Proposed UL Symbol and Pilot Structure for 802.16m

IEEE 802.16 Presentation Submission Template (Rev. 9)

Document Number:
IEEE C802.16m-08/283r1

Date Submitted:
2008-05-05

Source:
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Venue:
IEEE 802.16m-08/016r1, “Call for Contributions on Project 802.16m System Description Document (SDD)”, on topic of ‘Uplink Physical Resource Allocation Unit (Resource blocks and Symbol Structures) ’ and ‘UL Pilot Structure'

Base Contribution:
None

Purpose:
To be discussed and adopted by TGm for the 802.16m SDD

Outline

- Executive Summary
- for 16m Green Field (= TDM based Legacy Support)
  - Summary
  - Uplink Symbol Structure
  - Rationales for each PRU
  - Subchannelization Procedure
- for FDM based Legacy Support
  - Summary
  - Considerations
  - Coexistence Concept
  - Resource Separation
  - Subchannelization Procedure
- Proposed Text

Executive Summary

<table>
<tr><th colspan="2" rowspan="2">RU Type
Mode</th><th rowspan="2">Localized RU (LLRU)</th><th colspan="3">Distributed RU (DRU)</th><th rowspan="2">B.AMC & Diversity Multiplexing</th></tr>
<tr><th>For large packet</th><th colspan="2">For small packet</th></tr>
<tr><td rowspan="3">TDM (green field mode)</td><td>Num. of total tones</td><td>108</td><td>108</td><td>108</td><td>54</td><td rowspan="3">FDM</td></tr>
<tr><td>Tile structure</td><td>18 x 6</td><td>18 x 6</td><td>6x6</td><td>3x6</td></tr>
<tr><td>Pilot density</td><td>1, 2Tx (CSM): 11%</td><td>1, 2Tx (CSM): 11%</td><td>1, 2Tx (CSM): 11%</td><td>1 Tx : 11%</td></tr>
<tr><td rowspan="3">FDM based legacy support mode</td><td>Num. of total tones</td><td>108</td><td colspan="2">120</td><td>60</td><td rowspan="3">TDM</td></tr>
<tr><td>Tile structure</td><td>2 x 6 bins*
(= 18x6)</td><td colspan="2">4 x 6</td><td>4x3</td></tr>
<tr><td>Pilot density</td><td>1, 2Tx (CSM): 11%</td><td colspan="2">1, 2Tx (CSM) : 20%</td><td>1 Tx : 20%</td></tr>
</table>

* Bin represents contiguous 9 subcarriers by 1 symbol structure

1. for 16m Green Field
(= TDM based Legacy Support)

