Performance Analysis of Reservation MAC protocols for Ad-Hoc Networks

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Abstract Multimedia and real-time applications require bandwidth guarantees, which may be achieved by resource reservation. However, resource reservation in ad-hoc networks is a very challenging task due to the instability of radio channels, node mobility and lack of coordination between mobile nodes. Proposed reservation MAC protocols like CATA, FPRP, R-CSMA and SRMA/PA have limitations and are suitable only for particular situations. In this paper, we propose a comparative analysis of the most representative reservation MAC protocols. We identify the major issues unresolved by reservation MAC protocols. A performance evaluation and comparative analysis with the IEEE 802.11e are achieved through the NS-2 simulator.

1 Introduction

Mobile ad-hoc networks (MANETs) are collections of mobile nodes forming temporary networks without any infrastructure support. They can be set up anywhere anytime owing to their easy deployment and self-organization ability. As a result, MANETs become the primary mean of communication in several domains where the deployment of wired infrastructure is difficult. Such domains include battle fields, forestry fire, and disaster recovery.

The characteristics of MANETs like the lack of centralized coordination, node mobility and resource availability make the Quality of Service (QoS) support in MANETs a very challenging task. MAC protocols for MANETs define the manner channels are shared between mobile nodes. They have significant impacts on the overall system performances and their design is a very challenging issue.

Many solutions have been proposed to support QoS at the MAC sub-layer. Those solutions attempted to improve the channel access mechanism to provide QoS guarantees to multimedia and real-time applications. Proposed solutions may be classified into two categories: contention-based and reservation-based schemes.

Contention-based protocols are non deterministic and nodes compete to get access to the channel for the transmission of each data packet. The aim of these protocols is to avoid packet collisions, and resolve the hidden and exposed terminal issues. This is achieved through carrier sensing, handshaking and backoff mechanisms. Carrier sense ensures that nodes compete to access the channel only when the channel is detected idle. The handshake mechanism uses short control frames (RTS/CTS) to avoid the hidden and exposed terminals issues. The IEEE 802.11 standard is the most known example of contention-based protocols.

Reservation protocols seem to be attractive solutions for QoS provisioning in ad-hoc networks. Their characteristics such as the contention free medium access and the reduced collision rate are very interesting for MANETs. In this paper we provide a comparative analysis of these protocols and the major issues encountered in designing such protocols. Particularly, we analyze the effects of mobility on the performance of reservation MAC protocols. We also compare these protocols with the IEEE802.11e standard.

The rest of this paper is organized as follows. In section 2, we give an overview of the IEEE 802.11e standard and reservation MAC protocols. In section 3 we highlight the major challenges and limitations of reservation protocols. In section 4 we give a performance evaluation of reservation protocols. Section 5 gives our conclusions.

2 Background and Related Work

Channel access protocols in MANETs can be classified into two categories: contention-based and reservation-based protocols. The IEEE 802.11 [1] is the most known example of contention-based protocols. The IEEE 802.11 standard is considered as the de-facto MAC protocol for wireless networks. The DCF mode is based on the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). It uses two mechanisms to avoid collision: the physical carrier sensing and the virtual carrier sensing. The physical carrier sensing is used to detect the presence of signal on the common physical channel. The virtual carrier sensing uses the duration field of the MAC frame header to indicate the duration during which a node will reserve the channel.

DATA transmission in DCF is accomplished following the RTS / CTS / DATA / ACK handshake. A station which has a DATA packet to send waits the channel to be idle for the duration of DIFS (DCF Inter Frame Space). If the channel lasts idle for DIFS, the station transmits an RTS packet. Otherwise, the station enters in a backoff period, by choosing a backoff timer. The backoff timer is decremented for each idle time-slot. The station transmits its RTS packet when the backoff timer expires. When the receiver receives successfully the RTS packet, it waits for SIFS (Short InterFrame Space) before replaying with a CTS packet. Both the RTS and CTS packets contain the Duration field which is used in order to prevent neighbours from accessing the channel during the RTS / CTS / DATA / ACK handshake.

Unfortunately, the contention-based access of the IEEE 802.11 makes it unable to fit the requirements of multimedia applications over multi-hop networks. In [11], authors discovered that the IEEE 802.11 did not function well in a wireless multihop environment. The results revealed that the standard suffers from serious throughput degradation and unfairness. Performance degradations are mainly due to the hidden and exposed terminals problems, and the binary exponential backoff scheme. The IEEE 802.11e standard [12] enables deterministic QoS guarantees through MAC level service differentiation. However, the throughput of IEEE 802.11e is expected to degrade at high traffic load. Authors in [11] showed that the performance of MANETs running EDCF are not optimal, and the collision rate increases quickly when the number of contentions to access the medium is high.

