



An Efficient Adaptive Medium Access Control Protocol for Reliable Broadcast in Ad Hoc Networks

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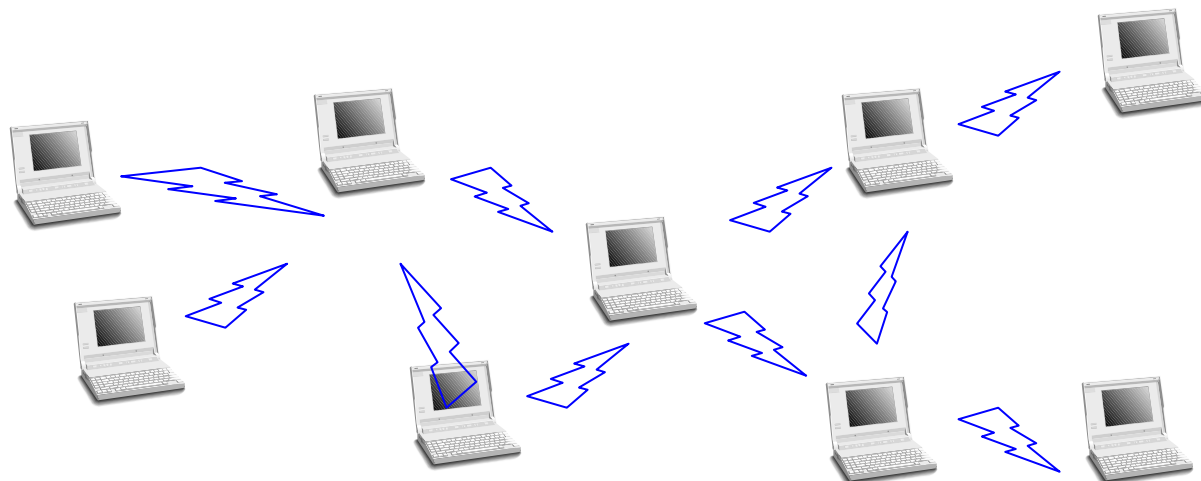


Outline

- 1. Preliminaries and Previous Work**
- 2. Efficient Adaptive Medium Access Control Protocol for Reliable Broadcast in Ad Hoc Networks**
- 3. Analysis (we are going to correct some error)**
- 4. Performance Evaluation (We compare the throughput performance of EABMP, ABROAD and IEEE 802.11)**

Mobile Ad Hoc Networks Model

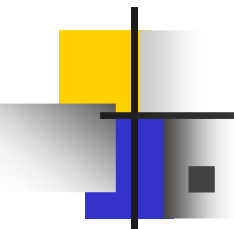
- a set of mobile hosts, each host can be a transceiver or receiver
- no base stations; no fixed network infrastructure
- multi-hop communication

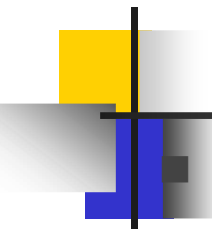




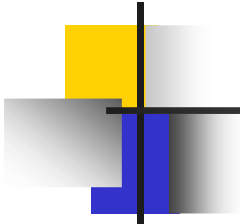
Challenge of Ad Hoc NETs

- **No centralized entity**
- **Host is no longer just an end system**
- **Acting as an intermediate system**
- **Changing network topology over time**
- **Every node can be mobile**

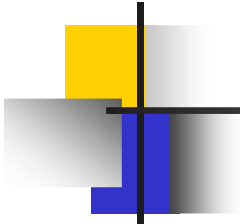
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- In this paper, we address the issue of reliable broadcast at the medium access control (MAC) layer.
 - A reliable packet transmission is defined as the successful delivery of the same packet from a source node to each neighbor. Reliable broadcast at the MAC layer is important, because network layer control functions need nodes to exchange topological information in their neighborhood.
 - Many reactive routing protocols, such as DSR and AODV, strongly depend on the supported broadcast scheme in the underlying media access control (MAC) protocol.



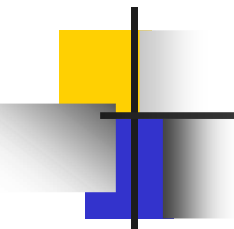
MAC protocol can be classified according to the access strategy employed. Probabilistic contention protocol utilizes direct, asynchronous competition between neighboring nodes to determine which node will transmit next. Early examples, including Aloha and CAMA, best effort transmission protocols principally designed to support unicast packet transmission, are unreliable. More recent protocols, including the IEEE 802.11 MAC standard, provide reliable unicast services by incorporating channel reservation schemes.