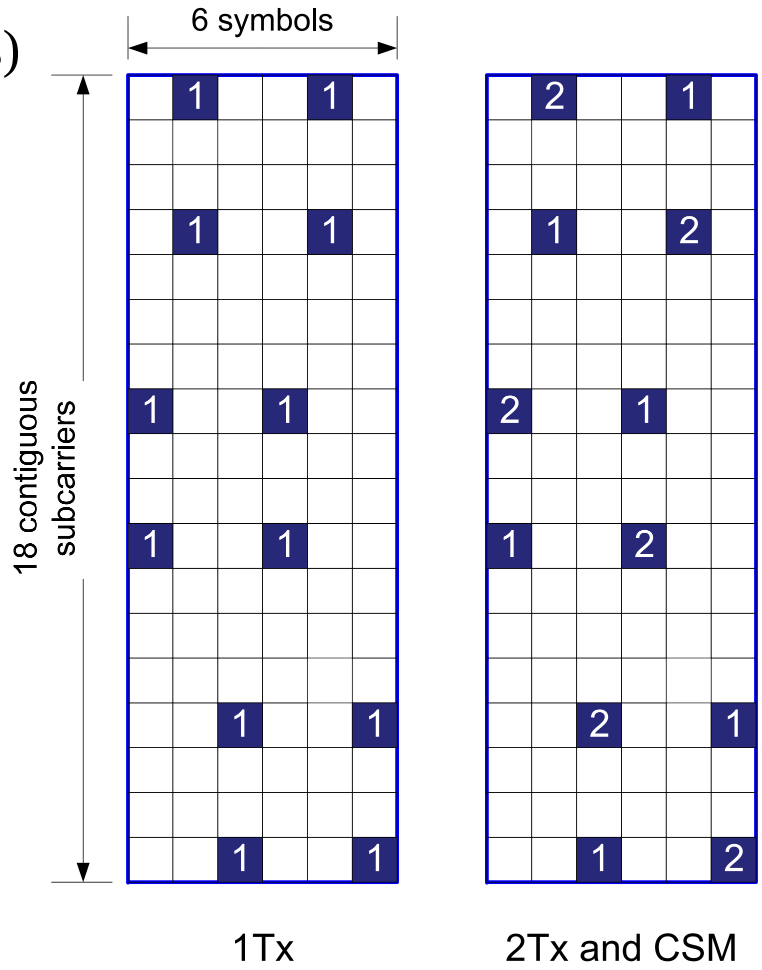
Summary

- PRU
  - 18 × 6 (subcarriers × symbols)
- LRU
  - 18 × 6, 9 × 6
- 3 Types of Tile Structure for DRU
  - Type A: 1 Tile = 18 × 6
  - Type B: 1 Tile = 6 × 6
  - Type C: 1 Tile = 3 × 6
- Pilot Structure
  - 1 Tx, CSM and 2Tx are considered
  - 11% per Antenna Pilot Density for 1Tx
  - 5.5 % per Antenna Pilot Density for 2Tx and CSM

UL Symbol Structure

- Tile Type A
  - 1 Tile = PRU (18 subcarriers × 6 symbols)
  - LRU structure
    - 1 LRU = 1 type A tile
    - 96 data tones and 12 pilot tones
  - Pilot density per antenna
    - 11% for 1Tx
    - 5.5% for 2Tx and CSM
  - Used for localized resource allocation unit (LLRU)
  - Used for diversity resource allocation unit (DRU) of large size packet

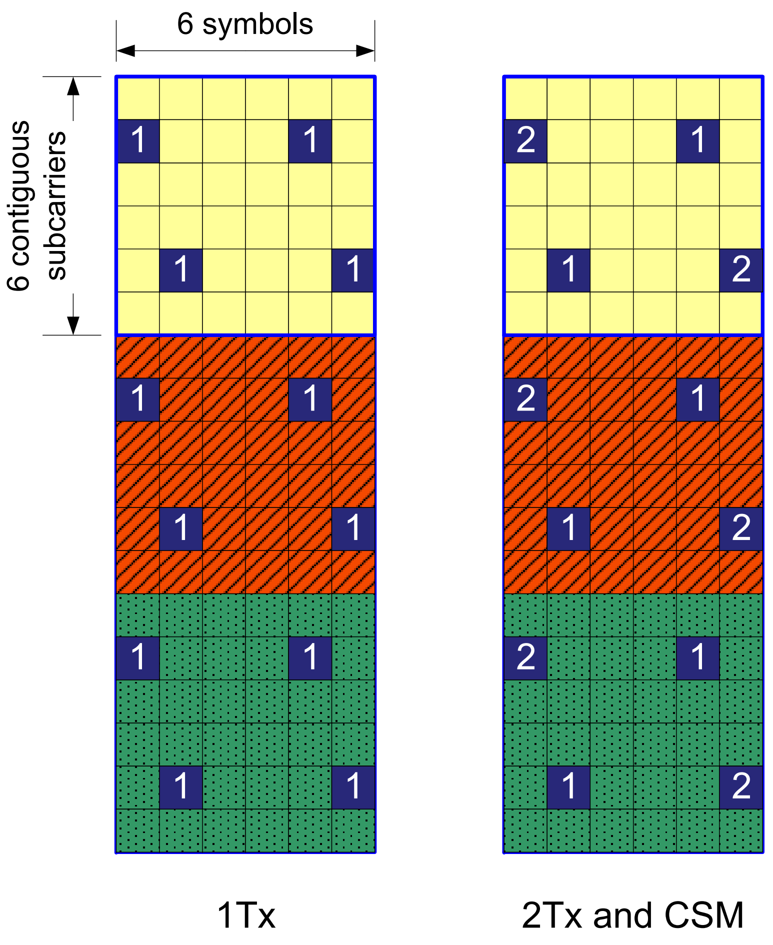
1 LRU with Type A Tile



UL Symbol Structure

- Tile Type B
  - 1 Tile = 6 subcarriers × 6 symbols
  - LRU structure
    - 1 LRU = 3 type B tiles
    - 96 data tones and 12 pilot tones
  - Pilot density per antenna
    - 11% for 1Tx
    - 5.5% for 2Tx and CSM
  - Used only for diversity resource allocation unit (DRU) of small size packet