On the other hand, reservation MAC protocols seem to be very suitable for multimedia and real-time applications since they reserve the required bandwidth to each source. The basis of these protocols is to give to each node a guaranteed periodic access to the wireless channel. In these protocols, channel is segmented into super-frames, and a global synchronization between nodes is assumed. The MAC protocol reserves a slot to each real-time node. Once the reservation is done, the node uses the same slot in subsequent super-frames without contention. Examples of protocols in this category are FPRP, D-PRMA [3], CATA, and R-CSMA. These protocols mainly differ in the super-frame structure and the medium access control mechanism adopted to reserve time-slots.

In FPRP [4], the super-frame is composed of a reservation frame (RF) followed by several information frames (IF). Each RF is composed of *N* reservation slots (RS), and each IF is composed of *N* information slots (IS). In order to reserve an IS, the nodes must make reservations during the corresponding RS. Each RS is composed of *M* reservation cycles (RC), and, in each RC, a five-step reservation process is followed to make a reservation in the current RS. These five steps are: Reservation Request, Collision Report, Reservation Confirmation, Reservation acknowledgement, and Packing and Elimination. These five phases are undertaken by each node to compete to reserve a time-slot, and to inform neighbors about the result of the competition (reservation success of failure). A node which fails in reserving the slot in a RC, enters in competition to reserve the slot in another RC. However, FPRP incurs a significant amount of overhead for slots reservation.

CATA [5] protocol divides time into equal size super-frames, and each super-frame is composed of *S* slots. Each slot is composed of four control mini-slots and one Data mini-slot (DMS). Control mini-slots are used to establish reservations, and prevent neighbors from using already reserved slots. The advantage of CATA over other reservation protocols is it permits to establish unicast / multicast / broadcast reservations. Its major drawback is the waste of bandwidth due to control mini-slots. Reserving four mini-slots in each slot reduces the available bandwidth dedicated for the transmission of data packets.

SRMA/PA [7] adopts the same concepts as CATA. The added feature is that it distinguishes higher-priority nodes from lower-priority nodes. It permits to a higher-priority node to grab reservation from lower-priority nodes.

In R-CSMA [6], time is segmented into super-frames. Each super-frame is composed of a contention period (CP) and a set of TDMA slots. A node which wants to establish a reservation follows a three way handshake during the CP in order to negotiate reservations with the receiver. Neighbor nodes record the reservation thus preventing any collision during reserved slots. The major advantage of R-CSMA against FPRP, CATA and SRMA/PA is that it doesn't reserve any bandwidth for control packets. R-CSMA doesn't allocate any control slot since control packets are transmitted only once at the reservation request step.

RTMAC [2] is a reservation MAC protocol that doesn't need global synchronization between mobile nodes. Each super-frame consists of a number of reservation-slots (resv-slots). The duration of each resv-slot is twice the maximum propagation delay. A node that has real-time packets for transmission, reserves a block of consecutive resv-slots, which is called connection-slot on a super-frame and uses the same connection-slot to transmit in successive super-frames. The reserved connection-slot is repaired using relative times of starting and ending times of the connection-slot. With relative time of connection-slots, RTMAC eliminates the need of time synchronization. Each node maintains a reservation table that records for each reservation the pair of sender and receiver identifiers, and the starting and ending time of the reserved connection-slot.

Despite their advantages, previously proposed reservation MAC protocols have many limitations. The most challenging issue with these protocols is mobility of nodes. These protocols consider that nodes are static and no mobility considerations are taken into account. When nodes are mobile, collisions may occur during reserved slots. This phenomenon is called reservation clash and must be handled at the MAC sub-layer. The other issues with reservation MAC protocols are the important control traffic overhead, the support of multimedia applications with different QoS requirements, and the lack of fairness between traffic flows. These issues and possible solutions are discussed in the next section.

3 Discussion of reservation MAC protocols

Reservation protocols provide some bandwidth guarantees for real-traffic sources. However, they suffer some drawbacks: the waste of bandwidth due to control traffic, reservation clash in case of mobility, lack of support of heterogonous classes of traffic, inefficiency of the reservation release scheme, and lack of fairness. These issues will be discussed in detail in this section.

