A Study on the Optimal Number of Interfaces in Wireless Mesh Network

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Abstract. In this paper, we obtain the optimal number of interfaces/channels in wireless mesh networks by simulation. The simulation study is done in static multi-channel multi-interface environment. When many nodes use a single interface/channel, collisions of RTS/CTS result in network performance degradation. To avoid such degradation and reduce interference among adjacent nodes, use of multi-interface/channel is considered. 802.11a and 802.11b offer 12 and 3 orthogonal channels and multi-interface/channel scheme could be applied. But rare research about the optimal number of interfaces/channels has been studied. In this paper, simulation study for the optimal number of interfaces/channels in wireless mesh network is performed.

Keywords: Wireless Mesh Networks, Optimal Number of Interface, Multi-channel, Multi-interface

1 Introduction

Wireless networks using IEEE 802.11 protocol in single-channel single-interface environment suffer end to end throughput decrease because of intra-flow interference and inter-flow interference in multi-hop environment. Accordingly multi-channel and multi-interface are needed to avoid these intra-flow and inter-flow problem. Nowadays IEEE 802.11a and 802.11b systems offer 12 and 3 orthogonal channels respectively to be used to reduced intra-flow or inter-flow interference. Although multi-channel in a single-interface may increase performance by reducing the interference, it may also give negative effects such as switching delay.

We considered adopting multi-interface as a solution to this problem. Recently with the advanced electronic technology, wireless nodes can have multi-interface for full-duplex transmission with low cost.

There are two schemes in multi-channel/multi-interface method; 1) when the number of channels is larger than the number of interfaces. 2) when the number of channels is the same as the number of interfaces. The first case gives channel flexibly but also needs efficient channel switching technique. Channel switching technique can increase channel usability but may increase switching delay [1]. In the second case, each channel is assigned to each interface and it is possible to receive and send signal simultaneously. It does not require switching technique or switching delay. So if wireless nodes use a single-channel per interface, it is expected to increase the performance. But research on the optimal number of interfaces has been rarely performed until now.

In this paper we consider only the case when the number of channels and interfaces is the same. We investigated the optimal number of interfaces by simulations.

After the Introduction, Section 2 analyzes related works and section 3 explains the multi-interface/channel model. Section 4 explains channel assign and routing. Section 5 analyzes simulation result in variously environment and section 6 concludes the paper.

2 Related Works

Many researches have been performed on channel assignment and its relations with the number of channels in multi-channel environment. [2] considered performance of multi-channel ad-hoc networks, especially when each channel is assigned an interface. In the work of [1], the relation of the number of channels per interface is analyzed. [3] studied routing, channel assignment and channel usage. Works [4]-[6] studied the increased performance in multi-channel single-interface. [7] and [8] proposed various methods for performance improvement in single-channel per interface.

Recently the cases when the number of interfaces are less than the number of channels are introduced [3][9][10].

However, the researches until now mostly studied on the method to increase network performance, channel assignment for efficiently channel usage, but did not suggest optimal number of interfaces.

3 Wireless Multi-interface/channel Model

Fig. 1 shows an example of the multi-interface/channel network model used for this research.

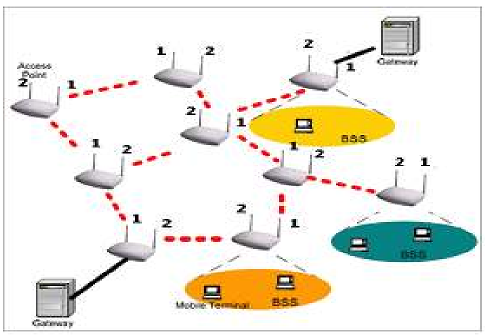

Fig. 1. An example of multi-interface/multi-channel network

We used a static wireless mesh network with several nodes. Each router in Fig. 1 has multi-interface and it is assumed that the number of channels is the same as the number of interfaces.

In Fig. 1 network, two interfaces are used by each router. The channel model of [1] is used where useable bandwidth is fixed. If useable bandwidth is W, each channel use same bandwidth. Accordingly if the number of channel is C, each channel use bandwidth only W/C. So with increased number of channels, each channel will use less bandwidth. In this research, we suggest that bandwidth is 11Mbps.

