Mobile Device-controlled Live Streaming Traffic Transfer for a Multi-Screen Service

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Abstract— **With the rapid increase in multimedia content and various screen devices, mobile users want to watch content regardless of device type anytime and anywhere, which is called multi-screen service (MSS), performed by service mobility technology. Although existing research studies support service mobility and MSS, they do not take into account inter-domain scenarios and live streaming services. In this paper, we describe mobile device-controlled service transfer (MDST), which mobile device is allowed to transfer this service target device first-hand. To support our mechanism, we extend the service discovery protocol in DLNA and present service flow-based mobility at the mobile device. In addition, we analyze the performance of the proposed mechanisms and confirm that MDST is superior in terms of signaling cost, packet delivery cost, and service disruption delay cost.**

***Keywords*— Service Transfer, Live Streaming, DLNA, Service Discovery.**

I. Introduction

With the increase in various multimedia content services, most people have various screen devices (e.g. pad, tab, laptop, TV) as well as mobile devices. In such an environment, multi-screen service (MSS) enables users to access their content services with various devices [1]. This MSS can be performed by the service mobility technology which allows users to transfer ongoing content services from one device to another without re-establishing them. It provides the best screen available for mobile users by switching their service to the specific devices that the users want to use in a real-time manner. Although many services categorized as multi-screen services, such as Dropbox, uCloud, and others, focus on ceaseless display covering various devices [2], currently, only MSS focuses on bookmarks for continuing content viewing. Therefore, many research studies have been conducted to improve MSS.

[3] and [4] proposed service mobility in heterogonous access networks when a mobile user is located in overlapped networks. However, it does not take into account transferring content service to multiple devices. [5] and [6] considered transferring multimedia streaming services to various home devices when a mobile user moves to a home network without restarting a multimedia streaming service. Although all of these research studies for MSS are well-defined to support service mobility, they have not addressed inter-domain case (i.e. different network providers) as well as live streaming services. For example, a mobile user who belongs to a network provider moves to a home network belonging to a different network provider and wants to watch the service on another device. If there is no interworking between two network providers, even though a user wants to transfer the current service, the network side cannot support it. Otherwise, even though the current service can be transferred regardless of the mobile device's location, it leads to significant service disruption and delay because the signaling between the target device and the streaming service, and authentication must occur to take interworking between the two providers [7].

To complement these drawbacks, this paper proposes mobile device-controlled streaming service transfer (MDST) mechanism for better MSS, which transfers a live streaming service to a target device from a mobile device without requiring any signaling on the network side and interworking between network providers. Thus, we extend the Digital Living Network Alliance (DLNA) mechanism for the target device to be allowed to accept the live streaming service from the mobile device.

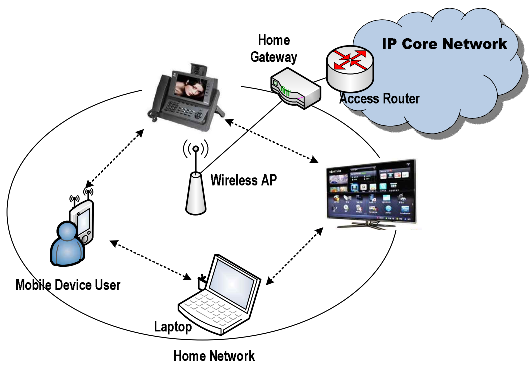

Figure 1. Reference model for Multi-screen service.

In addition, we employ a service flow-based mobility mechanism by presenting a service flow-based entry table in the mobile device to transfer only a specific service to the target device without affecting other services. Through a performance analysis and comparison of MSCT and the original live streaming service transfer (OSST) approach, we confirm that MSCT is superior to OSST in terms of signaling cost, packet delivery cost, and service disruption delay because it does not require any signaling on the network side.

The rest of this paper is organized as follows. In section II, we explain the features of live streaming services and DLNA. In section III, we propose the MDST mechanism. Section IV evaluates the performance of MDST based on an analytical model and presents the numerical results. In section V, we offer a conclusion.

