Electronic Preprint for Journal of Information Processing Vol.20 No.1

Regular Paper

IMS-based Fast Session Handover with Available Network Resources Discovery of Access Networks

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Received: March 31, 2011, Accepted: October 3, 2011

Abstract: The rapid spread of smart phones causes the explosion of media traffic. This encourages mobile network operators (MNOs) to coordinate multiple access networks. For such an MNO, the IP Multimedia Subsystem (IMS) is a promising service control infrastructure to ensure a QoS guaranteed communication path for the media in the multi-access network. IMS-based service continuity enables user equipments (UEs) to continuously use IMS-based services (e.g., VoIP) even when the UEs make handovers between different access networks where the UE is assigned the different IP address, respectively. In the case where the UE cannot simultaneously use multiple wireless devices, there is the possibility of a long media disruption time during handovers. This is caused by several consecutive handovers as a result of attempting to discover the access network where the UE can have the QoS-guaranteed communications. In this paper, we propose a method for reducing the media disruption time when the UE makes handovers between different access networks. In the proposal, the UE proactively performs the service continuity procedure, and selects an access network that can provide the required network resources to the UE. We implement and evaluate the proposed method, and show how the media disruption time can be reduced.

Keywords: IMS, service continuity, fast session handover, multi-access network, network resources

1. Introduction

The advent of smart phones, which feature the intuitive handling (e.g., by a touch panel, a motion sensor) and a huge number of attractive services, has greatly changed the usage of the mobile network. Mobile users are provided more opportunities to use richer multimedia services, which consume much larger bandwidth than that for voice calls. This causes the explosion of media traffic and it is getting harder for mobile network operators (MNOs) to provide stable network connections to their users. In order to deal with this problem, MNOs started making use of different access networks and encouraging mobile users to offload heavy traffic from one access network to others (e.g., from 3G to WiFi or WiMAX). For such a multi-access network environment, the IP Multimedia Subsystem (IMS) [1] is a promising service control infrastructure, which can coordinate multiple access networks and ensure a QoS guaranteed communication path for the media (such as, bandwidth allocation to the path, and/or selecting a communication path meeting the required delay) established between user equipments (UEs).

It is one of the fundamental requirements that the IMS-based services provided to the UE are continued even if the UE makes a handover to a different access network, where the UE could be assigned a different IP address. This service continuity is possible using the network layer mobility such as Mobile IP [2]. The network layer mobility is transparent to the IMS and the corresponding UE, thus it could nullify the adaptation of the IMS session in accordance with the new access network type (e.g., charging, codec, QoS) [3]. For QoS-sensitive applications, IMS-based service continuity is standardized in 3GPP [4], in which case, the IMS can be aware of the change of access network type. However, it has a potential issue of a longer media disruption because the communication between UEs does not resume until the UE completes the procedure for obtaining its new IP address and the service continuity procedure. Also, when multiple access networks are available, the UE desires to select ones providing a fully QoS-guaranteed communication path for some services. However, most of the proposed and standardized procedures verify whether the selected access network can provide the required network resources to the UE after the UE is attached to the new access networks. Therefore, the UE encounters multiple communication disruptions in a worst case scenario where the UE changes access networks one-by-one. Simultaneous use of multiple wireless devices (multi-radio mode) could reduce the media disruption for those cases, but due to the increase in cost and the design complexity of the multi-radio mode UE [5], the single-radio mode (the use of only a single wireless device at one time) will be an assumed condition at the inception of the multi-access network environment.

We propose a new method for reducing the media disruption time when the UE in the single-radio mode case makes handovers between different access networks. The proposal includes two features: one is a proactive handover procedure, which obtains the new IP address assigned in the new access network and com-

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pletes the IMS-based service continuity procedure before changing the access networks; and the other is the selection of an access network capable of providing the required network resources to the UE. Further, we implement and evaluate the proposed method, and show how the media disruption time can be reduced compared to other approaches. Further we also show how the media disruption time is affected by the access network delay.

The rest of the paper is organized as follows. Section 2 explains the IMS-based session handover procedure in the single-radio mode case, and describes the requirements of the session handover. Section 3 describes related work. In Section 4, we propose an IMS-based fast session handover method, which meets the requirements. Section 5 shows analytical comparisons. Section 6 presents a performance evaluation, and considers the result. Finally, Section 7 concludes the paper.

2. IMS-Based Session Handover Procedure in the Single-radio Mode Case

We present the way in which the service can be continued when the UE changes its IP address due to making handovers between access networks in the single-radio mode case. Then, we describe the requirements when the service can be continued.

2.1 IMS Network Configuration and Procedures

Figure 1 illustrates the IMS network configuration assumed in this paper. The IMS network is composed of call session control functions (CSCFs) that control service sessions for the UEs, a home subscriber server (HSS) that is a database server for managing subscribers, a service centralization and continuity application server (SCC AS) [4] that maintains ongoing communication sessions by cooperating with CSCFs, and a policy and charging rules function (PCRF) that controls resources and policies of access networks. There are three types of CSCF: a serving-CSCF (S-CSCF) which performs the session control, proxy-CSCFs (P-CSCFs) which establish a security association with the UEs, and an interrogating-CSCF (I-CSCF) which chooses the S-CSCF to be associated to the UEs. The IMS is reachable from UEs via access points (APs) and access routers (ARs) providing IP connectivity as default routers and entry points to the mobile core network. The PCRF collects the network resource-related information from the access networks. The point of service (PoS) devices defined in IEEE 802.21 media independent handover (MIH) [6] can be candidates for collecting this information for access networks having no functionality to provide this information.

