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A NOVEL APPROACH OF CHANNEL SPLITTING FOR REDUCING HANDOFF DELAY IN WIRELESS MESH NETWORKS

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Abstract: A channel splitting scheme is proposed to improve both link and network-layer handoffs in WMNs. We first considered two setups when an MC has one or two transceivers and proposed different handoff procedures using the channel splitting strategy. In the first design, the time for the link-layer channel scanning process can be reduced, whereas in the second design, the handoff process and data reception can be executed at the same time. In both designs, the channel contentions between handoff signaling packets and data packets at each MR are eliminated. In addition, we proposed two transmission strategies in the wireless mesh backbone, i.e., SCT and CCT, to improve the overall handoff performance as well as the ETE data performance. OPNET simulation results show that the SCT design is more suitable to the high handoff frequency situation; on the other hand, the CCT design is fit for the low handoff frequency scenario. Simulation results also show that the handoff delay and data packet ETE delay can be significantly improved using the proposed channel splitting strategy, as compared with the traditional single-channel-based and priority-queue-based methods. Moreover, the average channel utilization can also be greatly improved by our proposed SCT and CCT designs, as compared with the two-channel-based design.

Keywords: Channel splitting, handoffs, Mobile IP, wireless mesh networks (WMNs).

I. INTRODUCTION

Wireless communications is one of the most active areas of the technology development of our time. Moore's law, which asserts a doubling of processor capabilities every 18 months, has been quite accurate over the past 20 years and its accuracy promises to continue for years to come. Most of the researchers aimed at developing new wireless capacity through the deployment of greater intelligence in wireless networks. A key aspect of this movement has been the development of novel reduces handoff delay in internet based wireless network. Wireless mesh networks (WMNs) provides large scale wireless Internet access [1],[2]. The architecture of wireless mesh network consists a combination of static mesh routers (MRs) and mobile mesh clients (MCs). In a typical WMN, MRs forms a wireless multihop backbone network. Some MRs Serve as wireless access points (APs) to provide wireless mesh backbone entries to MCs. Some MRs, called gateway MRs, are connected to the Internet via wired links and serve as Internet entry points to other MRs via single-hop or multihop wireless links. MCs can move freely in WMNs when communicating with correspondent nodes (CNs) by means of handoffs between different Aps .Each subnet in the wireless mesh backbone has a different gateway to access Internet. There are two types of handoffs in WMNs: 1.The intergateway handoff.2.The intragateway handoff. When the mobile client travels from one place to another its access point changes. Changing of access point requires executing handoff process. The handoff process is of two steps: 1.The link-layer handoff.2.The network-layer handoff. Link Layer Handoff: During the link-layer handoff process, the MC chooses an AP with the best received signal strength (RSS) as its new AP and switches its transceiver to the access channel of the new AP. In the network-layer handoff process, since the MC has moved into a new subnet on the Internet, it obtains a new IP address, establishes a new route to the new gateway, and registers the new IP address to its home agent (HA). The intragateway handoff has the same link-layer handoff process as the intergateway handoff. However, since no IP address changes when an MC moves within a subnet, the MC does not need to update its IP address to its HA, and therefore, the intragateway network-layer handoff only includes the multihop routing between the gateway and the new AP. Project focuses on the intergateway handoff design in Internet-based multihop WMNs. Network Layer Handoff: During the network-layer handoff, network-layer signaling packets need to be transmitted between the MC and the Internet via the multihop wireless mesh backbone. If the network-layer signaling packet end-to-end (ETE) delay is short enough, the movement of MCs is transparent to applications. However, the existence of multihop wireless links in the mesh backbone network can degrade the throughput significantly due to the delay of channel access over multihop links [3], [4], which results in very long intergateway handoff delay in multihop WMNs As shown in Figs. 1 and 2, OPNET [5] results also indicate that the intergateway handoff performance can be largely degraded, particularly when the number of wireless hops connecting the MC and the Internet grows or the backbone traffic volume increases. In particular, the upsurge of the network-layer handoff delay is fueled by the increase in signaling packet ETE delay, which can account for up to 80% of the total intergateway handoff delay. Hence, the multihop ETE delay of signaling packets is a main component of the long intergateway handoff delay in Internet-based WMNs, particularly when the backbone traffic volume is high. However, this critical issue is ignored in existing WMN handoff solutions that mostly focus on shortening the link-layer channel scanning delay optimizing Mobile IP for better network-layer handoff support and improving multihop routing in the mesh backbone. Therefore, this paper focuses on reducing the long ETE delay of handoff Signaling packets in multihop WMNs. Particularly, we consider the improvement of the intergateway handoff performance by intelligently splitting channel resources to reduce the medium access delay and queuing delay of handoff signaling packets at each MR. MCs may suffer a long intergateway handoff delay if high traffic volume exists in the wireless mesh backbone. Due to the competition for accessing the channels among several MRs in the wireless mesh backbone, the shortage of channel resources can lead to long queuing delay and medium access delay of handoff signaling packets at each MR. The transmission design of handoff signaling packets in the wireless mesh backbone is crucial to the intergateway handoff performance in WMNs. Considering this point, we address the seamless intergateway handoff support issue from a different perspective and propose a channel splitting strategy to split each channel in the wireless mesh backbone into two channels by means of the frequency division multiple-access technique: a data channel and a control channel. The data channel is used to transmit data packets, whereas the control channel is specialized for delivering handoff signaling packets and other control packets.Signaling packets in multihop WMNs. Particularly, we consider the improvement of the intergateway handoff performance by intelligently splitting channel resources to reduce the medium access delay and queuing delay of handoff signaling packets at each MR.

In a single-radio 802.11-based [10] WMN, as can be seen in Fig. 2, MCs may suffer a long intergateway handoff delay if high traffic volume exists in the wireless mesh backbone. Due to the competition for accessing the channels among several MRs in the wireless mesh backbone, the shortage of channel resources can lead to long queuing delay and medium access delay of handoff signaling packets at each MR. Some packets, including handoff signaling packets, may be dropped by MRs due to buffer overflow or retry threshold exceed, leading to the failure of handoffs. Therefore, the transmission design of handoff signaling packets in the wireless mesh backbone is crucial to the intergateway handoff performance in WMNs.

