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Re:	IEEE 802.16m-08/053r1, "Call for Contributions for Project 802.16m Amendment Working document Text" Target topic: "DL PHY control structure"
Abstract	The contribution proposes the text of DL PHY control structure section to be included in the 802.16m amendment.
Purpose	To be discussed and adopted by TGm for the 802.16m amendment.
Notice	
Release	
Patent Policy	

Proposed Text of DL PHY Control Structure Section (USCCH) for the IEEE 802.16m Amendment

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1. Introduction

In order to decode DL burst, it is required to obtain control information through SCH, BCH, and USCCH. When an MS turns on power, it firstly acquires cell/sector ID from SCH and decodes essential system information (UL/DL ratio, DL frequency partition configuration, USCCH configuration, etc) through BCH [1]. Then it is possible to decode USCCH which enables to receive data burst.

The USCCH may have to provide control information to support the functions for burst reception as follows:

- Resource assignment indication
- Persistent/Group resource allocation
- Long TTI operation
- HARQ operation (including feedback)
- MCS indication
- MIMO operation
- UL power control

In this contribution, we propose the details of USCCH PHY structure. And for better understanding of USCCH operation, we introduce information elements (IE) based on the control mechanism which have to be supported in the USCCH. The proposed text only includes the PHY aspects of USCCH.

2. USCCH PHY Structure

The Unicast Service Control Channel (USCCH) is transmitted every 1 or 2 subframes. Within a subframe, it is multiplexed with data using FDM to increase link adaptation efficiency and reduce allocation granularity. Both control and data channels are transmitted on logical resource units (LRU) that span all OFDM symbols in a sub-frame.

The USCCH includes DL assignment channel, DL ACK channel, and DL power control channel. Such control channels are encoded separately because the requirements for detection error probability are different each other. The allocation proceeds in the order of DL ACK channel, DL PC channel, and DL assignment channel as described in Figure 1. To decode DL ACK channel and DL PC channel, the sizes of both control channels are indicated by BCH. The size may not be an integer multiple of LRU. The reason why those control channels are indicated by BCH is that required resource sizes for power control and ACK information are too small to add signaling overhead in a subframe. And to decode DL assignment channel, maximum USCCH size is pointed out through BCH. Note that the actual USCCH size can be changed on a subframe basis even if the size is indicated by BCH (Figure 2). It can decrease signaling overhead while enabling to change USCCH size every subframe. Both allocated and indicated USCCH sizes have to be an integer multiple of LRU.

The USCCH is multiplexed and allocated to the DRU in reuse 1 from the first LRU in this region.

For MIMO scheme (2 transmit antenna), the SFBC is used for every control channels.

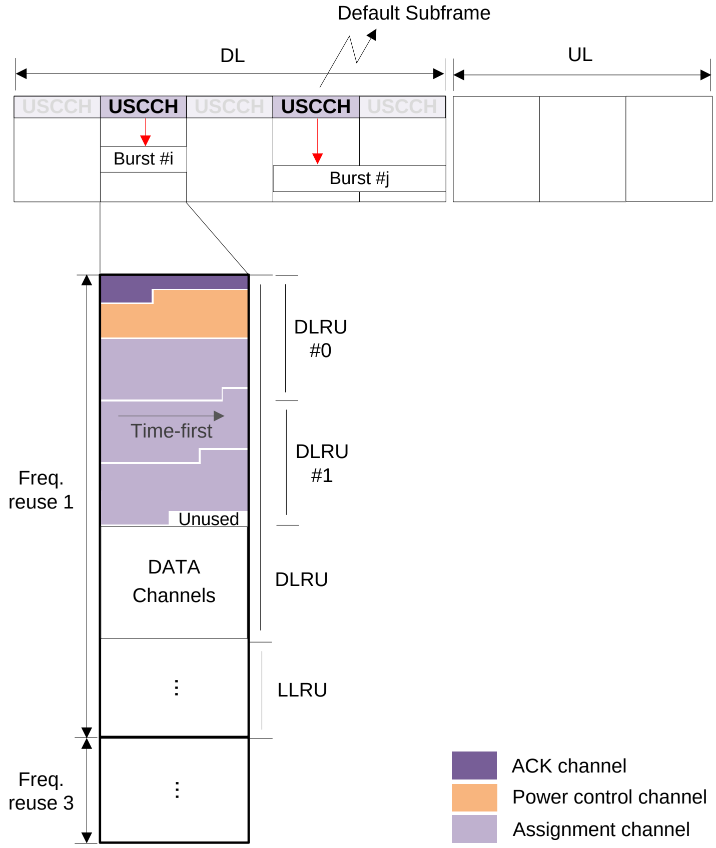


Figure 1 – Logical USCCH structure

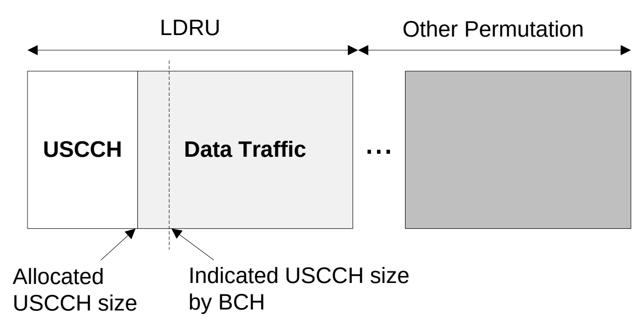


Figure 2 – Signaling of USCCH size

2.1. Assignment channel

The DL assignment channel includes one or multiple Assignment IEs and each of them is encoded separately to maximize link adaptation efficiency.

For modulation and coding scheme, fixed MCS (QPSK, 1/2 or QPSK, 1/4) is used and it is signaled through

PBCH. Fixed MCS has similar performance compared to variable MCS and enables to decrease decoding complexity and false alarm probability of IE decoding. For the same purpose, that is, to decrease decoding complexity and false alarm probability, the number of assignment IE size has to be minimized and the search space restriction scheme may be needed.

In case of GRA which requires large number of bits, the information bits are divided into multiple blocks and carried over multiple neighboring blocks. The first fragment contains length field to indicate the remaining number of blocks. A CRC is inserted in the first fragment in order to examine decoding error for the first fragment. An additional CRC is inserted in the last fragment in order to examine other fragments, while no CRC is added in the middles.

