Multiple Channel Implementations in Wireless Mesh Networks

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***Abstract*—The much research progress has been made in network capacity analysis of ad-hoc networks, WMNs have not been fully explored due to the difference between WMNs and ad-hoc networks. The result about network capacity and optimum node density of ad-hoc networks may not directly be applied to the WMNs because both stationary and mobile ad-hoc nodes exist in WMNs. In last decade much research has been carried out to study the capacity of ad-hoc networks which can be adopted to investigate the capacity of WMNs. In this topic we used two techniques, multi- channels per radio and multi- radios per node. These techniques can be used in WMNs to increase its capacity. In Wireless Mesh Networks each mesh node equips with multiple 802.11 network interface cards (NICs). The central design issues of this multi-channel WMN architecture are channel assignment and routing. In this paper we describes that technique to optimize the number of channels per radio and number of radios per node, also shows the intelligent channel assignment that utilize only local traffic load information. Mainly we try to avoid the channel dependency problem. Through an extensive simulation study, we shows that even with just 2 NICs on each node, it is possible to improve the network throughput by a factor of 6 to 7 when compared with the conventional single-channel ad-hoc network architecture. This has significantly driven the progress in capacity research of ad-hoc networks.**

***Keywords*—wireless mesh networks, multiple channels, multiple interfaces, channel assignment, channel dependency.**

I. Introduction

As various networks evolve into the next generation to provide better services, a key technology, wireless mesh networks (WMNs), has emerged recently. In WMNs, nodes are comprised of mesh routers and mesh clients. Each node operates not only as a host but also as a router, forwarding packets on behalf of other nodes that may not be within direct wireless transmission range of their destinations. A wireless mesh network is dynamically self-organized and self-configured, with the nodes in the network automatically establishing and maintaining mesh connectivity among themselves (creating in effect ad hoc network). This feature brings advantages to WMNs such as low up-front cost, easy network maintenance, robustness, and reliable service coverage.

Conventional nodes (e.g., desktops, laptops, PDAs, Pocket PCs, phones, etc.) equipped with wireless network interface cards (NICs) can connect directly to wireless mesh routers. Customers without wireless NICs can access WMNs by connecting to wireless mesh through, for example, Ethernet. Thus WMNs will greatly help the users to be always on-line any where anytime. Moreover, the gateway/bridge functionalities in mesh routers enable the integration of WMNs with various existing wireless networks such as cellular, wireless sensor, wireless-fidelity (WI-FI), worldwide inter-operability for microwave access (WI-MAX), WI-Media networks.

IEEE 802.11 [1] is a widely used technology for wireless local area networks. IEEE 802.11 offers multiple non-overlapping channels that are separated in frequency. For example, IEEE 802.11b offers 3 non-overlapping channels, while IEEE 802.11a offers 12 non-overlapping channels. Multiple channels have been exploited in infrastructure-based networks by assigning different channels to adjacent access points, thereby minimizing interference between access points. However, typical multi-hop wireless network configurations require a single common channel to be used by all nodes to ensure network connectivity. Our goal in this paper is to utilize the multiple channels in multi-hop wireless networks.

Inexpensive commodity IEEE 802.11 hardware has accelerated the use of wireless local area networks. This trend of reducing hardware costs is expected to continue [2], and it is already feasible to equip nodes with multiple 802.11 interfaces. However, it is still expensive to equip a node with one interface for each channel (recall that IEEE 802.11a has 12 non-overlapping channels). Today Multi-channel and Multi-interface are used in WMNs. That's why the capacity of WMNs can be increased. But we know that number of interfaces is lesser than the number of channels. For this purpose same channel number can be used among multiple interfaces. Whenever we can change a heavily loaded channel to lightly loaded channel then whole networks architecture can be changed, that interface used same channel number. So channel dependency problem can be arise. This problem can be minimised by channel assignment algorithm that is proposed in our paper.

This paper describes and evaluates a novel multi channel WMN architecture that is built on IEEE 802.11 based wireless LAN hardware and is specifically tailored to multi-hop wireless access network application. Although the multiple NIC approach has been mentioned in the past, We believe this work represents the first comprehensive study of this approach in the context of a wireless access network. In particular, this paper makes: a fully distributed channel assignment algorithm that can adapt to traffic loads dynamically and a comprehensive performance study that show the significant bandwidth improvements over single channel WMNs.

