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CDMA Mobile System Overview: Introduction, Background, and System Concepts

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ABSTRACT

The CDMA Mobile System (CMS) has been developed by Electronics and Telecommunications Research Institute (ETRI) and field-tested for commercial ser- vice deployment in Korea. The project was started in 1989 and completed in 1995 with the CMS commercial test. During the course of development, there had been active technical cooperation with Qualcomm, Inc. and Korean manufacturers. The CMS adopted the basic CDMA concepts conforming to Korean CDMA system which was derived from IS-95. The CMS functions are allocated to subsystems by considering efficiency and expandability. The CMS consists of mobile stations and the infrastructure which is composed of base stations, mobile exchanges and home location register/authentication center. The commercial field tests performed both in Taejon and Seoul have indicated that the CMS capacity is 10 to 15 times larger than that of AMPS. This paper overviews the development history, system characteristics, architecture and test results.

I. INTRODUCTION

The demand for the cellular service has more than doubled each year since the service was introduced in 1984 [1], [2], and the number of subscribers exceeded 2 million in April 1996 in Korea. This phenomenal growth created the lack of radio spectrum and caused the degradation of service quality due to the traffic congestion of the radio signals. The first generation wireless system was developed in 1970s and is based on the analog technology. It has limitation in the radio spectrum usage and the channel capacity enhancement. The second generation takes advantage of digital technology, through the advanced digital signal processing and VLSI technology. As compared to the predecessor, it offers more channel capacity, additional services features, improved service quality, and reduced service cost.

We decided to pursue the digital technology. Reflecting the Users' Performance Requirements (UPR) [3] which Cellular Telecommunications Industry Association (CTIA) recommends as the requirements for the next generation cellular system, we established the following requirements for the mobile system to be developed:

- More than tenfold increase over analog system capacity
- Long life and adequate growth of second generation technology
- Ability to introduce new features
- Privacy
- Ease of transition and interoperability with existing analog system
- Early availability and reasonable costs for dual-mode radios and cells
- Cellular open network architecture
- A base-transmit spectrum of 824-849 MHz, mobile-transmit spectrum of 869-894 MHz
- The provision of secure access and channel encryption.

We initiated the R&D work jointly with a few Korean manufacturers. The multiple access scheme had to be decided between the two candidates: time division multiple access (TDMA) [2] and code division multiple access (CDMA) [4]. The CDMA system proposed by Qualcomm, Inc. [4] was known to provide at least 10 to 20 times capacity over advanced mobile phone systems (AMPS). The CDMA was accepted to have advantages over the TDMA in terms of inherent privacy in direct sequence/spread spectrum (DS/SS), rake receiver diversity over multipath fading, small size and low power terminals through power control, soft handoff for better quality of service, voice activity cycle nature for increasing capacity and easy cell and frequency planning among others. The CDMA technology was then adopted as the national standard and the CDMA mobile systems (CMS) development took place. The CMS has the basic functionality satisfying Korean Common Air Interface (CAI) Standard (TTA-KO-0062 [4]). It was implemented mostly during 1993 and 1994, and field tested during 1995.

This paper surveys the background and history of the development, applied CDMA concepts, architecture, and field test results. Additional features, functions and system optimization issues are addressed.

II. DEVELOPMENT HISTORY

Since the deployment of AMPS in Seoul and its vicinity, the demands has been increasing rapidly to require more spectral bandwidth. To increase the capacity by using limited spectrum resource efficiently and to improve the service quality, the digital mobile system development project was initiated in 1989 as a national project. Through careful examination on digital technologies available at the time, we adopted the CDMA technology which has been proposed for commercial mobile communications by Qualcomm, Inc. Brief history of the CMS development is summarized as follows:

Jan. 1989 : Initiation of digital cellular system development
Aug. 1991 : Joint development agreement (JDA) with Qualcomm, Inc.
Dec. 1992 : Roving test system (RTS) by Qualcomm, Inc. delivered, installed and field tested in Taejon
Jan. 1993 : Manufacturers designated for joint development with Qualcomm, Inc. and ETRI
Mar. 1993 : Korean CDMA Systems (KCS)-1 high level design (HLD) started
Aug. 1993 : KCS-1 low level design (LLD) started
Nov. 1993 : RTS installed and field tested at Seoul
Dec. 1993 : KCS-1 hardware implemented and installed for integration
Apr. 1994 : KCS-1 software installed and the first successful call made
Jun. 1994 : CDMA mobile systems (CMS)-2 implemented and the first successful call made
Sep. 1994 : CMS V2.2 equipped with basic functions of IS-95 [6] developed and transferred to designated manufacturers (DMs)
Nov. 1994: CMS V2.3 equipped with more functions (handoff, frame staggering, etc.) developed and transferred to DMs
Jan. 1995 : CMS-2 commercial field test started in Seoul
Jun. 1995 : CMS-2 commercial field test completed
Oct. 1995 : Commercial systems began deployed and tested
Jan. 1996 : Commercial service deployed in Incheon by Korea Mobile Telecom Co.
Apr. 1996 : Commercial service began in Seoul, Taejon and connecting highways by Korea Mobile Telecom Co. and Shinsegi Telecom, Inc.

III. SYSTEM CHARACTERISTICS

The CDMA was considered to have three major drawbacks for the cellular applications: the necessity to assign each user a unique code, the need to synchronize the network, and the tight power control to secure channel capacity. The Qualcomm, Inc. suggested system, which is the second US digital cellular interim standard known as IS- 95, has overcome these drawbacks. The Korean CDMA system, TTA-KO-0062, conforms to IS-95. The CMS is developed in accordance with TTA-KO-0062 and employs such features as orthogonal Walsh codes, system pilot acquisition, forward and reverse link power control with open, closed, and outer loop control schemes to overcome such drawbacks. Other features related to system capacity, such as handoff and variable rate vocoders are among those important characteristics of CDMA [7].

1. CDMA Link Waveform

A. Forward Link Waveform

The forward link uses a combination of frequency division, pseudorandom code division, and code division multiple access by orthogonal signals. Frequency division is employed by dividing the available spectrum bandwidth into nominal 1.25 MHz channels. Multiple frequency allocation is possible in a service area. Pseudorandom noise (PN) binary codes are used to distinguish signals from different base stations. All CDMA signals in the system share a quadrature pair of PN codes. Two codes are generated for each quadrature carrier to provide quadriphase PN modulation. Different cells and sectors are distinguished by the time offsets from the basic code. The PN chip rate is 1.2288 MHz (128 times the 9600 bps information transmission rate). All signals transmitted from a cell in a particular CDMA radio channel share a common PN code phase. They are distinguished at the mobile station receiver by using a binary orthogonal code based on Walsh functions of 64 PN code chips long. Walsh code orthogonality provides nearly perfect isolation between the multiple signals transmitted by the base station.

Convolutional coding is used to detect and correct channel errors at the receiver. The code used has a constraint length of $K = 9$, and a code rate of 1/2. The encoded symbols are interleaved to combat fast fading. For privacy, each data channel is scrambled with a user-addressed long code PN sequence.

Thus the forward link signal is centered on an assigned radio channel frequency, quadriphase modulated by a pair of PN codes with an assigned time offset, biphase modulated by an assigned orthogonal Walsh function, and biphase modulated by the encoded, interleaved, and scrambled digital information as is represented in Fig. 1. Pilot signal is transmitted by each cell site and is used as a coherent carrier reference for demodulation by mobile stations.

B. Reverse Link Waveform

The reverse link also employs PN modulation using the same 32768 length binary sequences that are used for the forward