Considering this point, we address the seamless intergateway handoff support issue from a different perspective and propose a channel splitting strategy to split each channel in the wireless mesh backbone into two channels by means of the frequency division multiple-access technique: a data channel and a control channel. The

data channel is used to transmit data packets Whereas the control channel is specialized for delivering handoff signaling packets and other control packets. Although such channel splitting method has been proposed previously [11]–[13], it has not been well designed to reduce both the link-layer and network-layer handoff latencies in Internet-based WMNs. In our proposed handoff design, data packets and signaling packets are delivered in separate channels. They do not interfere with each other; thereby, the handoff latency can be maintained within a certain level regardless of the background data traffic. The rest of this paper is organized as follows. In Section II, related work on WMN handoff management is introduced. In Sections III and IV, our proposed channel splitting strategy for handoffs is described. In Section V, OPNET [5] simulation results are given, followed by the conclusions in Section VI.

II. BACKGROUND AND RELATED WORK

A. TRADITIONAL HANDOFF PROCEDURES IN INTERNET-BASED WMNS: The traditional handoff procedures of the link-layer and network-layer handoffs in IEEE 802.11-based WMNs based on extending the Mobile IP [7] scheme to multihop wireless networks.

When an MC detects that the RSS from the current AP is below a certain threshold, the channel scanning process of finding a new AP begins. The MC switches its transceiver to the first channel and sends a Probe Request message. Meanwhile, it starts the ProbeTimer. When the ProbeTimer expires, the MC proceeds to scan the next channel. Having finished scanning all the channels, the MC processes all the received Probe Response messages and determines the AP with the best RSS value as its new AP. Then, the MC switches to the new AP’s channel and sends an Authentication Request message to the new AP, which replies an Authentication Response message. After being approved by the new AP, the MC sends a Reassociation Request message to the new AP and then receives a Reassociation Reply message from the new AP to complete the link-layer handoff. If the new AP is connected to a new subnet in the Internet via a new gateway, a network-layer handoff is also needed to update the IP address and/or the routing path between the new gateway and the MC. To initiate the network-layer handoff, the MC first obtains a new IP address either from the new AP or the new gateway. The MC obtains a new IP address from the new AP based on the Mobile IP [7] process. Then, the MC searches an available route to the new gateway and sends a Registration Request message to its HA in the Internet for address update. The HA updates the new IP address of the MC in its database and sends a Registration Reply message to the MC. The whole handoff process is finished when the MC receives data packets from the new AP via the new gateway. In conclusion, during the entire handoff process, several network-layer signaling packets, such as Route Request/Response and Registration Request/Reply, are generated to facilitate the continuous communications of MCs, which may potentially compete with the data packets of other MCs to access channels in the multihop wireless mesh backbone.

B. RELATED WORK ON WMN HANDOFF MANAGEMENT AND OUR CONTRIBUTION: Various solutions on WMN handoff management have been proposed to optimize the handoff process to shorten the handoff latency [14]. Mishra et al. [15] point out that the channel scanning delay accounts for more than 90% of the overall link layer handoff delay in IEEE 802.11-based wireless networks. Hence, different link-layer handoff schemes are proposed on improving the channel scanning process to reduce the link layer handoff delay [6], [16]–[19]. To reduce the network-layer handoff delay, [20]–[22] exploit the two-channel technology as well as multiple transceivers to schedule the transmission of signaling and data packets; [23] and [24] propose new network Infrastructures to facilitate the overall handoff process; [25] introduces the concept of temporary IP addresses to shorten the delay of applying a new Care-of Address; [9] and [26] provide solutions to reduce the route discovery delay in the WMN network-layer handoff; and [8] presents a WMN mobility management scheme to shorten the handoff delay by reducing the signaling cost. In addition, [27] takes advantage of the priority queue solution to improve the performance of delay-sensitive applications.

To sum up, existing WMN handoff schemes do not consider resolving the wireless channel access contentions between handoff signaling packets and data packets during a handoff process. Since the network-layer handoff process generates network-layer handoff signaling traffic that needs to be delivered over the multihop wireless mesh backbone, the handoff delay is affected by the volume of the data traffic competing the wireless channels with the handoff signaling traffic in the wireless mesh backbone. When the background data traffic is heavy, the overall intergateway handoff delay could be very long due to the long queuing delay and the channel access delay of handoff signaling packets.

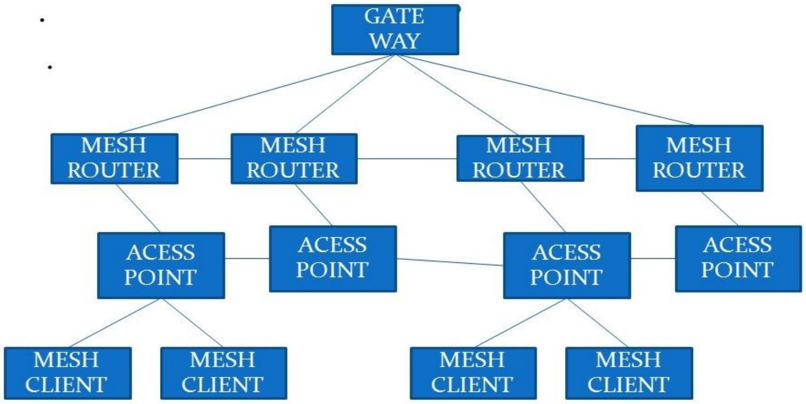

Fig 1: Traditional wireless mesh networks architecture.

In this paper, we propose a channel splitting strategy to address the foregoing unconsidered issue. With this strategy, data and signaling packets are transmitted via different frequencies of the backhaul channel in the mesh backbone network. The proposed strategy exploits the usage of a portion of the channel bandwidth to transmit handoff signaling packets in the wireless mesh backbone during the whole handoff process. Hence, it is different from multichannel protocols that require an additional full channel for control messages [20]–[22]. In addition, the additional full control channel usually has low traffic volume, which may cause the underutilization of the channel bandwidth. However, the split control channel bandwidth in our design is determined with the goal of not causing channel congestion or underutilization, as well as balancing the tradeoff between handoff delay and data packet ETE delay. In particular, the contribution of our work mainly lies in the following points: 1) designing a channel splitting strategy to shorten both the link-layer and network-layer handoff latencies; 2) proposing two transmission designs for splitting channel medium access control (MAC) in the wireless mesh backbone network to improve the performance of both handoff and data throughput; 3) evaluating the performance of the improved designs using OPNET simulations.