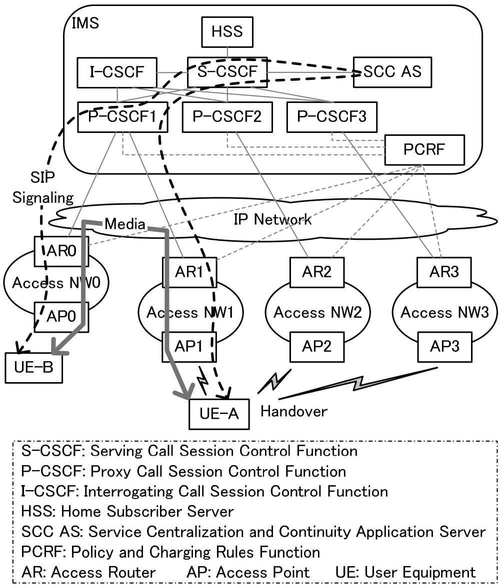


Fig. 1 IMS network configuration.

When a UE comes into an area of the access networks, the UE initiates the procedures for IMS registration. In this procedure, first, the UE connects to an AR through an AP, and obtains an IP address. Second, the UE conducts its registration with the S-CSCF via the P-CSCF and the I-CSCF. The S-CSCF assigned by the I-CSCF verifies the UE based on the UE information stored in the HSS. Third, the S-CSCF notifies the UE's registration to the SCC AS. The access technology-specific protocol is used for the UE attachment, while the session initiation protocol (SIP) [7] is used for the UE, IMS and SCC AS interaction. In Fig. 1, UE-A and UE-B are attached to Access NW1 and Access NW0, respectively, and registered with S-CSCF via P-CSCF1, and SCC AS. Although the figure has single S-CSCF and SCC AS, multiple S-CSCFs and SCC ASs can also separately register the UEs with themselves.

When a service-continuity-viable IMS-based service (such as, VoIP) begins between UEs, the service initiation is conducted via the registered S-CSCF and SCC AS. In this case, the exchanged signaling message takes, as shown in Fig. 1, the following path: UE-A, P-CSCF1, S-CSCF, SCC AS, S-CSCF, P-CSCF1, and UE-B. In order to involve the SCC AS in the initiation, an INVITE message is forwarded to the SCC AS according to the initial filter criteria (iFC), which is set in the UE registration. When some of the messages (the INVITE and 183 session progress messages) involving the session description protocol (SDP) are received by the P-CSCF, the P-CSCF has interactions with the PCRF to request a network resource assignment and gate-open (in order for the ARs to open the communication path relating to UE's IP address and port number).

The SCC AS plays the role of the UE to the S-CSCF for each of the UEs (UE-A and UE-B). Therefore, the S-CSCF deals with two different sessions for the session between UE-A and UE-B: one session is between UE-A and SCC AS, and the other is between SCC-AS and UE-B. Instead of S-CSCF, SCC AS links these two sessions.

The following subsection explains how the service can be continued, even when the UE changes its IP address due to making a handover.

2.2 IMS-based Session Handover Procedure

Figure 2 shows the IMS-based session handover procedure in the single-radio mode case by reference to the standard [4]. In this scenario, although there are multiple access networks, only some of them can provide the communication path meeting the required QoS for two UE communications. UE-A first happens to select an access network that cannot provide the required network resources to it when changing the access networks, and selects another access network. In the standardized procedure, there

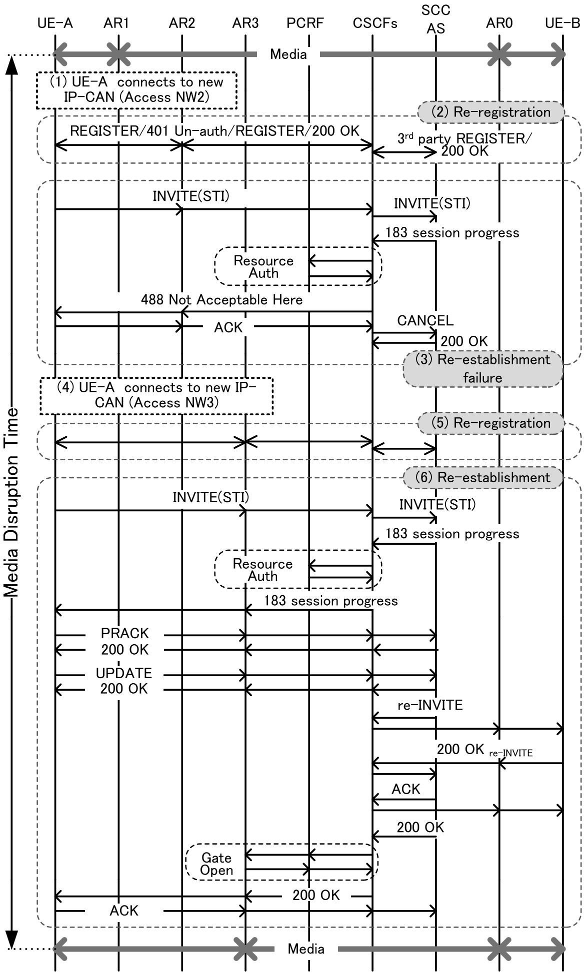


Fig. 2 IMS-based session handover procedure.

is no specific way to verify whether each of the access networks has the required network resources beforehand. Therefore, the UE repeats trials and errors till the UE finds that the connected access NW has the required network resources, as in Fig. 2.

The procedure begins from UE-A determining to change the access network. UE-A searches neighbor APs and selects an AP (e.g., AP2) and UE-A makes a handover to Access NW2, by switching the connection from AP1 to AP2 (APs are omitted in Fig. 2). After that, UE-A obtains a new IP address from a new AR (AR2) (procedure 1). Next, UE-A begins the service continuity procedure including the IMS re-registration and the session re-establishment.

In the IMS re-registration, UE-A registers itself with an S-CSCF identical to the previous one. The S-CSCF selection is conducted based on the UE's identifier (not IP addresses). After the re-registration, S-CSCF also notifies SCC AS of UE-A's re-registration to SCC AS again (by a third-party registration request). In this case, an identical SCC AS is also selected when there are multiple SCC ASs (procedure 2).

