FAST HANDOVER ALGORITHM FOR HIERARCHICAL MOBILE IPv6 MACRO-MOBILITY MANAGEMENT

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Abstract

The Mobile IPv6 (MIPv6) mechanism requires some handover algorithm when it changes its point of attachment to the Internet. This causes MIPv6 to incur long delays and signaling loads to the backbone networks. These limitations are the result of the lack of hierarchy in the MIPv6 mobility management; using the same mechanism for macro-mobility and micro-mobility, is an inefficient use of resources in the case of local mobility.

Hierarchical Mobile IPv6 (HMIPv6) is an extension of MIPv6 designed to reduce the signaling load and to improve the handover speed for mobile connections by introducing a new protocol agent called mobility anchor point (MAP) and splitting the mobility management into macro-mobility and micro-mobility schemes. However HMIPv6 only improves the micro-mobility problem while significant delay still occur in the HMIPv6 macro-mobility management because the handover algorithm is similar with the MIPv6 in this environment.

This paper proposes a new fast handover algorithm that overcomes the limitations in Mobile MIPv6 and its extension HMIPv6. Our design objective is to re-establish the communication traffic flow quickly and to minimize the service disruption delay that occurs during the handover process in a macro-mobility environment. This fast handover algorithm is based on modifying the HMIPv6 protocol using the multicast technique concept. This algorithm will enable the mobile node to receive packets faster than through the HMIPv6 protocol during handover in a seamless and transparent matter.

Keywords: Macro mobility, handover, Mobile IPv6, Hierarchical MIPv6

Introduction

User mobility and real time traffic (e.g., Voice over IP) are two expanding areas within communication systems. The concept of combining these two areas contains several challenging problems. Providing data access has become an ever more important feature of mobile networks in recent years. This development is undoubtedly the result of the success of the Internet together with the widespread use of the 2G mobile networks and has resulted in the specification and standardization of mechanisms such as the GPRS for enhancing the data traffic capabilities of 2G systems. At the same time, smaller scale wireless solutions intended for the provision of fast data access in a very limited have become more important. These

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mechanisms include most notably the wireless LAN systems based on the IEEE 802 series as well as the Bluetooth mechanism.

The development of these two different kinds of wireless access system has caused a demand for solutions in which the user is able to use a multi-mode terminal capable of accessing the IP network, using both the global mobile networks as well as the Wireless LAN system, the future 4G cellular networks aim to develop a framework for truly ubiquitous IP based access by mobile users, with special emphasis on the ability to use a wide variety of wireless and wired access technologies to access the common information infrastructure (Misra and Das, 2002).

Mobile IP is chosen to make slight alternation (Internet Engineering Task Force, 2001). The advantage of mobile IP is its physical layer independence, which means that any communication media, including wired and wireless networks will support mobile IP. Mobile IP will provide major benefits, including application transparency and the possibility of seamless roaming. Application transparency is almost required for all reasonable solutions, because it is unacceptable to force mobile users to buy all new mobile aware applications and mobile IP is the only current means for offering seamless mobility to mobile computers in the Internet. However, Mobile IP needs to be enhanced to meet the needs of future fourth generation cellular networks. IPv6 is the next generation of the Internet protocol that tries to replace IPv4 and support mobility. Mobile IPv6 faces some problems due to its handover management which provides only macro-mobility management.

The contribution of this paper is therefore as follows. We present a performance analysis of the macro-mobility management in HMIPv6 networks for real time traffic and we propose a modification to HMIPv6 macro-mobility to support fast handover by adopting the multicast mechanism to the HMIPv6 protocol and then the performance comparison for both schemes are reviewed. The remainder of this paper is organized as follows: Firstly, the nature of the problems pertinent in MIPv6 is discussed. Secondly, a brief review of MIPv6 and HMIPv6 is presented. Thirdly, a description of our proposed fast handover algorithm for HMIPv6 macro-mobility is introduced, Fourthly, simulation results and performance testing analysis are presented. Finally, the paper is concluded in section five.

