Mobility Management All-IP Core Network Standardization

Technology Reports

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Mobility Management for All-IP Core Network

PMIPv6 is a network-based IP mobility management protocol which is adopted in the 3GPP Release 8 SAE standardization. It allows mobile-terminal mobility management that is independent of the type of access system or terminal capabilities. NTT DOCOMO completed the standardization of PMIPv6 with the IETF and contributed proactively to its adoption in the standardization of SAE.

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1. Introduction

Proxy Mobile IPv6 (PMIPv6), which is an IP-based mobility management[*1] protocol actively promoted by NTT DOCOMO, was adopted in the Evolved Packet Core (EPC) specification, a provision in the 3GPP Release 8 System Architecture Evolution (SAE) standardization. PMIPv6 is a common mobility management approach that supports mobility of terminals not only within Long Term Evolution (LTE) radio access, but also spanning various other access systems including LTE radio access, 3G radio access, Wireless LAN (WLAN), WiMAX and radio access standards from the 3rd Generation Partnership Project 2 (3GPP2)[*2]. By specializing only on managing the transmission path for packets addressed to the IP address assigned to mobile terminals, PMIPv6 is able to achieve the efficient packet transfer required by an All-IP Network (AIPN)[*3], and flexible QoS[*4] and policy management[*5] through Policy and Charging Control (PCC) [1]. PMIPv6 also improves on utilization of wireless resources, handover performance, user privacy and network security compared to the previous IP mobility management protocol, Mobile IPv6 (MIPv6) [2].

NTT DOCOMO contributed proactively, since the Internet Engineering Task Force (IETF) Network-based Localized Mobility Management Working Group (NETLMM WG) was established in 2005 until completion of the PMIPv6 specification in May 2008. With the 3GPP [3], it secured prospects for finalizing the EPC architecture and standardizing PMIPv6 with the IETF, and it also completed 3GPP standardization work for PMIPv6 in the 3GPP Core Network & Terminals (CT) WG4.

In this article, we describe the IP mobility management requirements for the AIPN. We also review standardization activities with the IETF and 3GPP, describe the features of the PMIPv6 protocol and give an overview of its operation.

2. IP Mobility Management Requirements for Mobile Communications Operators

Since 2004, NTT DOCOMO actively proposed basic principles and

[*1] **Mobility management**: Management of terminals which provides transmission, reception and continuous communication even if terminals move.

[*2] **3GPP2**: A Third-Generation Mobile Communication System (3G) standardization project that is standardizing the cdma2000 technical specifications, which are part of the IMT-2000 specifications.

[*3] **AIPN**: A general term for the next generation core network which will use IP technology and accommodate various access systems.

requirements for an AIPN to the 3GPP Service & Systems Aspects (SA) WG1, with the goal of realizing a common core network independent of the radio access system [3][4]. In parallel with this, NTT DOCOMO also studied existing IP mobility management mechanisms to determine whether they meet mobile operator requirements as described below.

The first requirement for an AIPN is to accommodate a wide variety of IP-technology-based wired and radio access systems (3G, LTE, WLAN, WiMAX, etc.), allowing mobility between them. This is the key principle of an AIPN, and the fundamental requirement for mobility management.

The second requirement is that mobility management must achieve efficient packet transmission. An AIPN must be able to process huge volumes of IP packets with minimum transmission delay, in anticipation of the spread of rich communications[*6] services and the accompanying increase in IP-packet traffic.

The third requirement is that wireless resources must be used efficiently, to accommodate radio access. Wireless resources are shared by all users under the same radio access point so, to use them efficiently, transport overhead and mobility-management signaling must be minimized. Minimizing over-the-air signaling can also help reduce power consumption in mobile terminals.

The fourth requirement is that communication quality must remain high during handover, from a user-service perspective. Mobility management must be achieved seamlessly, so that users can perceive no interruption in communications while moving within and between different radio access systems.

Finally, mobility management must meet mobile-operator-level requirements for network security and user privacy, despite being IP-based. As an example, it is important to prevent leakage of network topology information[*7], in order to minimize potential security risks such as Distributed Denial of Service (DDoS) attacks[*8]. For user privacy, information related to the user's location, such as their IP addresses, must not be notified to the correspondent user or server without the user's permission.

3. Standardization Activities Related to IP Mobility Management

3.1 Standardization Activities at the IETF

Through our investigation of existing IP mobility management protocols based on the above requirements, we concluded it was necessary to create and standardize a new mobility management protocol to satisfying AIPN requirements. Thus, we began standardization work with the IETF, where IP protocol standards are created.