III. PROPOSED HANDOFF PROCEDURES BASED ON CHANNEL SPLITTING

In WMNs, network-layer handoff signaling packets, including the signaling messages for obtaining a new IP address for the MC (e.g., Agent Solicitation, Agent Advertisement), finding a new route to the new gateway, and updating the new IP address, may be transmitted over the multihop wireless mesh backbone with data packets on the same backhaul channel in traditional designs. In this scenario, signaling packets compete with data packets for the same wireless resources. Therefore, the more data packets are generated in the mesh backbone, the more possible collisions may occur between the two types of packets, which results in long handoff delay. In addition, the contention of the two types of packets on the same channel increases the ETE delay of both packets.

To solve the foregoing problem, we propose that data packets and handoff signaling packets are transmitted separately in their own channels. Since there is no collision between data packets and signaling packets by using different channels, it is possible to achieve lower handoff latency and higher channel throughput. In a single-radio 802.11-based WMN, every AP has two wireless channels: one serves as the access channel supplying the wireless interface to MCs, and the other is the backhaul channel providing connections to the mesh backbone. In our design, the access channel remains the same only for the transmission of data packets between an MC and its AP. The backhaul channel is split into two channels: a data channel and a control channel, dedicated to the data and signaling communications, respectively.

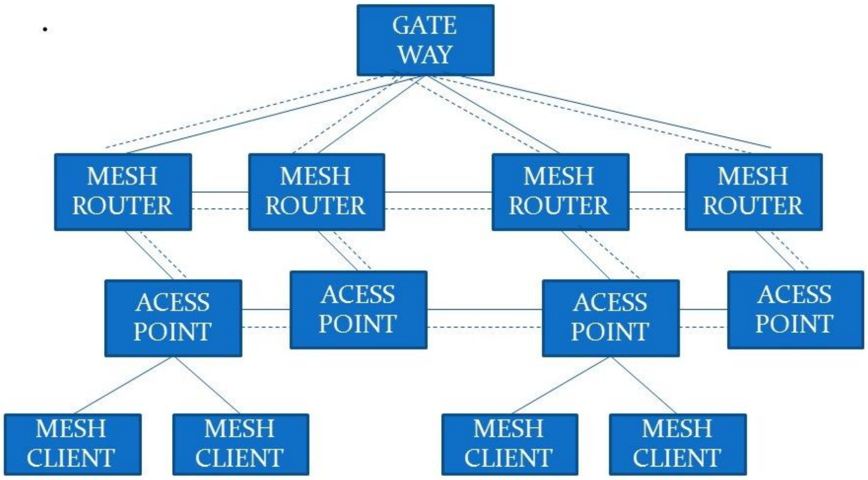

Fig 2: Existing wireless mesh networks with channel splitting.

MRs deployed in the wireless mesh backbone are configured with two transceivers; one transceiver always works on the control channel for transmitting/receiving signaling packets, and the other is used to transmit/receive data packets on the data channel. When an MC performs a handoff, it directly sends signaling packets on the backbone control channel to communicate with its new AP and new gateway without causing contentions with the data packets. Based on this channel splitting design, we propose 1) selective control channel scanning to reduce the link-layer handoff delay and 2) separate signaling transmissions to shorten the network-layer handoff delay. When an MC moves between different APs, it needs to know the control channel information of the possible APs it may be handed off to. To address this issue, we propose that APs are configured with a control channel list containing the control channel information of neighboring APs. The control channel list can be provided to an MC in a handoff signaling message. On the other hand, MCs can have either one or two transceivers. Therefore, the handoff procedures for the scenarios when an MC has one or two transceivers are different. Since our work mainly focuses on reducing the handoff delay by using split channels, we consider that there is only one backhaul channel to split in a WMN. The issues on how to dynamically allocate multiple backhaul channels to improve the network capacity when there are more than one backhaul channel in a WMN are out of the scope of this paper. The detailed proposed handoff procedures are explained as follows.

A. MC WITH ONE TRANSCEIVER: In this scenario, each MC is configured with only one transceiver. Thus, the data reception and handoff process at an MC cannot be executed at the same time. However, the MRs deployed in the WMN has two split backhaul channels. We propose two improvements for the overall handoff process as compared with the traditional method. 1) By using selective control channel scanning, the total channel scanning delay can be reduced in the link-layer handoff. 2) Both the link-layer and network-layer handoff signaling traffic is delivered in a separate control channel without competing with the data traffic. When an MC detects that the RSS is less than a certain threshold, it sends a Handoff Request message to its current AP informing that it needs a handoff. Having received the Handoff Request message, the AP sends a Handoff Reply message to the MC containing the control channel information of the surrounding APs. The number of channels in the list is usually less than the total number of available channels. Then, the MC first switches its transceiver to one of the channels in the control channel list. After sensing the control channel idle, the MC broadcasts a Probe Request message and starts the ProbeTimer simultaneously. When receiving the Probe Request message on the control channel, to avoid collisions, APs reply the Probe Response messages to the MC after waiting for a random time interval. When the ProbeTimer expires, the MC continues to scan the next control channel in the list. After finishing scanning all the channels in the list, the MC processes all the received Probe Response messages to choose the AP with the best RSS value as its new AP. Then, the MC switches its transceiver to the control channel of the new AP and continues to proceed the authentication and reassociation processes of the link-layer handoff as in the traditional design. It is worth mentioning that the access channel information can be obtained from the Reassociation Reply message from the new AP on the control channel. If a network-layer handoff is necessary, the MC needs to obtain a new IP address from the new subnet. To get a new Care-of Address, the MC sends an Agent Solicitation message to the new AP, which replies an Agent Advertisement message containing the new IP address. After getting the new IP address, the MC first finds an available route to the new gateway using the multihop routing protocol adopted in the mesh backbone and then sends a Registration Request message that is delivered through the split control channel by MRs in the wireless mesh backbone to the HA in the Internet . When getting this Registration Request message, the HA updates the binding information of the MC and sends a Registration Reply message to the MC. When receiving the Registration Reply message, the MC switches its transceiver to the access channel of the new AP. Finally, the HA forwards all the data packets through the split data channel to the MC's new Care of Address. To sum up, the MC only probes the channels in the control channel list to determine the new AP, its probe delay can be reduced. If there is only one backhaul channel in the same WMN, the MC only needs to probe one control channel when it moves inside the WMN. In addition, since the handoff signaling packets are delivered in a separate control channel, the channel access contentions between the handoff signaling packets and the data packets of the other MCs are eliminated during both link- and network-layer handoffs.

