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Source(s)	Jaehee Cho June Moon YongSeok Kim Kwanhee Roh Changyoon Oh Samsung Electronics #416, Maetan-3dong, Yeongtong-gu Suwon-city, South Korea Anuj Puri Beceem Voice: +82-31-279-5596 E-mail: jaehee1.cho@samsung.com
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Abstract	This contribution provides new MAP IE for closed loop power control. It shows performance gain of closed loop power control over open loop power control in FDD mode. The performance gain motivates a frequent transmission of closed loop power control command. The proposed new MAP IE provides sufficiently lower overhead compared to the current power control messages in the specifications. The propose new MAP IE support CLPC based on UL traffic burst and CQICH.
Purpose	Discuss and adopt
Notice	
Release	
Patent Policy	

Closed loop power control for FDD

Jaehee Cho, June Moon, Yongsuk Kim, Kwanhee Rho, Changyoon Oh
Samsung Electronics
Anuj Puri
Beceem

1. Introduction

It can be shown that fast power control brings benefit to UL channels having the characteristics of circuit mode like CQICH, ACKCH and possibly persistent allocation scheme being considered. For the fast power control, we need to compensate the UL fast fading and thus to use closed loop power control (CLPC) instead of open loop power control (OLPC) in FDD mode. It is because OLPC can't compensate the UL fast fading due to the lack of reciprocity of DL/UL channel in FDD mode. Further, for the fast power control, the frequent transmissions of power control command to MSs are needed. However, such frequent transmissions of the current power control messages defined in IEEE 802.16e specification cause large overhead.
In this contribution, firstly, I am going to show the benefit of the fast power control: performance gain of the fast power control over slow power control. Then, the problems of overhead of the current power control messages will be provided. A new efficient power control message (MAP IE) will be proposed to improve the problem. Lastly, the proposed text for the new power control message will be present.

2. Benefit of fast power control

In FDD mode, OLPC can only compensate the long term variation of the channel due to the lack of reciprocity. However, CLPC can compensate the short term variation of the channel as well as long term variation at the expense of frequent power correction transmissions. For the performance comparison, the following operation scenarios of OLPC and CLPC in FDD mode are assumed:

- OLPC
  - Only compensate long term path loss and shadowing
  - UL channel estimate is obtained from the DL channel estimation and no delay is assumed between DL estimation and applying OLPC to UL
  - Ideal UL channel estimate is assumed
- Fast CLPC
  - Compensate fast fading as well as path loss and shadowing
  - BS estimate the UL channel and send power control command to MS
  - 1 or 2 frame delay (5 or 10ms power control delay) is assumed between UL estimation and applying CLPC to UL
  - Ideal UL channel estimate is assumed
  -

We performed link level simulation to evaluate the SNR gain of fast CLPC over OLPC. Reflecting the operation scenario above, followings are assumed: 1) only fast fading is applied for the simulation, 2) constant Tx power is assumed for the OLPC, 3) power control applied for CLPC in every frame with appropriate channel estimate delay.
The following table shows SNR gain of fast CLPC over OLPC to meet the SER = 1% for CQICH and ACKCH defined in IEEE 802.16e specifications. For each channel, Ped-A and Ped-B 3km/h are assumed and 1 and 2 frame delay are applied only for fast CLPC.

Control CH type	Channel type	CLPC (1 frame delay)	CLPC (2 frame delay)
CQICH	Ped-A 3km/h	**4.7dB**	3.5dB
	Ped-B 3km/h	1.9dB	1.6dB
ACKCH	Ped-A 3km/h	**4.0dB**	3.2dB
	Ped-B 3km/h	1.6dB	1.5dB

As can be seen, up to 4.7 dB SNR gain is observed in fast CLPC with 1 frame delay. Even with 2 frame delay, 3.5 dB SNR gain is observed. The performance degradation of OLPC comes from that OLPC have to take fading margin to meet the SER requirements. Though not present, the similar results are expected for the persistent allocation scheme being considered. It is clear from the simulation result that fast CLPC in FDD mode bring SNR gain over OLPC and the SNR gain will guarantee better link performance for UL control channel and more VoIP users in the persistent resource allocation mode.

