# (2) IP² Transport Network Technologies

*Akira Miura, Noriteru Shinagawa,*
*Takatoshi Okagawa and Manhee Jo*

*This article describes the requirements for mobile carriers with respect to transport network technologies in the next-generation mobile communication network. It also reviews the two kinds of separation concepts included in the network.*

## 1. Introduction

NTT DoCoMo launched the Freedom Of Mobile multimedia Access (FOMA) service, offering various services utilizing the high speed data communication of mobile terminals in a wireless environment and the advanced functions of the network. Research on next-generation mobile communication networks based on the Internet Protocol (IP) is gaining momentum worldwide. Network Laboratories proposes the IP-based IMT network Platform ($IP^2$) [1] as the new architecture for the future, with the aim to fulfill large-capacity, low-cost and ubiquitous communications, and conducts research on various elemental technologies. $IP^2$ is distinctive in that it has a three-layered structure in order to: ① support devices ranging from sophisticated PCs and Personal Digital Assistants (PDAs) to wireless tags, sensors and other various types of limited-functionality devices; ② provide sophisticated mobility control; ③ accommodate more than one wireless access system in the common platform; and ④ provide seamless & ubiquitous services [2] (refer to this special article "(1) $IP^2$ Network Architecture").

This article extracts the requirements of $IP^2$ transport networks from the mobile carrier's point of view and reviews the technologies that are currently subject to research to satisfy these requirements.

## 2. $IP^2$ Transport Networks Requirements

IP-based networks are strong candidates as transport networks in the next-generation mobile communication system, considering cost reduction based on the convergence with services over the Internet and the application of a generic IP-based platform. A lot of research has been conducted recently on IP mobility [3] to offer mobility over the Internet.

This section shows the issues associated with the IP mobility based on the Internet architecture from the viewpoint of the user and the network design concept, and discusses the requirements for transport networks from the mobile carrier's standpoint in five aspects.

### 2.1 Adopting a Highly Extensible and Flexible Network Architecture (1st Requirement)

Under the current IP-mobility technology called Mobile IP, the specifications for IPv4 are different from those of IPv6. This means that if it is necessary to extend the transport networks from IPv4 to IPv6 in the mobile communication environment, it is also necessary to modify all the way up to the mobility mechanisms. Moreover, routers, which execute routing and forwarding of IP packets, need to support many types of protocols as various protocols are proposed for micro-mobility, which supports high-speed handover. Furthermore, it is believed that the concept of "IP over everything", that is, to process IP packets based on various transport technologies (ATM or Asynchronous Transfer Mode, optical router, etc) will further evolve in the future. Moreover, support functions to promote the creation of new services, efficient mobility control functions and Quality of Service (QoS) control functions for high-quality communications are required, and are likely to evolve independently of packet transport network functions.

In order to allow flexible modifications to the network configuration in the future, it is necessary to adopt a new network control mechanism including mobility control as well as a flexible network architecture that can ensure the independent evolution and replacement of transport networks.

### 2.2 Affordable and Fast Transport Networks (2nd Requirement)

The router is required to process many protocols as the network becomes more intelligent in terms of QoS control and mobility control. Additionally, as the types of protocols increase, ensuring interconnectivity between networks becomes a major problem as well. Routers used to be relatively cheap to implement as they were merely required to have simple functions such as routing and forwarding processing. However, more dedicated processors have to be installed if more types of protocols need to be supported due to the heavier processing load involved in protocol processing. Also, the processing load involved in resources management inside the router might increase and have an impact on its core transport functions.

Therefore, transport network functions must have a structure as simple (generic) as possible and enable fast packet processing while making the network more sophisticated.

### 2.3 Highly Secure Network Control (3rd Requirement)

Conventional IP networks are marred by security problems in that they are prone to attacks from malicious users, because an end terminal can learn about the address of a specific node in the network. In Mobile IP, the mobile terminal directly executes location registration with the Home Agent (HA), which acts as a location information management server. Therefore, it needs to inform the mobile terminal of the HA's address. As the HA has the vital function to manage the location information of mobile terminal and execute packet forwarding, no one other than the network as well as to administrator should be able to easily learn about the HA's address for security reasons.

