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Challenges and Solutions for Handoff Issues in 4G Wireless Systems An Overview

Chunming Liu
Ph.D. Candidate, Florida International University, Miami, Florida, USA

Dr. Chi Zhou
Assistant Professor, Florida International University, Miami, Florida, USA

Abstract
As the wireless communications technologies evolve dramatically, the recent research focus has shifted to the development of fourth-generation (4G) mobile systems. Instead of developing a new uniform standard for all wireless communications systems, 4G communication networks strive to seamlessly integrate various existing wireless communication technologies. One of the major challenges in this migration is to realize seamless handoffs among various communications systems with small handoff latency and packet loss. In this paper, we give a survey on existing handoff schemes for IP-Based 4G mobile networks. Specifically, we describe three handover algorithms, Mobile IPv6 protocol, Hierarchical Mobile IPv6 protocol, and IDMP-based fast handoffs. In addition, we compare these handover schemes at the end.

Keywords
4G, handover latency, IP-based, Mobile IPv6, IDMP, Fast Handoff

1. Introduction

In past decades, wireless communications technologies have developed very fast driven by the increasing demands for various multimedia applications and high service quality. The first generation (1G) emerged in the early 1980s, and the systems were analog, voice-centric, and typically limited in capacity. The second-generation (2G) systems appeared about ten years later with increased capacity. These systems are digital and still voice-centric. However, they provide limited data capabilities with about 10 kbps data rate. As the demand for high-bandwidth multimedia applications increases, the third-generation (3G) systems are designed to support integrated services, such as audio, video, real-time video conferencing or high-speed Internet connection. Nowadays, there are various wireless communication systems coexisting for different services, users and data rates, such as AMPS, GSM, IS-95, WCDMA, Wireless LAN, etc. It is preferable that 4G systems [Hui and Yeung, 2003, Nakjima and Yamao, 2001] can seamlessly integrate all existing and newly developed wireless communication systems other than develop a new uniform standard to replace all existing technologies.

To summarize, future 4G wireless networks are expected to have the following key features [Hui and Yeung, 2003]:

- Full packet switched network
- Anytime and anywhere communications based on IPv6 technology
- Integrated services
- Higher data transmission with speed up to 100Mbps

- Personalized service
- Support for multimedia services at low per-bit transmission cost

However, there exist a lot of challenges in design and implementation of 4G systems that will support all the expected features based on current communication systems and standards. One big challenge is how to implement handoffs in IP-based 4G networks with minimum handoff latency and packet loss. Traditionally, handoff management means that system maintains communication connection(s) with a mobile node (MN) when the MN moves from current serving area to a new serving area in a same system. However, in 4G systems, handoff management is more complex to deal with, as it covers not only horizontal handoff but also vertical handoff. Horizontal handoff handles the intra-system handoff when an MN moves between two different cells or access points within the same wireless communication system, while vertical handoff deals with the inter-system handoff when an MN moves from one wireless communication system to another different wireless system, for example, from GSM cellular network to Wireless LAN network. It is difficult to realize the vertical handoff among different wireless communication systems while meeting the various Quality of Service (QoS) requirements. If handoff latency (i.e., the time spent in handoff) is too long, packets may get lost or disconnections may occur during the handoff, which obviously degrade the QoS in 4G systems. Therefore, fast and seamless handover is a big challenge for 4G heterogeneous networks that are supposed to support real-time high-speed multimedia applications that require small handoff delay and high data-rate transmission.

Currently, most of research work on handoff issues in 4G systems focuses on keeping unbroken communications with timely location update or reducing handoff latency and packet loss in IP-based wireless networks. Mobile IPv6 [Johnson and Perkins, 2001, Montavont and Noel, 2002, Beloeil, 2002] is proposed as one of mobility management protocols in 4G IP-based wireless network. Mobile IPv6 tries to keep unbroken communications between a MN and its correspondent by creating a binding scheme between MN's home address and its care-of address during handoff process. However, Mobile IP can not control handoff latency, which results from creating new care-of address, exchanging information between mobile terminal and its home agent whenever status of MN's location information changes. Inheriting binding scheme from Mobile IPv6, Hierarchical Mobile IPv6 [H. Soliman et al., 2001, Pack and Choi, 2003] is proposed to minimize handoff latency and the amount of signaling traffic to correspondent(s) and the home agent by allowing an MN to locally register in a domain without informing the MN's home agent. In addition, Fast Handover [Dommety et al., 2001] is another new handoff proposal, which reduces the handoff latency through predicting the coming movement to initiate a handoff earlier.