B. MC WITH TWO TRANSCEIVERS: In this scenario, since each MC is configured with two transceivers, data packets and signaling packets can be delivered in separate channels simultaneously without competing and interfering with each other during the handoff process. When an MC detects that the RSS from the current AP is less than a certain threshold, it sends a Handoff Request message to its current AP on the control channel. The current AP replies a Handoff Reply message containing the control channel list of the surrounding APs. Then, the MC switches its control channel transceiver to one of the control channels in the list, and at the same time, the data channel still receives data packets from the current AP. After sensing the control channel idle, the MC broadcasts a Probe Request message and starts the ProbeTimer simultaneously. APs receiving the Probe Request message reply the Probe Response messages to the MC after waiting for a random time interval. When the ProbeTimer expires, it proceeds to scan the next control channel in the list. After finishing the scanning, the MC processes all the received Probe Response messages to determine the new AP. Then, the MC switches its control channel transceiver to the control channel of the new AP and continues to proceed the authentication and reassociation processes of the link-layer handoff. The access channel information can be obtained from the Reassociation Reply message from the new AP on the control channel. Then, the MC starts the network-layer handoff as in the traditional design. After receiving the Registration Reply message from the HA, the MC directly switches its data channel transceiver to the new AP's access channel and gets ready to receive the data packets forwarded from the HA. In this scenario, since the MC has two transceivers, it can manage data traffic and control traffic at the same time. Thus, while the MC performs the link- and network layer handoffs using the control channel via the new AP, it can still receive data packets destined to it on the data channel via the old AP. Therefore, in the ideal situation, the total handoff delay is only a channel switching time, and the packet loss during a handoff is minimized.

In conclusion, the handoff performance of an MC can benefit from our proposed channel splitting strategy under both one and two-transceiver scenarios. Moreover, it is also worth mentioning that traditional link-layer handoff procedures are still supported by our proposed design to avoid the compatibility problem on the client side. Therefore, MCs only designed for standard channels can still execute the traditional handoff procedures if the selective control channel scanning is not supported. However, the network-layer handoff delay for these MCs can still be greatly reduced due to the separate transmission of signaling packets in the wireless mesh backbone.

IV. PROPOSED PACKET TRANSMISSION DESIGNS IN THE WIRELESS MESH BACKBONE BASED ON CHANNEL SPLITTING

In the previous section, we proposed a channel splitting strategy such that handoff signaling packets are delivered through a split control channel in the wireless mesh backbone. Since the IEEE 802.11 carrier sense multiple access with collision avoidance (CSMA/CA)-based MAC protocol does not provide

an effective solution to multichannel models, it is necessary to find an efficient mechanism to schedule the delivery of data and signaling packets in the split channels. Although various multichannel MAC protocols are proposed [11]–[13], they cannot be applied to the handoff scenarios in WMNs, because the control channel in the existing multichannel MAC protocols is only for the transmission of the request-to-send (RTS) and clear-to-send (CTS) packets to reserve the data channel. Other signaling messages including handoff messages are not considered. Accordingly, the handoff signaling messages can be either transmitted on the data channel or on the control channel in the existing designs. However, since handoff signaling packets are very small, it is inefficient to transmit them in the same way as in the transmission of data packets by means of RTS/CTS reservations on the control channel. On the other hand, if the handoff signaling messages are directly transmitted on the control channel without RTS/CTS reservations, they may compete with the RTS/CTS packets of the data packets to access the control channel. When the signaling traffic load on the control channel is very high, the RTS/CTS packets of data packets cannot be transmitted in time on the control channel, which may result in long idle periods on the data channel. Therefore, existing multichannel packet transmission designs [11]–[13] are not applicable under handoff scenarios in multihop WMNs. In this section, we propose separate channel transmission (SCT) and combined channel transmission (CCT) for the scheduling of the transmission of data packets and signaling packets. This issue has not been well considered in other papers. We assume that data packets are transmitted based on the IEEE 802.11 CSMA/CA access mechanism with the RTS/CTS option, which is not required in the transmission of handoff signaling packets with —small packet size.

A. SCT: In this design, both the RTS/CTS reservation and the transmission of data packets are carried out on the data channel The control channel is only used to transmit signaling packets, such as Agent Solicitation, Agent Advertisement, Registration Request, and Registration Reply. Assume that Routers A and B are connected by the same split data and control channels. The contention to access the control channel is only among the signaling packets. All the data packets only compete on the data channel. Therefore, the two types of packets no longer affect each other. This method is applicable to the situation when the total number of handoffs in the WMN is high and a separate split channel is required to deliver the high volume of signaling packets to guarantee handoff delay. In addition, if the channel utilization of both channels is high, a high network throughput can be achieved.

B. CCT: When an MR has a data packet to send, the MR first checks the state of the data channel. If the data channel is idle, the MR performs the RTS/CTS reservation process on the data channel. However, when the data traffic load is high in the wireless mesh backbone, the data channel may be in the busy state most of the time. Under such situations, our proposed CCT scheme is designed to make use of the idle periods on the control channel to finish the RTS/CTS reservation in advance; therefore, the next data transmission can be executed right after the previous data transmission. In our proposed CCT design, MRs can determine to deliver the RTS/CTS reservation packets either on the control channel or on the data channels dynamically, depending on the backbone traffic load, thereby improving the overall channel utilization and data packet ETE delay. To realize this design, three network allocation vectors (NAVs) are proposed for MRs in the scheduling of data packet transmission: NAV _data, NAV _control, and NAV _backup. NAV _data is maintained for the data channel indicating the expiration time of the data channel busy state. It is dynamically updated when receiving RTS/CTS packets in both channels. NAV _control is obtained from the RTS/CTS packets transmitted on the control channel. It provides the time required for the next data packet transmission. NAV _backup is used to save the value of NAV _data each time before it is updated. In addition, reservation_time denotes the time required for an RTS/CTS reservation on the control channel. We use reserved_flag to indicate whether the next data channel transmission has already been reserved or not. To avoid idle periods on the data channel, the next RTS/CTS reservation should be finished before the completion of the current data transmission (i.e., NAV _data − current_time > reservation_time). The proposed protocol details of the CCT design are shown in flowcharts 1, 2.