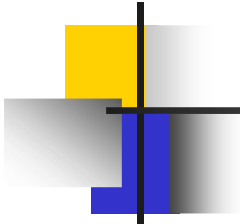
A reliable unicast protocol can support reliable broadcast transmissions. So by simply sending a copy of a packet to each neighbor can achieve reliable broadcast. It is the drawback of this approach that MAC protocols typically do not maintain link state information, such as the current neighbors of a node. Moreover, since the time to complete a broadcast increases with the number of neighbors, this approach is not scalable, and it will benefit greatly in term of channel utilization by multicasting applications.



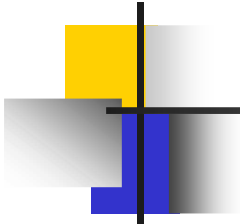
Some MAC protocol such as TDMA and TSMA assign each node a transmission schedule. These protocols were primarily designed to support reliable unicast transmissions by guaranteeing that each node is assigned at least one collision-free slot to each of its neighbors. However, most allocation protocols rely on rigid slot assignments, rendering them insensitive to variations in network load and node connectivity.



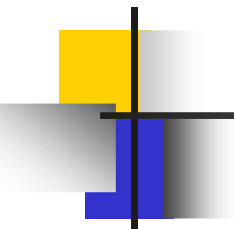
FPRP, one variant of reuse TDMA protocols, periodically compute TDMA schedules according to the current network topology. A reservation frame is used in FPRP to compute a TDMA schedule and two successive reservation frames are separated by a set of data frames. A node can reserve a slot in a data frame by contending only in the corresponding slot in the reservation frame. If the rate at which topology changes exceeds the rate at which the schedules can be updated, then the result is an unstable protocol which can lead to network failure.



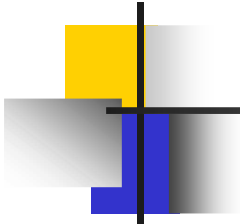
Recent efforts have focused on the combination of the allocation-based and contention-based design philosophies to achieve a hybrid protocol that shares the properties of both strategies. HRMA [4] and CATA [5] use the collision-avoidance schemes of contention protocols to reserve transmission slots. However, HRMA and CATA are also susceptible to instability as the network load is increased. The reliable operation would not be achieved.



We want to state some basic rules and describe ABROAD how to work. The wireless network is half duplex, so a transmitting node is prevented from receiving at the same time. We assume that a node is capable of determining the current channel state, i.e., whether there is currently zero, one, or multiple packet transmissions corresponding to as idle channel, a successful packet transmission, or a packet collision.



ABROAD, a hybrid MAC protocol, supports reliable broadcast transmissions in ad hoc networks. The ABROAD protocol incorporates a collision-avoidance contention protocol within each slot of a TDMA transmission schedule. ABROAD obtains bounded access delay from its base TDMA allocation protocol and remains stable for all traffic loads and node topologies. ABROAD does not require link state information and is scalable since the time to reliably broadcast a packet is not dependent on the number of neighbors.



An Adaptive Medium Access Control Protocol for Reliable Broadcast in Wireless Networks

I. Chlamtac, A.D.. Myers, V.R. Syrotiuk, and G. Zaruba, “ An adaptive medium access control Protocol for reliable broadcast in wireless networks,” IEEE ICC,vol. 3, pp.1692-1696, 2000.



Preliminaries : TDMA

- **Time is slotted and numbered 1,2,3,...**
- **In each round, a node acts either as a transmitter or as a receiver**