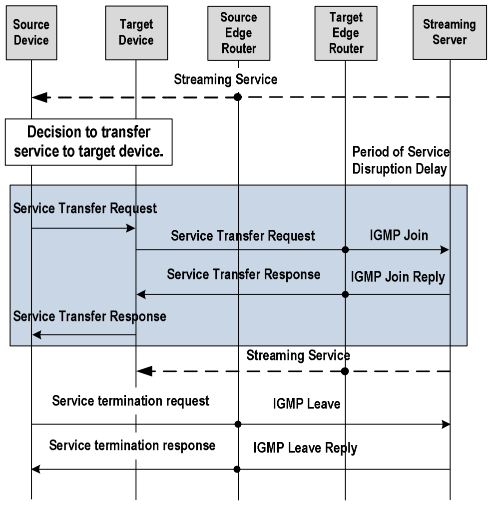

Figure 2. Protocol procedure for transferring a live streaming service.

II. RELATED WORK

A. Live Streaming Service

Generally, multimedia streaming services areis divided into two casestypes: video on demand (VOD) and live streaming services. "LThe live streaming service" typically refers to a continuous stream from a live event such as broadcasted TV that isand continuously pusheds to the clients using multicasting. Thus, in a live streaming service, because users want to watch the event in real time and do not miss out on content, the end-to-end delay should be minimized [8]. Due to this feature, when a user transfers a lives streaming service, it is crucial issue to minimize the service disruption delay caused by connection setup and media delivery delay, as shown in Figure 2.

To complement this issue, a novel live streaming service mobility mechanism is required.

B. DLNA Overview

The DLNA standard is an intermediate layer based on the original network framework to pursue to enable full interoperability and compatibility between devices distributing content anywhere in the home. It defines the media formats, communication protocol, and device types, which are called the digital media server (DMS), digital media player (DMP), digital media renderer (DMR), and digital media controller (DMC).

Currently, the DLNA uses UPnP architecture to perform device discovery and service discovery, and there are four steps to perform them. First, the DMS advertises its own service to other devices. Second, once the DMP has discovered a DMS, it retrieves the DMS description in detail. Third, after a DMP has retrieved a description of the DMS, the DMP sends action commands to the DMS. Finally, the DMS transports its own content to the DMP using HTTP [1] [9].

III. PROPOSED SCHEME

The Figure 3 shows the scenario when a mobile user who belongs to network provider A is goinggoes to a home network belonging to different provider, network provider B. Our proposed scheme allows mobile users to transfer an ongoing live streaming service in different network operators. Also, it minimizes signaling overhead on theat network -side and service disruption delay. To support our mechanism, there are two considerations as follows, assuming that the mobile device is equipped with multiple interfaces:.

(1) How can current live streaming service be detected from a mobile device and accepted at target device?
(2) How can an ongoing live streaming service be transferred to the target device from the mobile device?

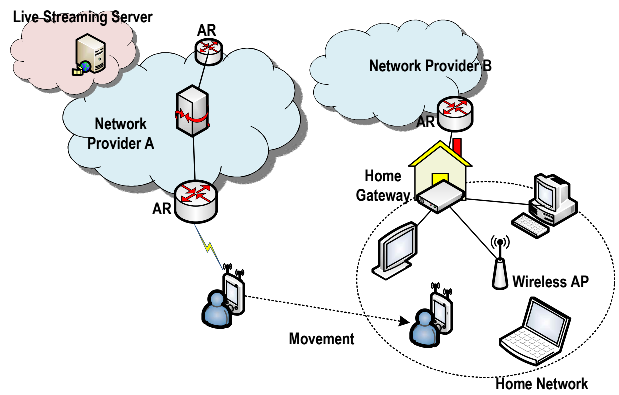

Figure 3. Protocol procedure for transferring a live streaming service.

Before transferring a live streaming service to a target device, the device and service discovery must be performed at either the source or the target device. After performing these procedures, the source device detects the target device and vice versa. Once it has detecting the target device, the source device determines whether the target device is allowed to accept an ongoing live streaming service.