In a mobile communication network, the address of important nodes in the network in charge of network control such as mobility control and QoS control needs to be concealed from end users and third parties. Also, the structure of the network must be concealed to avoid attacks against the network as a result of someone learning about the structure of the network.

### 2.4 Ensuring Location Privacy (4th Requirement)

The current Mobile IP informs the Correspondent Node (CN) of the Care of Address (CoA) containing the location information of the mobile terminal for the purpose of optimizing the packet propagation path in the network. Moreover, the location information of the mobile terminal in subnet units is divulged to CN as CoA is used as the source address of packets from the mobile terminal to CN. As such, Mobile IP fails to guarantee location privacy.

Since location information is an important subject of privacy to the user in mobile communication networks, it is necessary to provide a framework that does not disclose the location information of the mobile terminal to the destination or third parties.

### 2.5 Effective Use of Network Resources (5th Requirement)

Under mobile IPv6, packets are propagated from CN to the mobile terminal being encapsulated, which gives rise to redundancy due to header overhead. Moreover, even packets from CN are propagated directly to the mobile terminal without taking a triangular path via HA by using CoA and the route optimization mechanism, CN is not always expected to hold this CoA of the mobile terminal as cached information. Thus, it is often the case that packet propagation is executed based on a triangular path via HA. In such cases, packets are transferred along a redundant path, which involves the unnecessary use of network resources. Even if the path is optimized, the problem is that the overheads of the packets increase due to the use of the IPv6 optional header. Furthermore, considering that resources are scarcer in the wireless link than in the wired link, the overheads of packets should be reduced for the sake of wireless link in terms of the effective use of resources.

In next-generation mobile communication networks, IP traffic is likely to increase dramatically. Therefore, it will be important to effectively use network resources by supporting route optimization and reducing overheads.

## 3. IP$^2$ Transport Technologies Overview

This chapter reviews the transport network technologies in concrete terms, to satisfy the requirements for transport networks mentioned in Chapter 2.

### 3.1 Network Configuration Method based on Separation of NCPF and IP-BB

Processes of the router constituting a transport network can be divided into processes for network control and per-packet processes. Currently, these processes are performed in a router with respect to each control, leading to a high degree of redundancy. In order to fulfill the first and second requirements, IP$^2$ proposes an architecture model that separates the Network Control Platform (NCPF), which is in charge of sophisticated control, and the IP Backbone (IP-BB), which concentrates on packet forwarding and various per-packet processes, such that IP-BB does not depend on NCPF [4]. **Figure 1** shows the network configuration based on the separation of NCPF and IP-BB.

The router installed in IP-BB has only generic and simple packet processing functions (such as copying, filtering, header conversion, encapsulation, re-routing, composition/selection and buffering), and concentrates on fast packet forwarding. Since these functions are simple, fast processing can be achieved by implementing them by the hardware.

NCPF provides a complex control mechanism required for mobile communications network control, such as mobility management, QoS control and session/call control. These functions are implemented by giving instructions to the routers using generic primitives (the basic elements of control messages) and by combining generic functions mounted in the router.

These generic processing functions mounted in a router are also used for implementing various controls. For example, the re-routing function can also be used during call transfer upon handover control and call control. The copy function can commonly be used during downlink transfer concerning multicast and soft handover. Furthermore, a flexible network model for independent evolution and replacement of the entire layer can be provided by ensuring the independence between NCPF and IP-BB layers just through a common interface.

### 3.2 IP Host Address and IP Routing Address Separation

Mobile communication networks must provide an environment in which communication can be sustained while a terminal is in motion. As current IP network is designed based on non-mobile terminals, the IP address is used not only as an identifier of the terminal but also as an identifier of the physical location of the terminal. This means that communication is cut off and cannot be sustained if the IP address changes due to movement.

