Flow Mobility Management in PMIPv6-based DMM (Distributed Mobility Management) Networks

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Abstract

IP flow mobility enables selected traffic to offload among various access networks. However, until now, only flow mobility schemes in the centralized architecture were considered. In this paper, we propose a flow mobility-enabled scheme based on the distributed mobility management networks to address the scalability issue and single point failure problems which the centralized approaches suffer from. In this scheme, the centralized control function gathers every information about device, such as current location, multiple interfaces, and flow information, so it can trigger flow mobility for multi-interface device. On the other hand, data packets are forwarded in a distributed way without any centralized entity. Through numerical analysis, it is shown that the proposed scheme can achieve better packet delivery cost compared to the centralized ones.

Keywords: Distributed Mobility Management(DMM), Flow Mobility, PMIPv6

1 Introduction

In order to cope with challenges caused by the explosion of mobile data traffic, IP flow mobility is one of promising solutions. As mobile device has been equipped with various access technologies (e.g. 4G, Wi-Fi) and it can connect to multiple access networks simultaneously, flow mobility enables a single IP data traffic to offload among different radio access networks while maintaining seamless connectivity. Flow mobility helps network operators to solve traffic congestion problem and guarantee QoS depending on network policy [1]. For these reasons, a flow mobility scheme based on Proxy Mobile IPv6 (PMIPv6) has been proposed in IETF [2]. In that proposal, they allow Local Mobility Anchor (LMA) to have flow table which binds with binding cache so network can support mobility management with finer granularity such as per flow. Additionally, they enhanced mobile node to support logical interface to enable flow mobility without the involvement of mobile node IP stack.

However, in perspective of overall network architecture, there are still several limitations for balancing the traffic loads. Existing mobile core network architectures and mobility solutions utilize a hierarchical architecture with a centralized anchor. Centralized mobility solutions result in scalability issue and single point failure [3]. To overcome these issues, we propose a flow mobility-enabled scheme in the Distributed Mobility Management (DMM) environment. DMM scheme has been being researched by the IETF. In this scheme, mobility management functions are relocated to the edge of the network. To provide routing and mobility management, each function exchange signaling messages and make tunnel without a centralized anchor. This distributed manner can provide scalability and reduce packet data cost. Following our previous work in which we already proposed PMIP-based flow mobility scheme in the DMM networks to the IETF [4], We re-define network architecture and evaluate performance. To support flow schemes based on DMM, the centralized control function gathers information of all mobile

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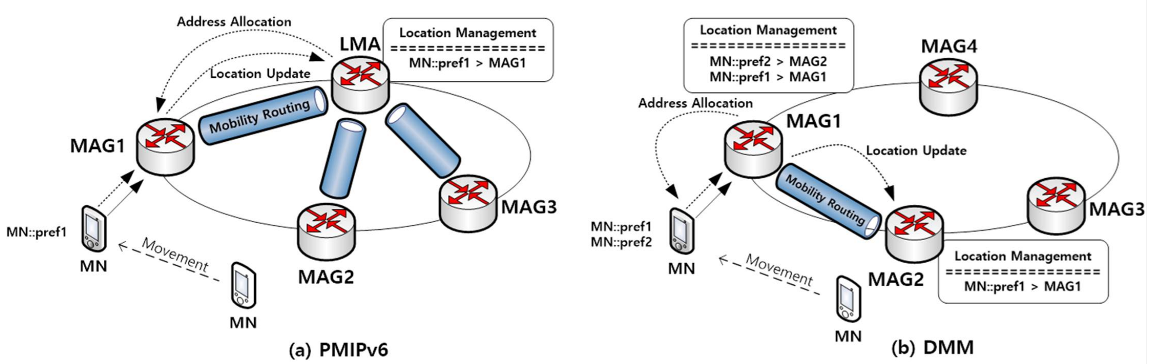
*Corresponding Author : 369, Sangdo-ro, Dongjak-gu, 156-743, Seoul, Korea, Tel: +82-2-820-0904 nodes in the network including identifier, address and traffic type. From that, although control messages are exchanged between mobility routers and control function, data traffic could be forwarded without any centralized entity. Our new flow mobility-enabled DMM architecture overcomes both issues of centralized schemes and offers an efficient data offloading mechanism.

