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LETTER

User-initiated Flow Mobility in the PMIPv6-based Evolved Packet System

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SUMMARY Flow mobility is an emerging technology to support flexible network selection for an application flow and to spread concentrated load over another acceptable access. Network-based flow mobility (FMO) provides many advantages that can avoid a massive amount of software logic and system resources on the mobile node. Under this approach, there are two kinds of modes available: network-initiated and user-initiated. Network-initiated FMO decides the best access network suited to specific flow, but the decisions depend on the operator's policy. Therefore, it has limitations in supporting the user's preference and private network selection. In the user-initiated mode, users can hand off specific flow so that information of both the current user's preference and the conditions of private network are reflected. This paper extends Internet Exchange Key v2 (IKEv2) and an Attach request message to support user-initiated FMO. Through performance analysis, we confirm that user-initiated FMO is superior to network-initiated FMO in terms of signaling overhead and handover latency costs.
key words: *PMIPv6, Flow Mobility, IP Flow Mobility, Evolved Packet System.*

1. Introduction

Multi-homing on mobile devices is gradually becoming more common. Under such a technical environment, flow mobility (FMO), making mobile users select access network per application flow possible, is one of the critical issues [1]. The FMO provides a better network experience for end users and also facilitates a network operator to appropriately balance traffic load, depending on the availability of network capacity.

Due to these reasons, several solutions have been proposed over Proxy Mobile IPv6 (PMIPv6) [3] [4]. They essentially allow the localized mobility anchor (LMA) to distribute application flows to the proper mobile access gateway (MAG) based on the user's preference, as shown in Fig. 1. [3] is a well-defined flow mobility solution, but it cannot reflect the user's preference. [4] reflects user preference according to the user's predefined policy between a 3GPP and non-3GPP access system, like Wi-Fi in the evolved packet system (EPS), but it has limitations in covering dynamic network status around the user. For example, when Wi-Fi is severely congested but 3G access is relatively free, the network-side would move this flow to Wi-Fi from 3G access, since Wi-Fi is designated as the default option while the user wants to hand off his flow to 3G access. In addition, the user wants to connect to a private Wi-Fi access point (AP); the network side cannot recognize

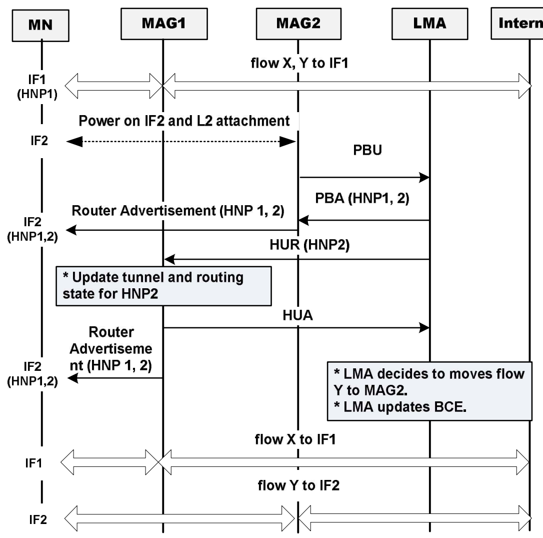

Fig. 1 Protocol procedure of network-based FMO

available private networks around the users. Furthermore, when the user is within a moving vehicle equipped with Wi-Fi overlapped with 3G access, once switching from 3G access to Wi-Fi, the network-side must switch back to 3G access a little later when the user leaves the Wi-Fi area [5].

To cover these limitations, we propose an enhanced user-initiated FMO approach (EUFMO). In EUFMO, the MN informs LMA of the user's current preference whenever the MN wants to move specific flow to another access network. To do this, we extend Internet Key Exchange v2 (IKEv2) protocol for Wi-Fi access [6] and a 3GPP-specific attach request message for 3G access [7], respectively, for the re-use of link layer-specific existing protocol. Through the performance analysis, we confirm that NFMO is higher than EUFMO in terms of total signaling cost and handover latency cost. This is because the routing table for the application is updated in advance in EUFMO.

The rest of this paper is organized as follows. Section 2 describes the proposed flow mobility scheme and its operational procedures. Then, we analyze the performance based on the analytical model and present the numerical results. Finally, we conclude with section 4.