3.1 Control traffic overhead

One important parameter in the performance of reservation MAC protocols is the control traffic overhead. The control traffic overhead determines the amount of control packets transmitted by mobile nodes in order to maintain coherent reservations. The transmission of control traffic results in an increase of energy consumption. In addition, increasing the amount of bandwidth reserved for control traffic results in decreasing the effective bandwidth offered to real-time traffic sources to transmit their data packets.

CATA allocates four control mini-slots (CMS1, CMS2, CMS3, and CMS4) on each slot. After reservation is successfully established, CMS1 is used by the receiver to provide a “busy tone” to senders attempting to reserve the slot for transmission. CMS2 is used by the sender to jam any possible RTS addressed to its neighbors. CMS3 and CMS4 are used only at the reservation setup. Once the reservation is established, these two slots are not used. However, the use of four control mini-slots in each slot incurs a significant overhead.

In FPRP, each RS is composed of M reservation cycle (RC), and a five control mini-slots are associated with each RC to establish reservation. If a node successfully reserves a slot during one of the RCs, the remaining RCs are not used any more for contention. Hence, depending on the number of RC associated with each reservation slot (RS), the control traffic overhead of FPRP may be high, and the waste of bandwidth may be significant.

Like CATA, SRMA/PA allocates four control mini-slots (SR, RR, RC, and ACK) in each slot. The SR is used by the sender to indicate the reservation to its neighbors once the reservation is established. Hence, only the SR slot is used to indicate the slot reservation in subsequent frames, the other control slots (RR, RC) are used only during the reservation handshake. However, allocating three control mini-slots in each slot to coordinate reservations results in a significant overhead.

The major advantage of R-CSMA and RTMAC against FPRP, CATA and SRMA/PA is that they don’t reserve any bandwidth for control packets. Control packets are transmitted only at the reservation request step. Instead of allocating control mini-slots to prevent neighbor nodes from reserving already reserved slots, R-CSMA and RTMAC use reservation tables that include for each slot its state “reserved” or “available”.

As bandwidth is limited in MANETs, the effective bandwidth offered to real-time traffic sources must be increased, and the wasted bandwidth must be reduced as much as possible. An efficient MAC reservation protocol should permit to maintain coherence of reservations with less control traffic overhead.

3.2 Heterogeneous classes of traffic support

The second drawback with almost all the reservation MAC protocols is that they consider that real-time traffic sources have the same QoS requirements, and the varying requirements of heterogeneous sources of traffic are not considered. They reserve a slot to each real-time traffic source, with the assumption that the traffic source will use the reserved slot in each frame to transmit its data packets.

Reserving one slot to each real-time traffic source is not efficient, especially when heterogeneous traffic streams are characterized by different QoS requirements. According to the encoding and compression techniques used to represent multimedia sources, traffic streams will have widely varying traffic characteristics (bit-rate, delay). Reserving one slot to each traffic stream (TS) results in a waste of bandwidth mainly when the packet inter-arrival time is greater than the super-frame length.

A well designed MAC protocol should provide an efficient mechanism to share the limited bandwidth resource and satisfy the heterogeneous and usually contradictory QoS requirements of each traffic class (voice, video, data …). The reservation MAC protocol should ensure that each reserving node will be allocated exactly its required share of bandwidth. To achieve such adaptive scheme, we need QoS mapping scheme which determines the quantity of bandwidth to reserve to each class of traffic in function of the considered channel structure (i.e. super-frame length and the number of slots per super-frame).

3.3 Efficiency of reservation release scheme

The reservation release scheme is a key component in reservation MAC protocols. Reservation release is required when the source of real-time traffic has finished its data transmission. At the end of a real-time session, the sender should inform the receiver and its neighbors about the end of transmission. The receiver also is required to inform its neighbors that the slots are no more reserved for reception.

The role of the reservation release scheme is to permit neighbors of the sender and receiver to reserve the slots that have been released. However, the efficiency of the reservation release scheme impacts performance of the reservation protocol. A flaw in the reservation release scheme may result in a saturation of the network where slots can not be reserved while they where released.

The reservation release schemes proposed by reservation protocols are inefficient because there exist situations in which some nodes (receiver, sender neighbors, or receiver neighbors) are not informed about the reservation release. Authors of R-CSMA consider that reserved slot is released automatically when it is left empty. However, this scheme is not efficient because reserving nodes may not use all their reserved slots periodically to send data packets, especially when the inter-packets arrival time is greater than the super-frame length. If a reserving node has no data packet to transmit in the current super-frame while it has not finished the transmission, the node loses its reservation, and the slot is available for reservation by other nodes. The node is required to re-establish reservation each time the reserved slot is not used for transmission. Another issue with the reservation release of R-CSMA is that only the sender is able to signal reservation release to its neighbors by leaving the reserved slot empty. The receiver has no way to indicate the reservation release to its neighbors. The slot will remain reserved from the viewpoint of the receiver’s neighbors.

