Appointed BrOadcast (ABO): Reducing Routing Overhead in IEEE 802.11 Mobile Ad Hoc Networks

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Abstract

In this report, we propose the Appointed BrOadcast (ABO) method to achieve packet overhearing to reduce the routing overhead in the IEEE 802.11 mobile ad hoc networks (MANETs). Using the ABO method, IEEE 802.11 frames are modified in such a way that the Intended Receiver Address (IRA) is appended to the frame body. These ABO frames are broadcasted to enable packet overhearing while keeping the transmission to specific node reliable. How ABO-enhanced and standard IEEE 802.11 nodes can coexist in a MANET is also discussed.

Keywords: mobile ad hoc network, promiscuous mode, broadcast, IEEE 802.11, routing.

1. Introduction

In mobile ad hoc networks (MANETs), routing protocols must be designed to be adaptive in the face of highly dynamic topology. However, the limited radio bandwidth dictates the amount of routing information exchanged and makes routing in MANET a laborious work. Routing protocols in MANETs can be either proactive or reactive according to the maintenance strategy of routing tables. Proactive routing protocols attempt to maintain an up-to-date routing table for each of other nodes using time-triggered and event-triggered routing updates and have potential wastage on the maintenance of unnecessary route information. On the contrary, reactive routing protocols discover routes only when needed. In many scenarios, reactive routing is more efficient than proactive routing [1]. A detailed description and comparison between proactive and reactive routing protocols can be found in [1]. In this report, reactive routing is considered.

In a typical reactive routing protocol, route request (RREQ) and route reply (RREP) packets are used to discover routes. The source node floods the RREQ packet to discover the route to the destination node. Having received the RREQ packet, either the destination node or intermediate nodes that have valid route information to the destination node can return the RREP packet to the source node. The RREQ and RREP packets are necessary in route discovery but introduce large overhead. One approach of reducing the routing overhead is to allow nodes to overhear packets [2-4] sent by neighboring nodes. Routing information may be obtained by analyzing the overheard packets and hence the overhead is reduced. To do so, the network layer should be able to receive packets that are not targeted to the tagged node. However, frames that are not targeted to the tagged node will be discarded at the MAC layer. Packet overhearing is not a default in the current MAC design. Here, we will first introduce how packet overhearing is achieved and then propose the *Appointed BrOadcast* (ABO) method to achieve packet overhearing for the IEEE 802.11 standard [5]. In addition, the problem of the coexistence of ABO-enhanced and IEEE 802.11 nodes is also discussed.

2. Packet overhearing in the IEEE 802.11

It has already been shown in the literature [2][3] that packet overhearing can significantly ameliorate network performance such as the data packet delivery ratio, the average end-to-end delay and the routing overhead. In the AODV-BR [4], backup routes are used to recover from route failures. By overhearing packets, backup routes can be constructed in the process of route discovery without producing extra control packets. However, in the current MAC design, only broadcast frames and those frames whose receiver address match with the node's MAC address will be received, all other frames will be discarded. If a node needs to overhear packets that are not targeted to itself, either of the following actions can be taken: 1) set the network interface card into promiscuous mode or 2) broadcast all frames that should be disseminated to neighbors. However, both actions introduce problems. For the former, once the promiscuous mode is set, a node will receive all frames that can be correctly received and these frames will be passed to the network layer. The processing load of a node will increase significantly and the node lifetime decreases because of its limited battery power [3]. The latter, however, will degrade the transmission reliability because broadcast in the IEEE 802.11 is unreliable. Broadcast frame is ACK-free and once it is lost because of collisions or channel failures, the transmitting node is not aware of the loss. One way to solve the reliability problem is to ask the intended receiving node to reply a network layer ACK to the transmitting node. However, the network layer ACK introduces other problems such as the network layer timeout and retransmissions. Besides, to acknowledge, the contention process must be performed at the MAC layer and hence the network throughput is degraded.

In the proposed Appointed BrOadcast (ABO) method, unicast frames that are to be disseminated to neighbors are transmitted in the ways of broadcast. To keep the transmission to the target node reliable, the intended receiver address (IRA) is appended in the frame body. On receiving of an ABO frame, the node whose address matches with the IRA will return an ACK frame to the sending node. This can be achieved by modifying the IEEE 802.11 data frame.

The IEEE 802.11 data frame structure in ad hoc mode is shown in Figure 1. The duration field is used to update the network allocation vector (NAV). Address 1 holds the address of the receiver, address 2 holds the address of the transmitter and address 3 holds the basic service set identification (BSSID) of the network. The ABO frame, as depicted in Figure 2, has the following modifications: 1)

[1] The duration value of broadcast frames is 0 in the IEEE 802.11 standard.

the IRA is appended at the end of the frame body, 2) address 1 is filled with the local broadcast address and 3) the duration field is filled with the short interframe space (SIFS) time plus the ACK frame transmission time. The IRA field is included in the frame check sequence (FCS) calculation. Note that if encryption is needed, the IRA field is viewed as a part of the plaintext. Address 1 of the local broadcast address and the value of duration field characterize the ABO frame[1].

