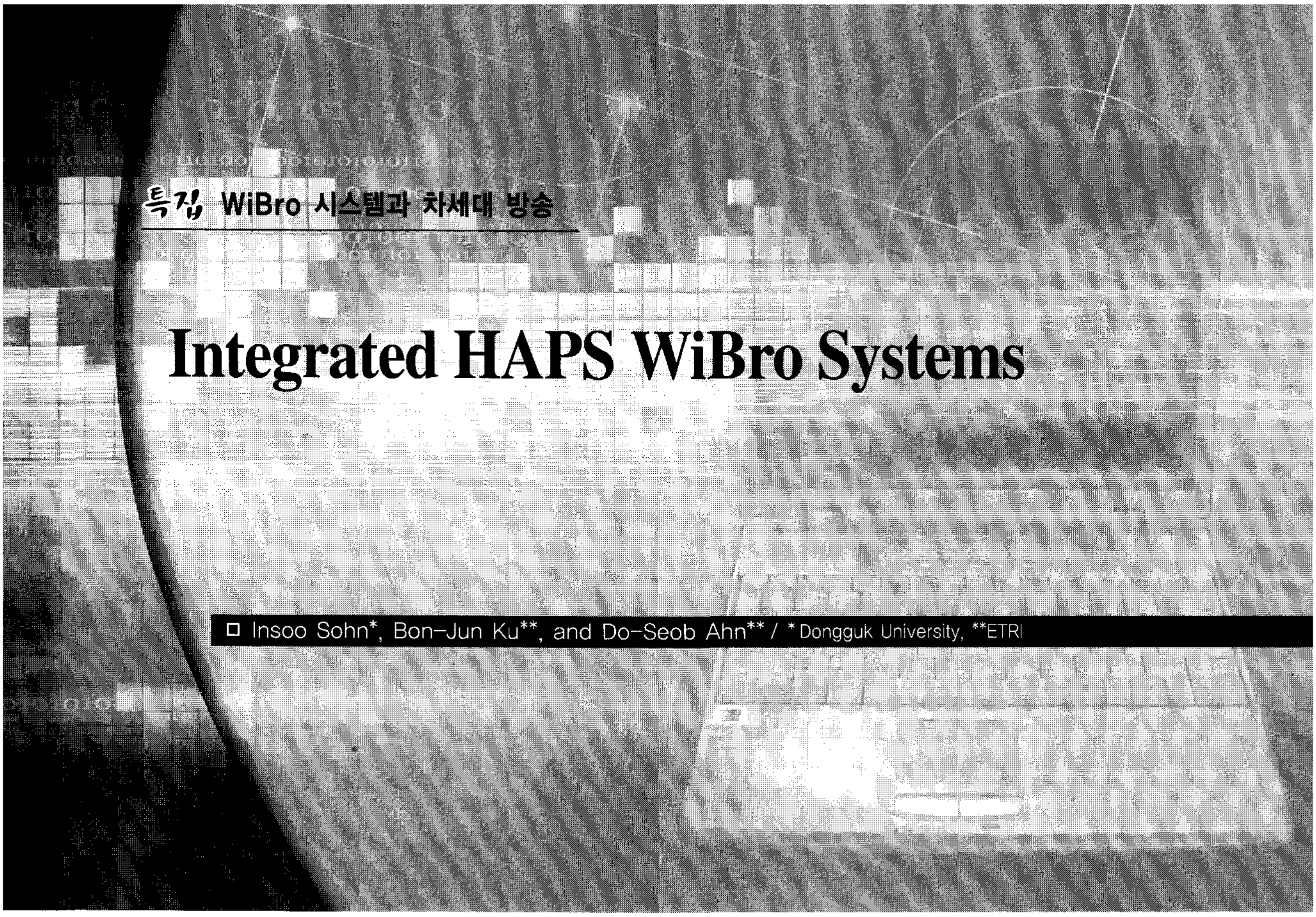

Integrated HAPS WiBro Systems

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I. Introduction

In realizing the next generation broadband multimedia wireless services, High Altitude Platform Station (HAPS) is recently being recognized as a key component in complementing the terrestrial infrastructure to provide a truly total coverage services. HAPS is a quasi-stationary aerial platforms operating in the stratosphere located 17-22 km above the Earth's surface providing services such as remote sensing, earth monitoring, positioning and navigation, homeland security, meteorological measurements, traffic monitoring and control, and various telecommunication services. The integration of the HAPS and the terrestrial wireless broadband system is possible due to HAPS' capability to cover remote and sparsely populated areas using considerably less ground infrastructure compared to the conventional terrestrial systems or satellite systems.

