LETTER

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

Jiwon JANG†, Seil JEON†, *Nonmembers,* and Younghan KIM†*a), *Member*

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 best access network suited to specific flow but the decisions depend on the operator's policy so it has limitation in supporting user's preference and private network selection. In user-initiated mode, it lets user to hand off specific flow so that information of both current user's preference and condition of private network is reflected. This paper extends Internet Exchange Key v2 (IKEv2) and Attach request message to support user-initiated FMO. Through performance analyze, 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 becoming gradually common. Under such technical environment, flow mobility (FMO), making mobile users select access network per application flow possible, is being as one of critical issues [1]. The FMO provides a better network experience for end users and also facilitates a network operator to balance traffic load depending on the availability of network capacity appropriately.

Due to these reasons, several proposals have proposed over Proxy Mobile IPv6 (PMIPv6) [3] [4]. Basically, they allow the localized mobility anchor (LMA) to distribute application flows to proper mobile access gateway (MAG) on its decision as shown in Fig. 1. [3] is well-defined flow mobility solution but it cannot reflect user's preference. [4] reflects user preference according to predefined user's policy between 3GPP and non-3GPP access system, like Wi-Fi in the evolved packet system (EPS) but it has limitation 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 default option while the user wants to handoff his flow to 3G access. In addition, the user wants to connect private Wi-Fi access point (AP), the network-side cannot recognize available

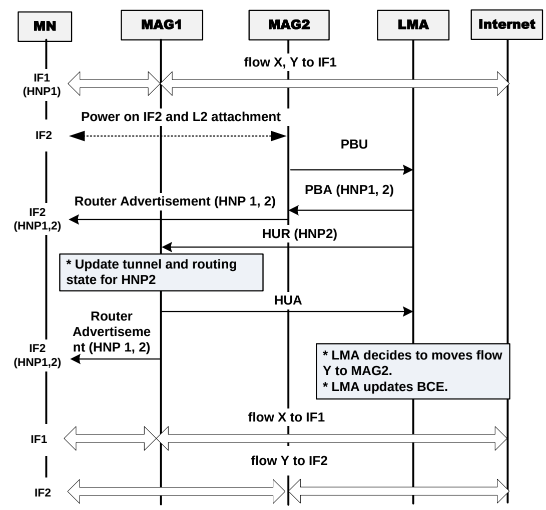

Fig. 1 Protocol procedure of network-based FMO

private network around users. Furthermore, when the user is within moving vehicles equipped with Wi-Fi overlapped with 3G access, once switching from 3G access to Wi-Fi, the network-side must again switch to 3G access a little later when 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 user's current preference whenever the MN want to move specific flow to another access network. For doing this, we extend Internet Key Exchange v2 (IKEv2) protocol for Wi-Fi access [6] and 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 NUFMO in terms of total signaling cost and handover latency cost. It is because routing table for application is updated in advance in NUFMO.

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 analytical model and present the numerical results. Finally, we conclude with section 4.

2. Proposed User-initiated Flow Mobility Scheme

Fig. 2 shows evolved packet system (EPS) where

†The authors are with the School of Electronic Engineering, Soongsil University, Seoul 156-743, Republic of Korea.
*Corresponding author.
a) E-mail: younghak@ssu.ac.kr

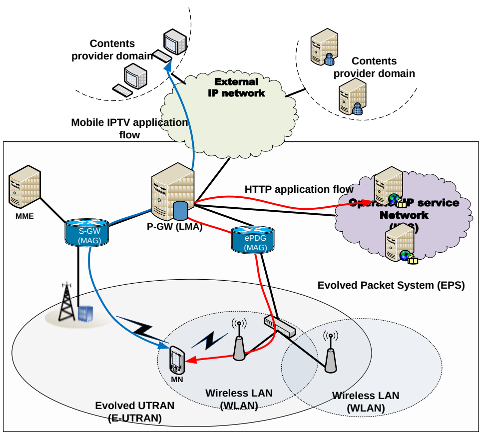

Fig. 2 Flow mobility reference model over EPS using PMIPv6

PMIPv6 is applied on. The serving gateway (S-GW) for 3GPP access and the evolved packet data gateway (ePDG) for untrusted non-3GPP access act as a MAG, while the PDN gateway (P-GW) acts as an LMA [7]. To trigger flow mobility in user-initiated approach, the MN is required to send its preference explicitly to the network. To reflect MN's preference, IKEv2 protocol for user's authentication and 3GPP-specific attach request command are used for Wi-Fi and 3G accesses, respectively but they have trouble in expressing to the network which flow should be moved.