The ABO method can be triggered whenever a packet is to be disseminated to neighbors. When an ABO-enhanced node receives a data frame, the node first checks address 1 and the duration fields to see if this is an ABO frame. If true, the following steps will be triggered,

Step 1: check if the IRA field matches its own address, if true, go to step 2, else go to step 3.

Step 2: prepare the ACK frame and transmit it after a SIFS time period.

Step 3: trim the IRA and send the frame body to the upper layer.

otherwise the received frame is processed as in the IEEE 802.11 standard.

In this way, the ABO method gives routing protocols the flexibility to selectively disseminate packets to neighbors while reliable transmission is ensured. The flexibility is useful to routing protocols. For example, in the AODV-BR [4], nodes only overhear the RREP packets, so only RREP packets are transmitted using the ABO method while other packets are transmitted with original unicast or broadcast processes. Besides, compared with the setting of promiscuous mode, using the ABO method can reduce power consumption in processing overheard packets while the network throughput does not decrease if only selected packets are disseminated to neighbors.

The ABO frame must not be fragmented at the link layer, besides, the ABO frame is not coupled with the RTS/CTS transactions as broadcast frames in [5]. The no-fragment rule avoids the potential problem that an overhearing node fails to receive all fragments and then requests for the lost ones. The no-fragment rule is convenient because in most systems, the maximum transmission unit (MTU) is set to be 1500 bytes, which is smaller than the frame body length limitation of 2312 bytes in the IEEE 802.11. The no-RTS/CTS rule has the potential of increasing the probability of collision, so an ABO frame is the shorter the better. A short frame results in less processing load, therefore, in the selection of disseminated packets, short packets (e.g., control packets) are preferred.

3. Coexistence with the standard IEEE 802.11 nodes

Since the IEEE 802.11 protocol [5] is widely used, the coexistence of both the ABO-enhanced and the IEEE 802.11 nodes in the network should be considered. In the ABO method data frames sent under the distributed coordination function (DCF) shall use the frame type Data and subtype Data as in the IEEE 802.11. Upon receiving an ABO frame, an IEEE 802.11 node will take it as a normal broadcast frame. In this case, the IRA field will be passed to the upper layer as part of the frame body. The IRA field will be simply trimmed by the packet length verification at the network layer [6], thus the higher layer transactions is prevented from error. How the IEEE 802.11 and ABO-enhanced nodes handle their respective frames are depicted in Figures 3, where the dotted lines between the NSDU and NPDU implies that they are present only at the source node and the destination node. The IEEE 802.11 nodes transmit standard IEEE 802.11 frames only, thus the higher the proportion of ABO-enhanced nodes in a network, the better the dissemination efficiency.

In case an ABO frame is transmitted to an IEEE 802.11 node, no IEEE 802.11 ACK will be returned even if the ABO frame is received properly. The transmitter will time out and take it as a transmission error, then enter the retransmission phase. To deal with this problem, each ABO-enhanced node maintains a neighboring ABO-enhanced node list to keep track of the neighbors that are ABO-enhanced. On receiving an ABO frame or the ACK frame for an ABO frame, an ABO-enhanced node will add the transmitter to its ABO-enhanced node list. If an ABO frame is transmitted to a node not in the list and experiences a transmission failure, the subsequent retransmissions of this frame should use the IEEE 802.11 unicast frame. In this case, the desired information is disseminated to other nodes in the transmission of the ABO frame while the subsequent retransmissions ensure reliable transmissions to the target node.

In an MANET consisted of both ABO-enhanced and IEEE 802.11 nodes, the increased link layer overhead introduced in the coexistence problem can be evaluated as follows. Given an MANET with N nodes. Let p be the probability that a data frame is successfully delivered to the target node which stays within the transmission range of the transmitting node. Let m be the percentage of ABO frames among all data frames and k be the percentage of ABO-enhanced nodes. Assume that there are no RTS/CTS transactions, no link layer fragmentation, and no ACK frame is lost. The mean number of transmissions of a data frame can be expressed as:

$$
\begin{aligned}
& mk\frac{N(1-k)}{N-1}\times(1+\sum_{i=2}^{7} ip(1-p)^{i-2})+(1-mk\frac{N(1-k)}{N-1})\times\sum_{i=1}^{7} ip(1-p)^{i-1} \\
& \approx mk(1-k)\times(1+\sum_{i=2}^{7} ip(1-p)^{i-2})+(1-mk(1-k))\times\sum_{i=1}^{7} ip(1-p)^{i-1}
\end{aligned}
$$

which is limited to 7 because in the IEEE 802.11 standard, a frame should not be transmitted for more than 7 times when failures occur.

