Multi-Channel Multi-Interface Wireless Network Architecture

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Abstract— With the increase of usage of wireless networks for purposes where the nodes are either stationary or minimally mobile, focus is also on increasing the network capacity of wireless networks. One such way is to use non-overlapping multiple channels provided by 802.11 by using multiple interfaces per node. Multiple non overlapped channels exist in the 2.4 GHz and 5 GHz spectrum. Under this scenario, several challenges need to be addressed before all the available channels can be fully utilized.

Keywords: channel assignment, mac, network simulator, routing protocol

I. INTRODUCTION

Wireless network technology, despite being extremely useful in mobile communication and computing application, suffers from low link-layer data rates. The 54 Mbps peak link-layer data rate of IEEE 802.11a/g wireless LAN interface stands no chance in front of huge bandwidths provided by wired technologies. Moreover, overheads of packet loss, packet errors, contention and packet headers, drastically reduce the actual good put available to the wireless network applications. The data rate also falls quickly with increasing distance between signal source and destination.

Interference from adjacent hops in a multi-hop network further decreases the available bandwidth. Usage of multiple channels thus removes both of the problems - it extends the available bandwidth and removes the problem of interference as now simultaneous communication is established between adjacent hops on a non-overlapping channel. it is now feasible to equip nodes with multiple 802.11 wireless interfaces. As we cannot equip the nodes with an interface for every non overlapping channel due to power consumption and size constraints, we need to devise channel assignment algorithms which would switch the interfaces from one channel to other albeit at the cost of switching delay. Multi-radio and multi-channel architecture has special usage is wireless mesh networks (WMN)[2]. In a mesh network, nodes act as repeaters to transmit data from nearby nodes to distant nodes in the network.

Their special utility is in case of providing inexpensive last mile broadband internet connectivity. In some cases the mesh may be serving as an extension to a wired backbone, thus decreasing the need of a dense physical wire network and hence the cost of maintenance Introduction of mesh networks also calls for efforts in the direction of increase in network capacity. Usage of mesh networks as an extension to a wired backbone will lead to surge in bandwidth-intensive applications like video-sharing. Usage of multiple channels available in IEEE 802.11a/g standards offers a promising avenue in this regard. the IEEE 802.11b/g standards and IEEE 802.11a standard provide 3 and 12 nonoverlapped frequency channels, respectively. Utilization of these multiple channels effectively would increase the bandwidth substantially.

II. CHANNEL ASSIGNMENT

To utilize a greater number of channels with fewer NICs per node we need the ability to switch a NIC between channels. For example, if we have a single NIC per node in a network of four nodes, and each node is fixed on the same channel, the opportunity to use the other available channels is wasted. We cannot fix the NIC to other channel, as then the nodes on two different channels will be unable to communicate with each other. Thus, we need a channel assignment algorithm which coordinates between the nodes and schedules assignment, and if necessary, switching of channels among the NICs to utilize multiple channels. For maximum benefit, such a channel assignment algorithm needs to adhere to certain demands of the network. There are a number of ways of approaching the channel-assignment problem each with some issues[3].

A. Fixed Channel Assignment

One such way would be to use as many channels as the number of NICs available per node i.e. if we have *n* number of NICs on a node we fix them to *n* different channels. This would lead to a very simplified scenario as we will just need to manage simultaneous communications on multiple channels. This is however not a optimal solution as it will leave many channels unused and be inefficient, specially in the case where the number of NICs is very less as compared to the number of channels. Another approach would be to fix NICs on different nodes to non-disjoint sets of different channels. Thus each node will share atleast one different channel with other nodes. This would balance the load on different channels and utilize all channels effectively. Though, this might simplify the protocol, a simple assignment of channels might hamper network connectivity. It might cause network partitioning i.e. disjoint sets of nodes which have no connectivity between them (Fig.1), even if nodes have multiple NICs.

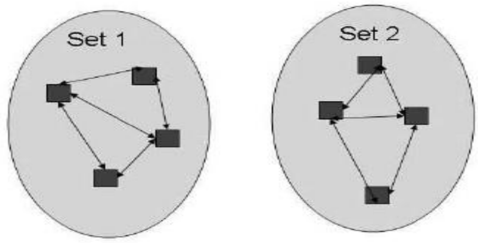

Fig. 1: Fixed Channel Assignment leading to disjoint set

B. Dynamic Channel Assignment

Through this flexible approach, each node balances its load over all channels in due course of time. However, this policy will require frequent channel switching leading to switch delays. Also it requires careful co-ordination between nodes to ensure that two nodes which need to communicate have alteast one of their interfaces use a common channel.

III. MULTI-CHANNEL MAC [4]

MMAC is a link-layer protocol for single interface networks to utilize multiple channels. MMAC requires time synchronization between nodes to coordinate channel assignment. In MMAC time is divided into quantum units called beacons. At the start of this beacon, each node is forced to assign a common channel to its NIC. This ensures connectivity between nodes and a chance for all nodes to exchange information for further communication.

