Korea Telecom IMT-2000 Testbed Based on Inter-cell Asynchronous Wideband CDMA

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Abstract

We have worked on two radio interfaces for IMT-2000 testbed systems, one of which is based on inter-cell synchronous code division multiple access (CDMA) and the other is based on inter-cell asynchronous CDMA. Both radio interfaces are designed to accommodate chip rates of 4.096, 8.192, and 16.384 Mcps (chip per second) corresponding to radio frequency (RF) bandwidths of 5, 10, and 20 MHz, respectively. This paper presents the design and implementation of Korea Telecom IMT-2000 testbed which is based on inter-cell asynchronous wideband CDMA. We describe its radio interface and system architecture with a focus on main features of the system such as cell search, soft handover, and power control.

1. Introduction

Korea Telecom has investigated and developed International Mobile Telecommunications-2000 (IMT-2000) testbed systems employing wideband CDMA based on direct-sequence spread-spectrum techniques as their radio interfaces. We have worked on two radio interfaces, one of which is based on inter-cell synchronous CDMA and the other is based on inter-cell asynchronous CDMA. Both radio interfaces are designed to accommodate chip rates of 4.096, 8.192, and 16.384 Mcps corresponding to bandwidths of 5, 10, and 20 MHz, respectively. The two systems have their own advantages and disadvantages relative to each other. The two radio interfaces are somewhat different from Korea IMT-2000 radio transmission technologies (RTT) proposals, namely Global CDMA I [1] and Global CDMA II [2], but many design features are similar.

The two radio interfaces have been implemented in the first and the second phase testbed system, respectively. In the first phase testbed system, we had designed and implemented an inter-cell synchronous CDMA system that has a chip rate of 8.192 Mcps, and that supports wireless communication services of up to 144 kbps. We finished the development of the synchronous CDMA system in August of last year. The services tested in the testbed include 32 kbps voice phone, 128 kbps video phone, wireless Internet service, and user identification module (UIM) applications. The system is configured with four mobile stations (MSs), a base station (BS), a radio network controller (RNC), and an ATM switch. Further details on the first phase system can be found in [3]. And, for more details on the design and implementation of wideband CDMA modem refer to [4].

An inter-cell asynchronous wideband CDMA with a chip rate of 8.192 Mcps has been designed and implemented in the second phase testbed. This testbed consists of four MSs, two BSs, an RNC, and an ATM switch. The system components in the first phase system except radio-related ones such as BS and MS were reused with substitution of protocol software. Same services as in the first phase system have been demonstrated. In addition, soft handover and power control have been implemented and tested in this system.

In this paper, we focus on the second phase system, especially on main features such as cell search, soft handover, and power control. In Section 2, we introduce the Korea Telecom IMT-2000 radio interface and testbed system. Main features of the testbed will be described in Section 3, followed by summary and conclusions in Section 4.

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2. Korea Telecom IMT-2000 Testbed System Overview

A. Radio Interface

The radio interfaces of the first and the second phase system are summarized in Table 1. In this section, we briefly describe the radio interface of Korea Telecom IMT-2000 testbed system, mainly the second phase testbed. In the testbed system, a CDMA system using a chip rate of 8.192 Mcps is implemented, which requires about 10 MHz bandwidth. Frequency division duplex (FDD) is adopted. The carrier frequency of the forward link is 2115 MHz and that of the reverse link is 1890 MHz.

Table 1: Summary of the radio specifications of Korea Telecom IMT-2000 testbed systems.