Mobility Management in MIPv6 and HMIPv6 Mobility Management

Mobile IPv6 provides a mechanism to support mobility in IPv6. A mobile node (MN) gets a new IP address when it moves to a new network other than the home network. This new address is called Care of Address (CoA) and essentially provides the MN’s current point of attachment. The MIPv6 protocol consists of a home agent (HA) that serves the MN when it is within its home network, and an access router (AR) which advertises the address every time an MN moves into its network. When the MN wants to roam to a foreign network, the MN will acquire a new care of address advertised by the AR. The MN then registers its new CoA to its HA and CN. This is done as follows:

1. MN sends binding update message (BU) to HA and CN through the new access router (AR).

2. The new AR begins to act as proxy so that it can perform the duplicate address detection (DAD) checks. If the DAD check is successful, the new AR must send binding acknowledgement (B_ack) to MN, confirming the address validation.

3. After MN receives B_ack, it sends BU to CN and HA.

A problem arises when the HA or CN is located geographically far away from the MN and when a mobile node moves in a small coverage area (micro-mobility), a situation which is not be suitable for such a scenario. The message exchange transmission time for MN to send BU to HA/CN will become very high causing long delays or service disruptions in both macro and micro-mobility. This generates significant signaling traffic load in the core network, even for local movement, followed by a long interruption during the handover (Figure 1).

HMIPv6 (Internet Engineering Task Force, 2001) improves the handover management of basic MIPv6 by introducing a new protocol agent called MAP. MAP splits the management of the handover process into macro-mobility and micro-mobility and deals with them separately. In HMIPv6, MN assigns two addresses, regional care of address (RCoA) and on-link care of address (LCoA). These two addresses are very useful for managing macro-mobility and micro-mobility (Figure 2).

Macro-mobility handover happens when MN moves globally from one MAP to another MAP both of which are located far away from each other. In this mobility management, the MN will acquire two new addresses, namely the new RCoA and the new LCoA. These addresses should be registered to the HA or CN by sending a binding update to the HA or to CN. After the HA or CN receive the binding update, they send their packets based on the MN's new RCoA to the MAP. MAP receives the packets and forward them to MN based on MN's new LCoA.

Micro-mobility handover happens when MN moves locally between access routers within one MAP domain. In this mobility management, the MN acquires only a new LCoA, but the RCoA remains unchanged. This new LCoA should be registered only to the MAP by MN sending a binding update to MAP. MN does not have to send a binding update to HA or CN, instead HA or CN send their packets only to the MAP based on the MN's RCoA. MAP receives the packets and sends the packets based on MN's new LCoA.

Proposed Macro-mobility Management Scheme

To further reduce the handover delay in the HMIPv6 macro-mobility protocol, we propose a modification for the handover mobility scheme.

Macro-Mobility Management

The HMIPv6 macro-mobility management is explained by modeling the routing scheme for every message exchange between MN and its correspondent agent (CN). The over-all delay is dependent on the time required for each step in the registration operation which in-turn depends mainly on the transmission time between the nodes. The message exchange for this operation is shown in Figure 3. We assume the scenario that the MN is currently receiving packets from CN and starts to move to a new MAP domain. After the MN receives router advertisements, it acquires two new addresses, the RCoA and LCoA.

The description for each message exchange is as follows:

1. Mobile node sends binding update (BU) to mobility anchor point (MAP) through

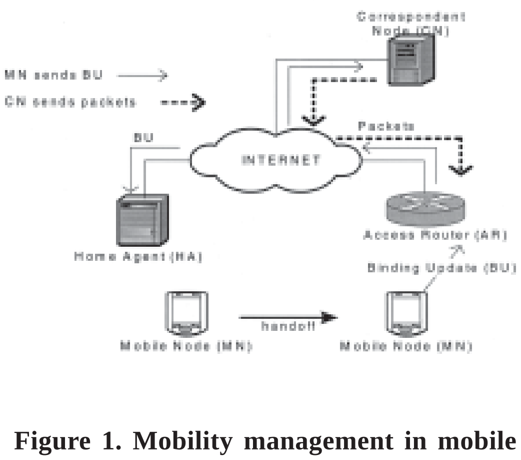

Figure 1. Mobility management in mobile IPv6.

