TDD ratio estimation scheme for WiBro system with flexible TDD frame structure

Eu-Suk Shim, Young-Il Kim, and Won Lyu

Electronics and Telecommunications Research Institute,
218 Gajeongno, Yuseong-gu, Daejeon, 305-700, Korea
{shimeu,yikim,wlyu}@etri.re.kr

Abstract. Since TDD (time-division duplex) operation provides several benefits including the flexibility to partition downlink and uplink ratio, several communication systems (such as long term evolution (LTE), Mobile worldwide interoperability for microwave access (m-WiMAX) etc) are operated with TDD. In the any systems mentioned above, it is hard to change the TDD ratio directly because the TDD ratio is received as the form of MAC message. Hence, if system want to change the TDD ratio, there are at least 2-frames time is needed to reassign the TDD ratio and receive MAC message including the information of the TDD ratio. This paper suggests TDD ratio estimation scheme based on the modified m-WiMAX preamble is designed for the purposed of fast TDD ratio tracking. The simulation results show that the proposed method can provide fast tracking of TDD ratio.

Key words: m-WiMAX, OFDMA, TDD, estimation

1 Introduction

Mobile worldwide interoperability for microwave access (m-WiMAX) is a commercial IEEE 802.16e based orthogonal frequency division multiple access (OFDMA) system [1].

The 802.16e physical (PHY) can support both time-division duplex (TDD) and frequency-division duplex (FDD). Since TDD operation provides several benefits including the flexibility to partition downlink and uplink resources as a function of asymmetric traffic demand and better channel reciprocity to support closed loop performance enhancing techniques, the m-WiMAX can support a wide range of data services and applications with various quality of service (QoS) requirements. Furthermore, transceiver complexity/cost is reduced since duplexers are no longer needed and performance is improved with the elimination of duplexer-related losses. More importantly, most initial products and deployment scenarios are currently focusing on TDD operation [2][3]. Fig. 1 shows the example of the TDD frame structure which are used by 802.16j based on 802.16e specification.

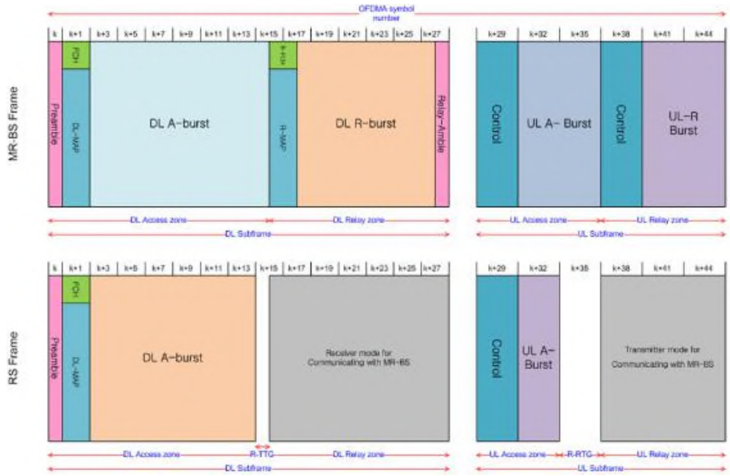

Fig. 1. Example of the TDD frame structure

One of disadvantage of the TDD operation is that it is hard to use the modified information of the downlink/uplink ratio immediately at the PHY layer because the information of the downlink/uplink ratio is transmitted by the MAP messages which are processed by media access control (MAC) layer. Hence, at least 2-frames are needed to receive the TDD information and modify that at the PHY layer.

In this paper, a TDD ratio estimation method using the 802.16e preamble is proposed to easily and immediately update the information of TDD ratio to the PHY layer.

The rest of the paper is organized as follows. Next section describes the preamble signal of 802.16e PHY and section 3 introduces the proposed scheme for the estimation of the downlink/uplink ratio. In section 4, we then present simulation results illustrating the probability of failure of the proposed method and we conclude this paper with Section 5.

2 802.16e Preamble Signal

The first symbol of the DL transmission of 802.16e based system is the preamble that is used for frame synchronization, channel state estimation, received signal strength, and signal-to-interference-plus-noise ratio (SINR) estimation. There are three differen preamble carrier sets are defined for each FFT size. Each carrier sets differs in the allocation of subcarriers. Those subcarriers are modulated using a boosted BPSK modulation with a specific pseudo-noise (PN) code [1].

The preamble carrier sets are defined as follows

$$S_I = I + 3k \tag{1}$$

where I is the designating number of the preamble carrier set indexed 0, 1, and 2 and k is a running index which are 0-567 for 2K-FFT, 0-283 for 1024-FFT, 0-142 for 512-FFT, and 0-35 for 128-FFT. Each segment uses a preamble composed of a single carrier-set in the following manner:

- Segment 0, 1, and 2 use preamble carrier set 0, 1, and 2, respectively. Each segment eventually modulates each third subcarrier.

The pilots in the DL preamble are modulated according to following equation.

$$\Re(X(k)) = 4 \times \sqrt{2} \times \left(\frac{1}{2} - W(k)\right), \quad \Im(X(k)) = 0 \tag{2}$$

where $\Re(x)$ and $\Im(x)$ denote the real and imaginary parts of x and $W(k)$ is the PN code of k-th pilot subcarriers.