Items	Phase 1	Phase 2
Multiple Access	DS-CDMA	DS-CDMA
Duplex	FDD	FDD
Chip Rate	1.024/4.096/**8.192**/16.384 Mcps	1.024/4.096/**8.192**/16.384 Mcps
Bandwidth	1.25/5/**10**/20 MHz	1.25/5/**10**/20 MHz
Frame Length	16 ms	10 ms
Channel Coding	Convolutional coding (R=1/2, K=7)	Conv. coding (R=1/2, K=9) for voice traffic RS coding + Conv. coding for data traffic
Channel Structure	FL: Pilot/Sync/Paging/Traffic/Signalling RL: Pilot/Access/Traffic/Signalling	FL: Pilot/Sync/Paging/Traffic/Signalling RL: Pilot/Access/Traffic/Signalling
Spreading Code and Channelization Code	FL: m-sequence (2^{17}) + Walsh (128) RL: m-sequence (2^{17}) + m-sequence (2^{42}) + Walsh	Group pilot: Gold codes (2048 chips) Cell pilot: m-sequence (81920 chips) Data channel: m-sequence (81920 chips) + Walsh (256)
Multirate Concept	Multi-code	Variable spreading factor and/or Multi-code
Inter-cell Synchronization	Synchronous	Asynchronous
Data modulation/ PN Spreading	*FL & RL: QPSK/QPSK	FL & RL: QPSK/QPSK
Detection	FL & RL: Pilot channel assisted coherent detection	FL & RL: Pilot channel assisted coherent detection

* FL: forward link, RL: reverse link

The forward link is composed of Pilot, Sync, Paging, Traffic, and Signalling channels. The forward link pilot channel structure is designed to facilitate the cell search in asynchronous cellular environment in which a group code and a cell code for the cell site are assigned to the in-phase and the quadrature pilot channel, respectively. We use extended Gold codes of period 2048 as group codes and m-sequences of length 81920 that are generated by a common generating polynomial with different initial seeds for different cell sites. The cell code, which has a 10 ms period, is also used as a scrambling code for all forward link data (traffic and signalling) channels in a cell site. This makes the cell search along frame synchronization done in two steps. A more details about the pilot channel structure and cell search are given in Section 3.

Each traffic connection has its own signalling channel. The traffic channel and the signalling channel are multiplexed using different channelization codes, i.e. code division multiplexed, in both the forward and the reverse link. The signalling channel is used for transmitting power control command bit and signalling messages for the corresponding connection. The forward link traffic and the signalling channels originated from a cell site are channelized by spreading with orthogonal variable spreading factor (OVSF) codes, and then scrambled by the m-sequence that is assigned to the cell site. As for forward error correction (FEC), the convolutional coding of rate $r = 1/2$ and constraint length $K = 9$ is adopted for voice traffic. For data traffic, a concatenated coding is applied in which Reed-Solomon code RS(49,41) is used as the inner code and convolutional code of $r = 1/2$ and $K = 9$ as the outer code.

The reverse link consists of Pilot, Access, Traffic, and Signalling channel. The reverse link channels from a mobile station are multiplexed onto I/Q channels and by channelization codes. The multiple access among different mobile stations is achieved by long codes with different time offsets. The pilot channel and the signalling channel are sent on the I channel and the Q channel, respectively, with two different channelization codes. The traffic channel is code-multiplexed with another channelization code and transmitted on both the I and Q channel

To support data rates greater than 128 kbps, multi-code scheme is applied to the both links. For example, to support a service requiring 256 kbps of data rate, traffic data are transmitted on two different 128 kbps code channels in parallel.

B. System Architecture

We have designed and implemented an inter-cell asynchronous CDMA system that has a chip rate of 8.192 Mcps, and that supports wireless communication services of up to 144 kbps. The services tested in the testbed include 32 kbps voice phone service, 128 kbps video phone service, wireless Internet service, and user identification module (UIM) applications.

The testbed consists of four MSs, two BSs, an RNC, and an ATM switch as shown in Figure 1. The BS has an RF transceiver, an analog interface module, a clock and reference signal generation card, and channel cards. Each channel card has wideband CDMA modem and performs baseband signal processing and control functions related with the physical layer. Figure 2 is the top-level block diagram of the channel card.