2. Objectives

In this paper, we present and discuss three representative types of handover management schemes including Mobile IPv6, Hierarchical Mobile IPv6, and Fast Handover. Among Fast Handover algorithms, we mainly introduce IDMP-based Fast Handoff scheme [Misra et al., 2002] that uses a duration-limited proactive packet multicasting solution as an improved fast handoff scheme, based on Intra-Domain Mobility Management Protocol [Misra et al., 2000].

The rest of the paper is organized as follows: we first introduce the Mobile IPv6 and give a discussion of its attributes. Then the Hierarchical Mobile IPv6 and Fast handover are presented as improved schemes for Mobile IPv6, respectively. We also compare Fast handover with Mobile IPv6 by investigating the impacts of Fast Handover on handoff latency. We give one improved example of Fast Handoff, called IDMP-Based Fast Handoff, after we introduce basic concepts of fast handoff schemes. Finally, we give a brief discussion for these handoff schemes before we conclude this paper.

3. Mobile IPv6 Protocol

Mobile IPv6 [Johnson and Perkins, 2001, Montavont and Noel, 2002, Beloeil, 2002] is proposed to keep any communication between a mobile node and a correspondent node (CN) while the mobile node moves from one IPv6-based sub-network to another one. In this design, each MN has a home address identifying its home network. Within its home network, each MN uses the traditional routing functions to exchange IP datagram with its CN. Whenever an MN moves from its local network to a new network, its home address becomes invalid. And then the MN can create a new address called care-of address (CoA) from a router advertisement message sent by the new visited network. A binding between MN's CoA and its home address is updated to the MN's home agent to keep continuous communications between the MN and its correspondent(s). In this way, MN's home agent can always detect coming communication packets to MN with MN's home address, and locate the current position of MN with MN's CoA.

At the beginning of the handover procedure, an MN can use "Neighbor Discovery" scheme, which is based on reception of Router Advertisement (RA) sent by current access router (AR), to detect its movement to a new subnet, as shown in Figure 1 (arrow line 1). After verifying the uniqueness of its link-local address on the new link, the MN will create an IPv6 address called CoA from the corresponding prefix in RA. After that, MN will exchange binding update information which include MN's CoA with its HA and its CN to allow all of them to maintain their connections, shown in Figure 1(arrow line 2).

Mobile IPv6 can reasonably keep track of MN's new address by timely binding update between the MN and its home agent. However, before finishing binding update, data packet communications are interrupted. The MN needs to spend time discovering new subnet, establishing new care-of address, and exchanging information between MN and its home agent. For 4G high-speed data multimedia communications, all of them will create a lot of signaling traffic and latency, resulting in packet loss. It is even worse when an MN roams between two ARs several times. This frequent roaming will cause ping-pong effects, which refer to the situation in which too frequent and unnecessary location updates and handoffs occur in a short time. In this case, MN cannot keep normal continuous communications with its CN(s). In the meantime, all packets destined for the old care-of address are dropped. Therefore, we need to improve binding update procedure of Mobile IPv6 handover schemes to reduce handoff latency and signaling traffic.

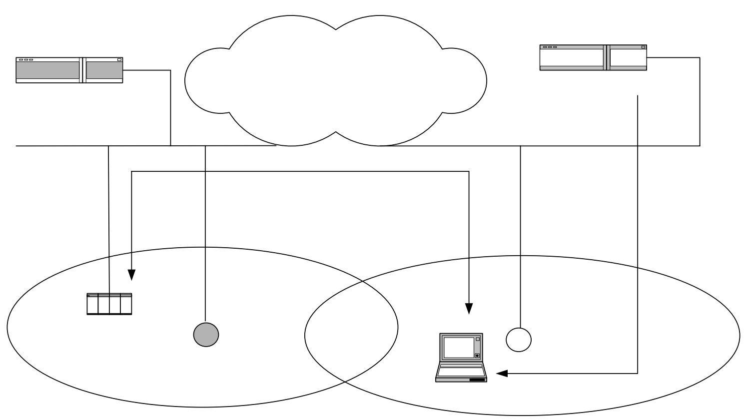

Figure 1. Mobile IPv6 wireless network

4. Hierarchical Mobile IPv6

Hierarchical Mobile IPv6 (HMIPv6) [Soliman et al., 2001, Pack and Choi, 2003] is developed to reduce the amount of signaling traffic required, which affects handoff latency of MN's communications. Unlike MIPv6, HMIPv6 addresses the issue of local mobility and global mobility separately, which means local handoffs are managed locally without notifying home agent, while global mobility is managed with the MIPv6 protocol.