After the IMS re-registration, UE-A sends an INVITE message to UE-B in order to re-establish the session with UE-B. At this moment, the session transfer identifier (STI) which identifies the currently established session is involved in the replace header. This explains the modification of the session parameters (e.g., the IP address). This message delivered to S-CSCF via P-CSCF2 is also forwarded to SCC AS by iFC, as described in the previous subsection. Then, SCC AS finds the appropriate session with the STI and sends a 183 session progress to UE-A. In this response, P-CSCF2 also requests PCRF to prepare the QoS-guaranteed communication path between UE-A with the new IP address and UE-B again (the resource authentication procedure). The PCRF verifies whether network resources can be prepared at AR2. If this is unacceptable to PCRF (e.g., due to unsupported codec), P-CSCF2 responds with an error message (e.g., 488 Not Acceptable Here) to UE-A (procedure 3).

In order to connect to another access network that can provide the required network resources to UE-A, UE-A searches neighbor APs again, and makes a handover to Access NW3 (procedure 4). After the IMS re-registration proceeds (procedure 5), the resource authentication procedure is conducted in the session re-establishment between P-CSCF3 and PCRF. If the resource authentication is successful, the session re-establishment proceeds to completion (procedure 6). Finally, UE-A can resume the communication with UE-B by using the new IP address.

Thus, the UEs can continue the service by performing the service continuity procedure. The new session established between UE-A and SCC AS is linked to the previous one, and bound to the session between SCC AS and UE-B, again. In this paper, we call this procedure an "IMS-based session handover."

Here, the media disruption time is, as shown in Fig. 2, the time from when UE-A disconnects Access NW1 until the service continuity procedure is completed. If the second selected access network cannot provide the required network resources either, the same procedures (access network attachment, IMS re-registration, and session re-establishment) are conducted, and the media disruption time increases further.

2.3 Requirements of IMS-based Session Handover

The following are requirements for a seamless and QoS-guaranteed service when the UE changes its IP address due to making handovers between access networks in the single-radio mode case.

(1) **Reducing the Media Disruption Time**
During IMS-based session handover, after changing access network, the UE obtains a new IP address and performs the service continuity procedure including IMS re-registration and session re-establishment. However, media disruption will occur until these procedures have been completed. Therefore, it is desirable to reduce the time it takes to perform these procedures.

(2) **Selecting the New Access Network where the Required Network Resources are Available**
Although the UE appropriately selects an AP where the radio link status is good, such an AP could be inappropriate in terms of the entire access NW (from UE to AR). This is because there is a case where the available bandwidth between the AP and the AR is insufficient, and the media codec originally selected at the beginning of the service cannot be used anymore. In order to maintain the QoS-guaranteed communication path, resource assignment and/or policy control are performed by the PCRF during session re-establishment, which is included in the service continuity procedure. However, if the UE cannot be

provided with the required network resources at a new access network to which it has changed, it will degrade the quality in order to continue the communication or make a handover to another access network until it can be provided the required network resources. If the UE repeatedly makes a handover, the media disruption time increases accordingly. For this reason, it is desirable that the UE can appropriately select a new access network that can provide it with the required network resources when making a handover.

3. Related Work

In the single-radio mode case, several methods have been proposed in order to reduce the media disruption time during the service continuity procedure that occurs when the IP address is being changed. Larsen et al. [8] and Renier et al. [9] have proposed solutions for reducing the media disruption time by reducing the number of messages exchanged between the UE and the IMS during the service continuity procedure. Reducing the number of messages is allowed by sharing the registration information and the session state with P-CSCFs. However, it is not sufficient to reduce the media disruption time, because media disruption occurs during the procedure for obtaining a new IP address and a short disruption still occurs during the service continuity procedure. In addition, these methods are not easily applicable to MNOs which have already introduced the IMS system because these methods require modifying the IMS specified in the standard.

If one interface of the UE can have several IP addresses assigned to it, it is considered that a method of utilizing FMIPv6 [10] technologies, which involves the pre-assignment of the IP address and the forwarding media through a tunnel, offers a solution to reduce the media disruption time without any modification of the IMS system. Although FMIPv6 is a technology designed to reduce the handover latency of MIPv6 [2], it can be applied to communications just by using the care-of address (CoA), which is assigned to the UE in access networks. Note that this method (hereinafter called "Fast-HO method") does not utilize an anchor node such as a home agent (HA) (utilizes only FMIPv6 technologies and the CoA mechanism). **Figure 3** illustrates the IMS-based session handover procedure with the Fast-HO method. In this method, the UE obtains a new IP address (NA#2), which will be assigned in a new access network, before making a handover. When the UE notifies that it is leaving the previous AR (PAR) (e.g., AR1), the AR1 begins forwarding the downlink media to the UE's new IP address through the tentatively established tunnel between the AR1 and the new AR (NAR) (e.g., AR2), and the AR2 starts buffering the forwarded media. After the UE is attached to the AR2, the UE performs the service continuity procedure immediately. After that, if the resource authentication and gate-open are successful, the AR2 forwards the buffered media to the UE. This enables the media disruption time to be reduced to a duration that is equal to the time needed to switch the attachment points to the access network and to complete the service continuity procedure. Although this method reduces the media disruption time for the procedure for obtaining the new IP address, it cannot select an appropriate new access network. Therefore, the UE has the potential to repeatedly make handovers, and the media disruption time will increase.

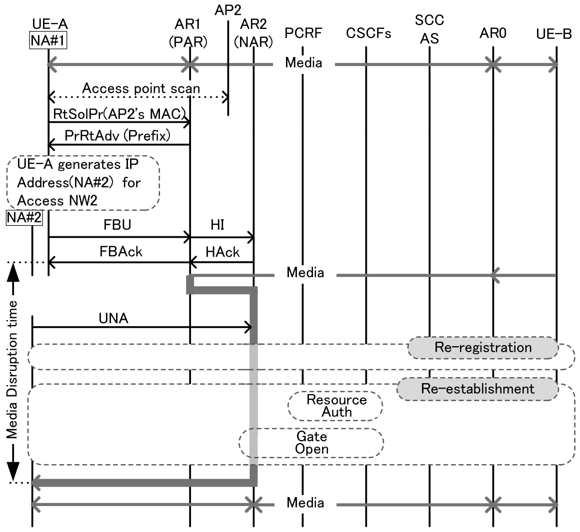


Fig. 3 IMS-based session handover procedure by the Fast-HO method.