Actually, since the current DLNA standard is used for stored content-sharing on stationary devices, transferring an ongoing live streaming service is required. Therefore, to address this limitation, we extend the DLNA standard by adding new signaling, as shown in Figure 4, as the solution to consideration (1).

It is assumed that the both the mobile device and the target device are DLNA standard equipment. After detecting the source device, the target device sends a service description message, including the "R." flag for supporting live streaming service and its IP address.

Having received this message, the source mobile device notifies the target device of its information, such as the current application type and port number. After that, the target device determines whether it accepts this information or not.

When the target device wants to retrieve a live streaming service, it sends a command request including a "T" flag for the source device to enable service-flow based mobility. From this procedure, the target device can predefine a configuration and can accept a live streaming service.

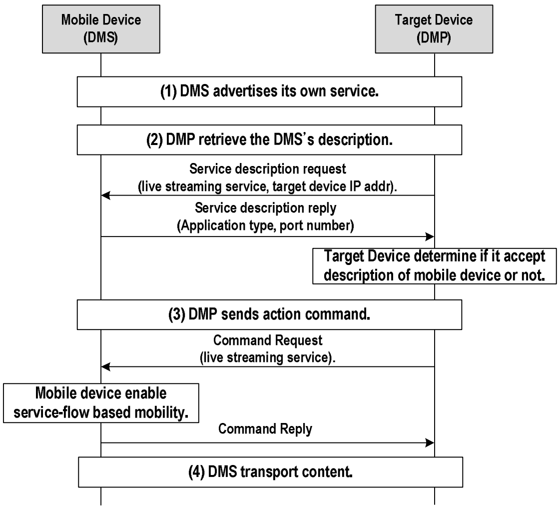

Figure 4. Extended discovery procedure.

Note that this procedure can be performed based on either the pull-mode or push-mode.

Because a lot of services, including ongoing live streaming and other background services, (e.g. Web browsing) are handled by a mobile device, it must transfer only a specific live streaming service. Therefore, we employ service flow-based mobility, which controls and transfers individual service flows from one interface to another based on a predetermined service type as the solution for consideration (2).

The service flow can be determined by 5-tuple information such as source IP address and port number, destination IP address and port number, and protocol type [10]. To perform flow-based mobility, we present a flow-based binding entry, which is kept by the mobile device, as shown in Figure 5.

To transfer a live streaming service, a mobile device can use two approaches: encapsulation or a changing IP address. In the case of encapsulation, after a packet of the live streaming service arrives at the mobile device, the mobile device checks the current service based on the proposed table and then adds an additional IP header.

This header consists of the target device IP and the mobile device IP for the destination and source IP address, respectively. In the case of a changing IP address, the mobile device changes the current IP packet address as the target device without adding an additional header.

The Figure 6 shows the protocol procedure of the OSST approach in an inter-domain scenario, while Figure 7 shows the MSCT approach.

Service Flow Binding Entry

Flag	FID-PRI	FID	Target Device
T	10	1	Target IP addr

Service Flow Type

FID	Src IP	Src Port	Dst IP	Dst Port	Protocol
1	Src IP	Src Port	Dst IP	Dst prot	Src prt

Figure 5. Proposed service flow binding entry for a mobile device.

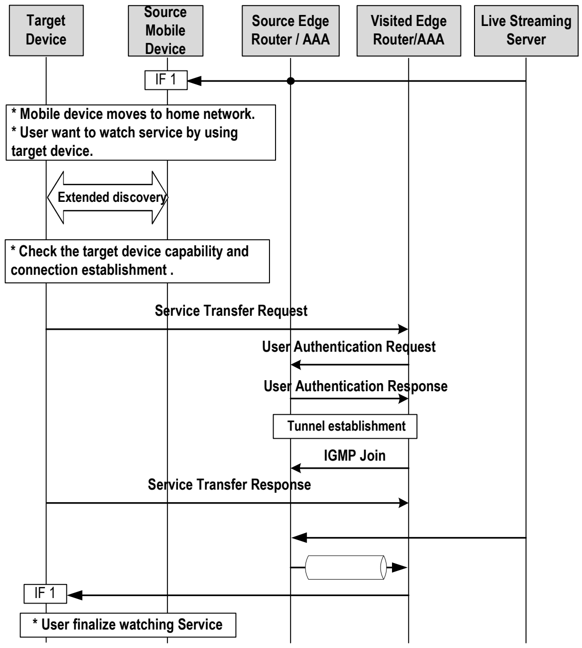

Figure 6. Protocol procedure of OSST between the different domains.

