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Title	**Reuse of the signaling 'SPID' for constellation rearrangement in HARQ**
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Re:	IEEE P802.16Cor1/D3
Abstract	The problem with constellation arrangement for 16-QAM and 64-QAM modulation in HARQ is using constellation rearrangement, the corresponding signaling are presented
Purpose	For Adoption
Notice	
Release	
Patent Policy and Procedures	

Reuse of the signaling 'SPID' for constellation rearrangement in HARQ

1 Introduction

HARQ with 16-QAM and 64-QAM and corresponding physical layer signaling has been defined in [1][2]. In this proposal an enhanced Hybrid ARQ method with constellation rearrangement for 16-QAM and 64-QAM modulation and the corresponding signaling are presented

2 Problem for constellation arrangement

In 16-QAM or 64-QAM(show as figure 1) constellation mapping, the reliability of each bit is not the same. For 16-QAM, b3 and b1 are more reliable than b2 and b0. Moreover, based on log-likelihood calculation, the reliabilities for b2 and b0 also depend on their contents (1 or 0). For 64 QAM, b5 and b2 have the highest reliability, b4 and b1 have medium reliability, and b3 and b0 have the lowest reliability. Also, the reliabilities for b0, b1, b3 and b4 depend on their contents (1 or 0).

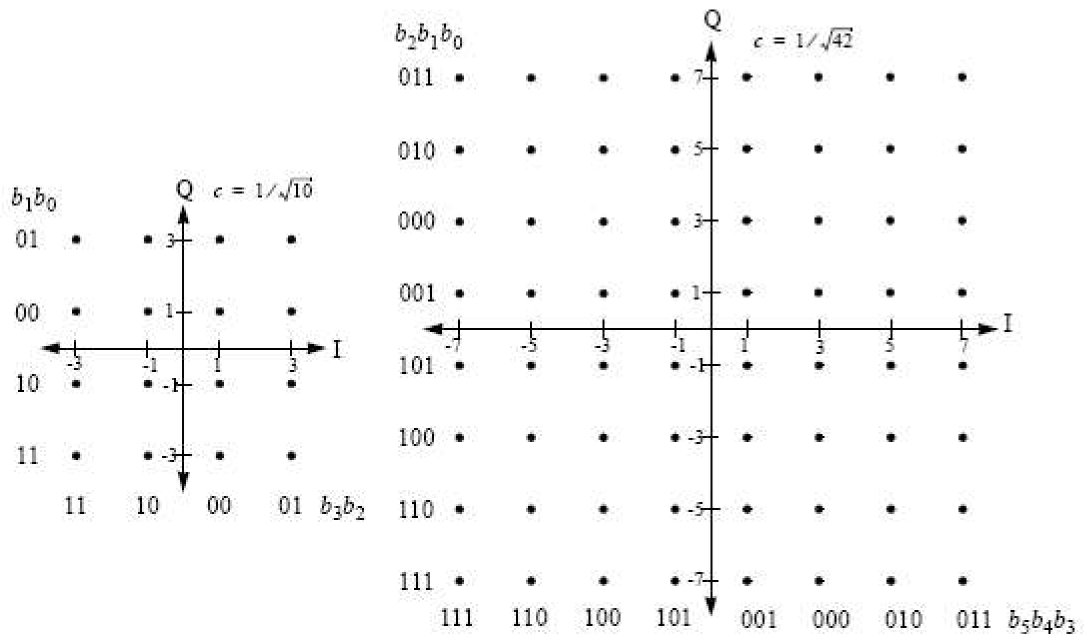

Figure 1 16-QAM and 64-QAM constellation

According to the current specification [1][2], in Chase mode, the same copy of the initially sent packet will be transmitted if NACK reported, thus the variations in bit reliabilities remain biased(for 16-QAM and 64-QAM). It is the same with the case of IR mode where part of the redundancy is non incremental. By the signal constellation rearrangement, the bit reliabilities over the retransmissions can be averaged out after soft combinations of log likelihood values. In IR mode, the reliabilities of the bits carry incremental redundancy will still variant, thus the effect of constellation rearrangement for IR will be variant for different IR schemes. Generally speaking, the more non-incremental redundancy symbols retransmitted the more performance gain can be achieved with constellation rearrangement. For both cases, due to a more homogeneous input of log-likelihood values to the FEC decoder (such as Convolution code, Turbo Code, etc), an increase in decoder performance can be achieved when using constellation rearrangement. While in IEEE802.16-2004 this scheme is not applied.

