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A Hybrid Adaptive Wireless Channel Access Protocol for Multimedia Personal Communication Systems *

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Abstract. This paper proposes a new medium access protocol (MAC) protocol for future wireless multimedia personal communication systems, denoted *hybrid and adaptive multiple access control* (HAMAC) protocol. The HAMAC protocol integrates fixed assignment TDMA protocol, reservation-based protocols, and contention-based protocols into a single wireless network so as to simultaneously and efficiently support various classes of traffic such as constant-bit-rate (CBR), variable-bit-rate (VBR), and available-bit-rate (ABR) traffic. In particular, the HAMAC protocol uses a novel *preservation* slot technique to overcome the packet contention overhead in *packet reservation multiple access* (PRMA) like protocols, while keeping most isochronous service features of TDMA protocols to serve voice and CBR traffic streams. A *preservation* slot is a very short slot which is used to represent a CBR connection when the traffic in the CBR connection is in a silent period in which there is no meaningful data to transmit. Due to the very short length of the *preservation* slot, it only takes minimal portion of the bandwidth pre-allocated to the CBR connection, so that the remaining bandwidth can be freed for other connections to use. When the CBR source becomes active again, the *preservation* slot is replaced by normal data slots without any reservation operation, extra delay, or significant bandwidth loss. Consequently, the guaranteed service and simplified signaling features of TDMA protocols, together with the adaptive bandwidth allocation features of PRMA-like protocols, are both realized in the HAMAC protocol. We have analyzed the performance of the HAMAC protocol using extensive simulations. The results show that the HAMAC protocol can achieve very low loss rates for various multimedia traffic with stringent quality of service (QoS) requirements and outperforms state-of-the-art PRMA-like protocols. As a result, the HAMAC protocol appears to be a good candidate for future generation multimedia personal communication systems.

Keywords: multiple access protocols, multimedia wireless networks, performance evaluation.

1. Introduction

By providing ubiquitous and tether-less network connectivity to mobile users, wireless personal communication systems (PCS) can supply people with a more flexible and efficient communication environment. Although initial proposals and implementations of PCS are generally focused on near-term voice and electronic messaging applications, it is recognized that future PCS will have to evolve towards supporting a wider range of applications, including audio, video, data, and images [11, 12]. One key precious resource in PCS is the wireless channel that gives access to mobile users. The wireless channel bandwidth in today's PCS is limited, and no substantial increase in bandwidth is predicted even though the demand for access continues to surge. As a result, one of the crucial technical issues related to the design of future multimedia personal communication systems is the selection of a suitable

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wireless channel sharing access technique, known as *medium access control* (MAC), that can efficiently accommodate all anticipated new applications while preserving their required quality of service (QoS) [12].

In general, there are three types of MAC protocols that can be used in PCS: pre-allocated protocols, reservation-based protocols, and contention-based protocols. Each of the three classes of protocols serves best certain types of traffic, but not others [5, 16]. Conventional *time division multiple access* (TDMA) protocols, and *frequency division multiple access* (FDMA) protocols can be denoted as pre-allocation protocols. Because they supply guaranteed service in a cyclic manner, they can perfectly serve constant-bit-rate (CBR) traffic, such as voice streams. In addition, the control signaling in these protocols can be very simple since the channel access schemes are deterministic. However, as well known, the voice streams can be in one of the two states: *silent* or *active* state (*talkspurt*) [6, 7]. During the silent period, there is no data to transmit. As a result, the bandwidth occupied by this period is wasted, and this leads to low channel throughput. In addition, future personal communication systems are expected to serve various types of traffic in a single network. That is, the wireless network should serve not only voice streams, but also various kinds of user data which are usually generated very randomly and in large burstiness. Using pre-allocation protocols to transmit these types of traffic streams is inefficient since the prefixed access scheme can not adapt to the diversity and dynamics of the traffic demands.

To adaptively utilize the wireless channel bandwidth, a reservation-based protocol, *packet reservation multiple access* (PRMA), was proposed by D.J. Goodman *et al.* in 1989 [6]. Since then, many variations of PRMA have been proposed [7–9, 11, 12, 16, 17]. A good survey of this research can be found in [14]. In the PRMA protocol, the bandwidth is allocated in the basis of *talkspurt*. At the beginning of a talkspurt, a reservation request is generated through a contention channel where a slotted ALOHA-like protocol is used. If the reservation is successful, one or more slots are allocated to this talkspurt in consecutive frames until the end of the *active period*. Using PRMA, the user data are transmitted in the remaining available bandwidth after the voice streams are served. It was shown that this protocol significantly increases the channel utilization when compared to TDMA. However, because of possible packet collisions in the contention channel, the time required to successfully reserve the bandwidth for a talkspurt can not be bounded. As a result, the first few packets in a talkspurt may be dropped if they cannot be transmitted on time. In the extreme case, if the talkspurt contains only few packets, the voice transmission quality can become intolerable, because most packets in the talkspurt have to be dropped.

Many schemes have been proposed to eliminate or reduce the effects of the uncertainty in the contention channel in the PRMA-like protocols. The *dynamic reservation multiple access* (DRMA) protocol by Qiu [11] uses a short slot (mini-slot) to carry out the contention so as to degrade the waste of bandwidth due to collisions. G. Anastasi *et al.* proposed a scheme that avoids the channel contention for data transmission reservation by allocating certain number of slots in each frame for the mobile devices to send their reservation requests [1, 2]. In this way, the reservation phase for data transmission becomes collision-free but the reservation cyle can become multiple frames long. However, the reservation requests for voice streams are still served using a contention channel, although the random access effect is reduced because the contention population is smaller. The MASCARA (*Mobile Access Scheme Based on Contention and Reservation for ATM*) [10] applies a priority-based scheduling algorithm and a *variable-length* frame to cope with the multimedia traffic. The length of the frame is determined in such a way that real-time CBR and real-time *variable-bit-rate* (VBR) can get guaranteed QoS and the *contention period* is long enough to sustain a reasonable successful access rate. In all these approaches, the reservation uncertainties are reduced but still exist, that may result in considerable loss due to exceeding of the transmission time limitation. Another related work is proposed by Z. Zhang *et al.* [18] where the contention protocol is completely eliminated and replaced with a mini-slot TDMA control channel. Hence, there is no uncertainty during the reservation phase. However, the problem with the mini-slot TDMA reservation channel is its scalability. That is, using this scheme, the mini-slots are exclusively allocated to all mobile devices that possibly come into the cell, no matter whether they intent to transmit packets or not. As a result, if the number of mini-slots in the reservation cycle is smaller than the number of mobile devices in a cell, some of the mobile devices can not send their reservation requests when they have packets to transmit. On the other hand, if the number of mini-slots in a cycle is too large, the reservation delay becomes very long and may result in a high loss rate for voice packets. In addition, if there are only few mobile devices sending reservation requests, the efficiency of the reservation channel becomes very low. Given the number of bits required by each mini-slot and the limitation on the reservation cycle time, the maximum number of mobile devices that can be served in a cell can be easily calculated. It seems that one has to face a trade-off between guaranteeing the transmission delay but wasting the bandwidth versus utilizing the channel efficiently but suffering extra unbounded reservation delay. Fortunately, the approach presented in this paper shows that there is a way to combine the advantages of both sides while reducing their disadvantages. In our proposal, the bandwidth for CBR connections is allocated at the connection setup time, i.e., it is a pre-determined allocation strategy as in a TDMA protocol. However, we can gain adaptability by using a *preservation* slot technique. A *preservation* slot is a very short slot whose length is properly chosen in such way that all mobile devices in the same cell can have enough time to recognize the existence of the *preservation* slot during the *preservation* slot transmission time. For example, with a 4 Mbps channel in a cell of 500 meters in diameter, 2-bytes transmission time is long enough to transmit some bits to any other mobile device in the same cell [3]. When a CBR source becomes silent, a *preservation* slot is placed at a position in the transmission frame where this talkspurt was allocated. By proper coordination, most of the bandwidth originally allocated to this CBR connection can be used by other traffic connections. When a CBR source becomes active again, the normal slots replace its *preservation* slot position, without any reservation operation. Using the *preservation* slots results in a very significant reduction in wastage of bandwidth compared to a round-robin TDMA protocol. For example, if a normal slots is 53 bytes in length as in an ATM cell, a 2-bytes *preservation* slot is just 1/25 the size of one normal slot! If the CBR traffic bit rate is high, like in a video stream, where more than one slot are needed in a frame, the improvement by using the *preservation* slots can be very remarkable. At the same time, this method avoids the reservation for active talkspurts while adaptively utilizing the bandwidth that is not used by CBR streams, as done in conventional PRMA-like protocols. Thus reducing the contention population and simplifying the implementation, consequently improving the overall network performance. More importantly, due to the use of *preservation* slots, the isochronous traffic can achieve guaranteed bandwidth, therefore, the traffic QoS can be improved significantly as shown in the results of this paper.

