Research on Interference-based Channel Assignment methods in 802.11-Based Wireless Mesh Network

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***Abstract*—The interference between wireless communications may cause packet loss and bit error. There are multi-channels in wireless standards such as IEEE802.11b/g, the packet loss rate caused by interference between channels is different. Experiments are done to show the transition feature between channels in IEEE 802.11b/g standard. The results show that the traffic throughput depends on the radio frequencies that the channels use, and the feature is different between TCP and UDP. The performance of TCP is further low on the interference environments, and there should be more suitable translation method in wireless network. Based on the results of experiments, a channel assignment algorithm is proposed to reuse the wireless space. Analyses show that the algorithm is simpler and can get similar performance improving in IEEE802.11-based Wireless mesh network.**

Keywords- Interference; WMN; channel assignment

I. INTRODUCTION

Wireless mesh network(WMN), a new promising wireless technology, which enables cost effective and scalable wireless networking to provide governmental agencies and individuals with access to fixed or mobile applications to enhance public safety, efficiency, productivity and responsiveness. Industrial standards groups are also enthusiastically researching on new specifications for mesh networks. In wireless mesh network, multi-channel assignment is a crucial problem. The scalability of WMN can be addressed by the MAC layer in two ways [1]. The first way is to enhance the existing MAC protocols to increase end-to-end throughput when only single channel is available in a station. The second way is to allow transmission on multiple channels in each station. But single channel assignment does not improve the last-mile wireless mesh network performance, so the proper way is to use multi-channel assignment to increase scalability and performance over single-channel MAC or multi-channel MAC. For increasing the bandwidth, lowering the latency and avoiding interference, optimal multi-channel assignment solution is obvious [2][3][4]. In wireless mesh network CSMA/CA is used than CSMA/CD, because collision detection is not applicable for wireless networking. CSMA/CA alone does not solve the interference issue; careful channel assignment is also influential for interference problem.

To show the influence of interference, experiments are done on the 802.11 test-bed. The results show that there are non-overlay channels in wireless transmit ions. Based on the results, a channel assignment method on WMN is proposed. The channel assignment method solves the multi-channel assignment problem by using minimum spanning tree and channel assignment algorithms. Analysis is performed to show the preferment of the method is similar with contributions by Hyacinth[5] and Bell Lab[6]. The experiments descriptions and results analysis will be presented in Section II. The channel assignment algorithm and analysis will be introduced in Section III. Section IV will be conclusion and future work.

II. INTERFERENCE EXPERIMENTS ON WIRELESS LINKS

The IEEE 802.11 standard establishes several requirements for the RF (Radio Frequency) transmission, which include the canalization schemes and the spectrum radiation of the signal. The 2.4GHz frequency ISM band is divided into 11 channels for the FCC or North American domain. These channels have a center frequency separation of only 5 MHz and an overall frequency occupation of 22MHz. So in IEEE 802.11b/g, the frequency from 2400MHz to2483MHz is divided into 11 channels. To show the influence of interference between different channels to upper layer, several experiments are done on a wireless test-bed.

A. Experiment scenarios

The test-bed is built up by two PCs with APs (access point) and two laptops with wireless cards, and the wireless standard is IEEE802.11b. The traffic flows transfer from laptop to AP, the distant of the two flows is less than 10 meters. One flow uses channel6 in the experiment, and the channels of the other flow change in every experiment. The flows will interfere each other when they work simultaneous. There are four kinds of flow pairs. The first scenarios are the frequency of two channels is non-overlapped such as channel6 vs. channel1. The second kind of scenarios is the center frequency of two channels is not overlapped, but the edge frequency of two channels is overlapped such as channel 6 and channel9. The third kind of scenarios is the center frequency of two channels

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is overlapped such as channel6 and channel7. The last scenarios are the two flows using the same channels.

The APs are set to "Long PLCP Preamble" in the physical layer and the work modes are infrastructure. The traffic rate of wireless cards and APs are set to 11Mbps. The traffic is TCP flows, with 1460 bytes payload, so the payload of MAC layer is 1500 bytes and there is no segment in these configurations. The goodput is computed by the received MAC layer frames in a unit time. Each experiment was done five times and the average goodput is recorded every second.