As soon as all nodes are on a common channel after a random interval (to avoid contention) the node which has data to transmit (SRC1) sends a ATIM packet to the destination (DST1). The ATIM packet includes channel information about the usage of channels in SRC1's neighborhood, termed as the Preferred

Channel List *(PCL)*. On receiving this ATIM packet, DST1 matches its own PCL and decides the least used channel as communication medium and replies with an ATIM-ACK packet containing the above information. The transaction is confirmed by SRC1 by sending an ATIM-RES packet. Meanwhile, the neighbors of SRC1 and DST1 update their PCL's on hearing the conversation. Similarly, other SRCDST pairs get ready for communication within the stipulated ATIM window. After the ATIM window, communication as decided earlier continues and data is sent by SRC1 to DST1 on the pre-decided channel. Simultaneously, other SRC-DST pairs do data transaction. The communication stops as the beacon interval approaches and all the nodes switch back to the common channel. Thus, MMAC enables equal load distribution on all channels as well as adequate opportunities for broadcast during the ATIM window.

IV. ROUTING PROTOCOL

Although most routing protocols for single channel assignment would work with proposed channel assignment algorithms, they will not be optimal. In multiple channel network, as opposed to single channel network, shortest-path metric is not optimal. Hence, the challenge is to suggest the best suitable metric for such networks. While deciding the metric for such a case, we need to keep in mind the switching delay, channel diversity and the conventional resource usage i.e. the number of hops.

When we choose a route for a packet in a multiple channel network, though it might be shorter than their paths, it might include channel switching for a majority of hops on its way. Switching of interfaces to different channels incurs switching delay which should be minimized. At the same time a node should transmit and receive on different channels as this enables it to do so simultaneously, increasing the throughput. Hence, a route where all nodes receive and transmit on different channels should be preferred[5]. However, total hops along the route also have a weight age as there should not be inefficient use of resources along the route.

V. NETWORK SIMULATOR

A network simulator is a software that simulates the network without a netwowrk actually being present. Compared to the cost and time involved in setting up an entire test bed containing multiple networked computers, routers, infrastructure, network simulators are relatively fast and inexpensive. They allow testing of scenarios that might be particularly difficult or expensive to simulate using real hardware. Networking simulators are particularly useful in allowing designers to test new networking protocols or changes to existing protocols in a controlled and reproducible environment. There are a wide variety of network simulators, ranging from the very simple to the very complex.

VI. NETWORK SIMULATOR- NS2[1]

NS2 is an open source simulator targeted for network research. NS2 official release does not support multi-channel wireless network environment. In the NS implementation of wireless networks, the layers are defined as:

- Routing- topmost layer
- Link Layer-either queue or send the packet
- ARP-address resolution
- Ifq- queueing
- MAC-MAC parameters and timers
- NetIF & Propagaton-Physical layer
- Channel – channel assignment and connectivity

A packet is passed from one layer to another by calling recv() function of the layer UPSTREAM or DOWNSTREAM. The neighbour nodes that will be affected.

VII. MULTI-INTERFACE MULTI-CHANNEL EXTENSION

The Multi-Interface Multi-Channel extension of NS-2.29 now enables us to simulate such wireless network environments in NS. Other simulators either do not provide sufficient features or are not freely available. The extension can serve as platform for performance evaluation of channel assignment protocols and routing protocols developed for such wireless environments. First we must generate the topology as required i.e. the placement of the nodes in the network[6]. Next we decide upon the traffic that we need to simulate on the given topology. Given the traffic and topology, the implementation of the protocol should assign different channels to the network interfaces of the nodes and also find routes for the traffic. The routing that is generated using this protocol can then be generated in the form of a script in the form of manual routing where we hardcode the route that each traffic flow needs to take Thus, the implementation can be any programming language with the end result as a tcl script. Though the number of interfaces on a node is 5, it can be increased by making changes in the NS code. For protocols that require fewer number of interfaces, the implementation can be done assuming the required number of interfaces and rest of the interfaces can be assigned a fixed channel that is never used. Unless an interface is specifically instructed to be used in a particular route it does not interfere with the performance[7]. The network environment can be altered by changing the network parameters available in NS.

VIII. CONCLUSION

Multi-interface multi-channel wireless algorithms are useful for exploiting the wasted bandwidth available in the form of orthogonal channels in the IEEE 802.11a/g interface. Special routing protocols and channel assignment algorithms are required for such network environments. Wide usage of such networks would be a great boon to last-mile internet connectivity and development of low-cost wireless mesh networks where only a wired backbone is used as a support. Extensive literature survey in this field shows that though there have been many theoretical advances in the field, there is lack of any real extensive deployment. Most of the implementation on simulators like Ns2 were either out of date or broken. The extension of NS provides a framework on which other channel assignment and routing algorithms for multi-channel multi-interface networks can be implemented.

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