In HMIPv6, the global internet is divided into regions for local area mobility and each region is connected to the rest of IP network with a new node called Mobility Anchor Point (MAP), which is a kind of anchor point in charge of several ARs (from 1 to k), as shown in Figure 2. In this scheme, each mobile node has two care-of addresses. One is a regional care-of address and the other is a local care-of address. The regional care-of address is local to the MAP's covered region. An MN communicates with its correspondent nodes via its regional care-of address.

When an MN moves into a new region or domain, it will first get a regional care-of address from MAP advertisement information, and then the MN will inform its home agent and its correspondents about its “regional location” as its raw location information. When the MN moves between two ARs in the same region covered by a same MAP, MN will update its localization into the domain and get a new local care-of address by sending local registration to the MAP, instead of sending to its home agent. The MAP intercepts data packets designated to MN’s regional care-of address and tunnels them to the corresponding MN’s local care-of address. So in this way, handoff latency and signaling traffic are reduced because each MN hides its local movements in a region from its home agent and correspondents, and meanwhile MN can keep unbroken communications with its correspondent(s).

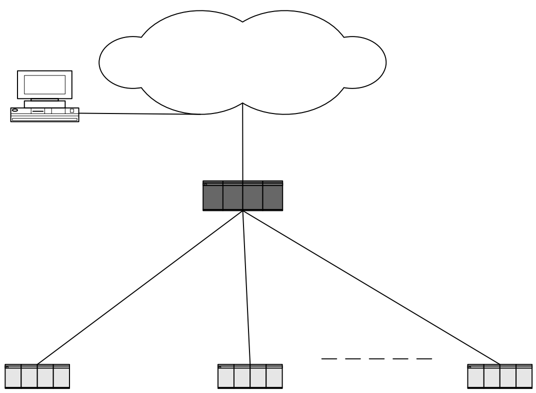

Figure 2. Hierarchical Mobile IPv6 Architecture

5. IDMP-based Fast Handover protocol

Intra-Domain Mobility Management Protocol (IDMP) [Misra et al., 2000] is a multi-CoA intradomain mobility solution. Based on modification of Mobile IP architecture, IDMP has a two-level infrastructure with a special node called the mobility agent (MA) providing an MN a domain-wide stable access point, as shown in Figure 3. Similar to HMIPv6, an MN can get two CoAs under IDMP: one is Local care-of address (LCoA) which identifies the MN’s present subnet, the other is Global care-of address (GCoA) which represents the MN’s domain location. The concept of fast handover [Dommety et al., 2001] is that an AR can predict an incoming Layer 3 (L3: IP layer) handover, which means handover between different APs in different subnets, by receiving certain messages from MN or system. The aim of IDMP-based Fast Handoff [Misra et al., 2002] mechanism is to eliminate intradomain update delay by anticipating incoming handover in connectivity between the network and MNs.

The anticipation of MN’s movement is based on Layer 2 (L2: link-layer) trigger [Dommety et al., 2001] which initiates L3 handover before ending the L2 handover which represents MN’s movement between APs belonging to a same subnet. An L2 trigger contains information on the MN L2 connection and on the link layer identification of the different entities. To minimize the interruption in the procedure, the scheme uses triggers from either MN or BS to notify the MA of an incoming handoff. Then MA multicasts all incoming packets to the entire set of neighboring subnet agents (SAs). Each of SAs buffers the packets in order to reduce the loss of inflight packets during the handoff procedure. After the MN finishes registration on the new subnet agent, the SA can directly transfer all buffered packets to the MN. So in this way, MN can keep communications continuous without waiting for MA to finish all location update procedures.