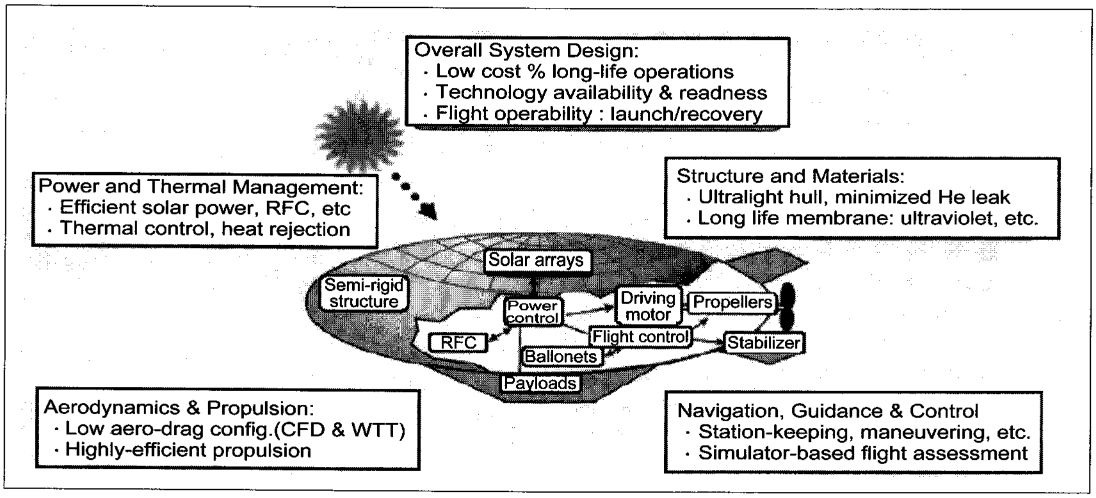
WiBro or Mobile WiMAX is a new wireless internet service using 2.3GHz frequency band providing high data rate wireless internet service with data rate over 1 Mbps. The WiBro service providers are scheduled to start the commercial WiBro services in June of 2006 providing world's first truly high speed mobile broadband internet services. Furthermore, by harmonizing the WiBro technology with IEEE 802.16e (Mobile WiMAX) technology, WiBro has become a global platform for the future mobile wireless broadband internet services. However, to provide the truly "anytime and anywhere" total solution services by WiBro, HAPS' capability to cover remote and sparsely populated areas with flexibility and low cost will be required.

In this article, we provide general description of the HAPS technology and recent research activities and study various HAPS WiBro integration architectures that combine the advantages of both HAPS and WiBro technologies.

II. HAPS System

1. Key Technologies

In 1997, the International Telecommunication Union (ITU) World Radio Conference (WRC) allocated 47.2~47.5 GHz and 47.9~48.2 GHz frequency band for HAPS services. Furthermore, at WRC-2000 held in the year 2000, it was decided that HAPS can be deployed for IMT-2000 services using 1885~1980 MHz, 2010~2025 MHz, 2110~2170 MHz for Europe and Asia (Region 1 & 3) and using 1885~1980 MHz, 2110~2160 MHz for America (Region 2). There are three major types of aerial vehicles that can be used for HAPS systems. The first aerial vehicle is the unmanned airships with length of 150~250 m, weight of around 1 ton, and propulsion system to stay in the stratosphere over five years. The second vehicle is unmanned aircraft or High Altitude Long Endurance (HALE) platforms with average fight duration of six months. The last type of aerial vehicle is the manned aircraft with average flight duration of several hours. In this article, we will consider using the airship as the aerial vehicle to develop the WiBro HAPS system. As shown in Fig. 1, the major technologies of the HAPS airships are



