A Multi-Channel MAC Protocol for AD-HOC Networks

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1. Introduction

Ad-Hoc networking is one of the fastest growing fields in today's wireless networking industry. One of the major challenges faced by the ad-hoc networking is the channel access mechanism to facilitate communication. The MAC protocol of IEEE 802.11 Distributed Coordination Function (DCF), designed to share a single channel between nodes works well in a managed environment. However, in the ad-hoc environment where there is no fixed infrastructure or an authority to manage the network activities, the current channel access mechanism does not work efficiently. It lead issues like hidden node and exposed node problems. Many researchers have attempted to investigate the relation between the channel access mechanism and the performance. Many have concluded that increasing the number of channels available for communication improves the performance drastically. In its basic form, DCF function supports the usage of single channel for communication, even if other channels are present and are not being used. The authors of [1 through 8] have proposed various multi-channel schemes to improve the performance of the wireless networks. In addition, the authors have also demonstrated in their work that the presence of multiple channels for data transmission improves the performance and reduces the effects of hidden/exposed node problems.

One of the major drawbacks of most of the related research is the fact that, even though there are many channels present for data transmission, only two or three non-interfering channels are selected for data transmission resulting in underutilization of other channels. Although the authors of [6] suggested the usage of all available channels, the method of channel selection is not clear. In this research work, the authors propose a new multi-channel channel access mechanism for the ad-hoc networks. The proposed scheme uses a Semi-Markov model (sMm) based algorithm for channel selection. In addition, compared to the other similar schemes, the proposed scheme also accommodates quality of service extensions at the layer 2 level. The proposed scheme is implemented using GlomoSim network simulator.

2. Multi Channel MAC-Protocol

One of the basic functions of MAC layer is to scan the channel for transmitting the signal. The main idea in this paper is to scan and select the available channels during the announcement traffic indication messages (ATIM) windows as in PSM of MAC layer. To select a particular channel parameters such as signal to interference with noise ratio (SINR), consumed battery power, traffic load, duration of transmission, mobile nature of each node and relative distances of node with respect to other nodes in the network are considered. If the channel remains in a state for a time frame of beacon interval then reserved channel is selected.

In wireless medium, signal strength decays as the distance between two communicating nodes increases. It results in an increase in the interference and noise. The SINR is considered while selecting channel. The battery power is available in finite amount at each node in ad hoc node, so plays vital role. So the residual battery power of each node is considered. Topology of ad-hoc network changes frequently over time because of mobile nature of the nodes. So data transmission duration along with the mobile nature of sender node and receiver node and their relative distance with respect to the other nodes in the network affect the overall throughput of the network. So the mobility measure of the nodes and their relative distances in the network topology over time are taken into account. By attaching particular weight to each parameter a composite metric 'CM' is calculated for each channel. 'CM' is calculated for each available channel at the sender node and the receiver node.

As per the value of 'CM' and the nature of traffic the channel preferences are set on channels available for transmission by the sender node and by

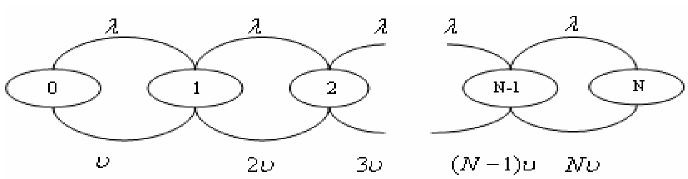

Figure 1: State Diagram for Channel allocation

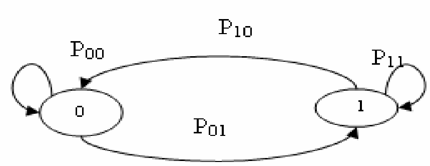

Figure 2: State diagram for channel availability

the receiver node. All available channels are marked with either of three preferences i.e. high, medium or low. If there is no channel marked as a high preference then the medium one is selected. The preferences are given to the channel as per interference caused by that channel to rest of the channel. The information about the preferred channels is exchanged during ATIM window. ATIM messages contain the preferred channels selected for the communication. After the ATIM window, the sender node and the receiver node switches to their respective selected channel among their preferred channel individually and start communication after exchanging Request-to-Send (RTS)/ Clear-to-Send (CTS) control messages. Other nodes in the vicinity of the sender and receiver node overhear ATIM messages exchanged by them and record the channels selected.