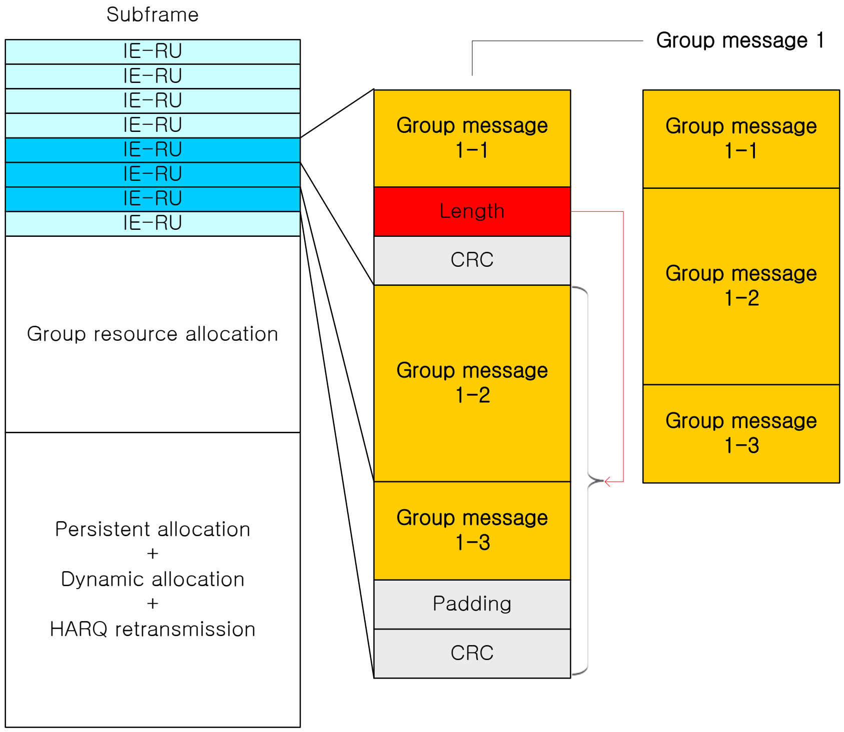


Figure 3 – Resource allocation for GRA

2.2. ACK channel

Once management entity decides the value of ACK, the 1bit-sized information is fed into DLACKCH modulator shown in the following figure.

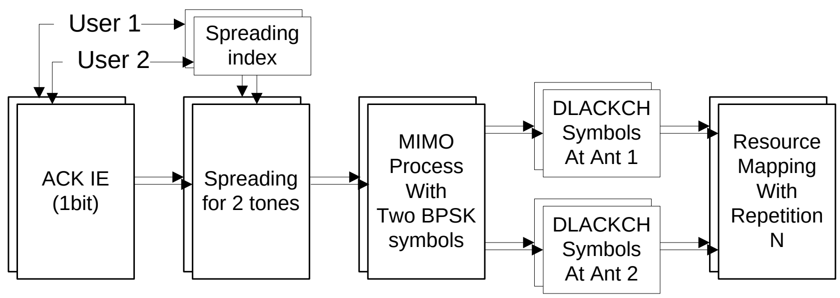


Figure 4 – Block diagram of DLACKCH symbol generator

1 bit information performs spreading with spreading index of user respectively. The output of spreading block has 2 symbols. By using obtained two BPSK symbols, SFBC modulation is performed. Finally, the output symbols of SFBC modulation are mapped into resource permuted by tone-pair subcarrier. The number of repetition N can be determined by BS so that the required link performance could be satisfied. In [2], N=3 is used for conditions that ISD is 1.5km and reference SNR of 0dB boosting is determined based on 50% user CDF.

Actually, the capacity of DLACKCH can be increased if user CDM is used. In this case, performance loss happens with under 0.5dB. However, to minimize the performance loss, the BS needs to schedule user pairing for CDM.

2.3. Power control channel

Once management entity decides the value of TPC, the 2bit-sized information is fed into DLPCCH modulator shown in the following figure.

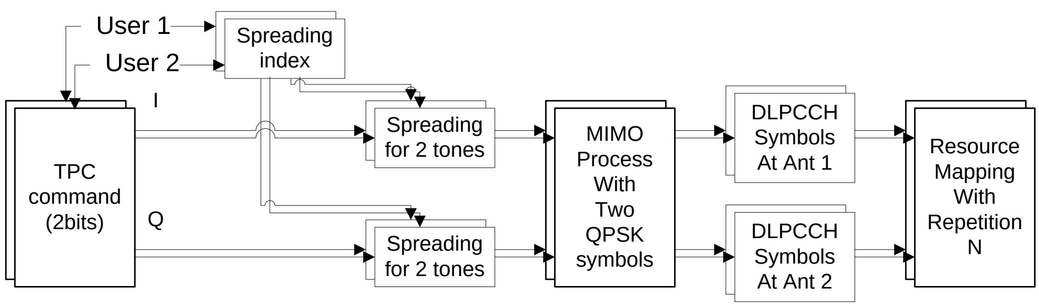


Figure 5 – Block diagram of DLPCCH symbol generator

In-phase and Quadrature-phase perform spreading with spreading index of user respectively. The output of spreading block has 2 symbols in I-phase and Q-phase respectively. With one symbol of I-phase and the other one symbol of Q-phase, one QPSK symbol is obtained. Like same method, the second QPSK symbol is obtained.

By using obtained two QPSK symbols, SFBC modulation is performed. Finally, the output symbols of SFBC modulation are mapped into resource permuted by tone-pair subcarrier. The number of repetition N can be determined by BS so that the required link performance could be satisfied. In [3], N=2 is used for conditions that ISD is 1.5km and reference SNR of 0dB boosting is determined based on 50% user CDF.

Actually, the capacity of DLPCCH can be increased if user CDM is used. In this case, performance loss happens with under 0.5dB. However, to minimize the performance loss, the BS needs to schedule user pairing for CDM.

3. Control Mechanism for Data Transmission/Reception

3.1. Resource assignment indication

Resource assignment indication represents the resource size and position occupied by the transmitted burst. A set of properties have to be kept in the resource assignment indication is as follows:

- Minimum LRU assignment: minimum indication size of 1 LRU has to be supported
- No unoccupied LRUs due to indication limitations

- For VoIP assignment: The assignment with 1, 2, 3, 4, and 6 LRUs granularity for VoIP traffic have to be supported
- Designed to support for distributed allocation (contiguous assignment)

To reduce control channel (USCCH) overhead, the resource assignment indication is defined for within each sub-frame. A channel tree based method (a hybrid of a triangular structure and a power of two tree structure) is used for the resource assignment indication. Figure 6 shows the channel tree structure for 50 LRUs (10 MHz BW). The base nodes (correspond to assignable LRUs) are located on the bottom levels. The channel tree maintains a triangular structure for the lowest three levels to support the assignment with the size of 1, 2, 3, and 4 LRUs. And then switches to a power of two tree structure for the 4th level and 5th level to reduce control channel overhead. For the remaining levels, the channel tree is composed by a triangular structure to maintain granularity. Table 1 shows the whole case of the resource assignment indication.

Eight bits are used to indicate the resource allocation because 248 nodes (each node indicates corresponding assignment LRU index) are required for resource indication of 50 LRUs (BW = 10 MHz).