Authors of RTMAC use explicit reservation release packets to inform neighbors about the reservation release. At the end of transmission, the sender informs the receiver and its neighbors by sending a ResvRelRTS packet. When the receiver receives the ResvRelRTS packet, it sends a ResvRelCTS packet. The purpose of the ResvRelRTS and ResvRelCTS packets is to request neighbours of the sender and receiver to release the reserved connection-slot. However, since the ResvRelease packets are transmitted using contention, they may collide with other transmitted packets. Consequently, there may be situations in which either the receiver or neighbors of the sender/receiver don’t receive the ResvRelease packet. In FPRP, CATA, and SRMA/PA no reservation release scheme is defined.

An efficient reservation MAC protocol should ensure that at the end of real-time session both the receiver and all nodes around the sender and the receiver receive correctly the reservation release. In addition the MAC protocol should ensure reuse of slots once these slots are released.

3.4 Impacts of the super-frame length

Unlike the IEEE 802.11e where nodes are enabled to transmit each time they wine contention to the wireless channel, nodes in reservation MAC protocols can transmit only on their reserved slots. A node which has the opportunity of transmission at time t, can transmit the next packet only after $t+T_{super\text{-}frame}$, where $T_{super\text{-}frame}$ is the super-frame length. The super-frame length (in term of number of slots per frame) affects the bandwidth and delay offered to real-time and multimedia traffic sources.

There is a trade-off between the super-frame length and delay and bandwidth requirements of real-time traffic sources. On one hand, choosing a small number of slots per super-frame guarantees a small delay equal to the super-frame length. This scheme is suitable for multimedia traffic sources with a short inter-packet arrival time and stringent delay requirements. However, the call acceptance ratio (the ratio of accepted reservations) is low since each real-time source reserves exclusively one slot on the super-frame. On the other hand, choosing a too large super-frame length results in more established connections, but does not meat the delay requirements of multimedia applications with stringent delay requirements.

Performances of reservation MAC protocols are strongly affected by the super-frame length. The impact of the super-frame length and the number of slots by frame should be carefully taken into account at network configuration step.

3.5 Mobility handling and reservation break detection

Unlike contention based protocols where mobility of nodes has not a strong impact on the MAC protocol performance, the mobility factor is a challenging issue in the design of reservation MAC protocols. When nodes are mobile, conflicts between reservations and collisions may occur during reserved slots. This phenomenon is called reservation clash and must be handled at the MAC layer. The reservation clash phenomenon due to mobility is illustrated in the following scenario. In fig. 1, nodes B and C establish reservation with A and D respectively on the same slot s. As long as A and C are far away from each other, no collision occur in reserved slots. If nodes C and D move toward A, reservation clash will occur at A. Both of B and C transmit on the reserved slot s and collision occur during slot s. Reservation clash has drastic consequences on the QoS, especially in highly mobile nodes. Reserving nodes affected by reservation clash will suffer excessive packets collisions and dropping.

Almost all proposed reservation MAC protocols are suitable only for static ad-hoc networks. They consider that nodes are static and no mobility considerations are taken into account. Reservation MAC protocols must provide efficient mechanisms to face mobility of nodes, and reduce the degradation of performance in dynamic ad-hoc networks. Particularly, reservation protocols should provide a reservation clash detection mechanism. In addition, a reservation recovery mechanism must be defined in order to permit to nodes that lost their reservations due to mobility to release their reservations and establish new reservations.

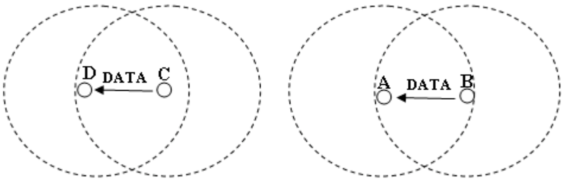

Fig. 1 Reservation clash due to mobility.