The remainder of this paper is organized as follows. In Section 2, we discuss related works on PMIPv6-based distributed mobility management. In Section 3, we specify the requirements for supporting flow mobility and describe the proposed scheme. In Section 4, we analyze the performance of existing schemes and the proposed scheme in terms of signaling and packet delivery cost. Finally, we state our conclusion in Section 5.

2 Related Works



(a) PMIPv6 (b) DMM

Figure 1: Overview of PMIPv6 and DMM

PMIPv6 is a network-based mobility management scheme meaning that it requires no software on the host for mobility [5]. Compared to the host-based mobility, such as MIPv6, PMIPv6 can reduce the handoff latency in terms of mobility detection and duplicated address detection. In PMIPv6 architecture, the LMA performs two mobility management functions: IP address allocation and location management. The Mobile Access Gateway (MAG) updates the location of the Mobile Node (MN) and performs mobility routing functions using an IP tunnel with the LMA as 1 (a). This management scheme provides mobility management transparent to the MN and the centralized LMA can efficiently manage domain traffic; however, it has numerous limitations. For example, in cases where two devices are in close proximity and are communicating within the same domain, all packets continue to be forwarded via LMA. This may result in non-optimal routing [5]. In addition, all data packets and signaling messages are routed to the LMA, resulting in a potential single point of failure. To solve these limitations, DMM architecture splits functions of LMA to multiple MAGs which are placed at the edge of the network as 1 (b). All MAGs in the DMM network may have address allocation functions. It means that the MN may be assigned multiple prefixes when the MN moves across multiple MAGs. When the MN moves and attaches new MAG, the new MAG should perform address allocation to the MN as well as perform location update function for prefixes of MN which were assigned by other MAGs. From the functional distribution, the DMM can achieve improving scalability, avoiding single point failure, optimized routes and so on.

To support distributed management, there have been several works which proposed the DMM architecture based on PMIPv6. PMIPv6-based DMM has been also divided into two approaches; partially distributed and fully distributed approaches [6]. The partially distributed approach employs a control function or database that stores MN information such as the IP address and the connecting access router.

When an MN connects to an access router, the router subsequently requests information of the MN from control function. For handover processing, centralized control functions may handle the exchange of signaling messages between access routers[7, 6], or provide the MN's location to a new access router to facilitate an exchange of signaling message between access routers [3]. [8] proposed the routing optimization schemes in flat architecture by extending PMIPv6. In this proposal, they added a new entity called Intermediate Anchor (IA) which is represented as the most adapted anchor to control the data path. The IA could be chosen to achieve near-zero triangular data path to offload the flow to a specific network. In the fully distributed approach, each access router shares information directly with other routers to determine if the MN's mobility can be supported. When an MN connects to an access router, the router may forward MN's data packet or a signaling message to neighboring routers, using multicast or broadcast messages [9]. [10] proposed a fully DMM scheme. In that proposal, all MAGs advertise the same network prefix and the MN sets its address by using DHCP request/response messages. When MN moves to the another MAG, the MAG judges whether MN performs handover or not by receiving the first packet of MN. If the MAG considers that the MN moves from another MAG, the MAG send binding message to the previous MAG by setting destination address to the address of the MN. In [11], they classified and compared all previous works about the DMM for PMIPv6. In their analysis, they additionally compared DMM schemes for PMIPv6 in terms of the control/data plane separation. In the partially distributed approaches, control messages are centralized to the control function and data traffics are distributed. The fully distributed approaches, without any centralized entities, both control messages and data traffics are distributed to multiple MAGs.

PMIPv6-based flow mobility schemes [1, 12, 13, 14] allow an MN to receive packets regardless of the physical link layer interface, utilizing the logical interface of the MN. LMA, a centralized anchor, employs flow binding entry to manage both the IP address and the flow type of an MN. However, in the DMM architecture, no previous research has proposed the combined utilization of flow mobility architecture and message flow.