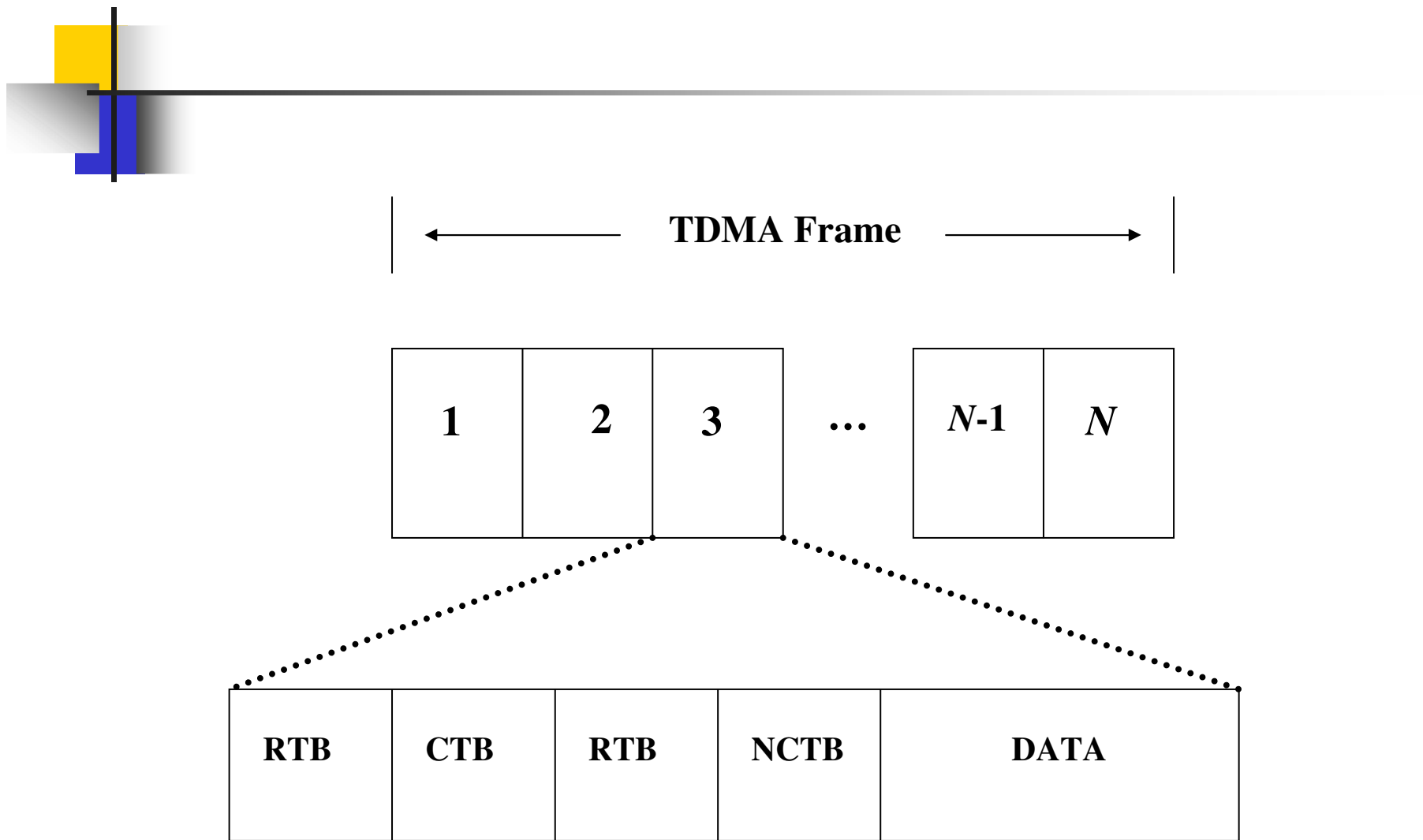
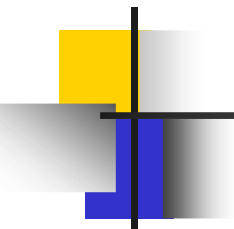
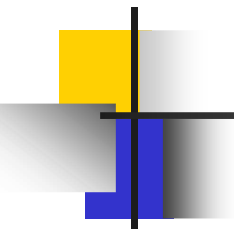
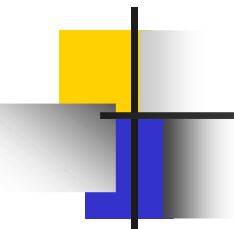


Fig.1 The ABROAD slot and frame structure

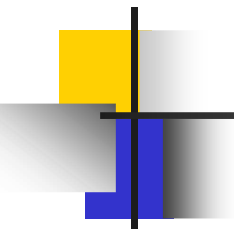


Now, we reiterate ABROAD protocol. As Fig. 1 illustrates, ABROAD integrates a CSMA/CA based contention protocol within each slot of a TDMA allocation protocol. Each node is assigned a transmission schedule frame consisting of N slots, where N is the number of nodes in the network. There is a one-to-one mapping between nodes and slots, and each node has priority to access the channel in its assigned slot.

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- If node s has a broadcast packet to send in its assigned slot, it immediately transmits a request-to-broadcast (RTB) control packet.
 - Each neighbor of s then responds with a short clear-to-broadcast (CST) control packet.
 - Therefore, if the channel remains idle throughout the sensing interval, any other node t with a broadcast packet may attempt to claim the slot by sending its own RTB.
 - A neighbor of t responds with a negative-CTB (NCTB) packet if and only if it detects a packet collision.