4 Channel Assignment and Routing

The channel assignment problem is a well known of NP-hard problem. It is also known that it is impossible to assign different channels to every flow in CSMA/CA environment[4]. Many researches of efficient channel assignment method are accomplished but these methods needed additional operation and complex assignment procedure.

In the paper, we concentrated on obtaining the optimal number of interface, so we used random channel assignment technique. Channel assignment and routing are set by static method. So the time to decide path and channel assignment are not included in the communication time. Below procedure show the channel assignment and routing process.

1) Select randomly source and destination node

2) Channel assign randomly to select relay node.

3) Repeat above procedure until to arrive destination.

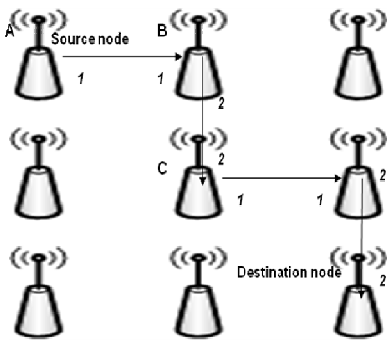

Fig. 2. An example of channel assignment and routing.

Fig. 2 shows one example of the above procedure. The small numbers in the arrows are channel numbers.

In Fig. 2, the flow started at node A. Path is selected by width, height direction order, so next B is selected. After selecting B as the relay node, a communication channel between A and B is assigned. In Fig. 2, channel 1 is selected. In A, select width direction node therefore in B height direction node C was selected. B and C are also assigned channel randomly, next configuration is continued in C. This procedure continued until to arrive the destination.

5 Simulation

In this research, we used ns2-2.30 for simulation and add some function to support multi-channel/interface [5]. Each node uses the number of interface between 1 to 7, and same number of channel. The total bandwidth is 11Mbps and assigned bandwidth of each channel is 11Mbps divided by the number of channels.

Wireless mesh nodes are arranged with fixed interval, so topology is like square form. Each nodes transmission range is 250m. For traffic generation, we create N x N, CBR(Constant Bit Rate) flows and set packet size of 1000byte. Flow was created at some nodes and destination nodes are randomly selected. We estimate network throughput as simulation result. Network throughput defined by the sum of all packets per second in all receiving nodes. Simulation was executed in 5 x 5 size networks and other sizes. Each simulation executed 100 times to get average, for a result.

5.1 Basis Simulation

As basis simulation, we used a static mesh networks with 5 x 5 network size. Fig. 3 shows a 5 x 5 network where each node is mesh router.

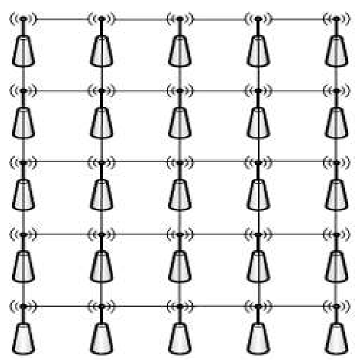

Fig. 3. A 5 x 5 size network.

Fig. 4 shows simulation result in 5 x 5 networks. We created 25 CBR flows and packet generation interval is 0.001sec.

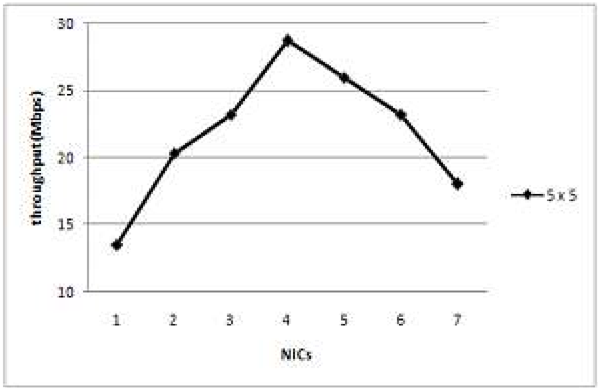

Fig. 4. Throughput when network size is 5x5, number of flows=25, and packet generation interval=0.001sec.

From Fig. 4, it is found that throughput increases when number of interface is less than 5. But with more than 4 interfaces, throughput decreases. This result informs that increasing the interface from 1 to 4 increases performance but increasing the number over 5 was useless.

5.2 Simulation in larger networks

In a large network, many nodes can be placed between source and destination nodes, resulting in a complex network states. Fig. 5 shows the simulation result with larger networks from 6x6 to 9x9.