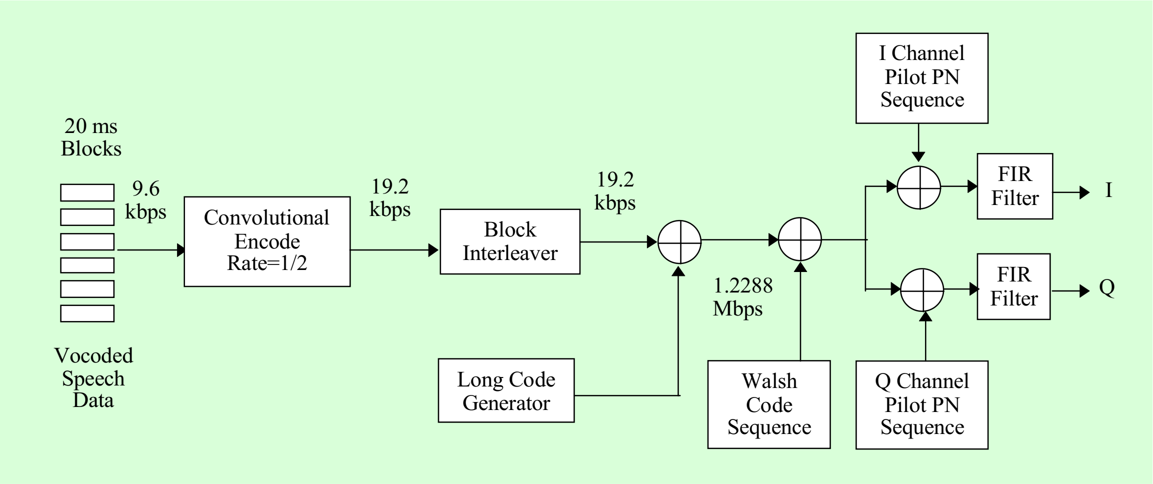

Fig. 1. Forward link channel structure.

link. Signals from different mobile stations are distinguished by the use of very long $(2^{42}-1)$ PN sequence with a user-address-determined time offset. No pilot signal is transmitted. Also, convolutional encoding of constraint length of 9 using a rate 1/3 is employed. The encoded information is then interleaved over a 20 msec interval. The interleaved information is then grouped in six code words to select one of 64 Walsh functions for transmission. The Walsh function chips are combined with the long and short PN codes. The use of the Walsh function modulation on the reverse link is a simple method of obtaining 64-ary modulation with coherence over two information bit times. PN chips generated by the long code mask and convolutional encoder are fed both for I and Q channels. By the different transmission rates of both bit streams, 1 bit from the encoder is replaced by 4 long code mask bits. These operations are summarized as shown in Fig. 2.

2. CDMA System Features

The CDMA system has many features for the ease of operation, and the improvement of link quality and capacity. Those can be briefly summarized by the following attributes and techniques.

A. System Pilot Acquisition

The forward link for each cell or sector generally employs a pilot modulated only by the specific pseudorandom sequence with different spread spectrum code offsets which are multiples of 64 bits. This pilot signal is used by mobile stations (MSs) to obtain initial system synchronization and robust time, frequency, and phase tracking of the signals. Also, a sync channel is transmitted for MSs to provide the cell identification, pilot transmit power and the cell site or sector specific pilot PN carrier phase offset.

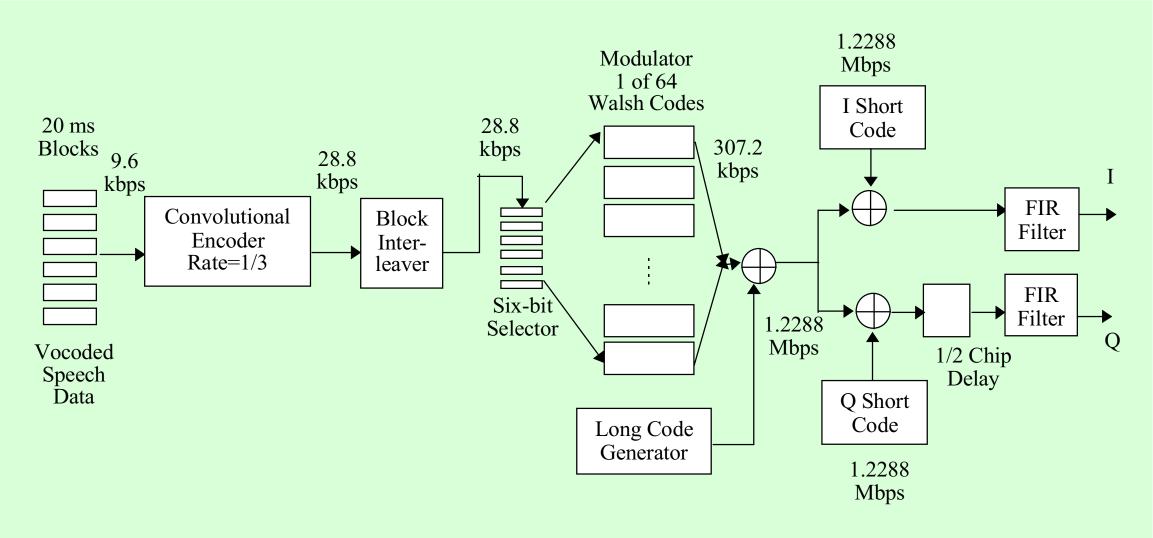

Fig. 2. Reverse link channel structure.