3 Estimation method of the TDD downlink/uplink ratio

The concept of the proposed TDD ratio transmition/estimation method is using the pilot locations of m-WiMAX preamble which are modified by transmitter to carry the TDD ratio information.

The procedure of the proposed TDD ratio transmition/estimation method is described as follows:

- *At the transmitter side*:
  1. Decide the number of TDD ratios which are used by system
  2. Decide the pilot reallocation method
  3. Relocate the pilot subcarrier based on the pilot reallocation method and corresponding TDD ratio
- *At the receiver side*:
  1. Receive the preamble
  2. Estimate the TDD ratio using the relocated pilot symbols
  3. Recover the pilot locations for Segment and IDcell estimation

Before the receiver recovers the pilot location, the receiver estimate the TDD downlink/uplink ratio using the pilots of preamble which are relocated by transmitter. The TDD ratio estimation exploits the pilot subcarrier power level. The basic idea is estimating the power of all possible pilot subcarrier sets which are decided by corresponding TDD downlin/uplink ratio. All possible pilot indices and corresponding TDD ratios are already known at the receiver side. The estimation can be expressed as

$$\hat{i} = \arg\max_i \sum_{k \in S_i} |Y(k)|^2, \quad i = 0,1,2,\cdots L-1 \tag{3}$$

where S_i is the set of indices of ith TDD ratio information, L is the number of TDD downlink/uplink radios, and $Y(k)$ is the received signal of the OFDM symbol in frequency domain at k-th subcarrier.

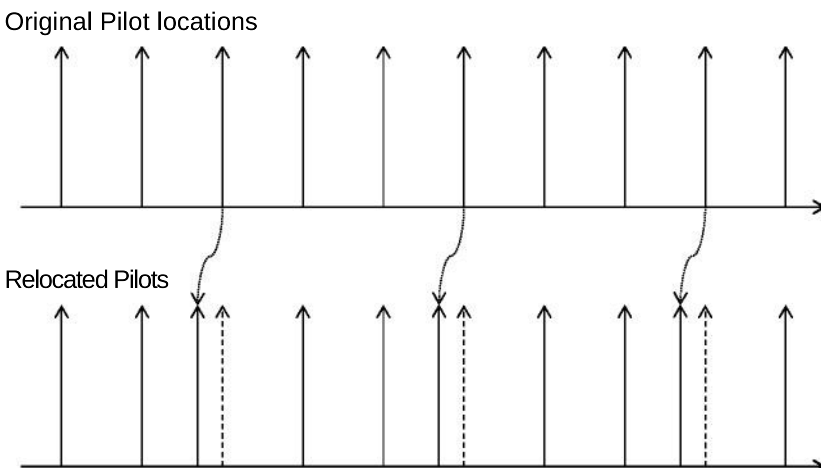

Fig. 2. The conceptual illustration of pilot relocation method

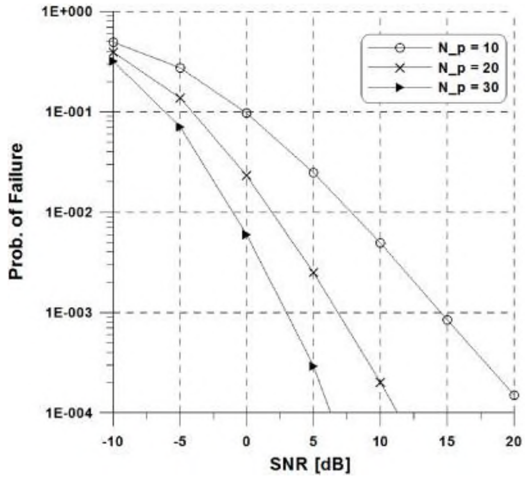

Fig. 3. Probability of failure of the proposed TDD ratio estimation method

Table 1. Simulation Parameters

Parameter List	Value
FFT size N	1024
Size of guard interval N_g	128
System bandwidth	10MHz
Carrier frequency	2.5GHz
Channel	Urban (60Km/h)

4 Simulation Results

In order to check the algorithm presented in the previous section, the proposed TDD estimation method is simulated. In this simulation, the system parameters are based on the m-WiMAX based on 802.16.e specification [1]. Therefore, the OFDM system with N = 1024 and N_g = 128 is considered. And, the number of TDD ratios is restricted by L = 5. Here, it is also assumed that the urban channel model [4]. More details of system and channel parameters are listed in Table 1.

Fig. 3 presents the probability of failure of TDD ratio estimator, defined by $\Pr\left\{\hat{i} \neq i\right\}$ under the urban channel condition. In the following examples, it is assumed that the fractional frequency offset (FFO) and timing error are perfectly corrected at the receiver. From this figure, it can be found that the performance of the system highly depends on the number of used pilot subcarriers and the proposed estimator is well operated under the simulation condition.

5 Conclusion

TDD operation provides several benefits including the flexibility to partition downlink and uplink resources as a function of asymmetric traffic demand and better channel reciprocity. In this paper, we proposed a TDD ratio estimation method using the modified preamble symbol. The estimation of TDD ratio at the PHY layer provides fast TDD ratio change and tracking. It has been found by extensive simulations that the proposed estimation technique is well operated at the m-WiMAX system.

Acknowledgment

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