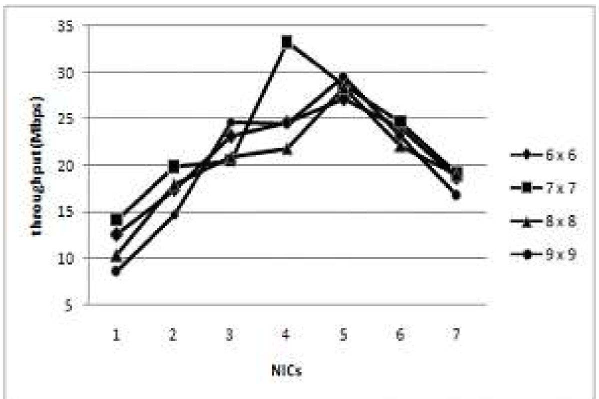

Fig. 5. Throughput when network sizes are NxN (6≤N≤9), number of flows=NxN, and packet generation interval=0.001sec.

In simulation test, if network size NxN(6≤N≤9), create NxN CBR flows and set packet generation interval is 0.001sec.

Figure 5 show that the result is optimization, when the number of interface is 4 or 5 in simulation as follow network size. It is informed that although network size more expand, number of interface is needed less than 6 for performance.

5.3 Simulation with change packet generation interval

Packet generation interval is more than short traffic is more generated, so network state is very complex. In this simulation we are change packet generation interval 0.1, 0.01, 0.001sec, respectively and observe the result. Figure 6 show that simulation result.

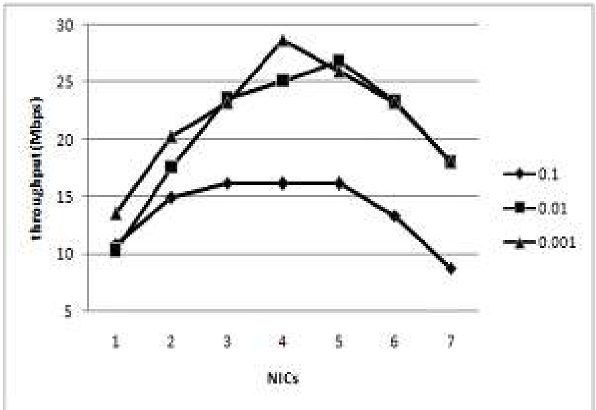

Fig. 6. Throughput when network size is 5x5, number of flows=25, and packet generation interval=0.001sec. 0.01sec and 0.1sec.

Also in this simulation show same result like before simulation. When packet generation interval is 0,1sec or 0.01sec, throughput increased before number of interface is less than 6 and in case 0.001sec, throughput increased before number of interface is less than 5. So this simulation is also informed that more than 5 interfaces are useless.

5.4 Simulation with different number of flows

We investigated the optimal number of interfaces for different number of flows from 20 to 35. Fig. 7 shows the simulation result.

Fig. 7 also informs that optimal number of interface is 4, when the number of flows changed.

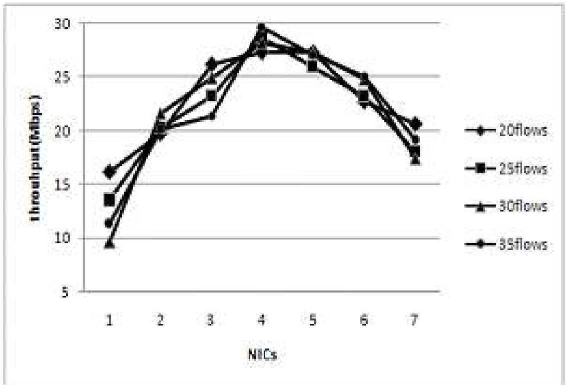

Fig. 7. Throughput when network size is 5x5, packet generation interval=0.001sec, and number of flows varies.

6 Conclusion

In this paper we find optimal number of interface through simulation in static wireless mesh networks. In simulation we use random assignment method because we concentrate on finding optimal number of interface. We considered network size, packet generation interval and number of flows as simulation parameters.

Simulation results informed that optimal number of interface is 4 or 5, for a grid static wireless mesh networks. It is shown from the simulation that the optimum number of interface is dependent on the network topology. It is a further study to consider various network topologies for simulation.

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