In January 2006, a number of leading telecommunications manufacturers and operators, including NTT DOCOMO, formed the NETLMM WG in the Internet Area of the IETF. The NETLMM WG was formed to specify a network-based mobility management protocol which required no involvement from the mobile terminal while allowing it to keep the same IP address when handed over from one access router to another. This basic concept was derived from requirements analysis and study by the initial members of the NETLMM WG.

The NETLMM WG first analyzed existing protocols [6], clarified the requirements [7], and prescribed the functions required for a network-based mobility management protocol as described above. A protocol design team including members from NTT DOCOMO was then formed to develop a protocol satisfying the agreed-upon objectives in the WG. The design team established a base protocol supporting the required functions. Then, taking into consideration the views of standardization organizations such as WiMAX and 3GPP2 that compatibility with MIPv6 was necessary, the NETLMM WG created a PMIPv6 specification [8] implementing the required base-protocol functions as an extension to MIPv6. This was based on the basic IETF policy that protocols implementing AIPN must be unified.

After standardization with the IETF, various functional extensions to the PMIPv6 protocol have been studied

[*4] **QoS**: A level of quality on the network that can be set for each service. The amount of delay or packet loss is controlled by controlling the bandwidth used.

[*5] **Policy management**: Technology for managing communications, such as QoS or packet transmission permissions, based on network and subscriber information.

[*6] **Rich communication**: A new form of communication merging individual forms of communication such as voice, messaging and video sharing.

[*7] **Network topology information**: Information related to network architecture such as IP addresses.

and standardized, such as support for IPv4 [9], Generic Routing Encapsulation (GRE)[*9] [10], and Heartbeat Mechanism[*10] [11].

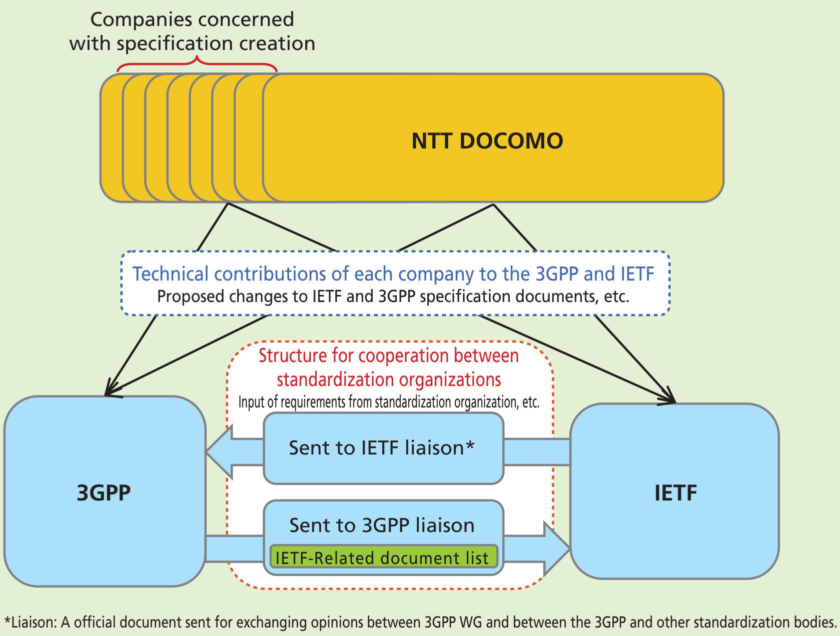
3.2 Cooperation between IETF and 3GPP

The standardization activities for PMIPv6 at the IETF and 3GPP have been achieved not only through cooperation between the two organizations, but also with continuous contributions from member companies in both organizations, as shown in **Figure 1**.

NTT DOCOMO made many contributions to completing the PMIPv6 specifications, with technical contributions to the IETF and 3GPP, as the specification document rapporteur for the 3GPP, providing leadership by summarizing discussion and guiding completion of related specifications, and by holding preliminary telephone conferences.

Furthermore, synergy of NTT DOCOMO's and other participating companies' activities with the IETF and 3GPP enabled the completion of PMIPv6 protocol and related specifications at the IETF, adoption of PMIPv6 in the 3GPP EPC architecture [12], and completion of PMIPv6 specifications in the CT WG4 [13], including extensions particular to 3GPP, all within the deadline for 3GPP Release 8.

This has been an excellent example of several different standardization organizations cooperating and succeeding in development of an open, industry-standard protocol and an architecture based upon the protocol.