The rest of the paper is organized as follows. Section II represents the Overview of WMNs, where components, Network architecture, Character, Capacity, multi-channel, multi-radio and system architecture are the sub point of this content. Section III presents channel assignment scheme. Section IV gives channel assignment algorithm. Section V shows the simulation results of both single channel and multi channel WMNs. Finally section VI gives the conclusion of system.

II. Overview of WMN

A. *COMPONENTS*

WMNs (Wireless Mesh Networks) it consists of two components.

(i) Upper Components i.e. Mesh Router

(ii) Lower Components i.e. Mesh Client

Upper Component: In upper components more routers are connected each other through wireless. Among those routers we can provides two or more as Gateway (i.e. Service Provider).Gateway are connected wired base. These routers are Infrastructure base so routers are fixed .These are the backbone of mesh router. To improve the flexibility of mesh networking then the mesh routers is usually equipped with multiple wireless interfaces built on either the same or different technologies. Compared with a conventional wire-less routers, a wire-less mesh router can achieve the same coverage with much lower transmission power through multi-hop communications. The MAC (medium access control) protocol in a mesh router is enhanced with better scalability in a multi-hop mesh environment.

Lower Component: In lower components consist of heterogeneous network i.e. Cellular network, Sensor network, Wi-Fi network etc. Mesh clients also have necessary functions for mesh networking, and thus, can also work as a router. In mesh client one system can communicate it's router through its near access point and then the multi-hop fashion one network can communicated another network. Mesh clients are wire or wireless connects to its router. Mesh clients can be a laptop/desktop PC, pocket PC, PDA, IP phone, etc.

B. *NETWORK ARCHITECTURE*

The architecture of WMNs can be classified into three main groups based on the functionality of the nodes i. e.

- Infrastructure/Backbone WMNs
- Client WMNs
- Hybrid WMNs

Infrastructure/Backbone WMNs: In Fig. 1 where dash and solid line indicate wireless and wired links, respectively. This type of WMNs includes mesh routers forming an infrastructure for clients that connect to them. The WMN Infrastructure/Backbone can be built using various types of radio technologies. Mesh routers form a mesh of self-configuring, self-organize among themselves. With gateway functionality, mesh routers can be connected to the Internet. This approach is also provides backbone for conventional clients and enables integration of WMNs with existing wireless networks, through/bridge functionalities in mesh routers. Conventional clients with Ethernet interface can be connected to mesh routers via Ethernet links. For conventional clients with the same radio technologies as mesh routers, they can directly communicate with the mesh routers. If different radio technologies are used, clients must communicate with the base stations that have Ethernet connections to mesh routers. Typically, two types of radios are used in the routers, i.e. for backbone communication and for user communication , respectively. The mesh backbone communication can be established using long-range communication techniques including directional antennas.

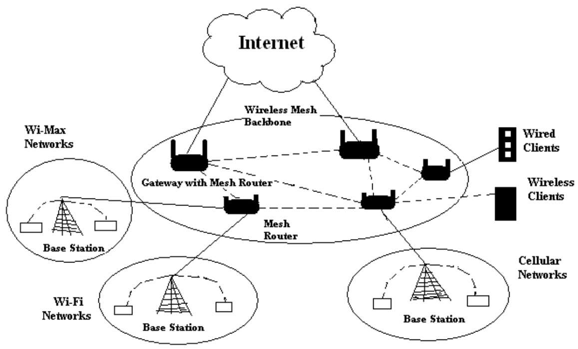

Fig. 1 Infrastructure/ Backbone of WMNs

Clients WMNs: In Client WMNs architecture, client nodes constitute the actual network to perform routing and configuration functionalities as well as providing end-user applications to customers. Hence a mesh router is not required for these types of networks. The basic architecture is shown in fig.2 in client WMNs, a packet destined to a node in the network hops through multiple nodes to reach the destination. Client WMN s are usually Formed using one type of radios on devices. Moreover, the requirements on end –user devices is increased when compared to infrastructure meshing, since, in client WMNs, the end –users must perform additional functions such as routing and self-configuration .