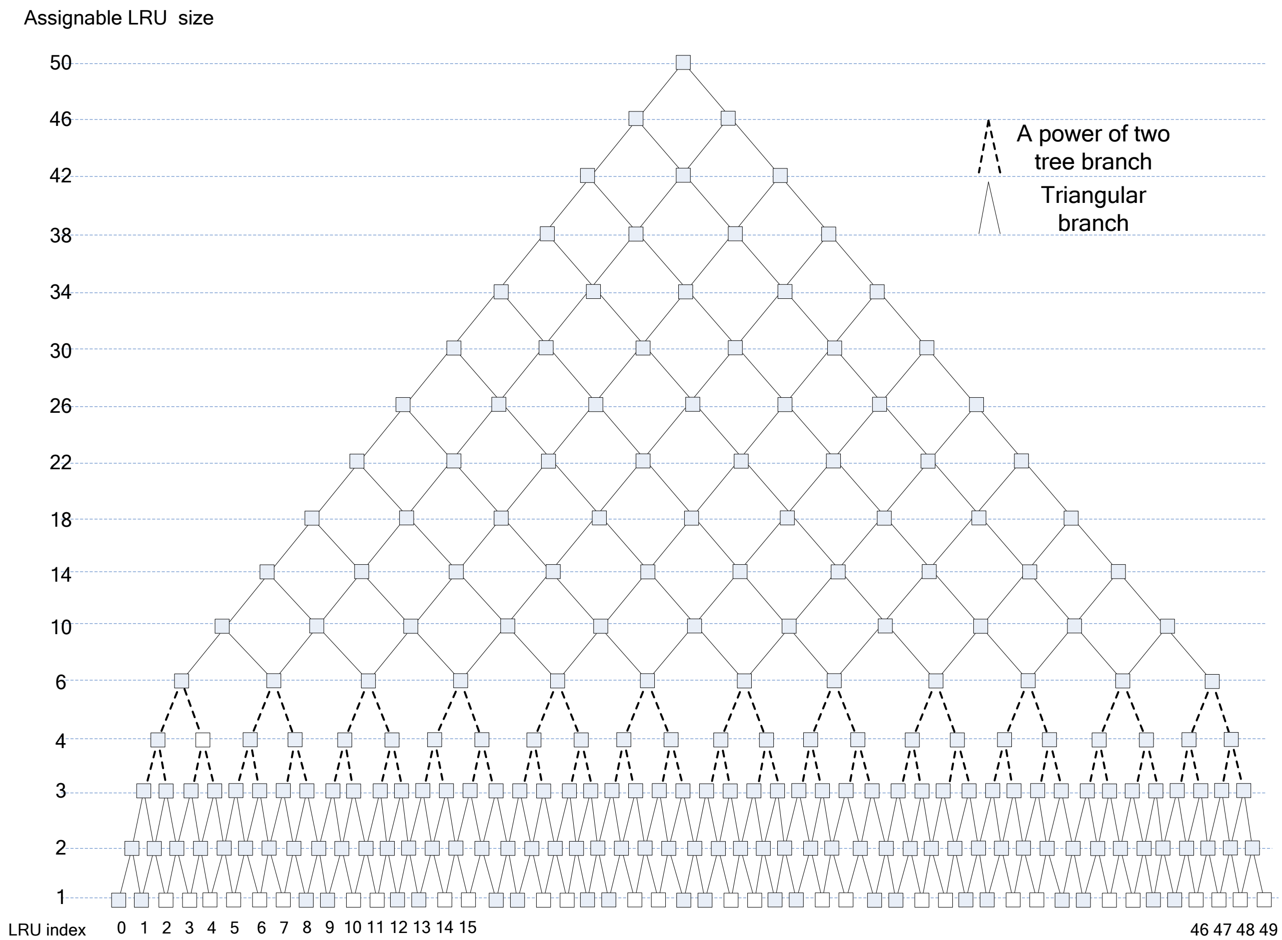


Figure 6 – Channel tree based resource indication structure for 50 LRUs (BW = 10 MHz)

Table 1 – Granularity for resource assignment indication (BW = 10MHz)

Available	Assignment LRU indices

LRU size	
1	{0}, {1}, {2}, {3}, {4}, {5}, {6}, {7}, {8}, {9}, {10}, {11}, {12}, {13}, {14}, {15}, {16}, {17}, {18}, {19}, {20}, {21}, {22}, {23}, {24}, {25}, {26}, {27}, {28}, {29}, {30}, {31}, {32}, {33}, {34}, {35}, {36}, {37}, {38}, {39}, {40}, {41}, {42}, {43}, {44}, {45}, {46}, {47}, {48}, {49}
2	{0, 1}, {1, 2}, {2, 3}, {3, 4}, {4, 5}, {5, 6}, {6, 7}, {7, 8}, {8, 9}, {9, 10}, {10, 11}, {11, 12}, {12, 13}, {13, 14}, {14, 15}, {15, 16}, {16, 17}, {17, 18}, {18, 19}, {19, 20}, {20, 21}, {21, 22}, {22, 23}, {23, 24}, {24, 25}, {25, 26}, {26, 27}, {27, 28}, {28, 29}, {29, 30}, {30, 31}, {31, 32}, {32, 33}, {33, 34}, {34, 35}, {35, 36}, {36, 37}, {37, 38}, {38, 39}, {39, 40}, {40, 41}, {41, 42}, {42, 42}, {43, 44}, {44, 45}, {45, 46}, {46, 47}, {47, 48}, {48, 49}
3	{0 ~ 2}, {1 ~ 3}, {2 ~ 4}, {3 ~ 5}, {4 ~ 6}, {5 ~ 7}, {6 ~ 8}, {7 ~ 9}, {8 ~ 10}, {9 ~ 11}, {10 ~ 12}, {11 ~ 13}, {12 ~ 14}, {13 ~ 15}, {14 ~ 16}, {15 ~ 17}, {16 ~ 18}, {17 ~ 19}, {18 ~ 20}, {19 ~ 21}, {20 ~ 22}, {21 ~ 23}, {22 ~ 24}, {23 ~ 25}, {24 ~ 26}, {25 ~ 27}, {26 ~ 28}, {27 ~ 29}, {28 ~ 30}, {29 ~ 31}, {30 ~ 32}, {31 ~ 33}, {32 ~ 34}, {33 ~ 35}, {34 ~ 36}, {35 ~ 37}, {36 ~ 38}, {37 ~ 39}, {38 ~ 40}, {39 ~ 41}, {40 ~ 42}, {41 ~ 43}, {42 ~ 44}, {43 ~ 45}, {44 ~ 46}, {45 ~ 47}, {46 ~ 48}, {47 ~ 49}
4	{0 ~ 3}, {2 ~ 5}, {4 ~ 7}, {6 ~ 9}, {8 ~ 11}, {10 ~ 13}, {12 ~ 15}, {14 ~ 17}, {16 ~ 19}, {18 ~ 21}, {20 ~ 23}, {22 ~ 25}, {24 ~ 27}, {26 ~ 29}, {28 ~ 31}, {30 ~ 33}, {32 ~ 35}, {34 ~ 37}, {36 ~ 39}, {38 ~ 41}, {40 ~ 43}, {42 ~ 45}, {44 ~ 47}, {46 ~ 49}
6	{0 ~ 5}, {2 ~ 7}, {4 ~ 9}, {6 ~ 11}, {8 ~ 13}, {10 ~ 15}, {12 ~ 17}, {14 ~ 19}, {16 ~21}, {18 ~ 23}, {20 ~ 25}, {22 ~ 27}, {24 ~ 29}, {26 ~ 31}, {28 ~ 33}, {30 ~ 35}, {32 ~ 37}, {34 ~ 39}, {36 ~ 41}, {38 ~ 43}, {40 ~ 45}, {42 ~ 47}, {44 ~ 49}
10	{0 ~ 9}, {4 ~ 13}, {8 ~ 17}, {12 ~ 21}, {16 ~ 25}, {20 ~ 29}, {24 ~ 33}, {28 ~ 37}, {32 ~ 41}, {36 ~ 45}, {40 ~ 49}
14	{0 ~ 13}, {4 ~ 17}, {8 ~ 21}, {12 ~ 25}, {16 ~ 29}, {20 ~ 33}, {24 ~ 37}, {28 ~ 41}, {32 ~ 45}, {36 ~ 49}
18	{0 ~ 17}, {4 ~ 21}, {8 ~ 25}, {12 ~ 29}, {16 ~ 33}, {20 ~ 37}, {24 ~ 41}, {28 ~ 45}, {32 ~ 49}
22	{0 ~ 21}, {4 ~ 25}, {8 ~ 29}, {12 ~ 33}, {16 ~ 37}, {20 ~ 41}, {24 ~ 45}, {28 ~ 49}
26	{0 ~ 25}, {4 ~ 29}, {8 ~ 33}, {12 ~ 37}, {16 ~ 41}, {20 ~ 45}, {24 ~ 49}
30	{0 ~ 29}, {4 ~ 33}, {8 ~ 37}, {12 ~ 41}, {16 ~ 45}, {20 ~ 49}
34	{0 ~ 33}, {4 ~ 37}, {8 ~ 41}, {12 ~ 45}, {16 ~ 49}
38	{0 ~ 37}, {4 ~ 41}, {8 ~ 45}, {12 ~ 49}
42	{0 ~ 41}, {4 ~ 45}, {8 ~ 49}
46	{0 ~ 45}, {4 ~ 49}