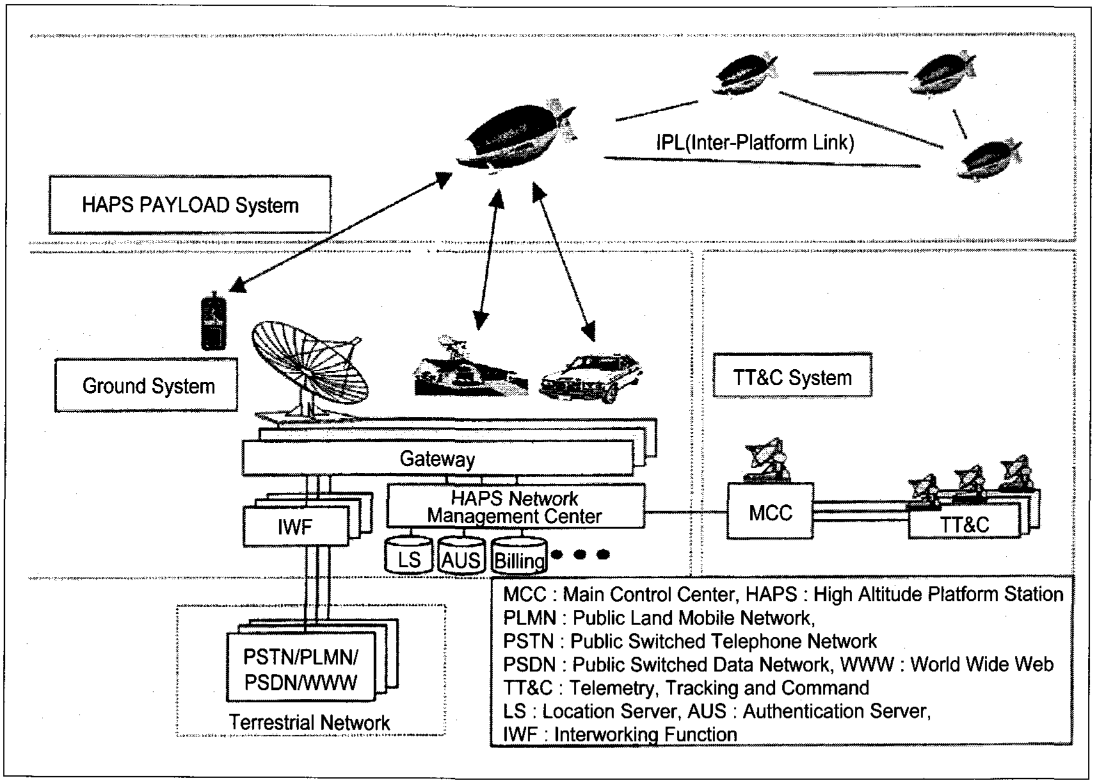
〈Figure 1〉 HAPS Airship Technologies

- Structure and material technology
- Navigation, guidance, and control technology
- Aerodynamics and propulsion technology
- Power and thermal management
- Overall system design technology

The general architecture of the HAPS systems is shown in Fig. 2 showing the three major sub-

⟨Table 1⟩ Terrestrial Wireless System, Satellite System, and HAPS System Properties

Issue	Terrestrial wireless	Satellite	High Altitude Platform
Availability and cost of mobile terminals	Huge cellular/PCS market drives high volumes resulting in small, low-cost, low-power units	Specialized, more stringent requirements lead to expensive bulky terminals with short battery life	Terrestrial terminals applicable
Propagation delay	Low	Causes noticeable impairment in voice communications in GEO	Low
System growth	Cell-splitting to add capacity requiring system reengineering; easy equipment upgrade/repair,	System capacity increased only by adding satellites; hardware upgrade only with replacement of satellites	Capacity increase through spot-beam resizing, and additional platforms; equipment upgrades relatively easy
Operational complexity and cost	Well-understood	High for GEOs, and especially LEOs due to continual launches to replace old or failed satellites	Some proposals require frequent landings of platforms (to refuel or to rest pilots)
Radio channel "quality"	Rayleigh fading limits distance and data rate, path loss up to 50 dB/decade; good signal quality through proper antenna placement	Free-space-like channel with Ricean fading; path loss roughly 20 dB/decade; GEO distance limits spectrum efficiency	Free-space-like channel at distances comparable to terrestrial
Indoor coverage	Substantial coverage achieved	Generally not available	Substantial coverage possible
Breadth of geographical coverage	A few kilometers per base station	Large regions in GEO (up to the 34% of the earth surface); global for LEO and MEO	Hundreds of kilometers per platform (up to 200km)
Cell diameter	0.1-1 km	50km in the case of LEOs. More than 400km for GEOs	1-10 km
Shadowing from terrain	Causes gaps in coverage; requires additional equipment	Problem only at low elevation angles	Similar to satellite
Communications and power infra-structure; real estate	Numerous base stations to be sited, powered, and linked by cables or microwaves	Single gateway collects traffic from a large area	Comparable to satellite
Esthetic issues and health concerns with towers and antennas	Many sites required for coverage and capacity;	Earth stations located away from populated areas	Similar to satellite
Cost	Varies	More then $200 million for a GEO system. Some billion for a LEO system	Less than the cost required to deploy a terrestrial network with many base stations