3 Constellation rearrangement Operation

The location of constellation rearrangement for 16-QAM and 64-QAM lies after bit interleaving and before normal Gray-coded constellation mapping, as shown below:

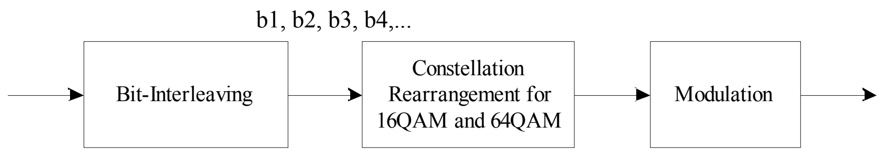

Figure 2 Channel Coding with Constellation rearrangement

For 16-QAM, the bits of the input of constellation rearrangement sequence are mapped in groups of 4 so that $b_{,k}$, b_{k+1}, b_{k+2}, b_{k+3} are used, where k mod 4 = 1. The following table describes the operations that produce the different rearrangements(Here we defined 4 constellation versions for 16-QAM and 64-QAM):

Table 1 Constellation rearrangement for 16-QAM

Constellation version	Output bit sequence	Notes
0	$b_k b_{k+1} b_{k+2} b_{k+3}$	Gray-mapped defined in [1], non operation b_{k+1}, b_{k+3} high reliability b_k, b_{k+2}low reliability
1	$b_{k+1} b_k b_{k+3} b_{k+2}$	swap MSBs with LSBs; b_k, b_{k+2} high reliability b_{k+1}, b_{k+3} low reliability
2	$\overline{b_k} b_{k+1} \overline{b_{k+2}} b_{k+3}$ *	Inversion of the logical values of LSBs: b_{k+1}, b_{k+3} high reliability $\overline{b_k}$, $\overline{b_{k+2}}$ low reliability
3	$\overline{b_{k+1}} b_k \overline{b_{k+3}} b_{k+2}$	Swapping MSBs with LSBs and inversion of logical values of LSBs b_k, b_{k+2} high reliability $\overline{b_{k+1}}$, $\overline{b_{k+3}}$ low reliability

* $\overline{b}$ means inversion of logical value b ('0' or '1')

For 64-QAM, the bits of the input of constellation rearrangement sequence are mapped in groups of 4 so that b_k, b_{k+1}, b_{k+2}, b_{k+3}, b_{k+4}, $b_{k+5}$are used, where k mod 6 = 1. The following table describes the operations that produce the different rearrangements:

Table 2 Constellation rearrangement for 64-QAM

Constellation version	Output bit sequence	Notes

0	$b_k b_{k\ 1} b_{k\ 2} b_{k\ 3} b_{k\ 4} b_{k\ 5}$	Gray-mapped defined in [1], non-operation b_{k+2}, b_{k+5} high reliability, b_{k+1}, b_{k+4} medium reliability, b_k, b_{k+3} low reliability
1	$b_{k\ 1} b_{k\ 2} b_k b_{k\ 4} b_{k\ 5} b_{k\ 3}$	left cyclic shift one bit with 6 bits: b_k, b_{k+3} high reliability, b_{k+2}, b_{k+5} medium reliability, b_{k+1}, b_{k+4} low reliability
2	$b_{k\ 2} b_k b_{k\ 1} b_{k\ 5} b_{k\ 3} b_{k\ 4}$	left cyclic shift 2 bits with 6 bits b_{k+1}, b_{k+4} high reliability, b_k, b_{k+3} medium reliability, b_{k+2}, b_{k+5} low reliability
3	$b_{k\ 2} b_{k\ 1} b_k b_{k\ 5} b_{k\ 4} b_{k\ 3}$	swap MSBs and LSBs b_k, b_{k+3} high reliability, b_{k+1}, b_{k+4} medium reliability, b_{k+2}, b_{k+5} low reliability

4 Simulation Result

This section describes the throughput of the proposed HARQ method with constellation rearrangement when Chase Combining mode is defined.
The simulation is performed with a simplified simulation link. Although some operations(such as FFT, subchannel allocation, and so on) are not included in the link, the simulation result can still show the effect of the constellation rearrangement, because the basic theory of it is independent with these operations.