We depict the results for m=30% and m=50% in Figure 4. Larger m results in more transmissions at the link layer except that when all nodes are either IEEE 802.11, i.e., k=0, or ABO-enhanced nodes, i.e., k=1. The number of transmissions can be reduced for certain m when using the criteria that frames targeted to an ABO-enhanced node are selected first to use the ABO method. When $0 \leqq k \leqq 0.5$, the mean number of transmissions for a data frame is directly proportional to k. Depending on the routing protocol used, the additional link layer load may be compensated by the reduction of routing overhead and which mitigates the impact to the network performance. When $0.5 \leqq k \leqq 1$, the mean number of transmissions for a data frame reduces as k grows. The network performance can be enhanced more apparently when higher proportion ($k \geqq 0.5$) of ABO-enhanced nodes is used in the network.

Conclusion

Packet overhearing can be used to reduce routing overhead and network performance is thus improved [2-4]. In this report, we propose the ABO method to achieve packet overhearing in the IEEE 802.11 protocol and simultaneously keep the reliable transmission property. The ABO method enables routing protocols to selectively disseminate routing information to neighbors. The coexistence problem of the ABO-enhanced node and the IEEE 802.11 node is discussed. Solution for the coexistence problem is also provided and evaluated in this report.

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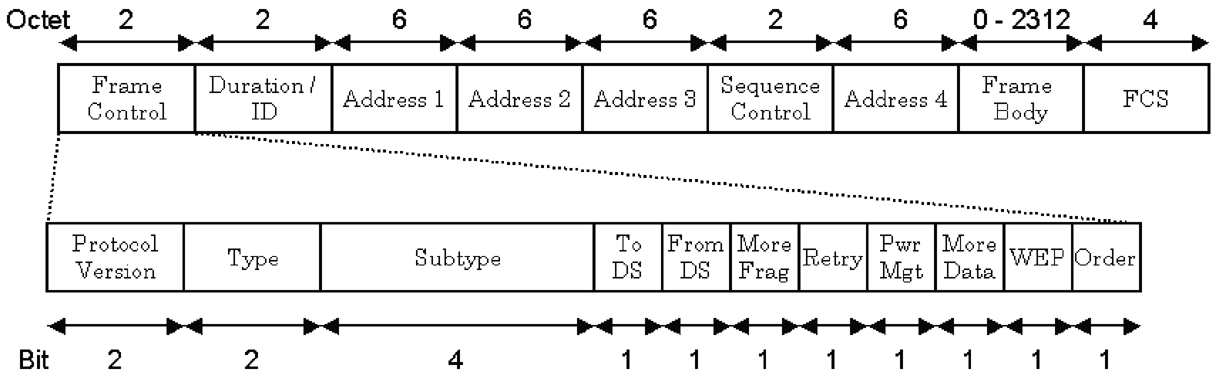