Mobile IP was proposed as solution to this problem, to support the terminal's mobility. However, Mobile IP is marred by a number of problems, as pointed out in Chapter 2.

In order to satisfy the third, fourth and fifth requirements, the IP address for identifying a mobile terminal and the IP address for routing packets inside the network are separated into the IP-host address (IPha) and the IP-routing address (IPra), respectively. We proposed a mechanism for converting IPha and IPra at an Access Router (AR) of the network in [5] and [6].

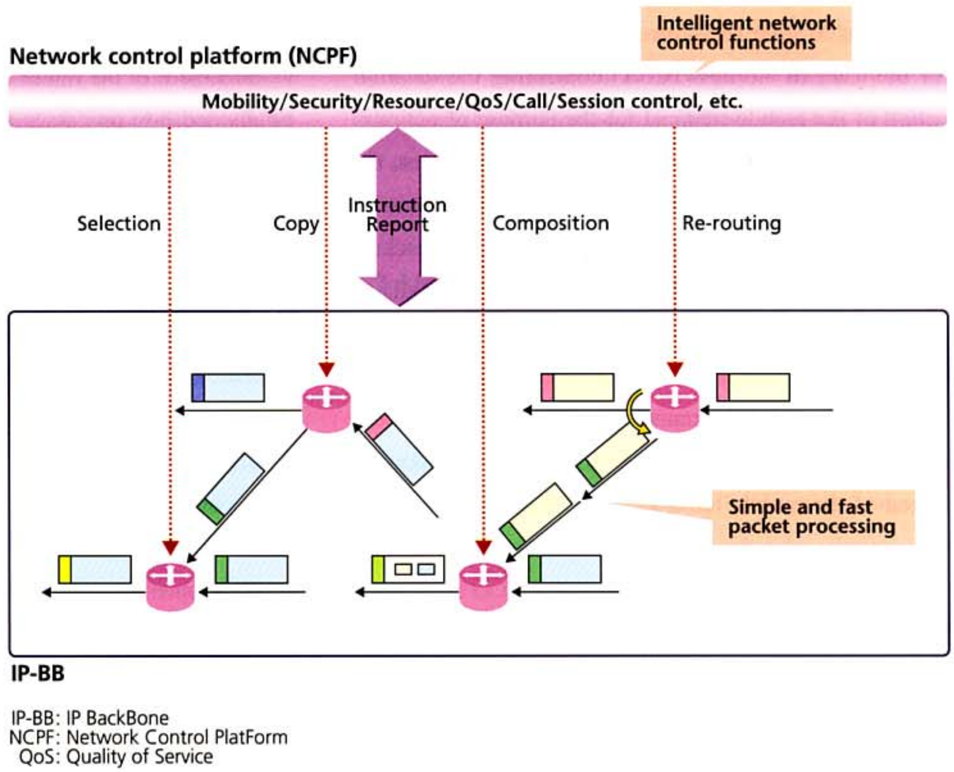



**Figure 1 Network Configuration based on NCPF/IP-BB Separation**

**Figure 2** shows the basic packet routing procedures in which IPha and IPra are separated. In $IP^2$, Mobility Management (MM) is one of NCPF function, as shown in the figure. MM consists of the Location Manager (LM), which manages location information of the mobile terminal and executes paging; and the Routing Manager (RM), which executes packet routing and handover control. IP-BB consists of ARs and the relay routers. For simplicity, this article assumes that an AR has the base-station function. Also, a globally unique IPha of 128-bit length is allocated to a mobile terminal for identification of the terminal.

The following is an explanation of the procedures from the activation of MT#M to the routing of packets to MT#C.

(1) MT#M in the area served by AR1 receives an advertisement from AR1, and then executes activation. (①, ②).

(2) AR1 receives an activation request from MT#M. Then, it assigns IPra to MT#M and registers IPra at RM in NCPF. After receiving Ack (acknowledge) from RM, it creates an entry in Table for Receiving Packet (TRP) for MT#M regarding the relationship between IPha and IPra (③, ④).