3.6 Fairness

Fairness is another parameter in the performances of MAC protocols. Proposed reservation MAC protocols lack the definition of mechanisms to ensure fairness between traffic flows, and between different service classes. In FPRP, CATA, SRMA/PA, and RTMAC there is no limit on the maximum bandwidth that can be reserved by a real-time traffic source. In addition, there is no limit on the amount of bandwidth that can be reserved to the real-time traffic class. Real-time traffic sources are allowed to reserve time slots as long as there are free slots in the super-frame. However, this scheme is not efficient since real-time traffic sources can monopolize all the available bandwidth leading to starvation of other classes of traffic like best effort traffic sources. Unlike, FPRP, CATA, and SRMA/PA, R-CSMA allocates a fraction of the super-frame for the transmission of best effort packets. Best effort traffic sources have always the chance to transmit their data packets during the contention period regardless the offered traffic load since no traffic class is authorized to monopolize the contention period.

Much attention should be paid on the bandwidth that can be allocated to real-time applications. Reservation MAC protocols should define a limit on this bandwidth, and the available bandwidth should be well partitioned between the different classes of service to avoid starvation of low priority traffic classes.

4 Simulations

We compare the performance of previously presented reservation protocols (R-CSMA, CATA, FPRP, and IEEE 802.11e). Particularly, we are interested in analyzing how these protocols provide QoS guarantees to voice and video traffic flows. Particularly, we analyze their control traffic overhead, their efficiency in regard to mobility and their control overhead. The comparative analysis is performed through a set of tests using the network simulator NS-2. We use the IEEE 802.11e simulation model of Wiethölter and Hoene available at [13].

We consider an ad-hoc network composed of 100 nodes randomly distributed on a 1 km^2 area. The wireless channel is 11Mb/s. We assume that the wireless channel is noise and distortion free. Nodes are considered equipped with omni-directional antenna with a 250 meters transmission range.

In our simulations we consider two voice traffic models (G.711 and G.723 models), and two video models (MPEG-4 and H263 video models). Table 2 summarizes the TSpec parameters for the classes of considered traffic. Each station can generate a G.711, a G.723 audio, an MPEG-4, or an H263 video flow. The TSpec parameters of G.711 and G.723 are taken from [8]. For MPEG-4 and H263, the TSpec parameters are extracted from traces of films available at [9].

Table 1. TSpec parameters for the considered traffic classes

	Traffic models			
Parameter	**G.711**	**G.723**	**MPEG-4**	**H.263**
ϱmin (kbps)	64	6.4	150	270
ϱmax (kbps)	64	6.4	1600	2300
average frame size (bytes)	160	24	770	1278
Mean inter-frame arrival time (ms)	20	30	40	40

Table 2. Simulation parameters

Parameter	**Value**
Channel bit rate (Mbps)	11
Slot payload size (bytes)	160
UDP/IP header (bytes)	8+20
MAC header (bytes)	38
PHY layer overhead (PLCP header+preamble) (bits)	8+48
Slot length (ms)	0.18
Guard time between slots (μs)	20
Super-frame length (ms)	5
Number of slots per super-frame	25
Simulation time (s)	1000s

The maximum payload of a slot is set to 160 bytes in our simulations. Each slot consists of the transmission time of a real-time packet (including different layer overheads), and the round trip propagation time. With 11Mbps channel bit-rate, the slot length is 0.18ms. Simulation parameters are shown in table 2.

Because video frames are larger than the payload of a TDMA slot, video frames are fragmented into several packets. After fragmentation, MPEG source generates one packet every 10ms, H263 generates a packet every 5ms, G.711 generates one packet every 20ms, and G.723 generates one packet every 30ms. The super-frame length is set to the smallest packet inter-arrival time (i.e. the packet inter-arrival time of H263 source) which is 5ms.

4.1 Analysis of the impact of the super-frame length and traffic load

We analyze the impact of the traffic load on the performances of the considered protocols in a static ad-hoc network. In this analysis we increase the traffic load by increasing the number of best effort (BE) and real-time (RT) sessions (MPEG, H263, G711, and G723) in equal numbers. The maximum number of sessions is 100, and sessions are uniformly distributed among the 100 nodes.

Fig. 2.a shows the reservation acceptance ratio of CATA, FPRP, and R-CSMA versus the increase of traffic load. The figure shows that the reservation acceptance ratio remains above 90% as long as the number of sessions is less than 40 sessions. When the number of sessions exceeds 40 sessions, the reservations acceptance ratio decreases linearly because the number of sessions become much higher than the number of slots per super-frame. Some sessions will be rejected because of the unavailability of resources. R-CSMA has a lower reservations acceptance ratio than the other protocols at high traffic load because of the portion of the super-frame allocated to the contention period. We don't give the reservation acceptance ratio of the IEEE 802.11e because this protocol doesn't make explicit reservations.

