Indirect Path Setup: A new Approach for Handoff in HAWAII

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Abstract

In the next generation wireless access technologies which are defined to be a pure IP based wireless networks; there are two types of IP mobility management: IP macro-mobility management (intra-domain), and IP micro-mobility management (inter-domain). HAWAII protocol is one of the prominent protocols for IP micro-mobility management. It supports two approaches of path setup handoff schemes: Forwarding Path Setup schemes and Non-Forwarding Path Setup schemes. In this paper, we proposed a new approach for fast path setup handoff in HAWAII. The proposed approach is implemented and evaluated using network simulator ns-2. Then, the performance of the proposed approach is compared against the two HAWAII path setup handoff schemes. The simulation results show that the number of packet loss is reduced to zero and the handoff delay and service disruption are reduced to minimum. The UDP and TCP performance are significantly improved in comparison with other HAWAII path setup schemes. The proposed approach can efficiently support real-time and non-real time applications.

1. Introduction

IP Mobility management is an important issue in design of the next generation all-IP based wireless access network. It has been classified in to two types: IP macro-mobility and IP micro-mobility management [1].

Mobile IP [2] is a standard for supporting IP mobility of mobile nodes in the wireless access networks with infrastructure. Mobile IP is an optimal solution for macro-mobility support and slow moving mobile nodes, but it has drawbacks and limitations in the micro-mobility environment with frequent handoff and high-speed movements of mobile nodes [3,4,5]. IP micro-mobility protocols are proposed to extend Mobile IP by supporting fast, seamless handoff in micro-mobility environment. Therefore, fast seamless handoff with high performance is an important issue in the designing of the IP micro-mobility protocols.

HAWAII [6,7] is one of the prominent solutions for IP micro-mobility management in next generation all-IP based wireless system [1,5]. It supports two approaches of path setup handoff schemes: Forwarding Path Setup and Non-Forwarding Path Setup. Forwarding Path Setup handoff schemes are optimized for wireless access networks where the mobile host is able to listen/transmit to only one base station at the same time as in the case of a Time Division Multiple Access (TDMA) network. In these schemes, data packets are buffered in the old base station for small duration of time. When the mobile host receives the agent advertisement message from the new base station, it initiates the handoff and then, it sends a registration request to the new base station. The new base station sends a path setup update message to the old base station using IP routing. When the old base station receives this message, it performs a routing table lookup for the new base station and determines the interface and next hop router and it adds a forwarding entry for the mobile host's IP address with the interface of next hop router. The old base station sends a path setup message toward old base station and then, it forwards the content of the buffer through new established forwarding entries to the new base station. In these schemes, data packets are first forwarded from old base station. After the last packet forwarded in the old path, packets diverts at a crossover node toward the new base station. In these schemes, the order of establishing the forwarding entries in the routers can lead to multiple streams of miss-ordered packets arriving at the mobile host and also it can lead to routing loop. The Forwarding Path Setup Schemes suffer from long handoff delay and packet loss, which make it inefficient for real-time applications. Non-Forwarding Path Setup Schemes suffer from high

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number of packet loss if it is used with a wireless network which does not enable mobile host to listen/transmit to more than one base station simultaneously for small duration of time, and it is optimized for a wireless network which enables the mobile host to do data connection to more than one base station at the same time. Therefore, handoff delay and packet loss have the serious impact on the performance of multimedia applications and TCP-like transport protocols and applications.

The above problems of HAWAII handoffs motivate us to propose a new approach for path setup handoff, called indirect path setup handoff (IPSH), with the following requirements: (1) Zero packet loss, (2) Minimum packet delay arrival, (3) Minimum handoff delay, (4) Minimum use of BS buffering, and (5) Minimum use of network resources. This approach allows UDP and TCP based applications and protocols to operate efficiently. It is used to reduce the packet loss to zero and reduce the handoff delay to minimum. Simulation results show substantial improvement in the UDP and TCP performance. Simulation results show that the proposed approach can efficiently support real-time and non-real time applications.

Above we present the problem statement and motivations for this research. The rest of this paper is organized as follows. Section 2 reviews the related work. In section 3, our proposed approach for handoff in HAWAII is introduced. In section 4, we describe the simulation model that includes simulation environment, and simulation results and discussion. Finally in section 5, we conclude this paper.