Fig. 1. The IEEE 802.11 frame format in ad hoc mode

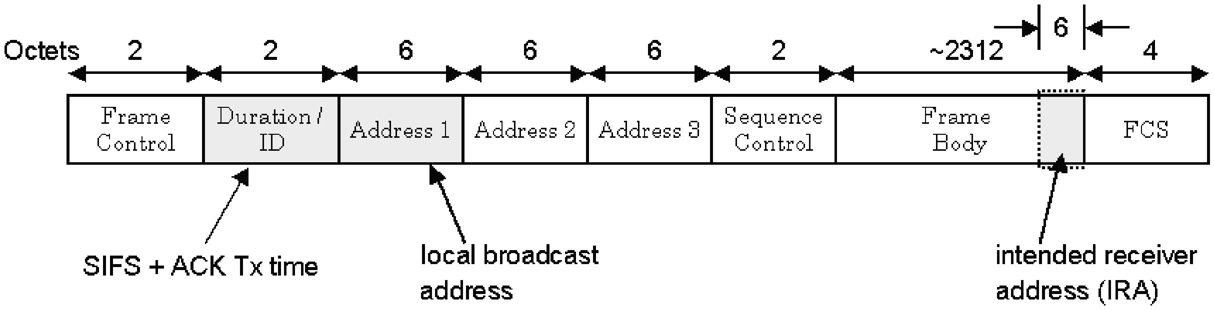

Fig. 2. The ABO frame structure

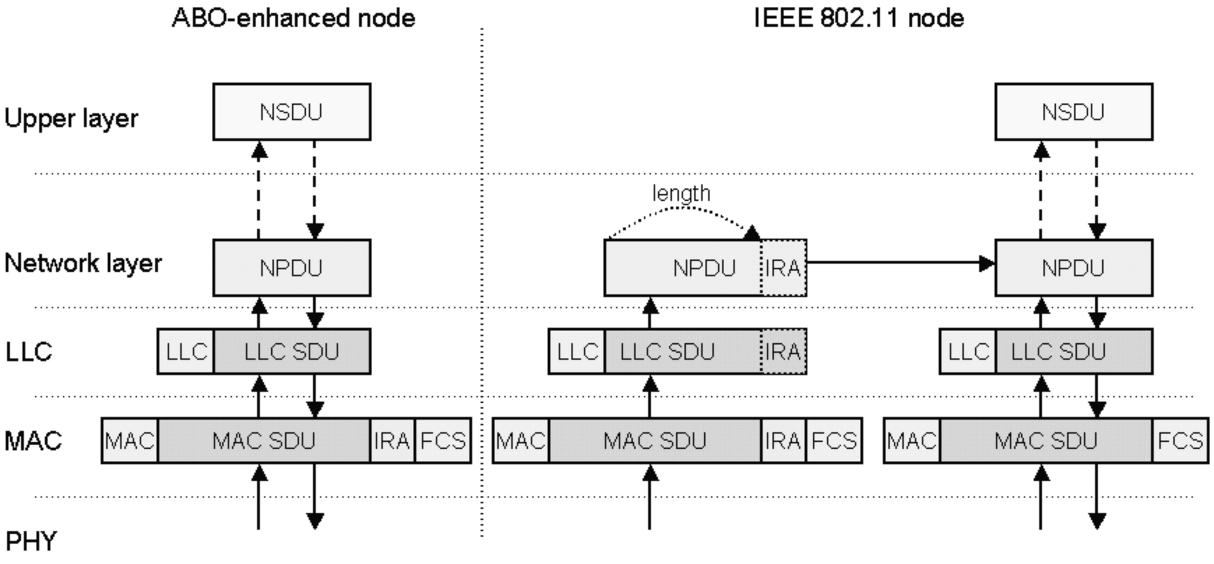

Fig. 3. Handling of the IEEE 802.11 and ABO frames

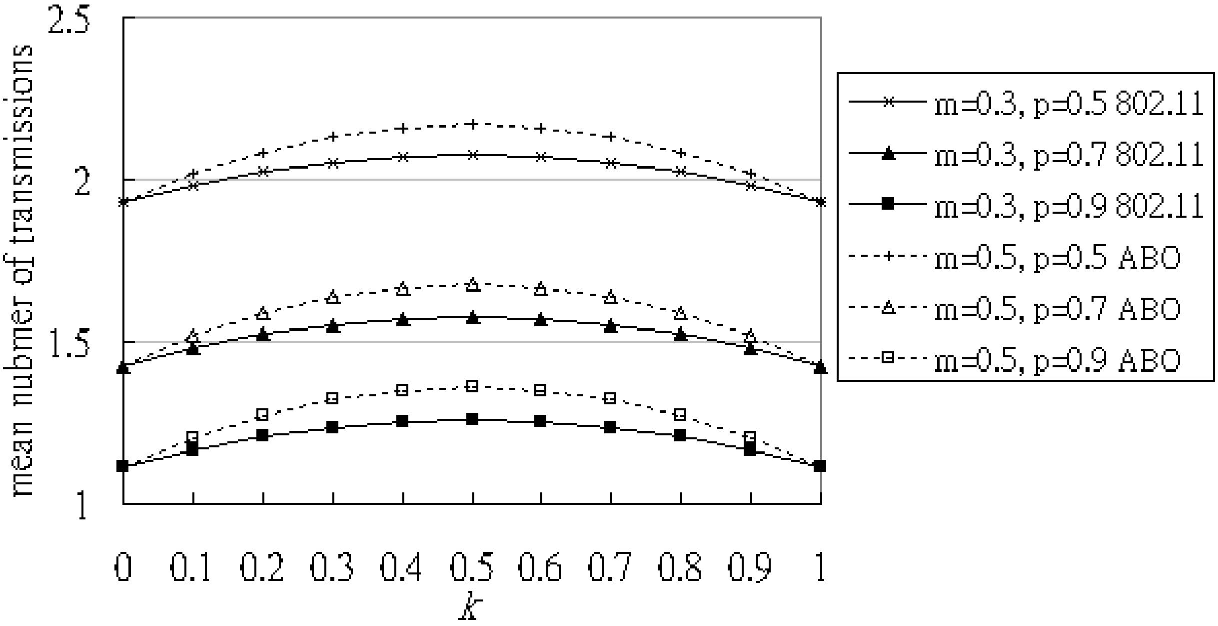

Fig. 4. Mean number of transmissions