Distance-Based Code-Collision Control Scheme Using Erasure Decoding in Orthogonal Code Hopping Multiplexing

Chong Woon Ryu*, Bang Chul Jung†, Sung Ho Moon‡, and Dan Keun Sung‡
*Network Service Development Team, Network Laborator, KTF 6F,
1010, Madu-dong, ilsandong-gu Koyang-si, Kyunggido, KOREA
Email: happylyu@ktf.com
†CNR Lab., School of EECS., KAIST, 373-1,
Guseong-dong, Yuseong-gu, Daejeon, 305-701, KOREA
Email: bcjung@cnr.kaist.ac.kr; dksung@ee.kaist.ac.kr
‡LG R&D Complex 533, Hogye-1dong, Dongan-gu, Anyang-shi,
Kyungki-do, 431-080, KOREA
Email: msungho@lge.com

***Abstract*— Orthogonal Code Hopping Multiplexing (OCHM) [1][2] was developed to accommodate more downlink orthogonal channels than the number of orthogonal codewords through statistical multiplexing. Therefore, code-collisions may occur due to random code hopping patterns. The conventional code-collision control schemes are synergy and perforation. In this paper, we propose a distance-based code-collision control scheme in OCHM. The proposed scheme utilizes the conventional synergy scheme when all of the code-colliding symbols are identical. However, a base station (BS) selects a symbol which the nearest mobile station (MS) among code-colliding MSs wants to receive and transmits it in downlink when any of the code-colliding symbols is different from others. This scheme yields better performance at the nearest MS from BS among code-colliding MSs. MSs except the nearest MS receive the symbol with much smaller amplitudes due to different path losses. Therefore, the performance of MSs except the nearest MS is not degraded, compared with that of the conventional perforation scheme.**

I. INTRODUCTION

Bursty data traffic has rapidly increased in wireless communication systems. From this trend, data traffic will be expected to be dominant in future wireless systems. Furthermore, there is more downlink traffic than uplink traffic. Several high speed downlink systems have been proposed to provide this asymmetric data traffic in wireless link.

High speed downlink packet access (HSDPA) has been developed within 3GPP framework. HSDPA provides downlink peak data rates up to 10Mbps and significantly reduces downlink transmission delay. In order to achieve high data rate transmission, several schemes have been proposed including adaptive modulation coding (AMC), hybrid automatic repeat request (HARQ), fast cell selection (FCS), and multiple-input multiple-output (MIMO) antenna processing.

The cmda2000 1xEV-DO standard provides a bandwidth efficient and high-speed wireless data service by supporting various data rates according to given channel conditions in both uplink and downlink. The data rates are determined by using feedback information from receiver. This system provides only data traffic using time division multiplexing for downlink.

Orthogonal code hopping multiplexing (OCHM) [1][2] is another approach for efficiently supporting packet services based on statistical multiplexing. The various fields on OCHM have been studied such as radio resource managements [3][4], antenna technologies [5], channel coding [6], and symbol collision mitigation method [7].

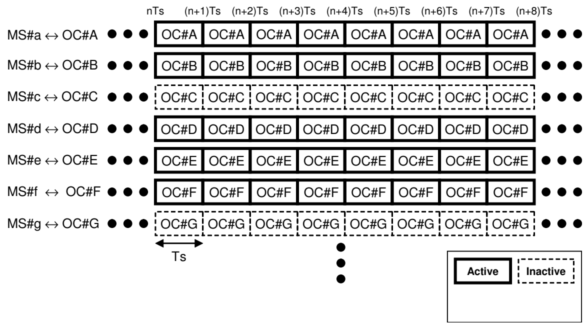
In the OCHM scheme, code-collisions may occur due to random code hopping patterns. Since these code-collisions degrade system performance, OCHM requires a code-collision control scheme such as synergy and perforation [2]. Such a conventional code-collision control scheme did not consider path loss based on the distance from Base Station (BS). If a BS selects a symbol which the nearest mobile station (MS) among code-colliding MSs wants to receive and transmits it with a controlled signal level in downlink when any of the code-colliding symbols is different from others, the MSs except the nearest MS receive the symbol with much smaller amplitudes due to path loss. These smaller signal amplitudes are erased by an erasure decoding scheme at a receiver. Nevertheless, the nearest MS receives the symbol that it wants to receive. Using this property, we propose an enhanced code-collision control scheme.

This paper is organized as follows: We introduce OCHM and the conventional code-collision control scheme in Section II. Our proposed code-collision control scheme is described in Section III. The performance of the proposed scheme is evaluated in terms of the required Eb/No for 1% frame error rate (FER) by simulation in Section IV. Finally, conclusions are presented in Section V.