The presence of collision indicates that two or more nodes are contending for the slot. If node t detects no NCTB packets, it then uses the remainder of the slot to broadcast its packet. Otherwise, its contention for the slot was unsuccessful, and t defers transmission until its assigned slot, or some later idle slot in the frame as determined by the backoff scheme, whichever comes first.



We outline the basic principles and operation of the EABMP protocol. As Fig. 2 illustrates, EABMP integrates a CSMA/CA based contention protocol within each slot of a TDMA allocation protocol. Each node is assigned a transmission schedule frame consisting of N slots, where N is the number of nodes in the network. There is a one-to-one mapping between nodes and slots, and each node has priority to access the channel in its assigned slot.

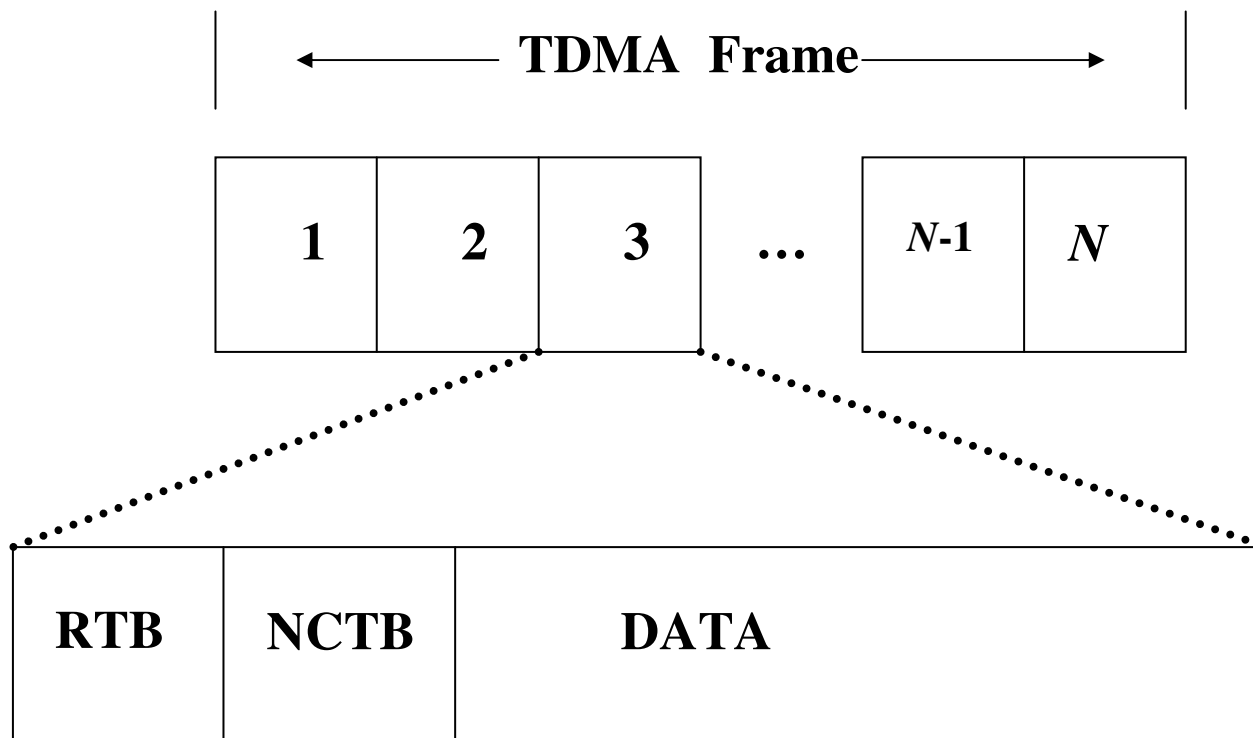
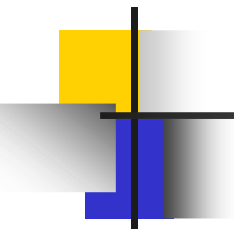
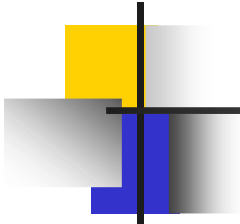


Fig. 2 EABMP slot and frame structure

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- **ny node wanting to broadcast can attend to compete. The competitors issue RTB control packets.**
 - **ny node listening to a packet collision issue NCTB control packets.**
 - **If a node is not the owner of the time slot and does not hear any reply, the node competes successfully. It has the right to broadcast in the coming data frame .**
 - **f a node is the owner of the time slot**

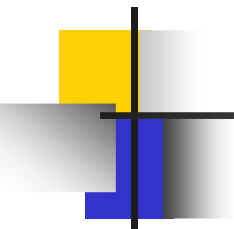


We can find that EABMP has higher performance than ABROAD because the contention slots are just two slots, comparing to ABROAD's four contention slots. EABMP decide the competition winner more quickly, so it can still work well in high mobility environment and can save more power.



