High-performance and Data-optimized 3rd-generation Mobile Communication System: 1xEV-DO

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OVERVIEW: Utilizing an identical frequency band (1.25 MHz) to that of the existing cdmaOne system, the 1xEV-DO (1x evolution-data only) system, which attains high-speed data transmission up to 2.4 Mbit/s (downlink), is expected to be the main platform for next-generation broadband mobile Internet services. At Hitachi Group, we have been actively involved in the concept development and standardization of this technology from the start, and through the development and testing of a trial 1xEV-DO system in collaboration with KDDI CORPORATION, we have successfully launched a 1xEV-DO system commercially. The various characteristics of this 1xEV-DO system — such as a flexible base-station line up, large-capacity network hardware, software upgrading without service interruption, a high-reliability OMC (operation and maintenance center) using a redundancy function, and high engineerability and maintainability — are presented in this paper.*

INTRODUCTION

WITH the popularization of the Internet and its continuing conversion to broadband access lines, various applications — such as e-commerce, Internet banking, streaming music and video, and music and video distribution — have been born, and demands to enjoy these applications anytime, anywhere have grown stronger. To meet these demands, at the same time as having to convert access lines to handle wireless connectivity, it is necessary to increase transmission speeds and ensure services can be utilized over a wide area while users are on the move.

Developed by QUALCOMM Incorporated of the USA as a next-generation wireless packet-transmission technology for mobile use, 1xEV-DO (1x evolution-data only) — based on CDMA (code division multiple access: cdmaOne) with a spread chip rate of 1.2288 Mchips/s — is a cellular system that provides a high-speed, mobile Internet environment. Utilizing a bandwidth of 1.25 MHz, this technology attains a downlink data transmission speed of 2.4 Mbit/s, and it combines features of mobile phones, such as a large cell radius and a handover function for moving terminals.

In January 2001, Hitachi was the first in the world to sign a licensing agreement with QUALCOMM Incorporated as a vendor for 1xEV-DO technology. Following that agreement, Hitachi independently developed specialized LSIs, cabinets, circuit cards, software, etc. for 1xEV-DO. A trial system was then delivered to KDDI Corporation (at that time called IDO Corporation), and from July 2002 various test trials (for example, on interference and quality conditions when multiple users are accessing the system at the same time) were performed in the Tokyo metropolitan area — which is extremely radiowave crowded — in collaboration with KDDI.

Based on this technology and the know-how amassed from these trials, we developed base stations and terminals for commercial services. This equipment is now being utilized by KDDI to provide their “1xWIN” services.

The rest of this paper describes
(1) the configuration and characteristics of 1xEV-DO,
(2) its characteristic functions, and
(3) its engineerability and maintainability.

CONFIGURATION OF 1xEV-DO SYSTEM

By applying the control techniques outlined below, 1xEV-DO attains a maximum access throughput of 2.4 Mbit/s (downlink) at a frequency bandwidth of 1.25 MHz.

(1) Each mobile terminal measures the C/I (carrier to interference) power ratio of the received pilot signal. And from the C/I ratio, it calculates the required rate for transmitting data (i.e. DRC: data rate control) at a PER (packet error rate) of 10^{-2} (see

* cdmaOne is a registered trademark of CDG (CDMA Development Group).

