Asian Journal of Information Technology 5 (1) : 44-47, 2006

A Novel Multi-Channel based Framework forWireless IEEE 802.11 Ad Hoc Networks

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Abstract: Most IEEE 802.11 based ad hoc networks do not support a node to perform simultaneous communications because there is only one wireless network interface card (NIC) at a node and multi-channel operation is not allowed in IEEE 802.11 ad hoc mode. In this study a novel multi-channel multi-NIC based scheme is proposed for IEEE 802.11 ad hoc networks. The novel framework and function of multi-NIC management layer (MML) are described. Qualitative analysis results shows that the overall saturation throughput of the network is linearly increased with the number of NICs per node.

Key words: Ad Hoc Networks, IEEE 802.11, Multi-NIC Management Layer (MML), saturation throughput

INTRODUCTION

A mobile ad hoc network (MANET)[1] comprises of a set of nodes equipped with wireless transceiver. In an ad hoc network, mobile nodes communicate with each other using multi-hop wireless links without any fixed infrastructure relay. Every mobile node acts both as a host as well as a router. Ad hoc network is one of the research hotspots in the area of computer networks and wireless communications. There are many networks and wireless communications. There are many applications of ad hoc networks in real world such as, collaborative computing in a conference, search and rescue collaborative computing in a conference, search and rescue collaborative computing in a conference, search and rescue vehicles engaged in action in enemy territory where one can not expect support of fixed infrastructures. IEEE 802.11[2] is the most popular MAC layer and PHY specifications in wireless local area networks (WLAN); it is also widely used in both simulations and test beds of ad hoc networks where the default MAC mechanism is IEEE 802.11 distributed default MAC mechanism is IEEE 802.11 distributed coordination function (DCF). There have been so many studies conducted for performance evaluation of IEEE 802.11 in ad hoc mode[3,4] . There are also lots of improvements on IEEE 802.11 to increase the performance of ad hoc networks. Currently, IEEE 802.11 supports the use of multiple channels; frequency bands that can be used simultaneously without any interference with each other. For example, in IEEE 802.11 or 802.11b, nodes can use up to three channels and in IEEE 802.11a, up to twelve channels can be used. In contrast to access points with multi-channel capability in infrastructure mode, mobile nodes in ad hoc mode are assumed to use only one channel in the current standard. To improve the utilization efficiency of precious wireless spectrum several multi-channel based MAC protocols[5,6] for IEEE 802.11 ad hoc networks have been proposed. In[7], a Adaptive acquisition collision avoidance multiple access (AACA) protocol was proposed mobile ad hoc networks. The AACA protocol was based on combination of multiple channels and random reservation. The whole wireless bandwidth is divided multiple channels, one is served as common channel for control packet and others are served as traffic channels for data transfer. Every node dynamically reserves an idle traffic channel on the common channel before data transmission. Although the above multi-channel based protocols outperform single-channel based protocols in mobile ad hoc networks, the application of multi-channel based protocols is complicated because the hardware at MAC layer should be modified over IEEE 802.11 and it is difficult for transceiver to quickly switch from one frequency-band to another. Another drawback of above schemes is that node was not allowed to perform simultaneous communications because there is only one wireless network interface card (NIC) at a node.

In this study a novel multi-channel based framework is proposed for ad hoc networks where each node is equipped with multiple IEEE 802.11 network interface

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cards (NICs) tuned at non-overlap frequency bands. Nodes in this scheme have the capability of full-duplex communications and parallel communications. The whole network can be seen as a combination of multiple sub-networks operated at different channels. In this way the available wireless bandwidth resources can be furthest used over conventional IEEE 802.11 resources can be furthest used over conventional IEEE 802.11 wireless networks. The throughput of network is expected to be improved greatly. This framework can be easily deployed in real applications because the cheap IEEE 802.11 products are available and upper layers in protocol stack need no modifications. The rest of this study is organized as follows. The proposed network framework is described in section II, the function of multi-NIC management layer (MML) is presented function of multi-NIC management layer (MML) is presented in section III, the analysis of saturation throughput is shown in section IV. Finally we conclude the paper in section V.

NETWORK FRAMEWORK

The multi-channel multi-NIC based framework for IEEE 802.11 ad hoc networks is shown in Fig.1, there are N mobile nodes forming a multi-hop wireless network. Each node is equipped with M IEEE 802.11 network interface cards (802.11 NICs) operating at different 802.11 channels (i.e., non-interfering channels). As indicated in Fig.1, from the view point of radio link layer the whole network can be seen as a superposition of M sub-networks operating at M channels. The m-th sub-network can be described in terms of a graph Gm(Vm, Em), where $m \in [1,M]$ and Vm = {1,2,…,N} denotes the set of nodes, Em = {e_1,e_2,… e_k} denotes the set of links between the nodes in the m-th sub-network. The whole network can be denoted by a graph G = (V, E), where V = Vm={1,2,…,N} denotes the set of nodes and $E = \sum_{m=1}^{M} E_m$ denotes the total set of links.