3 Proposed Scheme

3.1 Architecture

Figure 2 shows the architecture of distributed mobility management, employing a multi-interface device. This paper refers to the PMIPv6-based control/data separation approach in [9]. In the original scheme, the Mobile Control Function (MCF) manages the location, the address of the MN and signaling processing; additionally, data traffic is forwarded only between Mobile Function Routers (MFR). To support flow mobility and extending the functionality of network entities, we re-define it. First, MCF should have the following additional MN information: identifier, current location, IP address, service type, and Access Technology Type (ATT). MCF can utilizes this information to locate multi-interface devices and establish flow mobility policy. Second, MCF should store address of MN as well as flow information of MN. MRFs can upload and download information of MN because the MCF performs as a database. When MN attaches to the MFR, For example, MFR can ask MCF for previous information of MN. If the MFC has information, MFR can take it to maintain IP connectivity of MN. If the MCF has no information about the MN, it indicates that the MN is connecting to this network for the first time; the MCF commands the MRF to allocate an IP address and perform normal IP routing. Finally, MCF should make decision for flow mobility because that the MCF has all information of network. Mobility decision may be made by network status or policy of network operator. The details of decision methods are not discussed in this paper. Even though the MCF does not handle data forwarding, it may still have scalability issue and single point failure because that it is a single point which store information of all MNs in the network.

However, multiple MCFs can be easily deployed in the network to solve this problem. In multiple MCFs network, the MFR can update to the MFC where it is near to. Also, MCFs should share information between each other.

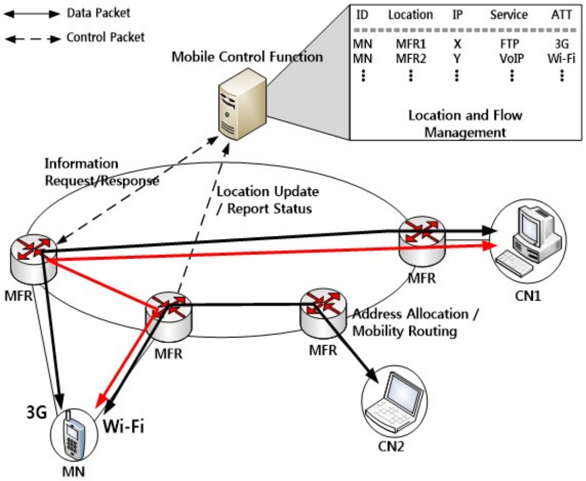


Figure 2: Distributed Architecture for Flow Mobility

3.2 Message Flow

Figure 3 illustrates message call flow for flow mobility. The handover procedure is initiated by making a decision about flow mobility at the MCF. In this scenario, we assume that the device supports multi-interface (e.g., 4G, Wi-Fi) and is able to utilize multiple interface simultaneously. When each interface connects to an MFR supporting its access technology, the MFR allocates an IP address and updates the MN's information on the MCF. Because the MCF is aware of the location and flow information of all devices in the network, it can make decisions to switch flows according to policy. Policy may be established by an operator or by analyzing real-time network status. In a scenario where flow A is switched from MFR1 to MFR2, MCF sends a flow request message to MFR2. When MFR2 receives the request packet from MCF, it transmits a Proxy Binding Update (PBU) message to MFR1. A PBU message is defined in PMIPv6 for binding addresses of mobile devices, and in this scheme, information about flow switching is added to the message. When MFR1 receives the PBU packet, MFR1 creates an IP tunnel for flow A with MFR2 and transmits a Proxy Binding Acknowledgement (PBA) message to MFR2. When the flow mobility procedure is complete, MFR2 transmits a flow response message to MCF for reporting.

4 Analysis

In this section, we compared performance of our proposed scheme with PMIP-based flow mobility. Our proposed scheme aims to reduce packet delivery costs in the networks with designing distributed architecture for flow mobility. Performance evaluation of DMM without flow mobility is already evaluated in [12], which analyzes the total cost required for the binding update and for data packet delivery from CN to MN. Utilizing this analysis method, we evaluated the performance of proposed flow mobility scheme. For analysis, we assume that both CN and MN are located within the same domain as illustrated in Figure 2. Table 1 displays the list of parameters defined for our analysis. Binding update cost and packet