Our proposed protocol is named *hybrid adaptive MAC protocol* (HAMAC) because it integrates three types of access schemes into a single shared channel, that is, TDMA, reservation, and contention. At the same time, it can efficiently adapt to the traffic dynamics due to the mobility of mobile devices and the variance in CBR, VBR, and ABR traffic. Note

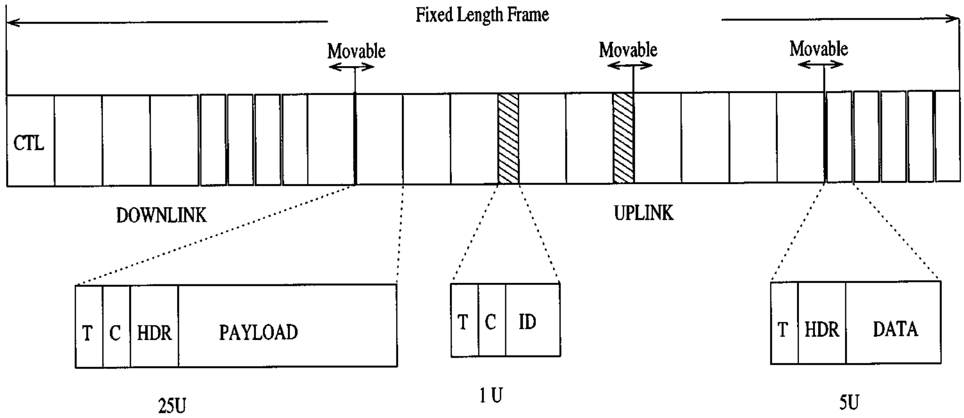

Figure 1. The HAMAC protocol's frame, segments and slots.

that in the HAMAC protocol, the contention channel can be used for data transmission, unlike many other proposals where the contention channel is used only for reservation and control signaling. We observe that although TDMA protocols and reservation protocols are collision-free protocols, they always require a *walk time* [15] to reach the service point after a packet arrives in the system. In other words, they can not support *immediate access* to the channel, thus the access delay can not be ideally low. While contention-based protocols can achieve very low access delay which is very important in many applications.

The remaining part of the paper is organized as follows. In Section 2, we detail the design and operation of our HAMAC protocol. In Section 3, we evaluate the performance of HAMAC using extensive simulations. In Section 4, we conclude the paper.

2. The HAMAC Protocol

The HAMAC protocol integrates three types of access schemes (i.e., TDMA, reservation, and contention), and supports three types of traffic (i.e., CBR, VBR, and ABR). We use a fixed-length super-frame which contains three segments where each segment belongs to one access scheme. We then dynamically adjust the borders between the different *segments* for high adaptability. In this section, we first introduce the HAMAC frames, segments and slots. Then, we discuss the HAMAC protocol operation.

2.1. The HAMAC Frame and Slots Definitions

Figure 1 shows the frames, segments and slots of the HAMAC protocol. A HAMAC superframe is divided into two frames, the *downlink frame* and the *uplink frame*. The length of the frames can be varied according to the bandwidth demand. The border between the downlink frame and the uplink frame is labeled DWN_{pnt}. The downlink frame is used by the ba se sta tion to broadcast the frame configuration information, the connection setup, the allocation information, the request information, and data to all mobile devices. Since only the base station controls the downlink, all those information and data can be broadcast using a single burst. Mobile devices can filter out irrelevant information upon receiving them. As shown in Figure 1, the first *segment* of the downlink frame is used for control signaling. This is necessary since the frame configuration has to be known by all mobile devices before starting the reception and the transmission.

Table 1. HAMAC slots.

Slot name	T bits	Length	Usage
Normal slot	01	25U	TDM, RSV
Preservation slot	10	U	TDM
Mini-slot	11	5U	CNT

In the uplink frame, there are three segments, named TDM, RSV and CNT. The starting position of the three segments are labeled by TDM_{pnt}, RSV_{pnt}, and CNT_{pnt} respectively. Note that DWN_{pnt} and TDM_{pnt} are always in the same position, i.e, $\mathrm{DWN}_{pnt} = \mathrm{TDM}_{pnt}$.

The TDM segment is used by the mobile devices to upload the CBR data using a TDMA round-robin scheme. There can be two types of slots in a TDM segment, the *normal slot* and the *preservation* slot. The *preservation* slot is used to "preserve" a position for a CBR connection when it is in a *silent* state. So the length of the *preservation* slot should be as short as possible. Let d be the diameter of a cell and D be the maximum bit rate of the radio channel, then the *preservation* slot length $l_{preservation}$ should satisfy $l_{preservation} \geq dD/S$ where S is the radio wave propagation speed in the air. During the transmission of such a *preservation* slot, all mobile devices in the same cell should have enough time to recognize the existence of the *preservation* slot or the existence of a silent CBR connection. In this paper, we take $l_{preservation}$ as the base unit, denoted by U. The *preservation* slot is not useful for the base station, so it is discarded by the base station and never appears in the downlink frame.

When a *preservation* slot of a CBR connection is present, the remaining bandwidth belonging to the connection is free. When the CBR connection becomes active again, the *preservation* slot is replaced by the normal slots, and all the allocated bandwidth for the connection can not be used by any other connections and mobile devices. Since we intentionally avoid the reservation operation before the transmission of an active talkspurt, the base station is not aware of the state transition of the CBR connection. As a result, there is no need to make the presence or absence of a *preservation* slot known to mobile devices using a downlink frame. That is, the *preservation* slot could "suddenly" appear or disappear without any needed notifications. Now the problem becomes how do mobile devices know whether a slot can be used or not. We use T bits and a C bit (as shown in Figure 1) to solve the problem.

