Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Uplink CQI channel for OFDMA PHY**
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Re:	This contribution is made for comment #221.
Abstract	Scheme for uplink CQI channel for OFDMA PHY is proposed.
Purpose	Adoption of proposed CQI channel for OFDMA PHY into 802.16-REVd
Notice	
Release	
Patent Policy and Procedures	

Introduction

In the current draft standard IEEE 802.16REVd/D4, there is a coding and modulation scheme of a fast feedback channel using uplink PUSC subchannel. But the same scheme cannot be applied to the optional uplink PUSC subchannel because the performance is not so good due to the less number of tones of optional uplink PUSC subchannel. So efficient coding and modulation scheme should be designed.

In this contribution, the new modulation and coding scheme for fast feedback channel (or CQI(Channel Quality Indicator) channel) using the optional uplink PUSC subchannel is proposed to improve the CQI performance. The subchannel structure for CQI channel is 6 pieces of 3x3 uplink tile. The CQI channel transmission consists of channel encoding over 9-ary alphabet and 9-ary orthogonal modulation for non-coherent reception. Simulation results are provided to exhibit the performance gain of the proposed CQICH scheme.

Suggested Change to the Standard

INSERT '8.4.10. Uplink Control channels' next to '8.4.9 Channel Coding'.

8.4.10 Uplink control channels

The CQI(Channel Quality Indicator) is periodically reported by the access terminal in the uplink. There are two modes of operation of the CQI channel : Full CQI feedback mode for Diversity user and Differential CQI mode for AMC user. In the Full CQI feedback mode for diversity user, the 5-bit average C/I of Downlink preamble is sent. In the differential C/I feedback mode for AMC user, 5-bit differential C/I feedback for selected bands is sent by access terminal. One CQI channel occupies one subchannel (6 pieces of 3x3 uplink tile).

8.4.10.1 CQI channel encoding

The CQI is represented by 5-bit symbol according to the channel SNR measured in the access terminal. The CQI information is either the full CQI value or the differential CQI value. These 5 bits are encoded into a length 6 codeword over 9-ary alphabet for the error protection as shown in Table 1.

Table 1- CQI Symbol and Codeword Assignments

Channel SNR [dB]	CQI symbol	CQI codeword
-10.0 to -9.0	00000	0 0 0 0 0 0
-9.0 to -8.0	00001	1 1 1 1 1 1
-8.0 to -7.0	00010	2 2 2 2 2 2
-7.0 to -6.0	00011	3 3 3 3 3 3
-6.0 to -5.0	00100	4 4 4 4 4 4
-5.0 to -4.0	00101	5 5 5 5 5 5
-4.0 to -3.0	00110	6 6 6 6 6 6
-3.0 to -2.0	00111	7 7 7 7 7 7
-2.0 to -1.0	01000	8 8 8 8 8 8
-1.0 to 0.0	01001	5 8 6 2 7 4

0.0 to 1.0	01010	3 6 7 0 8 5
1.0 to 2.0	01011	4 7 8 1 6 3
2.0 to 3.0	01100	8 2 0 5 1 7
3.0 to 4.0	01101	6 0 1 3 2 8
4.0 to 5.0	01110	7 1 2 4 0 6
5.0 to 6.0	01111	2 5 3 8 4 1
6.0 to 7.0	10000	0 3 4 6 5 2
7.0 to 8.0	10001	1 4 5 7 3 0
8.0 to 9.0	10010	8 6 2 7 4 3
9.0 to 10.0	10011	6 7 0 8 5 4
10.0 to 11.0	10100	7 8 1 6 3 5
11.0 to 12.0	10101	2 0 5 1 7 6
12.0 to 13.0	10110	0 1 3 2 8 7
13.0 to 14.0	10111	1 2 4 0 6 8
14.0 to 15.0	11000	5 3 8 4 1 0
15.0 to 16.0	11001	3 4 6 5 2 1
16.0 to 17.0	11010	4 5 7 3 0 2
17.0 to 18.0	11011	6 2 7 4 3 1
18.0 to 19.0	11100	7 0 8 5 4 2
19.0 to 20.0	11101	8 1 6 3 5 0
20.0 to 21.0	11110	0 5 1 7 6 4
21.0 to 22.0	11111	1 3 2 8 7 5

8.4.10.2 CQI channel modulation

The CQI channel is orthogonally modulated. After CQI encoding, the CQI codeword symbols are entered to the orthogonal modulator. Each code symbol of the CQI codeword makes one orthogonal modulation pattern. The modulation pattern of the n-th CQI channel, comprised of 9 symbols $M_{n,9k}^{CQI}$, $M_{n,9k+1}^{CQI}$, … , $M_{n,9k+8}^{CQI}$, is made from the k-th code symbols of the n-th CQI channel codeword $C_{n,k}^{CQI}$ as shown in Table 3.