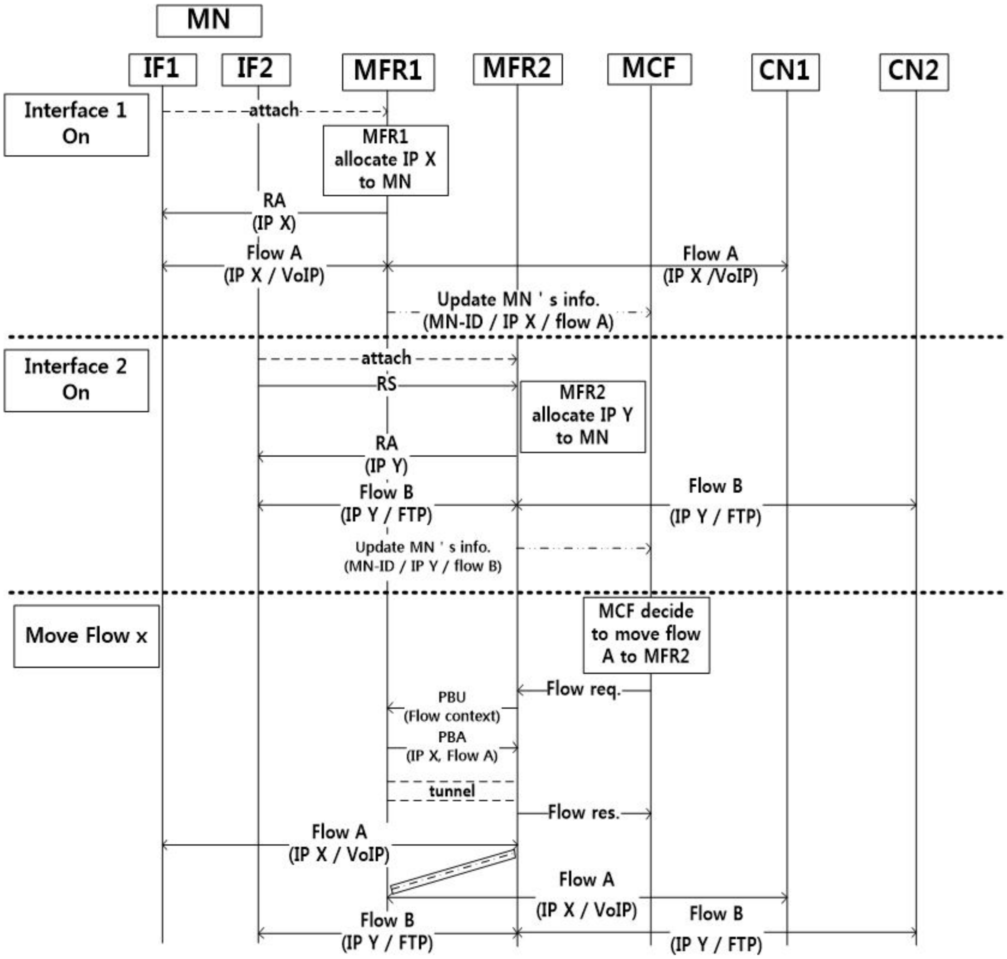


Figure 3: Message Flow

delivery cost are denoted by BUC and PDC. Total cost (TC) is represented as *TC = BUC + PDC*.

4.1 Cost Analysis

In this paper, we compare the existing flow mobility schemes based on PMIPv6 [1]. In PMIPv6-based flow mobility, data delivery cost is equivalent to the cost observed in the original PMIPv6 scheme. However, in the case of binding updates, costs differ depending on the mobility decision point. We choose LMA trigger procedure in [1] to compare with our scheme. Costs of this scheme can be represented as follows;

$$\begin{aligned} BUC_{PMIP} &= T_{setup} + S_{control} * 2T_{MAG-LMA} + P_{LMA} \\ &= T_{setup} + S_{control} * 2\tau H_{MAG-LMA} + \alpha log(N_{MAG} * N_{HOST/MAG}) \end{aligned}$$

$$\begin{aligned} PDC_{PMIP} &= S_{data}(T_{CN-MAG} + 2T_{MAG-LMA} + T_{MN-MAG}) + P_{LMA} \\ &= S_{data}(\gamma H_{CN-MAG} + 2\tau H_{MAG-LMA} + \gamma H_{MN-MAG}) + \beta log(N_{MAG} * N_{HOST/MAG}) \end{aligned}$$

Parameter	Description
T_{a-b}	Transmission cost of a packet between nodes *a* and *b*
P_c	Processing cost of node *c* for binding update or lookup
T_{setup}	Setup time of PMIP connection between MN and MFR
$N_{Host/MFR}$	Number of active hosts per MFR
N_{MAG}	Number of MAGs in the PMIP domain
H_{a-b}	Hop count between nodes *a* and *b* in network
$S_{control}$	Size of a control packet (in bytes)
S_{data}	Size of a data packet (in bytes)
α	Unit cost of binding update with MCF
β	Unit cost of lookup for MN at MFR
τ	Unit transmission cost of a packet per wired link (hops)
γ	Unit transmission cost of a packet per wireless link (hops)

