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On the Layer based Seamless Handover Schemes for Mobile Data Network

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Abstract

This paper presents seamless handover schemes survey based on layer approach. Efficient handover scheme is very important in order to minimize the handover latency in mobile network. Latency is mainly affected when new IP address has to be obtained in layer 3 and layer 4 handover mechanisms because this is processed by software. Therefore, we have to focus on the exact mechanism to obtain new IP address and delete old IP address. IPv6 tries to reduce the latency by using stateless-auto-configuration method instead of DHCP (Dynamic Host Configuration Protocol) in layer 3 handover. However, this method limits most of applications using IPv4. SCTP (Stream Control Transmission Protocol) uses multi-homing features with dual interfaces. L4 handover scheme using SCTP is well known to reduce the handover latency more than the handover scheme using TCP. However, SCTP handover scheme utilizes IP address in L4, which violates the strict layer independence. This paper provides us with the pros and cons to determine which handover scheme is applicable to the specific application environment.

Keywords: *Handover schemes, Layer based approach, SCTP, Data Network.*

1. Introduction

Handover scheme is one of very important issues in data communication networks. These schemes are classified into four categories: Layer 1(L1), Layer 2(L2), Layer 3(L3), and Layer 4 (L4) handover.

L1 handover performed in the physical layer mainly focuses on the change of signal power. That is, the main problem is how to detect the real signal power in order to handover to new AP (Access Point).

L2 handover performed in data link layer compose of three procedures. Movement detection is to first check the reachability of old AP and then discover new AP based on the beacon signal power and SIR (Signal-to-Interference Ratio). If necessary, L2 handover selects new AP and makes a reassociation for new AP through authentication.

L3 handover performed in the network layer conducts another movement detection: First, L3 handover investigates the reachablity of old AR(Access Router), then checks the validity of current AR, and then discovers new AR. L3 handover then selects new AR (if necessary) . Finally, it conducts DAD (Dynamic Address Determination) [1]. L3 handover configures new IP (Internet Protocol) address based on stateless auto-configuration with IPv6 or DHCP (Dynamic Host Configuration Protocol) [2] with IPv4/IPv6 and NAT (Network Address Translator) with IPv4. L3 handover also makes a registration with new AR using BU (binding update).

L4 handover performed in the transport layer conducts the following five steps: MN (Mobile Node) adds new IP to IP_list. MN sends ASCONF_add chunk to CN (Correspondent Node) and receives ASCONF_ACK chuck. And it then sends ASCONF_set_primary chuck to CN. Finally, MN updates IP_list [3].

Now, we investigate the handover schemes in detail based on the movement detection, the configuration IP address, and the binding updates. For the movement detection, IPv4 first check the reachabilty of old AR by using ARP (Address Request Protocol) request/reply mechanism [4]. It then checks the validity of old AR by using unicast RS (Route Solicitation)/RA (Route Advertisement) mechanism. And it then tries to discover new AR by using all-router multicast RS/RA [5] and then selects new AR. It finally performs DAD by sending the ARP multicast for all subnet. This procedure is the same in both IPv4 and IPv6.

In order to configure new IP address, IPv4 uses the DHCPv4 and link-local-IP (NAT). On the other hand, IPv6 uses DHCPv6 and stateless-auto-configuration-link-local-site-local-global mechanism [6]. For the binding update, MIPv4 (Mobile IPv4) uses HA (Home Agent) and FA (Foreign Agent) and CN. MIPv4 can also use the route optimization option. MIPv6 uses the route optimization as a default.

Seamless IP mobility is composed of two categories: One is the local mobility management mechanism and another is fast handover mechanism. Local mobility management scheme is classified into hierarchical mobile IP and independent region movement. In the hierarchical mobile IP scheme, MIPv4 uses regional registration mechanism. Meanwhile, MIPv6 uses HMIPv6 (Hierarchical Mobile IPv6 Mobility Management) mechanism. In the independent region movement scheme, MIPv4 uses mobile IP for global mobility, and host based routing mechanism such as Celluar and Hawaii [7]. Fast handover uses L2 trigger. MIPv4 uses the low latency handoffs and MIPv6 uses the anticipated handover or tunnel based handover mechanism.

The focus of this paper is to investigate several handover schemes to minimize the latency during handover process. Furthermore, this paper studies the factors to affect the seamless mobility.

