Forward-Based Handoff Mechanism In Cellular IP Access Networks

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Abstract

Handoff performance is one of the important metrics in mobility management where frequent handoff can occur in single session and that may degrade the performance of TCP (Transmission Control Protocol) and UDP (User Datagram Protocol) in wireless data networks. Cellular IP is one of the dominating IP micro-mobility management protocols. It supports two types of handoff schemes, hard and Semi-soft handoff. In this paper, an enhancement to the existing hard handoff mechanism in Cellular IP is proposed and subsequently assessed by simulation. The approach proposed in this paper, called Forward-Based Handoff Mechanism (FBHM), constitutes a new handoff mechanism in Cellular IP to reduce packet loss and enhance the UDP and TCP performance. The simulation results show that the packet loss of UDP traffic is reduced to zero. It also shows that the performance of TCP is improved in comparison with hard handoff.

1. Introduction

In the recent years, a rapid growth of wireless mobile communication technology has been observed. Lightweight portable computers like laptops and personal digits assistances (PDA) are becoming very popular. With the increase of powerful mobile computers and the popularity of Internet applications and services, the demand for wireless access to Internet with seamless mobility support will increase exponentially. Currently wireless networks are based on the circuit switching technologies such as in Global System Mobile (GSM) and other which represent second generation (2G) cellular telephony. Some enhancements to these networks are being deployed to support data traffic such as TCP/IP protocol suit. Wireless networks are evolving toward third generation (3G), and some of them are currently deployed. 3G wireless networks are designed to evolve toward all IP wireless networks such as in Universal Mobile Telecommunication System (UMTS). Future broadband wireless networks such as forth generation (4G) networks will be deployed based on packet switching technologies, which will entirely work on Internet Protocol (IP).

In Cellular Networks [1], the geographical area is split in to cells. Cells with large number of mobile users can be split into smaller cells to increase the capacity. The process of moving the mobile host from base station to another base station during connection is called handoff. As the cells get smaller, the handoff becomes much more frequent by mobile hosts.

Mobile IP [2] is the most widely known IP mobility management proposal that supports host mobility. Mobile IP was proposed by a working group within Internet Engineering Task Force (IETF). It was designed to enable the mobile host to change its point of attachment (access point) without changing the IP address. When the mobile host leaves the current network and enters a new foreign network domain, it acquires a new IP address called IP Care-of-Address (CoA) and informs its home agent about this new IP Care-of-Address. Mobile IP[3][4] suffers from many drawbacks, like high handoff delay which results in a high number of packet loss especially in the case of frequent handoff (within the domain) since the foreign agent must inform the home agent about the new IP Care-of-Address after each handoff. Many solutions have been developed to efficiently support local mobility inside IP wireless networks such as Cellular IP[5][6], Handoff-Aware Wireless Access Internet Infrastructure (HAWAII)[7][8], Hierarchical Mobile IP (HMIP)[9], which is called IP Micro-mobility protocols. The aim of these micro-mobility protocols is to manage local movement (within domain) of mobile hosts without interaction with the home agents. These lead to decrease the handoff delay and packet loss during handoff and reduce the signaling load experienced by Mobile IP registration in core network so that the wireless access network can scale a very large number of mobile subscribers. The micro-mobility protocols can interwork with Mobile IP to handle movement between domains.

The Cellular IP protocol proposal [5] [6] [10] from Columbia University and Ericsson enables routing IP Datagram from/to a mobile host. The protocol intends to provide local mobility (within the domain) and it interworks with Mobile IP to provide macro-mobility support (between domains). The protocol supports fast handoff and paging techniques. Micro-mobility support in a Cellular IP network is more important issue than the other micro-mobility protocols; duo to its simplicity, Cellular IP can support efficiently hundreds of, thousands of mobile hosts in a small local area network.