Analysis

We are going to analysis and correct the error in ABROAD. We consider a network of N identical nodes with a homogeneous load distribute. The model follows ABROAD. Let r represent the transmission radius of the nodes, a two and let A denote -dimensional geometric area in which all the node move. We first approximate the average number of nodes within a two_hop neighborhood.

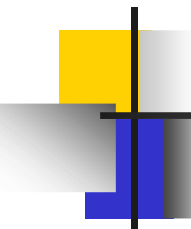


For any two nodes being in each other's transmission radius, the cumulative distribution function of distance x separating them is given by:

$$F(x) = \frac{\sum kx^2 / A}{\sum kr^2 / A} = \frac{x^2}{r^2}$$

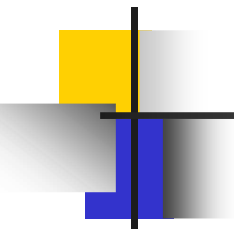
where $0 \leq x \leq r$, thus the expected value of x is:

$$E[f(x)] = \frac{2}{r^2} \int_0^r x^2 dx = \frac{2}{3} r$$



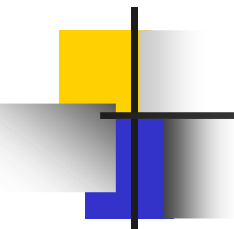
The radius of the average two-hop neighborhood is $5/3r$. The probability that there is a node in a two-hop neighborhood is $25\pi r^2/9A$. The number of nodes in a two-hop neighborhood is described by a binomial distribution, thus the average number of nodes β in this area can be approximated by its expected value:

$$\beta = \frac{25 \pi r^2 N}{9 A}$$



There are two distinct cases that need to be analyzed, according to whether or not the slot is assigned to a node. Let α be the probability that a node has a packet to transmit. The probability that a node contend for an unassigned slot can be expressed as $(1 - \alpha\beta / N) p$, where p is the probability that a node contends for a slot. The probability that such a node is successful in its contention is:

$$\frac{\mathcal{E}}{N} \left(1 - \left(1 - \frac{\mathcal{E} \setminus \mathcal{E}']}{N} \right) p \right)^{\mathcal{E}-1} \left(1 - \frac{\mathcal{E} \setminus \mathcal{E}']}{N} \right) p$$



Combining the two probabilities, we get an approximation of a node's average throughput, T_{node} :

$$\frac{\mathcal{E}[L]}{N} + \mathcal{E}[L] \left(1 - \left(1 - \frac{\mathcal{E}[L]}{N} \right) p \right)^{\mathcal{E}[L]-1} \left(1 - \frac{\mathcal{E}[L]}{N} \right) p$$

Through differentiation, we can find the optimal value.

$$p_{\text{opt}} = \frac{1}{\mathcal{E}[L] \left(1 - \frac{\mathcal{E}[L]}{N} \right)}$$

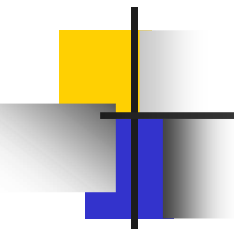


Substituting (6) into (5) we obtain:

$$T_{\text{node}} = \frac{\mathcal{E} \setminus \mathcal{E}^J}{N} + \left(1 - \frac{1}{\mathcal{E}^J}\right)^{\mathcal{E}^J - 1}$$

We can finally estimate the total network throughput by computing the average number of distinct two-hop neighborhood, N / β :

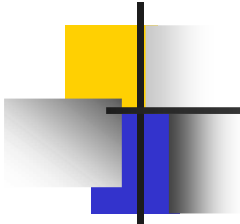
$$T_{\text{total}} = \mathcal{E} \setminus + \frac{N}{\mathcal{E}^J} \left(1 - \frac{1}{\mathcal{E}^J}\right)^{\mathcal{E}^J - 1}$$



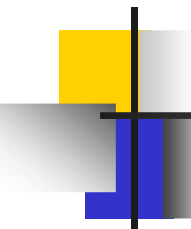
Substituting (3) into (8) and noticing β converges to $1/e$, we can estimate the optimal worst-case throughput:

$$T_{\text{total}} = \frac{9A}{25 \lambda k r^2} \left(\frac{\lambda \lfloor \lambda \rfloor}{N} + \frac{1}{e} \right)$$

From (9), we can find the total network throughput depends on the two hop neighborhoods.



