with its corresponding AP. Several APs can be connected to a CS. The CS is a server that provides configuration, authentication and management systems.

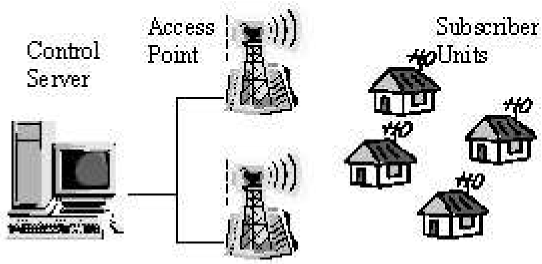

Figure 1: Broadband Fixed Wireless Access network components and layout

BFWA can be deployed rapidly and is ideal in situations where cable installation is difficult. Subscribers can be added or removed easily in an existing BFWA network by installing (or removing) a SU as compared to installing conduit and cable to the subscriber site in a wireline network. If the subscriber decides to terminate the service, the installed cable is difficult to remove.

In this paper a packet reservation based Media Access Control (PRMA) layer for BFWA is introduced and is compared with MAC layers using Pure-ALOHA or Slotted-ALOHA techniques. Section 2 explains the three MAC schemes considered and the simulation configuration, Section 3 gives the results and Section 4 is the conclusion.

2. MAC Schemes

The PRMA scheme uses a Time Division Duplex (TDD) similar to that proposed in [1] where a transmission cycle is equivalent to a single MAC frame with the structure shown in Figure 2. Only one type of priority class is considered in this paper.

With reference to Figure 2, the crossed boxes are idle timeslots where during these periods neither the SU nor the AP transmits. The shaded boxes in Figure 2 indicates that there may be a number of such fields per MAC frame while the non-shaded boxes indicates that there is only one such field per MAC frame. A Frame Descriptor packet is transmitted in the *Header* at the start of each MAC frame, which describes the entire content of the current MAC frame. A SU with packets to transmit will contend by sending a Reservation packet at the start of one of the contention timeslots (*CT*). The Reservation packet gives the number of uplink timeslots required by the SU. If a SU has won the contention, the AP will assign an appropriate number of uplink timeslots (*USLOT*) for this SU in the next MAC frame and this information will be sent to the SU in the next MAC frame in the Reservation Response *RR* timeslot. The SU granted the uplink timeslots sends data packet during the *USLOT* timeslot and is able to request for additional uplink timeslot in the next MAC frame by piggy backing on one of the uplink timeslot (*USLOT*) – hence no need for contention. The AP acknowledges each SU's uplink data burst in the *DACK* timeslots. If the SU fails to receive a Reservation Response, it will time-out and back-off a random time before contending for a packet reservation again. The AP broadcasts downlink data packets using a downlink timeslot (*DSLOT* – one per packet), which is acknowledged by the relevant SUs at the *UACK* timeslots.

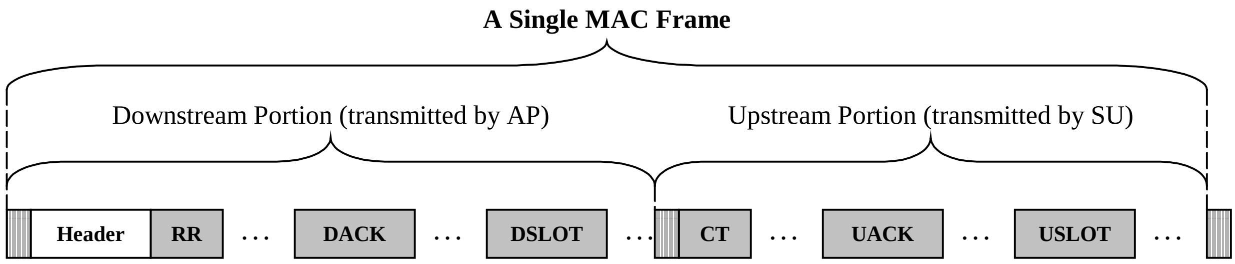

Figure 2: A single MAC frame structure for PRMA scheme

The AP decides which SU is able to transmit in each MAC frame using a round robin scheme. The number of different types of timeslots (shaded timeslots in Figure 2) varies according to traffic load. The maximum number of these timeslots and the maximum number of SUs, N_{SU} allowed to transmit in each MAC frame are fixed. Theoretically the throughput T will increase linearly with offered traffic load L up to a point where the throughput is saturated (i.e. it does not increase with offered load).