50	{0 ~ 49}

3.2. Persistent allocation

Persistent allocation is a technique used to reduce assignment overhead for connections with periodic traffic pattern and with relatively fixed payload size. The persistently allocated resource size, position and the MCS shall be maintained by the BS and MS until the persistent assignment is de-allocated, changed, or an error event occurs.

3.2.1. Allocation/De-allocation

To allocate resources persistently, the BS shall transmit the DL Allocation IE for DL allocations and the UL Allocation IE for UL allocations. The Persistent Flag is to distinguish between persistent and non-persistent operation. The Allocation Period and Number of ACID required for persistent operation is configured outside of USCCH. If the Persistent Flag is set to 1, the indicated resource is persistently assigned with fixed resource size, position and MCS. Persistent allocation is de-allocated when DL Allocation IE or UL Allocation IE contains empty resource assignment.

3.2.3. Assignment replacement

To adapt radio channel variation and avoid resource hole, the persistently allocated resource can be changed. To change the persistent assignment, the BS shall transmit the DL Allocation IE for DL reallocations and the UL Allocation IE for UL reallocations. If the Persistent Flag is set to 1 and the ACID assigned in DL Allocation IE is equivalent to the ACID assigned to persistent allocation, the MS shall assume that the previous persistent allocation is replaced to the assignment indicated in DL Allocation IE or UL Allocation IE.

3.2.4. HARQ retransmission

Asynchronous HARQ manner is applied for downlink persistent. DL Allocation IE is transmitted to indicate control information for HARQ retransmission. Synchronous HARQ manner is applied for uplink persistent allocation. The used resource position persists for subsequent retransmissions. UL Allocation IE is transmitted to replace the resource position when it is not available at the subframe. In each persistent transmission, the HARQ channel identifier is implicitly changed as cyclic pattern with ACID and Number of ACID. For example, if Allocation period is 4 frames, ACID=2, and Number of ACID=4, the HARQ channel identifier of persistent allocation follows the pattern 2, 3, 4, 5, 2, 3, 4, 5, etc. For multiple retransmission of persistent resource, each retransmission packet is distinguished by ACID.

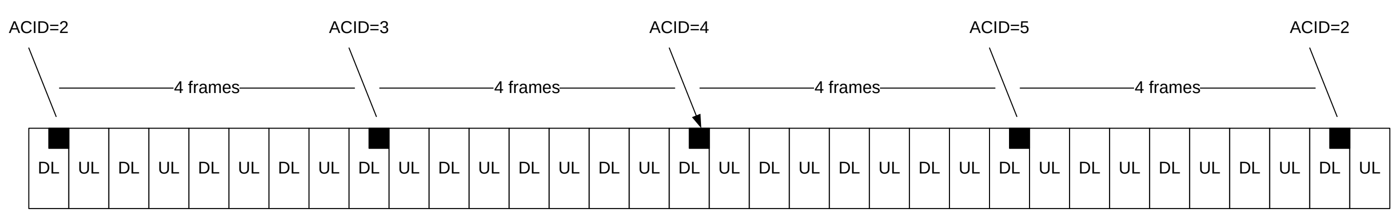


Figure 7 – An example of HARQ channel identifier

3.2.5. Error handling procedures

MS transmits the ACK signal to acknowledge of successful decoding of DL burst or the NACK signal to acknowledge of failure in decoding of DL burst. If the ACK or NACK signal is detected in ACK channel assigned in the DL Allocation IE, BS assumes that the MS had successfully received the DL Allocation IE and start persistent operation in DL subframe. If NULL is detected at the ACK channel assigned in DL Allocation IE, the BS assumes that the MS had not received the DL Allocation IE and the same DL allocation IE can be retransmitted to the MS afterward.

If BS fails detection of transmitted power from MS over assigned resources via UL Allocation IE, BS assumes that MS had not received the UL Allocation IE and the same UL allocation IE can retransmitted to the MS afterward. The detailed method of detecting NULL for DL and failure of power detection for UL are FFS.

3.3. Group resource allocation

Group resource allocation is a technique used to reduce assignment overhead by grouping users to send control signaling of group users via group message. Group message is sent for initial transmission only. The allocated resource size, position and the MCS level is maintained by the BS until the group allocation is de-allocated or an error event occurs. Group message can be transmitted periodically so that MS extend battery life by turning off over the interims. For the case, period is indicated in group message.

3.3.1. Allocation/De-allocation

To affiliate a user into a group, BS transmits Group message IE containing user ID and USER_BITMAP index which is bitmap position designated to the user. To de-allocate group resource allocation, BS transmits Group message IE indicating USER_BITMAP index of the de-allocated user. If a number of consecutive decoding errors occur, group resource allocation can be de-allocated. The number is FFS.

3.3.2. Resource assignment

User bitmap is transmitted to indicate the existence of resource assignment among group users where the corresponding bitmap is set to 1. For each assignment, a combination of MCS level and resource size is indicated in a separate bitmap called Resource bitmap.