Fig. 2.b shows the throughput achieved by FPRP, CATA, R-CSMA, and the IEEE 802.11e versus the increase of traffic load. The Figure shows that at low traffic load the considered protocols have approximately the same throughput. At high traffic load, reservation protocols achieve higher throughput than the IEEE 802.11e. Fig. 3.a shows the packets delivery ratio (i.e. the percentage of packets received by their destinations) of RT packets offered by FPRP, CATA, R-CSMA, and IEEE 802.11e versus the increase of traffic load. The figure shows that reservation protocols offer better packets delivery ratio than the IEEE 802.11e at high traffic load. The low throughput and packets delivery ratio of the IEEE 802.11e is due to the increase of contention and collision rate at high traffic load. The high delivery ratio of FPRP, CATA, and R-CSMA results from that packets in these protocols are transmitted periodically on reserved slots in collision-free way. Consequently, the probability of collision and packet dropping is very low.

Fig. 3.b shows the average RT packets delay with FPRP, CATA, R-CSMA, and IEEE 802.11e versus the increase of traffic load. The figure shows that reservation protocols give deterministic delay regardless the traffic load, while IEEE802.11e diverges with the increase of traffic load. At low traffic load, the IEEE802.11e outperforms the other protocols because low level of contention

results in a small number of collisions and short backoffs. At high input load, IEEE 802.11e nodes experience more contention, and thus more collisions and wider backoff windows, and consequently the access delay increases drastically. Reservation protocols provide quasi-constant delay because real-time packets are transmitted at regular intervals once the reservations established.

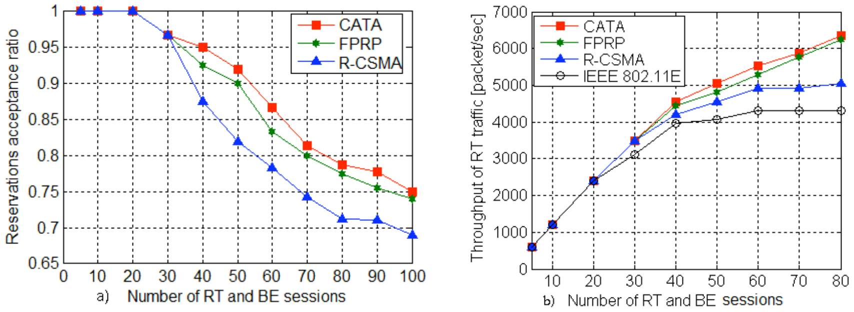

Fig. 2 a) Reservations acceptance ratio versus the increase of traffic load

b) Throughput of RT traffic versus the increase of traffic load

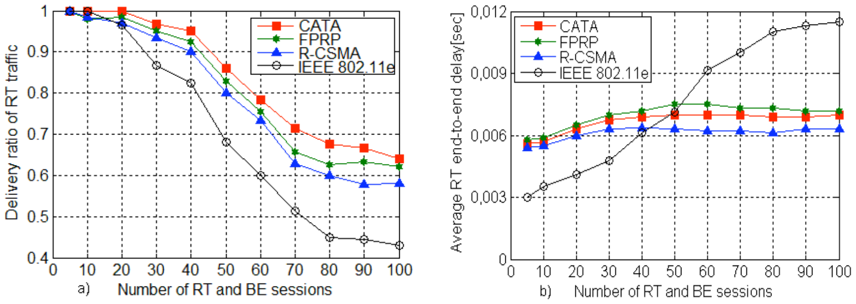

Fig. 3 a) RT traffic delivery ratio versus the increase of traffic load.

b) Average end-to-end delay of RT traffic versus the increase of traffic load.

4.2 Analysis of the effect of mobility

For mobility of nodes, we use the RWP (Random Walk Point) model. Each mobile node chooses randomly its next position and moves toward that position with a velocity uniformly distributed between *Vmin* and *Vmax*. We choose *Vmin=1 m/s and Vmax=10 m/s*. The node stays in its new position for a time *dt* (set to 30 seconds in our simulations) after witch it chooses another position.

Fig. 4.a shows that the packet dropping rate with CATA, FPRP and R-CSMA increases drastically with the increase of the number of mobile nodes. The packet dropping rate of IEEE 802.11e remains very low compared to other protocols. The drastic packets dropping ratio of FPRP, CATA, and R-CSMA is due to the reservation clash, and the high number of collisions. As mobility increases, reservations clashes increase and nodes start losing their reservations. Since no

reservation recovery mechanism is defined, reserving nodes have no way to establish new reservations, and reserving nodes continue sending their data packets on their reserved lost slots. The IEEE 802.11e is less affected by mobility of nodes because nodes are required to compete and acquire the channel for the transmission of each data packet no matter of their positions.