In a HAMAC protocol, there are three types of slots as shown in Table 1. The T bits are used to indicate the type of the slot by which a receiver can accurately estimate the end of a slot when the T bits are received. The C bit (*continuous bit*) has a similar function as in [5]. When $C = 0$, it means the next slot is still from the same mobile device. When $C = 1$, it implies this is the last slot from the given mobile device, and the next one may come f rom a different mobile device. In particular, a *preservation* slot always has a C bit set to 1 for any CBR connection. By using the continuous bit, it is possible to compress the header information of consecutive slots when they belong to the same traffic source.

One more advantage of applying the continuous-bit technique is that the position of the slots allocated to the connections can "float" in the uplink frame, rather than having the slots allocated to a connection be assigned to a fixed location as was proposed in many protocols [14]. In HAMAC, the location of the slots allocated to a connection, defined as an *access point*, is assigned as a function of the number of $C = 1$ bits rather than the absolute position relative to the beginning of the super-frame. For example, as shown in Figure 2, if a VBR connection

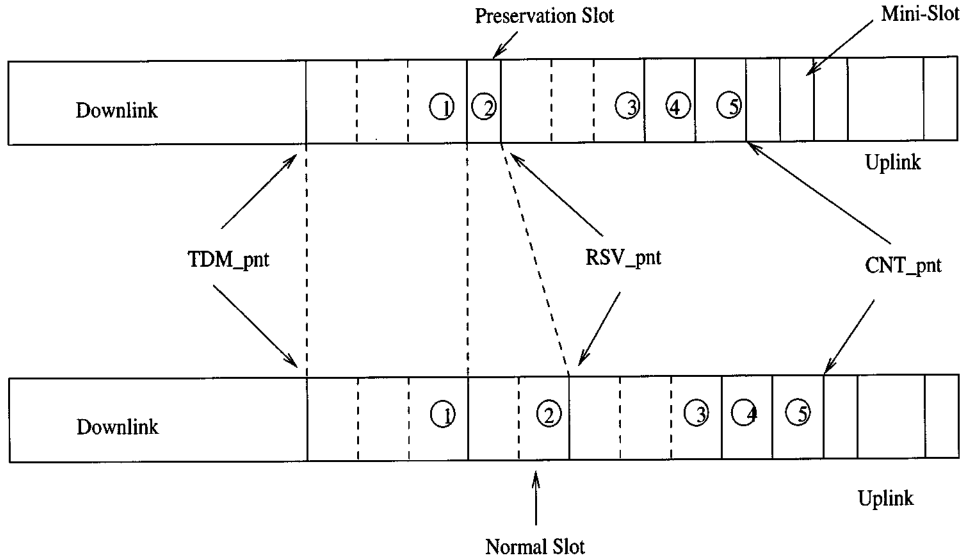

Figure 2. Example of *preservation* slot and continuous bit usage.

of a mobile device is assigned access point 5, the mobile device can start transmission in the next slot after 4 slots with $C = 1$ being observed, no matter whether the 4th or any previous slot is a *preservation* slot or a normal slot. As a result, the whole frame is utilized efficiently without any unusable fragments left. It is worth to note that the location should be re-adjusted once a CBR connection is dropped, or a new CBR connection is established since it may bias the coordination of the continuous-bit mechanism.

The RSV segment of the HAMAC protocol is used to carry bursty data packets which have to be reserved and allocated by the base station scheduler. Since bursty data traffic are usually of large volume, the RSV segment contains only the normal slots.

The CNT segment contains the contention slots only. As in [11, 12], we assign the contention slots a small size, so called *mini-slots* (see Table 1) in order to reduce the overhead due to collisions. All these slots are contended for under the control of a *permission probability* with respect to different types of packets. Reservation packets and control packets are more important since they may affect the performance of the RSV access or they may be network management packets that need to be served as fast as possible. Hence, they are assigned a higher permission probability. The ABR data packets should not significantly affect the system performance, so they are given relatively lower permission probability to contend for the mini-slots. Furthermore, to ensure that there is always a chance for reservation packets and control packets to transmit, we set a minimum length for the CNT segment.

2.2. Operation of the HAMAC Protocol

This subsection discusses the functional and timing relations among the various operations of the HAMAC protocol. Figures 3 and 4 depict the general states of the HAMAC protocol on the base station and the mobile devices.

The base station essentially operates in three states, BROADCAST, COLLECT and SCHEDULE. The transitions among the states correspond to the super-frame structure shown in Figure 1. The BROADCAST state synchronizes the down link frame, in which the base station broadcasts the packets allocated for the down link frame to all mobile devices in

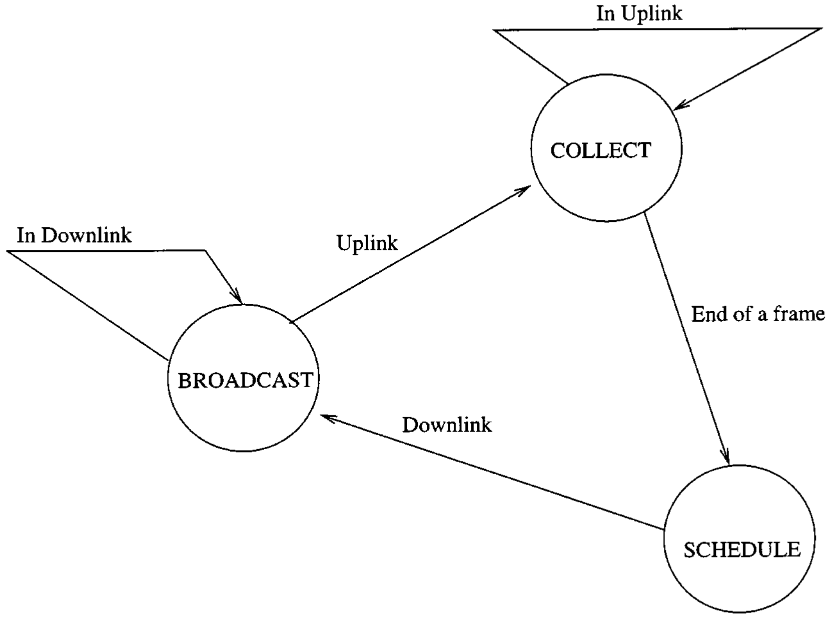

Figure 3. Operation of the base station.