3.3.3. HARQ retransmission

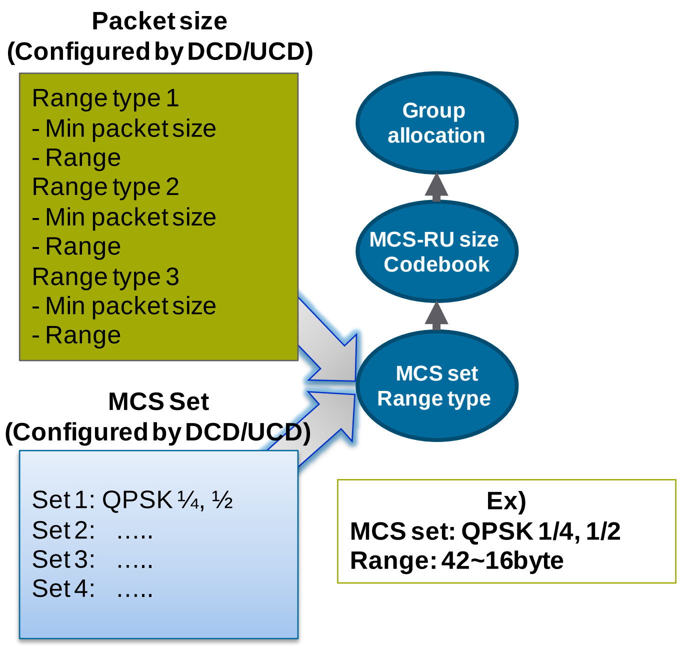
Asynchronous HARQ manner is applied for downlink group resource allocation. DL Allocation IE is transmitted to indicate control information for HARQ retransmission. Synchronous HARQ manner is applied for uplink group resource allocation. The used resource position persists for subsequent retransmissions. UL Allocation IE is transmitted to replace the resource position when it is not available at the subframe. For each initial transmission, all simultaneously transmitted packets have a same ACID indexed in the group message.

3.3.4. Various resource size/MCS support

Each group supports a limited set of MCS levels and a range of packet size among several candidate sets configured in DCD/UCD. The selected set of MCS level and range of packet size are indicated by group message. Upon selecting those, the supportable combinations of MCS level and required resource size can be calculated, and thus each combination is indexed by a particular codeword implicitly. Figure 8 shows an example when a group supports QPSK 1/4 and 1/2 and packet size range from 42 to 16 byte.

Resource bitmap is used to indicate the combination of assigned resource size and MCS level. Bit size per an assignment to indicate this combination can also be implicitly calculated to Ceil[log $_2$(total number of combinations)].

If radio channel is no longer valid for the supportable MCS levels provided in the affiliated group, the MS can be de-allocated from the group and affiliated to other group which can support an appropriate MCS levels.



Required RU (Ex)

Packet size	QPSK 1/4	QPSK 1/2
42	7	4
41	7	4
40	7	4
39	7	4
38	7	4
37	7	4
36	6	3
35	6	3
34	6	3
33	6	3
32	6	3
31	6	3
30	5	3
29	5	3
28	5	3
27	5	3
26	5	3
25	5	3
24	4	2
23	4	2
22	4	2
21	4	2
20	4	2
19	4	2
18	3	2
17	3	2
16	3	2

Codebook (Ex)

MCS	RU size	Code book
QPSK1/4	7	000
QPSK1/4	6	001
QPSK1/4	5	010
QPSK1/4	4	011
QPSK1/4	3	100
QPSK1/2	4	101
QPSK1/2	3	110
QPSK1/2	2	111

Figure 8 – An example of codebook design for a given MCS set and packet size range

3.4. Long TTI support

The transmission time interval (TTI) of data burst can be extended to multiple subframes. Primary purpose of such long TTI to improve the link budget, particularly in uplink. Another usage is the band selection and operation (i.e. band AMC operation in terms of 16e); longer time duration is more efficient than more subhcannels, for packet transmission from/to a low speed mobile. In addition, by utilizing the long TTI a large packet can be transmitted without fragmentation.

Allocation IE in USCCH has an indication of whether the assigned burst occupies one subframe (e.g. default TTI) or multiple subframes (i.e. long TTI).

3.5. HARQ support

Asynchronous HARQ manner is applied for downlink and DL Allocation IE is transmitted to indicate control information for HARQ retransmission. Synchronous HARQ manner is applied for uplink, and thus the used resource position persists for subsequent retransmissions. However, UL Allocation IE can be transmitted to replace the resource position when it is not available at the subframe. ACID is used to differentiate multiple packet (re)transmissions. SPID is to indicate the redundancy version and AI-SN is to indicate initial transmission toggled by new transmission.

3.6. MCS support

To determine the modulation and code rate for current transmission, the AMS shall read the 4-bit ’MCS index’ field and 1-bit ‘AI-SN’ in MAP.

The MCS index represents the different information according to AI-SN. For AI-SN=0 (initial transmission), it denotes the modulation and code rate, and for AI-SN=1 (retransmission), it denotes modulation, BitRe version, and SPID as shown in Table 2.

In Table xx, “+” and “-“ are utilized when modulation at retransmission is not same to that at initial transmission as follows.

- When modulation is QPSK at initial transmission, “-” and “+” represent 64QAM and 16QAM at retransmission, respectively.
- When modulation is 16QAM at initial transmission, “-” and “+” represent QPSK and 64QAM at retransmission, respectively.
- When modulation is 64QAM at initial transmission, “-” and “+” represent 16QAM and QPSK at retransmission, respectively.

Table 2

MCS for initial transmission (AI-SN=0)

MCS index	Modulation	code rate
0	QPSK	31/256
1	QPSK	47/256
2	QPSK	70/256
3	QPSK	98/256
4	QPSK	131/256
5	QPSK	166/256
6	QPSK	199/256
7	16QAM	123/256
8	16QAM	149/256
9	16QAM	176/256
10	16QAM	204/256
11	16QAM	229/256
12	64QAM	173/256
13	64QAM	196/256
14	64QAM	218/256

15	64QAM	234/256

MCS for retransmissions (AI-SN=1)

MCS index	Modulation	SPID	BitRe version
0	Modulation is the same as that of initial tx.	0	0
1		0	1
2		1	0
3		1	1
4		2	0
5		2	1
6		3	0
7		3	1
8	−	0	0
9	−	1	0
10	−	2	0
11	−	3	0
12	+	0	0
13	+	1	0
14	+	2	0
15	+	3	0

3.7. MIMO support

The operation of MIMO transmission requires the MS to know specific information about the transmission parameters selected by the BS. An MS may be receiving MIMO transmission in open-loop or closed-loop mode. An MS may be scheduled in single-user or multi-user mode. The assignment of SU MIMO or MU MIMO, OL MIMO or CL MIMO, and spatial multiplexing or transmit diversity, is specified by one of four values of MIMO_Mode. This information is sent to the MS in the DL MIMO Assignment IE.