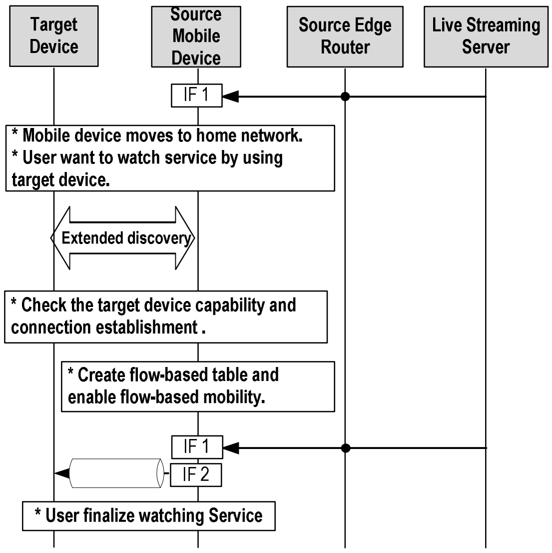

Figure 7. Protocol procedure of MDST between the different domains.

IV. Performance

In this section, we describe an analytical model according to [11] and [12] and analyze the proposed scheme in terms of signaling cost, service disruption latency cost, and packet delivery cost.

A. Network Model

Figure 8 illustrates the network model for the performance analysis. It is assumed that there are two networks belonging to different network providers. The HER represents an edge router to which the mobile device belongs originally, while VER represents the edge router to which the target device belongs in the home network after the mobile user goes to the home network. To handle the effects of our proposal, we assumed that two networks are overlapped; the mobile user is

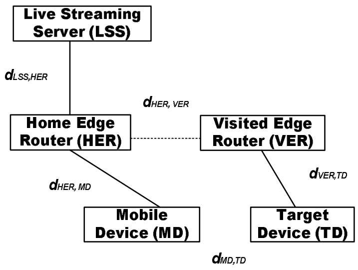

Figure 8. Network model.

using only one live streaming service. The $d_{x\text{-}y}$ denotes the hop distance between two network entities, x and y, assuming that the network consists of N cells and that all cells have a hexagon shape of size S. In addition, each mobile device moves at an average velocity of v; the service session arrival process to the mobile device follows a Poisson distribution; and the residence time of the mobile device follows an exponential distribution. Thus, we define μ_s and λ_s as the cell-crossing rates for which the mobile device keeps its residence in the same domain and at the same service session arrival rate. From these, we obtain the average number of movements, $E(N_s)$, and express it as follows [15]:

$$E(N_s) = \mu_s / \lambda_s. \tag{1}$$

$$\mu_s = 2 \cdot v / \sqrt{\pi \cdot S} \cdot (\sqrt{N} - 1) / \sqrt{N}. \tag{2}$$

B. Signaling Cost

We define the signaling cost as the amount of cost to perform a service transfer from the mobile device or content source. Then, we can calculate the signaling cost by the sum of the signaling and processing cost for each device and edge router, and it is expressed as follows. We define the signaling cost of MCST and OSST as C_{MCST} and C_{OSST} from equation (3), and it can be expressed as follows:

$$C_{MCST} = E(N_s) \cdot (4 \cdot \tau \cdot (d_{MD,TD} \cdot S_{Command}) + 3 \cdot P_{MD} + 2 \cdot P_{TD}), \tag{3}$$

$$\begin{aligned} C_{OSST} = {} & E(N_s) \cdot (4 \cdot \tau \cdot (d_{MD,TD} \cdot S_{Command}) + 3 \cdot P_{MD} + 2 \cdot P_{TD} \\ & + 2 \cdot \tau \cdot (d_{TD,VER} \cdot S_{STR}) + P_{VER} + 3 \cdot \kappa \cdot (d_{HER,VER} \cdot S_{AUR}) \\ & + P_{VER} + P_{HER}, \end{aligned} \tag{4}$$

where S_m is the size of the signaling message, P_R is the routing processing cost between routers, and P_x denotes the processing cost required in entity x.