Farahbakhsh et al. [11] have proposed a solution that combines these two solutions: the message reduction [8], [9] and FMIPv6. This method reduces the media disruption time for both the service continuity procedure and the procedure for obtaining the new IP address. However, this method does not take the selection of the appropriate new access network into consideration. Additionally, this method also requires the modification of the IMS system.

For selecting a new access network that can provide the required network resources to the UE, several architectures [12], [13], [14], which apply MIH to IMS session management, have been proposed. The MIH provides the information on the network resource availability of the access networks to the UEs. However, in order to achieve the seamless handover, these architectures are designed on the assumption that the UE is in the multi-radio mode.

4. Proposal of IMS-based Fast Session Handover

In order for MNOs to provide users with seamless and QoS guaranteed services even when the UE makes handovers between access networks, we propose a method of not only reducing the media disruption time but also selecting a new access network that can provide the required network resources to the UE by proactively completing the service continuity procedure.

4.1 Overview of the Proposed Method

A key of the proposed procedure is that the IMS requests proactively a network resource to the PCRF at the new access network to which the UE will make a handover. **Figure 4** illustrates the IMS-based fast session handover scheme by the proposed method. In this figure, UE-A makes a handover from Access NW1 to Access NW2 during an ongoing communication session. The procedure is as follows:

(1) when UE-A determines to switch the attachment points to the access networks, before making a handover, UE-A obtains the IP address that will be assigned in Access NW2;

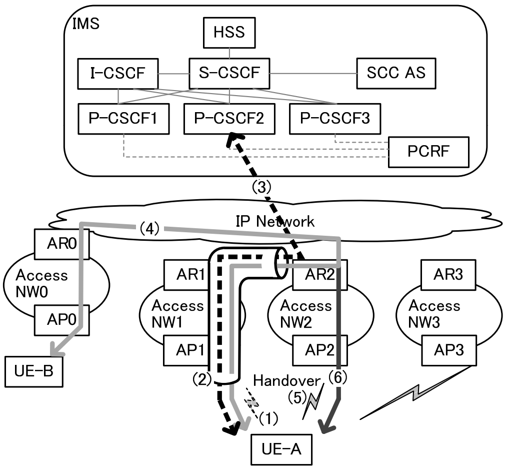


Fig. 4 IMS-based fast session handover scheme by the proposed method.

(2) UE-A establishes a tunnel with AR2 in order to communicate with the IMS through Access NW2;
(3) UE-A re-registers itself with the IMS again and reestablishes the session with UE-A through this tunnel;
(4) the media from UE-B are forwarded to UE-A in Access NW1 through the tunnel between AR2 and UE-A;
(5) UE-A makes a handover to Access NW2. Just before the handover, UE-A requests that AR2 stops forwarding and starts buffering; and
(6) UE-A can immediately restart the communication, since it has already completed the service continuity procedure.

At step 3, the SCC AS may fail to re-establish the session because the Access NW2 cannot provide the required network resources to UE-A. In this case, UE-A receives a response that the required network resource is unavailable, and the UE returns to step 1. At steps 5 and 6, AR2 buffers the media from UE-B during the handover, and forwards the buffered media to UE-A after the handover. The procedure not only enables the media disruption time to be reduced, but also selects a new access network that can provide the required network resources to UE-A. The following subsection describes the procedure in detail.

4.2 Detailed Procedure of the Proposed Method

In the proposed method, before making a handover, the UE obtains a new IP address and performs the service continuity procedure using this IP address. Each procedure is described as follows. Note that, although each procedure is based on IPv6 because we assume that all of the network components are based on IPv6, the use of IPv6 is not mandatory.

4.2.1 Procedure for Obtaining the New IP Address

Figure 5 shows the procedure for UE-A to obtain a new IPv6 address before making a handover. Note that this procedure is the same as the one for obtaining the new IPv6 address in the Fast-HO method. In this paper, we assume that each AR has [AP-ID, AR-Info] tuples, where AP-ID is AP identifier, AR-Info is an AR's L2 and IP addresses, and prefix valid on the interface to which the AP is attached [10]. UE-A connects to Access NW1 through AP1, and has a VoIP service session with UE-B. If UE-A determines to switch the attachment points to the access networks, UE-A searches neighbor APs and selects AP2. For determining to switch the attachment points, several methods [15], [16] could be applied, where various radio link information (such as, the signal strength, the error rate, the transmission delay and the number of frame retransmissions) were utilized. In this paper, UE-A selects a new AP on the basis of the signal strength for simplicity. After selecting AP2, UE-A sends to AR1 the RtSolPr (router solicitation for proxy Advertisement) including AP2 identifier. Then, UE-A receives the PrRtAdv (proxy router advertisement) including AR-Info of AR2 to which AP2 is attached [10]. UE-A obtains a new IPv6 address (NA#2) that UE-A will be assigned in Access NW2 by generating the IPv6 address from AR-Info.

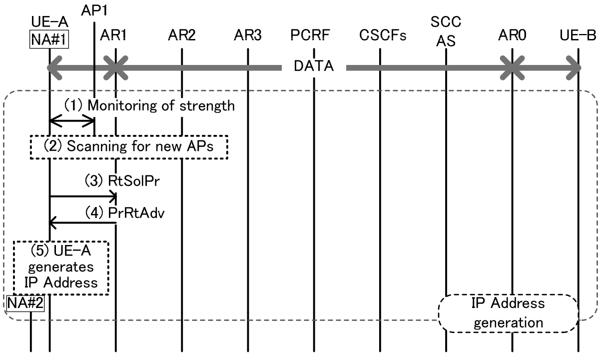


Fig. 5 Procedure for obtaining the IP address.