3. Proposed solution

3.1 Review of the current power control commands

For the fast CLPC, BS needs to send power control message to correct MS's transmitting power. In IEEE 802.16e specifications defines the following power control messages:

1) FPC (fast power control) message (6.3.2.3.34)
2) Power Control IE (8.4.5.4.5)
3) UL-MAP Fast Tracking IE (8.4.5.4.22)
    A. It can be sent to a MS only when there was UL burst for the MS in two frame earlier.
    B. It is not appropriate for CLPC

Assuming 25 power control commands have to be sent to MSs, the following table shows overhead due to the power control commands. 1/2-QPSK with 6 repetitions assumed since PC_IE and FPC message is broadcasting signaling. From the table above, it is needed to improve power control command overhead.

	No. bits	Req. No. OFDM symbols
Power control IE	1100 bit	9.17 symbols
FPC message	672it	5.60 symbols

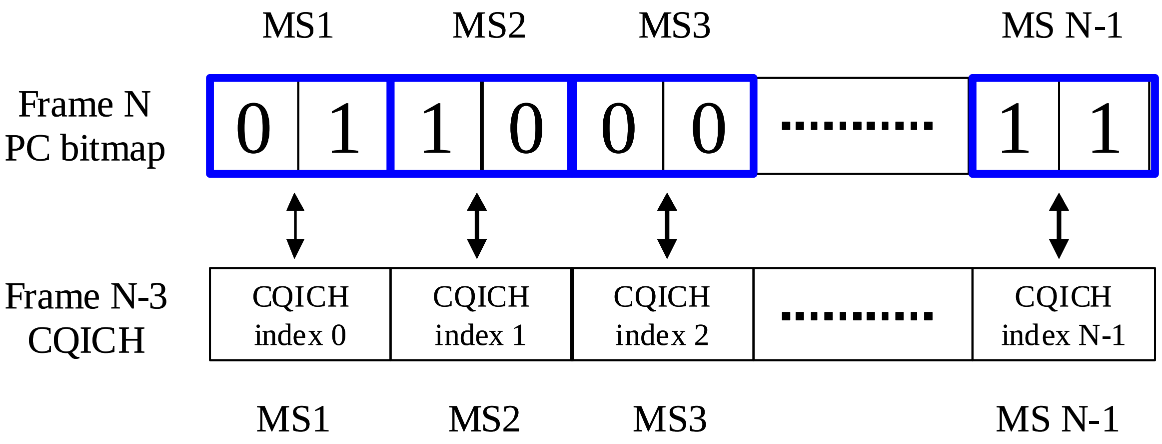
3.2 Proposed power control command scheme

Speculating the FPC message and Power control IE, the overhead mainly comes from CID to identify a MS for the power control command to be delivered. We propose new power control signaling scheme that does not need the explicit identifier to identify a MS for the power control command to be delivered. The main idea is to explicit CQICH in UL CQICH region in the following ways:

1) CQICH is sent from MS to BS in periodic manner where the power control measurement can be performed to compensate the fast fading
2) Each MS for which a CQICH is allocated knows an index of the CQICH used to send CQI in a frame. If power control commands to MSs are arranged in the order of MSs corresponding to the CQICH in the CQICH region in a specific frame, MS can take the corresponding power control command without

explicit MS identifier.

The following diagram illustrates the concept of the proposed power control signaling scheme. In Frame N-3, N MSs send CQI in CQICHs in UL CQICH region. In frame N, a power control bitmap is constructed. In the bitmap, total N 2-bits power control commands are arranged in the same MS order as in the CQICH region in the Frame N-3. No explicit MS identifier is needed to deliver the power control command to a MS.



For this end, we propose the following UL_PC_Bitmap_IE:

Syntax	Size	Notes
UL_PC_Bitmap_IE () {		
Extended-2 UIUC	4 bits	Fast power control = 0x0B
Length (L)	8 bits	Length in bytes
Power Control Bitmap	C*(B+1) bits	It is the sequence of power control commands with (B+1) bits each. No. of power control command(C) is Round[(8*length(L))/(B+1)] Depending on 'B', (B+1) bits power control command shall be interpreted as follows: B=0x00: 1 bit, '0':-0.5dB, '1':+0.5dB; B=0x01: 2 bits, '00':-0.5dB, '01': 0dB, '10':+0.5dB, '11':+1.0dB B=0x02: 3 bits, '000':-1.5dB ~ '111':+2.0dB, step size=0.5dB B=0x03: 4 bits, '0000':-3.5dB ~'1111':+4.0dB, step size=0.5dB
Reserved	*R bits*	Shall be set to zero R is 8*Length(L) – C*(B+1)
}		