Table 3 Simulation parameters (simplified simulink)

Parameter	**Value**	**Comment**
Channel Model	AWGN	
Channel Estimation	Ideal	
Maximum retransmission times	10	
Channel Coding	Convolutional code R=1/2	with Tail Biting, according to [1][2]
Log-Likelihood Calculation	Approximation	
Modulation	16-QAM, 64-QAM	
HARQ mode	Chase Combining	

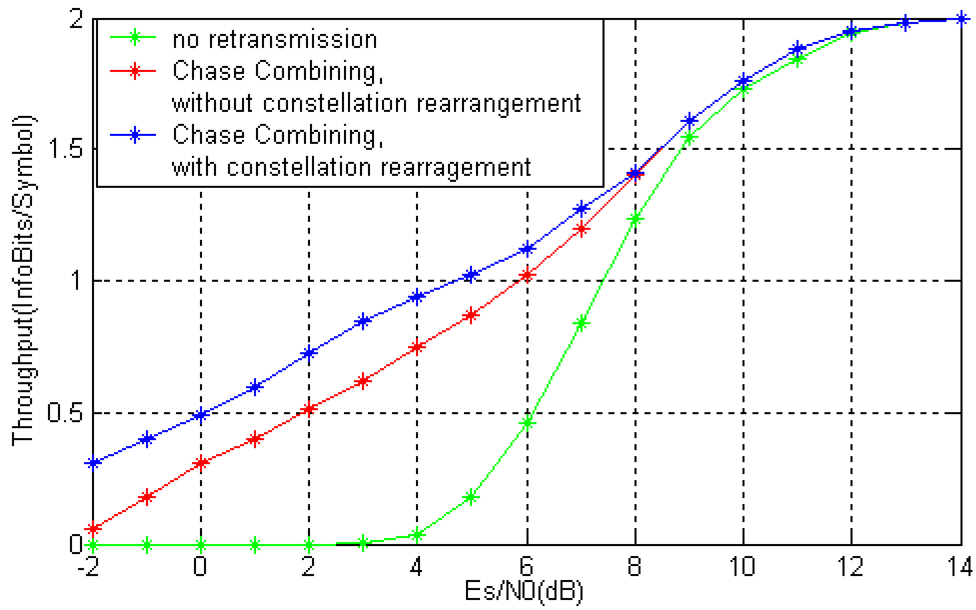

Figure 3 Throughputs for 16-QAM

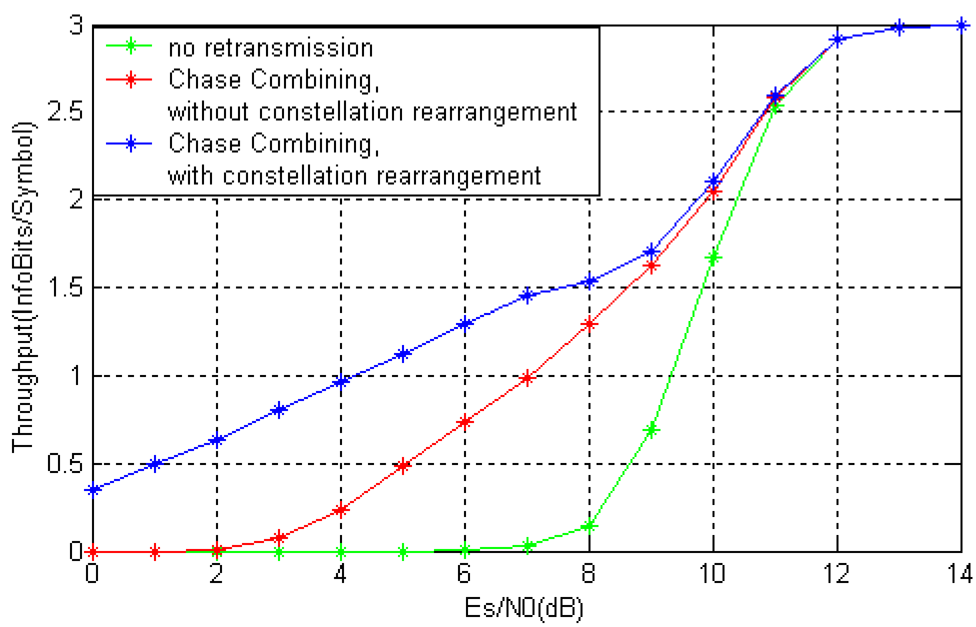

Figure 4 Throughputs for 64-QAM

The simulation results show that, comparing with the method without constellation rearrangement, the throughput of the method with constellation rearrangement are larger more or less. In low SIR area, the gain can be quite significant. In high SIR area, they have similar throughput due to actually fewer or even no retransmission. It can also seen that a higher throughput gain can be achieved for 64-QAM than for 16-QAM.

5 Complexity increased

BS complexity:

One more operation of constellation rearrangement before QAM mapping shall be added. But since the operation is really simple, little complexity increased in BS.

MS complesity

(1) to apply correct signal constellation for demodulation MS has to be aware of the constellation version current retransmissions

(2) Compared to Chase Combining using combining on a symbol-by-symbol basis for retransmissions, due to the bit-by-bit soft-combining required MS buffer-size will have to be increased:

16-QAM

symbol combining: I- and Q-part have to be stored per symbol

bit-combining: one LLR per bit and 4 bits per symbol

2 x buffer-size as for Chase Combining

64-QAM

symbol combining: I- and Q-part have to be stored per symbol

bit-combining: one LLR per bit and 6 bits per symbol

3 x buffer-size as for Chase Combining

(3) Compared to IR or Chase Combing using bit-by-bit soft-combing, MS buffer will no increase. Because it is mandatory for MS to support IR, it seems that MS is most likely to perform bit-by-bit soft combining.

Signaling complexity