We describe the Layer 2, 3, and 4 handover schemes in Sections 2, 3 and 4 respectively. We conclude this paper in Section 5.

2. Layer 2 handover schemes

We first describe the signal power detection problem and then investigate the L2 handover mechanism.

The important problem of L2 handover is how to detect the real signal power to indicate the real handover. The use of the signal strength as handover trigger requires the definition of a threshold. However, the signal strength threshold is a system-specific parameter. Moreover, the threshold might be even specific for devices from different vendors.

The signal strength usually includes interference. Consequently, in environments with high interference, the channel might be bad although the measured signal strength indicates a good channel. For example in IEEE 802.11 wireless LANs, the access point transmits a link layer beacon that can be used for signal strength measurements. The received signal strength may change rapidly. A typical, well-known example for such a scenario is the corner effect. In order to include the signals of other mobile devices in the same (or adjacent) cell, the wireless network card must be forced to work in promiscuous mode. In this mode, the mobile node consumes more energy.

If the signal strength is sampled at a fade-out, then a handover can be triggered without being necessary. Therefore, the signal is averaged with a time window of a certain size. The antenna system at the receiver as well as at the transmitter impacts the signal strength [8]. To determine L2 trigger, SIR (Signal-to-Interference Ratio), BER (Bit Error Rate) and FER (Frame Error Rate) are mainly used. L2 handover for wireless can be described [9].

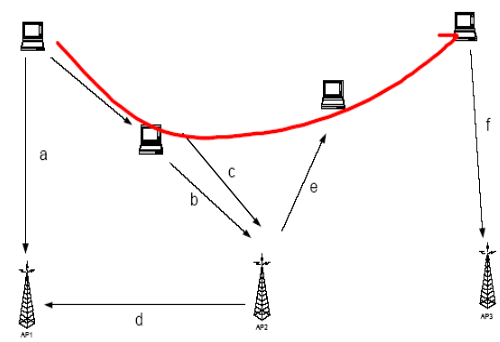

Fig. 1 L2 handover for wireless environment [9]

(a) MN finds AP1, it will authenticate and associate.
(b) As MN moves, it may pre-authenticate with AP2.
(c) When the association with AP1 is no longer desirable, it may re-associate with AP2.
(d) AP2 notifies AP1 of the new location of the station, terminates the previous association with AP1.
(e) At some point, AP2 may be taken out of service. AP2 would disassociate the associated stations.
(f) MN finds another access point and authenticates and associate.

Now, we present the timeline for L2 handover in Fig. 2. Mishra and Shin [10] found the followings: The probe delay is the dominating component – 90 % of handoff delay. The wireless HW used affects handover latency. There is large variation in handover latency. The different wireless cards follow different sequence. In [11], MN checks whether the corresponding BS (base station) is already in the list of base station within range. If BS is in the list, MN updates the expiration time. Otherwise, MN creates new entry.

Gowasmi [12] proposed that MIPv4 registration message are carried in the Information Elements of 802.11 frame in order to perform fast handoff on the layer 2 for MIPv4 with 802.11 AP. Yegin [13] proposed that MN sends the reassociation.request to new AP when BER (Bit Error Rate) on the link with the old AP has become too large (contains MAC address of MN). When MN receives the reassociation.reply (contains MAC address of new AP), it trigger IP (mobile-IP) stack. IP stack sends RS to the new AR without waiting RA.

