Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Open loop power control for uplink**
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Re:	Recirculation of P802.16 REVe/D4
Abstract	Open loop power control operation is proposed to determine uplink transmit power The simulation results are added.
Purpose	Adoption of suggested changes into P802.16e/D5
Notice	
Release	
Patent Policy and Procedures	

Problem Definition

In the current IEEE P802.16REVd/D5, the uplink transmission power for the data burst is controlled in the closed loop power control manner through the RNG-RSP, FPC and UL-MAP Fast tracking indication IE. Further, the SS should automatically update transmit power when the SS transmits in region of Fast-feedback, Ranging, and CDMA allocation. The current transmitting power is computed by adding a correction term power, based on the change in used bandwidth and CINR threshold, to the last transmission. The changes in network interference levels may be handled by changing the CINR threshold table with a dedicated UCD message TLV.

This close loop power control is very effective when SSs are fixed or stationary. However, as the speed of the SSs is increasing, the frequency of sending the power adjustment message is also increasing. Eventually, when the speed of the SSs is very high, the power adjustment message may not track the channel variation and it results in the bad uplink performance. For the uplink data burst transmission, the current power control scheme does not consider an SS specific link level non-ideality such as channel selectivity, propagation differences between uplink and downlink (especially for FDD systems), channel measurement error, and channel report delay under high mobility condition. To cope with these impairments, SS specific power margin is required to achieve desired packet error rate even for the uplink transmission.

In this contribution enhanced open loop power control scheme for uplink data bursts and the bursts in region of Fast-feedback, Ranging, and CDMA allocation is introduced. In the uplink open loop power control method, the uplink transmission power is determined at the SS with the most recent channel state. Thus, this scheme can track the channel variation as much as possible. Further, we combined outer loop power control scheme with the open loop power control scheme. It enables to cope with SS specific link level non-ideality such as channel selectivity, propagation differences between uplink and downlink. It can also compensate the BS scheduling mismatch due to the fast channel variation.

Additionally, we propose to remove path loss compensation and SS specific impairment compensation term from the open loop power control formula in (134). These terms may change uplink transmission power without noticing BS of the change and prevent BS from using bursts in region of Fast-feedback, Ranging, and CDMA allocation to gather the information useful for the closed loop power control. In other words, the received SINR itself does not reflect the channel variation because the uplink power already includes the channel variation. In this case, BS needs the additional feedback of the current uplink transmission power or equivalent to measure the uplink channel variation.

Simulation results

We performed link level simulation to see the effect of mobile speed on the closed loop and open loop power control scheme. Assuming there is no UL Tx power estimation error for the closed and open loop power control scheme, we simplify the difference of the two schemes as the difference of time between the estimation of UL Tx power and its actual use for the UL transmission. For the closed loop power control, BS may estimate the UL Tx power using the last UL burst then send the power control message after BS UL scheduling. The power control message can be used in a certain amount of delay. We assumed that it takes 4 frame delay (20 msec). For the open loop power control, DL path loss estimated with DL preamble can be used to estimate the UL Tx power for the UL burst in the same frame. We assumed that it takes 1 frame delay (5 msec).

The following graph shows the FER curves of the closed loop power control (4 frame delay, red line) and the open loop power control (1 frame delay, blue line) in OFDMA TDD mode using optional PUSC. It is simulated in ITU VEH-A channel model assuming 10 km/h vehicle speed. The QPSK and 1/2 CTC is used. Information bit size is 480 bits. For the BS, Rx antenna diversity (2 antennas) is assumed.

The open loop power control shows 2.55 dB CINR gain at FER 1% over the closed loop power control. It means that the closed power control shall use more power margin of 2.55 dB than the open loop power control. It results in the higher UL transmission power thus, more interference level for the overall system. Though not shown, the gain decreases as the vehicle speed decreases and the gain increases as the vehicle speed increases.

Because the closed loop power control estimates the UL Tx power based on the actual UL CINR, the estimated UL Tx power is more accurate. Thus, one can say that it is beneficial to exploit the closed loop power control scheme in low mobile speed. However, as the mobile speed increases, the open loop power control takes advantage over the closed loop power control due to short adaptation delay.