2. Related Work

Despite the large amount of literature of IP micro-mobility protocols [1,8,14,15], a little is available regarding the performance evaluation and enhancement of HAWAII protocol. An extensive study of Handoff-Aware Wireless Access Infrastructure (HAWAII) protocol is presented in [7]. The authors in [7] presented the design, implementation, and performance evaluation of HAWAII. This protocol supports two different handoff approaches: Forwarding path setup schemes and None-forwarding path setup schemes. The authors in [7] argue that the protocol reduces the Audio/video disruption time and improves the TCP throughput in comparison with Mobile IP, but this improvement is not sufficient as it is aimed by IP micro-mobility protocols and it still needs improvement in term of Audio/video handoff delay and TCP throughput. In case of forwarding schemes, packet losses are not eliminated, and data packets suffer from a delay during handoff [8,9]. None-forwarding schemes achieves a good performance if they are used in wireless access technology that enable mobile host to listen/transmit to more than one base station at the same time, but these schemes suffer form packet loss and bad TCP throughput if they are used in wireless access technology that enables mobile host to connect to more than one base station simultaneously, these results are reported in [8]. In case of high-speed mobile host and a small overlap area between cells; the mobile host spends short time in the overlap area, so that None-forwarding schemes suffer from multiple packet loss and bad TCP throughput.

In [10], IP based access network architecture for next generation networks are proposed to support different wide-area wireless network access technologies such as GPRS and CDMA. This network architecture uses Mobile IP as inter-domain protocol for macro-mobility and HAWAII as intra-domain protocol for micro-mobility and paging functionalities. [10] shows that HAWAII can be a powerful candidate for next generation wireless access networks.

Above we presented all the proposals for HAWAII performance analysis and enhancement. The approach presented in this paper represents the first attempt to improve the HAWAII handoff. The packet loss is eliminated and the handoff delay is reduced to minimum. The UDP and TCP performance are significantly improved in comparison with other HAWAII path setup schemes.

3. The Proposed Approach

To achieve a fast handoff with high performance that can support real time application in HAWAII micro-mobility, it is required to minimize the service disruptions (such as delayed arrival or loss of packets) and overheads (such as latency, BS buffering, and excess reservation of network resources). The proposed approach in this paper establishes the path to the new base station in advance prior to real handoff through the current base station.

It is assumed that the mobile host can receive link layer trigger or obtain link layer information by interaction with the data link layer, which inform the mobile host of leaving the current base station and entering new base station. The link layer trigger or information contains information such as received signal strength (RSS) and the new base station IP address identifier that can be resolved to the new base station's IP address by the mobile host or the base station. This is the case in many cellular networks. The IP address identifier is specific to the underlying wireless technology, and it can be derived from link-layer messages, for example of such identifiers: the access point ID, base station ID or base station MAC address.

When the mobile host receives a link layer trigger, it sends an indirect registration request message to the old base station with the new base station IP address identifier as a destination address. When the old base station receives the indirect registration request, it sends path setup update message destined for the new BS. The path setup message is routed by IP on a hop-by-hop basis to the new BS. When a node receives the path setup update message, it performs a routing table lookup for the new base station and determines the interface of next hop router. If the default route to DRR is equal to the next hop router to new base station, the intermediate node will forward path setup message to the next hop and this path is the old path. If the default route to DRR is not equal to the next hop router to new base station, this means this node is the crossover node. In the crossover node, the path setup message adds an additional forwarding entry to the mobile user and sends indicator message of the last packet to the old base station. The crossover node also sends the path setup message and the incoming packets toward the new path. The path setup message continues establishing the forwarding entries toward the new base station.

When the new base station receives the path setup message, it keeps the incoming packets in a buffer, and it sends agent advertisement message to the mobile host. When the old base station receives the indicator message of the last packet, it sends an indirect registration reply to mobile host. When the mobile host receives the indirect registration reply, it immediately switches the listening to the new base station and this completes the link layer handoff. When the mobile host receives an agent advertisements message after link layer handoff, it sends a registration request message to new base station. If mobile host could not receive an agent advertisements message, it should send agent solicitation message.

The mobile host listens to an agent advertisements message and then it sends a registration request. When the new base station receives the registration request, it checks the forwarding table entries. If the mobile host has a forwarding entry, then the new base station should sends the registration reply message and the content of the buffer to the mobile host. Otherwise, the new base station should send path setup message toward old base station, which adds entries for the mobile host in every router in the path toward the old base station. When the old base station receives the path setup message, it sends a forwarding acknowledgment message to new base station. When a new base station receives forwarding acknowledgment message, it sends a registration reply to the mobile host along with any data packet in the buffer.