Open-loop single-user MIMO transmission may use either transmit diversity or spatial multiplexing of multiple streams. Closed-loop single-user MIMO transmission with precoding based on feedback may use one stream (beamforming) or multiple streams. Closed-loop multi-user MIMO transmission may schedule 1 to 4 users on the same assigned resource, while specific pilot tones need to be assigned to each of these users. DL MIMO Assignment IE carries such information.

The information of MIMO transmissions is carried in the DL MIMO Assignment IE:

- The MIMO mode

. Whether the resource allocation supports a single user (SU) or more than multiple users (MU).

. Whether open-loop or closed-loop is used for the user(s) assigned to the resource allocation.

. Whether transmit diversity or spatial multiplexing is used in open-loop single-user mode.

- For SU-MIMO spatial multiplexing in open-loop or closed-loop mode: the number of streams for the user assigned to the resource allocation.

- For MU-MIMO: which users should be transmitted on the resource allocation.

- For MU-MIMO: the respective pilot stream index for the user(s) assigned to the resource allocation, if dedicated demodulation pilots are used.

- For closed-loop SU MIMO and MU-MIMO: the DL precoding matrix index (DLPMI) for the user(s) assigned to the resource allocation, if common demodulation pilots are used when the BS has 2Tx.

3.8. UL power control (Close loop power control, bit size, general operation scenario)

3.8.1. Transmit power control (TPC) command

BS sends TPC commands to all MSs which operate in closed loop power control (CLPC) mode. By using TPC command, a MS can perform fast power control (compensation of the fast fading) so that transmitted signal from the MS can be guaranteed to arrive at serving BS with the target SNR continuously.

3.8.2. Requirement for TPC command design

When TPC command is designed, the following requirements are satisfied.

- Overhead should be minimized
- A MS should obtain link performance gain by using fast power control w.r.t slow power control where the channel of the MS is nomadic (< 10km/h), even when practical impairment is considered where impairment is such as uplink channel estimation error, TPC command quantization and TPC command detection error.
- Target of TPC command error rate is 10%
- Transmission should be compliant to SDD.

TPC command size and downlink TPC channel (DLPCCH) should be designed considering requirements above.

3.8.3. TPC command size design

Infinite size of information is best only for accuracy of compensating channel unless the overhead is not considered. In real situation, however, it is not practical nor be desirable since resource is limited. The size of TPC command should be determined as the minimum value with which the other requirements can be satisfied.

According to [3], It seems that 2 bit size is adequate for one TPC command in 16m systems.

3.9. HARQ feedback

HARQ feedback information is transmitted through DL ACK channel, and its index (ACK channel resource assignment indication) is signaled in the assignment channel explicitly. Implicit signaling which maps ACK channel index to assigned LRU index of data can be possible, but it may require larger resource size for ACK channel and eventually not efficient with respect to spectral efficiency.

The timing of HARQ feedback follows the predetermined rule. Table 3 shows the HARQ feedback timing in DL for UL HARQ packet transmission in the TDD system. In the table, D and U denote the number of subframes in DL and UL, respectively, $i \in \{0, 1, \ldots, 3\}$, $m \in \{0, 1, \ldots, D\text{-}1\}$, $n \in \{0, 1, .., U\text{-}1\}$, and if $D \geq U$, $S = \lceil (D-U)/2 \rceil$, else $S = -\lceil (U-D)/2 \rceil$.

Table 3 - UL HARQ timing in D:U TDD; for $D \geq U$ (including DL HARQ feedback timing)

HARQ operation (direction)	Frame index	Subframe index	
UL USCCH (DL)	i	m	
Data Tx (UL)	i	$0 \leq m < S$	$n = 0$
		$S \leq m < U+S$	$n = m - S$
		$U+S \leq m < D$	$n = U - 1$
HARQ feedback (DL)	$i+1$	m	
Data ReTx (DL)	$i+1$	m	

Figure 9 illustrates the whole UL HARQ timing including HARQ feedback in 5:3 TDD system. The timing shown in this figure is derived from the formula in Table 1. We can see in the figure that the HARQ feedback is located in the same indexed subframe where the relevant UL USSCH was transmitted.

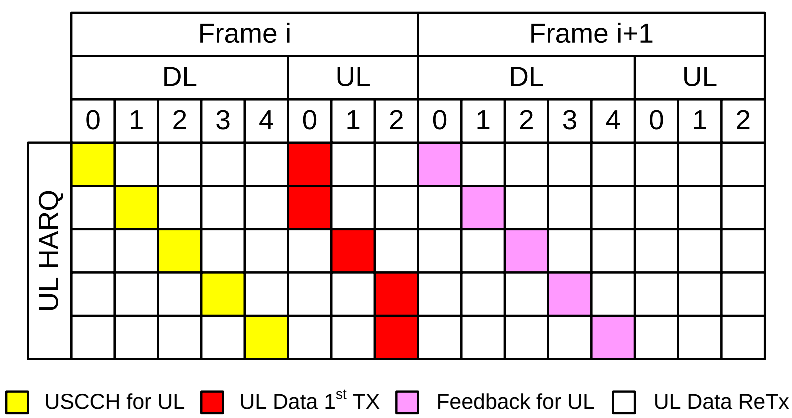


Figure 9 - UL HARQ timing in 5:3 TDD

4. User-specific information design

4.1. DL assignment IE

DL assignment IE is used to inform the allocation information for DL data transmission to the MS. The format of the DL assignment IE is given in Table 4.

Table 4 – DL allocation IE format

Syntax	Size (bit)	Notes

DL_ assignment IE {		
Allocation IE type	4	type = “0x00" (DL normal)
MCS	4	
Resource indexing	12	
Long TTI Length	1	0b0 = 1 sub-frame 0b1 = x sub-frames x: DL Long TTI sub-frame length
Persistent Flag	1	0b0 = non-persistent mode 0b1 = persistent mode
ACID	3	
AI_SN	1	
SPID	2	
reserved		
}		
CRC	16	

- Assignment IE type

This field indicates the usage of corresponding allocation IE.

- MCS

This field defines the burst type such as modulation and coding scheme.

- Resource indexing

This field indicates the resource region occupied by the transmission burst.

- Long TTI length

Represent a number of sub-frames in which the data burst is assigned.

- Persistent Flag

Indicates whether the transmission burst is persistent burst or dynamic (non-persistent) burst.

- ACID

Defines HARQ channel identifier, which is used to identify the HARQ channel.

- AI_SN

Defines ARQ identifier sequence number.

- SPID

Defines sub-packet identifier, which is used to identify the sub-packets generated from an encoder packet.

4.2. UL assignment IE

UL allocation IE is used to inform the assignment information for UL data transmission to the MS. The format of the UL assignment IE is given in Table 5.