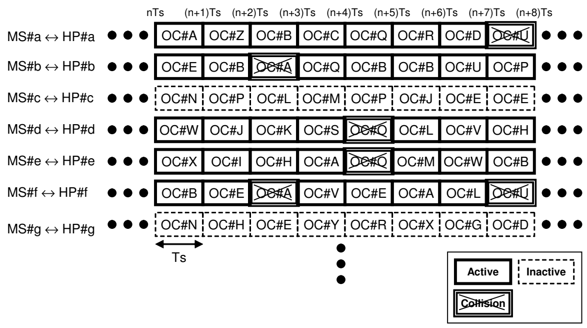
II. BACKGROUND

A. Orthogonal Code Hopping Multiplexing (OCHM)

In the conventional CDMA, which is called orthogonal code division multiplexing (OCDM), maximum N_{OC} connections can be supported in a single-code transmission environment where N_{OC} denotes the number of codewords. An attempt for the (N_{OC}+1)-th connection is not permitted even though some connections have long inactive periods. This waste is

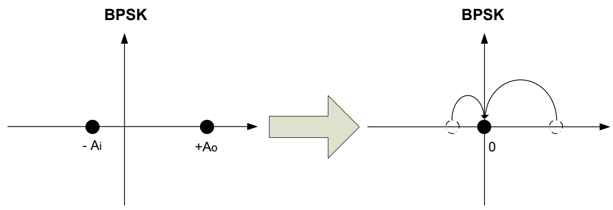


(a) Orthogonal Code Division Multiplexing (OCDM)

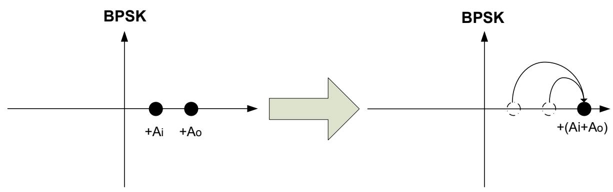


(b) Orthogonal Code Hopping Multiplexing (OCHM)

Fig. 1. Orthogonal Code Division/Hopping Multiplexing (OCDM/OCHM)



(a) Perforation



(b) Synergy

Fig. 2. Conventional Code-Collision Control Scheme

much severer for packet-based services than voice service. Scheduling-based systems can solve this channel inefficiency problem. However, they can not support many simultaneous connections due to scheduling complexity and additional signaling overheads. OCHM is a statistical multiplexing scheme for highly utilizing the inactive period without additional signaling overheads.

System capacity of 2G and 2.5G CDMA systems is typically limited by power or interference, which is called an interference(power)-limited situation, because major target services are based on voice with relatively high activity factors of 0.4-0.5. However, beyond-3G wireless systems will encounter a code-limited situation due to low user channel activities of data users. Moreover, advanced physical transmission technologies, such as smart antenna and low density parity check (LDPC) code, can reduce the required received E_b/N_0 and change the interference(power)-limited situation into a code-limited situation. Therefore, OCHM, which makes it possible to accommodate more downlink channels than the number of orthogonal codewords, is valuable for future wireless systems.

Figs. 1(a) and 1(b) show the basic operations of OCDM and OCHM. In the OCDM (Fig. 1(a)), each modulation symbol is spread by a specific orthogonal codeword (OC) during modulation symbol time, T_s. During a call or a session of each MS, an orthogonal codeword allocated to the MS is maintained. The MSs indexed from #a to #g maintain only one of the orthogonal codewords indexed from #A to #G regardless of the inactive periods for MS#c and MS#g. Thus, orthogonal codeword resources allocated to MS#c and MS#g are wasted.

On the other hand, OCHM allows to change the orthogonal codewords for every modulation symbol time T_s and to multiplex more MSs than the number of orthogonal codewords, as shown in Fig. 1(b). For example, MS #f changes an orthogonal codeword for each modulation symbol based on a hopping pattern (HP) indexed by #f. A variable MS-specific hopping pattern can be generated based on an MS identifier (ID), such as an electronic serial number (ESN) at an initial call setup period. From the random hopping of orthogonal codewords, BS can multiplex more downlink channels than the number of orthogonal codewords. However, collisions among codewords are inevitable for higher utilization of orthogonal codewords. A hopping pattern collision, which can be called a code-collision, occurs when two or more downlink channels utilize the same orthogonal codeword in a given symbol time. Fortunately, a BS can monitor all information of downlink channels. The BS compares each channel to the others during multiplexing process for finding which symbols collide with each other, and it controls code-collisions before transmitting.