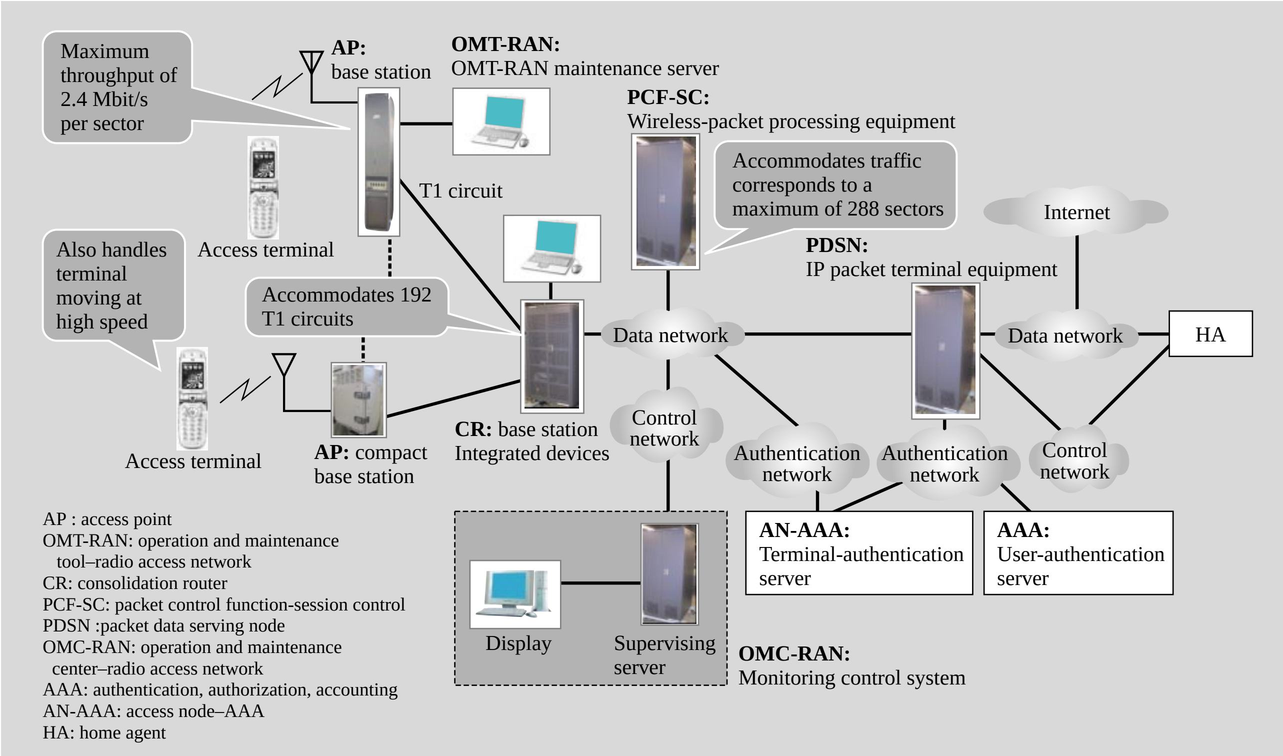

Fig. 1—Configuration of 1xEV-DO System.
With an access throughput of 300 kbit/s for the uplink (from the access terminal to the base station) and 2.4 Mbit/s for the downlink (from the base station to the access terminal), the 1xEV-DO system provides an extremely-high-speed data-transmission environment that attains the access speed for a mobile wireless transmission system.

Fig. 2). Each terminal then notifies the base station of its DRC; the base station compiles the required DRCs from each terminal and then assigns an available time slot for each terminal according to a scheduling algorithm.

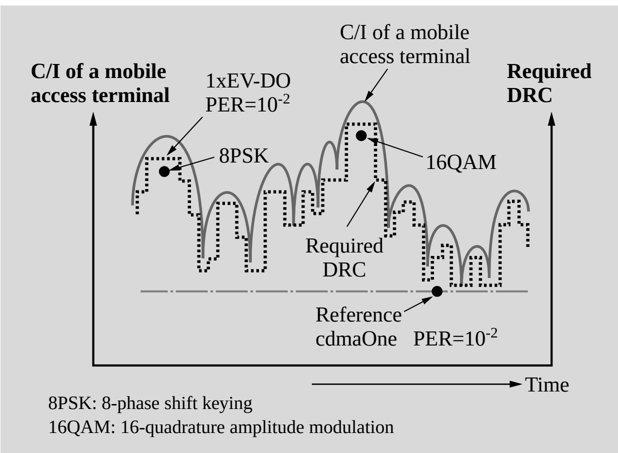

Fig. 2—Measured C/I and Calculated Required Rate for Each Terminal.
Each moving terminal measures the C/I power ratio, and requests the optimum DRC value. In the case that the ratio is high, a highly advanced multiple modulation technique is used. Thus compared with cdmaOne technology which keeps the power ratio constant, high-speed transmission is made possible.