C. Packet Delivery Cost

The packet delivery cost is defined as the cost of bandwidth consumption incurred by data packets in service from the live streaming server to a specific target device. PC_z denotes the packet delivery cost of the z scheme. It can be calculated as the sum of the processing cost issued by each entity and the data packet costs over a wired/wireless network:

$$\begin{aligned} C_{MCST} = {} & 2 \cdot \kappa \cdot (E(S) \cdot S_{data}) \cdot d_{LSS,HER} + P_{HER}) \\ & + 2 \cdot \kappa \cdot (E(S) \cdot S_{data}) \cdot d_{HER,MD} + P_{MD}) \\ & + \tau \cdot (E(S) \cdot (t + S_{data})) \cdot d_{MD,TD} + P_{MD}), \end{aligned} \tag{5}$$

$$\begin{aligned} C_{OSST} = {} & 2 \cdot \kappa \cdot (E(S) \cdot S_{data}) \cdot d_{LSS,HER} + P_{HER}) \\ & + 2 \cdot \kappa \cdot (E(S) \cdot S_{data}) \cdot d_{HER,MD} + P_{MD}) \\ & + \kappa \cdot (E(S) \cdot (t + S_{data})) \cdot d_{HER,VER} + P_{VER}) \\ & + \tau \cdot (E(S) \cdot S_{data}) \cdot d_{VER,TD} + P_{TD}), \end{aligned} \tag{6}$$

where $E(S)$ is the service session length in packets and κ, τ, and t denote unit transmission cost for the wired and wireless link and the tunnel header size, respectively.

D. Service Disruption Delay Cost

The service disruption delay cost is defined as the time cost period service can be transferred to the target device after the user triggers a transfer. D_z denotes the service disruption delay cost of the z scheme. It can be calculated by the sum of the signaling transmission cost and the processing delay cost issued in each entity and expressed by:

$$\begin{aligned} D_{MCST} = {} & 4 \cdot (\frac{1-q}{1+q} \cdot (\frac{S_{command}}{B_{wl}} + L_{wl}) \cdot (d_{MD,TD}) + 3 \cdot P_{MD} \\ & + 2 \cdot P_{TD} + (d_{LSS,HER} - 1) \cdot (\frac{S_{data}}{B_w} + L_w + P_R) \\ & + \frac{1-q}{1+q} \cdot (\frac{S_{data}}{B_{wl}} + L_{wl}) \cdot (d_{MD,TD}), \end{aligned} \tag{7}$$

$$\begin{aligned} D_{OSST} = {} & 4 \cdot (\frac{1-q}{1+q} \cdot (\frac{S_{command}}{B_{wl}} + L_{wl}) \cdot (d_{MD,TD}) + 3 \cdot P_{MD} \\ & + 2 \cdot P_{TD} + 2 \cdot ((d_{TD,VER} - 1) \cdot (\frac{S_{STR}}{B_w} + L_w + P_R)) + P_{VER} \\ & + 3 \cdot ((d_{HER,VER} - 1) \cdot (\frac{S_{AUR}}{B_w} + L_w + P_R)) + P_{VER} + P_{HER} \\ & + ((d_{LSS,HER} - 1) + (d_{VER,HER} - 1) \cdot (\frac{S_{data}}{B_w} + L_w + P_R)) \\ & + \frac{1-q}{1+q} \cdot (\frac{S_{data}}{B_{wl}} + L_{wl}) \cdot (d_{VER,TD}), \end{aligned} \tag{8}$$

where q is the probability cost of wireless link failure, B_{wl} and B_w are the bandwidth costs of wireless and wired links, respectively, and the L_{wl} and L_w are the wireless and wired link delay costs, respectively.