In this paper, a new handoff scheme is proposed as an enhancement to hard handoff algorithm in Cellular IP. The rest of this paper is organized as follows. Section 1.1 describes some of the problems in cellular network, especially Cellular IP access networks, and the motivations for this research. Section 2 describes background and related work. The next two sections (Sections 3 and 4) describe the proposed mechanism and the simulation model (simulation environment and simulation results). Section 5 details our conclusions.

1.1. Problems And Motivations

First: In Cellular Networks [1], to support a large number of mobile hosts and increase capacity, the cell can be split into smaller cells. As a result, the number of handoff will increase. If the handoff mechanisms are not designed properly, the performance of real time and non real time internet applications will not be acceptable especially multimedia applications. Second: As the cells get smaller, the overlap area between cells becomes very small. In case of a high-speed mobile host or cells without overlap area, the handoff process cannot be handled properly within the time [1][11], e.g, semi-soft handoff in Cellular IP. Third: Time Division Multiple Access (TDMA)[1] and Code Division Multiple Access CDMA [1] are the two major access techniques used to share the available bandwidth in a wireless communication system.

Not all wireless technologies have the ability to enable mobile hosts to transmit/receive from multiple base stations simultaneously. For the above reasons a new mechanism called Forward Based Handoff Mechanism (FBHM) is used to reduce the packet loss and improve performance of Cellular IP access networks during Handoff. The proposed handoff mechanism is required and better than semi-soft handoff in the following cases:

-- The Cellular IP access network cannot enable the mobile host to transmit/ receive from more than one base station simultaneously for a small period of time as in TDMA.

-- No overlap area between base stations.

-- As mentioned above, as cell size becomes smaller the overlap area also becomes smaller. So, under high speed, the semi-soft handoff technique is not applicable, approximately 50 m/s and above [11].

2. Review of Cellular IP

Cellular IP [7][8] proposed to handle the mobility within the domain. it support a passive connectivity , fast handoff, and paging mechanism. It can interwork with Mobile IP to provide a macro-mobility between the domains. Cellular IP connects to the Internet through a gateway. Cellular IP maintains two type of distributed cache for location management and routing purposes. Packets transmitted by the mobile host create and update entries in each node's cache. A mobile host also maintains its routing cache mappings even though it is not regularly transmitting data packets; through transmit rout-update packets on the uplink at regular intervals called rout-update time. When the mobile host moves to another access point, the chain of mapping entries always points to its current location because its route-update and uplink packets create new and change old mapping. The mobile host connected to a Cellular IP network is always in either idle state or Active state. The Idle mobile host transmits a paging-update packet when the paging time expires. Paging-update packets are used for location management. The paging update packet is routed from base stations to the gateway using hop-by-hop shortest path routing.

Handoff in Cellular IP is the moving from one access point to another access point during an ongoing data transfer. Cellular IP supports two types of handoff, hard handoff and semi-soft handoff. The following two sections describe these two handoff mechanisms.

2.1. Hard Handoff

Hard handoff is optimized for wireless networks where the mobile host is able to listen/transmit to only one base station as in the case of a Time Division Multiple Access (TDMA) network. Cellular IP base stations periodically emit beacon signals. Mobile hosts listen to these beacon signals and then initiate handoff based on signal strength measurements. The mobile host performs handoff procedure by tuning its radio to a new base station and then sending a route-update packet. The route-update packet creates or modifies routing cache entries in Cellular IP nodes to the gateway. The routing cache entries constitute a reverse path for the downlink packet to a new base station. When the crossover node receives the route-update packet, it diverts the incoming downlink packets toward the new base station. The data packets received by the old base station after the handoff will be dropped. The mechanism proposed in this paper uses a buffer at the old base station to save these packets and forwards them later to the new base station.

2.2. Semi-soft Handoff

Semi-soft handoff is optimized for networks where the mobile host is able to listen/transmit to two or more base stations simultaneously for a short duration, as in CDMA network. When a mobile host receives a beacon signal from a new base station, it sends a semi-soft packet to the new base station and immediately returns to listening to the old base station. The semi-soft packet will create new routing cache mappings from the new base station to the crossover node. The mobile host makes a final handoff decision after some delay called semi-soft delay. Cellular IP introduces delay at the crossover node to synchronize the delay difference between the old route and the new route from the crossover node in case the new route is shorter than the old route. The crossover node is notified that a semi-soft handoff is in progress from the semi-soft packet received from a mobile host that has mapping to another interface.