(2) By applying the latest adaptive modulation and coding techniques (turbo coding), 1xEV-DO can dynamically set up transmission speed and modulation techniques [QPSK (quadraphase shift keying), 8PSK, or 16QAM] according to each C/I ratio for each time slot .

(3) Variation of line quality with time is utilized, and a scheduling algorithm — which efficiently assigns a time-loss slot to the terminal with the best reception status at each time — is implemented.

In addition, aiming at improving performance and realizing new services such as broadcast, voice-over-IP, and video telephony, the standardization body 3GPP2 (3rd Generation Partnership Project 2) is currently investigating the possibility of increasing the maximum throughput of the uplink and down link speed to 1.8 Mbit/s and 3.1 Mbit/s, respectively, developing new broadcast/multicast functions and QoS (quality of service)-type transmission. Moreover, at Hitachi, setting our goal as enhancing IP (Internet Protocol) networks, we are investigating how to incorporate IPv6 (Internet Protocol version 6) into 1xEV-DO.

Hitachi's 1xEV-DO system is composed of an AP (access point) base station; a CR (consolidation router) for integrating base stations with 1.5-Mbit/s T1 lines; a PCF-SC (packet-control function/session control) function for terminating wireless packets; a PDSN (packet data serving node) with a terminating device for IP packets; an OMC-RAN (operation and maintenance center-radio access network) for monitoring and maintenance of the whole network; and various servers, for example, AAA (authentication, authorization, accounting) for each network. The main features of these systems are explained in the following sections.

Features of AP: Base Station

To meet various traffic demands in different area, Hitachi is offering the lineup of base stations described below.

Our standard base station can accommodate two carriers, and it can accommodate three sectors per carrier. It can therefore handle a maximum of 354 moving terminals connected at the same time. The capacity taken up by the base station is about 270 liters. Moreover, by utilizing five cabinets, it is possible to extend the capability to 10 carriers. The compact-type base station is designed to cover areas where traffic demand is low, and it can only accommodate one sector/one carrier. It occupies a space of 85 liters and can expand extra two stations.

In addition to the two base stations described above, an extra-compact base station (taking up a space of only 4.5 liters) for covering areas where radio waves cannot be received from aboveground base stations (e.g. underground passageways and rooms) is presently under development.

The external appearances of these three types of base stations are shown in Fig. 3.

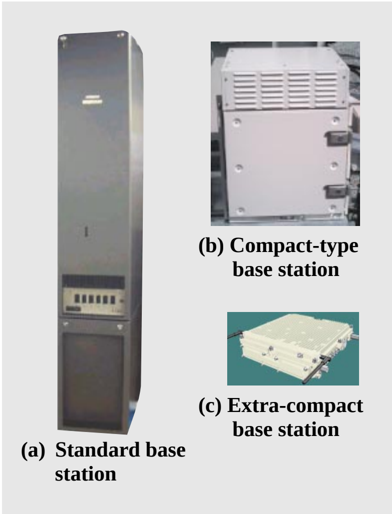

Fig. 3—External Views of Each Base Station.
Base stations are lined up in accordance with various kinds of traffic.

Features of Network Equipment

The network equipment of the 1xEV-DO system is composed of a data network, an authentication network, and a control network all connected by an IP interface in a multi-purpose, economical manner (see Table 1).

(1) CR

The CR can handle a large number of T1 lines.

(2) PCF-SC

PCF-SC can handle 288 sectors, and by assigning three sectors to one AP (base station), one PCF-SC module can accommodate 96 APs (which is a large number).