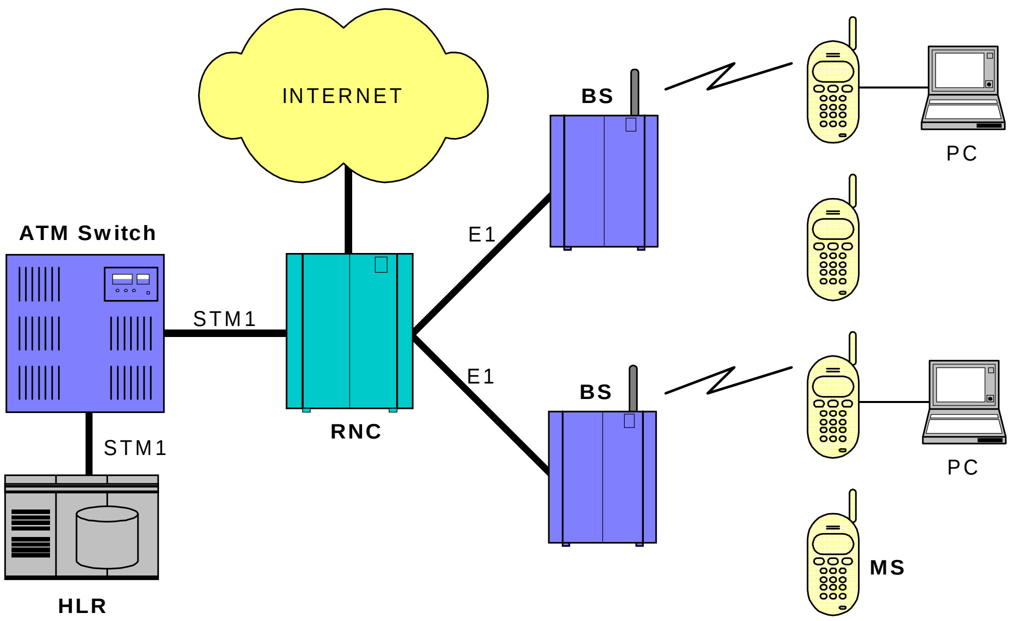

Figure 1: System architecture of Korea Telecom IMT-2000 testbed (inter-cell asynchronous).

In the testbed, most of the signal processing necessary in modulation and demodulation of wideband CDMA signals is carried out in the BS modem and the MS modem which were implemented in FPGA. The BS channel card has two types: one is for the forward link common channels such as Pilot, Sync, and Paging, and the other is for the user traffic channel. The channel card for the user traffic channel is designed to handle one traffic channel and the corresponding signalling channel in both the forward and the reverse link which corresponds to one mobile connection in this testbed. The transmit part of the BS modem includes Traffic Tx, Signalling Tx, Tx Channel Combiner, and Tx FIR. And, the receive part consists of Searcher, two Demodulating Fingers, Symbol Combiner, and Rx Buffer. Each component in the receive part was designed to process two receiving channels, a reverse traffic channel and its corresponding signalling channel, in parallel. The MS modem was designed similarly.