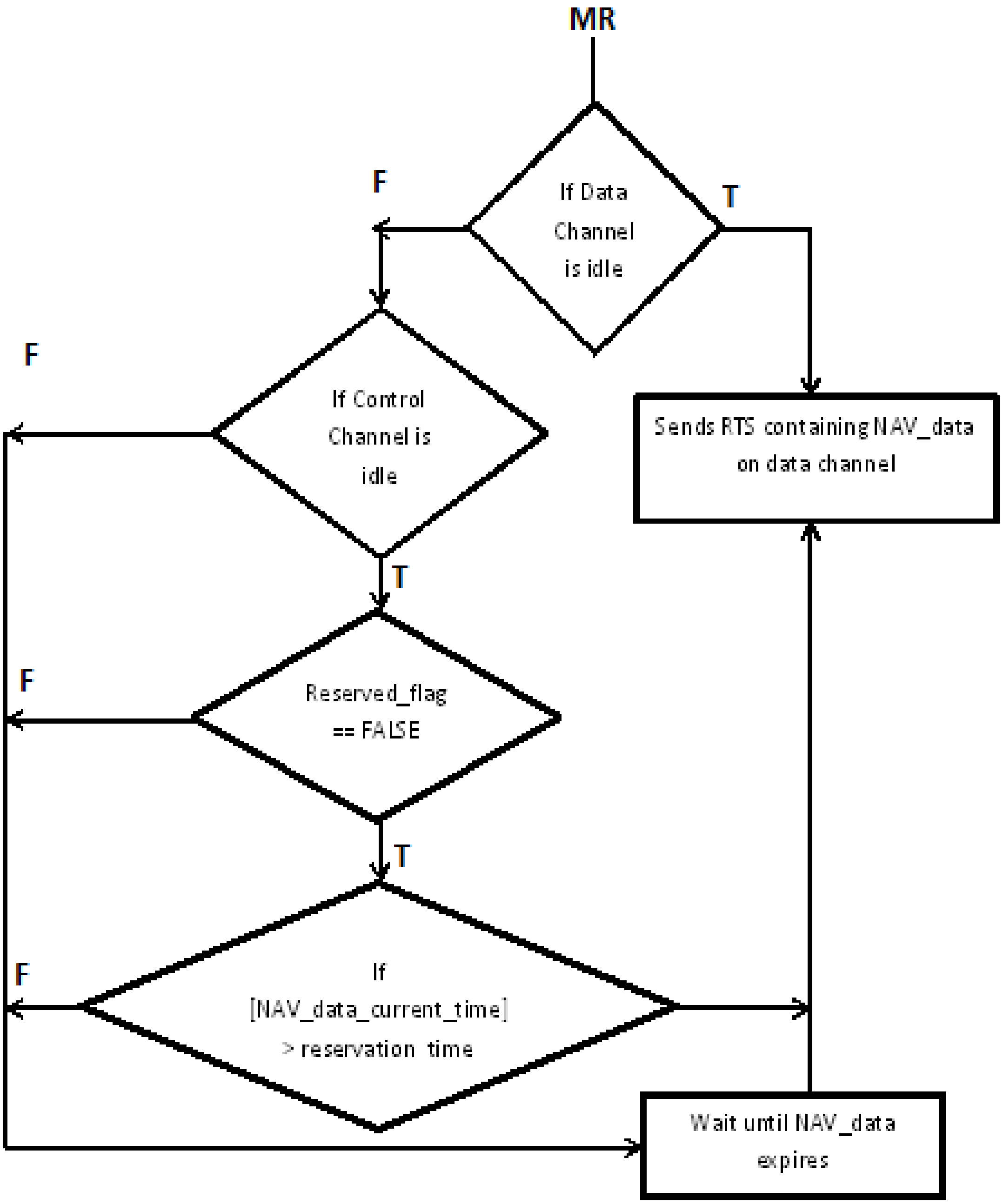

Fig 3: Flowchart showing CCT technic.