To evaluate the performance of EABMP, we modeled an ad hoc network consisting of 100 mobile nodes operating within a 1500m x 1500m field with a maximum speed of 30 m/s according to the random way point model. Control frame size equal 20 bytes, and data frame size equal 1024 bytes. In the model, packets arrivals at each node follow an independent Poisson process with identical mean arrival rates.



We compare the throughput performance of EABMP, ABROAD and IEEE 802.11 with broadcast only traffic. Offered load in the plots corresponds to the aggregate data transmitted by the senders in Mb/s while throughput refers to the total amount of data successfully delivered in Mb/s. In Fig.3, throughput obtained using EABMP has about 10 percent higher than using ABROAD. When the maximum speed increase to 60 m/s, as Fig. 4 illustrates, EABMP work much better than ABROAD.

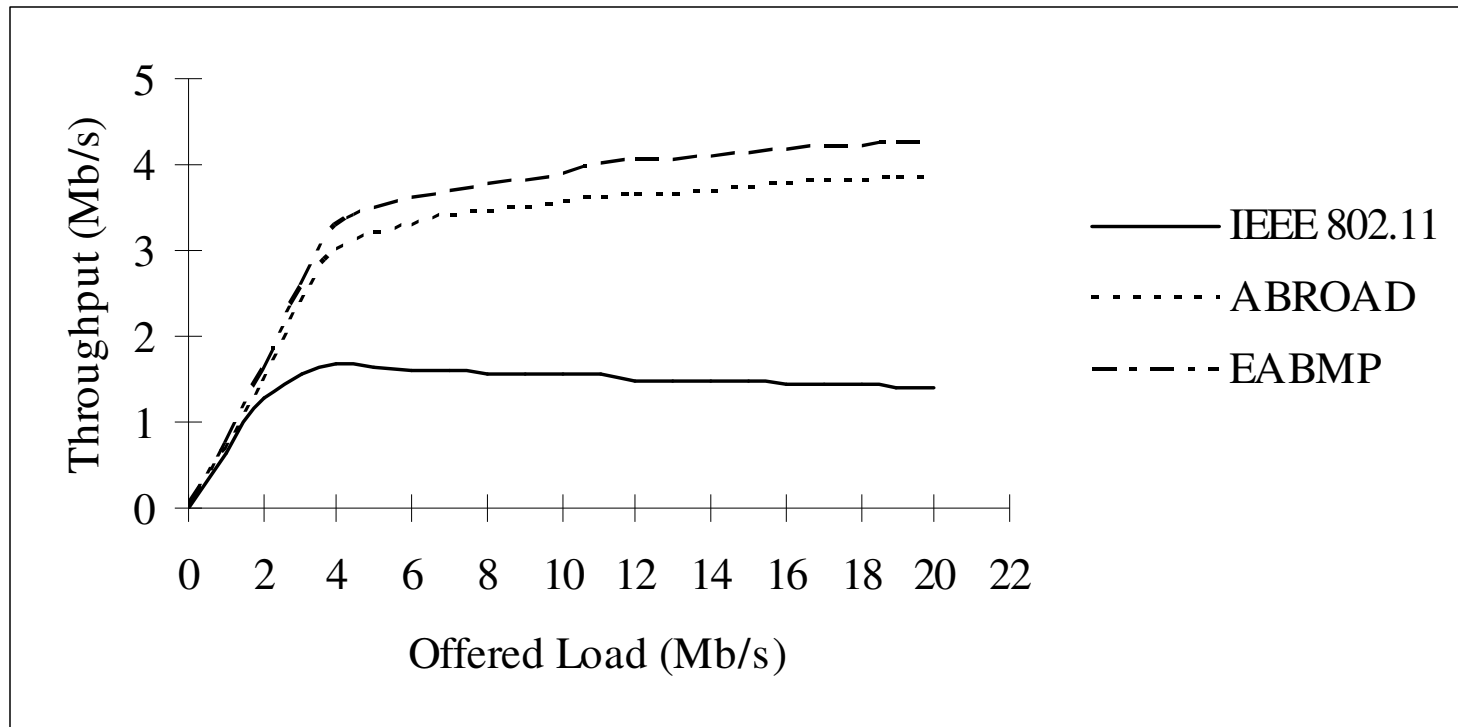
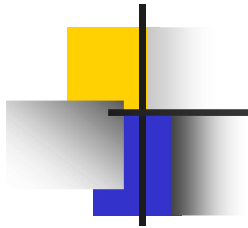