B. Experiment results

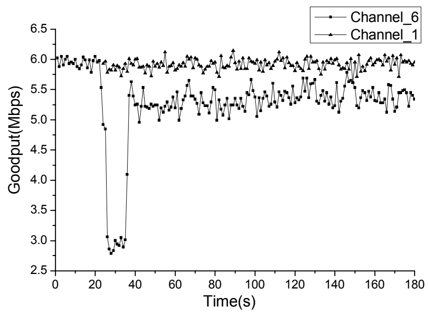

Fig.1 the results of goodput function time on the scenario1

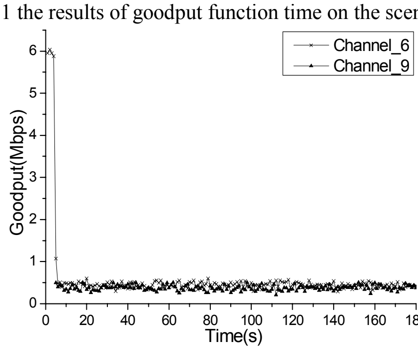

Fig.2 the results of goodput function time on the scenario channe2

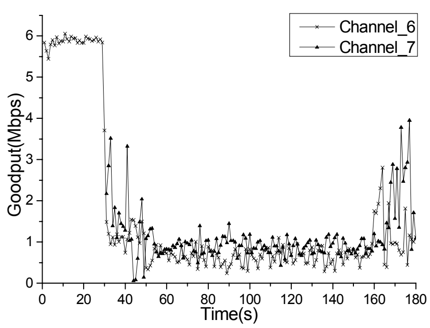

Fig.3 the results of goodput function time on the scenario3

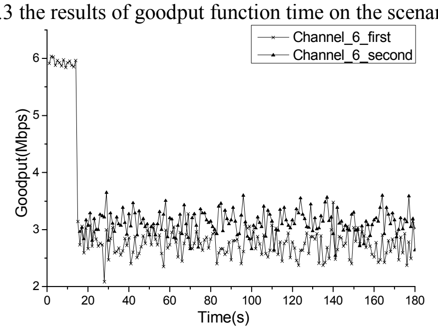

Fig.4 the results of goodput function time on the scenario4

Fig.1 is the results of the scenario which the frequency of two channels is non-overlapped, and the result of channel6 vs. channel1 is selected. The center frequency of chanel1 is 2412MHZ, and the center frequency of chanel6 is 2437MHZ. Because each channels use the bandwidth of 22MHZ, the frequency is non-overlaying between channel1 and channel6. The goodput of the two flows are between 5Mbps to 6Mbps. The jitter of the flows is lower that 0.5Mbps in most of time. The goodput of each flow is lower than the goodput of the goodput of single flow. The experiment results are similar under the scenarios of chanel6 vs. chanel11.

The center frequency of chanel9 is 2452MHZ. Fig.2 is the results of the scenario which the center frequency of two channels is not overlapped, but the edge frequency of two channels is overlapped. The experiment results are similar under the scenarios of chanel6vs chanel2, chanel6vs chanel3, chanel6vs chanel9, chanel6vs chanel10. The good put of each flow is change from 0.2Mbps to 0.5Mbps, and the goodput and jitter are both much lower than the first scenarios. Once the second flow started, the goodput decrease sharply.

The center frequency of chanel7 is 2442MHZ. Fig.3 is the results of the scenario which the center frequency of two channels is overlapped. The experiment results are similar under the scenarios of chanel6vs chanel4, chanel6vs chanel5, chanel6vs chanel8. the average thouput is higher than the second scenarios. Fig.4 is the results of the scenario which the two flows use the same channels. The goodput of flows is jittering obviously from 2.5Mbps to 3.5Mbps.

C. Results analysis

The goodput of one flow transferred alone is about 6Mbps, this is the highest throughput of TCP in this scenario. The goodput of two flows decrease when the second flow starts, but the influence to the throughput of TCP flows is different. The goodput of both flows are smooth in the first scenario, but they can not reach 6Mbps when they are work together. The total goodput of two flows are about 11Mbps, which is far higher than the goodput of single flow. It is obvious that there is a decrease from 25s to 35s in the flow started earlier, the decrease may be caused by other influence or by the adjust mechanism of TCP. The flow in channel1 is start later than the flow in channel6, the start of flow in channel1 may send messages in all channels, which may cause the congestion control mechanism of TCP in channel6.