TABLE 1. Main Features of Network Equipment
Each network equipment is connected with the IP interface in order to set up a high-performance system.

Device	Principle features
CR	192 T1 circuits Data network interface: 1000BASE-X (1 line)
PCF-SC	288 sectors/unit Throughput: approx. 200 Mbits/s; call processing capability: 2,000 calls/s; session no.: approx. 130,000
PDSN	PPP link no.: 85,000 links; packet-processing capability: approx. 200 kpps; call processing capability: approx. 900 calls/s
OMC-RAN	200 nodes/monitoring server

PPP: point-to-point protocol

(3) PDSN

The PDSN utilizes exclusive software to attain a large data capacity. Following instructions from the OMC, it has a function for monitoring traffic of specified users [i.e. domain name, IMSI (international mobile subscriber identity), etc.]. And by applying a dual-stack approach of simple IP and mobile IP, the PDSN can handle both protocols at the same time.

(4) OMC-RAN

The OMC-RAN is configured from a surveillance server that monitors each node and a monitoring server that displays operation and maintenance status by GUI (graphical user interface).

The monitoring server is a one-unit-size rack server, and the monitoring device is a standard PC with a 19-inch screen. A characteristic of the OMC-RAN is that it can be configured economically; that is to say, since it utilizes a commercially available server and PC, it can be easily upgraded in line with improvements in PC performance.

FUNCTIONS OF 1xEV-DO SYSTEM

High-reliability Software-upgrade Function

(1) Upgrading without service interruption

Aimed at adding new services and functions to base stations by upgrading software without interrupting services, a software upgrade function — which applies "hardware redundancy exchange" and "handoff between wireless sectors" — has been developed.

The method for performing hardware redundancy exchange is explained schematically in Fig. 4. The backup hardware is first reset and restarted, and then the old software loaded on the backup hardware is renewed. Then, after restarting the backup hardware with the new software, the working hardware and the backup hardware (with the new software) are exchanged. Finally, the old software on the (new) backup hardware (which was the working hardware) is renewed.

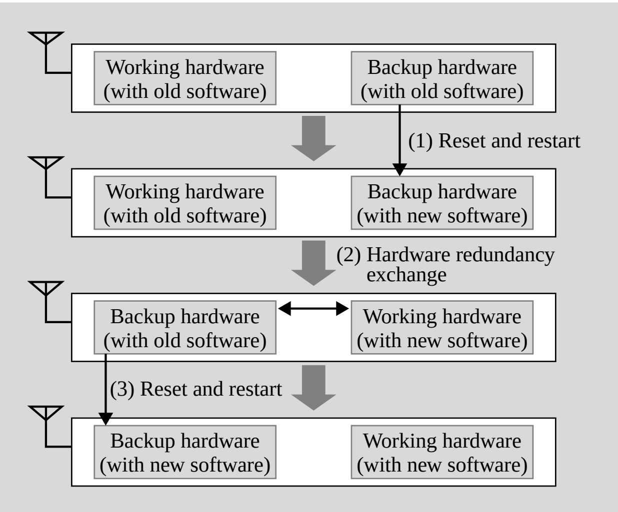

Fig. 4—Software Upgrading Utilizing "Redundancy Switching of Hardware."
By switching over active hardware with backup hardware, services can be upgraded without interruption.

As regards the so-called handoff of wireless sectors, first, the transmission power of specified sectors within plural sectors of a base station is gradually turned down. Then, as the transmission power is decreased, because the radiowave status of another base station in the terminal's line of sight is better, each terminal can be "handed off" to that other base station. The result of this process is to create a situation in which terminals do not exist in specified sectors of a base station. Software in that sector is then upgraded, and all the sectors possessed by that base station are then done in sequence. After that base station has been upgraded, the next one is done in sequence until all base stations have been upgraded.

(2) Duplex management of software

The software inside the base stations is replicated, so even in the unlikely event that a problem occurs in a particular field of the new software, by instantly switching back to the old software, the system is not stopped and services continue without interruption.