Fig. 3 Throughput comparison of EABMP, ABROAD and IEEE 802.11 for broadcast

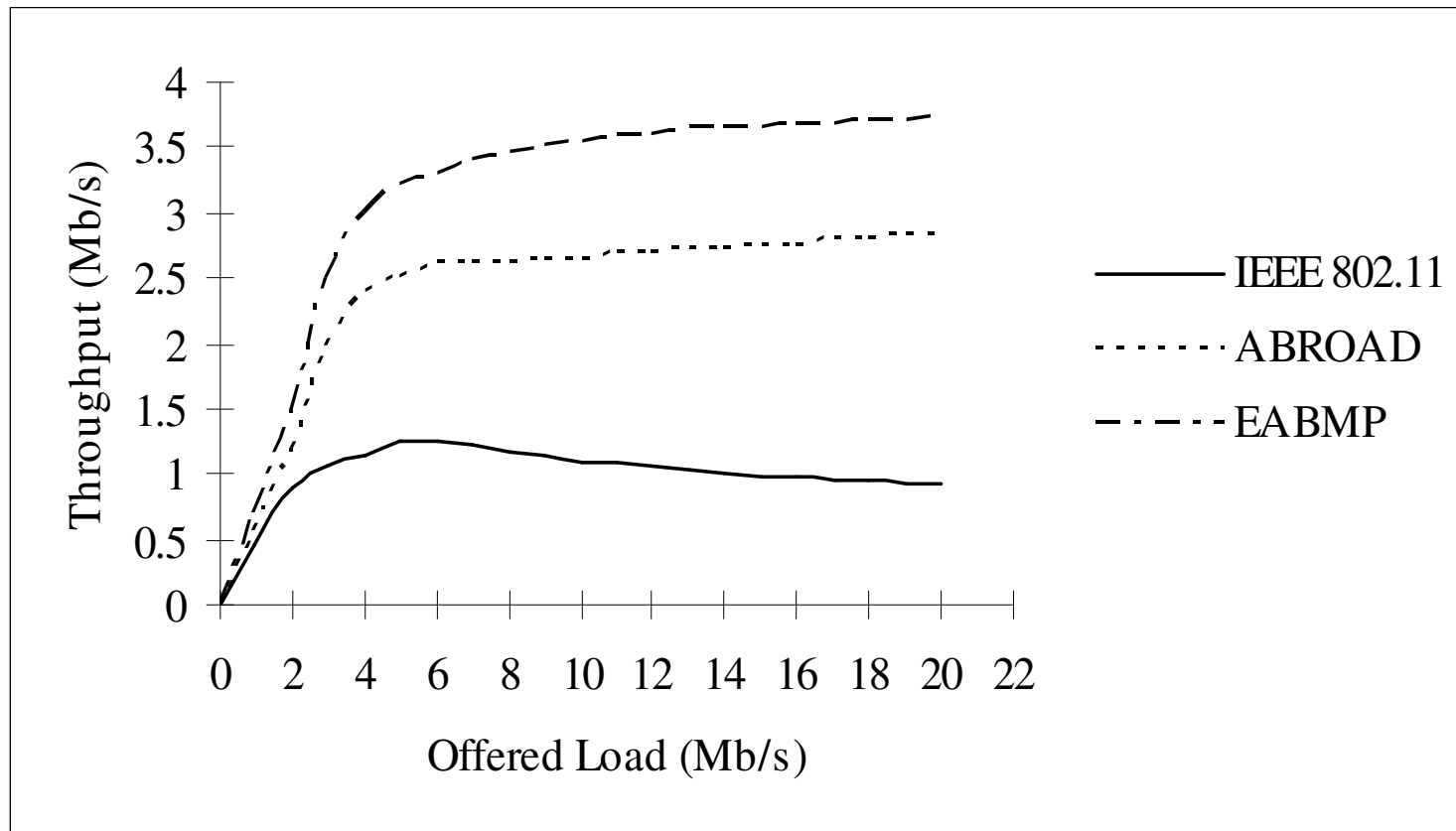
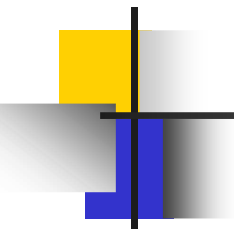


Fig. 4 Throughput comparison of EABMP, ABROAD and IEEE 802.11 for broadcast in high speed mobility



As a result, we suggest the contention slot should be shorter in high mobility environment. If the nodes are more static or the network is sparse, we should use more contention reservation slots to reuse the idle slot as Fig. 5 illustrates.