4. Simulation Model

The proposed path setup handoff scheme has been implemented and evaluated using network simulator ns-2, which is widely used by the research networking community to analyze IP networks. The proposed path setup scheme and other HAWAII path setup schemes are implemented according to the specification presented in [8]. Configuration parameters specified within this simulation are used unmodified as in the CIMS [11], unless otherwise noted.

4.1. Simulation Environment

To implement and evaluate the proposed scheme, the Columbia IP micro-mobility software (CIMS) is used [11], which is a micro-mobility extension for the network simulator (ns-2) based on version 2.1b6 [12]. Network Simulator ns-2 is an event-driven simulator used efficiently by the researcher as a powerful method and better than analytical models or experimental testbed to study most aspect of IP networks. We used ns-2 to analyze the performance of UDP and TCP protocol on the proposed path setup handoff and compare the simulation results against other HAWAII path setup schemes. The network topology used in this simulation is shown in figure 1 [9].

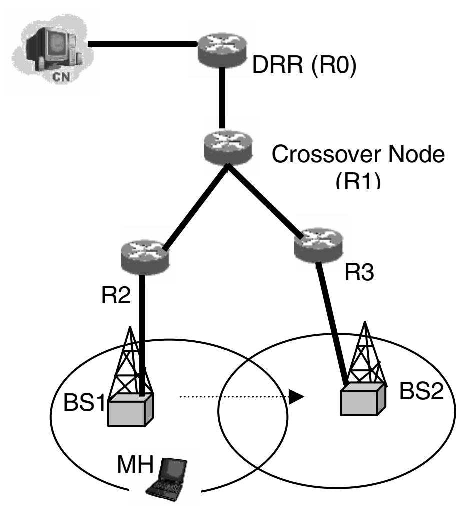

Figure 1. Simulation topology for HAWAII access network.

In this network topology each wired connection is modeled as 10Mb/s duplex link with 5ms delay [7]. The mobile host communicates with the base stations using IEEE 802.11 MAC enabled wireless link. Cell coverage boundary is 140mX140m. Overlapping region between base stations is 30m. The speed of the mobile host is 20m/s [8].

4.2. Simulation Results and Discussion

The following two subsections analyze the performance of the proposed approach and compare the performance of the proposed scheme with the performance of two HAWAII path setup schemes: Multiple Stream Forwarding (MSF) and Unicast Non-Forwarding (UNF). We investigate the impact of the proposed handoff and the two HAWAII path setup handoffs (MSF, UNF) on UDP and TCP performance.

4.2.1. UDP Performance. UDP with CBR (Constant bit rate) as traffic source is used in this simulation to model real-time Internet applications like audio. The CN acts as a CBR source, which is streaming audio data packets over UDP to the MH. The UDP packet size used is 160byte. Data rate used is 50kb/s to 700Mb/s. the MH acts as a sink for the data packet. For HAWAII's MSF scheme, a buffer with 11 packets size is used in the old base station in order to prevent any packet loss due to handoff. The buffer is implemented as a circular queue with a size of 11 packets. The performance of HAWAII path setup schemes are evaluated and compared with performance of the proposed scheme.

In the proposed scheme, when the new base station receives the path setup update message, it sends an agent advertisement message. At this time, the mobile host is already disconnected from old base station and switched to listen to the new base station. Upon receiving an agent advertisement message, the mobile host sends registration request as in mobile IP. Then the new base station sends the registration reply along with data packets, which came through the new path. So, a packet delay in the new base station is equal to the time required to send an agent advertisement message from the new base station to the mobile host plus the time of sending a registration request from the mobile host to the new base station.

In the first experiment, the corresponding host sends 160 byte UDP packet every 20ms (64kb/s audio) to mobile host [7]. In this experiment, the playout delay at the receiver is used to drop any packet that comes after playout time. Playout time is equal to packet send time + handoff delay [7]. The total packet loss in MSF, UNF, and the proposed handoff scheme (IPSH) are computed. Figure 2 shows the total of dropped and lost packets per handoff versus playout delay for one handoff from base station1 to base station2.

In UNF, packet loss is observed. It is due to mobile host disconnect from old base station. The lost packets are the packets that were in old path after handoff. Figure 2 shows about 2 packets are lost. In MSF, it is observed that 3 packets are dropped by the receiver for playout delay less than 30ms. The packet delay is due to packets buffering at old base station and packets forwarding to new base station. In the proposed handoff scheme (IPSH), it is observed that one packet is dropped by the receiver for playout delay less than 30ms. The packet delay is due to packet buffering at new base station. During this time, mobile host switches to new base station and receives agent advertisement message. Then, mobile host sends registration request and waits for registration reply.