Table 5 – UL allocation IE format

Syntax	Size	Notes

	(bit)	
UL_allocation IE {		
Allocation IE type	4	type = “0x01" (UL normal)
MCS	4	
Resource indexing	12	
Long TTI Length	1	0b0 = 1 sub-frame 0b1 = x sub-frames x: UL Long TTI sub-frame length
Persistent Flag	1	0b0 = non-persistent mode 0b1 = persistent mode
Allocation relevance	1	0b0: 1st sub-frame 0b1: 2nd sub-frame
ACID	2	
ACK channel index	4	
reserved		
}		
CRC	16	

- Allocation relevance

This field indicates the corresponding UL sub-frame in which the data burst is assigned.

- ACK channel index

Indicates the index number of ACK/NACK channel of corresponding transmission burst.

4.3. GRA IE

Table 6 – GRA IE

Syntex	Size (bit)	Notes
GRA_Assignment_IE{		
Type	4	
GROUP ID	4	
GRA Allocation IE size	2	00: 48 bits 01: 96 bits 10: 144 bits 11: 192 bits
MCS range	4	
Packet size range	4	
GROUP Offset	6	indicates the start RU offset of group resource
Long TTI	1	indicates long TTI length
ACK Channel Index Offset	4	indicates the start ACK channel index offset

		of users in a group
ACID	3	Indicate the ACID of users in a group. All uses in a group have same ACID index.
reserved	1	
CRC	16	
Number of allocation user	4	This field indicates the number of newly allocated users in a group. The number of allocation user is this field value minus 1.
if (Number of allocation user>0)		
{		
for i=1;Number of allocation user		
{		
CID	16	
USER BITMAP index	5	
}		
}		
Number of de-allocation user	4	This field indicates the number of de-allocated users in a group. The number of de-allocation user is this field value minus 1.
if (Number of de-allocation user>0)		
{		
for i=1;Number of de-allocation user		
{		
USER BITMAP index	5	
}		
}		
USER BITMAP SIZE	5	indicates the size of USER BITMAP
USER BITMAP	variable	USER BITMAP indicates active MSs and inactive MSs.
RESOURCE BITMAP	variable	RESOURCE BITMAP indicates the resource information assigned to active MSs. The size of RESOURCE BITMAP depends on the number of active users indicated in USER BITMAP. Resource information indicates the resource size and MCS level.
reserved	variable	

CRC	16	
}		

5. References

[1] IEEE C802.16m-09/0324, "Proposed Text of DL PHY Control Structure Section (USCCH) for the IEEE 802.16m Amendment"

[2] IEEE C802.16m-09/0209, "16m DL ACK Channel Design"

[3] IEEE C802.16m-09/0207, "16m Power Control Channel Design"

[4] IEEE P802.16 Rev2/D7, "Draft IEEE Standard for Local and Metropolitan Area Networks: Air Interface for Broadband Wireless Access," Oct. 2008.

6. Text proposal for inclusion in the 802.16m amendment

-- Text Start --

15.3.x Unicast Service Control Channel

The Unicast Service Control Channel (USCCH) shall be transmitted every n subframes (n=1, 2) and includes DL Assignment Channel (DLACH), DL ACK Channel (DLACKCH), and DL Power Control Channel (DLPCCH). Such control channels, if present, shall be multiplexed and allocated to the DRU in reuse-1 (15.3.5) from the first LRU in this zone. Also, the allocation shall proceed in the order of DLACKCH, DLPCCH, and DLACH as described in Figure 1. The logically allocated channels shall be mapped to subcarriers by the permutation rule which is specified in 15.3.5.x. The number of subcarriers occupied by the total control channels in the subframe is given by:

$$N_{SUBCARRIER,USCCH} = N_{SUBCARRIER,DLACKCH} + N_{SUBCARRIER,DLPCCH} + N_{SUBCARRIER,DLACH},$$

where $N_{SUBCARRIER,DLACKCH}$ is the number of subcarriers in the DLACKCH , $N_{SUBCARRIER,DLPCCH}$ is the number of subcarriers in the DLPCCH, and $N_{SUBCARRIER,DLACH}$ is the number of subcarriers in the DLACH. If $N_{SUBCARRIER,USCCH}$ is not an integer multiple of $N_{SUBCARRIER,LRU}$, no energy is transmitted at the remaining subcarriers of which the number is given by $\lceil N_{SUBCARRIER,USCCH} / N_{SUBCARRIER,LRU} \rceil \times N_{SUBCARRIER,LRU} - N_{SUBCARRIER,USCCH}$. $N_{SUBCARRIER,LRU}$ is the number of subcarriers in an LRU and specified in 15.3.5.x. $N_{SUBCARRIER,DLACKCH}$ and $N_{SUBCARRIER,DLPCCH}$ are derived by using N_{ACKIE} (number of ACK IEs) and N_{PCIE} (number of PC IEs) carried on the PBCH, respectively. For $N_{SUBCARRIER,DLACH}$, no information is provided by the PBCH and $N^{MAX}_{LRU,USCCH}$ (maximum number of LRUs in USCCH) is only indicated by the PBCH, where $N^{MAX}_{LRU,USCCH} \geq \lceil N_{SUBCARRIER,USCCH} / N_{SUBCARRIER,LRU} \rceil$.

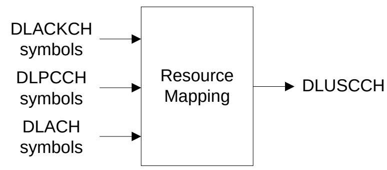


Figure 1 – Channel Structure for DL Unicast Service Control Channel

15.3.x.1 Downlink Assignment Channel

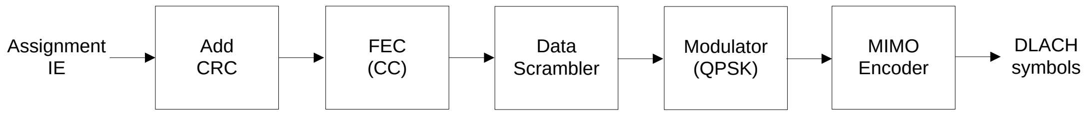


Figure 2 – Channel structure for DL Assignment Channel

The DLACH shall include one or multiple Assignment IEs and each of them is encoded separately. The DLACH shall be transmitted in each DL sub-frame if at least one Assignment IE is present. Figure 2 describes the procedure for constructing DLACH.

15.3.x.1.1 Information Contents and Allocation

The DLACH carries various Assignment IEs which define control information for DL and UL data channels as specified in x.x.

IE Allocation method is TBD. [e.g. user-specific search space restriction]

15.3.x.1.2 Channel Coding and Modulation

Each Assignment IE shall be appended with CRC. A CRC length of $N_{CRC,DLACH}$ shall be used for this IE. The resulting sequence of bits shall be randomized and encoded by the binary convolutional encoder specified in 8.4.9 in IEEE P802.16 Rev2 / D7 [4]. Coding rate shall be 1/2.

The encoded bit sequences shall be interleaved according to 8.4.9 in IEEE P802.16 Rev2 / D7 [4]. Repetition coding with rate 2 can be used to further increase signal margin over the modulation and FEC mechanisms. Thus coding rate of DLACH shall be 1/2 or 1/4, and signaled by PBCH.