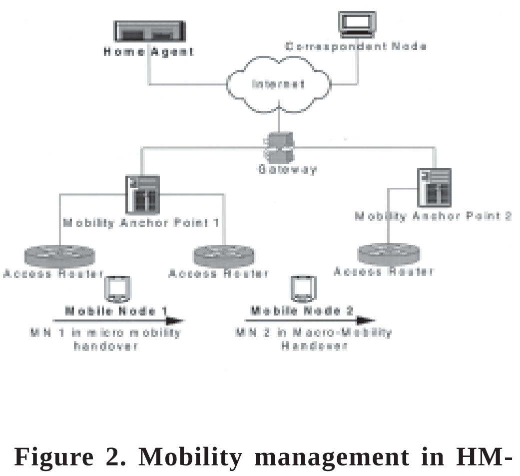

Figure 2. Mobility management in HM-IPv6 network.

access router (AR). MN needs to configure two care of addresses: A new RCoA and new LCoA,

2. AR receives BU and sends to MAP,
3. MAP receives the BU and performs a duplicate address detection (DAD) check. During this time MN must wait for the check to complete.
4. MAP sends binding acknowledgement (B_ack) to MN through AR. B_ack is used to indicate that it has successfully received MN's BU and the address is not duplicated,
5. AR sends B_ack and MN receives it,
6. Subsequently MN sends BU to CN through AR and MAP. This BU is used to inform the CN or HA to change their destination address for the packets belonging to MN,
7. AR receives BU and sends to MAP,
8. MAP receives and sends BU to CN,
9. CN receives the BU and changes the destination address from the old RCoA to new RCoA. CN sends the packets to MN through MAP based on MN's new RCoA,
10. MAP receives packets addressed to the MN's RCoA. Packets will be encapsulated and tunneled from the MAP to MN through AR based on MN's LCoA.
11. AR sends packet to MN.

After the MN receives packets from CN, it de-capsulates the packets and then processes them in the normal manner (this means the registration operation is done).

Proposed Multicast Scheme in Macro-Mobility Management

In HMIPv6, the delay comes from the DAD check and the message exchange transmission time during the process of the registration operation. We propose a multicast technique that is designed to minimize the service disruption delay occurring during the registration operation. Now assume the scenario depicted in Figure 4. The MN is within MAP1, specifically within AR3, and has an RCoA1 and LCoA3 and CN is currently sending packets to MN. When MN reaches the edge of MAP1 coverage area, MN sends a control message to MAP1 requesting it to build a multicast group for the MN. MAP1 receives the control message and constructs a multicast group for the MN and then sends a message to the adjacent ARs (in this case, these are AR2 and AR4) to join the multicast group. Thus when there are on-going packets, addressed to MN, in the network, MAP1 will multicast the packets to AR2 and AR4. If there is any request message from the MN, the ARs forward the packets based on MN's unique

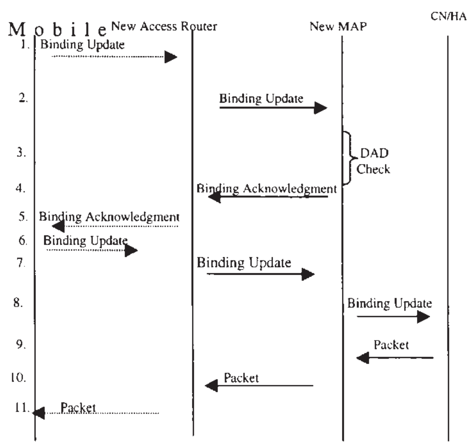

Figure 3. Macro-mobility handover routing scheme (dotted line represents wireless connection).

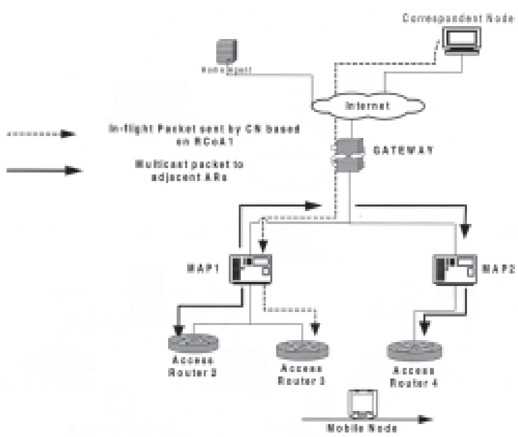

Figure 4. Proposed multicast scheme for HMIPv6 macro mobility management.

interface identifier.