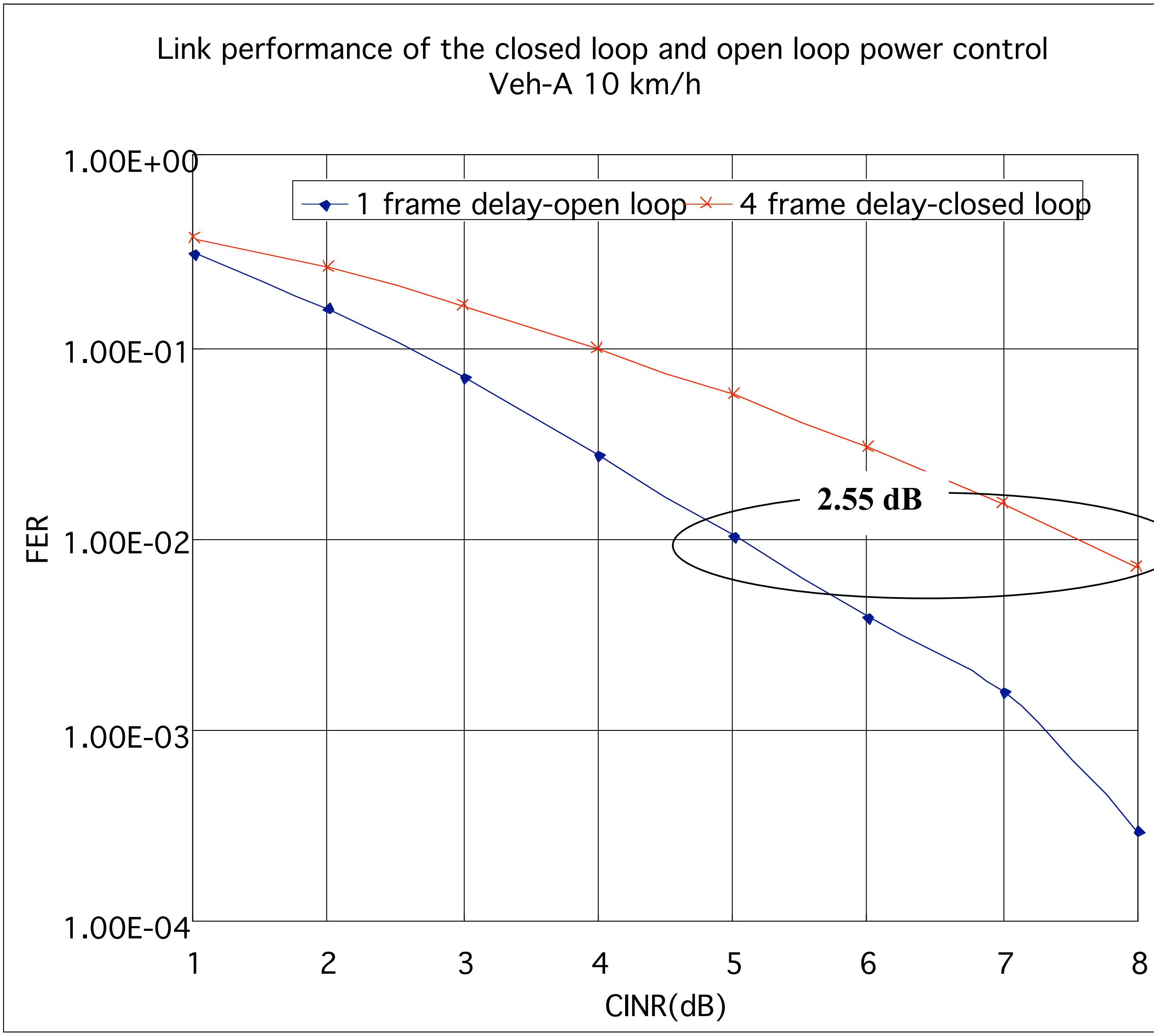

Figure: The FER curves of the closed loop and open loop power control schemes: The adaptation delay for the closed and open loop power control schemes are 4 frames(20 msec) and 1 frame(5 msec), respectively. ITU Vehicular model with mobile speed 10 km/h, QPSK CTC 1/2 with 480 information bit length. The optional PUSC is used in OFDMA TDD mode. In BS, 2 Rx antenna diversity is used.