B. MS-Assisted Handoff

A handoff mechanism is provided for a call to get an unceasing connection when an MS crosses the boundary between two sectors (softer handoff) or cells (soft handoff). At the call initiation, an MS is supplied a set of pre-assigned handoff thresholds and numbers of candidate sectors (or, cells) from a list of neighbor sectors (or, cells) for handoff. In the forward link, the MS can combine base station (BS) signals to improve performance, same as with multipath combining. For the reverse link, different BSs will decode the signals independently and those more reliable ones of BSs will generally prevail. In other words, the handoff is initiated either by the MS observing the received E_c/N_o or monitoring the pilot signals, or by the BS comparing the strength of the MS signals receiving via different cells. Through the proper power control, it is shown that with the soft handoff function the capacity of a heavily loaded system is more than doubled, and that the coverage area of each cell is more than doubled [5].

C. Power Control

The received power of each traffic channel at the cellular base station over the reverse link must be equal regardless of the MS location in the cell in order to minimize the near-far interference and maximize the number of users. The MS can adjust its transmit power by measuring the forward link received power. However, since the forward and reverse link propagation losses are not symmetric, particularly when their center frequencies are widely separated form one another, this method does not warrant the equal received power. So, the closed loop power control is introduced, in which case, when the base station determines that any user's received signal power level on the reverse link is too high or low, a command is sent to lower or raise its power with step size of 0.5 or 1 dB every 1.25 msec. This provides a "bang-bang" control loop (in the context of control theory). Forward link power control is also implemented. Power control ensures that each user receives and transmits signal energy just enough to convey information properly, while minimizing interference with other users.

D. Variable Rate Vocoder

A variable rate vocoder based on a Qualcomm-enhanced code excited linear prediction (QCELP) algorithm is implemented to supports 8, 4, 2, and 1 kbps operation and corresponds to channel rate of 9.6, 4.8, 2.4, and 1.2 kbps. Since the appearance of the modulated signal does not change when the baseband data is changed, the variable rate vocoder can accommodate various grades of voice quality.

IV. CMS ARCHITECTURE

Major attributes of the CMS are summarized as follows:

- The system is fully automatic and provide wide area, high capacity, cellular mobile communications.
- Cell sites can be configured to support omni/omni or sector/sector antenna configurations with multiple frequency assignments.
- The system automatically switches subscriber units between cell sites (soft handoff) and antennas (softer handoff in a sector configuration) with the optimization of channel quality.
- Subscriber unit power output is automatically and dynamically adjusted with the objective of keeping the MS power level as low as necessary but sustain effective communications, thus maximizing the capacity through power control.
- The system is designed to accommodate the evolution of infrastructure equipment orderly and appropriately to meet the increasing subscriber population.
- Various forms of diversity are implemented:
  1. Time: symbol interleaving, error detection, and correction
  2. Space: CDMA rake receivers for multipath, sectored cells, and soft handoff selection combining from different sites
  3. Frequency: wideband frequency signal (1.25 MHz).

The CMS [8] are consist of mobile stations (MSs), base stations (BSs), mobile exchange (MX) and home location register/authentication center (HLR/AC) as shown in Fig. 3. The major functionality of the CMS allocated to each of these subsystems is provided in Table 1. Also, ETRI CMS simulator (ECS) was developed for the research on system performance evaluation, parameter adjustments and cell planning for optimal operations. It could be enhanced for the next generation mobile system.

1. Design Objectives

The system design requires to consider all the requirements such as interoperability with AMPS, supporting network evolution trend, modularization of hardware to meet system capacity and new feature implementation, and redundancy for system failure. The CMS is composed of mobile stations (MSs) and the infrastructure of BS, MX, and HLR/AC. Only the infrastructure of CMS is described in the following subsections.

2. Base Station Subsystem

A base station subsystem (BS) is defined as the interface providing packet routes between MSs and a MX, and as the fixed end of radio interface which provides control and radio coverage functions for one or more cells and their associated MSs. A BS consists of a base station controller (BSC) and a number of remotely located base station transceiver subsystems (BTSs) and a base station manager (BSM). One BSC is collocated with an MX, and is responsible for allocation of air interface channels, intra-BS handoff and power control. Refer to Fig. 4.