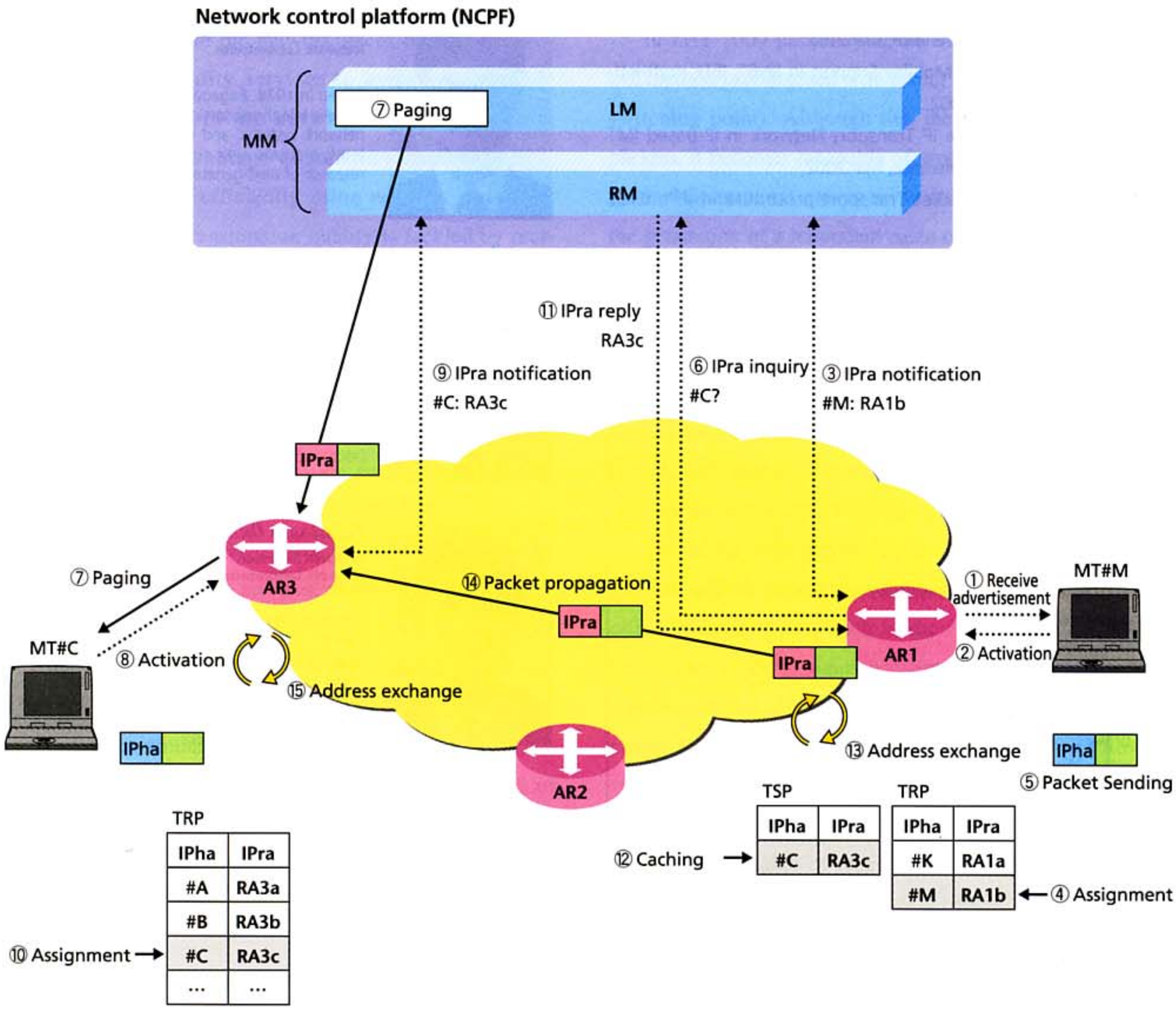
(3) MT#M sends packets to IPha of MT#C. AR1 temporarily buffers the received packets to convert their destination address from IPha into IPra, and inquires RM about IPra of MT#C (⑤, ⑥).