Power Control Bitmap

It is the sequence of C power control commands with (B+1) bits each. The j-th power control command is a power adjustment to the MS corresponding to the MS that transmitted the i-th CQICH on CQICH region in the (N-Frame offset)-th frame. N is the frame number of the current frame carrying this UL_PC_Bitmap_IE. No. PC command bits (B) and Frame offset are sent in UCD.

Additionally, one can optimize the UL_PC_Bitmap_IE using Power Control Bitmap Indicator to tell the existence of the power control command in the bitmap for a specific MS.

Syntax	Size	Notes
UL_PC_Bitmap_IE () {		
Extended-2 UIUC	4 bits	Fast power control = 0x0B
Length (L)	8 bits	Length in bytes
If (B != 0) {		
Indicator size (S)	4 bits	The number of bits of “Power Control Bitmap Indicator” equals to 4 * (S+1) bits.
Power Control Bitmap Indicator	4*(S+1) bits	It is the sequence of bits where the i-th bit indicates the presence of the power command to a MS. “C” equals to the number of ‘1’s in the Power control bitmap Indicator
}		
Power Control Bitmap	C*(B+1) bits	It is the sequence of C power control commands with (B+1) bits each. C is 8*length(L) for B=0, C is defined in Power Control Bitmap Indicator, otherwise. Depending on ‘B’, (B+1) bits power control command shall be interpreted as follows: B=0x00: 1 bit, ‘0’:-0.5dB, ‘1’:+0.5dB; B=0x01: 2 bits, ’00’:-0.5dB, ’01’: 0dB, ’10’:+0.5dB, ’11’:+1.0dB B=0x02: 3 bits, ‘000’:-1.5dB ~ ‘111’:+2.0dB, step size=0.5dB B=0x03: 4 bits, ‘0000’:-3.5dB ~’1111’:+4.0dB, step size=0.5dB
Reserved	*R bits*	Shall be set to zero R is 8*Length(L) – 4 – 4*(S+1) - C*(B+1) when B != 0. R = 0 when B = 0
}		

Power Control Bitmap Indicator

It is the sequence of bits where the i-th bit indicates the presence of the power command to a MS in the following power control bitmap and the MS corresponds to the MS that transmitted the i-th CQICH in CQICH region on the (N-Frame offset)-th frame. N is the frame number of the current frame carrying this UL_PC_Bitmap_IE and Frame offset is sent in UCD message. Each indicator represents no presence (‘0’) or presence (‘1’). A number ‘C’ is defined to be equal to the number of ‘1’s in the Power control bitmap Indicator.

Power Control Bitmap

It is the sequence of C power control commands with (B+1) bits each. The j-th power control command is a power adjustment to the MS corresponding to the j-th ‘1’ bit in the Power Control Bitmap Indicator. PC command bits (B) is sent in UCD message.

4. Improved overhead performance of the Proposed solution

Assuming 25 power control commands have to be sent to MSs, the following table shows overhead due to the power control commands. 1/2-QPSK with 6 repetitions and Ped-B 3km/h channel are assumed. Different from the previous overhead calculation for FPC message, FPC is sent only when the accumulation of power control corrections is larger than 1 dB. On average, only 8.1 MSs among 25 MSs needs to send the power control commands per frame. For UL_PC_Bitmap_IE, it is assumed that all 25 power control commands are sent in every frame.

	No. bits	Avg. Req. No. OFDM symbols
FPC (1dB accumulation)	265 bits	2.21 symbols
UL_PC_Bitmap_IE (B=1)	64 bits	0.53 symbols
UL_PC_Bitmap_IE (B=2)	88 bits	0.73 symbols

The proposed power control command message shows superior overhead performance over the current FPC. It is worth noting that an effective number of MSs that can be sent with the proposed scheme is larger than number of CQICH channels. It is because CQICH allocation can be made with period larger than 1 frame depending the MS's mobility. For example, when the allocation periods of the CQICH is 2 frames, the proposed scheme can carry 50 power control commands with the same overhead.