To make user-initiated flow mobility support flexible, we use IKEv2 protocol but extend it by adding application flow information, i.e. 'I' and 'U' bits, flow identification mobility option, and traffic selector sub-option as shown in Fig. 3. 'I' is used to check FMO support available while 'U' lets the LMA be informed that current FMO is user-triggered. Two options follow standard format to facilitate the LMA to classify traffic received from external network into individual flow, then to forward each flow to corresponding MAG. In network-initiated flow mobility, two optional information is generated by the MAG [8] [9] but if 'U' field is set to '1', it means that were generated from the MN.

1 2 3
0123456789012345 678901234567890 1

Next Payload	C	I	U	RESERVED	Payload Length
Number of TSs	RESERVED				
Flow identification mobility option (RFC 5648)					
Traffic selector sub option (RFC 6088)					

Fig. 3 Extended IKEv2 protocol message

Fig. 4 shows the protocol procedure of NUFMO with two moving scenarios where that the MN is within overlapped areas of 3GPP and Wi-Fi accesses. First, the MN attach to 3GPP access, E-UTRAN, and then Wi-Fi sequentially as shown in Fig. 4 (a), therefore the MN sends extended IKEv2 message by setting 'I' and 'U' fields to '1' and putting application flow information into two options. On receiving the IKEv2 message from the MN, the ePDG performs authentication and FMO procedure. If P-GW does not support FMO, the MN does not try FMO more. When accepted, the ePDG sends extended proxy binding update (PBU) including handover indicator (HOI) and application flow information to let the P-GW be informed.

Second, when an MN attach to 3G access from Wi-Fi access, the MN sends attach request message as shown in Fig. 4. (b). This message is sent to MME including indication of multiple access, two flags and flow