3. Proposed Mechanism

The idea of forwarding packets during handoff is not new [7][12]. In the case of HAWAII [7], Multiple Stream Forwarding scheme (MSF) and Single Stream Forwarding (SSF) have been proposed. In these schemes, old base station buffers the packets for small duration of time. When Mobile host crosses cell boundary and receives an agent advertisement message, it sends a registration request to new base station. Then, the new base station sends path setup message to the old base station. The old base station forwards the buffer content to the new base station in multiple or single stream according to the scheme used. In these schemes, the crossover node does not buffer the packet. The packets are diverted at the crossover node after forwarding the packets from the old base station. In case of [12], Mechanisms and hierarchical topology for fast handover in wireless IP Networks have been proposed. The scheme, used to handle handoff inside domain, uses path setup message to establish routing entries for the mobile host from the new base station to the old base station. When the old base station receives a path setup message, it forwards the content of the buffer along the new route. The forwarding routing entries at the crossover node cause the incoming packets to be forwarded along the new route toward the new base station. The [7][12] mechanisms use standard IP routing to forward the path setup messages between old and new base stations. They also use standard IP routing to create the forwarding entries in routers from old base station to the new base station. So that, these mechanisms are complex to implement and they generate more signaling and overhead. But, The proposed scheme does not need IP routing and it simply use Cellular IP (routing and paging) cache in the Cellular IP nodes. So, the proposed scheme is simple and easy to implement.

In this paper, it is assumed that every base station has the ability to buffer the downlink packets for a small duration of time. When the mobile host crosses a cell boundary and receives the first beacon signal from the new base station (BS), it sends route-update packet to the new base station, this packet will create routing cache entries in Cellular IP nodes to the gateway. This packet will also enforce the crossover node to keep the incoming downlink packets in temporary buffer. Then, the crossover node sends a forward message to the old base station. It will be forwarded to the old base station using mobile host entries in the old path. When the old base station receives the forward message, it will forward the buffer content through an uplink port toward the gateway. Any node receives data packets from down link port will check the destination IP address. If there is another down link port for this mobile host, this means it is a crossover node, it will send packets to this downlink path. Otherwise, it will send these packets to the uplink port toward gateway. When the crossover node receives the data packets from downlink port and its destination is the mobile host, the crossover node will send these packets to the new path toward the new base station. (The crossover node will check the destination IP address of these packets and send it to the new path). After sending the contents of the buffer to the uplink port, the old base station will send a forward acknowledgement packet to the crossover node. When the crossover node receives the forward acknowledgement packet, it will forward the buffer content toward the new base station in the new path. The incoming downlink packets after the arrival of a route-update packet from the new base station to the crossover node will be held in a delay buffer. When the crossover node receives the forward acknowledgment from the old base station, it will forward the content of the delay buffer along the new path toward the new base station.

4. Simulation Model

4.1. Simulation Environment

To study and evaluate the proposed scheme, the Columbia IP micro-mobility software (CIMS) is used [13], which is a micro-mobility extension for the ns-2 based on version 2.1b6[14]. The network topology used in this simulation is as shown in Figure 1.

Under this simulation we assume that the base stations and CIP Nodes are the wireless access point and router of IP packets while performing all mobility functions. The gateway node is a router, which connects the Cellular IP network to the Internet. The mobile host connects to the corresponding host using the IP address of the gateway as the care-of address.

The packet size used in the simulation is 1000 byte [15]. The mobile host moves from BS1 to BS2. Cell coverage boundary is 140 X 140. Overlapping region between base stations is 30m. The speed of the mobile host is 20m/s. Link delay and bandwidth between each node are 2ms and 10Mb respectively. The maximum buffer size used in simulation is 5 packets for every mobile host. The mobile host communicates with the base stations using IEEE 802.11 MAC enabled wireless link.