Table 3- Orthogonal Modulation for CQI channel

CQI codeword, $C_{n,k}^{CQI}$	$M_{n,9k}^{CQI}, M_{n,9k+1}^{CQI}, \ldots, M_{n,9k+8}^{CQI}$
0	1 1 1 1 1 1 1 1 1
1	$1\ \exp\left(j\frac{2\pi}{9}\right)\ \exp\left(j\frac{4\pi}{9}\right)\ \exp\left(j\frac{6\pi}{9}\right)\ \exp\left(j\frac{8\pi}{9}\right)\ \exp\left(j\frac{10\pi}{9}\right)$

	$\exp\left(j\frac{12\pi}{9}\right)$ $\exp\left(j\frac{14\pi}{9}\right)$ $\exp\left(j\frac{16\pi}{9}\right)$
2	1 $\exp\left(j\frac{4\pi}{9}\right)$ $\exp\left(j\frac{8\pi}{9}\right)$ $\exp\left(j\frac{12\pi}{9}\right)$ $\exp\left(j\frac{16\pi}{9}\right)$ $\exp\left(j\frac{2\pi}{9}\right)$ $\exp\left(j\frac{6\pi}{9}\right)$ $\exp\left(j\frac{10\pi}{9}\right)$ $\exp\left(j\frac{14\pi}{9}\right)$
3	1 $\exp\left(j\frac{6\pi}{9}\right)$ $\exp\left(j\frac{12\pi}{9}\right)$ 1 $\exp\left(j\frac{6\pi}{9}\right)$ $\exp\left(j\frac{12\pi}{9}\right)$ 1 $\exp\left(j\frac{6\pi}{9}\right)$ $\exp\left(j\frac{12\pi}{9}\right)$
4	1 $\exp\left(j\frac{8\pi}{9}\right)$ $\exp\left(j\frac{16\pi}{9}\right)$ $\exp\left(j\frac{6\pi}{9}\right)$ $\exp\left(j\frac{14\pi}{9}\right)$ $\exp\left(j\frac{4\pi}{9}\right)$ $\exp\left(j\frac{12\pi}{9}\right)$ $\exp\left(j\frac{2\pi}{9}\right)$ $\exp\left(j\frac{10\pi}{9}\right)$
5	1 $\exp\left(j\frac{10\pi}{9}\right)$ $\exp\left(j\frac{2\pi}{9}\right)$ $\exp\left(j\frac{12\pi}{9}\right)$ $\exp\left(j\frac{4\pi}{9}\right)$ $\exp\left(j\frac{14\pi}{9}\right)$ $\exp\left(j\frac{6\pi}{9}\right)$ $\exp\left(j\frac{16\pi}{9}\right)$ $\exp\left(j\frac{8\pi}{9}\right)$
6	1 $\exp\left(j\frac{12\pi}{9}\right)$ $\exp\left(j\frac{6\pi}{9}\right)$ 1 $\exp\left(j\frac{12\pi}{9}\right)$ $\exp\left(j\frac{6\pi}{9}\right)$ 1 $\exp\left(j\frac{12\pi}{9}\right)$ $\exp\left(j\frac{6\pi}{9}\right)$
7	1 $\exp\left(j\frac{14\pi}{9}\right)$ $\exp\left(j\frac{10\pi}{9}\right)$ $\exp\left(j\frac{6\pi}{9}\right)$ $\exp\left(j\frac{2\pi}{9}\right)$ $\exp\left(j\frac{16\pi}{9}\right)$ $\exp\left(j\frac{12\pi}{9}\right)$ $\exp\left(j\frac{8\pi}{9}\right)$ $\exp\left(j\frac{4\pi}{9}\right)$
8	1 $\exp\left(j\frac{16\pi}{9}\right)$ $\exp\left(j\frac{14\pi}{9}\right)$ $\exp\left(j\frac{12\pi}{9}\right)$ $\exp\left(j\frac{10\pi}{9}\right)$ $\exp\left(j\frac{8\pi}{9}\right)$ $\exp\left(j\frac{6\pi}{9}\right)$ $\exp\left(j\frac{4\pi}{9}\right)$ $\exp\left(j\frac{2\pi}{9}\right)$

Orthogonal modulation and subcarrier mapping is done as follows.