The resulting sequence of bits shall be scrambled using a cell-specific sequence. Scrambling sequence is TBD.

The block of scrambled bit sequences shall be modulated using QPSK.

The modulated symbols of each Assignment IE shall be scaled and concatenated in a sequence so that the set of modulation symbols of the i-th Assignment IE shall be scaled by $\sqrt{P_i}$ ($0 \le i < N_{AssignmentIE}$), where $N_{AssignmentIE}$ is the number of Assignment IEs.

15.3.x.1.3 MIMO Processing

The resulting sequence of symbols shall be encoded by SFBC.

15.3.x.2 Downlink ACK Channel

Downlink ACK Channel (DLPCCH) contains ACK IEs for HARQ feedback of the uplink transmission. BS shall transmit ACK IE to every MS which operates in HARQ mode for uplink burst transmission.

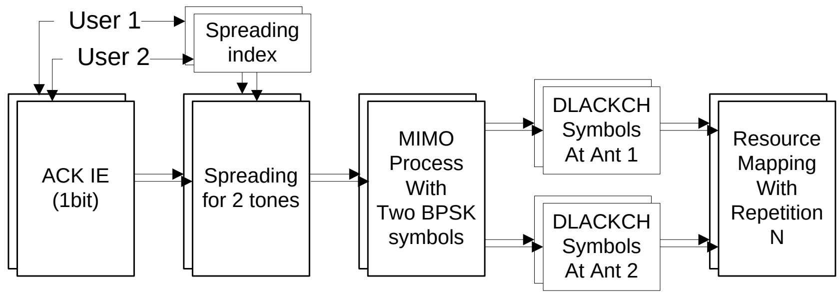


Figure 3 – Channel structure for DL ACK Channel

Figure 3 shows the construction procedure of DLACK symbols from ACK IE. After ACK IE is determined, 1 bit information is separately spreaded according to spreading index shown in Table 1. After scrambled, two subcarriers are fed into MIMO processor and then DLACKCH symbols are obtained.

15.3.x.2.1 Information Contents

The DLACKCH carries ACK IEs which defines acknowledgement information in response to the data received on the UL data channel. 0 indicates no acknowledgement and 1 indicates acknowledgement.

15.3.x.2.2 Channel Coding and Modulation

ACK IE has the size of one bit and it is spreaded by orthogonal sequence of which length is two, where spreading index is described in Table 1. Spreading index is determined by BS and different spreading index shall be used to differentiate two users CDMed together.

The set of symbols of the i-th ACK IE shall be scaled by $\sqrt{P_i}$ $(0 \le i < N_{ACKIE})$, where N_{ACKIE} is the number of ACK IEs and $\sqrt{P_i}$ is the value determined by management entity to satisfy the link performance. The zero power is loaded to the DLACKCH tones where an ACK IE is not allocated.

Table 1 – Orthogonal sequences for DLACKCH

Sequence index	Orthogonal sequence (spreading factor=2)
0	[+1 +1]
1	[+1 -1]

15.3.x.2.3 MIMO Processing

The output of power scaled symbols are then modulated according to MIMO processing. SFBC is used for MIMO processing. Two continuous symbols are adjusted to fit into SFBC transmission at each antenna.

15.3.x.2.4 Resource mapping

The output symbols of MIMO process is mapped to subcarriers which are permuted by tone-pair permutation. Total number of repetition N is transmitted to MSs through SBCH.

15.3.x.3 Downlink Power Control Channel

Downlink Power Control Channel (DLPCCH) contains power control IEs (PC IEs) for closed-loop power control of the uplink transmission. BS shall transmit PC IE to every MS which operates in closed-loop power control mode. Every subframe can transmit different number of PC IEs. Downlink subframe index which carries PC IE of a MS shall be identical to the subframe index in which UL assignment IE to the MS was transmitted.

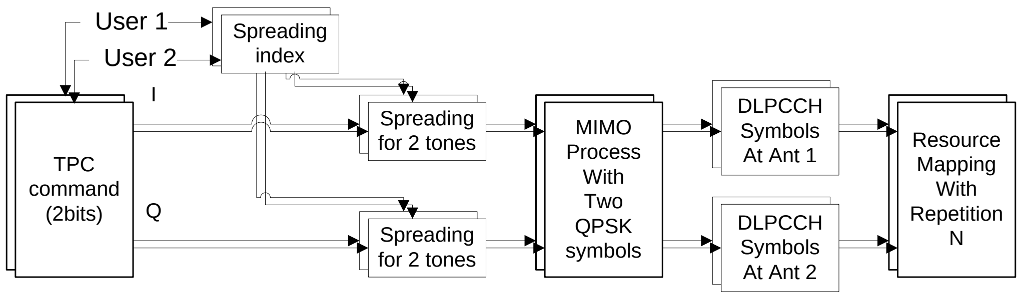


Figure 4 – Channel structure for DLPCCH

Figure 4 shows the construction procedure of DLPCCH symbols from PC IE. After PC IE is determined, LSB and MSB are separately spreaded according to spreading index shown in Table 2. In Inphase and Quadrature phase respectively, spreaded sequence are scrambled. After scrambled, two tones are fed into MIMO processor and then DLPCCH symbols are obtained.

15.3.x.3.1 Information Contents

The DLPCCH carries PC IEs which define power adaptation values to corresponding MS which are assigned to uplink subframes. PC IE are two bits and corresponding value for power correction is shown in Table yy2. If PC IE has the 0x00, it shall be interpreted as tone power (power density) should be reduced by 0.5dB.

Table 2 – power control IE

PC IE	Power correction value
0x00	-0.5dB
0x01	0dB
0x02	0.5dB
0x03	1dB

15.3.x.3.2 Modulation

PC IE has the size of two bits according to power correction value. LSB bit is fed into In-phase process and MSB bit is fed into Quadrature-phase process. Each bit of In-phase and Quadrature-phase is spreaded by orthogonal sequence which length is two, where spreading index is described in Table 3. Spreading index is determined by BS and different spreading index can be used to differentiate two users who are CDMed together.

The set of symbols of the i-th PC IE shall be scaled by $\sqrt{P_i}$ ($0 \le i < N_{PCIE}$), where N_{PCIE} is the number of PC IEs and $\sqrt{P_i}$ is the value determined by management entity to satisfy the link performance. The zero power is loaded to the DLPCCH tones where a PC IE is not allocated.

Table 3 – Orthogonal sequences for DLPCCH

Sequence index	Orthogonal sequence (spreading factor=2)
0	[+1 +1]
1	[+1 -1]

15.3.x.3.3 MIMO Processing

The output of power scaled QPSK symbols are then modulated according to MIMO processing. SFBC is used for MIMO processing. Two continuous QPSK symbols are adjusted to fit into SFBC transmission at each antenna.

15.3.x.3.4 Resource mapping

The output symbols of MIMO process is mapped to subcarriers which are permuted by tone-pair permutation. Total number of repetition N is transmitted to MSs through SBCH.

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