Since the reserved SPID can be used to carried the constellation version information in case of Chase Combining mode, it doesn't need additional air interface resource.

6 Conclusion

Constellation rearrangement and the signaling modification schemes are presented in this contribution. By redefining the signaling 'SPID', BS and MS can perform constellation rearrangement in chase combining mode and thus achieve higher HARQ performance.

7 Proposed text changes

(1) Change the text in Table 94 in section 6.3.2.3.43.4 in page63, as following

Table 94—HARQ_Control_IE format

syntax	Size (bits)	Notes
HARQ_Control_IE()	-	-
Prefix	1	0 = Temporary disable HARQ 1 = enable HARQ
if (Prefix == 1) {	-	-
AI_SN	1	HARQ ID Seq. No
SPID/Reserved	2	Subpacket ID when IR is defined by the FEC mode, <u>Subpacket constellation version ID when chase is defined by the FEC mode with the modulation scheme to be 16-QAM or 64-QAM ,</u> otherwise reserved (encoded 0b00)
ACID	4	HARQ CH ID

} else {	-	-
reserved	3	Shall be set to zero
}	-	-
}	-	-

(2) Change the text in section 6.3.2.3.43.4, from line 8 to 10 in page64, as following:

Defines SubPacket ID, which is used to identify the four subpackets generated from an encoder packet. The SPID field only applies to FEC modes supporting incremental redundancy.

When IR is defined by the FEC mode, it defines SubPacket ID, which is used to identify the four subpackets generated from an encoder packet; when Chase is defined by the FEC mode with the modulation scheme to be 16-QAM or 64-QAM, it defines Subpacket constellation version ID. In other case, the SPID is not applied.
When SPID is used to indicate constellation version, it shall be defined as table 333d for 16-QAM and table 333e for 64-QAM, where SPID shall replace the 'constellation version'

(3) Change the text in section 6.3.2.3.43.6.9 in page80, from line 37 to 38, section 6.3.2.3.57 in page142, from line 12 to 13, as following:

Defines SubPacket ID, which is used to identify the four subpackets generated from an encoder packet.