The protocol stack of the network framework is indicated as Fig.2, where the stack is derived from popular TCP/IP stack and there is a multi-NIC management layer (MML) between Media Access Control (MAC) layer and network layer. The traditional address resolution protocol (ARP)[8] used in wired Ethernet is modified to be suitable for multi-NIC based framework and is placed in MML. Thus the upper layers including network layer, transport layer and application layer do not require modifications. The details of multi-NICs are concealed from the view point of upper layers. Another advantage of our scheme is that existing IEEE 802.11 NICs can be directly used

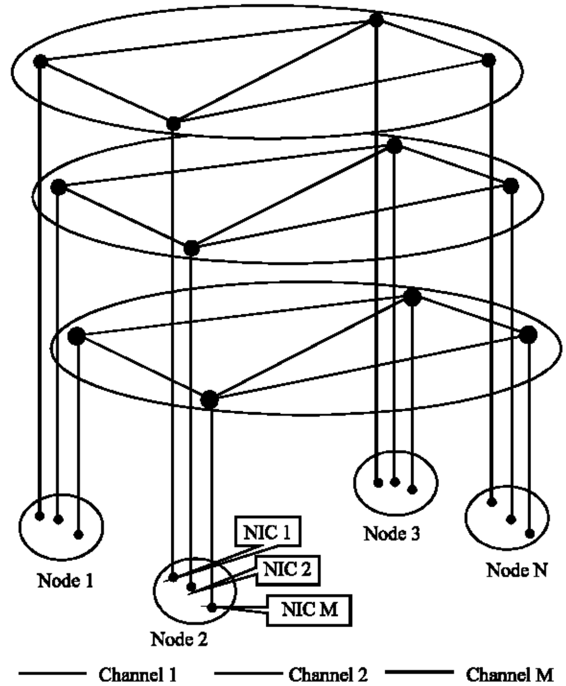

Fig. 1: Multi-channel based Model for Ad Hoc Networks

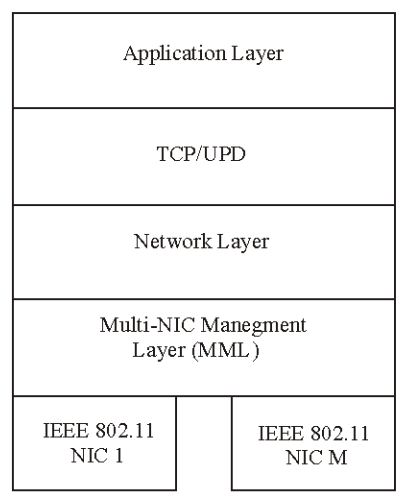

Fig. 2: Multi-NIC based network protocol stuck

without any hardware (MAC and PHY) modifications in our scheme. The main advantage is that the available wireless bandwidth in IEEE 802.11 specifications can be full exploited with sufficient NICs per node. The drawback of our framework is that the cost and energy consumption are increased linearly with the number of NICs per node. Therefore the framework is not suitable for energy limited ad hoc networks where nodes are supplied by batteries. Energy saving is of vital importance for such networks, for example, laptops or personal communication handsets and sensor networks. However, our scheme is suitable for tactical vehicular ad hoc networks (VANETs) or wireless mesh networks where the energy supply is no longer an issue.

MULTI-NIC MANAGEMENT LAYER (MML)

Multi-NIC management layer (MML) is under the network layer in the protocol stack. The main function of MML is to manage the multiple 802.11 NICs thus concealing the details of multi-NICs for upper layers. Another function in MML is address resolution protocol (ARP).

Address resolution protocol (ARP): According to Internet Protocol (IP) each node in our framework has a unique IP address. Because there are multiple NICs each node have multiple MAC addresses. In ARP entity there is a Neighboring Address Table (NAT) containing each neighboring node's mapping between the unique IP address and multiple MAC addresses. The ARP entity arranges one NICs of itself to broadcast an Address Information Packet (AIP) periodically. As shown in Fig.3, the format of AIP contains the IP address, MAC address list and the time stamp when the AIP is broadcasting. The neighboring node receives the AIP packet and then updates its Neighboring Address Table (NAT). The interval of AIP broadcasting is determined by the frequency of changing of network topology. The detail of NAT is indicated in Table 1, when the address information of a neighboring node is expired, the corresponding item will be deleted from NAT table. If a node does not know MAC addresses of its neighboring nodes, it will broadcast an address request packet that contains the IP address of a neighboring node and then the corresponding neighbor will broadcast an AIP as a reply.

Schedule of data packet in MML: MML entity receives data packets from its upper layer (network layer); the head of the data packet contains the IP address of destination node and source node (itself). The MML entity hands over the packet to MAC layer, then the destination MAC address and source MAC address is added in the head of the packet. Because there are multiple NICs per node, the schedule and dispatch of the data packet is the task of MML entity. The schedule mechanism is described as follows. The MML entity is always monitoring the transmission queue of each NIC and chooses a NIC with the shortest queue length to transmit the outgoing data packet. The MML entity chooses a NIC randomly in the case of several NICs have the same queue length of transmission (e.g., length of all the transmission queue is null or other value). Once the NIC was chosen the MML entity can obtain the corresponding MAC address of destination node by checking its Neighboring Address Table (NAT) in ARP entity. In this way the and source MAC address information is added in the head of the data packet and then the data packet becomes a MAC layer frame. The transmission of this frame is performed by the corresponding 802.11 NIC in distributed coordinate function (DCF) mode (basic access or RTS/CTS access mechanism).

