Time Slot Exchange Protocol in a Reservation Based MAC for MANET

Mamata Koirala, Qi Ji, Jaeho Choi

Abstract

Recently, much attention to a self-organizing mobile ad-hoc network is escalating along with progressive deployment of wireless networks in our everyday life. Being readily deployable, the MANET (mobile ad hoc network) can find its applications to emergency medical service, customized calling service, group-based communications, and military purposes. In this paper we investigate a time slot exchange problem found in the time slot based MAC, that is designed for IEEE 802.11b interfaces composing a MANET. The paper provides a method to maintain the quality of voice call by providing a new time slot when the channel assigned for that time slot gets noisy with interferences induced from other nodes, which belong to the same and/or other subgroups. In order to assess the performance of the proposed algorithm, a set of simulations using the OPNET modeler has been performed assuming that the IEEE 802.11b interfaces are operating under a modified MAC, which is a time slot based reservation MAC implemented in the PCF part of the superframe. In a real-time voice call service over a MANET of a size 500 x 500 meter squares with the number of nodes up to 100, the simulation results are collected and analyzed with respect to the packet loss rate and packet delay. The results show us that the proposed time slot exchange protocol improves the quality of voice call over that of plain DCF.

Keywords : MANET, Time slot reservation MAC, Real-time service, Time slot exchange, PCF, IEEE802.11b

I. Introduction

Ad hoc network is a collection of wireless mobile nodes, dynamically forming temporary networks, without the use of any pre-existing network infrastructure or centralized administration. Since no fixed infrastructure is committed to pass on packets from sender to receiver, every node should act both as a host and as a router in these networks. As every node should act as host and router, each and every node have responsibilities to maintain resources within the changing nature of the topology. Due to rational design of an ad hoc network, there can be a number of problems related to the QoS such as noise interference, packet loss, delay, and bandwidth.

There are several literatures concerning TDMA based time-slot reservation protocols proposed for real-time support in MAC layer. In Ref. [1], it describes a time-slot assignment method to resolve the conflict that occurs during the slot assignment between two adjacent links. The conflict between two links occurs when they are assigned with same time slots. The time slot assignment algorithm is integrated into a quality of service (QoS) call admission scheme for QoS call requests. This method mostly focuses on a network topology, where the communicating nodes are relatively stationary. Ref. [2] presents QoS AODV, which provides an integrated route discovery and bandwidth reservation protocol. The QoS-AODV is designed to operate within a TDMA network; and it incorporates time-slot scheduling information to ensure that the end-to-end bandwidth is reserved. Ref. [5] describe an algorithm to guide the destination to choose the route that is most likely to satisfy the QoS requirement and an algorithm to reserve the proper time-slot and thus keeps more free time-slots for other requests. On the other hand, Ref. [6] presents an approach to maintain the required interference level in order to establish the connection between nodes. They discover the equation to find the noise level along with the threshold value, so that there is normal transmission and reception of packets between the nodes. Ref. [7] studies the problem of resource allocation with spatial TDMA as a medium access control scheme. Some other literatures related to this topic can be found in Ref.[3],[4],[8],[9].

Most of literatures reviewed above explain the way to utilize the free time-slot and reserve time resources; none of them have discussed how to maintain the time-slot when there is a problem in the existing time-slot. Without a proper time-slot maintenance, a call may not be able to carry on even when there exist enough free time-slots for a call in the system.

After analyzing these credentials, we have designed a new concept which includes the time-slot problem along with the noise interference problem. In this paper investigates an efficient way of maintaining a call even when there is a significant level of noise or interference in the channel, especially in the real-time communication system due to interactions within the same time-slots in the mobile nodes. In our study, the mobile nodes are self-organizing an ad-hoc network, and each one of them is assumed to operate spatial

*Dept. of Electronic & Information Engineering
Chonbuk National University
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reuse of time-slots in a time-synchronized manner. The MAC frames are assumed to be synchronized among the nodes by some means such as GPS or a MAC frame synchronization technique. However, the synchronization issue is out of our scope of this study.

Normally, the IEEE 802.11b super-frame is consisted PCF and DCF, our time slot exchange protocol is for a modified MAC protocol. Here, the superframe is divided into a number of smaller time slots. Using those time slot, the reservation based MAC protocol provides a pair of time slots to a corresponding pair of communication nodes requesting a real-time service such as a voice call. The problematic situation occurs when two nodes in same contention area try to use the same time slot or when more than one pair of nodes belonging to different contention areas moves along and comes into some other pairs communications area and causes an interference to a one or more time slots they are currently using.