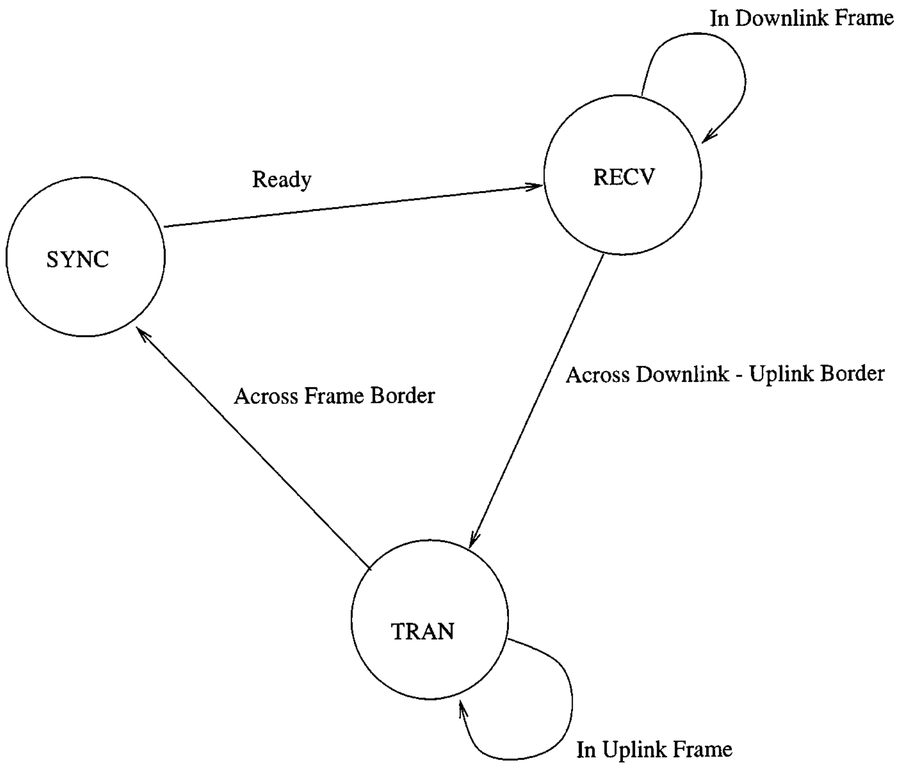

Figure 4. The operation of the mobile devices.

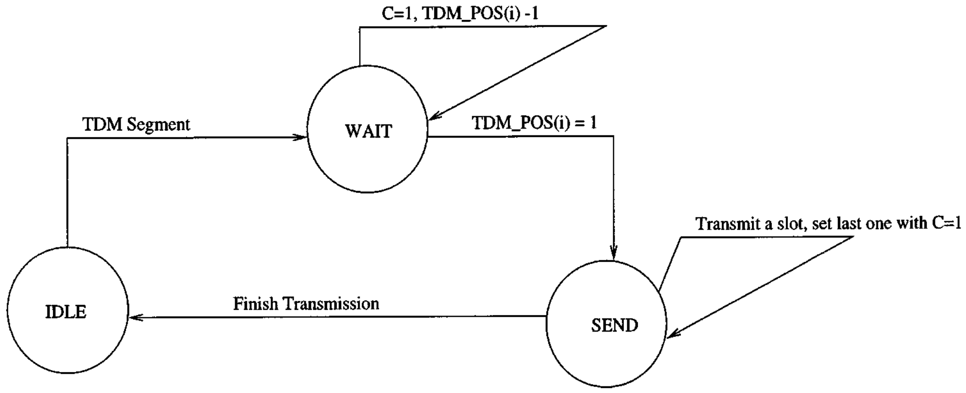

Figure 5. TDM segment process.

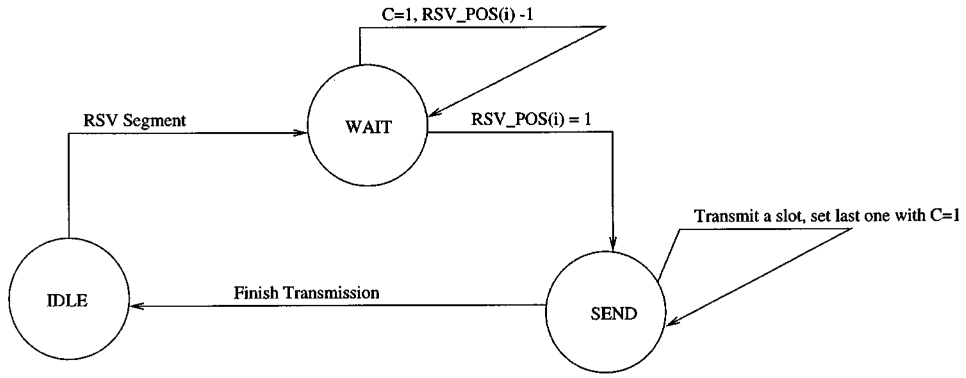

Figure 6. RSV segment process.

the cell. Note, the packets broadcast by a base station may not come only from the uplink frame of this cell, they may come from other cells through the BS-BS network. Thus, the number of packets to be broadcast is unpredictable. For example, in case there is a video-on-demand server in one of the cells, then there will be more request packets loaded on the downlink frames in the cell, but more data (video) packets out going from the cells. As a result, less bandwidth is needed by the downlink frame, but more is needed by the uplink frame in the cell. This is the point why the downlink frame length is best to be adjustable. When the border between the downlink frame and uplink frame is reached, a transit occurs from a BROADCAST state to a COLLECT state, which indicates that the base station is ready to collect informations from mobile devices. At the end of a frame, the base station comes to a SCHEDULE state in which the transmission of the next super-frame is scheduled.

Correspondingly, a mobile device has three general states (Figure 4). After synchronization with the super-frame, in the state of SYNC, the mobile device starts to receive and select the base station broadcast information, in the state of RECV. At the border between the uplink frame and the downlink frame, the mobile device changes the state to a TRAN state in which three sub-processes are executed as shown in Figures 5–7.

As shown in Figure 5, the TDM process consists of an IDLE, WAIT and SEND state. As we discussed in the previous section, once a CBR connection is established, one or more normal data slots are allocated to the connectio with an access point assigned. The mobile device can only send the packets out at its access point. To realize this, each mobile device

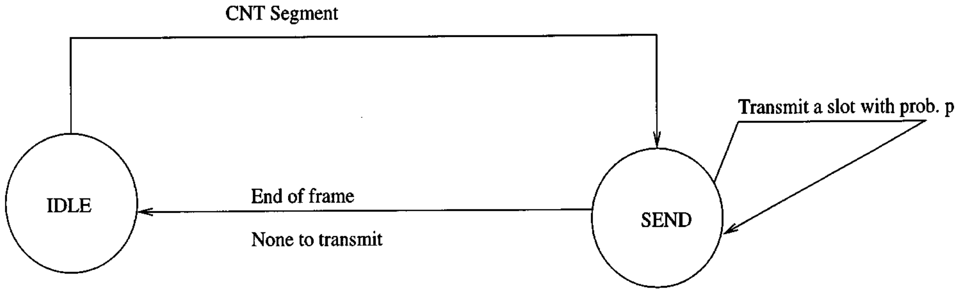

Figure 7. The CNT segment process.

has a C bit counter, labeled TDM_POS(i) which is initially set to be the number of access popints ahead of this connection. Here i indicates the mobile device id. When an access point, i.e., a slot with C bit equal to 1, is observed, the TDM_POS(i) decreases by one. When TDM_POS(i) of mobile device i is equal to 1, that means the next slot is the access point of mobile device i. Hence, the mobile device can start to transmit its packet in the next slot. If its voice active detector senses that the source is in a silent period, the mobile device simply uploads a *preservation* slot. Otherwise, if it is in an active state, one or more normal slots are transmitted. The mobile device goes back to its IDLE state after finishing the transmission, or when the border between the TDM segment and the RSV segment is reached.

Similar to the TDM process, the RSV process has also three states as shown in Figure 6 where the access point counter is RSV_POS(i) for mobile device i. A tricky aspect about the RSV segment is that the length of the RSV segment can be reduced down to zero. Because the TDM slots have higher priority and there is always a minimum number of the CNT slots in the fixed length super-frame, in case a large number of active CBR connections are served together, the RSV segment size has to be reduced. A problem is caused when the active RSV connections are confirmed but may not be successfully transmitted in the current super-frame, because requesting again may cause unnecessary delay and network load, while keeping the former allocation may cause ambiguous access point assignments. This problem can be solved by letting the base station scheduler keep track of the RSV transmission, and re-issue a confirmation in the next cycle in case a RSV connection is not transmitted successfully.