〈Figure 2〉 HAPS System Architecture

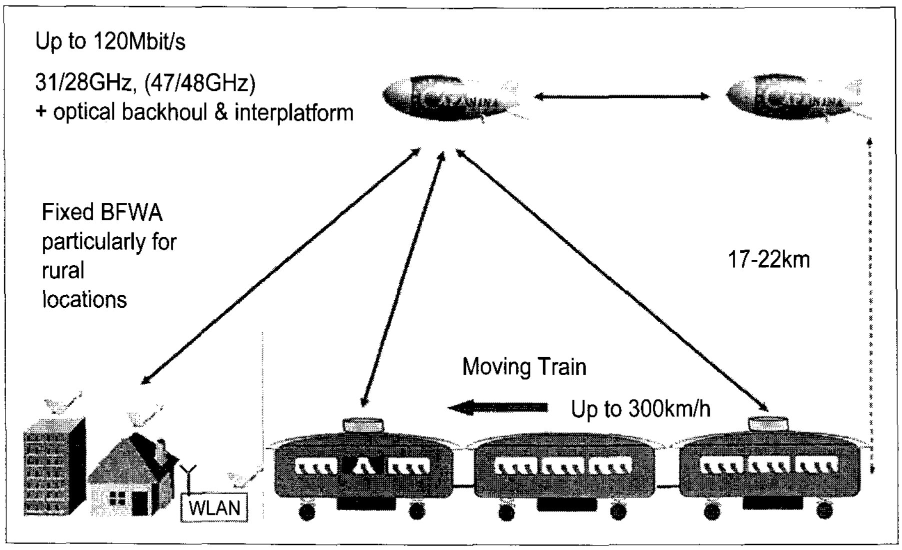
systems: HAPS Payload Sub-system, Ground Sub-system, and Telemetry, Tracking, and Command (TT&C) Sub-system. Table 1 shows the major different properties between the terrestrial wireless system, satellite system, and HAPS system.

2. Research Activities

In this section, we provide the recent research activities for commercial exploitation and for advanced research around the world.

1) Europe

Various HAPS platforms were developed by Advanced Technology Group and by Lindstrand Balloons in the United Kingdom. However, the first major HAPS research activity in Europe was funded by the European Commission's 5^{th} Framework Programme initiative called HeliNet project. In this project, a small prototype solar powered airframe was partially developed. The following project shown in Fig. 3, named CAPANINA was funded by European Commission's 6^{th} Framework Programme initiative to develop low



〈Figure 3〉 CAPANINA Project

cost broadband communications technology using HAPS system.

2) Japan

In Japan, "SkyNet" project was started in 1998 led by the Science and Technology Agency and the Ministry of Posts and Telecommunications to develop low cost and highly efficient broadband communication system using 15 airships in the 28 GHz frequency band.

3) United States

In U.S., SkyStation Inc. proposed a national broadband communication network using 250 stratospheric airships. Also, U.S. Missile Defense Agency (MDA) funded project, has been interested in using HAPS system for homeland security.