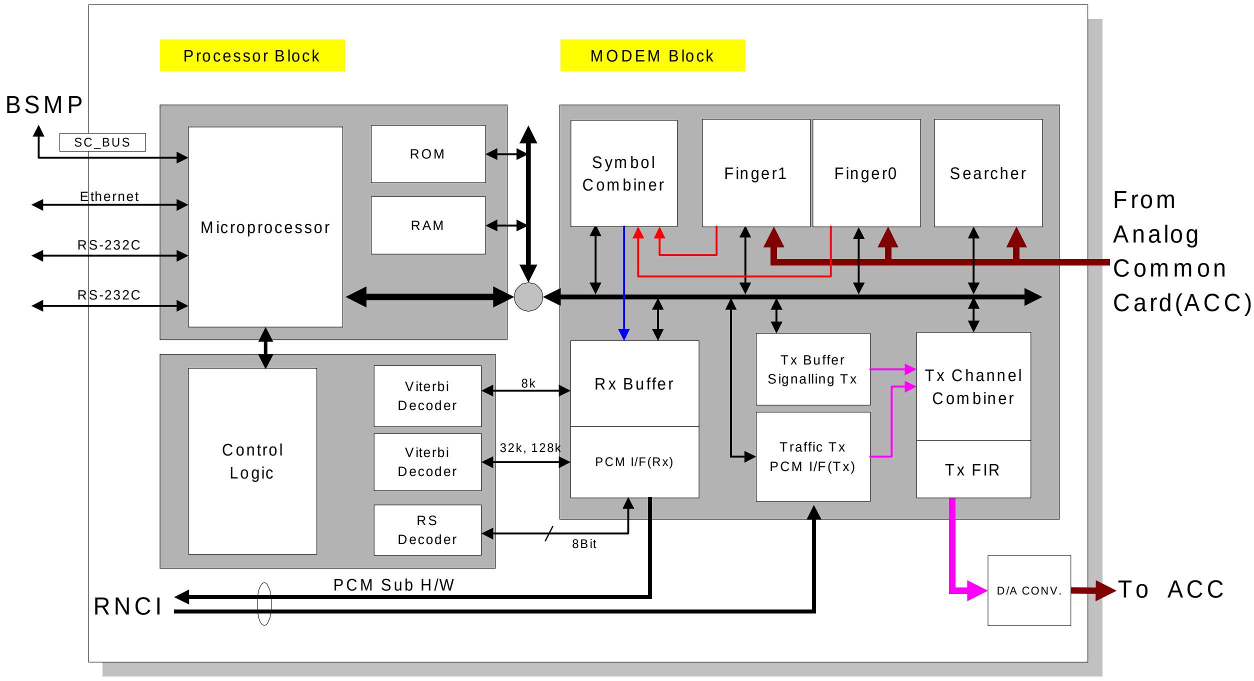

Figure 2: Top-level block diagram of BS channel card.

3. Physical Layer Main Features

A. Cell Search

For inter-cell asynchronous operation, a new pilot code assignment scheme, namely I/Q multiplexed code assignment, is proposed to minimize the cell search time in which a group code is assigned to the in-phase (I) pilot channel and a cell-specific code assigned to the quadrature (Q) pilot channel [5]. Every cell in the cellular system are divided into a number of groups with same size, and hence cell search is accomplished by first detecting a group code assigned to the I channel of the strongest pilot signal and then finding a cell-specific code assigned to the corresponding Q channel. We use extended Gold codes of length 2048 as group codes and truncated m-sequences of length 81920 as cell-specific codes. Frame structure of the pilot channel is shown in Figure 3. Because all forward link data channels in a cell are also scrambled by the same m-sequence as Q pilot code of the cell, frame synchronization is also achieved in the cell search procedure.

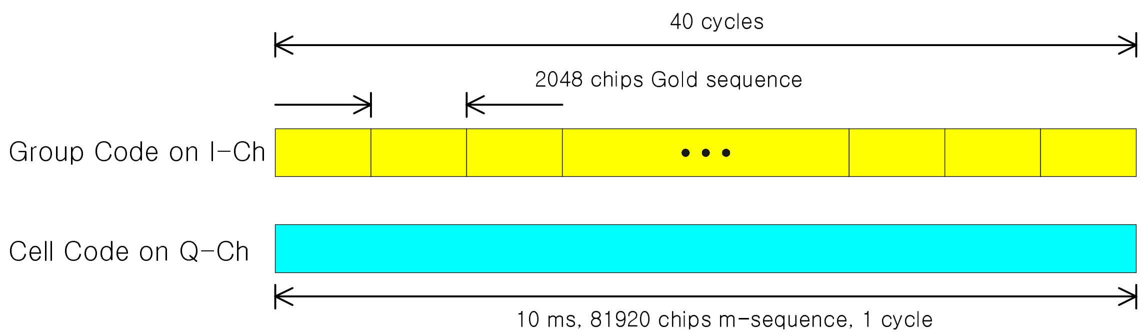

Figure 3: I/Q multiplexed pilot code assignment for inter-cell asynchronous operation.