The CNT process is simpler and more straight forward than the above two processes as shown in Figure 7. All its operations are based on a slot-by-slot and there is no access point regulation. At each slot, the mobile device checks its permission probability and tries to send the packet out. Since in a CNT segment, the receiver is no longer busy observing the C bits as in the other two segments, it now can be used to detect the potential collisions. According to the slotted ALOHA principle, the first few bits of a slot are enough to detect a collision. Thus, the contention acknowledgement can be obtained within a slot time. As a result, it is possible to re-transmit in the consecutive mini-slots. It is an interesting feature that the dynamical segment allocation can supply a self-adjusting mechanism. When the RSV load is light, the CNT segment length may be larger than the minimum limitation. Hence, more contention chances are given, consequently high success rate can be achieved. It implies that more VBR transmissions can be accommodated. On the other hand, when the RSV segment expands, the CNT segment shrinks, up to the minimum CNT segment size. Then, the number of slots that can be contended for becomes less, hence higher collision rate occurs and the effect of the RSV load is reduced.

At the end of the CNT process, the mobile device finishes the operation of the super frame and changes the state to the SYNC state (Figure 4) for the next cycle.

3. Performance Evaluation

In this section we evaluate the performance of our HAMAC protocol through extensive discrete-event simulations. We also compare its performance with related state-of-art protocols denoted *Dynamic Reservation Multiple Access* (DRMA) [11] and *Mobile Access Scheme Based on Contention and Reservation for ATM* (MASCARA) [10]. The DRMA employ mini-slots for contention transmission while most other features are similar to PRMA. The MASCARA supports the TDM and the RSV traffic by a priority based scheduling scheme, and the contention period is used only for control purposes. Moreover, the MASCARA uses variable length frame so that the contention period duration can be kept at a reasonable length in which a reasonable contention success rate is attained.

In our simulation of the HAMAC protocol, the contention segment takes all the remaining bandwidth after the allocation for the downlink frame, the TDM segment, and the RSV segment. This method is quite different from PRMA-like protocols such as the DRMA and the MASCARA where the number of slots used for voice reservation requests is fixed or controlled according to the current collision rate. To fairly compare the HAMAC with the DRMA and the MASCARA, we apply the same contention slots allocation strategy for all protocols, i.e., after allocating the downlink frame, the TDM and the RSV segments, all the remaining space in the frame is allocated to the CNT segment for contention. In simulation of MASCARA, the frame length is determined according to the length of the contention period remaining after TDM and RSV allocation. As we described in Section 2, there is a minimum length for the CNT segment so that in each frame there is always a high chance to send a control or a request packet.

In the simulation, we assume the radio channel capacity to be 4 Mbps (including both the downlink and the uplink), the the frame time (including both the downlink frame and the uplink frame) to be 10 ms. The mean talkspurt active and silent periods are chosen to be 1.0 second and 1.35 seconds respectively. The performance of the protocols is evaluated using three sets of traffic load patterns and parameters. In the first set, we evaluate the performance of the CBR traffic. In this case, we fix the amount of the RSV and the CNT traffic loads while adjusting the CBR traffic load. The second set of simulations focuses on the performance of the RSV protocol. Thus, we fix the CBR traffic load and vary the VBR traffic load. Similarly, we design the third set of simulation parameters, in which the TDM and the RSV traffic are fixed while CNT traffic are varied.

Figures 8–12 compare the performance of the HAMAC protocol, the DRMA protocol and the MASCARA protocol using the first set of parameters. In Figure 8, we can see that the HAMAC protocol has a lower mean delay than that of the DRMA and MASCARA protocols. This is what we expected since each talkspurt has to go through a reservation procedure using the DRMA and the MASCARA protocols before the voice data packet is transmitted. The reservation confirmation is issued in the next frame if a reservation request is successful.

The MASCARA is little better than DRMA in terms of the mean delay when the traffic load is low, because the variable length frame can lead to a higher contention success rate higher. However, when the traffic load is higher, the MASCARA has to over-expend the frame length so that the reserved TDM traffic can be accommodated and reasonable length of the

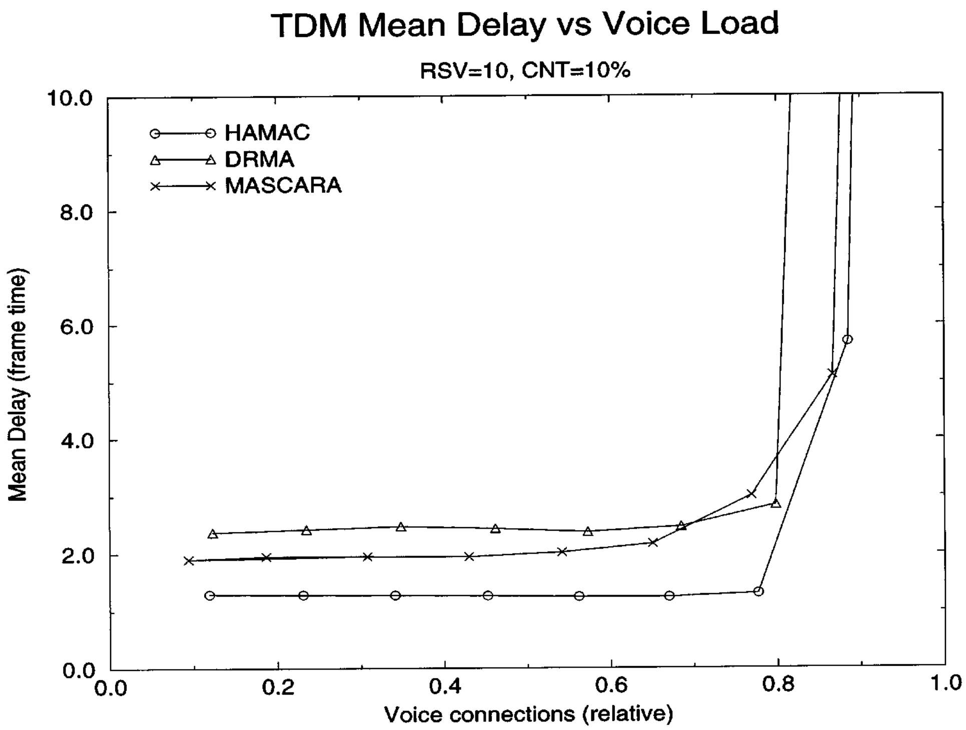

Figure 8. Comparison on the mean voice packet delay.