The performance of the second scenario is far lower, the good put of both flows are about 0.5Mbps, the bandwidth is too low to use. This kind of frequencies are overlapped sharply, most of the frequencies are desperately. The wireless device may detect the channel is clear while the other flow is transmitting data. When the packets are dropped because of collection or error, it must be retransmitted in TCP, so the goodput is low for wrong judgments. The goodput of the third scenario is higher than the second scenario, the total throughput of two flows only reach 3Mbps. While the total goodput of last scenario reach 6Mbps as the single flow traffic. It shows the influence of the last scenario is smaller, but he jitters is further high. There is competition between the flows, and the two TCP flows share the bandwidth. It is said that in the non-overlapped channels, the flows can transmit simultaneous while the throughput decreases.

The low throughput in TCP may cause by several reason, the packet loss, the time out of transition and the congestion control mechanism on the routers. To show whether there are packet loss in wireless media, experiments based on UDP are done. The experiment environment of UDP is the same to that of TCP. One of the flows uses channel6 at every transition and the other flow changes from channel1 to channel11 in turn. MN1 and MN2 send 1000 UDP packets to AP1 and AP2 separately. The results of packet successful sent and received are listed in fig.5.

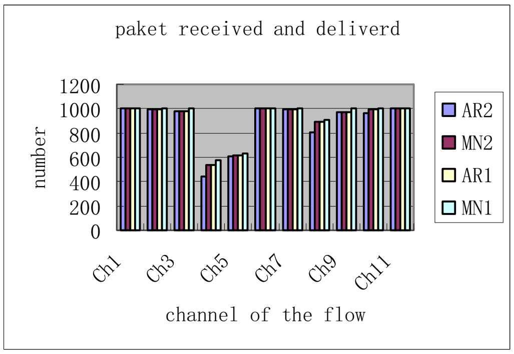

Fig.5 the result of channel contention using UDP

The results show that there is no packet lost in channel1 vs. channel6, channel6 vs. channel6, channel11vs. channel6, and there are packet loss in other channels. It is said that the low goodput in the traffic of channel6 vs. channel6 in TCP is caused by TCP mechanism and there should be TCP enhance method to deal with the problems. The experiment results of both TCP and UDP may depend on the wireless services, while most of wireless services are accord to international standard, the influence of service is not very big. The results confirmed that there are non-overlapped channels in wireless links, and the traffic throughput is acceptable between non-overlapped channels and the same channels. Correctly assign channels in WMN may highly improve the performances of transitions.

III. Channel Assignment Algorithm

Channel assignment is crucial in wireless mesh network. It extremely depends on the network topology. Especially, to avoid the interference that may arise because of several routers within range using a common channel. Competition gives the result of packet loss, degradation of throughput while increasing latency. For each router, there are multi-channels in deferent wireless standard, out of these channels some non-overlapped channels can be used sinuously, which were proved in the experiments above in IEEE802.11b. There are also non-overlapped channels in other wireless communication standards such as IEEE802.16, IEEE802.11a and so on. Many vendors are producing single antenna with multiple transceivers which use the MIMO technic, it also need channel assignment algorithm to improve the space reuse rate. The main constraints that a channel assignment algorithm needs to satisfy are:

- The number of distinct channels that can be assigned to a WMN router is bounded by the number of NICs it has, which means each NIC has only one channel to simultaneously communicate.
- Two routers that communicate with each other directly must share at least one common channel.
- The raw capacity of a radio channel within an interference zone is limited.
- The non-overlapped radio channels are fixed.

Channel assignment and routing issues are closely related. Both these channel assignment and routing algorithms should be considered together. In this section we will describe the algorithm and compare with other related issues in turn.

A. MST (Minimum Spanning Tree) Based Algorithm

Wireless mesh network topology will be loop-free, which is crucial for channel assignment to reduce interference. After known the topology of wireless mesh network, the assumptions and the algorithm are described below.

- Using MST (Minimum Spanning Tree) each router will be connected to each other is confirmed (assumed within wireless range).
- Any path, from any router to or from other routers or wired network typically it will be the shortest path, further discussion will be proceed next on this for different situations.
- Periodically check the connectivity. Because of router failure or addition of new routers, reconfigures the topology and reestablishes the wireless link by activating the path.
- Increase the stability and scalability of wireless mesh network through confirming stable communication.

B. Algorithm Description

The Kruskal's algorithm is used to find the minimum spanning tree.

Step-1: Find the least weight wireless RF range in the topology, if there is more than one then pick one at random. Store two routers R_i, R_j and RF range E_k in MST.