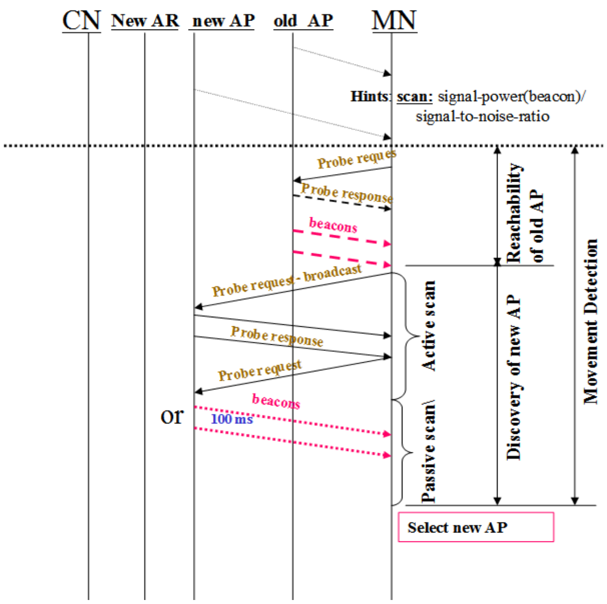

Fig. 2.A Timeline for L2 handover

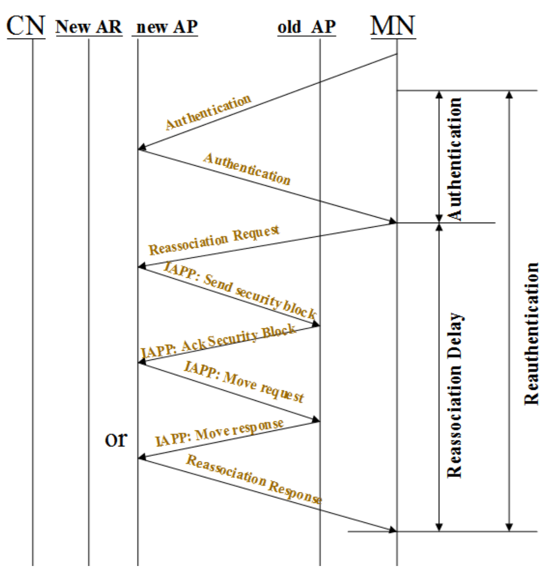

Fig. 2.B Timeline for L2 handover (continued)

Tan [14] allows AP to advertise the capabilities information of its associated network and deals with IPv6 handover in IEEE802.11. Montavont and Noel [15] found that L2 handover can be very important. When there are several users connected an AP, the L2 handover strongly increase, hence, available throughput is restricted. FMIPv6 offers shorter disruption time than MIPv6. The reason is why MIPv6 is restricted by the time needed to detect the new network prefix. In FMIPv6, tunnel based handover introduces less latency than the anticipated handover because MN does not need to interact with the AR. However, unacceptable delays for real time applications may occur.

In MN movement [16], no all L2 mobility indication from the L2 driver indicates movement of the MN to a new subnet. There are three entities which may change in connection with MN movement, Access Point (Link-layer connection), Access Router and On-link Prefixes (IP Subnet). These changes are indicated to MN with the following:

(1) Link-layer triggers
(2) A new IP address (in source address field of RA)
(3) A new Subnet Prefix (in Prefix Information Option in RA)

To get the above indications, MN can perform ICMPv6 NS (Neighbor Solicitation) /NA (Neighbor Advertisement) exchange, RS/RA exchange or just receive unsolicited RAs.
An MN's movement detection scheme should combine the available information to detect movement correctly. It should not mistake some hint as movement while the MN hasn't moved. That may result in continual handoff, and hence excessive mobility signaling. If the MN moves, it needs to detect movement sufficiently fast so that it can complete handover signaling without significantly degrading application performance. On the other hand, if the MN doesn't move though it receives some hints, it is not imperative to detect its non-movement so fast. It will not degrade performance even if MN can't quickly confirm that it still remains at the same subnet. A movement detection scheme should not result in excessive signaling traffic. It should not flood the network with unnecessary RS/RA or NS/NA messages. The delay time between AP (L2 handover) with the number of users decrease the throughput sharply [16].

3. Layer 3 handover schemes

3.1 Movement Detection

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For reachability of old AR and validity of old CoA (Care-of-Address), MIPv4 generally uses LCS (Lazy Cell Switching) based on the <lifetime> field within the ICMP RA, prefix matching (option) based on the prefix-length within the prefix-length extension, and ECS(Eager Cell Switching) based on different network identifier. MIPv6 uses the prefix matching. Perkins [17] insists that for SCTP over ordinary IPv4, we can't use LCS method since the MN already passes the overlapped region. Especially, advertisement interval time can be set between 3 sec and 30 minutes. This time is so long for fast moving MN. Also, we can't use the prefix method since the ordinary ICMP router discovery message doesn't have the prefix or CoA. Thus, we can only consider ECS in ordinary IPv4 environment. In this case, we may use the lifetime or address of router in the RA message.