Companies concerned with specification creation
NTT DOCOMO
Technical contributions of each company to the 3GPP and IETF
Proposed changes to IETF and 3GPP specification documents, etc.
Structure for cooperation between standardization organizations
Input of requirements from standardization organization, etc.
Sent to IETF liaison*
Sent to 3GPP liaison
IETF-Related document list
3GPP
IETF

*Liaison: A official document sent for exchanging opinions between 3GPP WG and between the 3GPP and other standardization bodies.

Figure 1 Relationships between the IETF, 3GPP and related companies for standardization work

4. Overview of the Latest PMIPv6 Technology

An overview of the PMIPv6 mobility management protocol is shown in **Figure 2**. PMIPv6 establishes and releases a tunnel for transporting user data between a Local Mobility Anchor (LMA) and Mobility Access Gateway (MAG). The LMA provides an anchor function[*11] for mobility management and transports packets to the MAG, to which the terminal is connected. In other words, in a PMIPv6 IP network, there are multiple MAG nodes but only one LMA for a given mobile terminal's connection.

MAG nodes provide the mobility agent function[*12] for mobility management, managing mobility of the mobile terminal with respect to the LMA and establishing and releasing a user-data transport tunnel for the IP address allocated by the Packet Data Network (PDN)[*13]. When the mobile terminal connects to a different MAG, the MAG establishes a new user-data transport tunnel with the same LMA as the previous user-data transport tunnel.

The user-data transport tunnel is provided through GRE [10] (GRE tunneling) as described above, so that IPv4 and IPv6 user packets can be transported over either IPv4 or IPv6 networks.

[*8] **DDoS attack**: A method of attack in which multiple terminals simultaneously launch an attack on the equipment providing a specific service, such as a Web server, causing the service to stop.

[*9] **GRE**: A mechanism for encapsulating and transporting packets of an arbitrary protocol over IP.

[*10] **Heartbeat Mechanism**: A mechanism which checks whether the communications counterpart device or application is operating correctly.

[*11] **Anchor function**: A function which switches the communications path according to the area where the terminal is located, and transports packets for the terminal to that area.

With the GRE tunnel, both the LMA and MAG attach a pre-issued and exchanged GRE key to the header information when transporting user-data. This allows the required processing to be done, such as determining the PDN of a destination when the LMA receives a packet addressed to a counterpart from the mobile terminal.

In EPC, mobility management for all user data transport interfaces (S5, S8, S2a and S2b) in the core network is provided by PMIPv6 (**Figure 3**).

In contrast to the General Packet Radio System Tunneling Protocol (GTP), the tunneling protocol for GPRS, PMIPv6 functions only manage mobility, and policy management such as QoS and billing are implemented through other EPC equipments and interfaces. The fact that mobility management is independent of other functions is an important feature of PMIPv6-based EPC. This mechanism not only simplifies mobility management, it allows maximum use of flexibility and extensibility in the policy management and billing infrastructure. Please refer to [14] for more detail.

An overview of the operation of PMIPv6 is shown in **Figure 4**, using four basic EPC procedures.

1) Establish a PDN Connection

Establishes a GRE tunnel between the LMA (PDN Gateway (P-GW)[*14]) and the MAG (Serving Gateway (S-GW)[*15]#1), enabling transmission of IPv6 packets to and from the mobile terminal. At this point, no IPv4 address is allocated to the mobile terminal.

2) Allocate an Additional IPv4 Address

An IPv4 address is allocated to the mobile terminal, enabling packet communication using either the IPv4 or IPv6 address.

3) Handover between MAGs

A GRE tunnel is created between the LMA (P-GW) and the new MAG (S-GW_#2), enabling packet communication over the new path. The same IP addresses are used before and after the