Step-2: Next least weighted wireless RF range not stored in MST, and that doesn't make cyclic graph or loop in topology. If Ri, Rj and E_k not stored in MST, store it.

Step-3: Repeat step-2 until reach out to all routers and there is only one tree in the topology.

After finishing this flow, we will get the minimum spanning tree where each router is connected in the topology according to their nearest wireless RF range.

C. Multi-Channel Assignment

The most important part for channel-assignment and routing is done after configuring the minimum spanning tree. Now, multi-channel assignment can be assigned in any combination such that -

- Router R_i is connected to router R_j and router R_k is connected to router R_j, then R_iR_j and R_jR_k should be assigned with channels for avoiding interference.

• In addition with the above situation, say, router R_1 is connected with R_k, within the RF range of R_j but not R_i, then RkR1 should not use the same channel as R_iR_j and R_jR_k.
• If R_k and R_1 routers are not within RF range of routers R_i and R_j, then same channel assignment as R_iR_j or any combination of channel assignment would be no problem, because both these nodes and their links are out of range to each other, no interference will be present there.
• Non-overlapped channels are first preferential.
• For each router using different channel combinations, given above, is helpful to avoid as maximum interference as possible, which ensures maximum performance and least latency.

D. *Performance Analysis*

- [5, 6] and our proposed algorithm, all consider that most client traffic is to access internet for resources, which is typically on wired networks.
- Wireless mesh topology is static (not mobile), this idea was implemented by all of these work.
- [5], [6] and our proposed multi-channel assignment is fixed channel assignment.
- [5] proposed a 10 node architecture with 5 channels, [6] proposed 4 node architecture with 4 channels. Increasing the wireless network size will increase the multi-channel assignment complexity there. On the other hand, our proposed architecture will support more than that without increasing complexity.
- [6] and our proposed algorithm implement the same idea that "channel-assignment and routing is inter-dependent". [5] Proposed a 10-node architecture with 5 channels, [6] proposed 4-node architecture with 4 channels. Increasing the wireless network size will increase the multi-channel assignment complexity there. On the other hand, our proposed architecture will support more than that without complexity.
- From the above discussions and performance analysis, we can say that our proposed multi-channel assignment will perform, at least same or better than other proposed algorithms [5] and [6]. Especially, it will depend on what configuration we are using for the test bed. As wireless mesh network multi-channel assignment critically governed by the topology design, our algorithm proposed the flexible solution to assign channels.
- Grid network design is counted as a tight network design, especially for wireless networking. Because, in grid network of wireless mesh routers, interference issues are very difficult to handle that influence network bandwidth and latency. In fig.6 shows the channel assignment result of MST algorithm in 4x4 grid wireless mesh network. Most of the links can transmit at the same time if there is only one transceiver on mesh router. But there are still a set of links will interfered each other at some scenario, the channel assignment problem is not solved completely.

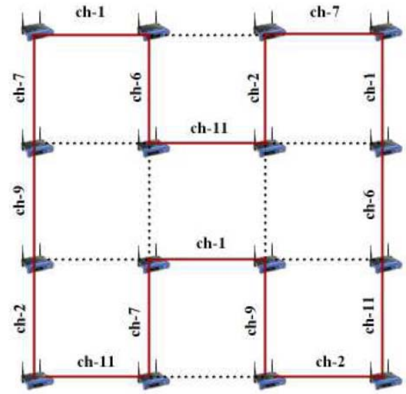

Fig.6 4x4 Grid WMN multi-channel assignment

IV. Conclusions and Future Work

This paper researches on the feature of wireless interference between different kinds of channels through experiments on IEEE802.11b test-bed. The experiment results of TCP and UDP show that there are non-overlapped channels according to the radio frequency the channel used. The throughput of TCP is decreased sharply during competition, while the packet loss rate in UDP decreases not so further than TCP. It is said that TCP is more sensitive in wireless communications. The experiments also proved that the non-overlapped channels can be used synchronous.

The channel assignment problem is an NP-hard problem. There is still overlapping on some links if the routing algorithm does not choose the best path. The proper way to solve the problem is assigning the suitable channels dynamic according to the next hop of routing algorism. Finding a dynamic routing and channel assigning algorithm is on of our future work. The performance of TCP decreases in the competition, design a modified TCP for wireless multi-hop network is on of our future work.

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