B. Conventional Code-Collision Control Scheme in OCHM

When a code-collision occurs among the hopping patterns of active downlink channels, a comparator and controller in the transmitter perform one of the following two operations: 1) If a negative-code-collision occurs, then none of the data symbols colliding during a symbol time are transmitted. This scheme is called *perforation* as shown in Fig. 2(a) where A_i

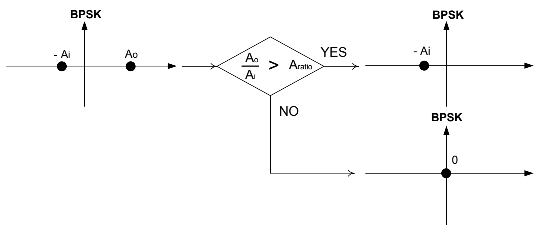


Fig. 3. Proposed Negative-Code-Collision Control Scheme in OCHM

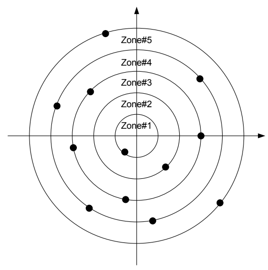


Fig. 4. User Distribution in a Cell

and A_o denote the transmission symbol amplitudes at a BS for MS#i and MS#o, respectively. The transmission amplitude during the symbol time in negative-code-collision is zero for all related channels. Regardless of perforated symbols, the channel decoder in the receiver of the corresponding MS can recover the transmitted data with a high probability if the number of perforated data symbols in a channel-encoded block (frame) is less than a threshold. 2) If a positive-code-collision occurs, then all the data symbols with collisions are transmitted without perforation. Although the transmission signal amplitude assigned to each related MS is not changed during the symbol time, the transmission signal amplitude of the orthogonal codeword during the symbol time is the sum of the signal amplitudes assigned for all of the corresponding downlink channels. This scheme is called *synergy*, as shown in Fig. 2(b). The modulation symbols spread by the same orthogonal code word are illustrated as a double-lined box in Fig. 1(b)

III. Proposed Code-Collision Control Scheme Considering Distance in OCHM

In OCHM, code-collisions may occur due to random code hopping. To control such code-collisions, OCHM requires a code-collision control scheme. In the conventional negative-code-collision control scheme such as perforation, path loss according to the distance from BS is not considered. Although a BS transmits the symbol that the nearest MS among the code-colliding MSs wants to receive in downlink for negative-code-collisions, Other MSs receive the correct or incorrect symbol with relatively smaller amplitudes due to path losses.

We assume that MS#i is nearer to the BS than any other MSs among code-colliding MSs and MS#o is next. If a BS transmit symbol that MS#i wants to receive for negative-code-collision and path loss is considered only without AWGN, R_o is assumed as follows:

$$R_o = \left\{ \frac{d_i}{d_o} \right\}^2 \cdot R_i. \tag{1}$$

where R_o and R_i denotes the amplitudes of received symbol by MS#o and MS#i, respectively, d_o and d_i is distance from the BS to MS#o and MS#i, respectively. If difference between d_i and d_o are enough large, code-colliding MSs except MS#i received the symbol with amplitude of nearly zero such as conventional negative-code-collision scheme. However, MS#i receives the correct symbol with the amplitude that it wants to receive.

Utilizing this property, we propose an enhanced code-collision control scheme considering path loss as explained above. The proposed scheme modifies the perforation scheme for negative-code-collision and uses the conventional synergy scheme for positive-code-collisions. Fig. 3 illustrates the proposed negative-code-collision control scheme where A_i and A_o denote the transmission symbol amplitudes at a BS for MS#i and MS#o, respectively. A_{ratio} is decision threshold to apply proposed negative-code-collision control scheme. If $\frac{A_o}{A_i}$ is bigger than A_{ratio}, proposed scheme is applied. That is, a BS transmits the symbol with an amplitude of A_i to colliding MSs. However, if $\frac{A_o}{A_i}$ is not bigger than A_{ratio}, the BS transmits nothing in downlink such as conventional scheme.

IV. Simulation Result

A simulation environment is described as follows:

- Data Modulation: BPSK
- Wireless channel: AWGN
- Length of a frame : 1024bits
- Code rates: 1/3
- Channel coding: Turbo codes [9]
- Decoding algorithm : Max-Log-MAP

An ideal power control scheme is assumed. We first consider BPSK. However, simulation results can be applied to QPSK because QPSK can be characterized as two orthogonal BPSK channels. Wireless channels are assumed to experience AWGN. No specific code hopping patterns are designated and random hopping patterns are considered, and thus, positive-code-collisions and negative-code-collisions occur randomly with the same probability. The distribution of MSs is uniform in a cell. A cell is divided into 5 zones and all of the MSs are assumed to be located at the edge of each zone, as shown in Fig. 4.