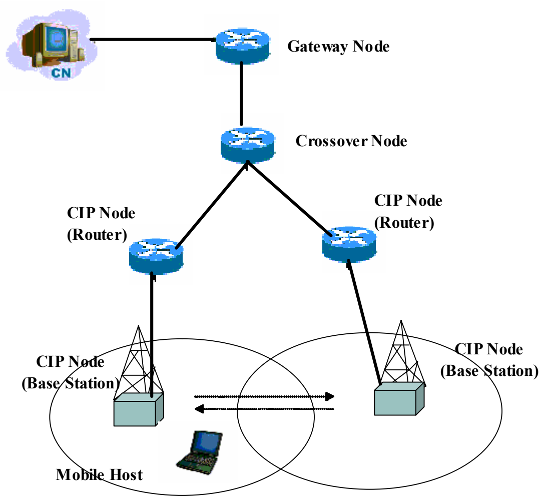

Figure 1: simulation topology.

4.2. Simulation Results

4.2.1. UDP Performance

UDP with CBR (constant bit rate) as traffic source is used in this simulation to study the performance of Cellular IP during different type of handoff. As it can be seen in figure 2, the proposed handoff scheme has no packet loss. Also semi-soft handoff does not have any packet loss. Figure 2 shows that with different data rate, both the proposed scheme (FBHM) and semi-soft handoff achieve zero packet loss. This is because the proposed scheme buffers packets at the old base station and forwards it towards the new base station after the handoff and the semi-soft handoff is capable of starting bi-casting of the data at the cross-over node early during the handoff.

Figure 2 shows that the hard handoff suffers from a packet loss, because the hard handoff initiates handoff after disconnection from old base station and that means all packets in the old path will get lost until the crossover node receives a packet from the mobile host through the new base station.

Figure 3 shows that the mobile host in the proposed scheme receives very less duplicate packets in comparison with semi-soft handoff. The reason for these duplicate packets is that during the handoff the old base station forward content of the buffer to the new base station, where the mobile host already receives it through the old base station.

It can be seen in figure 3 that semi-soft handoff suffers from a lot of duplicate packets. The reason for duplicate packets in semi-soft handoff is because of semi-soft delay in crossover node and bi-casting of the data at the cross-over node to both old and new path. So that, the mobile host receives same packets from the old and new base station.

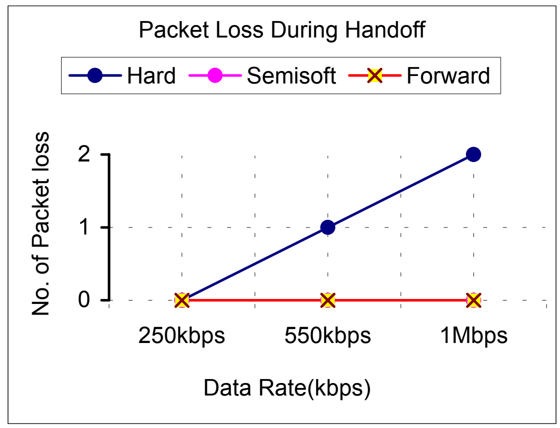

Figure 2: packet loss during handoff in 3 handoff schemes

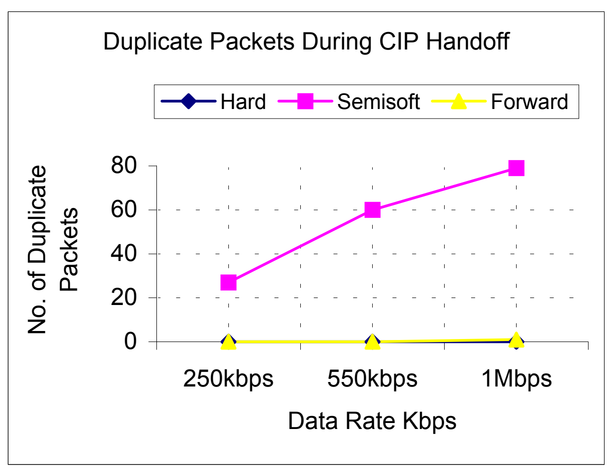

Figure 3: duplicate packets during handoff in 3 handoff schemes.