The concept of setting preferences to the available channels is similar to the one discussed by authors of [4, 5] but there is difference in the parameters which are considered for channel selection and the further analysis in the proposed mechanism. The channel selection mechanism is presented with analytical model in proposed mechanism. The mechanism uses the sMm based mathematical model to find the channel availability. This mathematical model along with previously mentioned factors enhances the performance of proposed dynamic channel selection method**.**

The mathematical model is based on special case of Markov model named Erlangs's B Formula stated as $M/M/N/N/\infty$. N represents the number of channels and each state represents the number of channels busy as shown in Fig 1. The model gives the probability of availability of number of channels as a function of time by considering parameter such as SINR, number of interference free and contention free channels.

The transmissions also get affected by mobile nature of nodes, the location and distance among the nodes, the load of traffic shared by the nodes and duration of current transmission at that instant of time. To consider these factors the model is extended by Semi-Markov model. In this model, the Markov chain consists of two states, namely 1 and 0 as shown in Fig 2. A node will be in state 1 if it has an interference free channel available for transmission. Otherwise, it will be in state 0. Then, the node waits for a random amount of time and will remain in this state until it any interference free channel available. Once the channel is available, it makes a transition to state 1 and starts the transmission. This model calculates the probability of availability of channel throughout the route from source to destination node in multi-hop scenario for successful transmission as a function of time. To evaluate the performance of the proposed mechanism, simulations will be carried out by using network simulator GlomoSim 2.03 in different scenarios.

3. References

1. J. Deng, Z. J. Haas, "Dual Busy Tone Multiple Access (DBTMA): A new Medium Access Control for Packet Radio Networks," In international conference on Universal Personal Communication, October 1998.
2. S. Wu, C. Lin, Y. Tseng, J. Sheu, "A new Multichannel MAC Protocol with On-Demand Channel Assignment for Multi-Hop Mobile Ad Hoc Networks," In IEEE Wireless Communications and Networking Conference (WCNC), Chicago, IL, September 2000.
3. Sudthida Wiwatthanasaranrom, Anan Phonphoem, "Multichannel MAC protocol for Ad-Hoc Wireless Networks,"
4. Jungmin So, Nitin Vaidya, "Multi-Channel MAC for Ad Hoc Networks: Handling Multi-Channel Hidden Terminals Using a Single Transceiver,"
5. Jungmin So, Nitin H. Vaidya, "A Multi-channel MAC Protocol for Ad Hoc Wireless Networks," Technical Report 2003.
6. N. Jain, S.R. Das, A. Nasipuri. "A Multichannel MAC Protocol with Receiver Based Channel Selection for Multihop Wireless Networks," Proc. of IEEE International Conference of Computer Communication and Networks (ICCCN 2001), October 2001.
7. Asis Nasipuri, Samir R. Das, "Multichannel CSMA with Signal Power-Based Channel Selection for Multihop Wireless Networks,"
8. Asis Nasipuri, Jun Zhuang, Samir R. Das, "A Multichannel CSMA MAC Protocol for Multihop Wireless Networks," Proc. of IEEE Wireless Communication and Networking Conference (WCNC'99), September 1999
9. Y. Tseng, C. Hsu, T. Hsieh, "Power-Saving Protocols for IEEE 802.11-Based Multi-hop Ad Hoc Networks," in IEEE INFOCOM, June 2002
10. Byung-Jae Kwak, Nah-Oak Song, "A Mobility measure for Mobile Ad-hoc Networks," Member, IEEE, Leonard E. Miller, Senior Member, IEEE