A. Base Station Transceiver Subsystem

A base station transceiver subsystem (BTS) is made up of BTS control processor (BCP) which accomplishes general management over a BTS, CDMA digital unit (CD) for CDMA signal processing, radio frequency unit (RF), BTS interconnect network (BIN), and a global positioning system (GPS). The functions of RF include low noise, high power amplification, signal filtering, frequency conversion, and especially signal combining/distributing for multiple frequency assignments. A CD is for CDMA channel coding/decoding, analog common functions for modulation/demodulation, generating and distributing desired clocks, and providing interfaces among sectors. A BCP is for digital unit interconnection, BTS call processing, operation and maintenance of BTS. A BIN provides call and control paths to BSC and other units (e.g., CD, BCP) in BTS. The structure for BIN, CIN for BSC, and INS for MX are the same and implemented with redundancy.

B. Base Station Controller Subsystem

A BSC is composed of CDMA interconnect networks (CINs) which provide common transmission paths among units as packet router, transcoder and selector banks (TSBs) for voice coding, allocating selectors, packet assemble/disassemble, power control and intra-cell hard handoff, and call control processors (CCPs) for allocating and managing resources, soft (softer) handoff along with call control, and clock distributor (CKD) for receiving clock signals from GPS, generating and distributing clocks. Messages between BTS and BSC are sent over T1/E1 link with packet transmission rate of 1.544/2.048 Mbps. A CIN functions as a packet router which converts serial packet data into 8 bit parallel data to route it by round-robin. Self-routing by hardware control ASIC is implemented. It also supports generating T1/E1 frame synchronizing signal to provide interface between BTS and BSC by non-channeled scheme in which a packet is transmitted without any classification of channels. A TSB performs speech coding/decoding function. A TSB converts between 64 kbps PCM and QCELP coded speech. Power control (forward, reverse and outer-loop) and soft handoff are performed by TSB. A TSB supports voice transmission between subscriber units and CAI protocol message processing. It also provides T1/E1 transmission path between MXs. For the efficient use of trunks, a frame staggering scheme is implemented. A CCP performs control functions related to call processing and soft handoff. A CCP is designed to integrate BSP in it for serial information transmission with CIN and MX. A CKD generates and distributes clocks for system synchronization.

C. Base Station Manager

A BSM is composed of base station manager platform (BSMP) supporting MMI, program downloading and operations and maintenance of BS, and an Alarm (ALM) for collecting and processing of faults. A BSMP is a general purpose workstation where redundancy for its communication ports is implemented. Also, redundancy for disk is implemented by mirroring disc.

3. Mobile Exchange

For mobile switching system design, both the traffic and call processing characteristics have to be taken into account. Since the reference load is 0.1 to 0.2 Erlang for wireline calls, while as 0.03 to 0.06 Erlang for radio, the number of subscribers supported by an MX should be three times more than that of a landline switching system. Since there are approximately three times more control signaling among subsystems in CMS to several mobile calls, a mobile exchange (MX) requires more processor capability. Also handoffs require more processor capacity. So, the landline switching system can support only one third of its load in BHCA. Also, about 60 % of the landline switching system software blocks need modifications for mobile switching system.

TDX-1, a switching equipment, developed by ETRI is modified to serve as an MX. Mobile switching and visitor location registration functions are combined and implemented in an MX. An MX is composed of access switching subsystem (ASS), interconnection network subsystem (INS) and central control subsystem (CCS). Conceptually, an MX can be divided into telephony part (TP) which provides call and data paths, control part (CP) which is responsible for call control and telephony control part (TCP) which provides interfaces between TP and CP. It is implemented as a fully distributed control system with hierarchy and control interworking for inter processor communication (IPC). It is also modularized by its allocated functionality and provides redundancy for fault tolerance.

A. Access Switching System

An ASS is composed of line and trunk access subsystem, signaling message handling subsystem, local switching subsystem, signaling and service subsystem, access switching maintenance subsystem, the main control processor (access switching processor) and control interworking subsystem for IPC. It can be implemented as an application subsystem by its subsystem composition, such as ASS-Mobile for mobile subscriber, ASS-Trunk for interface with PSTN and switching center, and ASS-7 for supporting SS No. 7. ASS-Ms are connected to a BS and provide call process, mobility management and self maintenance.