Table 1: Negiiboring address table (NAT)

IP address 1	MAC address 1	...	MAC address M	time stamp
IP address 1	MAC address 1	...	MAC address M	time stamp
...				
IP address K	MAC address 1	...	MAC address M	time stamp

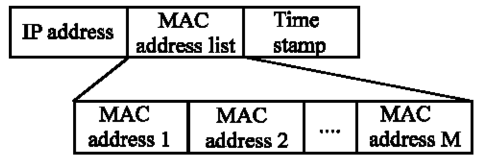

Fig. 3: Formal of address Information Packet (AIP)

When each of the M wireless cards receives a MAC layer data frame from a neighboring node, the MML entity will hand the packet to upper layer by removing the MAC layer head information of the frame (including destination and source MAC address fields).

Supporting by MML entity, a node in our scheme can communicate with multiple neighboring nodes simultaneously or perform duplex communications with a neighboring node.

SATURATION THROUGHPUT ANALYSIS

In the proposed framework the routing, transport and application protocols do not require modifications because the MML layer conceals the details of multi-NICs. For the sake of simplicity, we analyze the s aturation throughput at MAC layer for a single-hop multi-NICs based ad hoc network. The data packets are generated at MML layer as if the packets are received from network layer. The notation "saturation" means that each NIC's transmission queue is always n ot empty. The MML entity monitors the status (i.e., the length of transmission queue) of each NIC in real-time mode. Once a queue is empty, the MML entity will generate a packet and then dispatch this packet to the empty queue as soon as possible. It is easily proved that the overall saturation throughput of the network is the summation of that of M 802.11 WLAN operating at different channels.

The normalized system throughput S is defined as the successfully transmitted payload bits over a periods. According to the conclusions in literature[3], the saturation throughput of the m-th sub-network can be presented as the function of number of nodes N, DCF access mechanism (i.e., basic access method or RTS/CTS method) and other protocol parameters (e.g., bit rate of physical channel, SIFS, DIFS, etc).

S_M = f (number of the nodes, DCF access mechanism, protocol parameter of channel m) (1)

Then the overall saturated throughput S can be expressed as follows.

$$E = \sum_{m=1}^{M} E_m \quad (2)$$

This conclusion is also tenable in multi-hop mode for proposed framework. The overall saturation throughput S is increased linearly with the number of NICs per node. Obviously the number M should be equal or less than number of non-overlap channels specified in IEEE 802.11 standard (3 channels in IEEE 802.11 and 802.11b, 12 channels in IEEE 802.11a).

CONLUSIONS

A multi-channel based framework is presented for IEEE A multi-channel based framework is presented for IEEE A multi-channel based framework is presented for IEEE effectively by tuning different NIC at different channels (i.e., non-overlap frequency bands in 802.11). The throughput of the network is improved linearly with the number of NICs per node. The proposed framework is suitable for tactical vehicular ad hoc networks where power consumption is no longer a main issue. In future we will study the overall performance (end-to-end throughput and delay at application layer, TCP performance and routing performance) for ad hoc networks based on the proposed framework via simulations.

REFERENCE

1. Toh, C.K., 2002. Ad-Hoc Mobile Wireless Networks: Protocols and Systems, Prentice Hall PTR, 1 Edition.
2. IEEE, 1999. Working group, Wireless LAN Medium Access Control (MAC) and Physical layer (PHY) Specifications,
3. Bianchi, G., 2000. Performance analysis of the IEEE 802.11 distributed coordination function, IEEE J. Select. Areas Commun., pp: 535-547.
4. Li Xiaolong, *et al.*, 2004. Modeling and analysis of multi-hop wireless mobile ad hoc networks using the IEEE 802.11 DCF protocol, in Proc. International Conference on Wireless Networks, ICWN.
5. Jiandong, LI. *et al.*, 2003. Performance evaluation of modified IEEE 802.11 MAC for Multi-Channel Multi-Hop Ad Hoc Network, in Proceedings of the17 th International Conference on Advanced Information Networking and Applications (AINA').
6. Choi, N., S. Yongho and C. Yanghee, 2003. Multi-Channel MAC protocol for mobile Ad Hoc networks, in Proc. IEEE VTC, pp: 1379-1382.
7. Kai Liu, *et al.*, 2001. Adaptive acquisition collision avoidance multiple access for multi-hop ad hoc networks, In Proceedings of GlobeCom, pp: 2280-2284.
8. David C. Plummer, 1982. An Ethernet address resolution protocol, in IETF RFC 826, Network Working Group.