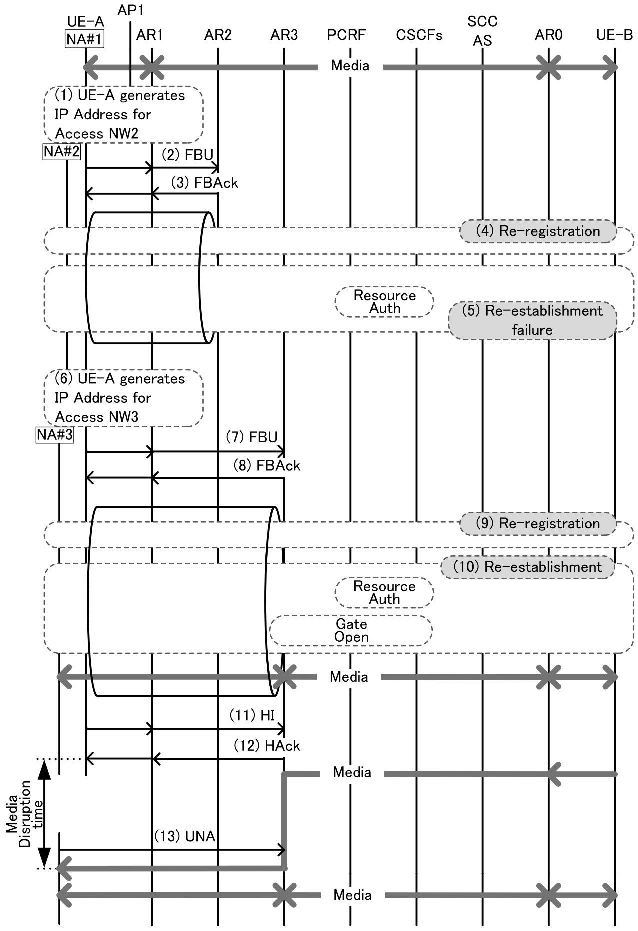


Fig. 6 IMS-based fast session handover procedure by the proposed method.

4.2.2 Service Continuity Procedure

Figure 6 shows the service continuity procedure using the IP address obtained proactively before making a handover. In this figure, UE-A fails to re-establish the session during the session handover to Access NW2 because the Access NW2 cannot provide the required network resources to UE-A. As a result, UE-A again attempts to perform the session handover to Access NW3, which is the next candidate access network. The detailed procedures are as follows.

With the obtained NA#2 (procedure 1), first, UE-A establishes a bidirectional tunnel to AR2 (via AR1) by exchanging the fast binding update (FBU) and fast binding Acknowledge (FBAck) messages specified in FMIPv6 [10] (procedure 2 and 3). Note that FBU/FBAck messages are extended as the UE interacts with the new AR because the UE can establish a bidirectional tunnel between itself and the new AR. In exchanging FBU/FBA messages, AR2 evaluates the UE-A's IP address to ascertain whether it has not been used for any other UE connecting to the AR2, as well as the authorization if needed. If this is accepted, UE-A is ready to send and receive packets as if UE-A connects to the AR2.

Next, UE-A re-registers itself with the IMS (procedure 4). The signaling messages from UE-A are sent through the tunnel between UE-A and AR2. Then, UE-A uses the newly obtained IP address for this and the following procedure.

After the re-registration, UE-A begins the session reestablishment procedure by sending the INVITE message (procedure 5). However, in this scenario, UE-A receives a message stating that the session re-establishment has failed (e.g., 488 Not Acceptable Here).

To discover the available access networks, UE-A again attempts to perform the session handover to Access NW3 at obtaining the IP address (NA#3) assigned in Access NW3 (procedure 6). After establishing a bidirectional tunnel between UE-A and AR3 (procedure 7 and 8), UE-A performs the service continuity procedure (procedure 9 and 10).

After completing this procedure successfully, the media that UE-B sends to and receives from UE-A's NA#3 pass through the tunnel between UE-A and AR3.

As the final steps, just before making a handover to Access NW3, UE-A sends to AR3 a handover initiation (HI) message specified in FMIPv6, in order to start buffering the media at AR3 during the handover (procedure 11). The flag (u flag) in HI is used to indicate buffering. AR3 receiving the HI starts to buffer the media that AR3 forwards to UE-A before returning the handover acknowledgement (HAck) (procedure 12) to UE-A. Note that HI/HAck messages are extended as the UE interacts with the new AR because the UE can request buffering the media after completing the service continuity procedure.

After receiving the HAck, UE-A makes a handover from Access NW1 to Access NW3. UE-A sends to AR3 the Unsolicited Neighbor Advertisement (UNA) message as soon as UE-A establishes a link connectivity with AR3 (procedure 13). When AR3 receives the UNA message, it deletes the tunnel and forwards the buffered media to UE-A.

The media disruption time is, as shown in Fig. 6, from when AR3 starts to buffer the media triggered by sending the HAck until UE-A receives the media by sending the UNA.

4.3 Deployment of the Proposed Method

In the real world, since it is not realistic to replace all existing ARs to our ARs which have implemented the proposed method at the same time, the existing ARs and our ARs would coexist. In such an environment, if the UE is not aware whether the new AR has implemented the proposed method or not, the UE fails to establish a tunnel with the new AR which has not implemented the proposed method. In order to prevent this, the UE desires to be aware of the capability of the new AR. In the proposed method, the UE obtains the information of the new AR by receiving the PrRtAdv, which is the response to the RtSolPr, from the current AR (as mentioned in Section 4.2.1). By extending the PrRtAdv as it includes the capability of the new AR, the UE can be aware whether the new AR has implemented the proposed method or not.

