Channel Re-Assignment in Wireless Mesh Networks based on Link Load Estimation

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ABSTRACT

A channel assignment scheme for multi-radio WMNs (Wireless Mesh Networks) to provide high-throughput paths especially for the highly loaded node with the best connectivity to the gateway(e.g. in terms of highest rate, lowest interference or both) is provided in this paper. We observed the flows on the links and data packets at each wireless access point in an existing wireless mesh backbone from logs files of traffic flows generated at gateway level. After observing, we estimate the traffic load for each network link using load estimation algorithm. We provide the links having maximum load to minimum interference channel i.e. non-interference channel based on IEEE 802.11. The performance evaluation shows that by using the proposed channel assignment, the network performance is improved.

KEYWORDS - wireless mesh networks; Multichannel; Multi-interface; load estimation; channel assignment.

1. INTRODUCTION

A Wireless Mesh Network (WMN) [3] is defined as being an infrastructure network working with an ad hoc mode. WMNs are dynamically self-organized and self configured networks that employ multihop [7] communications to transmit data traffic to and from Internet entry points. WMN is an upcoming technology that supplements wired infrastructure with wireless backbone to provide Internet connectivity to mobile nodes (MN) or users in residential areas and offices. The Wireless Mesh solution enables cost-effective and secure deployment of outdoor Wi-Fi networks. Outdoor wireless access takes advantage of the growing popularity of inexpensive Wi-Fi clients, enabling new service opportunities and applications that improve user productivity and responsiveness. As the demand for outdoor wireless access increases, customers faced with tight budgets and reduced resources must respond with wireless LAN (WLAN) solutions that take full advantage of existing tools, knowledge, and network resources to address ease of deployment and WLAN security issues in a cost-effective way.

In recent years, wireless mesh networks (WMN)**,** together with related applications and services, have been actively researched. New applications include digital home, broadband, and wireless home Internet access, community and neighborhood networking, enterprise networking, metropolitan area networks[1][2], building automation, health and medical systems, public safety and security surveillance systems, intelligent transportation systems, emergency and disaster networking, etc. Generally speaking, a WMN is a group of self-organized and self-configured mesh clients and mesh routers interconnected via wireless links.

The wireless mesh backbone node operates both as a *wireless router* that forwards packets of other nodes & as a *wireless bridge* transmitting the packets of its clients. WMN has the potential to deliver Internet broadband access, wireless local area network coverage and network connectivity for stationary or mobile hosts/users. There are several Internet gateways located at the edge of the backbone network so as to provide Internet access for the mesh network.

The core technology is based on routing packets in multihop fashion. When multi-channel wireless mesh nodes are considered, new routing protocols are needed. First, the routing protocol needs to select not only the optimal path in-between different nodes, but also the most appropriate communication channels on the path. Second, cross-layer and common-layer design become a necessity because changes in routing paths involve channel switching in a mesh node. Without considering cross-layer or common-layer design, the switching process may be too slow to degrade the performance of WMNs.