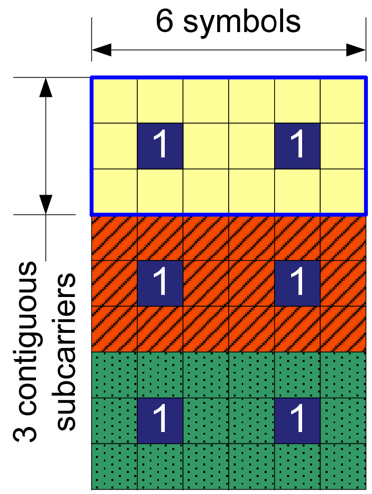
1 LRU with 3 Type B Tiles



UL Symbol Structure

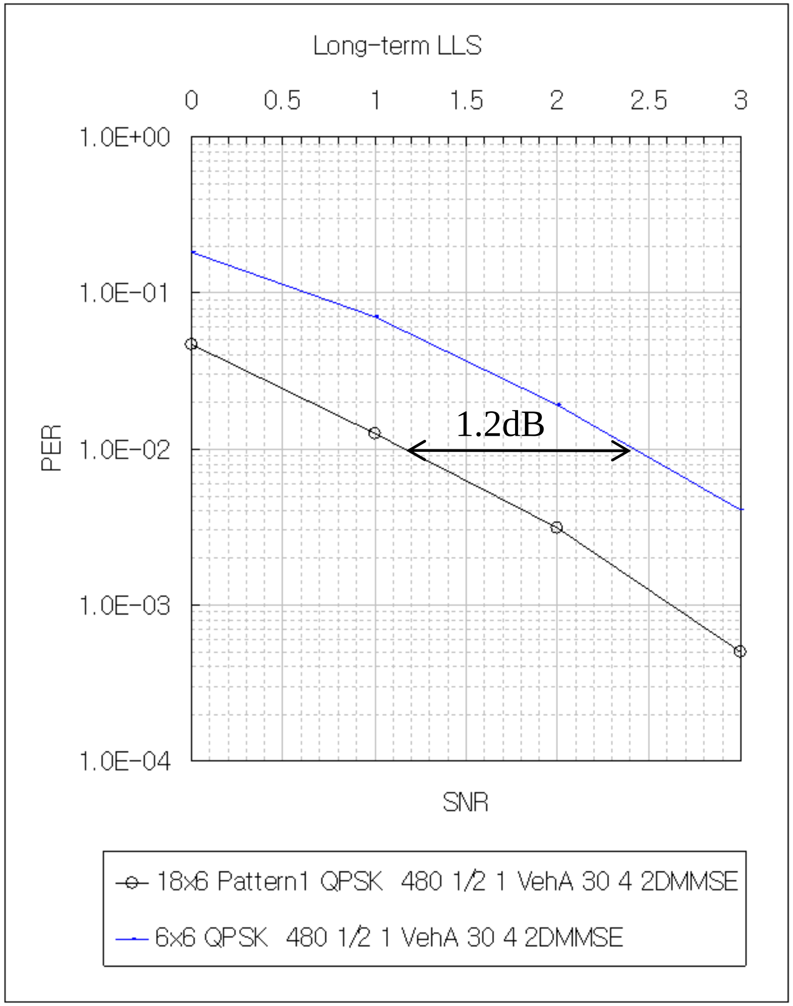
- Tile Type C
  - 1 Tile= 3 subcarriers × 6 symbols
  - LRU structure
    - 1 LRU = 3 type C tiles
    - 48 data tones and 6 pilot tones
  - Pilot density per antenna
    - 11% for 1Tx
  - Used for control message and control channel

1 LRU with 3 Type C Tiles



Rationale for Tile Type A

- Same Structure to Downlink PRU
  - This enable to leverage DL/UL reciprocity in TDD systems
- Better Channel Estimation Performance
  - Channel estimation would benefit from a large number of dedicated pilots in a big-size tile, especially in case of 2Tx or CSM
  - LLS comparison
    - 1Tx and 4Rx with CSM antenna pattern of Type A and Type B (Per ant. pilot density 5.5%)
    - Nep 480
    - QPSK, 1/2
    - VehA 30km/h