In the case where the UE makes a handover from our AR to the existing AR, since the UE can be aware that the new AR has not implemented the proposed method by receiving the PrRtAdv, the UE makes a handover by the standard method instead of establishing a tunnel with the new AR. In the contrary case where the UE makes a handover from the existing AR to our AR, since the current AR has not implemented the proposed method, the UE cannot receive the PrRtAdv when sending the RtSolPr to the current AR. In this case, the UE simply makes a handover by the standard method. Thus, the existing ARs and our ARs can coexist just by extending the PrRtAdv without extending the existing ARs.

5. Analysis

Table 1 shows analytical comparisons of our proposed method (as shown in Fig. 5 and Fig. 6) with the standard method (as shown in Fig. 2) and the Fast-HO method (as shown in Fig. 3).

In the standard method, media disruption will occur during the procedure for obtaining an IP address and the service continuity procedure in addition to the time to switch the attachment points to the access networks. The Fast-HO method can reduce the media disruption time for the procedure for obtaining an IP address by the pre-assignment of the IP address. Furthermore, the proposed method can reduce the media disruption time for the service continuity procedure. Thus, the time is equivalent to the time of switching the attachment points to the access network.

In the service continuity procedure, it is verified whether the selected access network is appropriate. Because of this, the standard method and the Fast-HO method, which perform the service continuity procedure after switching the attachment points to the access networks, cannot select an appropriate new access network before switching. On the other hand, the proposed method can select an appropriate new one because it proactively performs the service continuity procedure before making a handover.

As the access network delay increases, the time it takes to perform the service continuity procedure gets longer, due to the large number of messages exchanges between the UE and the IMS. Thus, the media disruption time in the standard and Fast-HO method, where media disruption occurs during the service continuity procedure, is likely to be affected by the access network delay.

Table 1 Analytical comparison of session handover methods.

Session Handover Methods	Media Disruption Time	Appropriate Access Network Selection	Effect of Access Network Delay	Packet Loss	Impact in IMS
Standard Method	Most	Disable	Large	Large	None
Fast-HO Method	Medium	Disable	Large	Small	None
Proposed Method	Least	Enable	Small	Small	None

For packet loss during media disruption, the Fast-HO method and the proposed method can prevent it by forwarding and buffering the media at the ARs during making an IMS-based session handover. Buffering can also prevent waste of radio resources because the packets, which might not reach the destination, are not sent out over the air.

The implementation of the proposed method includes the following functions: the pre-assignment of an IP Address, the tunnel establishment, and the notification of handover initiation and termination. Although these functions require to be implemented in the UE and the AR, the proposed method does not require changing the function of the IMS client, the IMS network components and the messages, which are exchanged between the UE and the IMS network, specified in the standard. This is an advantage of the proposed method because IMS systems are already deployed in some MNOs' networks.

6. Implementation and Evaluation

We evaluate the proposed method through an experiment, and show how the media disruption time can be reduced. We also show how the media disruption time is affected by the access network delay.

6.1 Experimental Network Configuration

Figure 7 shows our experimental network configuration for checking the behavior of the method and verifying its effectiveness. The IMS network and the Access NWs are connected via a router. The IMS network contains P-CSCFs, PCRF, S-CSCF, I-CSCF, HSS, and SCC AS. These nodes are connected via a hub. In this configuration, P-CSCFs (P-CSCF1, 2, 3) are deployed in each Access NWs (Access NW1, 2, 3). By setting up the policy of Access NW2 for PCRF, we simulated an Access NW that cannot provide the required network resources to the UE (e.g., due to insufficient available bandwidth). Access NWs contain an AR and an 802.11g WLAN AP connected via Delay in order to simulate the delay of Access NWs. In addition, the UEs connect to the Access NW via WLAN AP.

Table 2 shows the experimental network components. In the table, '*' implies that the function for the proposed method is implemented in the node. For P-CSCFs, I-CSCF, S-CSCF, and HSS, we used Open IMS Core [17], which is an open-source SIP server conforming to the IMS. For PCRF, we adopted the UCT Policy Control Framework [18], which is also open-source software. For SCC AS, we implemented the function specified in the standard [4]. For the UE, we implemented the function of the IMS Client on the Android OS. We implemented the required modules of the UE and AR for our proposed method (as shown in Fig. 5 and Fig. 6) and the Fast-HO method (as shown in Fig. 3) based on fmipv6.org [19]. Regarding the determination of switching WLAN APs, we utilized the signal strength as radio link information. **Figure 8** shows the appearance of the UEs and the implemented application. The device (on the left of the figure) calls the other device (in the middle). The screen on the right of the figure shows the selection menu of the handover modes used in the verification.

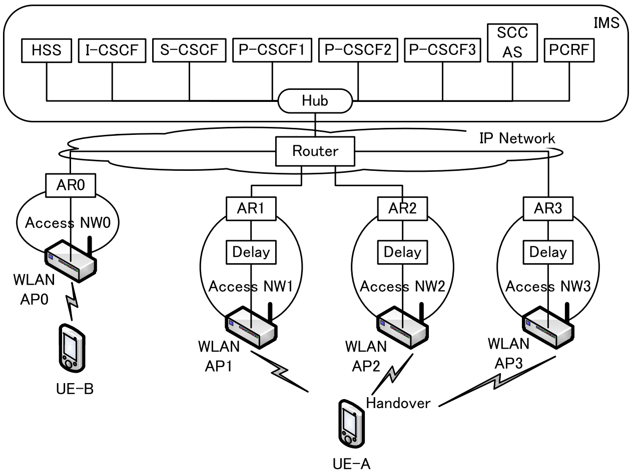


Fig. 7 Experimental network configuration.

6.2 Media Disruption Time of Each Handover Procedure

For the evaluation, we measure the media disruption time of the standard method (as shown in Fig. 2), the Fast-HO utilization method, and the proposed method.