When IR is defined by the FEC mode, it defines SubPacket ID, which is used to identify the four subpackets generated from an encoder packet; when Chase is defined by the FEC mode with the modulation scheme of 16-QAM or 64-QAM, it defines Subpacket constellation version ID. In other case, the SPID is not applied.

(4) Change the text in section 6.3.17, in page 159, from line 13 to 18, as following:

Two main variants of HARQ are supported, Chase Combining or Incremental Redundancy (IR). SS may support IR. MS may support either Chase Combining or IR. For IR, the PHY layer will encode the HARQ packet generating several versions of encoded subpackets. Each subpacket shall be uniquely identified using a subpacket identifier (SPID). For Chase Combining, the PHY layer shall encode the HARQ packet generating only one version of the encoded packet. As a result, no SPID is required for Chase Combining.

Two main variants of HARQ are supported, Chase Combining or Incremental Redundancy (IR). SS may support IR. MS may support either Chase Combining or IR. For IR, the PHY layer will encode the HARQ packet generating several versions of encoded subpackets. Each subpacket shall be uniquely identified using a subpacket identifier (SPID). For Chase Combining with 16-QAM or 64-QAM modulation, the PHY layer shall perform constellation rearrangement. Each constellation version shall be uniquely identified using a subpacket constellation identifier(SPID). For Chase Combining with QPSK modulation, the PHY shall not perform constellation rearrangement. As a result, no SPID is required Chase Combining with QPSK modulation.

(5) Insert a new subclause 8.4.9.5.3 after 8.4.9.5.2 in page484

8.4.9.5.3 Constellation Re-arrangement for 16QAM and 64QAM in Chase Combining HARQ

When Chase Combining HARQ is enabled, constellation re-arrangement shall be performed for 16QAM and 64QAM. For QPSK modulaton, constellation re-arrangement is not used.. The location of constellation rearrangement for 16-QAM and 64-QAM lies after bit interleaving and before modulation, as shown below:

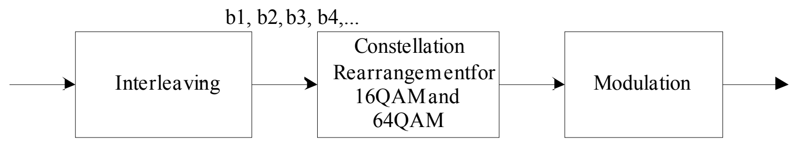

Figure 263a —Constellation re-arrangement

For 16-QAM, the bits of the input of constellation rearrangement sequence are mapped in groups of 4 so that b_k, b_{k+1}, b_{k+2}, b_{k+3} are used, where k mod 4 = 1. The following table describes the operations that produce the different rearrangements(Here we defined 4 constellation versions for 16-QAM and 64-QAM):

Table 333e Constellation rearrangement for 16-QAM

Constellation version	Output bit sequence	Notes
0	$b_k b_{k+1} b_{k+2} b_{k+3}$	Gray-mapped defined in [1], non operation b_{k+1}, b_{k+3} high reliability b_k, b_{k+2} low reliability
1	$b_{k+1} b_k b_{k+3} b_{k+2}$	swap MSBs with LSBs; b_k, b_{k+2} high reliability b_{k+1}, b_{k+3} low reliability
2	$\overline{b_k} b_{k+1} \overline{b_{k+2}} b_{k+3}$	Inversion of the logical values of LSBs: b_{k+1}, b_{k+3} high reliability $\overline{b_k}$, $\overline{b_{k+2}}$ low reliability
3	$\overline{b_{k+1}} b_k \overline{b_{k+3}} b_{k+2}$	Swapping MSBs with LSBs and inversion of logical values of LSBs b_k, b_{k+2} high reliability $\overline{b_{k+1}}$, $\overline{b_{k+3}}$ low reliability