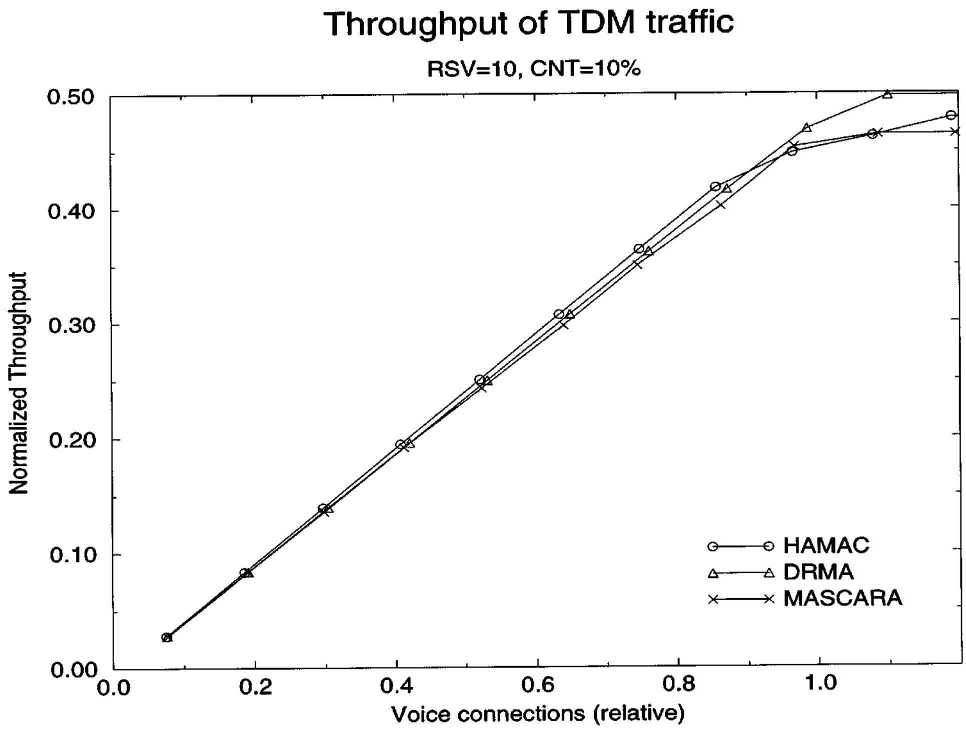

Figure 9. Comparison on the throughput for voice traffic.

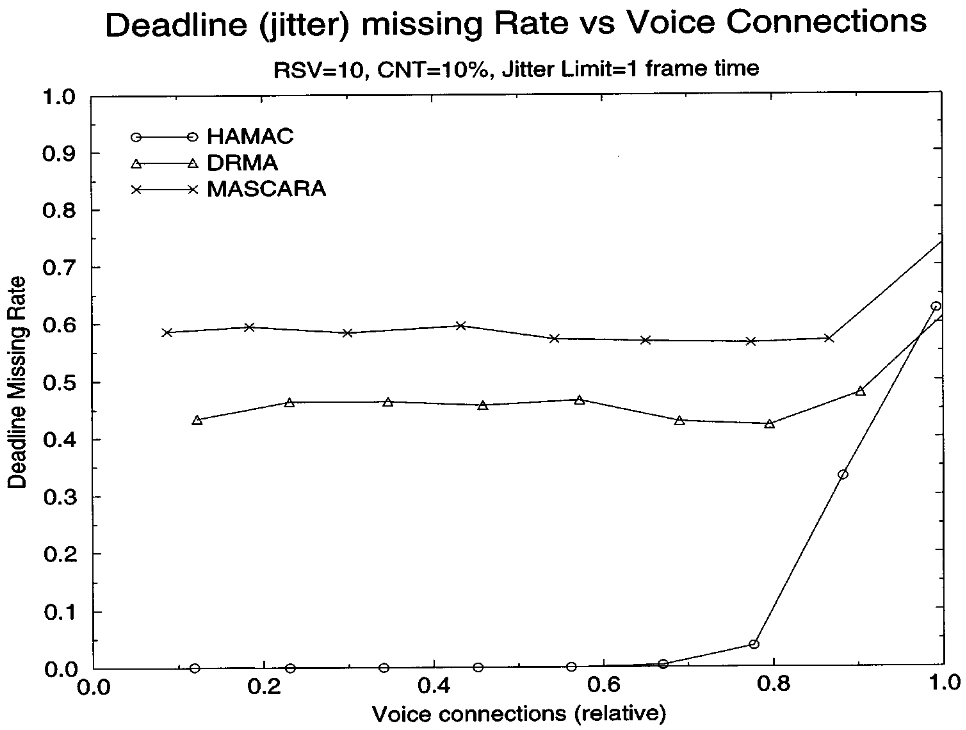

Figure 10. Comparison on deadline missing rate.

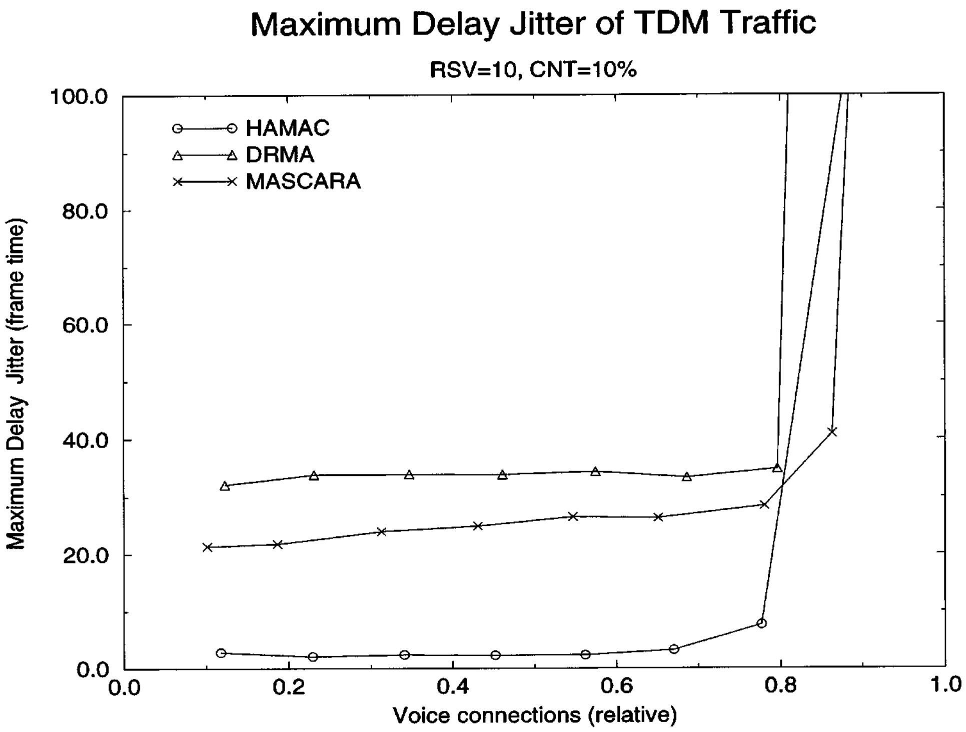

Figure 11. Comparison on maximum delay jitter.