B. Interconnection Network Subsystem

An INS provides paths connecting ASS and CCS, and accomplishes centralized call processing such as routing, switching and number translation. Network synchronization, system clock generations for distributing to INS, ASS and CCS are accomplished by INS.

C. Central Control Subsystem

A CCS is composed of administration and maintenance subsystem (AMS) for operations and maintenance for MX and location register subsystem (LRS) for managing and storing the information on subscribers (visitors) to provide location registration, authentication, etc. Mobility management by LRS is carried out by either an MS initiated registration or an MX initiated registration.

4. Home Location Register/Authentication Center

A home location register (HLR) is a location register designed for storing permanent and temporary information such as location, supplementary service profiles, and billings to mobile subscribers. An HLR is composed of application entity subsystem (AES) to provide the communication and information transmission paths among application processors such as database subsystem (DBS) for managing all the events using database, network interface subsystem (NIS) to support lower layer functions for SS No. 7 and operations and maintenance subsystem (OMS).

An authentication center (AC) is implemented on the same hardware platform for subscriber security and fraud management.

5. Interfaces

The interface between subsystems are as shown in Fig. 3. The interface between an MS and a BS is defined in Common Air Interfaces Standard [4]. The signal interface between BS and MX are provided by T1/E1 for traffic signal and by IPC implemented in an MX (a modified TDX-10 for mobile communication) for control, which will be replaced by SS No. 7 Protocol. And, the interface between MX and HLR/AC is implemented according to IS-41/MAP.

6. Maximum Capacity Configuration

The maximum capacity system configuration is provided for system planning, which might provide an upper bound (Refer to Fig. 3). A three sector cell can support up to 320 traffic channels with four frequency assignment by BTS. And, each BTS can support eight T1/E1 trunks.

A BSC Group (BSCG) is defined as a configuration consists of a local CIN (LCIN) which is the same as CIN described previously, TSB and CCP. A BSC is made up of 12 BSCGs. Up to 512 BTSs can be supported by a BSC, and 576 E1 trunks for 512 BTSs and 768 E1 trunks for an MX. Also, 23,040 transcoding channels can be supported by a BSC.

An MX can support over 500,000 BHCA and an inherent VLR can support 350,000 subscribers. Up to 350,000 radio subscribers and 512 landline subscribers can be handled, and the offered load of 27,000 Erlangs can be treated. Also, 12 ASS-Ms are implemented within an MX and 65,000 trunks can be connected to PSTN through ASS-T.

Up to 1 million subscribers can be supported by an HLR with computing power of 240 MIPS including subscriber authentication. The transaction rate is assumed to be 1,100 transactions/sec. And up to 64 SS No. 7 signaling links can be supported.

V. FIELD TEST

We used 30 mobile stations for the field tests [9] on the critical functions of the CMS, which include power control, handoff (softer, soft, and hard) and multi-call processing. We also conducted the capacity and performance tests by connecting the CMS to PSTN environment. The field test [9] for the Markov calls and mobile to mobile calls indicated that the FER is lower than 0.7% for 7 dB E_b/N_o received by the BS, and the estimated capacity is between 30 and 40 (15 to 20 times of AMPS). It is also revealed that the CMS can be in good operating condition with the capacity approximately 10 to 15 times of AMPS capacity without any degradation of blocking probability, call drop rate and voice quality.

The field test was carried out in Taejon for the purpose of subsystem integration for commercial services, system parameter optimization, verification of additional features, evaluation of system capacity and performance. One HLR/AC, one