E. Numerical Results

We employ some of the parameter values used in the literature [10] [11], as shown in Table 1.

Table 1. Parameters used for numerical results.

Parameters	Values	Parameters	Values
τ, k	10, 20	P_R, P_{HER}, P_{VER}	10, 8, 8
L_{signal}, L_{data}	70, 100	B_w, B_{wl}	100, 11
λ_s, S, N	10, 31400, 30	L_w, L_{wl}	2, 10
P_{MD} P_{TD}	12	t	46

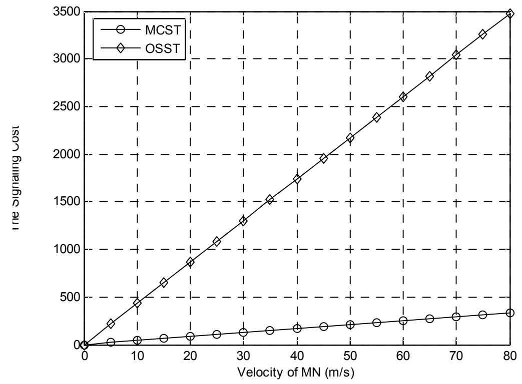

Figure 9. The signaling cost as a mobile device's velocity.

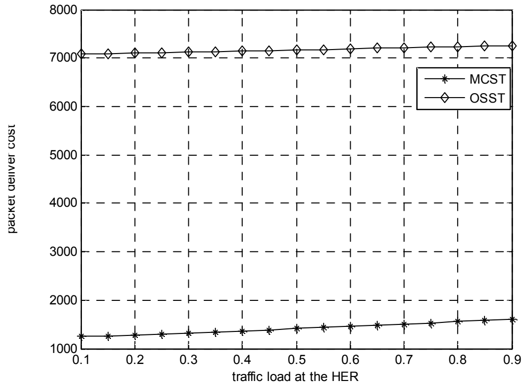

Figure 10. The packet delivery cost as traffic load at the HER.

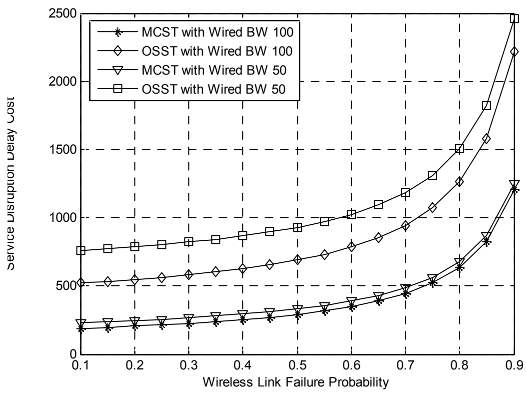

Figure 11. Service disruption delay cost as wireless link failure probability.

Figure 9 shows the total signaling cost where the MN's velocity varies from 0 to 80. Since MSCT requires signaling only between the mobile device and the target device, the signaling cost is lower than that of the OSST. In the case of OSST, there is signaling on the network side to support interworking in different domains and authenticate mobile users. Figure 10 shows the packet delivery cost where the traffic load at the HER varies from 0.1 to 0.9. Since packets in the service must go through two different domains, OSST is more inefficient than MDST. Figure 11 shows the service disruption delay cost where the wireless link failure probability varies from 0.1 to 0.9. The results show that MCST is more efficient than OSST because the live streaming service is transferred to the target device as soon as the target device configures its capability to accept this service from the mobile device. This means that mobile users can avoid missing out on content.

V. CONCLUSION

The service mobility is a promising technology that can help users to use their content service regardless of their various devices without restarting the content service. Because research studies for supporting service mobility do not focus on inter-domain cases (i.e. the different network operator case) or live streaming service support. Therefore, we proposed the MSCT mechanisms in which a current live streaming service belonging to a mobile device is transferred to a target device from the mobile device. We extended the service discovery protocol in the DLNA standard and employed service flow-based mobility at the mobile device. Through the performance analysis, we confirmed that MSCT is a solution to the inter-domain scenario.

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