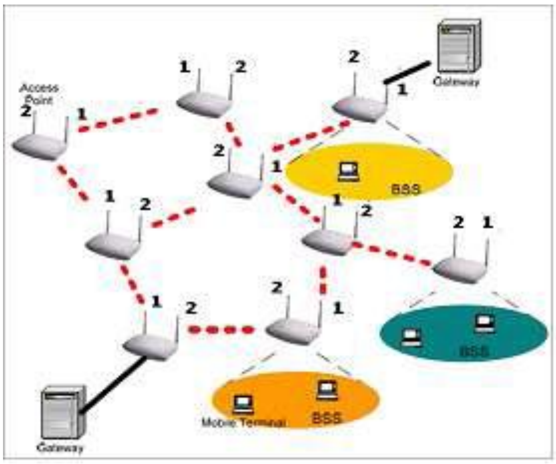

Fig1 : A multi-interface/multi-channel network

2. LITERATURE SURVEY

An important design goal for wireless mesh networks is *capacity*. It is well-known that wireless interference severely limits network capacity in multi-hop settings [5]. One common technique used to improve overall network capacity is use of multiple channels [6]. Essentially, wireless interference can be minimized by using orthogonal (non-interfering) channels for neighbouring wireless transmissions. The current IEEE 802.11 standard for WLANs (also used for mesh networks) indeed provides several orthogonal channels to facilitate the above. Presence of multiple channels requires us to address the problem of which channel to use for a particular transmission; the overall objective of such an assignment strategy is to minimize the overall network interference. IEEE 802.11 /b/g defines at least 11 channels and of these, at least three are completely non-overlapping (channels 1 [2402 MHz, 2422 MHz], 6 [2427 MHz, 2447 MHz], and 11 [2452 MHz, 2472 MHz]) as depicted in Fig2. Now, the issue of medium contention arises only when we are using the same channel or overlapping channels

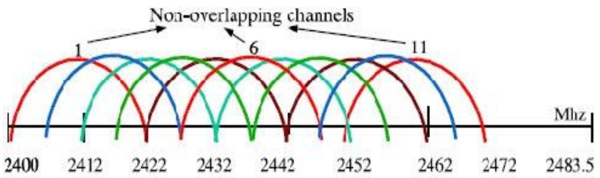

Fig 2

In Dynamic Channel Assignment, channels are frequently changed on the interface. The *dynamic channel assignment* approaches [4] require channel switching at a very fast rate (per packet or a handful of packets). The fast-channel switching requirement makes these approaches unsuitable for use with commodity hardware. Some of the dynamic channel assignment approaches also require specialized MAC protocols or extensions of 802.11 MAC layer. In order to use multiple channels with commodity hardware, there is need to develop techniques that assign channels statically [8][9][10]. Such static assignments can be changed whenever there are significant changes to traffic load or network topology; however, such changes are infrequent enough that the channel-switching delay and traffic measurement overheads are inconsequential.

The centralized quasi-static channel assignment algorithm is proposed in the context of networks with multi-radio nodes. In *quasi static channel assignments,* If there is only one radio interface per router, then the above channel assignment schemes will have to assign the *same* channel to all radios/links in the network to preserve network connectivity. In this channel assignment, novel load estimation technique is use to measure the link traffic load. The estimation considers the traffic load on link itself as well as the interference influence introduced by its neighborhood traffic load. Having the estimated load information, the algorithm can intelligently select channels for mesh radios with minimal interference, which as a result maximizes the network capacity. Quasi-static channel assignment strategies preserve the original network topology. Prior works on topology preserving channel assignment strategies are as follows. Adya et al. [11] propose a strategy wherein they assume a hard-coded assignment of channels to interfaces, and then determine which channel/interface to use for communication via a measurement-based approach. They do not discuss how the channels are assigned to interfaces. In [12], Raniwala et al. propose a centralized load-aware channel assignment algorithm; however, they require that source-destination pairs with associated traffic demands and routing paths be known a priori. In [13], Das et al. present a couple of optimization models for the static channel assignment problem in a multi-radio mesh network. However, they do not present any practical (polynomial time) algorithm. In [14], a purely measurement-based approach is taken for channel assignment to radios (instead of links). Here, one radio at each node is tuned to a common channel to preserve the original topology; however, this can be wasteful when only a few interfaces are available. Moreover, assignment of channels to radios still leaves the problem of which channel to use for a transmission/link. In the most closely related work to ours, Marina and Das in [15] address the channel assignment to communication links in a network with multiple radios per node. They propose a centralized heuristic for minimizing the network interference.

In quasi-static channel assignment, the gateway needs to estimate the expected load either when it receives the traffic information for the first time, or when the difference between the new traffic and the last one is large enough. In order to simplify the load estimation, we assume there is a link between every router pair in direct communication range and all shortest usable paths between a access router pair can perfectly balance the traffic load. If the number of all shortest usable paths between node s and d is $P(s, d)$, and in those paths there are $P\lambda(s, d)$ paths passes link *l*, then the initial expected load for link *l* to carry is calculated as follow:

$$\emptyset(l) = \sum_{s,d} \left(\frac{Pl(s,d)}{p(s,d)}\right) \gamma(s,d)$$

From equation the load share that one shortest usable path between a router pair is expected to carry is the end-to-end traffic divided by the total number of all shortest usable paths between the router pair. The sum of all load shares passing link l is its initial traffic load. Here only count the shortest usable paths because short paths always have more eximious performance compared with longer paths in multi-hop wireless networks if they all have enough usable bandwidth.