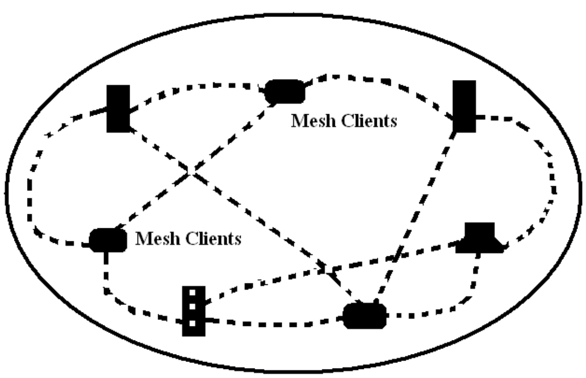

Fig. 2 Client WMNs

Hybrid WMNs: This architecture is the combination of infrastructure and client meshing as shown in fig. 3 mesh clients can access the network through mash routers as well as directly meshing with other mesh clients. While the infrastructure provides connectivity to other networks such as the: lnternet, WI – FI, WIMAX, cellular networks and sensor networks. The routing capabilities of clients provided connectivity and coverage inside the WMN.

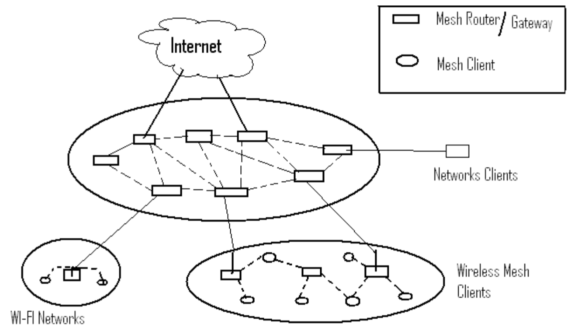

Fig. 3 Hybrid WMNs

C. CHARECTERSTICS

- Through Multi-hop wireless network the routers are communicated between them. Then the different networks can communicated between each other.
- Support for ad-hoc networking, and capability of self configuring and self organized.
- Mesh router have minimal mobility.
- Multiple types of network access.
- Mesh routers usually do not have strict constraints on power consumption. However mesh clients may require power efficient protocols.
- Capability and interoperability with existing wireless networks.
- WMNs consist of wireless backbone with mesh routers. The wireless backbone provides large coverage area, connectivity and robustness in wireless domain.
- User in one networks are provided with services in other networks, through the use of the wireless infrastructure.
- Through dedicated routing and configuration, the WMNs consume lower energy and high-end application capabilities to possibly mobile and energy constrained end-users.

D. CAPACITY ANALYSIS

The capacity of WMNs is affected by many factors such as network architecture, network topology, traffic pattern, network node density, number of channels used for each node, transmission power level and node mobility.

When the two node can communicated between each other then the throughput capacity can be increased by deploying relaying nodes and nodes need to be grouped into clusters.

Capacity of WMNs can be increased by multi-channels per radio and multi-radio per node. In multi-channels scheme to find the optimum number of channels where the information can easily transmitted. Through multi direction antennas one router can send the data packet to different routers or node.

E. MULTI-CHANNEL & MULTI-RADIO

Through the multi-radios and multi-channel s facilities one node can communicate different node at a same time. So it can show the advantages of speed of data flow. If a node can send the data to another node then a path can be established for transmit the data, the path is called as channel. The channels are carries information. So in multi-channel a huge amount of data can be transmitted from source node to destination node at a same time. In the multi-channel the least-use channel can use for send the data. The optimal channel can be found through channel-assignment algorithm. In multi-radio fashion a node can send the data to different nodes through directional antennas.

F. SYSTEM ARCHITECTURE

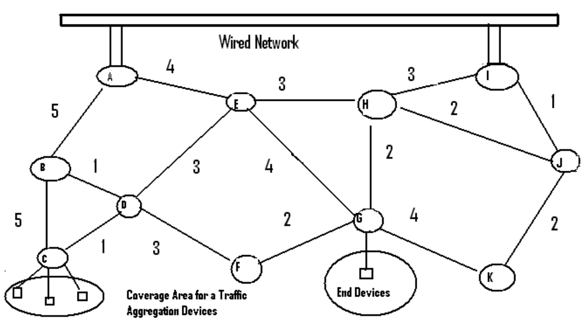

Fig. 4 Architecture of WMNs as shown Multi-Channel

In this Fig. 4 consists of fixed wireless routers, each of which equipped with a traffic aggregation access point that provides network connectivity to end-user mobile stations within its coverage area. In turn, the wireless routers form a multi-hop ad hoc network among themselves to relay the traffic to and from mobile stations. Some of WMNs nodes serve as gateways between the WMN and a wired network. In the most general case, the physical links between gateways and the wired network can be a wired link, or a point-to-point 802.11 or 802.16 wireless link.