$$c_{n,k}^{CQI} = M_{n,k}^{CQI} \qquad if\ k = 0,1,\ldots,53$$

where

$c_{n,k}^{CQI}$ = mapping symbol of the k-th CQI subcarrier in the n-th CQI channel

$M_{n,k}^{CQI}$ = modulation symbol index of the k-th modulation symbol made from the n-th CQI bit as shown in Table 3

n = CQI channel index from the set $[0 \sim N_{CQI} - 1]$

k = CQI subcarrier index of an CQI channel from the set [0 ~ 53]

Performance

Simulation results of CQICH link performance are shown in Figure 1. In the simulations, AWGN and Ped-B (3km/h) channel models are considered. Figure 1 shows CQICH packet error rate versus SINR (Signal to Interference and Noise Ratio per subcarrier) with Samsung and Runcom schemes. We can see that in the error rate of 10^{-3} region, Samsung scheme is superior to Runcom scheme by 1.6dB in AWGN and 0.8dB in Ped-B 3km/h channel respectively. Also note that Samsung scheme can transmit 5 bit per CQICH, whereas Runcom scheme can transmit 4 bit, using the same amount of time-frequency resource.

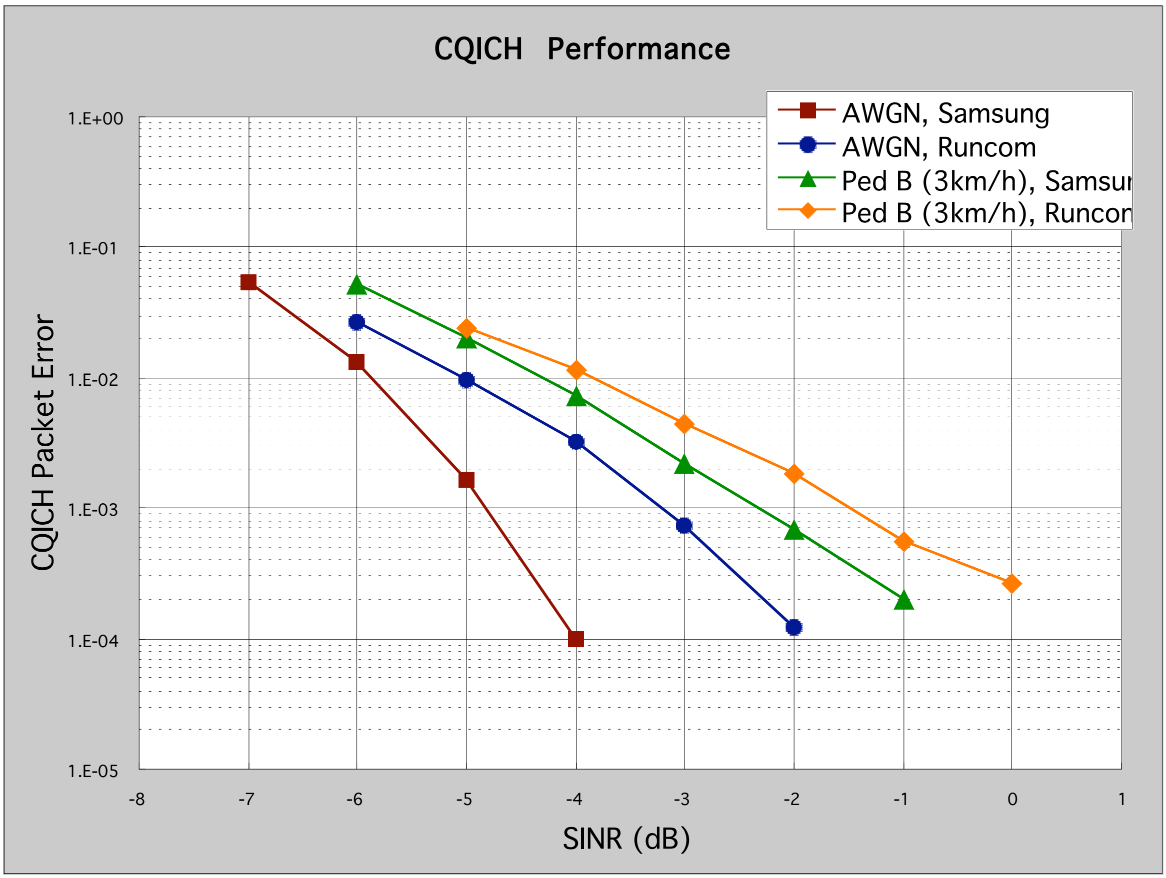

Figure 1 – CQICH link performance of Samsung and Runcom