4) Korea

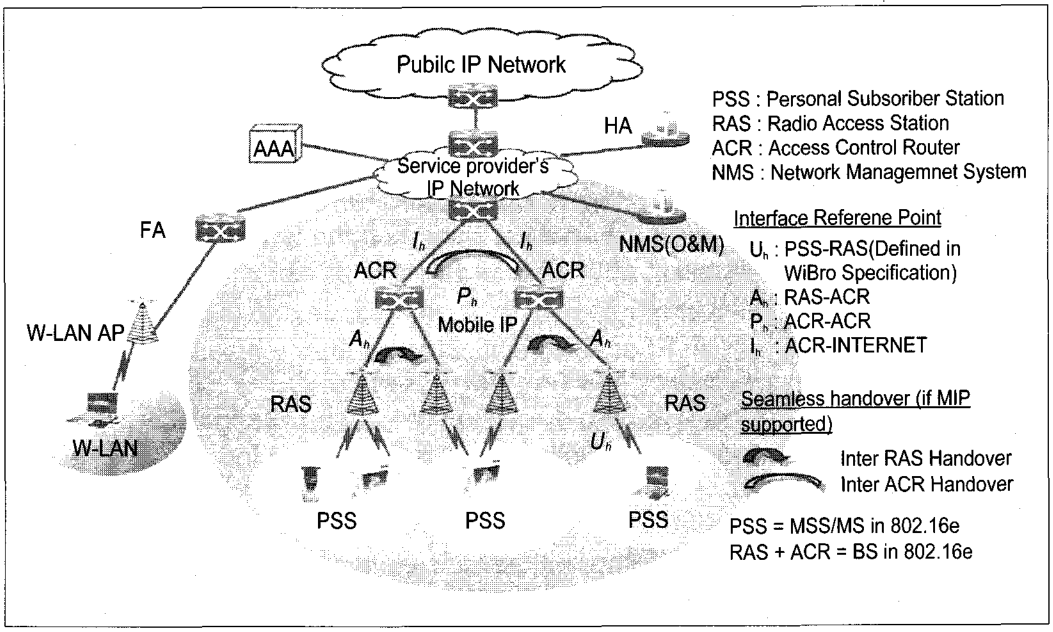
From 1998, Electronics and Telecommunications Research Institute (ETRI) is developing a broadband communication system based on HAPS funded by the Ministry of Information and Communications. Recently, ETRI is also working with a WiBro service provider to study the feasibility of using HAPS technology to provide WiBro services in rural areas.

Ⅲ. HAPS WiBro Architectures

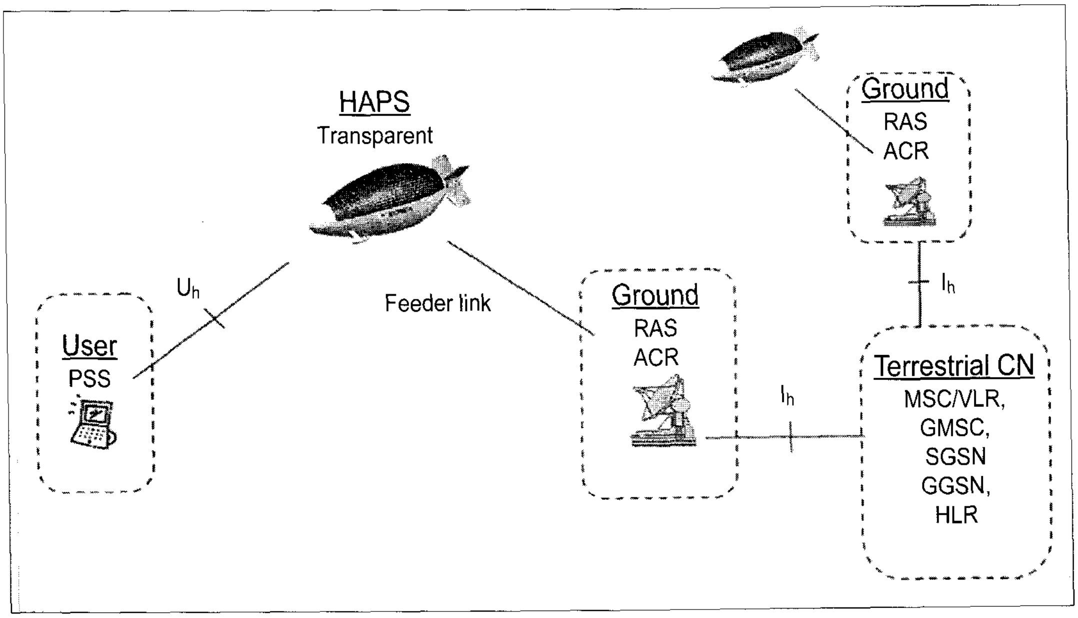
As discussed in the previous sections, the HAPS system overcomes the main drawbacks of the satellite technology, which is the long propagation delay with value around 250 ms, whereas the HAPS system has propagation delay value around 15 ms similar to wireless terrestrial systems. Furthermore, considering HAPS' capability to cover remote and sparsely populated areas with flexibility and low cost, an integrated HAPS WiBro architecture where the terrestrial WiBro system provides coverage in the urban area and HAPS WiBro providing WiBro services to the users in remaining suburban and rural area seems to be the most feasible approach in developing low cost national WiBro network infrastructure. In the HAPS WiBro system, the same WiBro (Mobile WiMAX) profile shown in table 2 that was fixed in the December 2005 Beijing Meeting will be used to provide the forward and reverse link between the HAPS WiBro Airship and the user' s Portable Subscriber Station (PSS). The general WiBro system architecture is shown in Fig. 4. As for the possible