In this paper we have presented an solution method called a time slot exchange protocol (TSEP). This protocol is mainly design for real-time communications over the MANET. The main objective of our study is to efficiently utilize the network capacity while

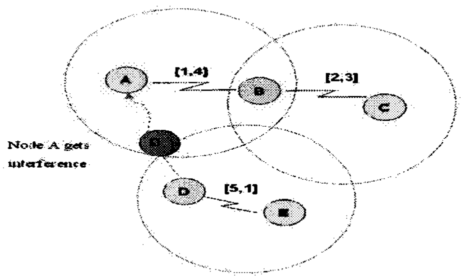

Fig. 1. Interference among the nodes

maintaining the quality of service in real-time communications. In the following, Section Ⅱ describes the detailed description of TSEP. It explains the approach to find the free time-slot and replace it with current time-slot, whenever the communicating node undergoes the interference problem due to time-slot reuse. is section Ⅱ . Section Ⅲ presents the simulation parameters and simulation results, and, finally, conclusions are made in Section Ⅳ.

Ⅱ. Proposed Protocol

In this section, we present our time slot exchange protocol (TSEP). The main function of the proposed protocol is to find the free time slots and replace the current that is undergoing a noisy, interference problem. As mentioned briefly in the previous section, the real-time service, voice calls in our case, support over the MANET is the base of the problem in this paper. The modified MAC for IEEE 802.11b interface, which is a time slot reservation MAC that is implemented in the point coordination function (PCF) part of the superframe, is assumed here. The main role of our time slot exchange protocol (TSEP) is to combat the noisy channel condition and to maintain the quality of the current voice call between two node.

Consider the communication conditions that the nodes are getting interfered one another. The first case is when two nodes are in the same subarea and are assigned with the time slot because of spatial reuse of time slots; we call this an intra-subarea interference condition. The second case is when two nodes belonging to two different subarea move into each other's interference region. Fig 1. illustrates this interference relation in which Node D communicating with Node E using the time slots 5 and 1 moves into the interference region of Node A, which is in communication with Node B using the time slots 1 and 4. In this inter-subarea interference example, the time slot 1 goes into a noisy channel, and it needs to call our time slot exchange protocol in order to maintain

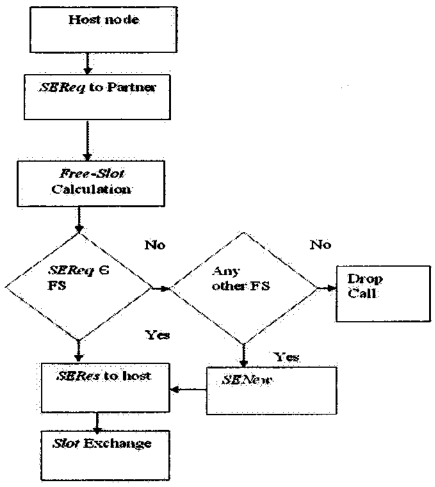

Fig. 2. Flowchart for the proposed protocol

the quality of its voice call. Innovative features of TSEP include a unique frame structure and a procedure for time-slot exchanging to provide robust and continuous communications as described in the following.

2.1. Time slot exchange procedure

Using any MAC frame synchronization method, it is assumed that the synchronized super-frame is divided into a fixed number of time-slots. Those time-slots are reserved for real-time voice call service. In order to increase the channel utilization the spatial reuse of time-slot is exploited. In other words, for those nodes spatially away from the transmission range of one another can be assigned with the same set of time-slots as long as their interference is negligible. However, due to node mobility, the interference may rise above a certain threshold, and there will be decrease in the signal reception quality, which will generate nuisance in sound and sometime it need to end the call or can find appropriate way to overcome that. The proposed TSEP finds free time-slots and replaces the current interfered ones.

Fig. 2 presents the procedural relation of main functional blocks of TSEP. Going back to Fig 2, no sooner than the signal-to-interference noise ratio (SINR) goes below the threshold, i.e., is less then 10 dB, Node A (host node) looks into its node table, which shows the status of time-slots, sends out the control packet SEReq (time-slot exchange request) destined to the partner Node B. SEReq is a control packet containing a message for a time slot replacement and vacant, new time slot number to its partner. Upon reception of SEReq, Node B searches its node

Sync	H_ID	P_ID	CTS	NTS

Fig. 3. The typical control packet format (SEReq).

table for valid free time slots and checks if the requested time-slot is one of them. If there is a match, it sends back a positive response SERes to node A. Then, Node A sends out a four-way handshaking control packet SECon (time-slot exchange confirmation) to confirm the successful completion of time slot replacement and that ends the TSEP procedure. On the other hand, if Node B does not find a matching free time-slot, it sends back a recommendation for another possible time-slot to the requesting Node A by sending out the control packet SENew (new time-slot exchange request). A few cycles of control packet exchanges for this time slot replacement continues until two nodes come down to an agreement. If two node cannot make an agreement within some time interval and the channel noise persists, the voice call is only to drop.