Fig. 5 - 8 illustrate the required E_b/N_o performance of the conventional and the proposed code-collision control schemes in a 1% FER requirement for varying the collision probability in an AWGN channel. The code rate is fixed to 1/3. Since the proposed scheme is for the nearest MS among code-colliding MSs from a BS in a cell, we can observe the significant FER performance enhancement in the zone near the BS. When the collision probability is 0.4 and A_{ratio} is 3.0, the reduced E_b/N_o is approximately 2dB in Zone 1 and There is no performance degradation in Zones 4 and 5.

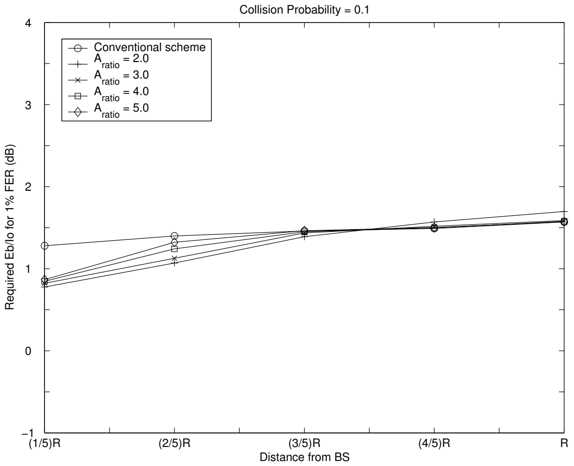


Fig. 5. Simulation Result for Collision Probability of 0.1

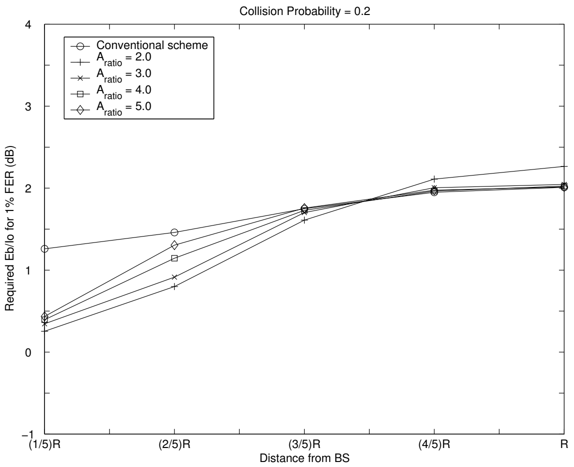


Fig. 6. Simulation Result for Collision Probability of 0.2

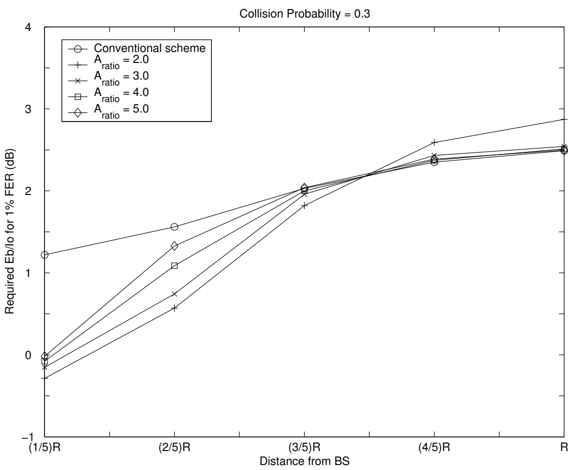


Fig. 7. Simulation Result for Collision Probability of 0.3

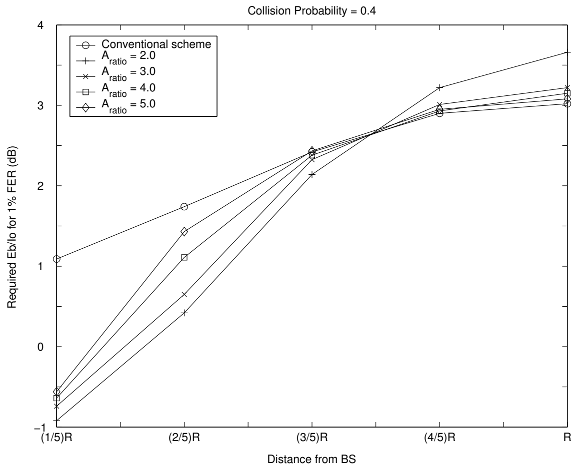


Fig. 8. Simulation Result for Collision Probability of 0.4

V. Conclusions

In the OCHM system, code-collisions may occur because of random code hopping patterns. We propose an enhanced code-collision control scheme to control such code-collisions more efficiently. The simulation results show that the proposed scheme saves the required energy more, compared with the conventional code-collision control scheme.

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