In quasi-static channel assignment, all the highly loaded channels (within a path between source and destination) are not assign by orthogonal channels. The objective of our problem is to present a channel assignment scheme for multi-radio WMNs (Wireless Mesh Networks) to provide high-throughput paths especially for the highly loaded node with the best connectivity to the gateway(e.g. in terms of highest rate, lowest interference or both).

Proposed Method

In this paper, we present a channel assignment scheme for multi-radio WMNs (Wireless Mesh Networks) to provide high-throughput paths especially for the highly loaded node with the best connectivity to the gateway(e.g. in terms of highest rate, lowest interference or both). We observed the flows on the links and data packets at each wireless access point in an existing wireless mesh backbone from logs files of traffic flows generated at gateway level. After observing, we estimate the traffic load for each network link using load estimation algorithm. We provide the links having maximum load to minimum interference channel i.e. non-interference channel based on IEEE 802.11. we show some problem arising in WMN and we discuss possible strategies to retrieve the problem and exploit it.

We are considering a Wireless-optical Broadband Access Network (WOBAN) for internet access. A WOBAN is an optimal combination of a wired network (optical backbone) and a wireless network (Wireless Mesh backbone). A set of wireless nodes or routers forms a wireless mesh network as wireless backbone. End users connect to the network through these mesh routers to access internet. A selected node called gateway are connected to the optical part (i.e. wired network) of the network. An end user sends/receive packets to a nearby wireless node. This packet travels through the wireless mesh possible over multiple hops via the gateway node. The architecture is shown below. Here we consider only download traffic, neglecting upload traffic as being very less. Our motive is to improve the performance of wireless mesh backbone network based on link load estimation. We observed the flows on the links in an existing wireless mesh backbone from logs files of traffic flows generated at gateway level. After observing the log files, we estimate the link load among different channels based on flows of data on the links. Now, we provide the links having maximum load to minimum interference channel i.e. non-interference channel to increase the channel bandwidth, data flow rate and thus the performance of whole mesh backbone network. We propose a scheme that estimates the link load among different channels based on the flows on the links from log files of traffic flows. A mesh backbone network with assigned channel is shown below:

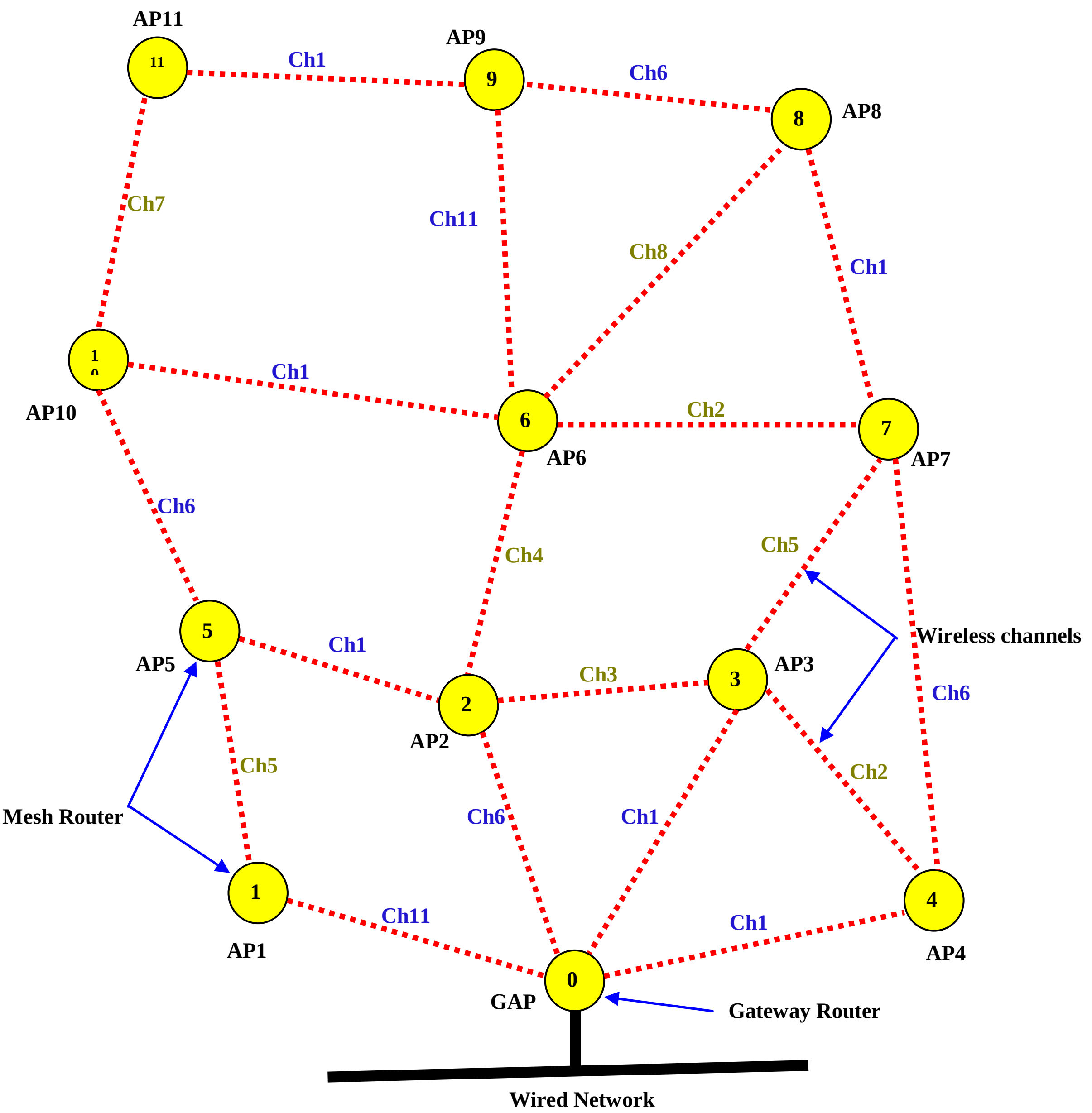

Fig 3 : Pre-allocated Wireless Mesh Backbone

3. TRAFFIC MEASUREMENT

Optimizations of channel assignment using load estimation require knowledge of network traffic information, so we need to measure the traffic load of mesh backbone nodes. The traffic load measurement is based on log file generated at gateway router. The log files define all traffic flows from source router (Gateway) to different destination routers. After receiving the information from log file, we calculate out the end-to-end traffic value between every pair of source and destination routers according to the aggregate flows information. Now we are arranging several source and destination in descending order of download traffics.

4. LINK LOAD ESTIMATION

In order to simplify the load estimation, we assume there is a link between every router pair in direct communication range and all shortest usable paths between a router pair can perfectly balance the traffic load. There are different methods for deriving a rough estimate of the expected link traffic load. These methods depend on the routing strategy used (e.g., load balanced routing, multipath routing, shortest path routing, and so on). A possible approach is based on the concept of load criticality [16]. Let P(s, d) denote the number of loop-free paths between a source-destination pair of nodes (s, d) and let *Pl* (s, d) be the number of them that pass through a given link *l*. Then the expected traffic load $\emptyset l$ on link is calculated as

$$\emptyset(l) = \sum_{s,d}\left(\frac{Pl(s,d)}{p(s,d)}\right)\gamma(s,d)$$

This equation implies that the initial expected traffic on a link is the sum of the loads from all acceptable paths, across all possible node pairs that pass through the link. Consider the logical topology as shown in Fig 4 and assume that we have the four flows reported in Table.

Table 1: Traffic profile with three flows

Source (*s*)	Destination (*d*)	γ (*s*,*d*) (Mbps)
GAP(S1)	AP9(D1)	1.5
GAP(S1)	AP10(D2)	1.2
GAP(S1)	AP7(D3)	0.9
GAP(S1)	AP5(D4)	0.5

Table 2: Possible flows between communicating nodes.