When MN examines that it receives the router advertisement from AR4, the MN acquires two addresses, e.g., RCoA2 and LCoA4. Then MN must register its presence with the HA and CN. Similar to HMIPv6, we can explain the registration operation (Figure 5) as follows:

1. MN sends binding update (BU) and requests message to AR4 to request AR4 to forward the packets.
2. AR4 receives request message and BU. AR4 forwards the multicast packets based on MN's unique interface identifier. Simultaneously AR4 sends BU to MAP for DAD check. MN receives temporary multicast packet from AR4 until registration operation completes.
3. MAP2 receives BU, performs DAD check.
4. MAP2 finishes the DAD check and then changes the destination address of MN from (RCoA1, LCoA3) to (RCoA2, LCoA4) and sends binding acknowledgement (B_ack) to MN.
5. AR4 receives B_ack and sends to MN.
6. MN receives B_ack, containing the validation of RCoA2 and LCoA4, and sends BU to CN to inform CN about its new addresses.
7. AR4 receives BU and sends it to MAP2.
8. MAP2 receives BU and sends to CN.
9. CN receives and changes the MN's old RCoA (RCoA1) to MN's new RCoA (RCoA2) and sends the packets to MN.
10. MAP2 receives packets addressed to the MN's RCoA2 and sends to MN through AR4 based on MN's LCoA4.
11. AR4 receives the packets and sends to MN.

Consequently with this scheme, the new AR will have a copy of the on-going packets when the MN is still within old MAP. When the MN moves to a new MAP, the new AR starts forwarding the packets to MN during the registration operation.

Simulation Setup and Performance Testing

Registration operation of the mobile IPv6 handover starts when the MN sends a binding update to its new access router and ends when MN receives any packet addressed to it. The objective of this simulation is to find out the time for the MN to re-establish the communication, from the time the MN sends the BU message until the time when the MN receives packets from its new AR. This time difference is defined as the handover delay. The analysis of the handover delay is very useful to indicate and evaluate the performance of each scheme. We used the network simulator (NS-2) (University of Berekley, 2003) to test the performance for our proposed multicast scheme.

NS-2 is a discrete event simulator targeted at networking research. It provides substantial support for simulation of transport protocol, routing protocols and traffic analysis over wired and wireless networks. The NS-2 is object oriented, discrete event simulator for networking research. Figure 6 shows the general architectures of NS. In this figure, a general user (not an NS developer) can be thought of as standing at the left hand bottom corner, designing and running simulations in TCL (Tool Command Language) using the simulator objects in the Object Tool Command Language (OTCL) library. The event schedulers and most of the network components are implemented in C++ and are available to OTCL through an OTCL linkage that is implemented using TCLCL. The whole thing together makes NS, which is an OO (Object Oriented) extended TCL interpreter with network simulator libraries.

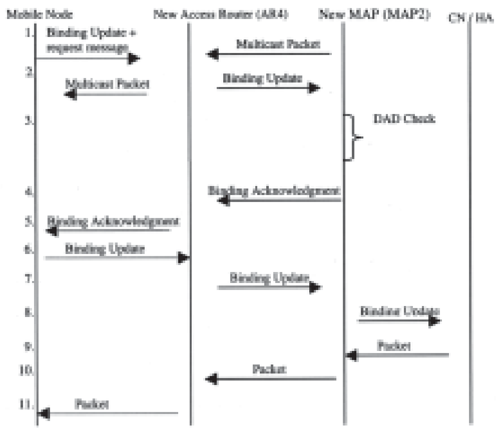

Figure 5. Proposed handover routing scheme.

In order to simulate real traffic, we set up the Correspondent Node (CN) as a traffic source of a Constant Bit Rate (CBR) source over a User Datagram Protocol (UDP), producing fixed length packets of 200 bytes each every 20 ms. This simulates a host that is streaming audio or Voice Over Internet Protocol (VoIP) traffic. Then the mobile node acts as a sink receiving packets from CN.

The setup link topology consisted of a wired link and a wireless link. The wired link was fixed and used to connect the CN to MAP and MAP to the access router (AR). The bandwidth was set to 100 Mbps and the wired link propagation delay was set to 2 ms. To gauge the handover delay performance of our scheme for different possible wireless networks, we performed our simulation using wireless networks of different link delays and different bandwidth. For macro-mobility network we varird the link delay, from 10 ms to 50 ms for link delay and the bandwidth were set each time to a different level, such as 1 Mbps, 2 Mbps and 5.5 Mbps, respectively.