Proposed Solution

Propagation loss estimation

The change in propagation loss can be estimated by measuring the signal strength of preamble and/or pilot tones and then comparing it with transmitting power level. To get a better estimate, IIR filtering and linear interpolation can be applied. An example of implementation algorithm using DL preamble is shown as below (in dB scale)

$$L_{DL}(n) = \alpha(P_{TX,DL,Peamble} - P_{RX,DL,Preamble}(n)) + (1-\alpha)L_{DL}(n-1) \text{ (IIR filtering)}$$
$$L_{UL}(n) = L_{DL}(n) + \beta\{L_{DL}(n) - L_{DL}(n-1)\} \text{ (Linear interpolation)}$$

where $L_{DL}(n)$, and $P_{RX,DL,Preamble}(n)$ are an estimated downlink propagation loss, a received preamble strength at n-th frame and $L_{UL}(n)$ is an estimated uplink propagation loss. The parameter α is an IIR filter coefficient and β is an offset considering time delay between uplink transmission slot and downlink preamble.

SS specific power offset estimation

The power offset for an SS-specific non-ideality ~~can~~ may be estimated by observing the Ack/Nack of uplink burst. The specific algorithm can be described as follows (in dB scale).

$$\begin{cases} Offset_{perSS} = Offset_{perSS} + UP\_STEP & \text{if NAK is received} \\ Offset_{perSS} = Offset_{perSS} - \dfrac{1}{1/FER_{target} - 1} \cdot UP\_STEP & \text{else if ACK is received} \\ Offset_{perSS} = Offset_{perSS} & \text{else where} \end{cases}$$

$$\begin{cases} Offset_{perSS} = Offset\_Bound_{upper} & \text{if } Offset_{perSS} \geq Offset\_Bound_{upper} \\ Offset_{perSS} = Offset\_Bound_{lower} & \text{else if } Offset_{perSS} \leq Offset\_Bound_{lower} \end{cases}$$

The operating parameters UP_STEP, $Offset\_Bound_{upper}$, $Offset\_Bound_{lower}$ are signaled by a UCD message TLV. The FER_{TARGET} is also handled by a UCD message if not defined in service level negotiation process.

Proposed power adjustment formula

The proposed open loop power control algorithm can be summarized as follows,

$$P\text{ (dBm)} = L + C/N + NI - 10\log10(R) + Offset_{perSS},$$

where correction terms for propagation loss difference and SS-specific power offset are added. NI is the estimated uplink noise and interference level and it is broadcast from BS.

New bandwidth request and uplink transmission power report header

For the uplink open loop power control, BS needs the uplink transmission power to schedule uplink burst for a SS. Because many uplink transmission starts with bandwidth request, bandwidth request is a good place to report the current uplink transmission power. In this contribution, a new bandwidth request and uplink transmission power report header is introduced. This header reports both bandwidth request and uplink transmission power. It has less bandwidth request bits field that may not span whole bandwidth a SS wants. However, grant management subheader may be used in the following uplink transmission burst for the additional bandwidth request.

Uplink power control mode change message

As it is mentioned, the vehicle speed can be a criterion to switch the closed loop and open loop power control scheme. We introduce Uplink power control mode change message. Further, the open loop and outer loop power control capabilities are negotiable items during SBC. Thus, the open loop and outer loop power control can be optionally operated depending SS's capability and BS decision.

Suggested text changes to 16.e standard

[Delete the subclause of 8.4.10.3 “Power control” in 802.16e ~~REV/~~D4]

[Add the following subclause at the end of the 8.4.10.3 “Power control”]

8.4.10.3.1 Open loop power control

When the open loop power control is supported and the uplink power control mode is changed to open loop power control by PCS_RSP, the power per a subcarrier shall be maintained for the UL transmission as follows. This open loop power control shall be applied for the all uplink bursts.

$$P\,(\text{dBm}) = L + C/N + NI - 10\log10(R) + Offset_{perSS} \qquad \text{(aaa)}$$

Where,

P is the TX Power level (dBm) per a subcarrier for the current transmission.

L is the estimated current UL propagation loss. It includes Tx/Rx antenna gain, and path loss..

C/N is the normalized C/N of the modulation/FEC rate for the current transmission, as appearing in Table 332. Table 332 can be modified by UCD (Normalized C/N override). Additionally, the normalized C/N values for UL ACK region and QPSK 1/3 also can be obtained through UCD.

R is the number of repetitions for the modulation/FEC rate.