(source, destination)	**(S1,D1)**	**(S1,D2)**	**(S1,D3)**	**(S1,D4)**
Possible paths	0-2-6-9 0-3-7-8-9 0-4-3-7-8-9 0-1-5-10-6-9 0-3-7-6-9	0-1-5-10 0-2-5-10 0-3-7-6-10 0-4-3-7-6-10	0-2-6-8 0-3-7-8 0-1-5-10-6-8 0-4-3-7-8 0-2-6-9-8	0-1-5 0-2-5
P(source, destination)	5	4	5	2

Furthermore, we calculate P(s, d) for each flow. To this end, we need to determine all the possible source–destination paths, which can be achieved through a Route Discovery procedure [17]. Table reports the results for the topology in Fig 4. For practicality reasons, we have set an upper limit for the path length to 5 hops, e.g., by imposing a Time-To-Live to the Route Discovery broadcast packets. From the above information, we can now calculate how many paths pass a specific link in the network topology. These values and the corresponding link traffic load $\emptyset l$ calculated. Based on these calculations, we can estimate the load between each neighboring node. The meaning of $\emptyset l$, which we have calculated is the expected traffic load of link l, i.e., the amount of traffic expected to be carried over a specific link. The higher $\emptyset l$, the more critical the link. The idea is now to use this metric to decide which are the most congested points in the network, so as to assign possibly non interference frequency to heavily loaded links(route) and non-interference channels, or interference channel at all, to less congested links.

5. CHANNEL RE-ASSIGNMENT

After Knowledge of several sources and destination route in descending order of download traffics and the expected load on all network links, we can start to assign channels to the responding link. We provide the links of route having maximum load to minimum interference channel i.e. non-interference channel to increase the channel bandwidth, data flow rate and thus the performance of the whole mesh backbone network. The algorithm of channel assignment is described as follows:

ALGORITHM:

1> Find high loaded route to different destination from gateway and arrange them in descending order.
2> Select route (descending order of load).
3> Select first link of route.
4> Check channel assignment status(‘A’ for assigned and ‘NA’ for not assigned)
5> If channel assignment status is ‘NA’ then check previous two link assigned channel(non interfering channel), other interfaces assigned channel number and assign the link with next non interfering channel (used reused channel after 3 hops).
Say if first link has assign channel 1 and second link has channel 6 then third link is assigned channel 11.
Select next link of route and go to step 4.
6> If channel assignment status is ‘A’ then select next link of the route.
7> Check if hop=5 then go to step 2, else go to step 4.
8> After assigning the channels to all selected route, we assign the other links of mesh network with non-interference channel or interference channel.

After channel re-assignment, the mesh backbone network is shown in following figure:

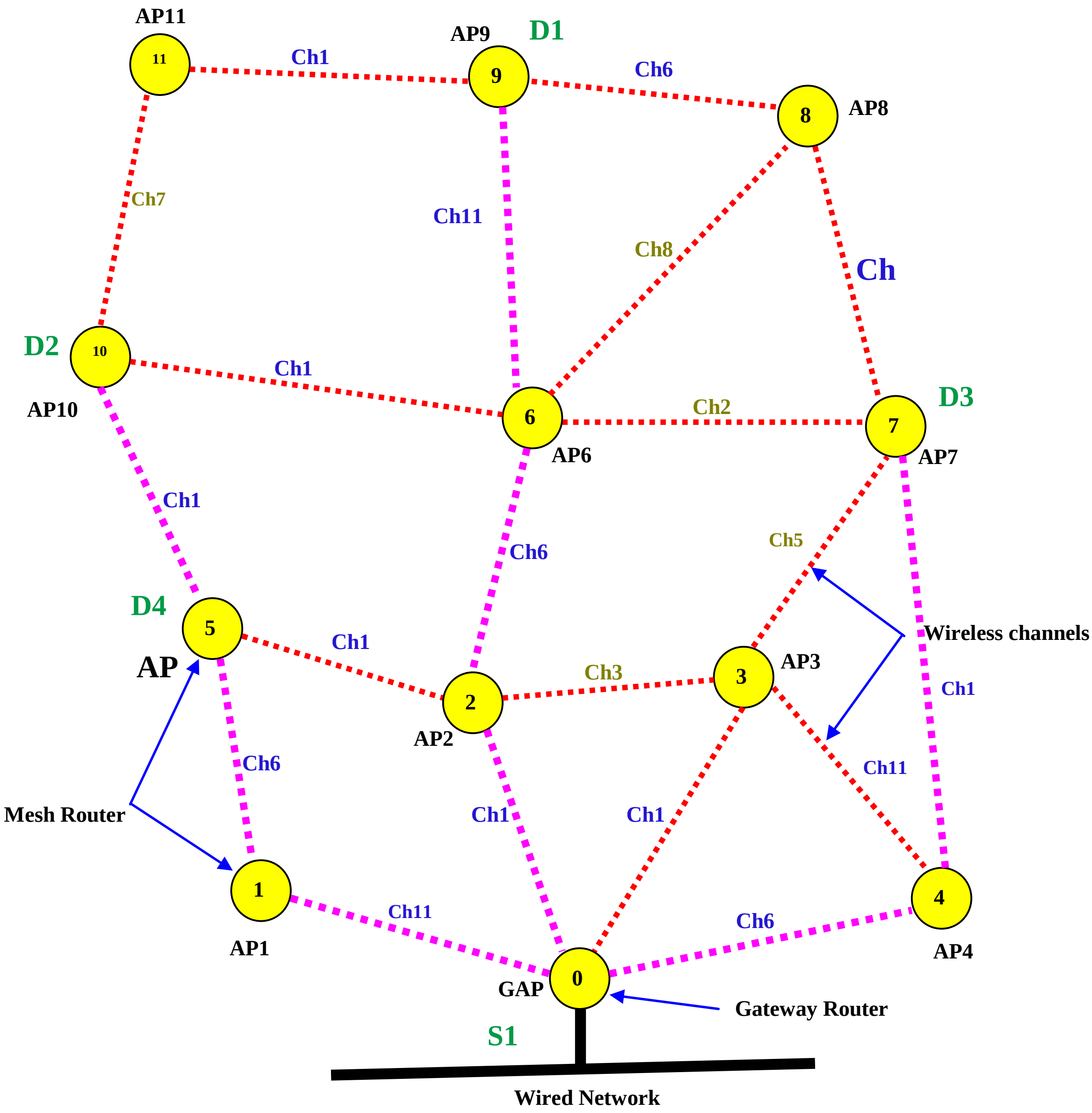

Fig 4 : Proposed Wireless Mesh Backbone

Here we assign channels statically to use multiple channels with commodity hardware. This techniques assign non-interference channels to the links having maximum load to increase the channel bandwidth, data flow rate and thus the performance of the whole mesh backbone network. Such static assignments can be changed whenever there are significant changes to traffic load or network topology. Since WMN is an infrastructure network and aims to provide reliable broadband services, such changes are infrequent enough that the channel-switching delay and traffic measurement overheads are insignificant.

6. SIMULATION ENVIRONMENT

We incorporate a corresponding channels assignment protocol in Network Simulator version 2 (ns-2) [18] to evaluate the channel assignments and algorithm performances. The ns-2 is a deterministic discrete event network simulator, initiated at the Lawrence Berkeley National Laboratory (LBNL) through the DARPA funded Virtual Internetwork Test bed (VINT) project. The VINT project is collaboration between the Information Sciences Institute (ISI) at the University of Southern California (USC), Xerox's Palo Alto Research Center (Xerox PARC), University of California at Berkeley (UCB) and LBNL. The AODV protocol is used as the routing protocol for the single-radio IEEE 802.11 network simulations. The topology of mesh networks (WOBAN network) in the simulations has 12-node as shown in figure 7. The bandwidth of each channel is 2 Mbps.

We modified the following files to make "Multi-channel Multi-interface" work in ns-2.33 for WMN.

1. Modifications in tcl/lib/ns-lib.tcl
2. Modifications in tcl/lib/ns-mobilenode.tcl
3. Modifications in mac/channel.h
4. Modifications in mac/channel.cc
5. Modifications in apps/udp.h
6. Modifications in apps/udp.cc

7. Modifications in tcp/tcp.h
8. Modifications in tcp/tcp.cc

7. SIMULATION RESULTS

We are taking three different traffics load to evaluate the channel assignment and algorithm performance. First taking 3 FTP traffics and 1 CBR traffic of packet size 200 bytes and interval 0.015 seconds. Second taking 3 FTP traffics and 1 CBR traffic of packet size 500 bytes and interval 0.015 seconds and third taking 3 FTP traffics and 1 CBR traffic of packet size 1000 bytes and interval 0.015 seconds. The obtained results are as follows.

