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Empirical Study on Wireless Multimedia & Mesh Ad-Hoc Network

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ABSTRACT

In this paper, we present about the construction of a wireless multimedia & mesh ad-hoc network needs to go across the mixed environment with the indoor, the wall-penetration, and the outdoor condition. This paper presents contribution to address the system design aspects of a multimedia enabled network based on IEEE 802.11g ad-hoc mode. There are distinct differences between indoor and outdoor environment and penetrating he walls stressed the system limit of the 802.11g ad-hoc mode. Therefore, routing decisions should be made intelligently with the environmental respect to maximize the bandwidth support on the end-to-end paths. One of the biggest issues in routing is providing adequate connectivity whiles calling the network. IEEE 802.16 employs TDMA (Time Division Multiple Access) as the access method and the policy for selecting scheduled links in a given time slot will definitely impact the system performance. We propose a collision-free centralized scheduling algorithm for IEEE 802.16 based Wireless Mesh Networks (WMN) to provide high-quality wireless multimedia services. We design a relay strategy for the mesh nodes in a transmission tree, taking special considerations on fairness, channel utilization and transmission delay

Keywords : MANET, Ad-Hoc Network, Topology.

I. INTRODUCTION

Many places (especially rural areas or military battlefields) are lack of the support of access points or base stations. Thus, a wireless multimedia network will not be complete without the support of the ad-hoc mode. Ad-hoc networks do not go through the conventional network infrastructures like access points/base stations or routers. Thus, the routing functions need to be provided by the peer nodes in the middle of the paths. Building an ad-hoc network imposes more difficulty since the communication relies solely on the ad-hoc mode (instead of infrastructure mode). In addition, since a truly ad-hoc network will possibly go across the mixed environments from indoor, walls to outdoor condition, it is important to obtain the baseline performance with different conditions. There are distinct differences between indoor and outdoor environments for the 54-Mbps 802.11g networks. Indoor environment always imposes with ceiling and walls, which allow the signal to have more ways to propagate the signals. It is also true that indoor environments may also impose many objects (e.g., desks and chairs) which intend to scatter the signals. On the other hand, outdoor environments do not impose ceiling, thus the signals tend to propagate like water ripples. But the natural obstacles as well as temperature and humidity condition may also play a role on the effective bandwidth that the system can achieve. The moving objects such like cars and people are also the factors affecting the results. Consider Fig. 1 as a simplified example: The source nodes in Building 1 can't directly talk to the destination nodes in Building 2 due to long distance. Thus, the connection needs to be built via the routing nodes in between. Some of these routing nodes are within the building 1, some of them are located outdoors. Since the ad-hoc mode of 54-Mbps 802.11g network interface cards only reach no more than 30 meters, some routing needs to be performed within the indoor environments.

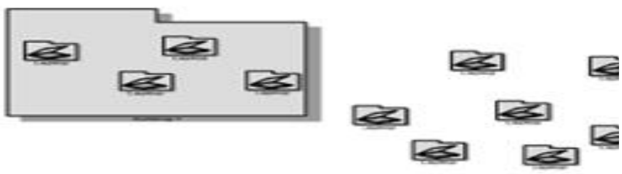

Figure.1 An Example of the ad-hoc 802.11g network (every laptop is served as a node)

After the connection setup reaches to the edge of the building, the signals need to penetrate the building walls to reach the routing nodes outside the building. Then the connection will be maintained by the routing nodes in the outdoor environments. Eventually the connection reaches to the edge area of the Building 2, which needs another signal penetration to reach the nodes inside the indoor environment again. Ideally, the paths can be constructed automatically by locating the proper routing nodes such that the overall bandwidth can be maximized. Nevertheless, it is not clear how 802.11g ad-hoc mode performs under these different environments and how much the distance factor will contribute the overall performance. The environmental effects should be taken into consideration when it comes to distributed multimedia applications which require high bandwidth support. Therefore, the routing algorithms should be also adaptive with respect to the different environments. In order to construct a truly ad-hoc network, we thus firstly investigate the average throughput between two laptop computers with the ad-hoc mode. Most importantly, it is our hope that different performance characteristics between indoor and outdoor settings can be collected. Then, these characteristics will be used by us to model a large-scale wireless ad-hoc network. Since wireless environment (including ad-hoc networks) does introduce much higher error rates for the data transmission, users hardly enjoy the peak performance reported by the nether tools. Instead, the average performance is perhaps the true one experienced by the common users. We thus developed the software tools that benchmark the average performance achieved by the ad-hoc communication. Our benchmarking software emulates the constant streaming of multimedia data between two hosts. One host decides the sizes of messages in block of video/audio frames, and transmits the messages to the other host. Once the other host receives the messages, it will prepare the identical sizes of messages for sending back to the sending host.