Figure 7 and Figure 8 represent the performance of handover delay for a macro-mobility network for HMIPv6 and our proposed multicast scheme respectively. We can see from the graphs that for a typical wireless network of 2 Mbps and 20 ms link delay, in HMIPv6, MN must wait for about 300 ms to start receiving the packets from the correspondent node since MN sends BU to its new access router. For our proposed multicast scheme, MN must wait for about 100 ms only to start receiving the packets, a savings of 200 ms.

However to find out the time needed to complete the handover, we should include the rendezvous time, that is, the time for MN to hear the beacon from a new AR after roaming out of the old AR's network. Thus the time to complete the handover is the handover delay and the rendezvous time. The rendezvous time determines how soon a mobile node can detects its movement out of the wireless access router coverage area and initiate a handover (Tan and Pink, 2000). In a wireless environment with approximately synchronous beacon systems (all ARs send out beacons approximately at the same time, with a small time offset just enough to prevent collisions of beacons between adjacent access router), the worst case of the rendezvous time is equal to the beacon period. Typically the beacon periods would be around 100 ms in a wide area cellular network (De Silva and Sirisena, 2001).

Voice transmission is critical when assessing suitability for supporting delay sensitive transmission. For packetized voice to be translated back in real time mode, various

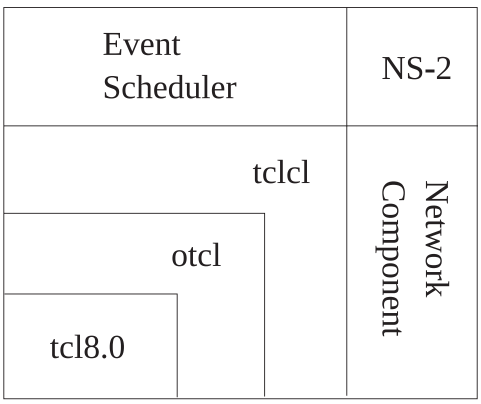

Figure 6. Handover delay for proposed multicast scheme for different bandwidths and link delays in a macro-mobility network.

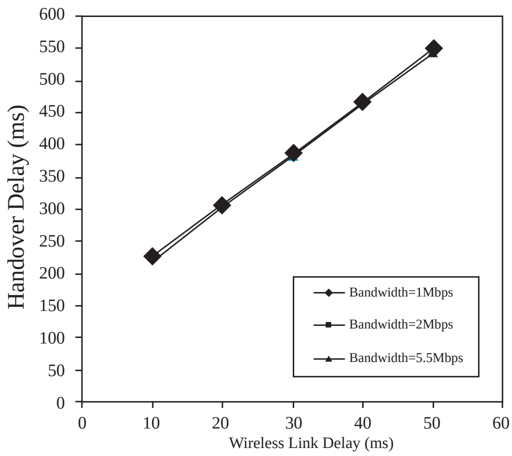

Figure 7. Architectural view of NS-2.

human factor studies have shown that the maximum tolerable delay for voice interactive communication is approximately 200 ms (Tan and Pink, 2000) and for the intelligible voice communication is approximately 400 ms (Chuan, 1999). If the delay becomes too long, beyond the maximum tolerable delay, the communication appears phony and can be quite annoying.

From the Figure 7, if we assume that the rendezvous time is approximately 100 ms, the complete handover delay for HMIPv6 macro-mobility for the various link delays from 10 ms to 50 ms and fixed bandwidth 2 Mbps is approximately 330 ms to 650 ms. From Figure 8, the complete handover delay for the various link delays from 10 ms to 50 ms and the bandwidth 2 Mbps for our proposal is approximately 140 ms to 315 ms.

If we refer to the maximum tolerable delay for voice communication, HMIPv6 cannot meet the maximum tolerable delay requirement for interactive voice and can only meet the requirement for intelligible voice communication if the link delay is less than 10 ms. As for our proposed multicast scheme, the scheme can meet the requirement for interactive voice communication if the link delays is less than 20 ms and for intelligible voice communication, our scheme can meet the requirement in every wireless environment.

In the next simulation, we examined the packet loss rate. The packet loss rate is directly proportional to the accumulated link transmission time over the wired and wireless portions during the registration operation. During this period, the MN is unreachable. If any CN sends packets to MN, the packet will be lost.