Fig. 4.b shows the throughput with the increase of mobility. The throughput with R-CSMA, CATA and FPRP decreases drastically with the increase of mobile nodes. Like the packets dropping rate, the reduced throughput of these protocols is linked to the increase of the number of collision slots.

This section has shown that the IEEE 802.11e is more efficient than reservation protocols in the case of high mobility of nodes.

4.3 Bandwidth wasting analysis

We analyze the waste of bandwidth incurred by reservation schemes, especially when heterogeneous classes with different QoS requirements are considered. Fig. 5.a shows the ratio of unused reserved slots with the increase of the number RT sessions. With FPRP, CATA, and R-CSMA the ratio of unused slots increases linearly with the increase of the number of RT sessions. This waste of bandwidth is due to the low rate of voice sources. G711 and G723 sources consume only 3/12 (2/12 respectively) of their reserved slots. The IEEE 802.11e doesn't suffer waste of bandwidth because bandwidth is shared between all nodes, and bandwidth unused by some node is available for utilization by other nodes.

This section points out the need to define a more efficient and flexible reservation MAC protocol. The MAC protocol should distribute the available bandwidth to reserving nodes based on their QoS requirements so that bandwidth wasting is reduced. Low data rate sources (like G.711 and G.723 voice) should be allocated less bandwidth than the high data rate sources such as video.

4.4 Control traffic overhead

Fig. 5.b shows the control traffic generated by nodes as a function of the number of RT sessions. On one hand, we observe that the amount of control traffic generated by R-CSMA remains very low. This is because R-CSMA does not use any control slots to coordinate reservations. Control packets are transmitted only at the reservations setup. On the other hand, we observe that CATA and FPRP and IEEE 802.11e generate high quantity of control traffic. CATA requires each reserving node to transmit RS and RTS packets on each reserved slot. FPRP requires the repetition of the five-phase reservation steps on each Reservation Frame. The IEEE 802.11e requires the transmission of the RTS and CTS packets before the transmission of each data packet.

This section reveals that CATA and FPRP and IEEE 802.11e suffer significant control traffic overhead when the number of traffic streams in the network is high.

R-CSMA has the advantage that it uses less control traffic.

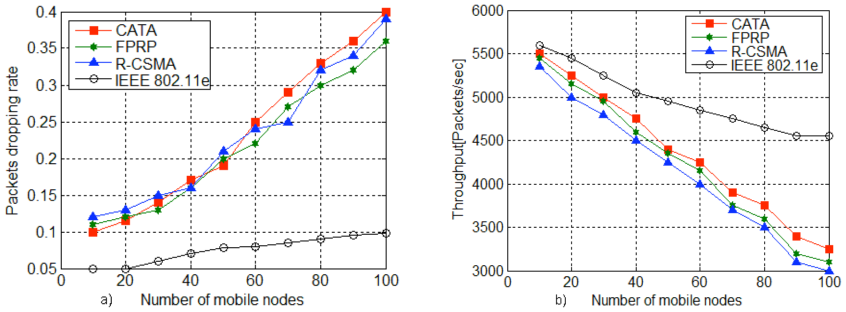

Fig. 4 a) Packet dropping rate versus the increase of number of mobile nodes.
b) Throughput versus the increase of number of mobile nodes.

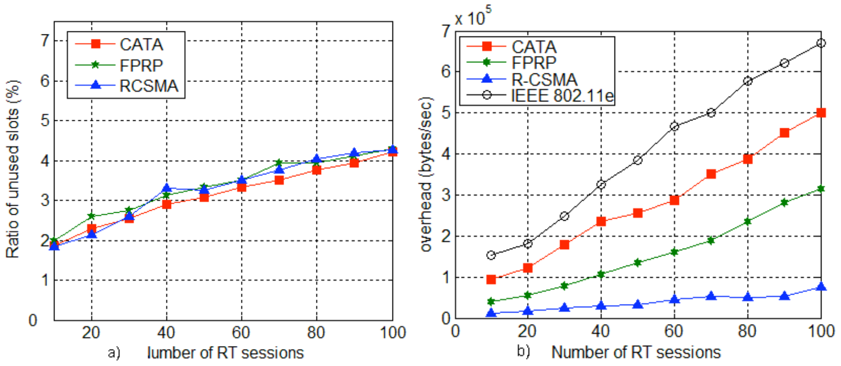

Fig. 5 a) Ratio of unused slots versus the increase of number of RT sessions.
b) Control traffic overhead versus the increase of number of RT sessions.