Each node in WMN is equipped with multiple 802.11 compliant NICs, each of which is tuned to a particular radio channel for a relatively long period of time, such several minutes or hours. For direct communication, two nodes need to be within communication range of each other, and need to have a common channel assigned to their interfaces. A pair of nodes that use the same channel and are within interference range may interfere with each other's communication, even if they cannot directly communicate. Node pairs using different channels can transmit packets simultaneously without interference. For example in Fig. 4 each node is equipped with 2 NICs. The "virtual links" shown between the nodes depict direct communication between them, and the channel used by a pair of nodes is shown as the number associated with the connecting link. In This Fig. 4 network totally uses 5 distinct channels.

III. CHANNEL-ASSIGNMENT

Two types of Channel-Assignment

- Neighbour-to-Interface Binding
- Interface-to-Channel Assignment

A. NEIGHBOR-TO-INTERFACE BINDING

It determines through which interface, a node uses to communicate with each of it's neighbours with whom it intends to establish a virtual link.

Channel dependency problem is arises in Neighbour-to-Interface binding which is illustrated in Fig. 5. Here we can assume that the node D finds that the link D-E is heavily loaded and should be moved to a lightly loaded channel 7. As D only has 2 NICs, it can only operate on two channels simultaneously. To satisfy this constraint, link D-F also needs to change its channel. The same argument goes for node E, which needs to change the channel assignment for link E-H. This ripple effect further propagates to link H-I. Similar ripple effect would ensue if link A-E were to change its channel. In this case link E-G and G-K will need to change their channels as well. This channel dependency relationship among network nodes makes it difficult for an individual node to predict the effect of a local channel re-assignment decision. This is cascade in nature.

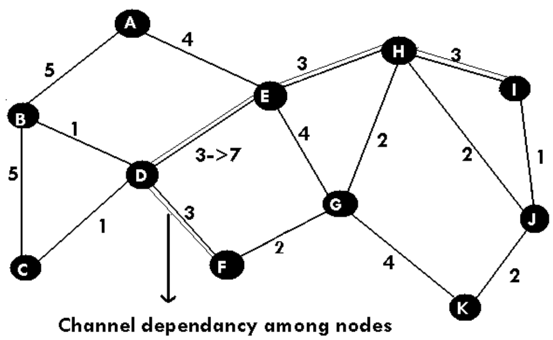

Fig. 5 Channel Dependency Problem

B. *Elimination of Channel Dependency Problem*

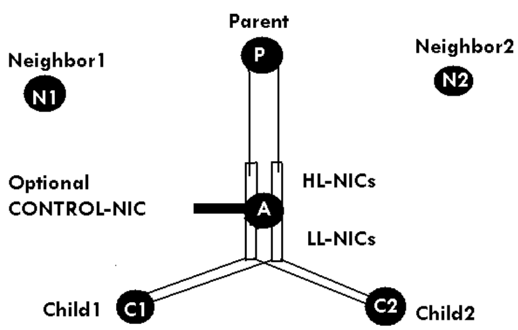

Fig. 6 Eliminate channel dependency by separating the set of NICs

To avoid this problem we can separate the set of NICs into two parts

i. HL-NICs
ii. LL-NICs

The set of NIC used to communicate with Parent node is termed as HL-NIC. Also set of NIC used to communicate with its children nodes are termed as LL-NIC as shown in fig. 6. Each WMN node is responsible for assigning channels to its LL-NICs. The HL-NICs of each node can associated with a unique LL-NIC of its parent node and assigned the same channel as the parent's corresponding LL-NIC. By this restriction effectively prevents channel dependencies problem from propagating from a node's parent to its children, and thus ensures that a node can assign or modify its LL-NICs' channel assignment without ripple effects in the network. Because the gateway node does not have any parent, it uses all its NICs as LL-NICs. To increase the relay capability, each non-gateway node attempts to equally divide its NICs into HL-NICs and LL-NICs. By this process we can eliminate the above problem.