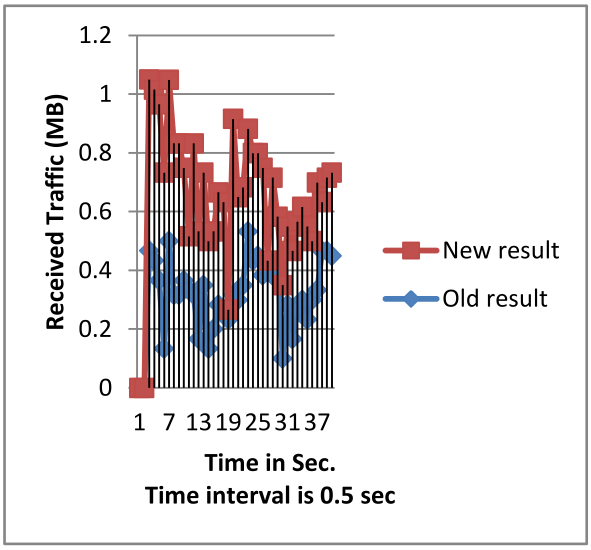

Fig 5

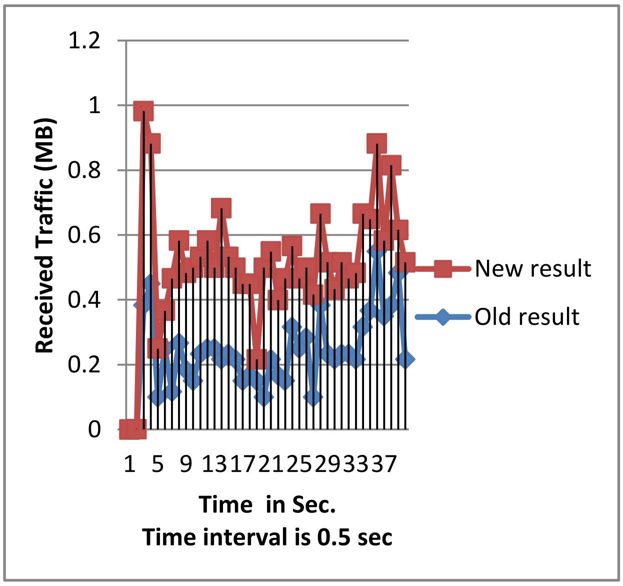

Fig 6

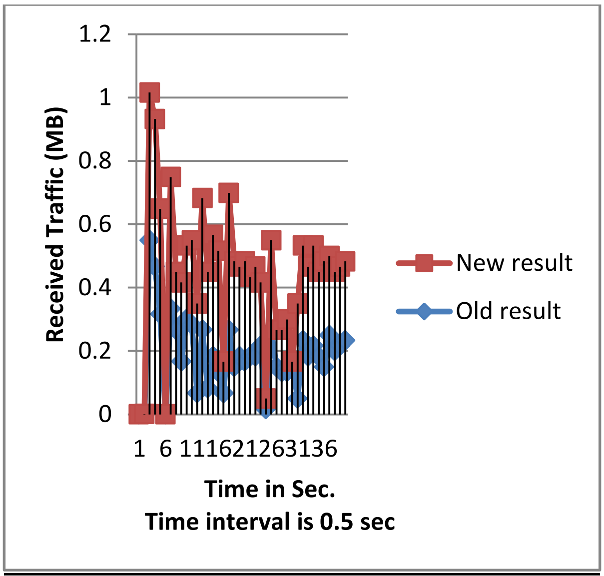

Fig 7

Future Research Works

Here an attempt has been taken to identify the best possible routes to the gateways from & to mesh client In Wireless Mesh Network due to multihop scenario throughput is considered. In future we incorporate this channel assignment method in dynamic channel assignment technique to minimize the interference of highly loaded route in WMN and hence increase the mesh network performance to a great instant.

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