5 Conclusion

In this paper we analyzed the advantages of reservation-based protocols against their counter-part contention-based protocols, especially the IEEE 802.11e standard. Also, we provide a detailed analysis of the main drawbacks, and challenging issues

First, we found that reservation MAC protocols perform well in static ad hoc networks. Simulation results show that these protocols outperform the IEEE 802.11e standard in low mobility scenarios. However, the performances of these protocols are expected to degrade as mobility of nodes increases. All reservations which are being built since the initialization of the network overlaps one with each other and collisions during reserved slots appear. In these situations the IEEE 802.11e is more efficient since no permanent transmission scheduling is established. Nodes compete to get access to the channel no matter their positions in regard to their neighbors. Second, we found that some protocols like FPRP, CATA, and IEEE 802.11e suffer significant control traffic overhead. R-CSMA has the advantage it generates less control traffic overhead since control packets are transmitted only at the reservation establishment step.

Finally, we conclude that reservation protocols are a promising solution to provide QoS in MANETs provided that degradation of performance due to the node mobility is reduced. However, the other issues related to the waste of bandwidth, fairness, and control traffic overhead must be also resolved. The waste of bandwidth can be reduced by allowing neighbors of reserving node to use slots when these slots are not used for transmission. Fairness can be ensured through defining a limit on the bandwidth that can be allocated to each traffic class.

References

1. IEEE Std. 802.11-1999, Part11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, Reference number ISO/IEC 8802-11:1999(E), IEEE Std 802.11, 1999 edition.
2. Manoj B.S., Siva Ram Murthy C.: Real-time Traffic Support for Ad hoc Wireless Networks, IEEE ICON 2002, pp. 335-340 (August 2002).
3. Shengming J., Jianqiang R., Dajiang H., Xinhua L., Chi, C.K.: A Simple Distributed PRMA for MANETs, IEEE Trans. Veh. Technol., vol.51, no.2, pp.293–305 (2002).
4. Zhu C., Corson M.S.: A Five-Phase Reservation Protocol (FPRP) for Mobile Ad hoc Networks, IEEE INFOCOM'98, vol.1, pp. 322–331 (1998).
5. Tang Z., Garcia-Luna-Aceves J. J.: A Protocol for Topology-Dependent Transmission Scheduling in Wireless Networks, IEEE Wireless Communications and Networking Conference, vol. 3, pp. 1333-1337 (September 1999).
6. Inwhee J.: Qos-Aware MAC With Reservation For Mobile Ad-Hoc Networks, IEEE Vehicular Technology Conference (September 2004).
7. Ahn C.W., Kang C.G., Cho Y.Z.: Soft Reservation Multiple Access with Priority Assignment (SRMA/PA): A Distributed MAC Protocol QoS-guaranteed Integrated Services in Mobile Ad-hoc Networks, IEICE Transactions on Communications, vol. E86-B, no. 1, pp. 50-59 (January 2003).
8. Sharafeddine S., Riedl A., Glasmann J., and Totzke J.: On Traffic Characteristics and Bandwidth Requirements of Voice over IP Applications, IEEE International Symposium on Computers and Communication (ISCC'03) (July 2003).
9. Video Traces for network Performance Evaluation, available at http://www.tkn.tu-berlin.de/research/trace/trace.html
10. Hsieh H.-Y., Sivakumar R.: IEEE 802.11 over Multi-hop Wireless Networks: Problems and New Perspectives, Proc. IEEE VTC 2002 Fall (September 2002).
11. Romdhami L., Ni Q., Turletti T.: Adaptive EDCF: Enhanced Service Differentiation for IEEE 802.11 Wireless Ad-Hoc Networks, IEEE Wireless Communications and Networking Conference (WCNC), New Orleans, USA (March 2003).
12. IEEE 802.11WG. Drat Supplement to Standard for Telecommunications and Information Exchange Between Systems-LAN/MAN Specific Requirements-part11: MAC Enhancements for Quality of Service (QoS). IEEE 802.11e Standard Draft/D13.0 (January 2005).
13. Wiethölter S., Hoene C., Wolisz A.: Perceptual Quality of Internet Telephony over IEEE 802.11e Supporting Enhanced DCF and Contention Free Bursting, TKN–04-11 Technical Report Series, Technische Universität Berlin (September 2004).