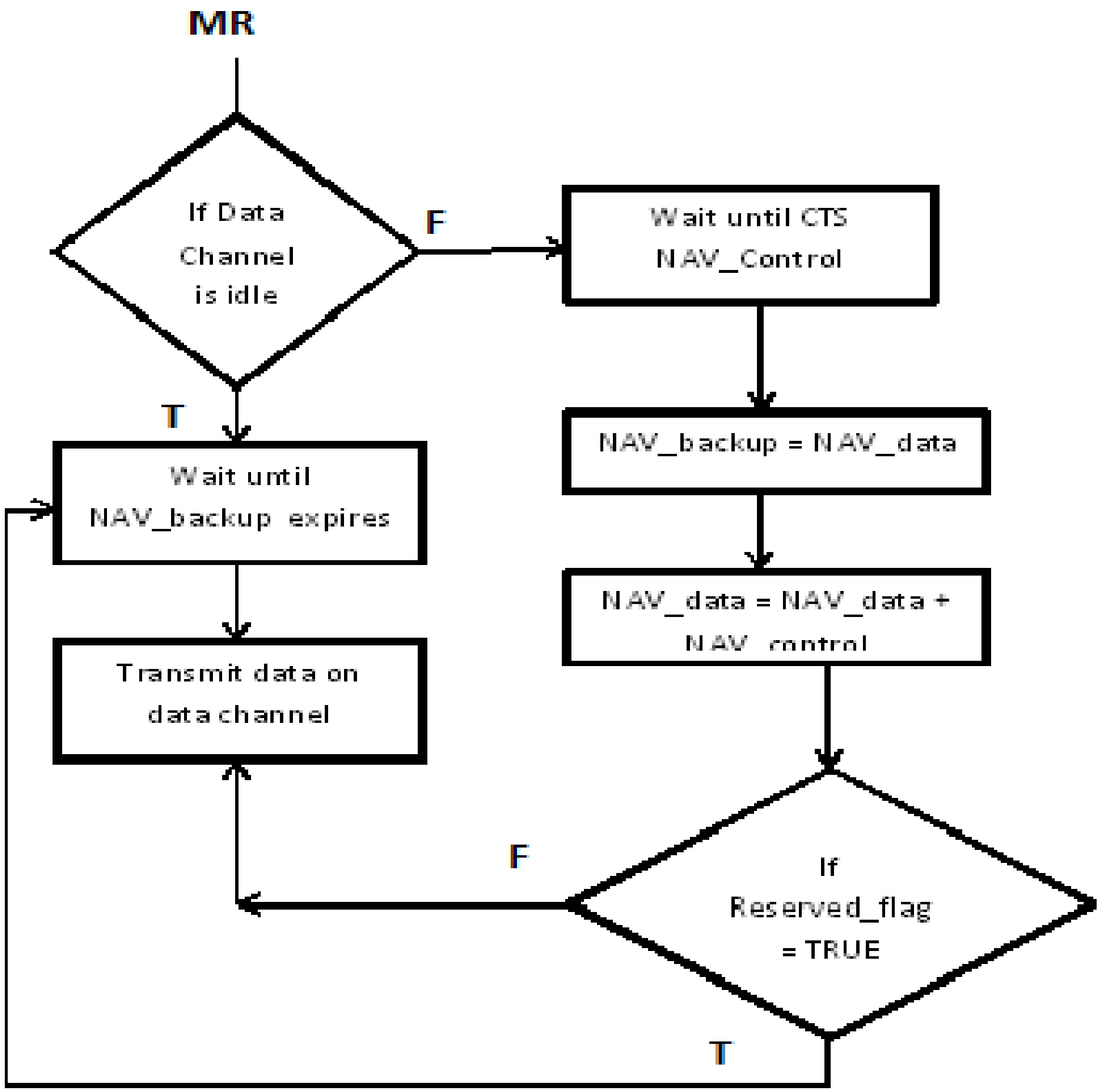

Fig 4: Flowchart showing CCT technic.

The routers A and B, connected with the same data and control channels, can determine the delivery of the RTS/CTS of data packets either on the control channel or on the data channel dynamically according to the current channel status. Initially, since the control and data channels are idle, the signaling packet of Router A and the kth data packet of Router B can be transmitted simultaneously in separate channels. After finishing the transmission on the control channel, Router A needs to send its ith data packet to Router B. At this moment, since Router B still has not finished its kth data packet transmission, the data channel is still busy, but the control channel is idle. After checking that the reserved_flag is FALSE and that the reservation of its ith data packet on the control channel can be finished before the completion of the kth data packet of Router B on the data channel, Router A sends an RTS packet to Router B on the control channel containing NAV _control to reserve its ith data packet transmission. Other neighboring APs receiving this RTS packet save the current value of NAV _data to NAV _backup, update the value of NAV _data, and then set their reserved_flag to be TRUE, meaning that the data channel has been reserved. Similarly, when receiving a CTS packet from Router B containing NAV _control on the control channel, other neighboring Aps as well as Router A set their reserved_flag to be TRUE, save the current value of NAV _data to NAV _backup, and then update the value of NAV _data. Once NAV _backup expires, Router A transmits its ith data packet on the data channel. Other neighboring APs with no transmission reset their reserved_flag to be FALSE, meaning that the next data channel transmission can be reserved at this moment. During the transmission of the ith data packet of Router A, Router B needs to send its (k + 1)th data packet. At this moment, the data channel is busy while the control channel is idle. Hence, Router B repeats the steps as in the ith data packet transmission of Router A. Later, during the transmission of the (k + 1)th data packet of Router B, since the control channel is idle, Router A starts to transmit a handoff signaling packet on the control channel.

In conclusion, this design can utilize the data channel with high efficiency because the time required to reserve the data channel is consumed in the idle period of the control channel. Therefore, the RTS/CTS overhead on the data channel is reduced, and the overall channel throughput is improved. However, this design may be unfair to signaling packets, because it brings more contentions on the control channel, as compared with the SCT design. Therefore, the CCT design can be applied to the WMN where the handoff traffic volume in the mesh backbone is low, leaving sufficient idle periods on the control channel for data channel reservation.

V. PERFORMANCE EVALUATION

In this section, we assess the performance of the packet transmission designs proposed in Section IV based on the channel splitting strategy using the OPNET [5] simulator. Since OPNET 14.5 does not provide multi transceiver MR models, we implement new AP and MR models to support our proposed transmission designs. In the simulation, APs and MRs are configured with three and two wireless transceivers, respectively, and each transceiver has one IP address.

SIMULATION SETUP: We implement handoffs in multihop WMNs using five different channel transmission methods: traditional single-channel based method, priority-queue-based method, proposed SCT method based on split channels, proposed CCT method based on split channels, and two-channel-based method. In the traditional single-channel-based method, MRs are configured with one transceiver operating on a single backhaul channel. Data packets and signaling packets are transmitted in the same queue via the same backhaul channel. In the priority queue- based method, MRs are configured with one transceiver operating on one backhaul channel. However, the data and signaling packets are transmitted in different queues via the same backhaul channel, and the queue for signaling packets has a higher priority than the data packet queue. Hence, data packets can be transmitted only when the signaling packet queue is empty. In our proposed SCT and CCT methods, MRs are configured with two transceivers operating on one backhaul channel that is split into a data channel and a control channel. Data and signaling packets are transmitted separately via the split data and control channels. In the two-channel-based method, MRs are configured with two transceivers operating on two full backhaul channels. Data packets and signaling packets are transmitted separately via different channels. In addition, APs in all transmission methods have one additional transceiver operating on a standard access channel to provide wireless services to MCs.