NI is the estimated average power level (dBm) of the noise and interference per a subcarrier at BS.

$Offset_{perSS}$ is the correction term for SS-specific power offset. ~~It shall be zero when an outer loop power control support is disabled during SBC process.~~SS may use the Offset value signaled by BS through PMC_RSP MAC message as its initial value.

The actual power setting shall be quantized to the nearest implementable value, subject to the specification (8.4.12.1). For each transmission, the SS ~~may~~ shall limit the power~~reduce the power by a constant factor~~, as required to satisfy the spectral masks and EVM requirements.

A SS may adjust $Offset_{perSS}$ value within a range.

$$Offset\_Bound_{lower} \le Offset_{perSS} \le Offset\_Bound_{upper} \qquad \text{(bbb)}$$

where,

$Offset\_Bound_{upper}$ is the upper bound of power offset adjustment

$Offset\_Bound_{lower}$ is the lower bound of power offset adjustment

~~When a outer loop power control support is enabled during SBC process,~~Or the $Offset_{perSS}$ ~~shall~~ may be updated automatically based on the Ack/Nack of uplink burst within the range as specified by (bbb). ~~Its initial value is signaled by BS through PMC_RSP MAC message.~~ The specific algorithm is described as follows (in dB).

$$\begin{cases} Offset_{perSS} = Offset_{perSS} + UP\_STEP & \text{if } NAK \text{ is received} \\ Offset_{perSS} = Offset_{perSS} - \dfrac{1}{1/FER_{target} - 1} \cdot UP\_STEP & \text{else if } ACK \text{ is received} \\ Offset_{perSS} = Offset_{perSS} & \text{else where} \end{cases} \qquad \text{(~~bbb~~ccc)}$$

$$\begin{cases} Offset_{perSS} = Offset\_Bound_{upper} & \text{if } Offset_{perSS} \ge Offset\_Bound_{upper} \\ Offset_{perSS} = Offset\_Bound_{lower} & \text{else if } Offset_{perSS} \le Offset\_Bound_{lower} \end{cases} \qquad \text{(~~ccc~~)}$$

Where,

UP_STEP	is the adjustment step
FER_{TARGET}	is the target frame error rate
$Offset\_Bound_{upper}$	is the upper bound of power offset adjustment
$Offset\_Bound_{lower}$	is the lower bound of power offset adjustment

The operating parameters *UP_STEP*, FER_{TARGET}, $Offset\_Bound_{upper}$, $Offset\_Bound_{lower}$ are signaled by a dedicated UCD message TLV. The default normalized C/N values per modulation are given by Table 332. These values may be overridden by the BS by using a dedicated UCD message TLV. The minimum step size and accuracy of the RF transmit power level shall satisfy the transmitter requirements in Section 8.4.12.1.

Table 333—Normalized C/N per modulation

Modulation/ FEC rate	Normalized C/N (dB)
ACK region	-3.0
Fast Feedback IE	-3.0
CDMA code	0.0
QPSK 1/3	0.5
QPSK 1/2	3.0
QPSK 2/3	4.5
QPSK 3/4	6.0
16-QAM 1/2	7.5
16-QAM 2/3	10.5
16-QAM 3/4	13.0
16-QAM 5/6	15.0
64-QAM 1/2	15.0
64-QAM 2/3	17.0
64-QAM 3/4	20.0
64-QAM 5/6	23.0

Additionally, BS may change the $Offset_{perSS}$ using Fast Power Control (FPC) message (6.3.2.3.34) and Power Control IE (8.4.5.4.5). In this mode, the power control value shall be added to the current $Offset_{perSS}$ value rather than to the current transmission power.

[Add the following subcaluse at the end of 6.3.2.1.3 "PHY channel report header"]

6.3.2.1.4 Bandwidth request and UL Tx power report header

The Bandwidth Request and UL Tx power report PDU shall consist of bandwidth request and UL Tx power report header alone and shall not contain a payload. The bandwidth request and UL Tx power report header is illustrated in Figure ddd.