5. Proposed text

[Add the following text at the end of 8.4.5.4.28 on page 828]

8.4.5.4.29 UL_PC_Bitmap_IE

Syntax	**Size**	**Notes**
Power_Control_IE() {		
Extended-2 UIUC	4 bits	
Length		Length in bytes
CQICH based Power Correction Included	1 bit	0: CQICH based power correction is not included 1: CQICH based power correction is included
Data burst based Power Correction Included	1 bit	0: Data burst based power correction is not included 1: Data burst based power correction is included
If (CQICH based Power Correction Included == 1) {	-	-
CQICH Power Control Bitmap	*variable*	It is the sequence of C power control commands with (Bq+1) bits each. The i-th power control command is a power adjustment to the MS that transmitted the i-th CQICH on CQICH region in the (N-Frame_offset_CQICH)-th frame. N is the frame number of the current frame carrying this UL_PC_Bitmap_IE. No. PC command bits (Bq) and Frame_offset_CQICH are sent in UCD. C is the total number of CQICHs in CQICH region in frame N-Frame_offset_CQICH. Depending on 'Bq', (Bq+1) bits power control command shall be interpreted as follows: B=0x00: 1 bit, '0':-0.5dB, '1':+0.5dB; B=0x01: 2 bits, '00':-0.5dB, '01': 0dB, '10':+0.5dB, '11':+1.0dB B=0x02: 3 bits, '000':-1.5dB ~ '111':+2.0dB, step size=0.5dB

		B=0x03: 4 bits, '0000':-3.5dB ~'1111':+4.0dB, step size=0.5dB
}	-	-
If (Data burst based Power Correction Included == 1) {	-	-
No. of PC commands (D)	4bits	No. of PC commands in Data Burst Power Control
Data Burst Power Control Bitmap	*variable*	It is the sequence of D power control commands with (Bd+1) bits each. The i-th power control command is a power adjustment to the MS that transmitted a burst in the frame (N-Frame_offset_Data) and the burst is the i-th allocation made by the UL MAP in the frame (N-Frame_offset_Data-1). No. PC command bits (Bd) and Frame_offset_Data are sent in UCD. Depending on 'Bd', (Bd+1) bits power control command shall be interpreted as follows: B=0x00: 1 bit, '0':-0.5dB, '1':+0.5dB; B=0x01: 2 bits, '00':-0.5dB, '01': 0dB, '10':+0.5dB, '11':+1.0dB B=0x02: 3 bits, '000':-1.5dB ~ '111':+2.0dB, step size=0.5dB B=0x03: 4 bits, '0000':-3.5dB ~'1111':+4.0dB, step size=0.5dB
}	-	-
Reserved	*variable*	Padding for byte alignment
}		

The value in the Power Control Bitmap is the change that MS applies to its transmit power by changing the offset value.

[Add the following text at the end of table 539 on page 1062]

Name	Type (1 byte)	Length	Value
Frame offset	215	1	Bits #0-3: **Frame_offset_CQICH:** The offset between the frame of the corresponding CQI channel and the current frame. 0x0 shall not be used. (See 8.4.5.4.29) Bits #4-7: **Frame_offset_Data:** The offset between the frame of the corresponding UL burst and the current frame. 0x0 shall not be used. (See 8.4.5.4.29)
No. PC command bits (B)	216	1	Bits #0-1: Bq (see See 8.4.5.4.29) 0b00: 1 bits, '0':-0.5dB, '1':+0.5dB; 0b01: 2 bits, '00':-0.5dB, '01': 0dB, '10':+0.5dB, '11':+1.0dB

			0b10: 3 bits, '000':-1.5dB ~ '111':+2.0dB, step size=0.5dB 0b11: 4 bits, '0000':-3.5dB ~'1111':+4.0dB, step size=0.5dB Bits #2-3: Bd (see See 8.4.5.4.29) 0b00: 1 bits, '0':-0.5dB, '1':+0.5dB; 0b01: 2 bits, '00':-0.5dB, '01': 0dB, '10':+0.5dB, '11':+1.0dB 0b10: 3 bits, '000':-1.5dB ~ '111':+2.0dB, step size=0.5dB 0b11: 4 bits, '0000':-3.5dB ~'1111':+4.0dB, step size=0.5dB Bits #4-7: Reserved