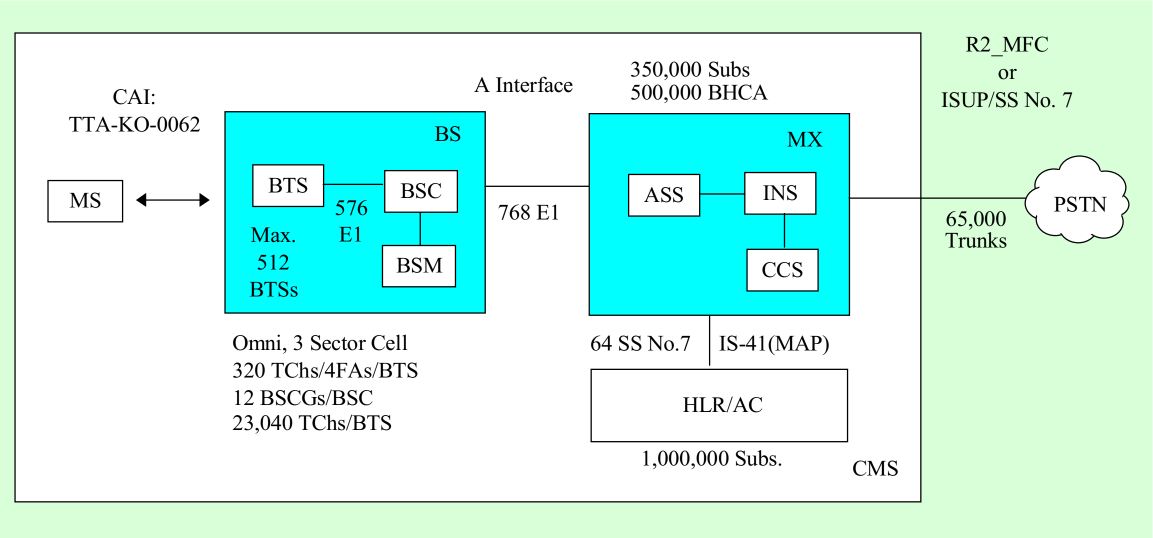

Fig. 3. CMS architecture.

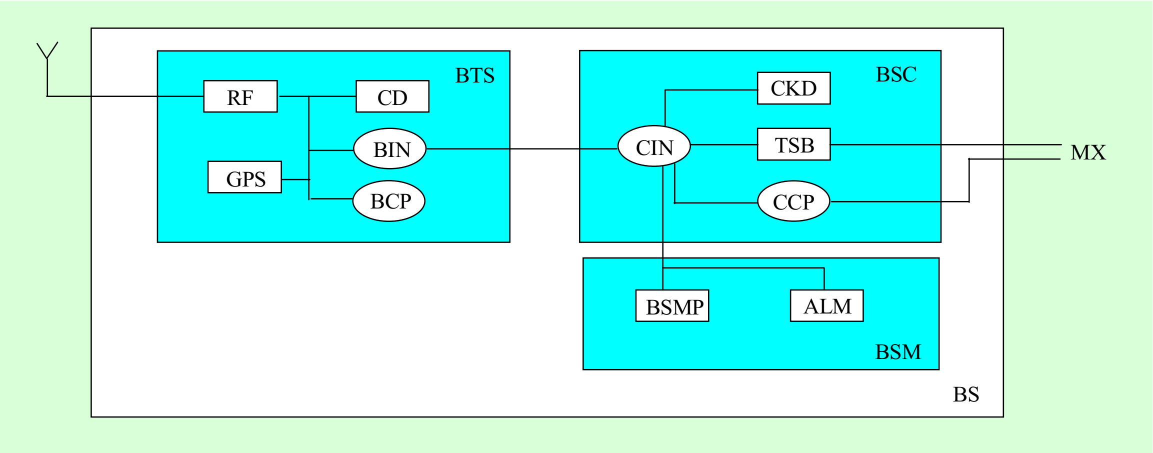

Fig. 4. BS architecture.

MX, two BSCGs, three BTSs (one omni and two three-sector cells) were installed. A three sector cell site with multiple (two) frequency assignments, a BSC, the MX, and the HLR/AC were collocated at ETRI. Such minimum system configuration was to test soft handoff among BTSs, softer handoff between sectors, hard handoff between BSCGs, power control during soft handoff, and to evaluate the BTS capacity. We developed test equipment such as mobile call simulator (MCS) and logging data analysis tool such as CDMA data analysis tool (CDAT) for the field test.

Table 1. CMS functional allocation.