In the standard method, if the service continuity procedure is successfully completed without a retrial, the media disruption time, T_{SHO}, can be calculated as:

$$T_{SHO} = T_{L2} + T_{AG} + T_{reRG} + T_{reES-S}. \tag{1}$$

where T_{L2} represents the link switching delay taken for the UE to perform the data-link layer handover (L2 handover), T_{AG} represents the IP address generation and configuration delay for the auto-configuration mechanism, T_{reRG} represents the delay for re-registration, and T_{reES-S} represent the delay for successful re-establishment. If the service continuity procedure fails at the first try and is retried as shown in Fig. 2, the media disruption time, T_{SHO-R}, can be calculated as:

$$\begin{aligned} T_{SHO-R} = {} & (T_{L2} + T_{AG} + T_{reRG} + T_{reES-F}) \\ & + (T_{L2} + T_{AG} + T_{reRG} + T_{reES-S}). \end{aligned} \tag{2}$$

where T_{reES-F} represents the delay whereby re-establishment fails.

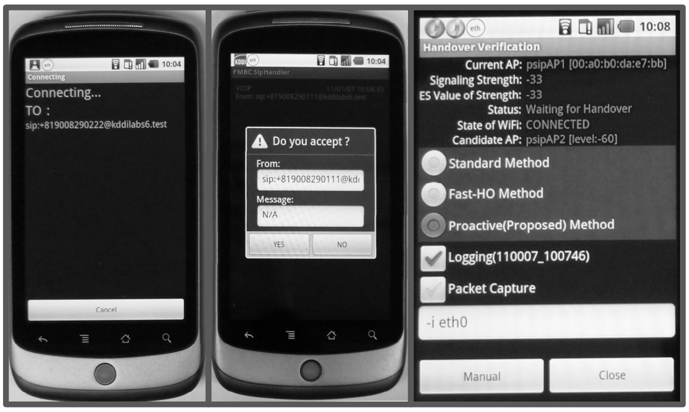
In the Fast-HO method, as show in Fig. 3 the media disruption time, T_{FHO}, can be calculated as:

$$T_{FHO} = T_{L3-L2} + T_{L2} + T_{L2-L3} + T_{reRG} + T_{reES-S}. \tag{3}$$

Table 2 Experimental network components.

Node	Spec			
	Hardware	CPU	Memory	OS
P-CSCF, PCRF, I-CSCF, S-CSCF, HSS, SCC AS, Router, Delay, AR*	EPSON Endeavor AT970	Core2Duo E8600 3.33 GHz	4 GByte	Fedora 11
UE*	Nexus One	ARMv7 QCD8250 1 GHz	512 MByte	Android 2.2
AP	IODATA WN-G54/R4 (802.11g)			

*: The function for the proposed method is implemented in the node.



Connecting

Connecting...

TO :

sip:+819008290222@kddilabs6.test

FMBC SipHandler

VOIP 11/01/07 10:04:35

From: sip:+819008290111@kddilabs6.test

Do you accept ?

From: sip:+819008290111@kd

Message: N/A

Handover Verification

Current AP: psipAP1 [00:a0:b0:da:e7:bb]

Signaling Strength: -33

ES Value of Strength: -33

Status: Waiting for Handover

State of WiFi: CONNECTED

Candidate AP: psipAP2 [level:-60]

○ Standard Method

○ Fast-HO Method

● Proactive(Proposed) Method

☑ Logging(110007_100746)

☐ Packet Capture

-i eth0

Fig. 8 UEs and the Implemented Applications (Outgoing Call Screen (left), Incoming Call Screen (middle), Handover Verification Application (right)).

where T_{L3-L2} represents the delay from when the AR starts forwarding the media until L2 handover starts, and T_{L2-L3} is the delay from when L2 handover ends until the UE sends the UNA. If the service continuity procedure fails, the media disruption time, T_{FHO-R}, can be calculated as:

$$\begin{aligned} T_{FHO-R} = {} & (T_{L3-L2} + T_{L2} + T_{L2-L3} + T_{reRG} + T_{reES-F}) \\ & + (T_{AG} + T_{FBU/FBAck} + T_{L3-L2} + T_{L2} + T_{L2-L3} \\ & + T_{reRG} + T_{reES-S}). \qquad (4) \end{aligned}$$

where $T_{FBU/FBAck}$ represents the delay in exchanging the FBU and the FBAck.

In the proposed method, as shown in Fig. 6, the media disruption time, T_{PHO}, can be calculated as:

$$T_{PHO} = T_{L3-L2} + T_{L2} + T_{L2-L3}. \qquad (5)$$

Even if the service continuity procedure fails, media disruption occurs only once for T_{PHO}. Thus, the media disruption time under the condition with retrial, T_{PHO-R}, is the same as T_{PHO}.

6.3 Measurement Methods

In the experiment, UE-A makes a handover from Access NW1 to the other Access NWs during an ongoing VoIP session in the experimental network as shown in Fig. 7. When UE-A detects the weakness of the signal strength of the AP1 that UE-A connects to, UE-A searches neighbor APs and selects AP2 of which the signal strength is highest in the candidate APs. When UE-A cannot reserve the required network resources by performing the service continuity procedure in Access NW2, to which UE-A connected via AP2, UE-A selects AP3 of which the signal strength is second highest. During the VoIP session, UE-A and UE-B send RTP (real-time transport protocol) packets, encoded using G.711 codec, at 20 ms intervals from each other. In the first experiment, we measured the media disruption time of each method in the case of successfully completing the service continuity procedure without any retrial. In the second experiment, we assumed a situation where Access NW2 cannot provide the required network resources to UE-A, and measured the media disruption time when the service continuity procedure fails at the first trial and is then retried. In the third experiment, we increased the access network delay by 50 ms and measured the media disruption time under conditions without any retrial. We performed each measurement 10 times and calculated the average. Regarding the trigger for the handover, UE monitors the signaling strength of the AP that the UE connects to and makes a handover when the exponential smoothing value of the strength ($A_t = \alpha A_{t-1} + (1-\alpha)a_t, 0 \leq \alpha \leq 1$) drops below a threshold value, where a_t is the signaling strength of the AP at time t and A_t is the calculated result at time t and $\alpha = 0.5$ in this experiment.