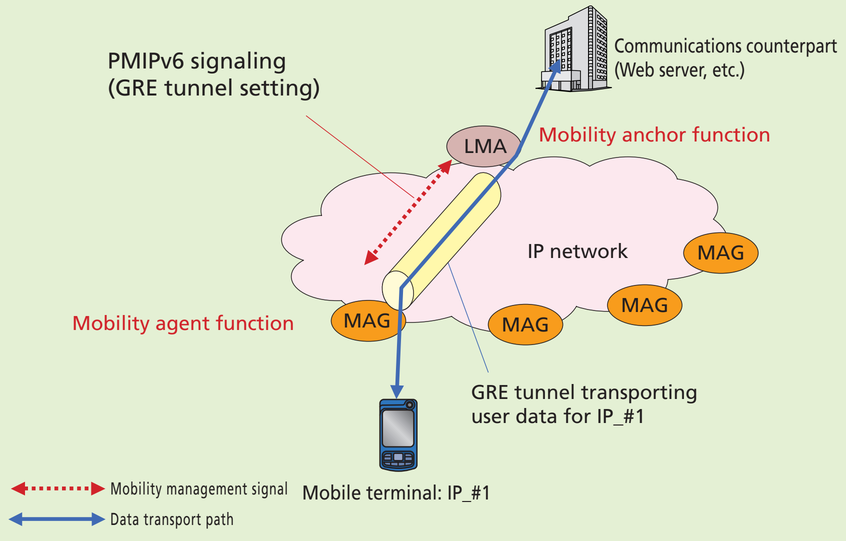


Figure 2 Overview of the PMIPv6 protocol

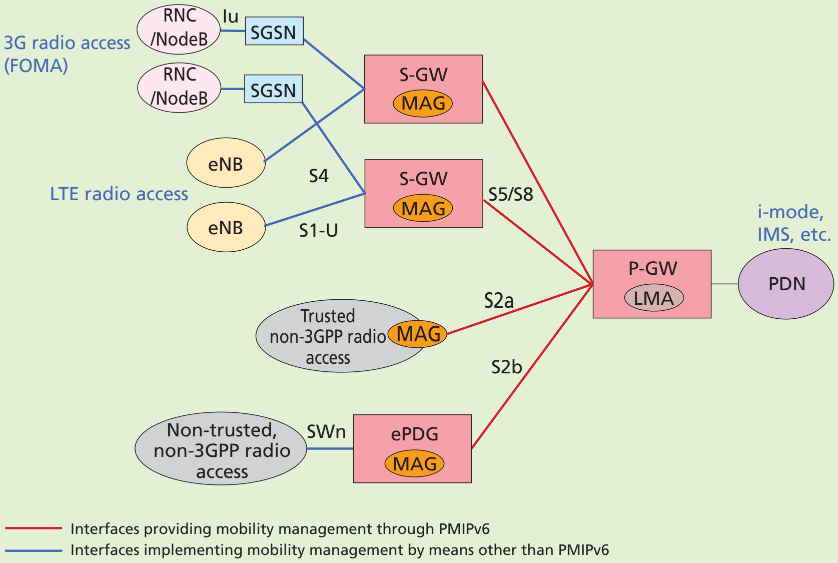


Figure 3 PMIPv6 protocol application interface for the EPC architecture

[*12] **Agent function**: Notifies the mobility anchor of changes in the location of the mobile terminal on behalf of the terminal.

[*13] **PDN**: A packet network such as IMS.

[*14] **P-GW**: A gateway acting as a point of connection to a PDN, allocating IP addresses and transporting packets to the S-GW (see *15).

[*15] **S-GW**: The area packet gateway accommodating the 3GPP access system.