To test the performance, we fixed the wireless bandwidth of 2 Mbps and we varied the packet service rate transmitted by the CN. Packet service rate is given in packets/second and is the number of packets transmitted per unit time. The variation of packet service rate were 25 packets/second, 50 packets/second and 100 packets/second – corresponding to date rates of 40, 80 and 160 Kbits/second which covers PCM transmission rate, plus higher rate internet audio streaming sources to represent some of the higher coding rates proposed for 3G systems (De Silva and Sirisena, 2001).

The performances are plotted in Figure 9 for basic HMIPv6 and Figure 10 for our multicast scheme.

Our proposed multicast scheme can reduce the packet loss during the handover operation. Packet loss rate in HMIPv6 for a typical fixed bandwidth of 2 Mbps and wireless link delay of 10 ms is 19%, and for 50 ms is 44% respectively for 100 packets/second service rate. For our scheme with link delay 10 ms, the packet loss rate is 2% and for 50 ms is 10% respectively for

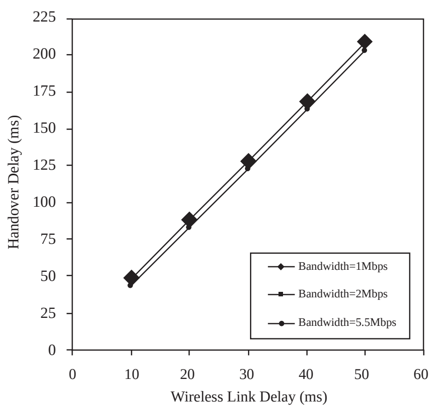

Figure 8. Handover delay for HMIPv6 networks for different bandwidths and link delays in a macro-mobility network.

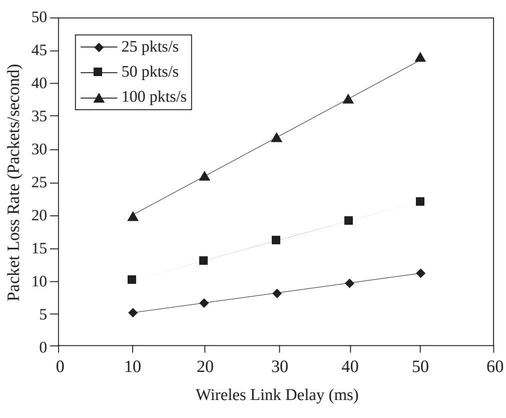

Figure 9. Packet loss rate for HMIPv6 in macro-mobility.

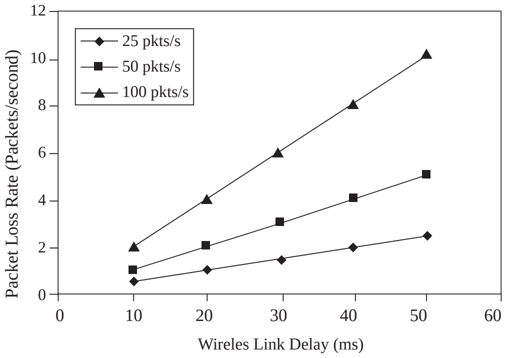

Figure 10. Packet loss rate for our multicast scheme.

100 packets/second service rate, and the efficiency of our scheme is apparent.

Conclusion

In this paper we have proposed a scheme to perform fast handovers for hierarchical mobile IPv6 networks in the macro-mobility management. Fast handover performance is achieved by forwarding multicast packets from the mobility anchor point to every adjacent access router. We have simulated the performance in network simulator 2. From the simulation results, we have shown that for our proposal, the MN will receive packets faster than in the basic HMIPv6 scheme, and our proposed scheme can meet the requirement for voice communication for a minimum link delay environment.

However, our multicast technique can cause more usage of the bandwidth especially in the new access router network since the MAP should forward the copy of the packets to the one mobile node in a different access router network. To solve this problem we recommend to the MN to require some means of obtaining some information about the capabilities of the ARs, such as different load conditions, different QoS availability, etc, thus that the best decision about the handover target can be made. This can be achieved by using some new protocols that still under discussion in the Internet Engineering Task Force (IETF) called Context Transfer Protocol (Internet Engineering Task Force, 2003) and Handover Candidate Discovery.

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