In a Pure-ALOHA scheme, all the SUs are free to transmit whenever they have data to send. Collisions will occur and packets that collide are destroyed. The theoretical relationship between the throughput T and offered traffic load L (packets per seconds) is given in Equation (1) where the total number of SUs is assumed to be infinite [2].

$$T = L \exp^{-2L} \tag{1}$$

In a Slotted-ALOHA scheme, time is divided into equal discrete periods. Packets arriving are transmitted at the start of the next timeslot and hence the SUs must be synchronised with each other. Similarly, packets that collide are destroyed. The relationship between the throughput T and the offered traffic load L is given in Equation (2) where the total number of SUs is assumed to be infinite [2].

$$T = L \exp^{-L} \tag{2}$$

The simulation is performed using the OPNET Modeler/Radio software package. A scenario with one AP surrounded by 20 SUs is used where each packet arrival follows a Poisson distribution with the total mean traffic of all the SUs ranging from 0.2 packet/packet frame to 5 packets/packet frame. A packet frame is the time required to send a data packet (i.e. *USLOT*) and it is assumed to be constant (i.e. ATM cell) so that the performances of the MAC schemes are normalised. The packet delay is the time a packet spent waiting in a queue before it is being transmitted (i.e. transmission delay is ignored) and there are no retransmissions for data packets that fail to reach the AP.

3. Results

The simulated channel throughput and theoretical results for each MAC scheme are shown in Figure 3. The peak channel throughput for Pure-ALOHA and Slotted-ALOHA are 0.189 packet/packet frame and 0.398 packet/packet frame respectively. The throughputs are higher than predicted by theory because the number of SUs transmitting is limited rather than infinite.