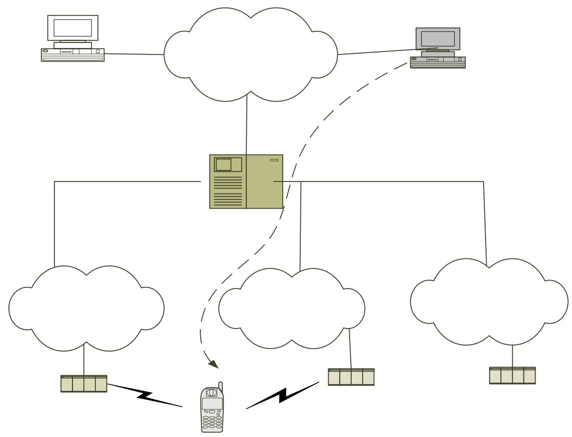

Figure 3. IDMP Architecture

Unlike other handoff proposals mentioned before, IDMP-based fast handoff [Dommety et al., 2001, Misra et al., 2000, Misra, et al., 2002] only focuses on intradomain location update procedures. And multicasting scheme in IDMP can save wireless bandwidth because all other BSs or SAs do not need to transfer packets to an MN except only one certain SA or BS which is chosen by the MN can forward packets to corresponding MN. Furthermore, IDMP is a network-controlled handoff technique, in which MA decides the set of target SAs or BSs.

6. Comparison and Analysis

Because of long handoff latency in Mobile IPv6 systems, Hierarchical Mobile IPv6 and IDMP-based Fast Handoff are proposed as two extensions of Mobile IPv6.

For Hierarchical Mobile IPv6, binding updates between MN and its home agent can be successfully reduced with Mobility Anchor Point (MAP) in charge of MN's local movements in a domain. However, the burden of MAP will increase if MAP handles too many MNs in one domain. It is easy for an MAP to appear "bottleneck" phenomena, which affects the speed of data packets to MNs. Even worse, if an MAP "die" or work abnormally, it is disastrous to all MNs in same domain. One new scheme [Montavont and Noel, 2002] is proposed to relieve the burden of MAP by adding a few more MAPs per domain. However, this method will cause other problems such as dynamic load distribution among MAPs.

While Hierarchical Mobile IPv6 deals with both intradomain and interdomain handoffs, IDMP-based Fast Handoff protocol is proposed mainly for reducing packet loss during intradomain handoff in 4G networks. Each SA in a domain buffers inbound information when the MA in the same domain multicasts all incoming packets to the entire set of neighboring subnet agents (SAs). In this way, MN can keep communication unbroken by receiving buffered packets from the new SA, without waiting for the MA to receive the corresponding intradomain location update. Nevertheless, the set of neighboring BSs covered by each MA is constant, which means each BS permanently belongs to one multicast group and the size of the set is not dynamically changed according to traffic load. With this method, some MA will become very busy in multicasting data packets frequently because the corresponding set of SAs cover too many MNs and related movement activities, while other MA will become "idle". This situation will easily cause communication instability or overload, which in turn increases the probability of packet loss during handoff procedures.

7. Conclusions

In this paper, we give an overview of current handoff techniques for IP-based 4G mobile networks. Specifically, we have described and discussed three major handoff schemes in details, Mobile IPv6, Hierarchical Mobile IPv6, and IDMP-based fast handoff.

Mobile IPv6 protocols define a care-of address for MN in a new visited network. The binding between MN's home address and its care-of address is often updated to keep communication continuous. However, an MN needs to spend time in exchanging information between MN and its home agent whenever its access point changes, which in turn causes a lot of traffic and packet loss, especially for high-speed multimedia applications.

As two extensions of Mobile IPv6, Hierarchical Mobile IPv6 and IDMP-based Fast Handoff are proposed to reduce handoff latency. Hierarchical Mobile IPv6 focuses on reducing binding update for MN's local movement in a domain by adding Mobility Anchor Point which keeps MN's local handoff hidden from correspondent home agent in network. IDMP-based Fast Handoff is proposed mainly for reducing packet loss during intradomain handoff, which is realized in a way that each candidate SA in a set buffers arriving packets during each related intradomain handoff.

Although HMIPv6 and IDMP-based Fast handoff have improved handoff latency in 4G systems in some aspects, they also bring other new obstacles in handoff procedures and need to be improved in future work.

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