(3) Upgrading target software

Since the base-station software is configured from multiple modules, it is easy to upgrade only the modules that require modification remotely from the OMC.

High Reliability Through Redundant Configuration of OMC-RAN

To realize a redundant configuration with the minimum amount of equipment, one backup server is allocated for every *N* number of working servers (where *N* is a maximum of 10). This configuration is

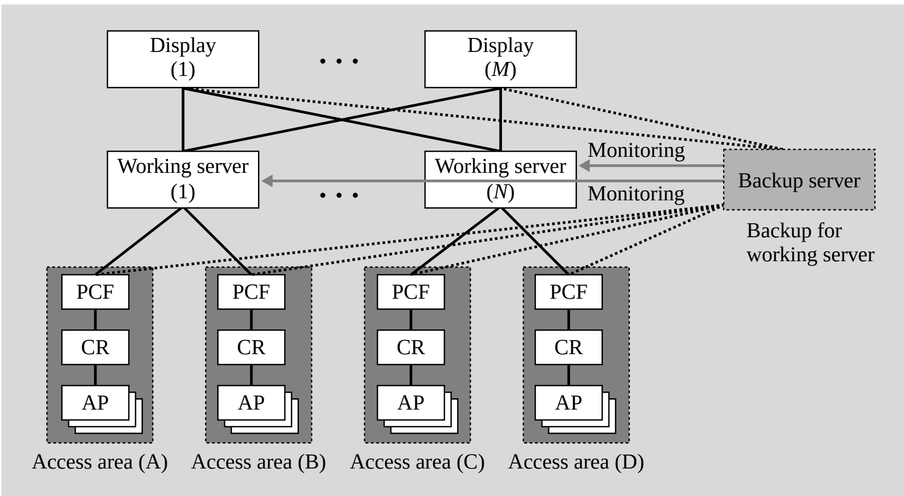

Fig. 5—N+1 Configuration of OMC-RAN.
The backup server monitors the active server and backs it up in the case a fault occurs.

thus referred to as an “*N*+1 backup configuration” (see Fig. 5). The backup server monitors a working server targeted for backup, and in the event that a fault occurs in the working server, it provides a “supervisory control service” (automatic exchange) of the nodes provided by the targeted working server. Moreover, even in the event that a maintenance engineer is needed, the node supervisory control service is provided (manual exchange).

IMPROVEMENT OF ENGINEERABILITY AND MAINTAINABILITY

From the viewpoint of mobile communication providers, providing a high coverage ratio of a population is one of the requirements for acquiring subscribers, and a network configuration on a national scale needs many thousands of base stations. How to set up and maintain such a large amount of equipment after installation in an efficient manner raises the three following issues:

(1) Ensure on-site adjustments are efficient
(2) Simplify training to perform on-site adjustments
(3) Simplify maintenance

As a solution to the issues (1) and (2) above, a testing function using a TAT (test access terminal), a kind of pseudo-terminal, was developed and installed at the EV-DO base station for automatic on-site adjustment. Moreover, since the testing functions are mostly on the maintenance server, a GUI was developed so that they can be executed simply by operating a PC mouse. Utilizing this testing function significantly reduces the working time needed for testing. And since the training time required by an operator is shortened, a large number of operators needed for the engineering work could take part in the training.

To solve the issue (3) above (i.e. simplify maintenance), a remote maintenance network — which can remotely “log in” to any equipment in any region of Japan — was set up. As for this network configuration, especially from the security viewpoint, clients were reassured through discussions. In the case that a fault occurs at any place in the 1xEV-DO hardware, analysis of collected log data, etc. and emergency measures can be executed for the server in question through the remote maintenance network.

CONCLUSIONS

This paper described the characteristics regarding the configuration, functions, engineerability, and maintainability of the 1xEV-DO system developed by Hitachi. From now onwards, applying our amassed experience and technical know-how, we will strive to further contribute to the development of mobile telecommunications.

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