For 64-QAM, the bits of the input of constellation rearrangement sequence are mapped in groups of 4 so that b_k, b_{k+1}, b_{k+2}, b_{k+3}, b_{k+4}, $b_{k+5}$are used, where k mod 6 = 1. The following table describes the operations that produce the different rearrangements:

Table 333f Constellation rearrangement for 64-QAM

Constellation version	Output bit sequence	Notes
0	$b_k b_{k\ 1} b_{k\ 2} b_{k\ 3} b_{k\ 4} b_{k\ 5}$	Gray-mapped defined in [1], non-operation b_{k+2}, b_{k+5} high reliability, b_{k+1}, b_{k+4} medium reliability, b_k, b_{k+3} low reliability
1	$b_{k\ 1} b_{k\ 2} b_k b_{k\ 4} b_{k\ 5} b_{k\ 3}$	left cyclic shift one bit with 6 bits: b_k, b_{k+3} high reliability, b_{k+2}, b_{k+5} medium reliability, b_{k+1}, b_{k+4} low reliability
2	$b_{k\ 2} b_k b_{k\ 1} b_{k\ 5} b_{k\ 3} b_{k\ 4}$	left cyclic shift 2 bits with 6 bits b_{k+1}, b_{k+4} high reliability, b_k, b_{k+3} medium reliability, b_{k+2}, b_{k+5} low reliability
3	$b_{k\ 2} b_{k\ 1} b_k b_{k\ 5} b_{k\ 4} b_{k\ 3}$	swap MSBs and LSBs b_k, b_{k+3} high reliability, b_{k+1}, b_{k+4} medium reliability, b_{k+2}, b_{k+5} low reliability

(6) Change the text in table 308a in section 8.4.5.8.1 in page385, as following:

Table 308a—Reduced AAS private DL-MAP message format *(continued)*

Syntax	Size (tibs)	Notes
DL HARQ ACK bitmap	1	HARQ ACK for previous UL burst.
ACK Allocation Index	6	ACK channel index within HARQ ACK region
ACID	4	HARQ channel ID
AI_SN	1	HARQ Seq. Number Indicator
SPID	2	Applied for Encoding Mode 01, 10 and 11
If (IR Type) {		Incremental Redundancy
NSCH	4	Applied for Encoding Mode 10
~~SPID~~	~~2~~	~~Applied for Encoding Mode 10 and 11~~
~~Reserved~~	~~2~~	~~-~~
}		-
}		-
Repetition Coding Indication	2	0b00 - No repetition coding ob01 - Repetition coding of 2 used 0b10 - Repetition coding of 4 used 0b11 - Repetition coding of 6 used
If (UL-MAP appended) {		
Reduced_AAS_Private_UL-MAP()	variable	

Reserved	3	-
}		
Nibble Padding	variable	Padding depends upon HARQ options.
CRC-16	16	
}		

(7) Change the text in table nsert a new subclause 8.4.9.5.3 after 8.4

Table 308b—Reduced AAS private UL-MAP message format (continued)

Syntax	Size (tibs)	Notes
if(HARQ Enabled) {	1	HARQ ACK for previous UL burst.
ACID	4	HARQ channel ID
AI_SN	1	HARQ Seq. Number Indicator
SPID	2	Applied for Encoding Mode 01, 10 and 11
Reserved	~~3~~1	Shall be set to zero
If (IR Type) {		Incremental Redundancy
NSCH	4	Applied for Encoding Mode 10
~~SPID~~	~~2~~	~~Applied for Encoding Mode 10 and 11~~
~~Reserved~~	~~2~~	~~-~~
}		-
}		-
Repetition Coding Indication	2	Applied for Encoding Mode 00 and 01 0b00 - No repetition coding 0b01 - Repetition coding of 2 used 0b10 - Repetition coding of 4 used 0b11 - Repetition coding of 6 used.

References:

[1] IEEE, IEEE Std 802.16, Oct, 2004

[2] IEEE, IEEE P802.16e/D9, June 2005