〈Table 2〉 WiBro System Profiles

	Specifications
PHY	OFDMA, TDD 7, 8.75, 5, 10 MHz BW DL-PUSC, DL-FUSC, UL-PUSC, DL/UL B-AMC All 4 Rangings, 6bit CQI, TB-CC, CTC, H-ARQ Modulation : DL-4, 16, 64QAM UL-4, 16QAM Open loop, Closed loop power control RSSI, CNIR measurement, ECINR Normal MAP, Compressed MAP
MAC	PHS, ROHC, ARQ, H-ARQ MAC support QoS (BS-initiated), QoS (MS-initiated) BE, rtPS, nrtPS, ertPS, UGS IPv4 CS, IPv6 CS Scanning, PKMv2 Sleep & Idle mode



〈Figure 4〉 WiBro System Architecture



⟨Figure 5⟩ Transparent HAPS System Architecture

HAPS WiBro architectures, there are following four possible systems and the transparent HAPS architecture is shown in Fig. 5.

Standalone HAPS

- HAPS : Performs the functionality of Radio Access Station (RAS), Access Control Router (ACR), Mobile Switching Center (MSC), and Visitor Location Registration (VLR).
- Ground Sub-System: Performs the functionality of Gateway and Home Location Registration (HLR).
- Inter-HAPS handoff is performed through Inter-platform link (IPL).

ACR HAPS

- HAPS : Performs the functionality of Radio Access Station (RAS) and Access Control Router (ACR).
- Ground Sub-System: Acts as a data-relay station between the HAPS and the terrestrial core network.
- User-HAPS-user interface is possible.

RAS HAPS

- HAPS : Performs the functionality of Radio Access Station (RAS).
- Ground Sub-System : Performs the functionality of Access Control Router (ACR).
- Has better U_h link quality compared to the transparent HAPS architecture.

Transparent HAPS

- HAPS : Acts as a data-relay station between the user and the terrestrial WiBro network
- Ground Sub-System: Performs the functionality of Radio Access Station (RAS) and Access Control Router (ACR).
- This architecture has the lowest payload.

IV. Conclusions

Many research activities for commercial exploitation and for advanced research using High Altitude Platform Station (HAPS) for the next generation wireless broadband communication services in the form of standalone and complementary architecture have shown that the HAPS will be very important role in the future broadband multimedia communication systems.

In this article, High Altitude Platform Station (HAPS) has been suggested as a complementary system to the terrestrial WiBro system due to the various outstanding features, especially the capability to provide wide area wireless communication with low cost. To successfully, integrate the conventional terrestrial WiBro system and HAPS system, different architectural scenarios were studied in this article with advantages and disadvantages with each possible scenarios. However, further work in the link-level and system-level study of the HAPS WiBro system is needed to fully exploit the potential offered by the integrated system.

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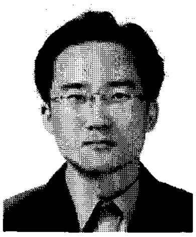

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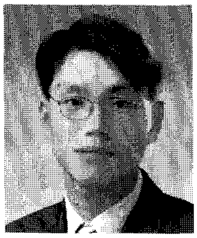

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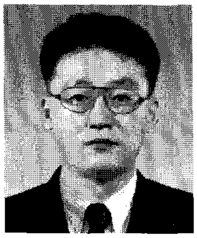

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