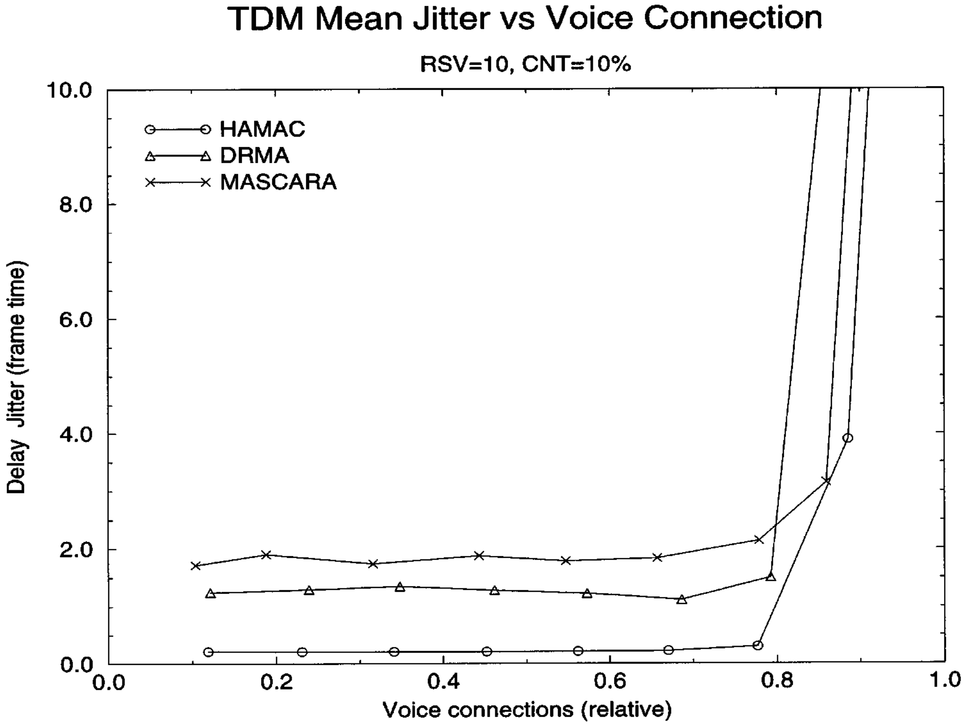

Figure 12. Comparison on average delay jitter.

contention period is kept. As a result, the service cycle becomes longer and the mean delay becomes higher.

In Figure 9, we can see that the maximum throughput of the HAMAC protocol is little higher than that of the DRMA protocol. This is because more bandwidth is used for reservation in the DRMA protocol especially at high network loads.

Figure 10 shows the *deadline missing rate* comparison between the HAMAC protocol and the DRMA protocol as well as MASCARA protocol. In the context of multimedia traffic, the transmission time requirement is one of the most important metrics to evaluate the QoS of a network. The deadline missing rate a method to describe the transmission time requirement which is defined as the ratio between the number of packets which are missing the transmission deadline over the total number of packets to be transmitted. For the CBR traffic, the deadline is given corresponding to the delay jitter, instead of delay time. Hence, the deadline missing rate becomes the portion of packets whose maximum delay jitter exceeds a given delay jitter limitation. We have set this delay jitter limitation to be one frame time. As we can see, the DRMA protocol and MASCARA protocol have higher loss rate due to their relative unstable operation and large delay jitter.

This point is further illustrated in Figures 11 and 12 where the maximum delay jitter and average delay jitter are depicted for both protocols. It is interesting to observe that the average delay jitter of MASCARA is lower than that of DRMA, but the maximum jitter is higher. This implies that the MASCARA produce higher transmission variance due to varying the frame length.

Figure 13 compares the RSV performance of the HAMAC protocol, the DRMA protocol and the MASCARA protocol under the second set of parameters where CBR traffic are fixed

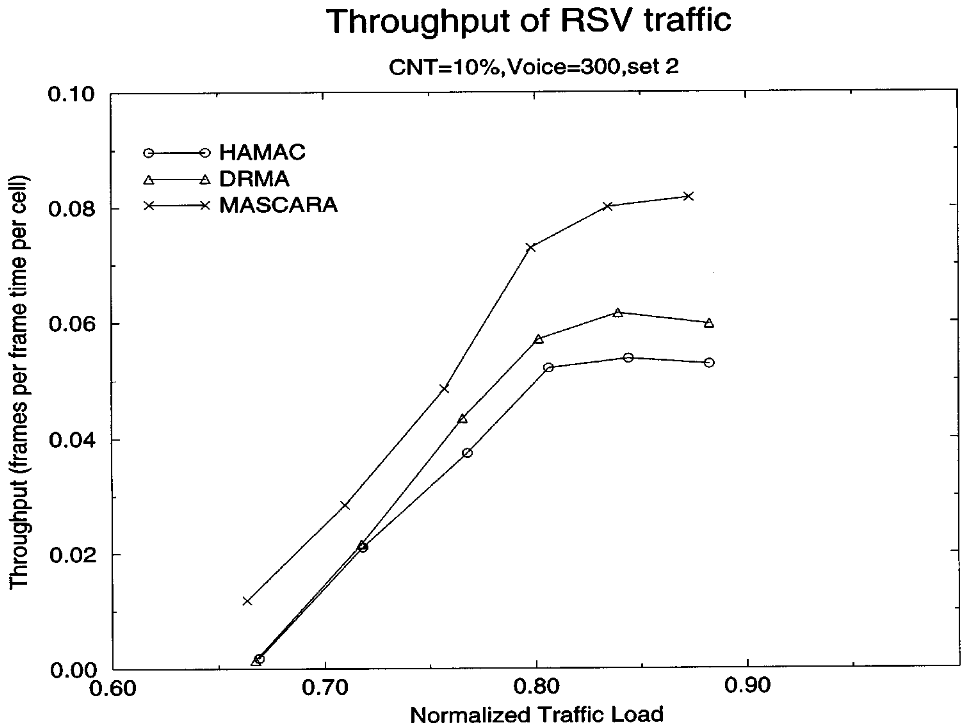

Figure 13. RSV throughput using traffic set 2.

while varying the VBR traffic load. When the system is loaded with certain CBR traffic which are of highest priority in consuming the bandwidth, in both HAMAC and DRMA, the remaining bandwidth if any, is used by the VBR and the ABR traffic using a reservation scheme and a contention scheme, respectively. The performance of these two types of traffic depend on the amount of bandwidth available. The HAMAC protocol eliminates the reservation overhead of CBR traffic, which results in less contention in the CNT segment, so more bandwidth is expected to be free for contention or data transmission. On the other hand, a *preservation* slot takes out a certain amount of bandwidth which can not be used by any traffic. This point can be observed by comparing the maximum throughput. The MASCARA protocol is more efficient for the VBR traffic due to its variable-length frame.

Figure 14 compares the performance of the HAMAC protocol, the DRMA protocol and MASCARA in serving the RSV traffic. As we can see, the HAMAC can achieve more or less the same service as in DRMA, even though HAMAC can supply much better QoS for CBR traffic. By observing Figures 14 and 15, we can see that the MASCARA supplies better performance in RSV traffic because of its variable length frame.

Figure 16 shows the simulation results with the third set of the parameters where TDM and RSV traffic are fixed while varying the CNT traffic.

It is obvious that MASCARA can serve CNT and RSV traffic better than HAMAC and DRMA because of the adaptable bandwidth allocation for the contention period. However, it is worthy to note that this gain sacrifices the QoS of TDM or CBR traffic.