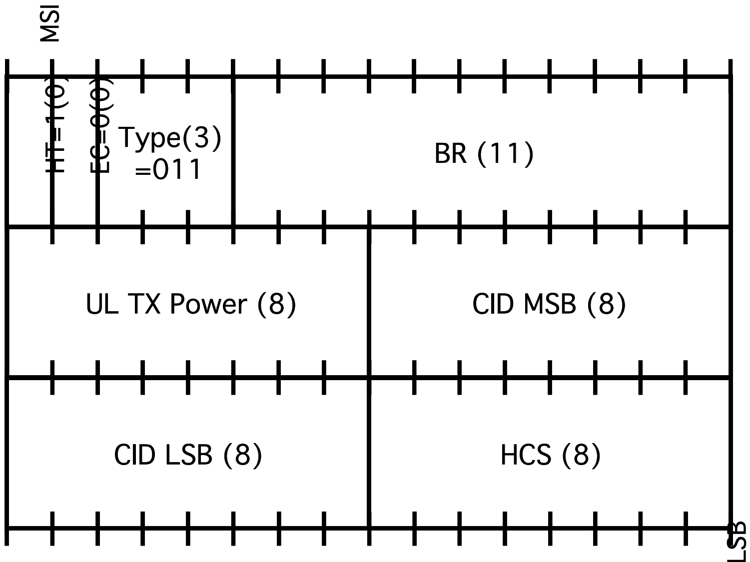

Figure ddd - Bandwidth request and UL Tx power report header format

The The bandwidth request and UL Tx power report header shall have the following properties:

a) The length of the header shall always be 6 bytes.
b) The EC field shall be set to 0, indicating no encryption.
c) The CID shall indicate the SS basic CID.
d) The TYPE field should be "011".

The fields of the PHY channel report header are defined in Table eee.

Table eee – Description of fields of the PHY channel report header

Name	Length (bits)	Description
HT	1	Header Type = 1
EC	1	Always set to zero
Type	3	Type = 011
BR	11	Bandwidth Request The number of bytes of uplink bandwidth requested by the SS. The bandwidth request is for the CID. The request shall not include any PHY overhead. It is aggregate BW request.
UL Tx power	8	UL Tx power level for the burst that carries this header(11.1.1). When the Tx power is different from slot to slot, the maximum value is reported.
CID	16	SS basic CID
HCS	8	Header Check Sequence (same usage as HCS entry in Table 5).

[Add the following subcaluse at the end of 6.3.2.3.56 “BS Broadcast Paging (MOB_PAG-ADV) message”]

6.3.2.3.57 Power control mode change request (PMC_REQ) message

PMC_REQ is sent from SS to BS when BS wants to change uplink power control mode. SS’s intention to change the power control mode to the open loop or closed loop power control can be made by this message. PMC _RSP from the BS confirms the power control mode change and the corresponding power control scheme shall be applied after the PMC_RSP. SS shall change the uplink power control mode when the unsolicited PMC_RSP from BS is received. The closed and open loop power control scheme is described in 8.4.10.3.

Table fff— PMC_REQ message format

Syntax	Size	Notes
PMC_REQ message format{		
Management Message Type = 62	8 bits	Type = 62
Power control mode change	1 bits	0: Closed loop power control mode 1: Open loop power control mode
UL Tx power	8 bits	UL Tx power level for the burst that carries this header (11.1.1). When the Tx power is different from slot to slot, the maximum value is reported.
Reserved	7 bits	
}		

CID shall be the basic CID of SS. SS shall generate the PMC_REQ message including the following parameters

Power control mode change

0: Closed loop power control mode
1: Open loop power control mode

UL Tx power

UL Tx power level for the burst that carries this header (11.1.1). When the Tx power is different from slot to slot, the maximum value is reported.

6.3.2.3.58 Power control mode change response (PMC_RSP) message

PMC_RSP is sent from BS as a confirmation of SS’s uplink power control change intention with PMC_REQ message or it is sent unsolicited manner to command SS to change the uplink power control mode as indicated in the PMC_RSP. When the open loop power control is indicated, $Offset_{perSS}$ is included. When the closed loop power control is indicated, power adjust can be signaled. BS may allocate the CQICH or update the CQICH allocation using PMC_RSP.