In TSEP the signal to interference noise ratio (SINR) is a decision factor. Its measurement is defined as follows:

$$SINR = \alpha P_t / (N_B + I) \cong \alpha P_t / I \qquad (1)$$

where P_t is the transmission power, N_B is the background AWGN noise, I is the interference component, and α is a propagation constant, which is distance and path dependent.

2.2. Control packets

In construction of TSEP as illustrated in Fig. 2 and 3, we need four different control packets. Those include SEReq, SERes, SENew, and SECon, which are exchanged between two partners involved in a voice call. These control packets are responsible for TSEP initiation, new time slot agreement, and completion confirmation. All of these control packets contain some of the attributes according to their requirement. The basic attributes are defined as follows:

a. Sync (Synchronization)
b. H_ID (Host Id)
c. P_ID (Partner Id)
d. CTS (Time slot requiring replacement due to noise)
e. NTS_h (Newt time slot for replacement)
f. NTS_p (Alternative, new time-slot for replacement)
g. Conf (TSEP completion confirmation)

where Sync is for synchronization between the nodes; H_ID is the identity of the host node that initiates the TSEP, which

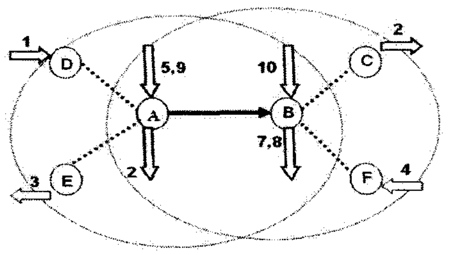

Fig. 4. Time-slot assignment for a call

encounters a channel interference problem over its time-slot in use; P_ID is the identity of the partner node currently exchanging voice packets with the host node; CTS is the current time-slot used by the host node, that is going through an interference problem; NTS_h is the new, vacant time-slot that the initiator node prefers to use instead of CTS; and NTS_p is the alternative, new time-slot suggested by the parter node when the partner node cannot find a free time-slot matching to NTS_h.

For example, the SEReq control packet basically has five attributes <Sync, H_ID, P_ID, CTS, NTS_h >, the packet format shown in Fig. 3. SERes contains the similar information as SEReq. On the other hand, the control packet SENew contains NTS_p, which is new, alternative time-slot suggested by the partner node to the host node. Lastly, SECon contains the Conf filed, that is used for the successful TSEP completion confirmation. With this, the noisy time slot is replaced by a new one, and the two parties can continue a quality voice call.

2.3. Free time slot

In our TSEP, the finding a free time slot is the key. The host node initiating the TSEP and the partner node receiving SEReq has to maintain a cache table for maintaining the status of the time slots. Since the network area is relatively larger than the transmission range, the spatial reuse of time slot are also possible. By overhearing the packet exchanges between the neighbor nodes, the contents of the cache table get updated. Also, depending the type of routing protocols, the periodic exchange of the time-slot table can also be implemented.

Let's consider Fig. 4. It shows the case that Nodes A wants to call Node B and to exchange voice packets while and four other nodes C, D, E, and F are in their neighbor. In order to place a voice call between A and B, there should be two free time slots common to both. The definition of free time slot is established when two conditions are met, which is defined as follows:

Condition 1: The time slot should not be currently in use by both of the host node and the partner node.

Condition 2: The time slot should not be currently in use by its neighbor nodes located within one hop distance.

Table 1. Simulation parameters

Parameters	Values
Transmission Area	500mX500m
Number of mobile nodes	20 to 50
Transmission range	300m
Rate of transmission	2Mbps
Transmission power	0.001 W
Frame length	1.28 ms
Total timeslot in a frame	8
Slot duration	0.16ms
SINR Threshold	10 dB
Simulation time	10 min

Ⅲ. Computer Simulations

In order to assess the performance of the proposed protocol, a set of network simulations has been performed using the OPNET modeler 12. The TSEP process modules are built for IEEE 802.11b interface, which is modified to run a time slot based reservation MAC instead of the DCF. The importance parameters used in the simulation are summarized in Table 1. The random way-point mobility model is used for the mobiles nodes, and the network size of 500 x 500 m^2 accommodates nodes up to fifty.