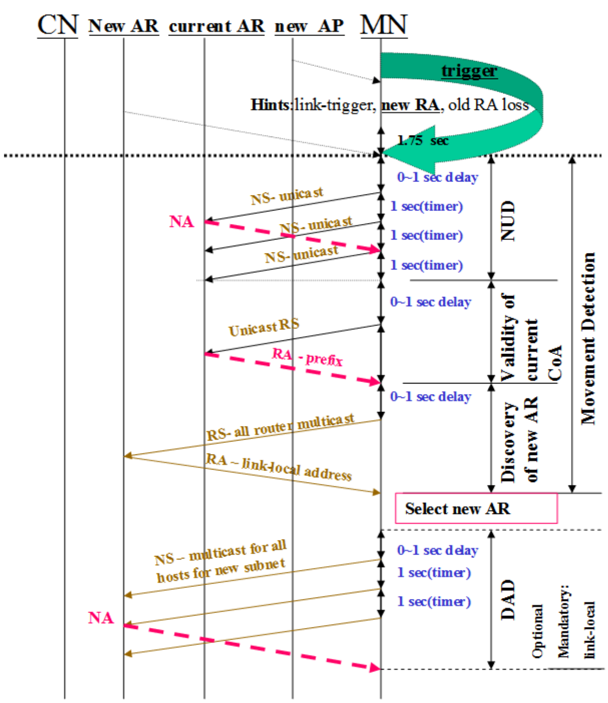

Fig. 3.A Timeline for L3 handover

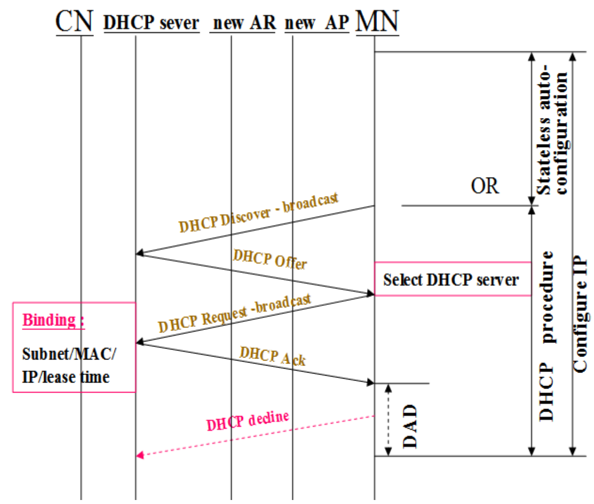

Fig. 3.B Timeline for L3 handover (continued)

Trossen [18] assumes that wireless link protocol is capable of delivering a layer 2 identifier for the new AP or the radio interface of new AR to the current AR or to the MN. MN delivers the layer 2 addresses to current AR. Current AR gets the new IP for new AR using layer 2 address.

3.2 Discovery of new AR

Daley [16] uses the timer and NS in order to discover new AR. When MN checks the reachability of current AR, it takes 3 sec. The reason is why MN should send three NS's during each one second interval. After MN sets timeout, it sends just one NS. If the RA is not arrived, it assumes that it is unreachable.

Choi [19] utilizes fast router discovery with RA caching in AP. AP caches the RA message. AP sends reassociation.reply message and RA to MN simultaneously. MN can configure the IP without sending RS or waiting RA.

Kempf [20] uses IPv6 fast router advertisement. Currently, when the router receives the RS, it should wait random time. Router sends the RA immediately upon receiving RS.

Hong [21] utilizes AR based movement detection and CoA configuration method. AR performs the movement detection. MN sends the L2 trigger to both AP and AR. AR caches MN's layer 2 addresses and configures the new IP address using the MAC address and its own prefix. When the MN sends the RS, AR sends the RA with the preconfigured CoA.

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3.3 New IP address Configuration

Gwon [22] proposed the enhanced forwarding from previous CoA for fast mobile IPv6 handovers. During L2 handoff, MN can find the information of new AR relevant with this ID when it receives the beacon with ID from new AP. Before starting L3 handover, MN can know the information about new AR. In order to do this, MN should maintain the list of candidate ARs using CARID (Candidate Access Router Information Discovery) protocol. When MN makes a bidirectional tunnel to reduce the delay configuring new CoA, it uses the IP address of router as its own temporary IP address. After some time, MN configures its own CoA using the prefix of router.

Moore [23] proposed optimistic duplicate address detection that omits DAD procedure. To reduce the DAD delay, it is proposed to use the tentative IP address. In IPv6, we cannot use the IP address obtained by using stateless-auto-configuration immediately. That is, we can use the valid IP address after performing DAD process. The reason is why there is little probability of conflict. Han [24] proposed the Advance DAT which caches DAD in AR. AR already has the CoA’s pool which has completed the DAD process. When MN sends the modified RS, then AR sends with the modified RA that contains the CoA. MN can use the CoA immediately.