In IEEE 802.16 protocol stack, the medium access control layer (MAC) supports both point-to-multipoint (P2MP) mode and mesh (multipoint-to-multipoint) mode. In the mesh mode, scheduling is one of the most important problems that will impact the system performance. A scheduling is a sequence of fixed-length time slots, where each possible transmission is assigned a time slot in such a way that the transmissions assigned to the same time slot do not collide. Generally, there are two kinds of scheduling - broadcast and link. In broadcast scheduling, the entities scheduled are the nodes themselves. The transmission of a node is intended for, and must be received collision-free by all of its neighbors. While in a link scheduling, the links between nodes are scheduled. The transmission of a node is intended for a particular neighbor, and it is required that there be no collision at this receiver. WMNs have much longer duration times.

II. BASELINE EXPERIMENTS

Laptop computers are adopted to perform the actual experiments. Both of them have Pentium IV processor (with Centurion Technology), 512M memory and 40G hard disk. We then used two identical wireless adapters to be installed within the laptop to carry out this experiment. The Linksys 802.11g wireless cards use 2.4-GHz frequency with the theoretical bandwidth up to 54Mbps.The mode has been set in ad-hoc mode and the number of channel

is set to six. The subnet mask is set as 255.255.255.0 with gateway function disabled. In addition to the identical hardware, we also adopted the same operation system

(Microsoft Windows XP) on the laptops. This typical OS/hardware configuration perhaps represents the popular platform for over 90% of end users. We then built our own benchmarking software on top of the TCP/UDP/IP protocol stack embedded in Windows XP operating system. Our benchmarking process can be repeated with a predefined number of times (e.g., 100 times in our experiments) to provide the useful statistics based on the round-trip delay time measurement. In addition, our benchmarking software discards the top 2.5% and bottom 2.5% of the measured results. Thus, our results represent the 95% interval of the average performance. Therefore, instead of reporting the best or worst results, our reported data actually reflect what the typical performance will be. We believe this approach of measurement will be more trustworthy for the common users. In order to get a complete view of the throughput result, we used both TCP and UDP to test the throughput. And we also did the experiments in three different environments: indoor without obstructions, outdoor without obstructions, and one laptop indoor with the other outdoor but one wall in-between them, we call this situation as the wall-penetration situation.

2.1 Indoor without obstructions

For this experiment, we chose the Computer Information Science Engineering building basement as our experiment location in order to minimize the interference of access point of the infrastructure wireless connections. In the basement, we chose a straight hallway about 30 meters long, and then put one laptop at each side. The experiment environment is as Figure 2. And then we did the experiment at three distances: TCP, UDP with distance within 5m; TCP, UDP with distance at between 5m and 10m; TCP, UDP with distance between 10m and 20m.

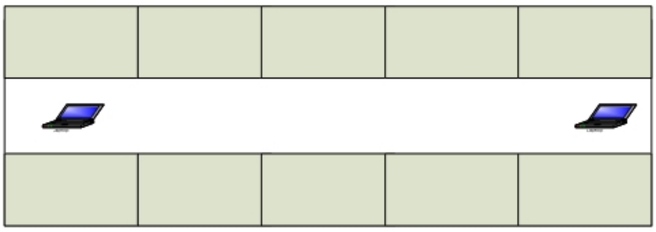

Figure 2. Indoor Experiment Environment

2.2 Outdoor without obstructions

For this experiment, we chose a large parking lot at VA hospital, and did the experiments when there are few cars far away parked in order to minimize the interference of cars. And also, as we did in the indoor without obstructions experiment, we did the experiment at 5m, 10m, 15m 20m and 25m.

2.3 Penetrating wall

For this experiment, we put one laptop indoor, and the other laptop outdoor, then we fixed the indoor laptop's position, moved the outdoor laptop so that the distance between them is changing with distance: 5m, 10m, 15m, and 20m. In between them there is a wall as the obstruction, the wireless signal has to penetrate the wall. In order to minimize the interference of the AP wireless connection, we chose New Physics Building basement as the experiment environment. The experiment environment is as in Figure 3:

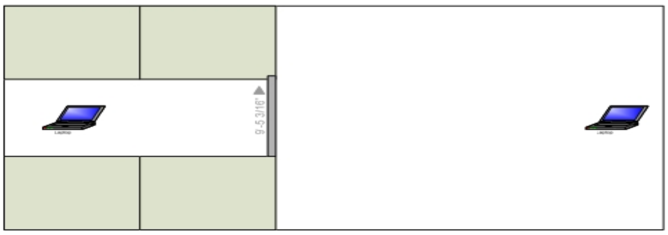

Figure 3. Penetrating Experiment Environment

III. IEEE 802.16 WIRELESS MESH MODE

In IEEE 802.16 P2MP operation, wireless links operator among a central Base Station (BS) and a set of Subscriber Stations (SSs). The BS is the only transmitter operating in the downlink (from BS to SS), so it transmits without having to coordinate with other stations. Subscriber stations share the uplink to the BS on a demand basis. Whereas in the mesh mode, all nodes are organized in an ad hoc fashion, each node can relay traffic for others and Quos is provisioned on a packet-by-packet basis. A system that has a direct connection to backhaul services outside the mesh network is termed the Mesh BS. All the other systems of a mesh network are termed Mesh SSs. Uplinks and downlinks are defined as the directions to and from the Mesh BS, respectively. Mesh differs from P2MP mode in that in the mesh mode, traffic can be routed through other Mesh SSs and can occur directly between the Mesh SSs, whereas in the P2MP mode, traffic only occurs between the BS and SSs. Moreover, unlike P2MP mode, the mesh mode only supports Time Division Duplex (TDD) for uplink and downlink traffic [3]. For the transmission, several SSs share the wireless channel in a TDMA fashion. In what follows, unless specified otherwise, we will refer to BS and SS as Mesh BS and Mesh SS, respectively. And we will use the terms SS and node interchangeably. A new SS, say u, entering IEEE 802.16 based WMN obeys the following procedures. At first u scans for MSH-NCFG (Mesh Network Configuration) messages to establish coarse synchronization with the network (the cost of synchronization phase is beyond the scope of this paper). Then u shall build a physical neighbor list from the acquired information. From this list, u selects a Sponsoring Node (SN) according to some policy. A sponsoring node is defined as a neighboring node that relays MAC messages to and from the BS for u. namely, it is an upstream node that is closer the BS. Registration is the process where u is assigned its node ID. After entering the network, a node can also establish links with other nodes. Fig. 1 gives an example of network topology which is composed of one BS and 11 SSs. There is a link between two SSs if they are within the transmission range of each other. Fig. 2 shows the corresponding scheduling tree (or called transmission tree) that only contains the transmission links between a node and its SN. We define the omitted links in Fig. 2 (compared with Fig. 1) as interference links. BS will periodically broadcast MSH-CSCF (Mesh Centralized Scheduling Configuration) messages that include the complete topology of scheduling tree to the nodes. Due to the centralized nature of the scheduling algorithm, there is no hidden terminal problem here. In IEEE 802.16 based WMNs, communications going through all the transmission links shall be controlled by a scheduling algorithm. There are three kinds of scheduling in IEEE 802.16 mesh mode: centralized, coordinated distributed and uncoordinated distributed scheduling. We will brief the general idea of centralized scheduling (the focus of this paper) below. For distributed scheduling, we refer interested readers to [9]. Using centralized scheduling; the BS shall gather traffic demands through MSH-CSCH (Mesh Centralized Scheduling) messages from all the SSs within a certain hop range and communicates the information to all the SSs. Subsequently,

the SSs determine their own transmission opportunities in a distributed fashion, using a common predetermined algorithm with the same input information. Therefore, the outputs are the same for all these SSs. The SSs will let the BS know their changes of traffic demands through MSH-CSCH messages. Then the BS will rebroadcast the adjusted traffic demands and the SSs can recalculate their transmission opportunities. To quote IEEE 802.16 standard [9], the advantage of centralized scheduling is that "it is typically used in a more optimal manner than distributed scheduling for traffic streams, which persist over a duration that is greater than the cycle time to relay the new resource requests and distribute the updated schedule". However, the detail of this centralized algorithm is not defined in IEEE 802.16 standard.

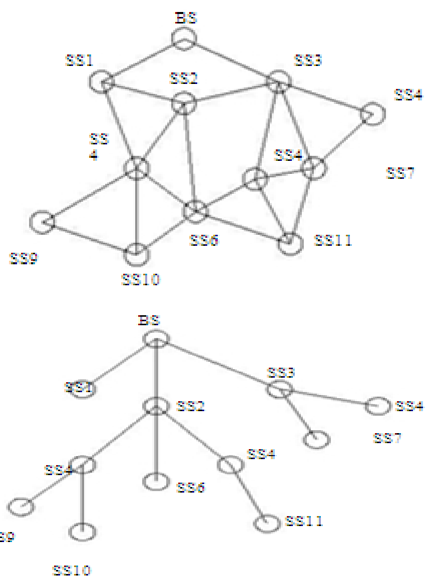

Figure 4. Network Topology

IV. CONCLUSION

There are distinctly performance differences between indoor/outdoor environments and penetrating the walls using the ad-hoc mode. We have performed the systematic experiments to collect the performance characteristics. With the unique findings, our proposed routing schemes have improved the end-to-end bandwidth significantly. Our proposed schemes carefully choose the node-to-node routing distances (e.g., 7 meters and 20 meters in our 802.11g model), therefore improves the quality of user-level applications by providing sufficient bandwidth across the selected paths. We are in the process to further optimize the performance improvement to suggest that some routing nodes can move away from their current locations (to increase/decrease the distance with some other nodes). With the placement flexibility in the outdoor environment, the system designer can relocate the selected ad-hoc networking nodes into the proper locations. Wireless mesh networks are a large-scale solution to provide Internet access to mobile users. Routing data to the gateways is fundamentally different from routing towards specific mesh nodes. We proposed a collision-free centralized scheduling algorithm for IEEE 802.16 based WMNs.

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