Rationale for Tile Type B (1/2)

- Better Frequency Diversity
  - Small packet will be maintained in 16m
  - Such like TCP ACK etc
- LLS verification
  - For SNR gap due to freq. diversity btw tile type A and tile type B
    - Real channel estimation (2D MMSE)
    - Pilot pattern for 1 Tx
    - 2 Rx antennas and MCS of QPSK 1/2

Small size packet ← → Large size packet

Case / Target PER \ Nep Size		96	192	384	960
Ped B 3km/h	1%	2	1.6	0.5	0
Ped B 3km/h	10%	0.4	0.4	0	0
Veh A 30km/h	1%	2.2	1.3	0.1	-0.6
Veh A 30km/h	10%	0.6	0.1	-0.4	-0.4
Veh A 120km/h	1%	2.2	1.2	-0.2	-0.6
Veh A 120km/h	10%	0.4	0	-0.6	-0.6

When Nep < 384, small tile (type B) is better than big tile (type A) because of frequency diversity gain

Rationale for Tile Type B (2/2)

- SLS Verification for Performance comparison with various tile size
  - Total 4 different tile size (based on legacy PUSC 4x3 tile)

Small tile ↑
- Tile 1. 1 subchannel = Six 4×3
- Tile 2. 1 subchannel = Three 8×3
- Tile 3. 1 subchannel = Two 12×3
- Tile 4. 1 subchannel = One 24×3 tiles

Big tile ↓

* Simulation conditions and assumptions are aligned with NGMN scenario in 802.16m EMD except
- number of users per sector (40/sector)
- number of assigned subchannels (Case I : 7, Case II : 2)
- channel model & mix : ITU PedB 100%

- Case I : Packet size is large
  - Total 7 subchannels are assigned to a user
  - Full freq. diversity for all tile types
  - With HARQ, system perf. degradation due to 'big tile' is not severe (<3%)
- Case II : Packet size is small
  - Only 2 subchannels are assigned to a user
  - Tile type 3 & 4 has lack of freq. diversity
  - Even with HARQ, degradation due to 'big tile' is serious (>8%)

Case I

HARQ	OFF	OFF	OFF	OFF	ON	ON	ON	ON
Tile Type	4x3	8x3	12x3	24x3	4x3	8x3	12x3	24x3
Sector	1.9663	1.9597	1.9592	1.9	2.1035	2.0844	2.0679	2.0438
Tput(Mbps)	0.0%	0.3%	0.4%	3.4%	0.0%	0.9%	1.7%	2.8%
Cell edge	4.42	4.41	4.3	4.2	6.15	6.15	5.592	5.58
Tput(kbps)	0.0%	0.2%	2.7%	5.0%	0.0%	0.0%	9.1%	9.3%

Case II

HARQ	OFF	OFF	OFF	OFF	ON	ON	ON	ON
Tile Type	4x3	8x3	12x3	24x3	4x3	8x3	12x3	24x3
Sector	2.1231	2.0232	1.9096	1.82	2.2089	2.1403	2.0984	2.0189
Tput(Mbps)	0.0%	4.7%	10.1%	14.3%	0.0%	3.1%	5.0%	8.6%
Cell edge	5.3	5.3	4.7	4.25	6.55	6.25	6.29	6.2
Tput(kbps)	0.0%	0.0%	11.3%	19.8%	0.0%	4.6%	4.0%	5.3%

Only with large tile, system performance would be degraded especially when packet size is small

→ Type B can be good complement to Type A for small packet

Rationale for Tile Type C

- Current 16e has MAC header
  - Which size is only 48 bits (ex. BR request)
  - HARQ is not applied to
  - This might be retained in 16m
- Currently Used Feedback Header
  - RoHC related
    - RoHC Feedback Header** (under 10B)
    - RoHC-TCK ACK* (min. 6B)
- New Control Message and Control Channel
  - Which could be designed as under 96 data tones
- These need guaranteed transmission which supports sufficient frequency diversity