Montavont [15] omitted the DAD or perform it in parallel. Performing DAD generates too much delay in the handover latency. Considering that the probability of address duplication on the same link is extremely low, the MN can choose not to perform DAD or MN should perform DAD in parallel with its communication.

3.4 Binding Updates

MIPv4 first discovers agent. HA and FA inform itself by using AA (Agent Advertisement) message similar to ICMP Router Discovery. MN also can advertise agent using Agent Solicitation message. MN decides if it is in the home network through such an advertisement message.

MN exchanges Registration Request and Registration Reply message with the HA. It registers the CoA in the HA. There are two types of CoA’s: CoA of FA is used for MN (CoA). Temporary IP address by DHCP is used for MN (Co-located CoA). Such a registration message uses UDP port 434 and contains CoA and lifetime of MN.

After successful registration between HA and MN is performed, Datagram sent from CN to the home address of MN is tunneled to the CoA of MN. Datagram from MN to CN has not been tunneled. It is forwarded to the destination using the standard IP routing.

We now investigate Fast Handover (FMIPv6) with MIPv6 which is composed of anticipated Handover and tunnel based handover.

The anticipated handover is performed as followings:

(1) MN senses the movement to NAR by using L2 trigger.
(2) MN sends PRS (Proxy Router Solicitation) message for NAR to PAR. This message contains link-layer ID for NAR. For example, SSID of NAR in the wireless LAN.
(3) PAR configures NCoA using the information of NAR which PAR already has. PAR sends PRA (Proxy Router Advertisement) containing NCoA to MN.
(4) MN sends FBU (Fast Binding Update) requesting for binding the old CoA with NAR to PAR (old CoA→ NAR).
(5) PAR sends HI (Handover Initiate) to setup the bi-directional tunneling with NAR. Also, it requests that NAR will the verification of newly configured CoA.
(6) NAR sends HACK (Handover ACK) to PAR. It builds bi-directional tunnel and checks the new CoA.
(7) PAR sends acknowledgement for NCoA to NAR through FBACK. It also intercepts data for the previous CoA of MN and forwards to NAR through tunneling.
(8) After new link between NAR and MN is established, MN sends RS including FNA (Fast Neighbor Advertisement) which represents MN itself.
(9) NAR confirms new CoA to MN through RA with NACCK option.
(10) MN sends the BU to both CN and HA.
(11) CN/HA reply with ACK.

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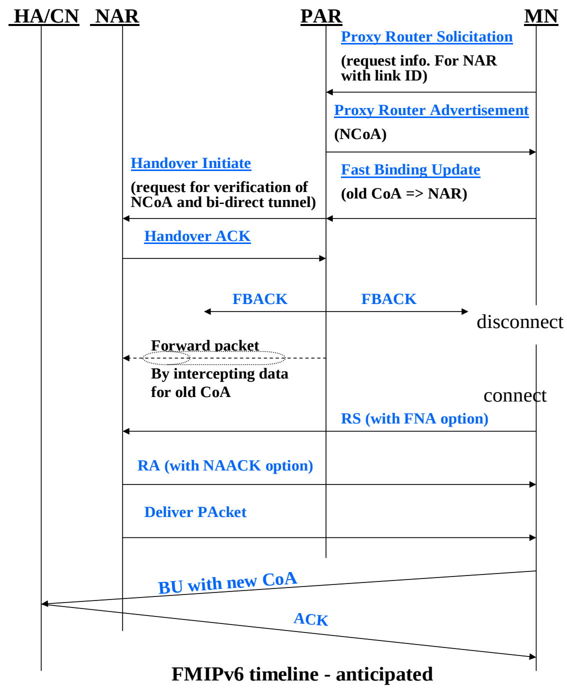

Fig. 4 Timeline for FMIPv6- anticipated handover

The tunnel based handover is performed as followings:

(1) Old AR senses the movement.
(2) Old AR initiates L2 trigger which contains MAC address of MN and IP address of newAR.
(3) Old AR sends HI to new AR.
(4) New AR replies with HIACK and establishes the bi-directional tunnel.
(5) MN starts L2 handover.
(6) Old AR forwards data from CN to MN or from MN to CN through bi-directional tunnel.
(7) MN sends the BU to CN/HA and releases the tunnel.
(8) CN/HA reply with the ACK.