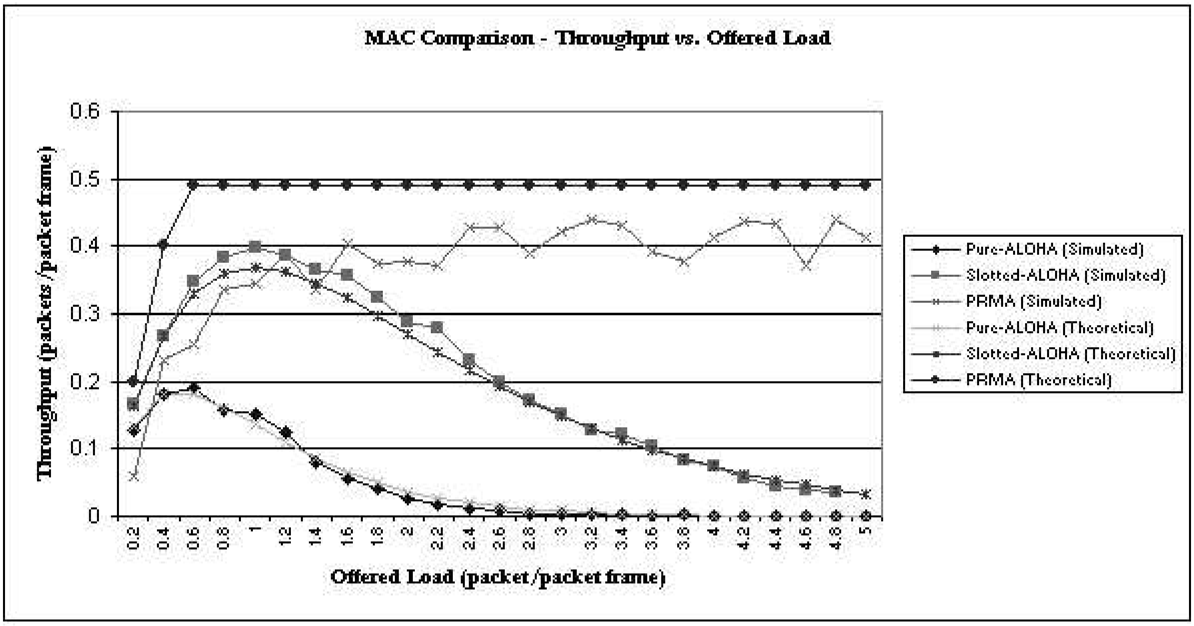

Figure 3: Channel throughput (packet/packet frame) comparison

The simulated PRMA channel throughput is about 0.44 packet/packet frame. This is lower than the theoretical limit because in the simulation, the SUs that fail to win a contention need to back-off a random time and if the number of SUs transmitting is larger than N_{SU} some of the SUs that successfully win a contention may not get any uplink timeslots in the next MAC frame since the AP uses a round robin scheme. This causes the SUs to delay packet transmission and hence the lower channel throughput. The theoretical limit assumes that all the SUs need only to contend once and continuously transmit thereafter. This is possible if the number of SUs per AP is less than or equal to N_{SU}. The PRMA channel throughput does not degrade as the offered traffic load increases as compared to the situation with Pure-ALOHA and the Slotted-ALOHA.

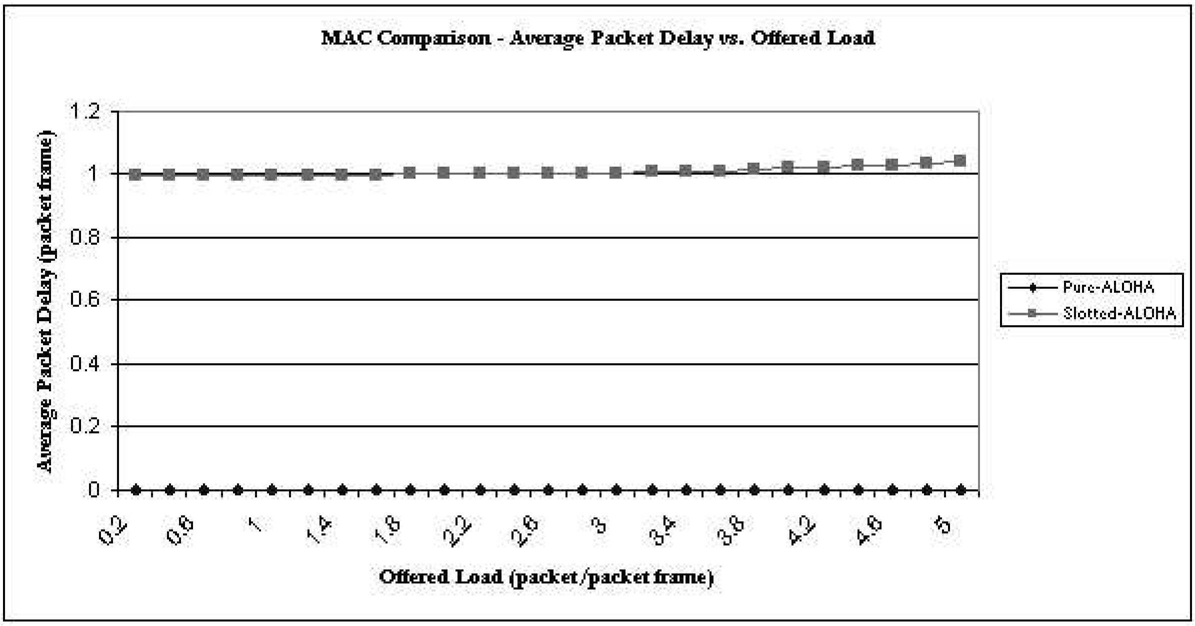

Figure 4: Average packet delay for Pure-ALOHA and Slotted ALOHA

The simulated average packet delay results for each MAC scheme are shown in Figure 4 and Figure 5. There is no packet delay for the Pure-ALOHA scheme as the packet is transmitted once it is available and retransmission and transmission delay are not taken into account.