4.2.2. TCP Performance

At the beginning of TCP Performance analysis, the behavior of TCP Tahoe during handoff is studied using simulation. TCP Tahoe uses FTP as a traffic source to download data from the corresponding host to the mobile host. The simulation configuration used is identical to the Cellular IP simulation environment shown in figure 1. The TCP packet size used in the simulation is 1000 byte [15]. Simulation time is 15 seconds.

Figure 4 shows the packet trace of TCP traffic during hard handoff. It shows the TCP packet sequence numbers vs. simulation time observed at mobile host. It can be observed that TCP Tahoe takes a long time to recover from the loss during hard handoff. After initiating the handoff, all remaining packets in window get lost. The TCP Tahoe receiver is forced to wait until retransmission time out (RTO) gets over. The packet loss and long handoff delay cause the TCP Tahoe sender to decrease window size and initiate slow-start algorithm. It is observed that hard handoff does more than one retransmission time out. The TCP time out interval is doubled with every successive timeout, which is called TCP exponential backoff [16]. So that, the performance of Cellular IP access network is decreased during hard handoff.

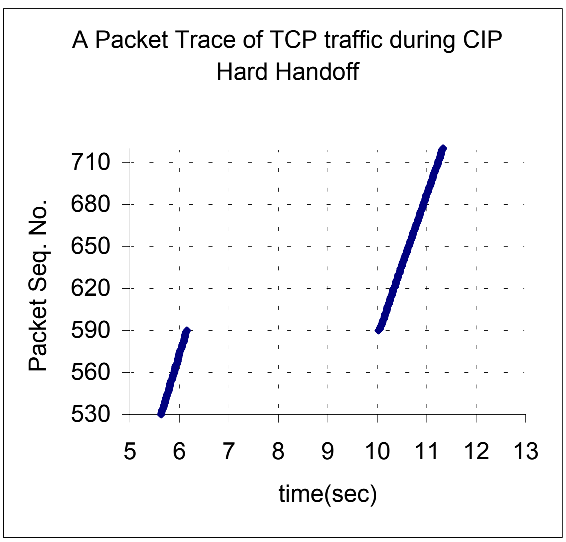

Figure 4: a packet trace of TCP traffic during CIP hard handoff.

Figure 5 shows the packet trace of TCP traffic during the proposed handoff (FBHM). It shows the TCP packets sequence numbers vs. simulation time observed at mobile host. It can be observed that TCP Tahoe takes less time to recover from the loss during the proposed handoff in comparison with hard handoff. After initiating the handoff, twelve packets get lost. When the handoff completed, the remaining packets continue to arrive at the mobile host. These packets are out of order and it triggers the TCP receiver to send duplicate acknowledgment for every packet. When TCP sender receives 3 duplicate acknowledgments, the sender invokes fast retransmit and sends the lost packet. Then, the TCP sender triggers slow-start algorithm. The number of packet drops and the handoff delay in the proposed handoff scheme are less than the number of packet drops and the handoff delay in hard handoff scheme. So that, as it can be seen from figure 6, TCP Tahoe takes less time to recover from the loss in this scheme in comparison with hard handoff scheme.

Figure 6 shows the packet trace of TCP traffic during Semi-soft handoff. It is observed that TCP Tahoe does not have any loss during semi-soft handoff, but there is some delay because of Semi-soft delay at crossover node and that delay can be an arbitrary value that is proportional to the mobile-to-gateway round-trip delay.