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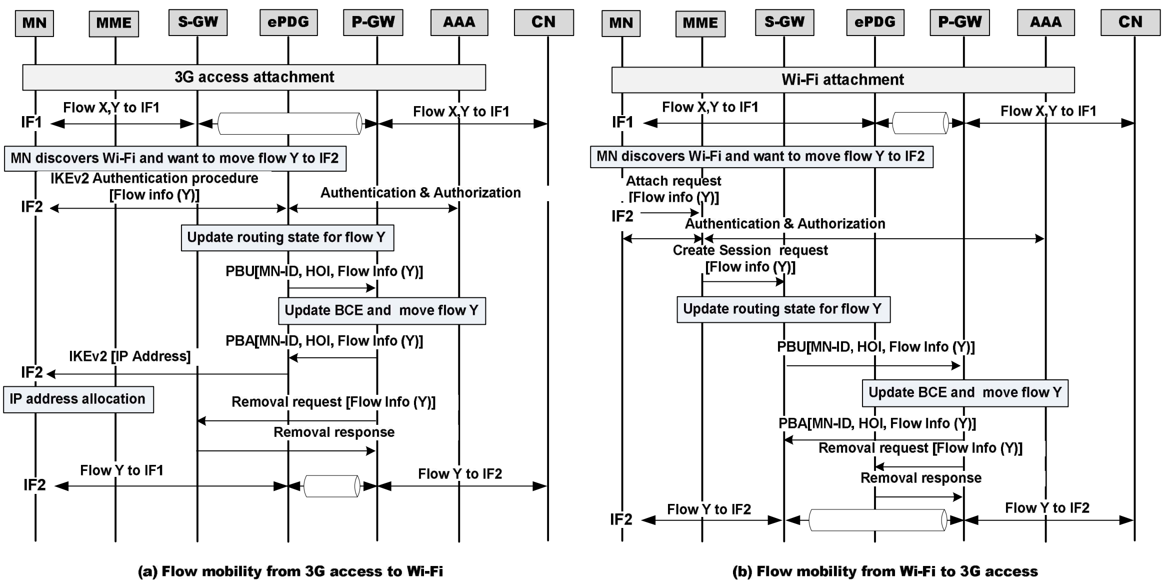

Fig. 4 Entire protocol procedure for proposed EUFMO

access, the MN sends an attach request message, as shown in Fig. 4(b). This message is sent to the MME, including indication of multiple access, two flags and flow information issued at MN to perform EUFMO. On receiving the attach request, the MME sends a create session request message with specific flow information to S-GW. Then, extended PBU/PBA signaling operations are performed between S-GW and P-GW.

3. Performance Analysis and Numerical Results

This section presents performance analysis of the proposed EUFMO in comparison with NFMO. For simplicity, the network assumes that all flows are admitted whenever a user tries to perform flow mobility and a flow is supposed to move from MAG1 (S-GW) to MAG2 (ePDG). Under these assumptions, total signaling cost and flow handover latency cost are analyzed and the numerical results are presented.

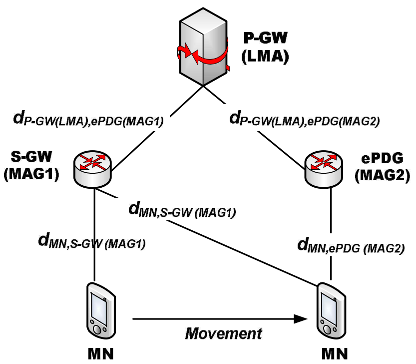

Fig. 6 Network topology for performance analysis

A simplified network model for our cost analysis is shown in Fig. 6. It is assumed that there are two access networks, a 3G access network and a WLAN. To handle the effects of the flow mobility among two overlapped networks, only an MN within the overlapping areas are considered after movement. The $d_{x\text{-}y}$ denotes the hop distance between two network entities x and y.

3.1 Signaling Cost

We define the signaling cost, C_z, as the elapsed time cost required to conduct FMO operation of the z scheme, as shown in Eqs. (2) and (3). It can be calculated as the sum of the flow information registration and removal costs. Each scheme's signaling cost is expressed by

$$C_{NFMO} = T_{L2HO} + T^{NFMO}_{PBU/PBA} + T^{NFMO}_{FMO\_registraion} + T^{NFMO}_{FMO\_removal}, \quad (1)$$

$$C_{EUFMO} = T_{L2HO} + T^{EUFMO}_{PBU/PBA} + T^{EUFMO}_{FMO\_removal}, \quad (2)$$

where T_{L2HO} is the L2 handover and router advertisement processing time. To calculate delay time for signaling transmission, we use the unit transmission delay cost per hop distance as κ and τ for a wireless and wired link used in [10], respectively.

$$\begin{aligned} T^{NFMO}_{PBU/PBA} &= T^{EUFMO}_{PBU/PBA} \\ &= 2\cdot(\tau\cdot d_{LMA,MAG2}\cdot S_{PBU/PBA}) + P_{MAG2} + P_{LMA}, \end{aligned} \quad (3)$$

$$\begin{aligned} T^{NFMO}_{FMO\_registraion} &= T^{NFMO}_{FMO\_removal} = T^{EUFMO}_{FMO\_removal} \\ &= 2\cdot(\tau\cdot d_{LMA,MAG1}\cdot S_{HUR/HUA}) + P_{MAG1} + P_{LMA}, \end{aligned} \quad (4)$$

where S_m is the amount of the signaling or data message. The P_x is the processing cost required in the x entity.