With 40ms playout delay, the proposed handoff scheme (IPSH) achieves a zero packet drop. Figure 2 shows the total packet loss (packet loss + packet drop) for the 3 path setup handoff schemes. It shows that the proposed handoff is better than other HAWAII path setup handoff schemes for supporting real time Internet applications.

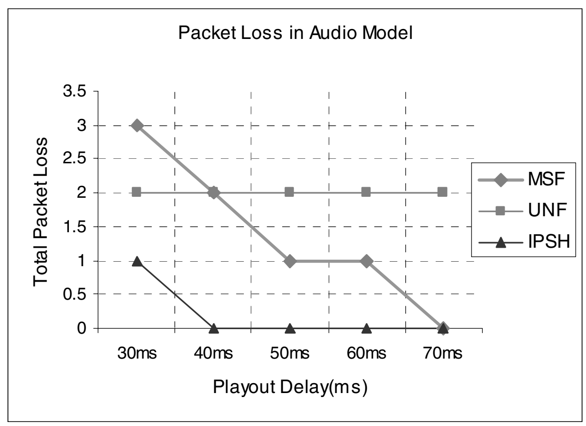

Figure 2. Packet loss in HAWAII path setup handoff schemes

In the second experiment, we compute the number of packet loss in the 3 path setup handoff schemes with different data rates. The buffer size of MSF scheme in old base station is set to 11 packets, such that the zero packet loss can be achieved. Figure 3 shows that packet loss in MSF is zero with 11 packet buffer size with different data rate. The buffer size of the proposed scheme (IPSH) in the new base station is set to 4 packets, such that the zero packet loss can be achieved. Figure 4 shows that the proposed scheme needs 3 packets buffer sizes in order to achieve zero packet loss. The proposed scheme does not cause duplicate packets. Figure 3 shows that packet loss in the proposed scheme (IPSH) is zero with 4 packet buffer size. For UNF, it is observed that, after the actual handoff all the packets in the old path get dropped until the path setup update message received by the crossover node. When the crossover node receives the path setup update message, it bi-casts the new incoming packets to the old and new path. As a result, the proposed indirect path setup handoff scheme (IPSH) is better than the MSF and UNF schemes.

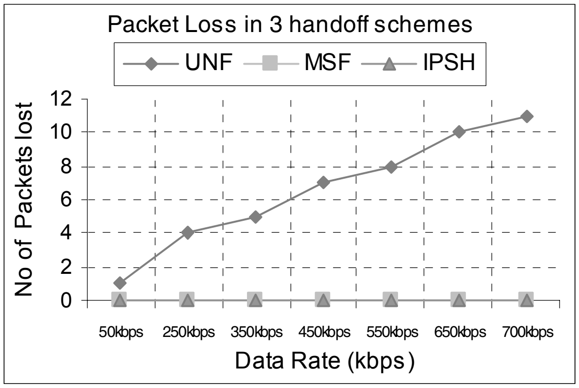

Figure 3. Packet loss during handoff in HAWAII path setup handoff schemes.

Figure 4 shows the relation between data rate and the buffer size. With higher data rate, a large buffer size is needed. In MSF scheme, Packet loss occurs if the buffer size in the old base station is small. Figure 4 shows the buffer size required in order that handoff schemes can achieve zero packet loss for different data rate. It is observed that the buffer size needed for IPSH scheme is smaller than the buffer size needed for MSF scheme.

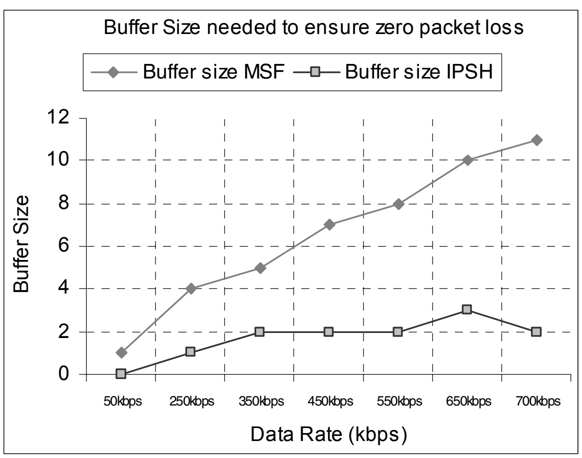

Figure 4. Buffer size required for HAWAII MSF and IPSH schemes.