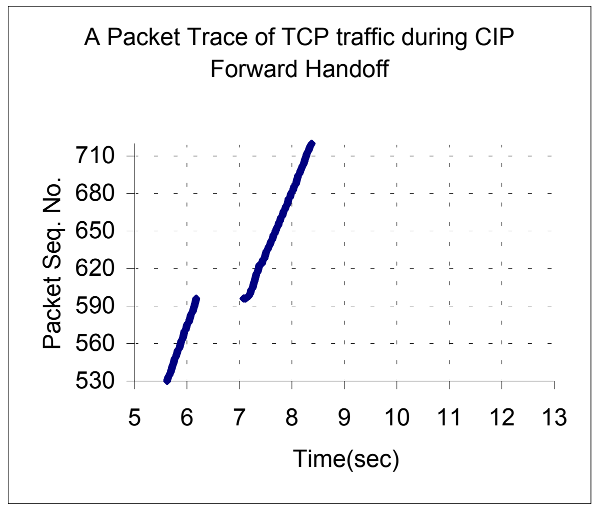

Figure 5: a packet trace of TCP traffic during the proposed handoff scheme.

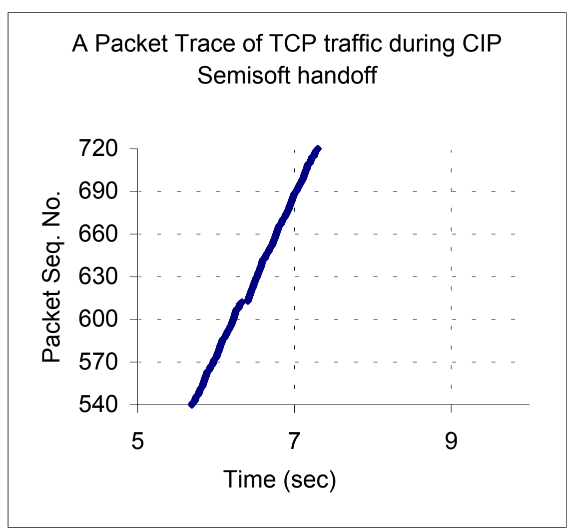

Figure 6: a packet trace of TCP traffic during CIP semi-soft handoff.

From the figures above, we can observe that the disruption time in the proposed scheme is less than the disruption time in hard handoff.

Figure 7 shows TCP throughput during handoff mechanisms. This figure shows that the proposed scheme has a better TCP performance than hard handoff.

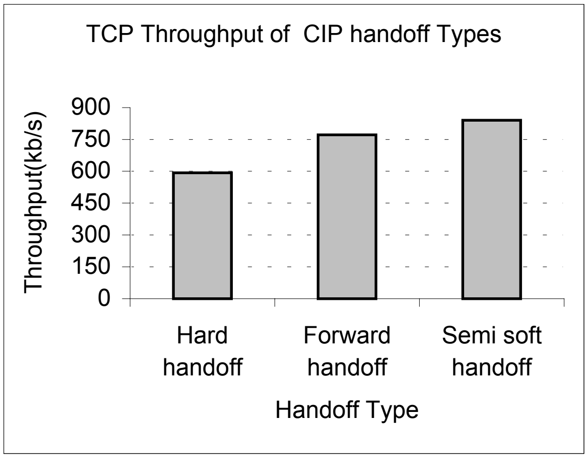

Figure 7: TCP throughput during simulation in 3 handoff schemes.

5. Conclusion

In this paper, we have proposed a new handoff scheme as an enhancement to hard handoff algorithm in Cellular IP. The approach proposed in this paper is called Forward-Based Handoff Mechanism (FBHM), which uses buffering technique at the old base station and the crossover node and it forwards packets from the old base station to the new base station.

The performance of Forward-Based Handoff Mechanism (FBHM) is studied using network simulator Ns2. The simulation result shows that the packet loss of UDP traffic during handoff in this proposed scheme is reduced to zero, which is better than hard handoff and equal to semi-soft handoff. The simulation study shows that the number of duplicate packets received at the receiver is very less in comparison with semi-soft handoff. TCP performance in the proposed scheme is improved in comparison with hard handoff.

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