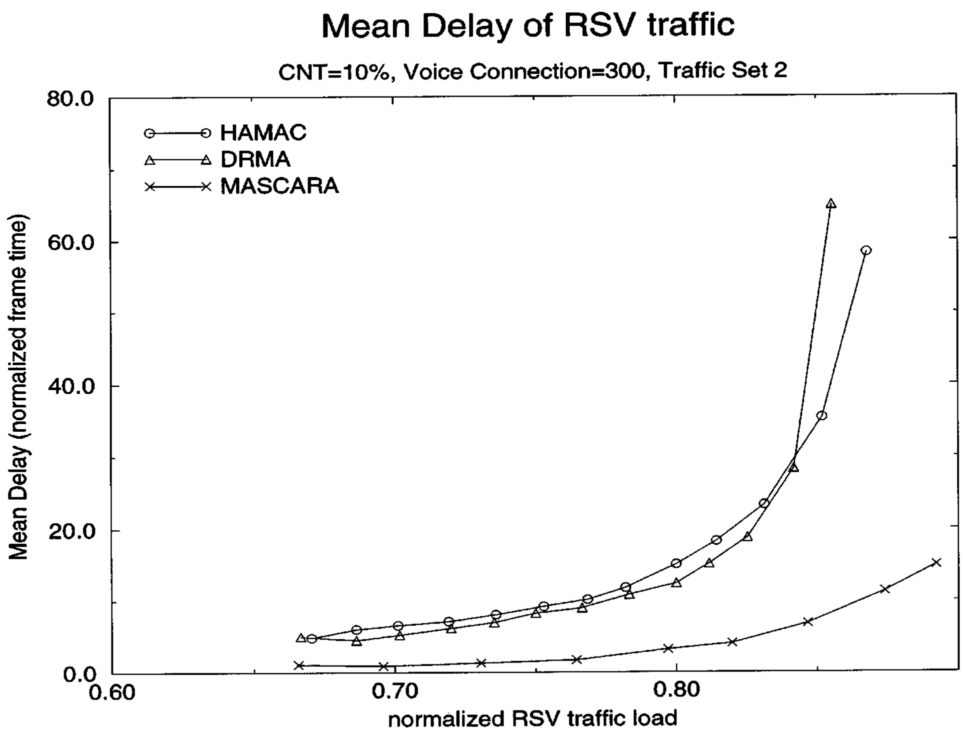

Figure 14. VBR delay using traffic set 2.

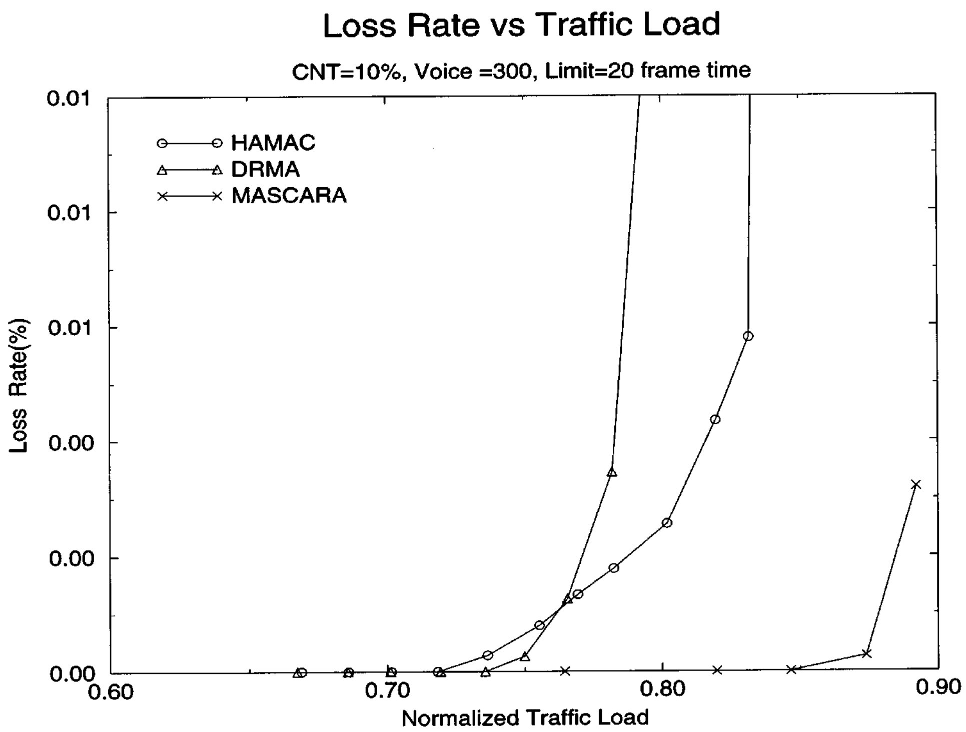

Figure 15. VBR loss rate using traffic set 2.

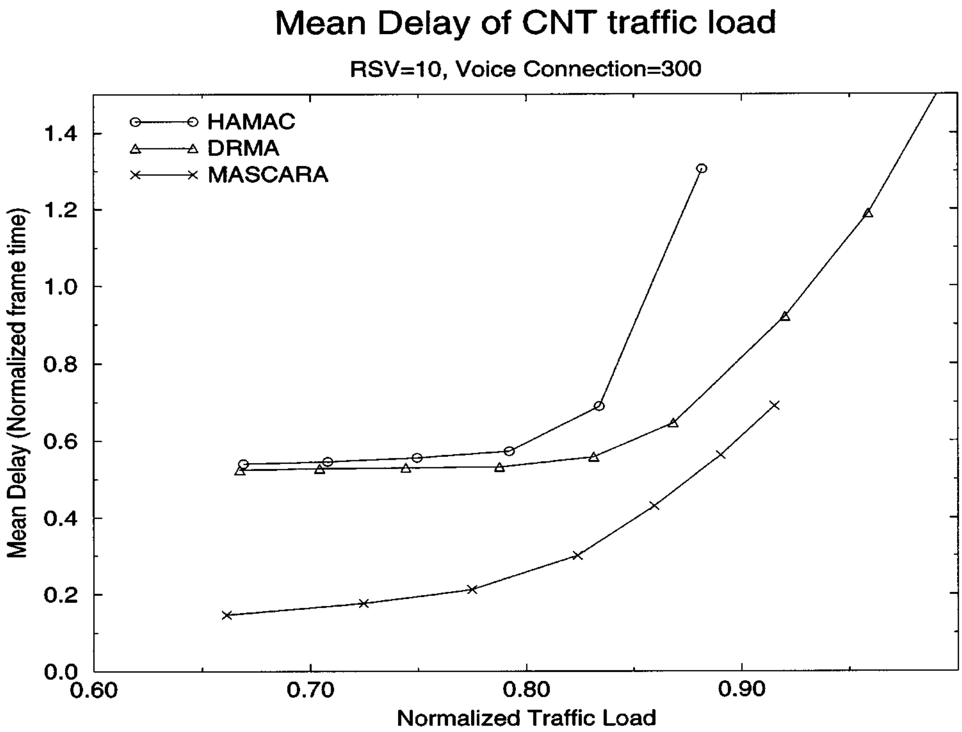

Figure 16. CNT mean delay using traffic set 3.

4. Conclusion

In this paper, we propose a hybrid and adaptive wireless MAC protocol that can efficiently and dynamically allocate the bandwidth for multimedia in very dynamic wireless communication environments. By using *preservation* slots, the contention for voice/video traffic, as done in the PRMA-like protocols, is reduced when using the HAMAC protocol. Thus, the QoS of multimedia applications can be improved remarkably. At the same time, the overhead of a *preservation* slot does not degrade VBR or other traffic performance. Since the number of *preservation* slots is proportional to the number of CBR traffic, the more bandwidth a connection is allocated, the higher the ratio of normal slots to the *preservation* slots is, then the more efficient the HAMAC protocol would be. This can be expected from a networking environment where video or high quality audio services are demanded. Extensive simulation results of HAMAC are presented in this paper. These results show that our proposed protocol and dynamic bandwidth allocation strategy are efficient and compare favorably to state-of-the-art protocols, and thus the HAMAC protocol can have a good potential of being used for future generation wireless multimedia communication systems.

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