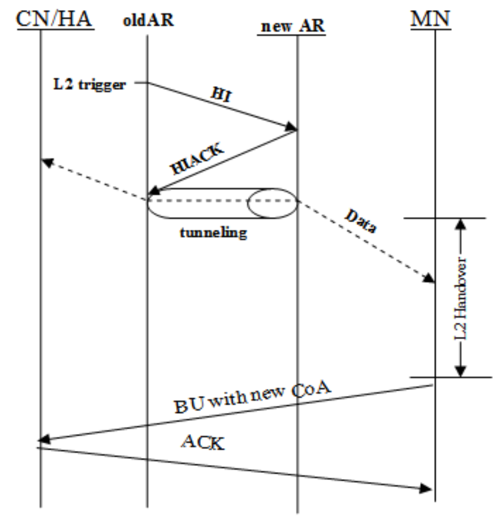

Fig. 5 Timeline for FMIPv6- tunnel based handover

4. Layer 4 handover schemes

When prefixes of routers are not changed, SCTP (stream control transmission protocol) handover in layer 4 (Fig. 6, [24]) is performed as follows:

(1) Physical layer of MN detects the signal power from the new AP when it enters the overlapped region.
(2) Physical layer receives beacons/RA from new AP and new AR.
(3) MN asks for new IP addresses from DHCP server in new subnet.
(4) MN starts handover with IP addresses.
(5) MN sends ASCONF:add_ip (new) chuck to CN.
(6) CN replies ASCONF-ACK:add_ip (new).
(7) MN sends ASCONF: set_primary_IP(new) to CN.
(8) CN replies ASCONF-ACK that primary has been switched.
(9) MN sends ASCONF:delete_IP(old) to CN.
(10) CN replies ASCONF-ACK:delete_IP(old) to MN.

In step (3), it is reasonable that first, to obtain the IPv6 address first by using stateless-auto-configuration, if we fail, then use the state full method such as DHCP. The reason to do this is that if the DHCP server is far away from the location of MN, the time to send the DHCP request message and receive the DHCP reply can be longer than the time to obtain the prefix from Access Router attached to MN. That is, as soon as we receive the RA from the attached router prior to receiving the RA, we

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can send the RS. Hence, we obtain the IP-address by using the stateless-auto-configuration of IPv6 (MIPv6).

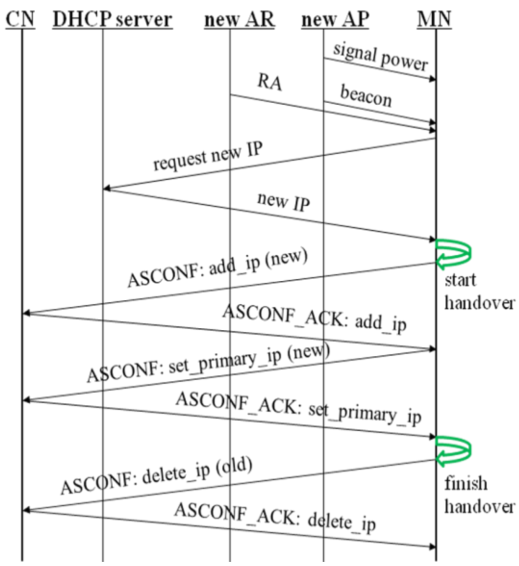

Fig. 6 Timeline for L4 (SCTP) handover

If this procedure fails, we can use the state full method such as DHCP based on MAC address. Assume that we use the FMIPv6 (Fast Handover for Mobile IPv6) when we detect the signal from the physical layer. Then, we can get the CoA of new router (subnet B) prior to the handover. Therefore, we can find new IP address of host by using the stateless-auto-configuration.

5. Conclusions

In this paper, we address the layer based handover schemes. Layer 2 handover mainly depends on how to detect the signal power and is performed using hardware. The performance of Layer 3 handover scheme is affected by how to exchange old IP address with new IP address rapidly. Additionally, how to obtain new IP address fast is the important factor for handover latency. Generally, MIPv4 and MIPv6 including FMIPv6 are used for supporting mobility. L4 handover scheme using SCTP is very simple and known to have better performance than TCP based handover schemes. However, it has cross-layer problem and requires the dual interfaces. Efficient handover mechanism is one of the important issues in mobile network in order to obtain more fast communication. This paper describes the pros and cons of several handover schemes, which help us to develop new handover mechanism.

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