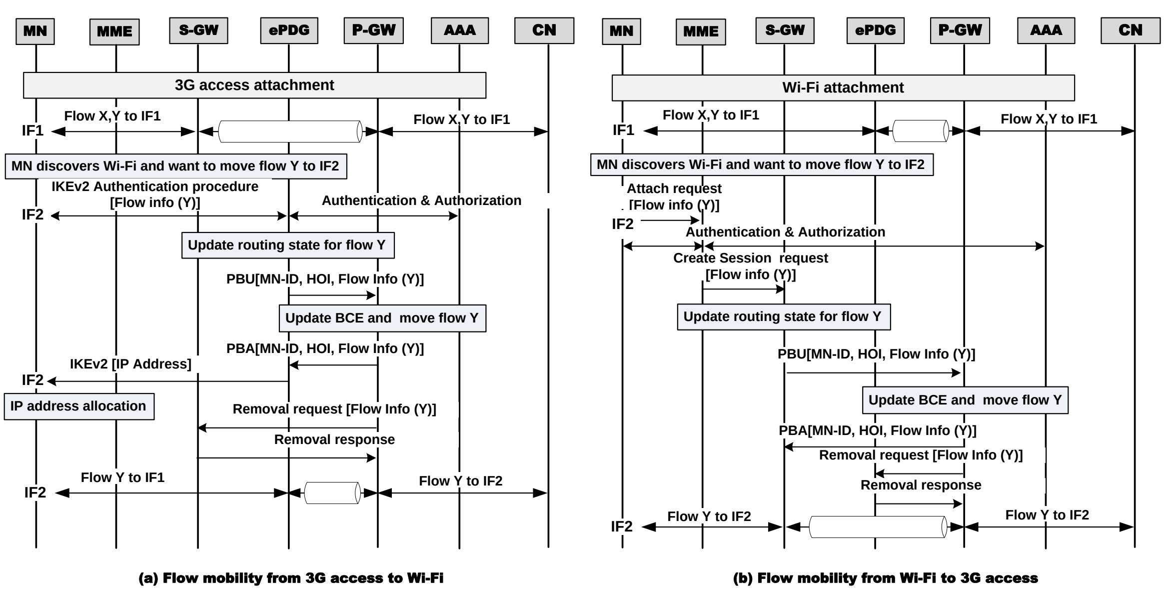

Fig. 4 Protocol procedure for proposed EUFMO

information issued at MN to perform NUFMO. On receiving the attach request, the MME sends 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 NUFMO and PFMO. For simplicity, the network is assumed 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.

3.1 Network Model

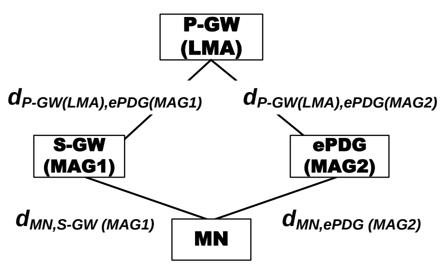

Fig. 6 Network topology for performance analysis

$d_{x\text{-}y}$ denotes the hop distance between two network entities x and y. We assume that PMIPv6 domain consists of N cells and all cells in the given domain have the circular shape with size S. Each MN moves with average velocity of v, and movement direction is assumed to be uniformly distributed. The inter-session arrival time follows a Poisson distribution with λ_s and the residence time of the MN is exponentially distributed with μ_s. Hence, we calculate average number of movement, $E(N_s)$ as follows [10]:

$$E(N_s) = \mu_s / \lambda_s, \quad \mu_s = \frac{2 \cdot v}{\sqrt{\pi \cdot S}} \cdot \frac{\sqrt{N-1}}{N} \tag{1}$$

3.2 Signaling Cost

The signaling cost is defined as mobility signaling overhead during FMO operation. As shown Eqs. (2) and (3), the C_z denotes signaling cost to conduct FMO operation of z scheme and it can be calculated as sum of the flow information registration and removal costs, considering MN's movement. Each scheme's signaling cost is expressed by

$$\begin{aligned} C_{NFMO} &= E(N_s)\cdot 2\cdot(\tau\cdot(d_{LMA,MAG2}\cdot L_{PBU/PBA}) \\ &\quad +\tau\cdot(d_{LMA,MAG2}\cdot L_{HUR/HUA}) + P_R\cdot((d_{LMA,MAG2}-1) \\ &\quad +(d_{LMA,MAG2}-1) + P_{LMA} + P_{MAG2} + P_{MAG1})) \\ &\quad +\kappa\cdot((d_{MN,MAG2}\cdot L_{RA}) + (d_{MN,MAG1}\cdot L_{RA})), \end{aligned} \tag{2}$$

$$\begin{aligned} C_{EUFMO} &= E(N_s)\cdot(2\cdot\kappa\cdot(d_{MN,MAG2}\cdot L_{IKEv2}) \\ &\quad +2\cdot(\tau\cdot(d_{MAG2,LMA}\cdot L_{PBU/PBA}) + P_R\cdot(d_{MAG2,LMA}-1) \\ &\quad +P_{LMA}+P_{MAG2}), \end{aligned} \tag{3}$$

where τ and κ are unit transmission cost over wired link and wireless link, respectively, and L_m is the and the amount of the signaling or data message. The P_R is the routing processing cost within a router, and P_{LMA}, P_{MAG} is the processing cost required in LMA, MAG, respectively.