6.4 Measurement Results

Table 3 shows the details of the media disruption time. In the case of successfully completing the service continuity procedure without any retrial, the media disruption time of the Fast-HO method are reduced by about 2.4 seconds compared with the standard method, and the proposed method are reduced by about 3.5 seconds. This is because the Fast-HO method and the proposed method can reduce the time of the procedure for obtaining an IP address. Furthermore, in the proposed method, media disruption does not occur during the service continuity procedure.

In the case of completing the service continuity procedure with one retrial, the media disruption time of the Fast-HO method is re-

Table 3 Mesurement result of media disruption time.

Session Handover Method		Standard	Fast-HO	Proposed
Each step time [ms]	T_{L3-L2}	N/A	146	148
	T_{L2}	3885	3943	3938
	T_{AG}	2670	778	N/A
	T_{L2-L3}	N/A	118	121
	$T_{FBU/FBAck}$	N/A	319	N/A
	T_{reRG}	352	340	N/A
	T_{reES-S}	776	754	N/A
	T_{reES-F}	584	569	N/A
Total [ms]	$T_{SHO}, T_{FHO}, T_{PHO}$	7683	5301	4207
	$T_{SHO-R}, T_{FHO-R}, T_{PHO-R}$	15168	11529	4208

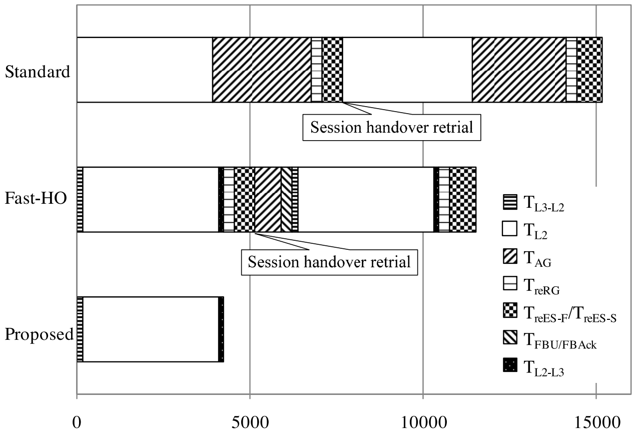


Fig. 9 Media disruption time under conditions with a retrial.

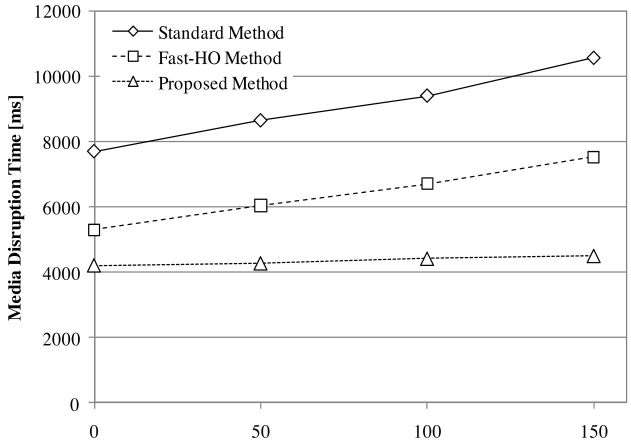


Fig. 10 Media disruption time with increasing access network delay.

duced by about 3.6 seconds compared with the standard method, and for the proposed method, it is reduced by about 10.9 seconds. **Figure 9** shows the composition of the media disruption time under conditions with one retrial. In the standard method and the Fast-HO method, the time increases as a result of the service continuity procedure failing at the first trial. This is because both methods disrupt the media until the resource authentication and gate-open, performed after making handovers, are successful. On the other hand, in the proposed method, the media disruption time is the same as in the case of a successful completion without any retrial.

Figure 10 shows the media disruption time while increasing the access network delay under conditions without any retrial. The access network delay has less impact on the proposed method compared to the standard method and the Fast-HO method. As the access network delay increases, the media disruption time in the proposed method increases about 7 times more slowly than the standard method and the Fast-HO method.

6.5 Discussion

In this experiment, we verified the behavior and effectiveness of the proposed method. The proposed method enables the media disruption time to be reduced to a duration that is almost equal to the time needed to switch the attachment points to the access networks. This is because the procedures performed at the new access network are proactively completed at the current access network with the newly assigned IP address while the media is continuously sent and received with the current IP address on the same network interface. Furthermore, in the proposed method, several consecutive handovers causing a long media disruption time do not occur by selecting the appropriate new access network before making a handover.

The media disruption time in the proposed method is less likely to be affected by the network delays (such as, access network delay, IP network delay and IMS network delay) than in the other methods. This is because the proposed method can prevent the media from being disrupted during the service continuity procedure where a large number of messages are exchanged between the UE and the IMS. In the proposed method, the access network delay affects only two messages which are exchanged between the UE and the AR: the HAck which the UE receives before changing the physical radio link, and the UNA which the UE sends as soon as the UE establishes a link connectivity with the AR.

Although the proposed method enables the media disruption time to be reduced compared to the other methods, the media are disrupted for about 4.2 seconds. As indicated by Fig. 9, the L2 handover time (T_{L2}) accounts for a large fraction of this long media disruption time. In order to effectively reduce this long disruption time, the L2 handover time, that is, the time to change the physical radio links, needs to be reduced. In the environment used in Ref. [20], for example, the L2 handover time is reported to be several microseconds. Therefore, it is anticipated that the media disruption time can be reduced to about 0.5 seconds depending on the implementation environment.

7. Conclusion

In this paper, we described what is required to reduce the media disruption time and to successively provide QoS-guaranteed communications to UEs in an environment where the UE connects to the IMS and uses services across access networks. In order to solve these issues without any modification of the IMS network and the standard procedure, we proposed a method of not only reducing the media disruption time but also selecting a new access network that can provide the required network resources to the UE by proactively completing the service continuity procedure. Further, we demonstrated experimentally the behavior and effectiveness of the proposed method. We showed that the media disruption time becomes roughly equivalent to the time of switching the attachment points to the access networks.

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