Two 4 × 4 grid topology WMNs are deployed in the simulation. Each WMN contains four APs, one gateway, and 11 back bone MRs. The three non over lapping IEEE 802.11b standard channels are used in the simulation, and the data rate is set to be 1 Mb/s. In the SCT and CCT simulation scenarios, the backhaul channel in each WMN is split into a control channel and a data channel. MRs have two transceivers for the split data and control channels separately. APs are configured with three transceivers. One transceiver is for the access channel to provide wireless services to clients; the other two transceivers are for the split data and control channels in the wireless mesh backbone. MCs move from one AP in one WMN to another AP deployed in a different WMN. Hence, both link- and network layer handoffs are needed during the movement of MCs. The moving speed of MCs is randomly selected between 3 and 6 mi/h. The HA of MCs is located in the Internet, so signaling packets need to be delivered from MCs to the HA via multihop wireless transmission during the network-layer handoff.

The average data packet size is set to be 8184 bits [28] in the simulation. Every MC sends a data packet flow (10 packets/s) to their CNs. Similarly, CNs located in the Internet send the same amount of data traffic to MCs. When background data traffic is added in the wireless mesh backbone, every AP generates additional two, four, and six such data packet flows to its gateway via the data channel, which are considered to be 33%, 67%, and 100% background data traffic, respectively. The signaling packet size is set based on the size of Registration Request and Registration Reply messages defined in Mobile IP [7]. When the background signaling traffic is added in the wireless mesh backbone, every AP generates additional one, two, and three signaling packet flows to its gateway via the control channel, which are considered to be 33%, 67%, and 100% background signaling traffic, respectively. The data traffic between CNs and MCs starts at 100 s. The Internet backbone network has a constant latency of 0.1 s. The simulation lasts for 20 min, and the data traffic between CNs and MCs ends at the end of the simulation. The simulation results are obtained from the average of 30 simulation trials with different seeds and based on a 90% confidence interval.

VI. RESULTS

Fig 5: shows the comparison graph of UDP between proposed and existing throughput.

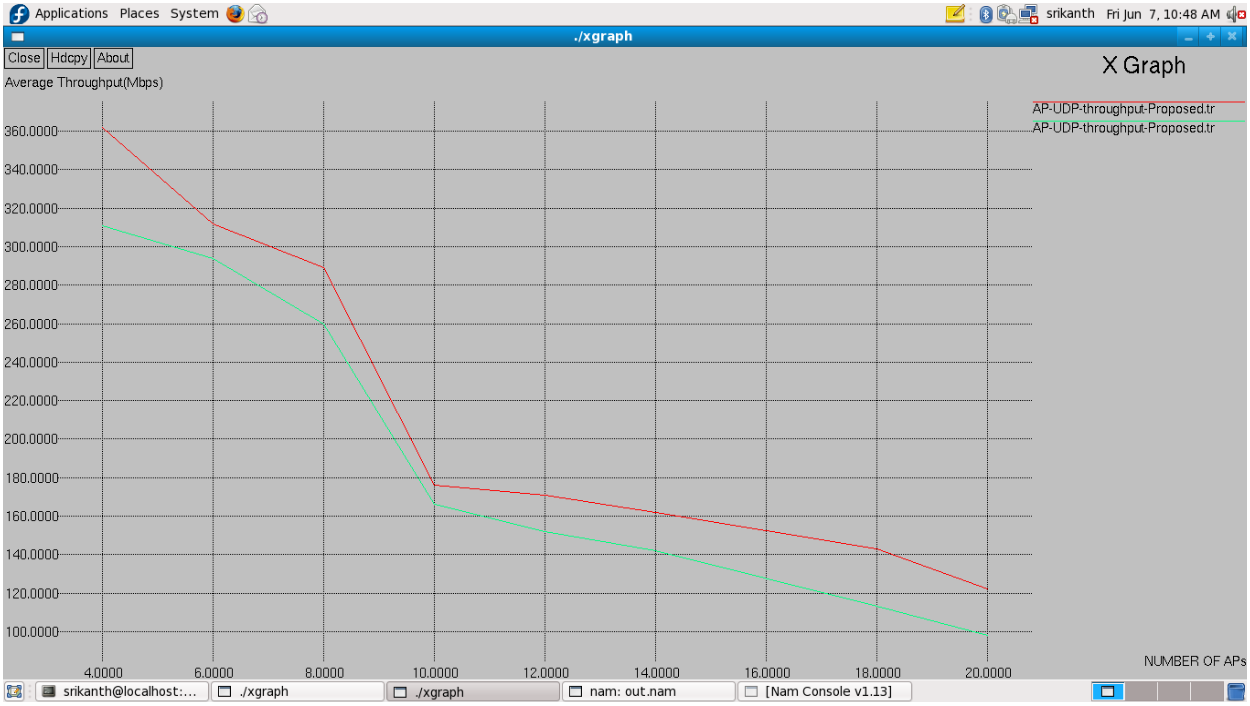

Fig 5: Accessing point verses UDP throughput.

Fig 6: shows the comparison graph of TCP between proposed and existing throughput.

Fig 6: Accessing point verses TCP throughput.

Fig 7: shows the comparison graph of AP between proposed and existing throughput.