3.3 Flow Handover Latency Cost

The flow handover latency cost is defined as the time cost elapsed for the flow moved to 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

$$\begin{aligned} D_{NFMO} &= 2\cdot(\frac{1-q}{1+q}\cdot(\frac{L_{RA}}{B_{wl}}+L_{wl})) + 2\cdot(d_{LMA,MAG2}-1)\cdot(\frac{L_{PBU/PBA}}{B_w} \\ &\quad +L_w+P_R) + 2\cdot(d_{LMA,MAG1}-1)\cdot(\frac{L_{HUR/HUA}}{B_w}+L_w+P_R) \\ &\quad +2\cdot P_{MAG} + P\cdot t_{LMA}), \end{aligned} \tag{4}$$

$$\begin{aligned} D_{EUFMO} &= 2\cdot(\frac{1-q}{1+q}\cdot(\frac{L_{IKEv2}}{B_{wl}}+L_{wl})) + 2\cdot(d_{LMA,MAG2}-1)\cdot(\frac{L_{PBU/PBA}}{B_w} \\ &\quad +L_w+P_R)+P_{LMA}+P_{MAG}, \end{aligned} \tag{5}$$

where q is the probability of wireless link failure, 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 [10] [11], which are shown in Tables 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}	100, 11
λ_s, S, N	10, 31400, 30	L_w, L_{wl}	2, 10

Figs. 7 and 8 show the total signaling cost of where MN's velocity and the session arrival rate are varied from 0 to 80 and from 0.1 to 0.8. The results show that EUFMO's signaling cost is lower than NFMO. It is

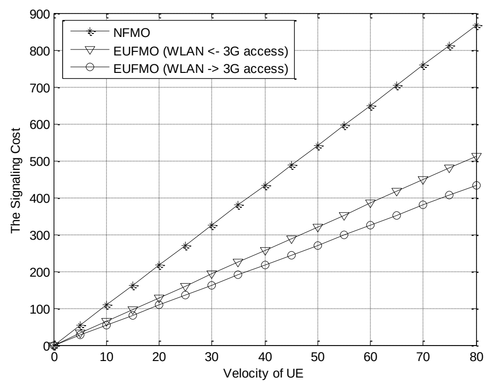

Fig. 7 Total signaling cost as MN's velocity.

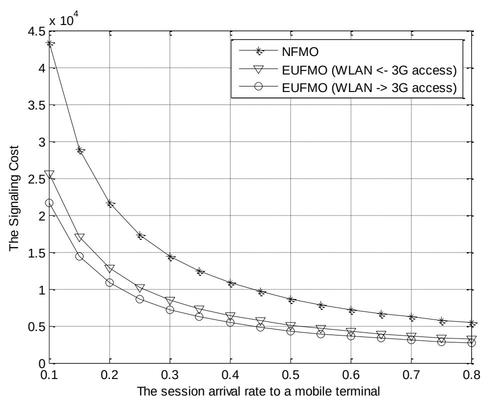

Fig. 8 Total signaling cost as session arrival rate.

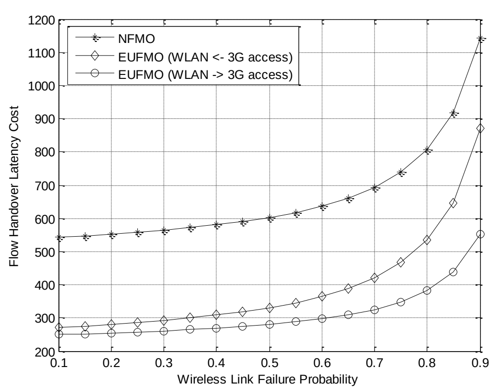

Fig. 9 Flow handover latency as wireless link failure probability

because NFMO requires additional signaling messages network-side even if FMO is inactive. In EUFMO, although the signaling is required at the MN to announce the beginning of FMO to network-side, because it reuse existing signaling message as well as MN attaches to Wi-Fi or 3G access the result is lower than NFMO.

The Fig. 9 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 PBU including flow information, it updates BCE according to user's preference. In NFMO, the LMA decides and update its BCE for performing FMO after sending signaling message entire MAGs to which the MN attaches. Also each MAG sends RA message to all of the MN's interfaces. Due to this reason, NFMO's result is inferior to EUFMO.

4. Conclusion

The PMIPv6-based flow mobility is a promising technology that can help the operators to comprise various heterogeneous access networks without requiring signaling at the MN. Because NFMO cannot cover user's current preference and intention, we proposed a EUFMO approach by extending authentication protocol messages, IKEv2 and 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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