Table 1: Parameters

In the proposed scheme, called distributed flow mobility, flow mobility procedures are initiated by transmitting flow request messages from an MCF, and terminated by flow response messages from an MFR. Binding update cost can be represented as follows;

$$BUC_{DFM} = (T_{setup} + S_{control} * 2T_{MFR-MFR} + P_{MFR}) + (S_{control} * 2T_{MCF-MFR})$$

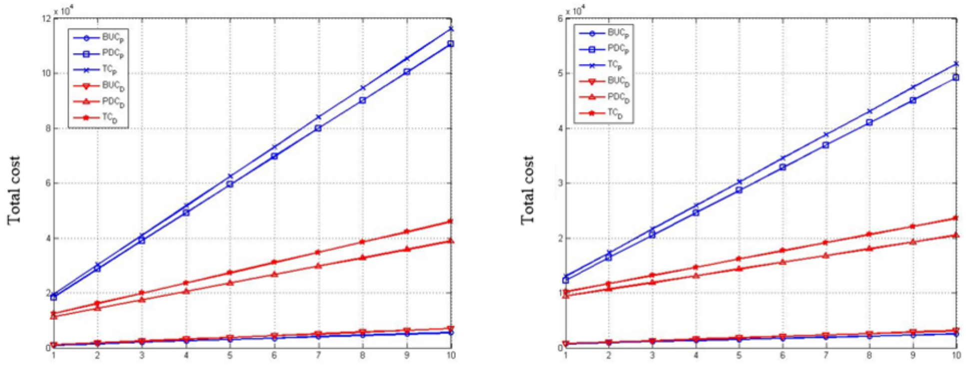
When supporting flow mobility, previous MFRs assume the role of LMA, because that flow moves between MFRs utilizing an IP tunnel. The packet delivery cost of the proposed scheme can be represented as follows;

$$\begin{aligned} PDC_{DFM} &= S_{data}(T_{CN-MFR} + 2T_{MFR-MFR} + T_{MN-MFR}) + P_{MFR} \\ &= S_{data}(\gamma H_{CN-MFR} + 2\tau H_{MFR-MFR} + \gamma H_{MN-MFR}) + \beta log(N_{HOST/MFR}) \end{aligned}$$

4.2 Numerical Results

For numerical analysis, parameter values referred to [12, 15]. Figure 4(a) illustrates the impact of unit transmission costs on total cost. Unit transmission cost is combined with wire and wireless link cost. Figure 4(a) illustrates that although BUC is almost equivalent, the PDC of the proposed scheme is favorable when compared to the PMIPv6-based scheme. This result occurs because the distributed scheme does not require packets to be forwarded through a centralized anchor; therefore, packets can be delivered over a shorter path compared to the centralized scheme. Similar BUCs are observed in Figure 4(a), because both schemes exchange PMIPv6 signaling messages for establishing the IP tunnel when devices perform flow mobility.

Figure 4(b) illustrates the impact of hop count on total cost. These figures demonstrate that our proposed scheme has a more expensive binding update cost than PMIPv6-based flow mobility scheme. However, the proposed scheme reduces packet delivery cost. In the PMIPv6 protocol, PBU messages must be forwarded from the entity where the flow will be switched. In the proposed scheme, MCF should request the MRF to transmit a PBU message utilizing an additional signaling message. This procedure results in greater costs for binding updates in distributed schemes. However, for PDC, there is a substantial gap between the two schemes, because the proposed scheme separates control and data. As a result, it is demonstrated that the proposed scheme delivers superior performance compared to the centralized scheme.



(a) Unit transmission cost over wired link

(b) Hop counts between MFR(MAG) and MCF(LMA)

Figure 4: Impact of (a) unit transmission costs (b) hop counts on total cost

5 Conclusion

In this paper, we propose a flow mobility scheme employing PMIPv6–based distributed mobility management architecture, utilizing detailed messages for flow mobility. In this scheme, device location and flow information are managed by a centralized control function, whereas data packets are forwarded by a distributed MFR. According to numerical analysis, it is demonstrated that the proposed scheme reduces packet delivery cost. Further, in future work, we will subsequently enhance this scheme to be more suitable for flat network and more dynamic. In future research and development, a control function will be designed in detail, and message format for additional signaling messages will be established.

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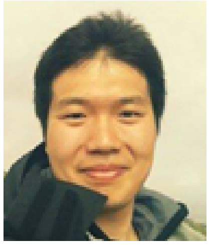

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