Subsystem		Functions
BS	BTS	Resource Management Radio/Antenna Interconnect, RF Modem Reference Timing/Frequency Reception/ Distribution Power Control Handoff (Softer, Soft)
	BSC	Call Processing Voice Coding Power Control Handoff (Softer, Soft) BS Control/Management
	BSM	System Initialization (Down Loading) Fault, Configuration, Event Management Data Collection and Handling MMI
MX		Call Processing Handoff Visitor Location Registration Additional Services
HLR/AC		Location Registration Mobility Management Database Management Authentication

The commercial field test had been executed in Seoul simultaneously. Four BTSs (three 3-sector cells and one omni cell) were installed by three different manufacturers so that three densely populated urban areas could be covered by different test systems. The commercial test for over 940 test items were successfully carried out. The test included the hardware characteristics, MX functions, BS interface modules and their functions, HLR/AC functions, interoperability, performances and environmental characteristics. Test for call set-up, teardown, handoff (softer, soft, sequential) and power control of mobile originating, terminating calls had been executed. Subscriber registration, authentication, supplementary services were successfully verified. For the performances, call delay (M-M, L-M, M-L), signal strength and voice quality were measured to satisfy the requirements. Also, for the capacity, each test system carried about 700 channel elements and over 800 transcoder/selectors to support the traffic. The operating frequency band for the test was 2.5 MHz for two frequency assignments in 10 MHz (835 to 845 MHz for mobile transmit, and 880 to 890 MHz for BS transmit) out of 25 MHz allocated to mobile telecommunications, since the frequency band remained unused in Seoul.

The deployment for the commercial service is started after the successful field demonstration early 1996 by two service operators.

VI. CONCLUSION

The CMS, a CDMA-based digital cellular infrastructure, is described. Its development history, CDMA concepts and its design requirements, system characteristics, architecture, and functional allocation to subsystems are described. After the functional test of CMS, the field trial for performance and capacity was carried out in Taejon, whose results are provided. Development support systems are employed for those purposes. Authentication is to be implemented as a system option in 1996. Additional services such as data and short message services will be provided by the commercial system.

Also, ETRI CMS simulator (ECS) developed plays an important role for the research on the next generation mobile system implementation. For the efficient use of limited resources and cost efficient operation, better schemes for adaptive power management, handoff, power control schemes over existing ones are under investigation.

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Youngnam Han received his B.S and M.S. in electrical engineering from Seoul National University in 1978 and 1980, respectively. He received his Ph.D. from the University of Massachusetts, Amherst in 1992. From 1980 to 1983, he served as a full time lecturer at the Korean Naval Academy. Also, during that period, he joined the research team for the under water vehicle simulator at Agency for Defense Development. From 1983 to 1985, He had been with the Kumoh Institute of Technology as a faculty member in the Department of Control Engineering. He joined ETRI in 1992 and currently serves as Section Head in Mobile Telecommunication Division. His research interests include performance evaluation of mobile communication systems, optimization of handover algorithms and multiple access technology. He is currently managing the project of design and performance analysis of radio transmission technology for IMT-2000.

Hang Gu Bahk received his B.S. and M.S. from Hanyang University in 1970 and 1979, respectively. He got his Ph.D. form Korea University in 1985. From 1970 to 1972, he was with Keumsan Electronics Co. as a design engineer. From 1972 to 1977, he was a research engineer at Korea Institute of Science and Technology (KIST). He joined Korea Electrotechnology and Telecommunication Research Institute (KETRI), former ETRI, in 1977 and has been with ETRI to be involved in national projects of developing a switching system (known as TDX) as Director, and later Vice President. Currently, he serves as Vice President of Mobile Telecommunication Division being in full charge of developing CDMA mobile systems (CMS). After successful development of CMS, he initiated IMT-2000 system development project as a national project. He has been serving as Vice President at the Korea Institute of Telematics and Electronics, an academic institute, since 1997 and chaired many international conferences.

Seungtaik Yang was educated at Seoul National University, Seoul, Korea, where he received a B.S. degree in electrical engineering in 1961, and Virginia Polytechnic Institute, Virginia, USA, where he received a M.S. degree in electrical engineering in 1968 and the Polytechnic Institute of New York, New York, where he was awarded a Ph.D. degree in electrical engineering in 1976. Between 1968 and 1979, he was with Bell Telephone Laboratory, New Jersey, as a member of research staff working on transmission systems. He was President of Korea Telecommunications company and Korea Telecommunications Authority International between 1979 and 1981, between 1989 and 1992 respectively. He was with Electronics and Telecommunications Research Institute (ETRI) at Taejon, Korea, between 1981 and 1986, as an executive director of TDX Development Division, all in the area of TDX switching system development. Since May 1992, he has been with ETRI as President. His whole life has been devoted to the information and telecommunications technology development, especially with TDX switching system: its planning, development, marketing and improvement for the forthcoming information society.