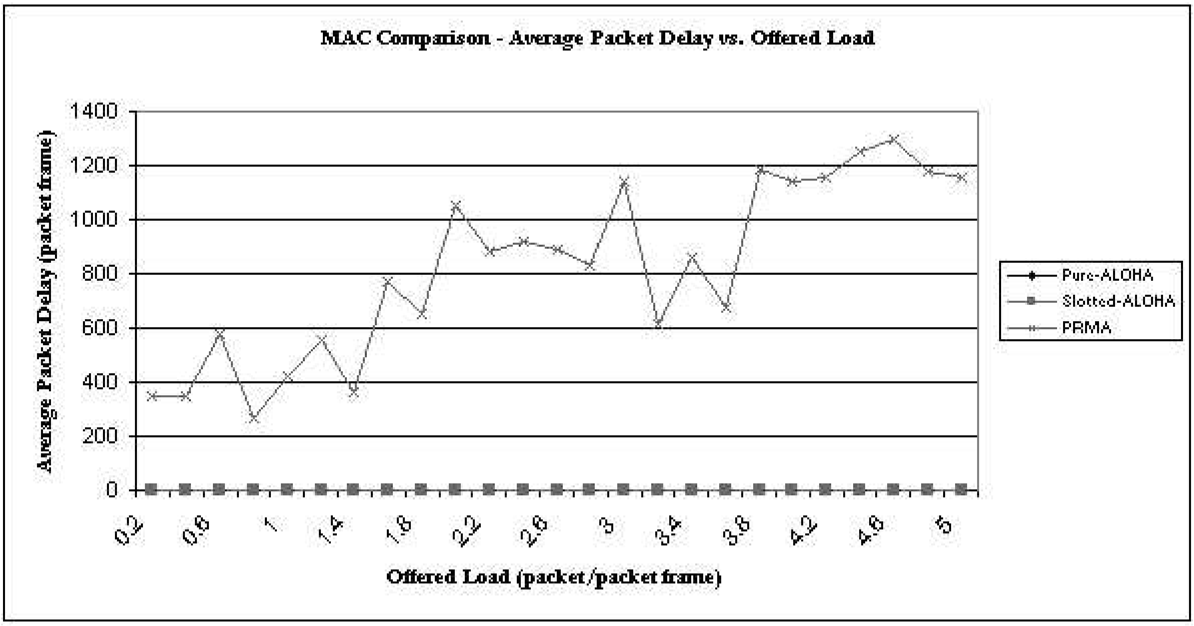

Figure 5: Average packet delay (packet frame) comparison

In Figure 4 the average packet delay for Slotted-ALOHA is about 1 packet frame because each packet needs to wait about 1 packet frame before it can be transmitted. The slight increase in average packet delay is due to having more than one packet created in a packet frame, which is rare but more likely at higher offered loads.

In Figure 5 the average packet delay for the PRMA scheme increases exponentially when the offered traffic load is higher than the peak channel throughput. The service time of PRMA scheme is at best one MAC frame, which is much slower than that in Slotted-ALOHA. When the offered traffic load is above the peak channel throughput of 0.44 packet/packet frame, the queue becomes unstable causing queue size to increase. Hence the queue delay is several times the MAC frame period causing it to increases exponentially in terms of packet frame units.

4. Conclusion

A packet reservation based MAC scheme (PRMA) is introduced and is compared with Pure-ALOHA and Slotted-ALOHA schemes. The PRMA scheme has the highest peak throughput and does not degrade as the offered traffic load increases as compared with the Pure-ALOHA and the Slotted-ALOHA MAC layers. Pure-ALOHA has no packet delay while Slotted-ALOHA has an average packet delay of about one packet frame. PRMA scheme has the highest average packet delay due to the time needed for reservation and this delay increases exponentially if the offered traffic load is above the peak channel throughput.

Acknowledgments

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References

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[2] Andrew S. Tanenbaum, *Computer Networks*. New Jersey: Prentice Hall, 1996.