The objective for the first set of simulations is to investigate the behavior of the TSEP with respect to the packet loss in bits. The simulation results for two different nodal density are illustrated in Fig. 5. The nodes are moving at relatively slow speed in this simulation. As expected, the quality of voice calls are limited by the interference from the neighboring nodes, and the simulation results agree with the expectation where the higher nodal density in a packed are yields a higher packet loss.

On the other hand, the objective of the second set of simulations are focused on the packet delay in second. Fig.6 and 7 give the results for the end-to-end delay, and they show the curves are converging to around 80 μsec for both nodal densities of 20 and 40. The results are supporting the fact that the proposed TSEP operating in cooperation to the time slot based reservation MAC is working sufficiently enough to provide a real-time application like the voice call, which needs channel delay no more than 30 ms. Noticeably, the network here is relatively small size in comparison to the transmission range, however, as the network size increases making more multi-hop connections, the delay profile may well be changed and will have a longer tail.

Ⅳ. Conclusions

We have presented a novel time slot exchange protocol for providing a real-time service over MANET. The proposed protocol TSEP is specially designed for supporting a quality voice call in ad hoc network situation where the modified IEEE 802.11b is running a time slot based reservation MAC. The TSEP is useful for maintaining the voice quality of a call by replacing the noisy time slot with another free one on the fly whenever the channel assigned for a certain time slot goes noisy due to interference. The simulations have been also performed to assess the behavior of the TSEP. The results show us that the cooperative operation of TSEP and the time slot based reservation MAC is sufficient enough to provide a quality voice call in a relatively small sized MANET.

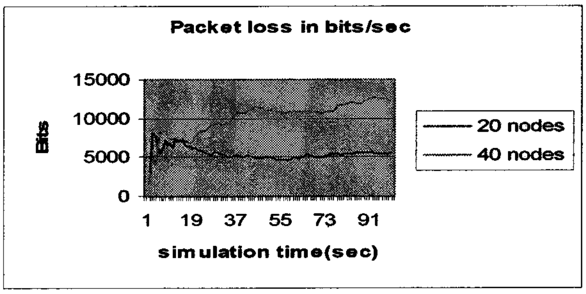

Fig. 5. Performance in terms of packet loss.

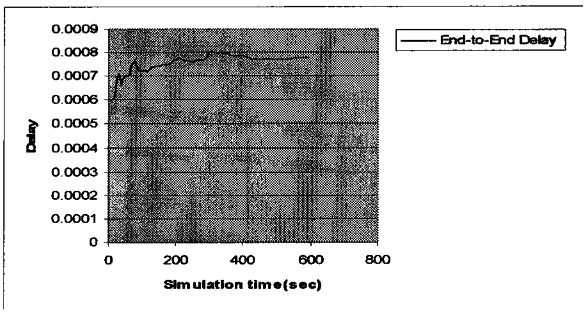

Fig. 6. Performance in terms of end-to-end delay given 20 nodes

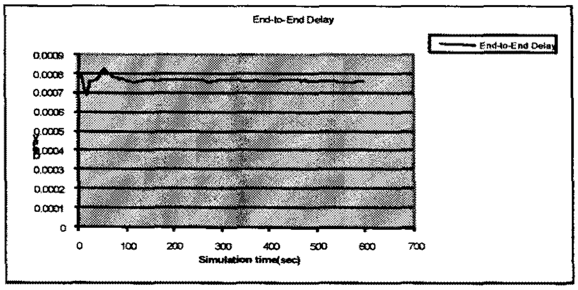

Fig. 7. Performance in terms of end-to-end delay given 40 nodes

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Mamata Koirala

received the bachelor in electronics and communications engineering at Pokhara University, Nepal in 2006, and the master of engineering in computer engineering from Chonbuk National University, Chonju, Korea in 2008, respectively. Her research interests include wireless mobile networks, real-time service in MANET, and network security.

Qi Ji

received the bachelor in computer science from Wuhan University, Wuhan, China in 2008. Now, she is with Chonbuk National University, Chonju, Korea as a master's degree program student at the department of electronic engineering. Her research interest includes wireless communications networks, grid networks, sensor networks, and network security.

Jaeho Choi

received his B.S.E.E., M.S.E.E., and Ph.D. in computer engineering from North Carolina State University, Raleigh, NC, USA in 1985, 1988, and 1993, respectively. Since 1994, he has been with Chonbuk National University, Chonju, Korea, as a faculty member. Now, he is full professor at the division of electronic engineering. His current research interests include wireless and mobile communications networks, sensor networks, and ad hoc networks.