C. *INTERFACE-TO-CHANNEL ASSIGNMENT*

Once neighbour to interface mapping is determined then the final question is how to assign a channel to each of NICs. The channel assignment of a WMN node's HL-NICs is responsibility of its parent. To assign channels of a WMN node's LL-NICs, it needs to estimate the usage status of all channels within its interference neighbourhood. Each node therefore periodically exchange information as a CHNL_USAGE packet with all its (K+1) hop neighbours; Where K is the ratio between interference range and communication range. Because all the children and parent of a node, say A, can interfere with their own k hop neighbours, A's (k+1)-hop neighbourhood includes all the nodes that can potentially interfere with A's communication. The aggregate total Traffic-Load of a particular channel is estimated by summing of the load contributed by all interfering neighbours and the total-Load of a channel is weighted combination of aggregate Traffic-Load and number of node using the channel. Based on the per-channel total load information, a WMN node determines set of channels that are least-used in its vicinity.
The main constraints for channel-assignment are:

- In WMNs, the number of distinct channels can be assigned to NICs.
- Two nodes that communicate with each other directly should share one common channel
- Capacity of radio channel within an interference zone is limited
- The non-overlapped radio channel is fixed

IV. CHANNEL-ASSIGNMENT ALGORITHM

Step 1: All the NIC of a mesh node is divided into two groups HL-NICs and LL-NICs

Step 2: Set of NIC used to communicate with Parent node is termed as HL-NIC.

Step 3: Set of NIC used to communicate with its children node are termed as LL-NIC.

Step 4: HL-NIC ∩ LL-NIC = ɸ

Step 5: Each of node HL-NIC is associated with a unique LL-NIC of the parent node and is assign the same channel as LL-NICs of the parent node.

Step 6: Each node periodically exchange its individual channel uses information by CHNL_USAGE packet

Step 7: Total traffic load of a particular channel is estimated using CHNL_USAGE packet

Step 8: Based on the total traffic load of the channel optimized channel is found and is assign to the interface.

V. SIMULATION RESULTS

By the help of ns-2 simulations we can evaluate the performance of single channel and multi channel is shown in Fig. 7. Here this graph, the rectangular shows multi channel and the circle shows single channel. In this graph we take one axis as Network cross-section goodput and other axis as topologies; here we take ten different topologies. The Network cross section goodput is measure by the unit of mbps. We can see in this graph as the single channel gives below 5 mbps goodput but the multi channel gives 25 mbps goodput. So multi channel is better than single channel. The fact that only single channel is used within a tree means that there is still heavy collision and interference on the wireless links around each gateway, which is mostly likely where the bottleneck is. In contrast, the multi-channel mesh network architecture can split the wireless links around each gateway into as many collision domains as possible, thus delivering higher effective bandwidth.

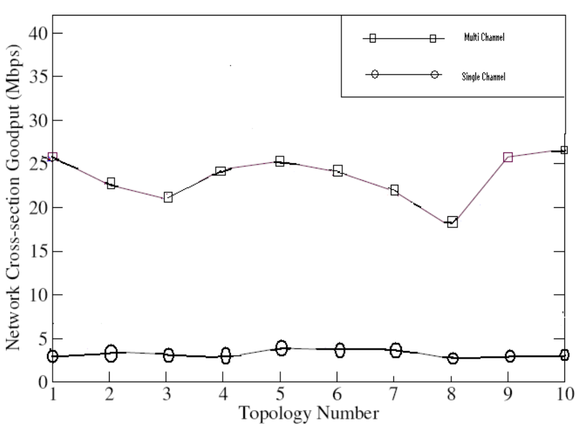

Fig. 7 Network Cross-Section Goodput is increase in Multi-Channel as compare in Single-Channel

VI. CONCLUSION

In this topic we have described the channel assignment algorithm that's helps us to avoid the channel dependency problem. Even if the bandwidth problem is even more serious for multi-hop wireless mesh networks (WMNs) due to interference between successive hops on the same path as well as that that between neighbouring paths. As a result conventional single channel WMNs can not adequately support the bandwidth requirements of last mile wireless broad band access networks, let alone a campus backbone that completely replaces the wired Ethernet. In this paper, we describe a novel multi-channel WMN architecture that effectively addresses this bandwidth problem by fully exploiting non-overlapped radio channels that the IEEE 802.11 standards make available

In particular, this paper addresses two fundamental design issues in the proposed multi-channel WMN architecture. First, which of available nom-overlapped radio channel should be assigned to each 802.11 interface in the WMN? For two nodes to communicate with each other, their interfaces need to assign to a common channel. However, as more interfaces within an interference range are assigned to same radio channel, the effective bandwidth available to each interface is decreases. Therefore, a channel assignment algorithms need to balance between maintaining network connectivity and increasing aggregate bandwidth. Second, how packets should be routed through a multi-channel wireless mesh network? The routing strategy in the network determines the load on each 802.11 interface, and in turn affects the bandwidth requirement and thus the channel assignment decision for each interface.

We will try to develop some other techniques for channel assignment which will further improve the performance of wireless mesh networks (WMNs).

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