Based on the I/Q multiplexed code assignment as above, cell search and frame synchronization can be accomplished in two steps:

1. Group code identification – acquire a group code on the I pilot channel and slot synchronization with a resolution corresponding to 2048 chips.
2. Cell code identification and frame synchronization – acquire a cell-specific code on the Q pilot channel and the frame synchronization of a long code assigned to data channels in a cell site. This can be done by correlating the received signal with all possible cell codes corresponding to the group code at the 40 possible time positions. The group code and the possible time positions are obtained from step 1.

Simulation results of this cell search method in a typical cellular environment with Rayleigh-fading channel model can be found in [6].

B. Handover

One of specific features in inter-cell asynchronous CDMA systems is handover among two or three base station that are operating in their own time with time offsets between them. In soft handover, the forward link signals are combined in the Rake receiver of the mobile station and in the reverse link combining of signals is done in the network. The frame synchronization among forward link connections involved in soft handover is most critical in implementing soft handover. In the testbed, we accomplished this in two folds: first a new base station adjusts the Tx frame boundary to align to the frame from the old base station in symbol time resolution; and more precise time alignment is achieved in Rake combining procedure in the mobile station. The Tx frame timing adjustment in the base station to help the frame synchronization in the mobile station during soft handover facilitates the implementation of Rake receiver of the mobile station.

The mobile station continuously monitors the pilot channels from neighboring cells, the list of which is broadcast from the network. When a new additional base station is included in the active set, the mobile station determines the time offset between the frames from the old and the new base station by measuring the code phases of the corresponding pilot channels. And, then this information is sent to the old base station with the handover message so that a new base station can adjust the transmission timing of the new connection in the forward link. As mentioned above, the Tx frame timing adjustment is done in symbol time unit, i.e., 256 chips, in order to maintain the orthogonality among the forward data (traffic and signalling) code channels.

C. Power Control

The testbed employs fast closed-loop power control for the reverse link. The power control rate is 1.6 kHz. For the close-loop power control, the base station constantly observes the received signal strength, which is accomplished by measuring the signal power of the desired mobile station's pilot. The base station receiver compares the signal power with a target value and determines power control commands that are transmitted on the corresponding forward signalling channel. The mobile station demodulates the power control command bits and controls the Tx power amplifier accordingly through pulse density modulation (PDM) digital-to-analog interface. The target power values are controlled by an outer power control loop. This outer loop measures the link quality, frame error rate (FER) in our case, and adjusts the target power values according to the quality of service of the connection.

Open-loop power control is used in the random access. The path loss of the reverse link is estimated from that of the forward link with an assumption that there is some correlation between the two links.

For the forward link power control, the mobile station periodically sends link quality indicators for the received frames. We use FER as the link quality indicator from which the network determines the Tx Channel Gain for the connection. The Tx Channel Gain is adjusted digitally in the base station modem, which is equivalent to adjusting the allocation of the transmit power to the corresponding connection because an RF amplifier is shared among all the forward transmit channels.

4. Summary and Conclusion

Korea Telecom IMT-2000 testbed that is based on inter-cell asynchronous wideband CDMA was explained about its radio interface and system architecture. The testbed has a chip rate of 8.192 Mcps and supports wireless communication services of up to 144 kbps such as 32 kbps voice phone service, 128 kbps video phone service, and 128 kbps wireless Internet service. We also described main features of the system such as cell search, soft handover, and power control. From this year, we are carrying on a continuing project the main objective of which is developing wideband CDMA technologies necessary to support a likely IMT-2000 RTT, 3GPP UTRA radio interface.

Acknowledgement

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