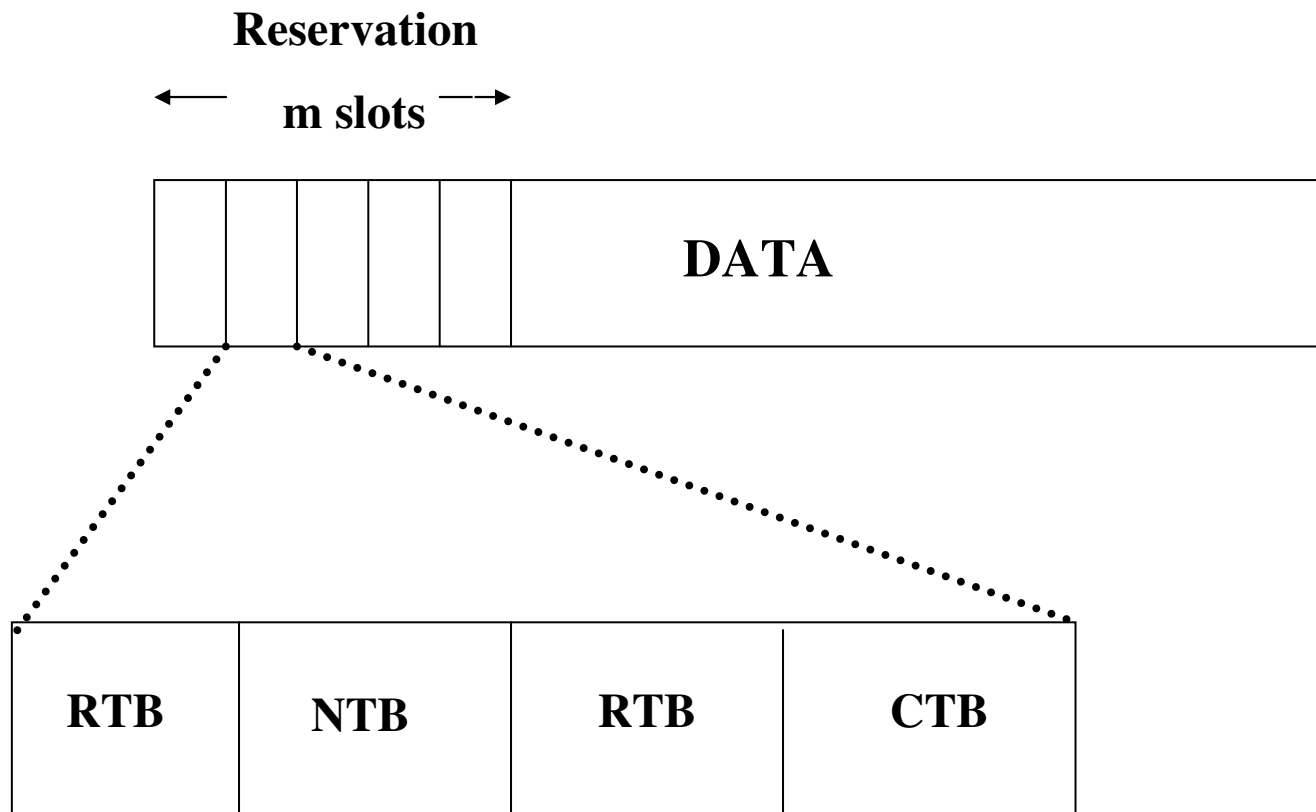
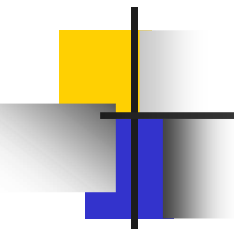


Fig. 5 A mac protocol efficient in static or sparse environment

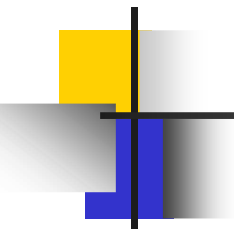


If the nodes are more static or the network is sparse, we repeat m reservation. There are four subslots in a reservation.

- **In the first subslots, any node wanting to broadcast can attend to compete, then the competitors issue a RTB packet.**
- **In the second subslot, any node listening to a packet collision or being a reserved node (explained behind) issue a NCTB packet.**
- **The successful competitors send a RTB packet in the third subslot.**
- **The nodes hearing the RTB single should send a CTB packet in the forth subslot.**



The nodes hearing RTB in third subslot or CTB in the forth subslot are called reserved nodes. In the following reservation slots, when reserved nodes hear RTB in the first subslot, they should send a NCTB packet in the second subslot.



We suggest the contention slot should be shorter in high mobility environment. If the nodes are more static or the network is sparse, we should use more contention reservation slots to reuse the idle slots.