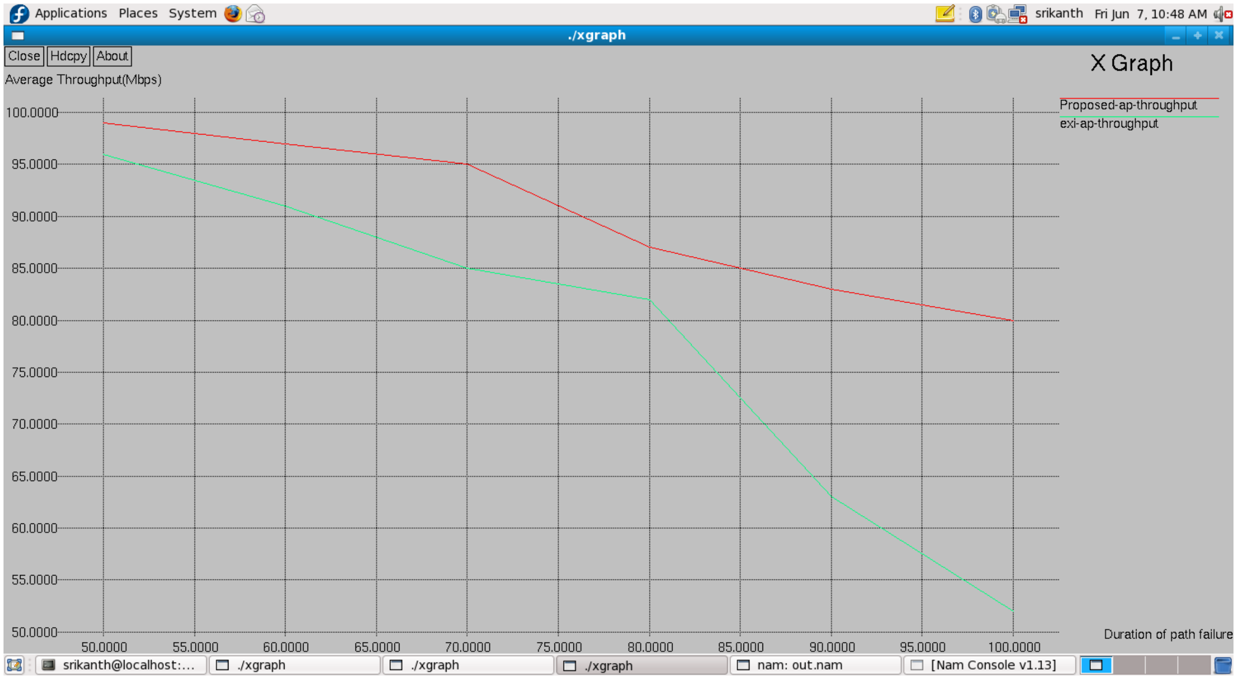

Fig 7: Accessing point throughput.

Fig 8: shows the comparison graph of delay between proposed and existing throughput.

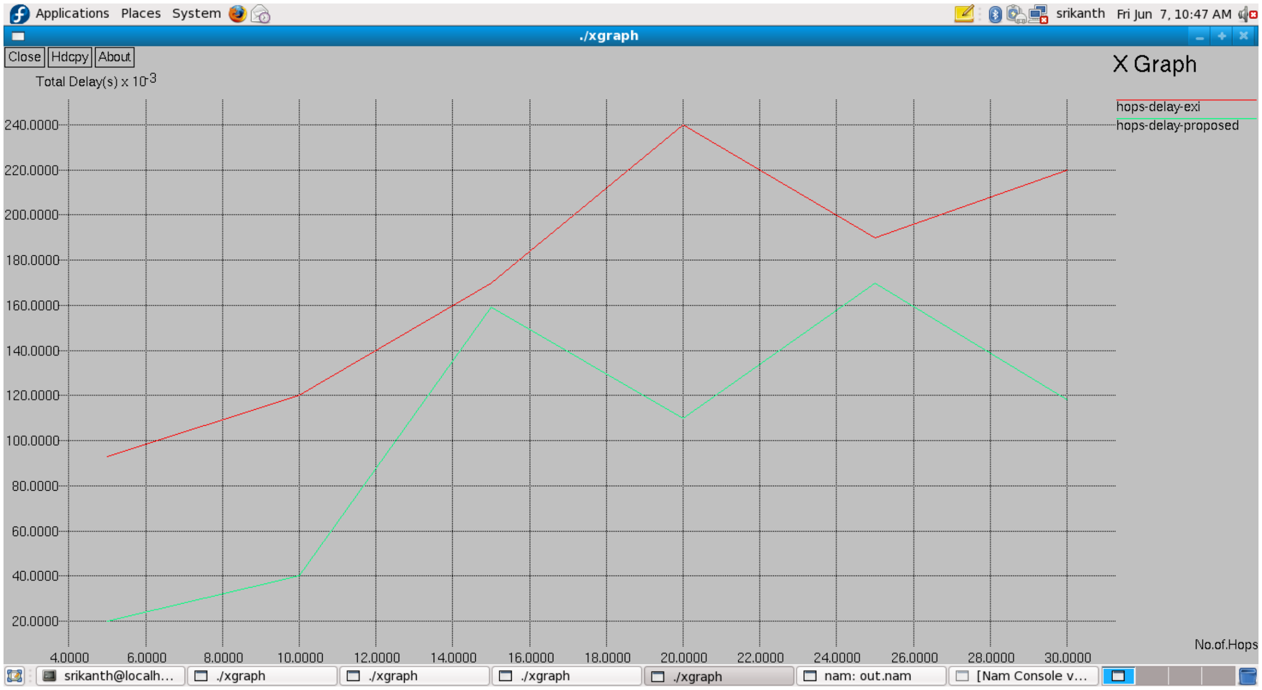

Fig 8: Delay verses No of Hops.

From the out graphs, we conclude that the intergateway handoff performance can be significantly improved using our proposed SCT and CCT designs as compared to the traditional single-channel-based and priority-queue-based methods, particularly under the situation when background data traffic is high in the wireless mesh backbone. In addition, the performance of the CCT design is better than that of the SCT design in this scenario. On the other hand, when the background signaling traffic is added on the control channel, the performance of the SCT method becomes better than the CCT method. Therefore, the CCT design can be applied to WMN, where the handoff traffic volume is low but the background data traffic volume is high, whereas the SCT design is applicable to WMN with high handoff frequency requiring a separate control channel to deliver these handoff signaling packets.

VII. CONCLUSION

Inter gateway handoff support is an essential issue to ensure continuous communications in internet-based wireless mesh networks (WMNs). Because of the multihop wireless links, customary handoff schemes designed for single-hop wireless access networks can hardly guarantee the low handoff latency requirement in multihop WMNs. The paper proposes a channel splitting strategy to reduce the channel access delay of handoff signaling packets over multihop wireless links. The handoff procedures of two setups when a mobile node has one or two transceivers are designed, and two transmission schemes for scheduling the delivery of handoff signaling packets are proposed. The simulation results show that by using the proposed channel splitting schemes, the handoff delay requirement in WMNs can be guaranteed, irrespective of the background data traffic, and the average channel utilization can also be improved.

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