Table ggg— PMC_RSP message format

Syntax	Size	Notes
PMC_REQ message format{		
Management Message Type = 63	8 bits	Type = 63
Power control mode change	1 bits	0: Closed loop power control mode 1: Open loop power control mode
Start frame	~~3~~ 7 bits	~~3~~ 7 LSBs of frame number when the indicated power control mode is activated. When it is same with the current frame number, the mode change shall be applied from the current frame.
If (Power control mode change=0)		
Power adjust	8 bits	Signed integer, which expresses the change in power level (in multiples of 0.25 dB) that the SS shall apply to its current transmission power. When subchannelization is employed, the subscriber shall interpret the power offset adjustment as a required change to the transmitted power density.
else		

$Offset_{perSS}$	8 bits	Signed integer, which expresses the change in power level (in multiples of 0.2 dB) that the SS shall apply to the open loop power control formula in 8.4.10.3.1.
~~Reserved~~	~~4 bits~~	
}		

CID shall be the basic CID of SS. SS shall generate the PMC_REQ message including the following parameters.

Power control mode change

0: Closed loop power control mode
1: Open loop power control mode

Start frame

3 LSBs of frame number when the indicated power control mode is activated. When it is same with the current frame number, the mode change shall be applied from the current frame.

Power adjust

Signed integer, which expresses the change in power level (in multiples of 0.25 dB) that the SS shall apply to its current transmission power. When subchannelization is employed, the subscriber shall interpret the power offset adjustment as a required change to the transmitted power density.

OffsetperSS

Signed integer, which expresses the change in power level (in multiples of 0.2 dB) that the SS shall apply to the open loop power control formula in 8.4.10.3.1.

[Add the following subcaluse at the end of 8.4.5.3.18 “Macro-MIMO DL Basic IE format”]

8.4.5.3.19 UL noise and interference level IE format

For the open loop power control, UL interference and noise level shall be broadcast to MSSs in the given BS coverage by BS. UL interference and noise level IE broadcast the UL interference and noise level (dBm) estimated in BS. All the UL interference and noise level are quantized in 0.25 dBm steps from – 110 dBm (encoded 0x00) to – 46.25 dBm (encoded 0xFF).

Table hhh— UL interference and noise level extended IE

Syntax	Size	Notes
UL interference and noise level IE{		
Extended DIUCUIUC	4 bits	H-ARQ_DL_AllocationUL NI = 0xXX0x0D
Length	4 bits	Length = 0x05
CQI/ACK/Ranging region NI	8 bits	Estimated average power level (dBm) per a subcarrier in CQI/ACK region.
PUSC region NI	8 bits	Estimated average power level (dBm) per a subcarrier in PUSC region.
Optional PUSC region NI	8 bits	Estimated average power level (dBm) per a subcarrier in optional PUSC region.
AMC region NI	8 bits	Estimated average power level (dBm) per a subcarrier in AMC region.
}		

[Add the following subcaluse at the end of Table 355 in 11.3.1.1 “Uplink burst profile encodings”]

Table 355—UCD burst profile encodings—WirelessMAN-OFDMA

Name	Type	Length	Value
Normalized C/N overridefor UL ACK region and QPSK 1/3	153	81	This is a list of numbers, where each number is encoded by one nibble, and interpreted as a signed integer. The first LS nibble corresponds to the C/N difference of the UL ACK region comparing to the CDMA code in table 332. The last nibble corresponds to the C/N difference of the QPSK 1/3 comparing to the CDMA code in table 332.1st LS Byte: normalized C/N for UL ACK channel Remaining: This is a list of numbers, where each number is encoded by 5 bits and interpreted as a signed integer multiplied by 0.25 dB. Each 5 bits corresponds in order to the list define by Table 333, starting from the second line, such that the LS 5 bits of the 2nd byte corresponds to the second line in the table (Fast feedback IE). The number encoded by each 5 bits represents the difference in normalized C/N relative to the previous line in the table.

[Add the following subcaluse at the end of 11.8.3.7.5 “OFDMA SS Permutation support”]

11.8.3.7.6 OFDMA SS uplink power control support

This field indicates the uplink power control options supported by a WirelessMAN-OFDMA PHY SS for uplink transmission This field is not used for other PHY specifications. A bit value of 0 indicates “not supported” while 1 indicates “supported.”

Type	**Length**	**Value**	**Scope**
155	1	Bit#0: Uplink open loop power control support ~~Bit#1: Uplink outer loop power control support~~ Bits#~~2~~1-7: reserved, shall be set to zero.	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)
156	1	The minimum number of frames that SS takes to switch from the open loop power control scheme to the closed loop power control scheme or vice versa.	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)