4.2.2. TCP Performance. At the beginning of TCP Performance analysis, the behavior of TCP Sack during handoff is studied using simulation. TCP Sack uses FTP as a traffic source to download data from corresponding host to a mobile host. TCP Sack is an enhancement to TCP Reno, which can handle multiple packet loss in one round trip time using Sack option [13]. The simulation topology used is identical to the simulation topology shown in Figure 1. The TCP packet size used in the simulation is 1000 byte. Simulation time is 60 seconds.

Figure 5 shows the packet trace of TCP traffic during a handoff in the UNF path setup scheme. It shows the TCP packet sequence numbers vs. simulation time observed at mobile host. In UNF, at simulation time 11.769038s, the TCP Sack started suffering from service disruption due to packet drop from a single window. In this experiment, 3 packets are lost in the old path to old base station. TCP sack could not receive any duplicate acknowledgment packet due to the disconnection from the old base station and waiting for agent advertisement message. TCP sack waits for timeout of the send packets and it retransmits the lost packet.

Figure 5 shows the packet trace of TCP traffic during a handoff in the MSF scheme. It shows the TCP packet sequence number vs. simulation time observed at mobile host. In MSF, we set buffer size to 11 packets and the maximum elapsed time allowed for packet to stay in buffer is 25ms as an optimal value. In this experiment, when the old base station receives path setup message, it discards all packets, which was in buffer more than maximum elapsed time, and they are already received in MH through the old base station. Then, the old base station forwards the remaining buffer content to the new base station because its elapse time is less than the maximum specified elapsed time. Figure 5 shows that MSF has disruption time but it is less than a disruption time observed in UNF.

Figure 5 shows the packet trace of TCP traffic during a handoff in the proposed IPSH scheme. It shows the TCP packet sequence number vs. simulation time observed at mobile host. In this experiment, it is observed that TCP sack has zero packets loss and very small service disruption. The mobile host initiates handoff to new base station after it received indicator message of the last packet. During that time, the data packets was arrived to new base station and stored in buffer. After mobile host registration with new base station, the new base station forwards the content of buffer and the incoming data packets toward mobile host. The handoff delay in the proposed scheme is the time spent in mobile host registration with new base station, so that the proposed scheme has very small disruption time, which is less than the disruption time observed in MSF or UNF in figure 5.

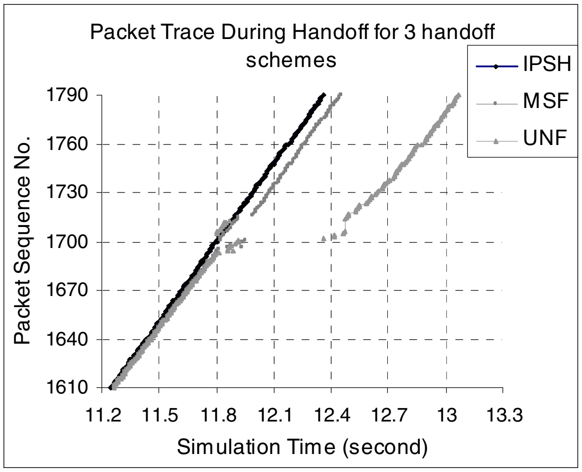

Figure 5. Packet trace of TCP traffic during handoff in HAWAII MSF scheme.

5. Conclusion

HAWAII forwarding path setup schemes suffer from long handoff delay and packet loss, which make it inefficient for real-time applications. HAWAII non-forwarding path setup schemes suffer from high number of packet loss if it is used with a wireless networks which does not enable mobile host to listen/transmit to more than one base station simultaneously for small duration of time. In this paper, we propose a new approach for fast handoff in HAWAII. The proposed approach is implemented and evaluated using network simulator ns-2. Then, its performance is compared against two of HAWAII path setup handoff schemes (MSF, UNF). The simulation results show that the packet loss of UDP traffic during handoff in the proposed scheme is reduced to zero. The handoff delay is negligible in the proposed scheme in comparison with HAWAII path setup schemes. It has zero duplicate packets, and it needs smaller buffer size than MSF. TCP performance in the proposed scheme is better than other HAWAII path setup schemes. Simulation results show very small service disruption during handoff in the proposed scheme.

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