(4) After confirming that MT#M is inactive, RM makes a paging request to LM, and LM executes paging with respect to MT#C (⑦).

(5) After paging, IPra for MT#C is assigned by AR3, and IPra for MT#C is notified to AR1 via RM. Subsequently, an entry of the Table for Sending Packet (TSP) is generated inside AR1 for packet transmission (⑧～⑫).

(6) AR1 makes reference to TSP and converts the address of the received packets from IPha into IPra. The packets are routed to AR3 based on the IPra for MT#C. AR3 makes reference to TRP and reconverts them from IPra into IPha. The packets of IPha are routed to MT#C (⑬～⑮).

As explained above, $IP^2$ solves IPra for transfer based on the liaising of AR at the transmitting end with RM up to AR at the receiving end to which the mobile terminal is connected at the beginning of packet forwarding, so that the packets are always transferred along the optimal path. It also enables efficient packet forwarding by implementing address conversion rather than packet header encapsulation. Moreover, the user's location privacy can be protected because the mobile terminal always uses only IPha, and IPra including the location information is




IPha: IP-host address
IPra: IP-routing address
LM: Location Manager (Call state management)
MM: Mobility Management (Mobility management function)
MT: Mobile Terminal
NCPF: Network Control PlatForm
QoS: Quality of Service
RA: Routing Area
RM: Routing Manager
TRP: Table for Receiving Packet
TSP: Table for Sending Packet

**Figure 2 Basic Packet Routing Procedures using IPha and IPra**

concealed within the network. Furthermore, this method conceals the MM mechanism in the network from mobile terminals, meaning that no one will know about the address of network control devices. The third, fourth and fifth requirements in Chapter 2 can be fulfilled simultaneously thereby.

## 4. Conclusion

This article defines the requirements with respect to IP-BB from the mobile carrier's point of view, and reviews our research topics on transport networks to meet those requirements. Specifically, a flexible and intelligent mobile network can be configured by separating network control functions from transport network functions into different layers. Thereby, it is expected that a simple and fast packet transport network will be achieved. It is also expected that location privacy will be protected, network resources will be effectively used, and highly secure network control will be provided by means of IPha and IPra separation, and address conversion at the access router.

In the future, we will verify the scalability and the feasibility of the $IP^2$ separation architecture.

## REFERENCES

[1] H.Yumiba, K.Imai, and M.Yabusaki, "IP-Based IMT Network Platform," IEEE Personal Communication Magazine, Oct.2001.

[2] T.Ihara, et al, "Mobility/Transport Design Philosophy in IP-based IMT Platform," IEICE Society Conference, Mar.2002.

[3] David B. Johnson, et al, "Mobility Support in IPv6", IETF draft-ietf-mobileip-ipv6-18.txt, Jun.2002.

[4] T.Okagawa, et al, "Active IP Transport Network in IP-based IMT Platform", IEICE Society Conference, Mar.2002.

[5] T.Okagawa, et al, "IP Packet Transport procedure in $IP^2$", IEICE Conference, Sep.2002.

[6] Nishida, et al: Proposal of Packet Transport Methods for IP-host Address and IP-routing Address Separation Model in IP-based IMT Network Platform, Technical Report of IEICE, NS2002-109 pp.105-110, Sep. 2002.


## GLOSSARY

AR: Access Router
ATM: Asynchronous Transfer Mode
CN: Correspondent Node
CoA: Care of Address
FOMA: Freedom Of Mobile multimedia Access
HA: Home Agent
IP: Internet Protocol
$IP^2$: IP-based IMT network Platform
IPha: IP-host address
IPra: IP-routing address
IP-BB: IP BackBone
LM: Location Manager (Call state management)
MM: Mobility Management (Mobility management function)
MT: Mobile Terminal
NCPF: Network Control PlatForm
PDA: Personal Digital Assistant
QoS: Quality of Service
RA: Routing Area
RM: Routing Manager
TRP: Table for Receiving Packet
TSP: Table for Sending Packet