3.3 Flow Handover Latency Cost

The flow handover latency cost is defined as the time cost elapsed for the flow moved to the target access network after triggering FMO. The D_z denotes flow handover latency cost of z scheme. It is calculated by sum of signaling transmission cost and processing delay cost issued from MAG and LMA. Corresponding D_z can be derived by

$$\begin{aligned} D_{NFMO} = 2\cdot(&\frac{1-q}{1+q}\cdot(\frac{S_{RA}}{B_{wl}} + L_{wl})) \\ &+ 2\cdot(d_{LMA,MAG2}-1)\cdot(\frac{S_{PBU/PBA}}{B_w} + L_w + P_R) \\ &+ 2\cdot(d_{LMA,MAG1}-1)\cdot(\frac{S_{HUR/HUA}}{B_w} + L_w + P_R) \\ &+ 2\cdot P_{MAG} + P_{LMA}), \end{aligned} \quad (5)$$

$$\begin{aligned} D_{EUFMO} = 2\cdot(&\frac{1-q}{1+q}\cdot(\frac{S_{IKEv2}}{B_{wl}} + L_{wl})) \\ &+ 2\cdot(d_{LMA,MAG2}-1)\cdot(\frac{S_{PBU/PBA}}{B_w} + L_w + P_R) + P_{LMA} + P_{MAG}, \end{aligned} \quad (6)$$

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

3.3 Numerical Results

We employ some of parameter values used in the literature [11] [12], which are shown in Table 1.

Table 1 Parameters used for numerical results.

Parameters	Values	Parameters	Values
τ, k	10, 20	P_R, P_{LMA}, P_{MAG}	8, 12, 24
L_{signal}, L_{data}	76, 146	B_w, B_{wl}, L_w, L_{wl}	100, 11, 2, 10

Fig. 7 shows the total signaling cost where the number of times for flow mobility increases to 10. The results show that EUFMO's signaling cost is lower than NFMO. This is because NFMO requires additional signaling messages network-side, even if FMO is inactive.

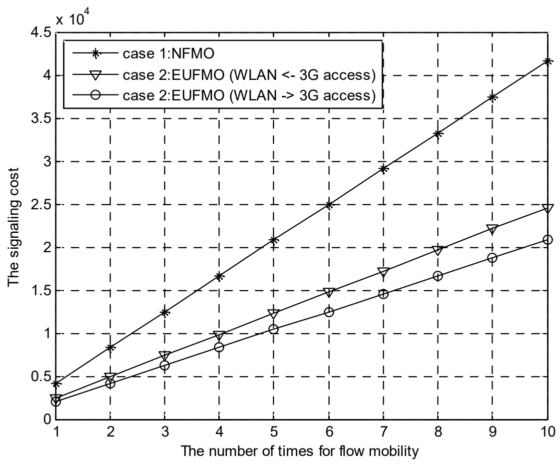

Fig. 7 Total signaling cost as the number of times for flow mobility.

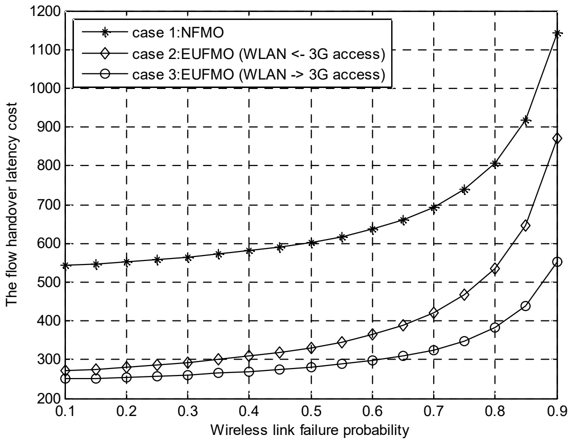

Fig. 8 Flow handover latency as wireless link failure probability

Although the signaling is required at the MN to announce the beginning of the FMO to network-side in EUFMO, the result is lower than NFMO because it reuses existing signaling message as long as MN attaches to Wi-Fi or 3G accesses.

Fig. 8 shows that the flow handover latency cost of the EUFMO is much lower than that of NFMO, where the q varies from 0.1 to 0.9. In EUFMO, once LMA receives the PBU including flow information, it updates BCE according to the user's preference. In NFMO, the LMA decides and update its BCE for performing FMO after sending signaling message to all MAGs to which the MN attaches. Also, each MAG sends an RA message to all of the MN's interfaces. Thus, the NFMO's result is inferior to EUFMO.

We observed that since the IKEv2 signaling is used to allocate IP address as well as to inform the network-side of the FMO in case 2, as shown in Figs. 7 and 8, the results are higher than in case 3.

4. Conclusion

The PMIPv6-based flow mobility is a promising technology that can help operators to comprise various heterogeneous access networks without requiring signaling at the MN. Because NFMO cannot cover the user's current preference and intention, we proposed a EUFMO approach by extending authentication protocol messages, IKEv2 and an attach request message. Through the performance analysis, we confirm that the signaling costs of two schemes are not significantly different, but EUFMO is superior to NFMO in terms of flow handover latency.

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