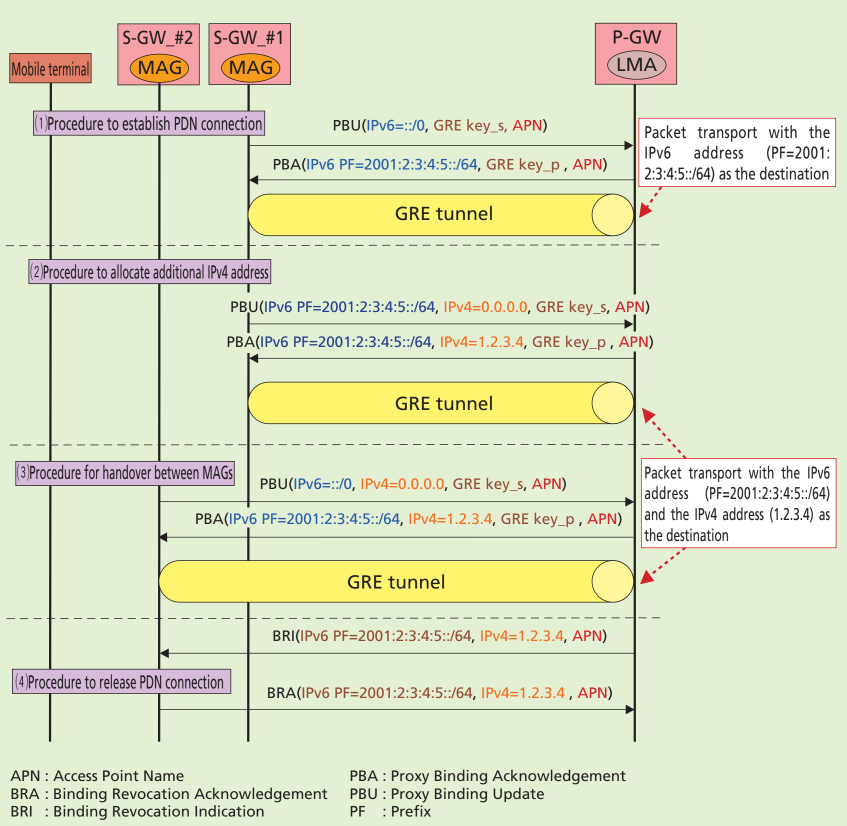

Mobile terminal
S-GW_#2
MAG
S-GW_#1
MAG
P-GW
LMA
(1) Procedure to establish PDN connection
PBU(IPv6=::/0, GRE key_s, APN)
PBA(IPv6 PF=2001:2:3:4:5::/64, GRE key_p , APN)
Packet transport with the IPv6 address (PF=2001:2:3:4:5::/64) as the destination
GRE tunnel
(2) Procedure to allocate additional IPv4 address
PBU(IPv6 PF=2001:2:3:4:5::/64, IPv4=0.0.0.0, GRE key_s, APN)
PBA(IPv6 PF=2001:2:3:4:5::/64, IPv4=1.2.3.4, GRE key_p , APN)
GRE tunnel
(3) Procedure for handover between MAGs
PBU(IPv6=::/0, IPv4=0.0.0.0, GRE key_s, APN)
PBA(IPv6 PF=2001:2:3:4:5::/64, IPv4=1.2.3.4, GRE key_p , APN)
Packet transport with the IPv6 address (PF=2001:2:3:4:5::/64) and the IPv4 address (1.2.3.4) as the destination
GRE tunnel
BRI(IPv6 PF=2001:2:3:4:5::/64, IPv4=1.2.3.4, APN)
(4) Procedure to release PDN connection
BRA(IPv6 PF=2001:2:3:4:5::/64, IPv4=1.2.3.4 , APN)
APN : Access Point Name
BRA : Binding Revocation Acknowledgement
BRI : Binding Revocation Indication
PBA : Proxy Binding Acknowledgement
PBU : Proxy Binding Update
PF : Prefix

Figure 4 Basic processing sequence for the PMIPv6 protocol

handover.

4) Release a PDN Connection

Initiated by the network, the IP connection established with the PDN network is released.

The following procedures are also provided, besides those shown in Fig. 4.

- Release a PDN connection initiated by the mobile terminal
- Extend the expiration of a PDN connection
- Release an IPv4 address

These example procedures have assumed a connection to a single PDN, but the MAG is able to independently manage GRE tunnels for each of the PDNs to which the mobile terminal connects. Because of this, the same management can be achieved per PDN even when the mobile terminal connects to multiple PDNs simultaneously.

Also, by using 3GPP-specific identifiers allocated by the IETF in the PMIPv6 protocol, extensions for the following functions specifically required by the 3GPP can be implemented independently of the IETF [15].

- A function for transporting PDN connection-configuration parameters exchanged by the mobile terminal and P-GW between the S-GW and the P-GW.
- Notification of 3GPP specific error codes.
- A function for transporting billing identifiers between S-GW and P-GW.

These 3GPP protocol extensions were done independently of the IETF in this way because it is IETF policy that extensions for environments that are not closely related to the IETF must be standardized outside of the IETF.

5. Conclusion

In this article, we have described the protocol requirements for AIPNs in relation to PMIPv6, which is an IP-based mobility management protocol adopted in the 3GPP EPC standard specifications. We have also described related standardization activities with the IETF and 3GPP, in which NTT DOCOMO took a proactive leadership role. We have also provided an overview explanation of the features and process of the PMIPv6 protocol.

PMIPv6 is a network-based IP mobility management protocol satisfying the requirements for mobile communications networks. It is adopted not only in EPC, but also in other mobile communications network specifications aimed at AIPNs, such as WiMAX and 3GPP2.

EPC manages mobility based on PMIPv6 and manages QoS separately from mobility management. This approach is very compatible with Next Generation Networks (NGN)*16, so a very promising possibility for the future is to consolidate the core network as an AIPN based on EPC. Discussion of international roaming using PMIPv6 has also begun, including study of interworking with existing GTP networks*17.

Further extensions to PMIPv6 functionality are also being studied at the IETF, and there are plans to standardize functions such as bundled cancellation of LMA-MAG sessions, LMA switching, and user-data transport tunnel path optimization in the future.

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*16 **NGN**: Next-generation telecommunication networks that will provide the flexibility and economy of IP networks, while maintaining the stability and reliability of the conventional telephone network.

*17 **GTP network**: A network performing packet transmission using GTP.