→ ***Type C can be good solution for control message and header transmission***

* RfC4996 – ROHC TCP July 2007   ** RfC3095 – ROHC July 2001

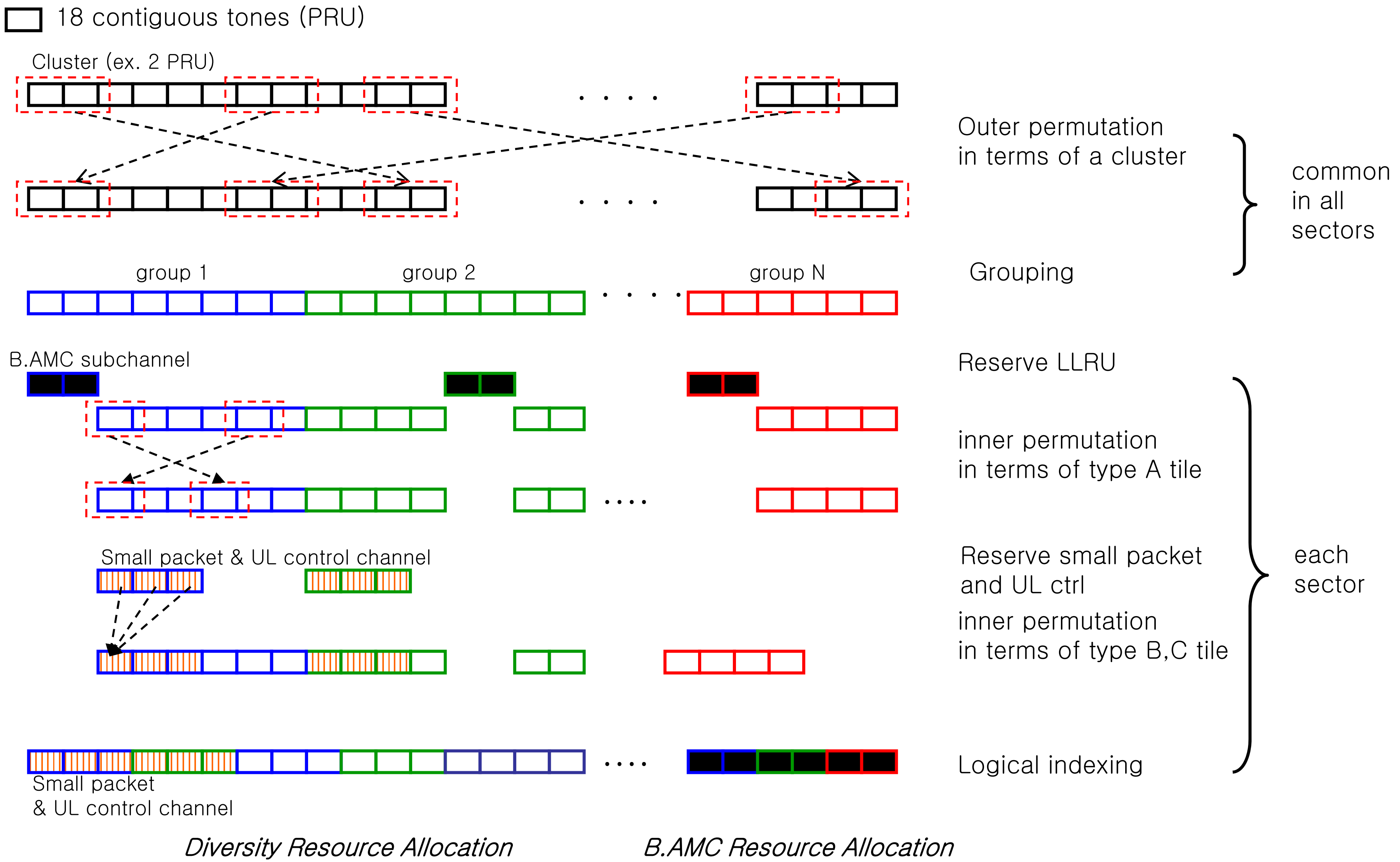
Subchannelization Procedure

- Requirements
  - Sufficient frequency diversity for DRU
  - Able to reserve preferred band for LLRU
  - FFR supportable

- High Level Concept

Subchannelization Procedure

- Details of Procedure



2. for FDM based Legacy Support

Summary

- Objectives
  - To Find a Way 16e/16m Coexist based on FDM-manner
  - 16m Symbol Structure Design is Restricted due to Coexistence

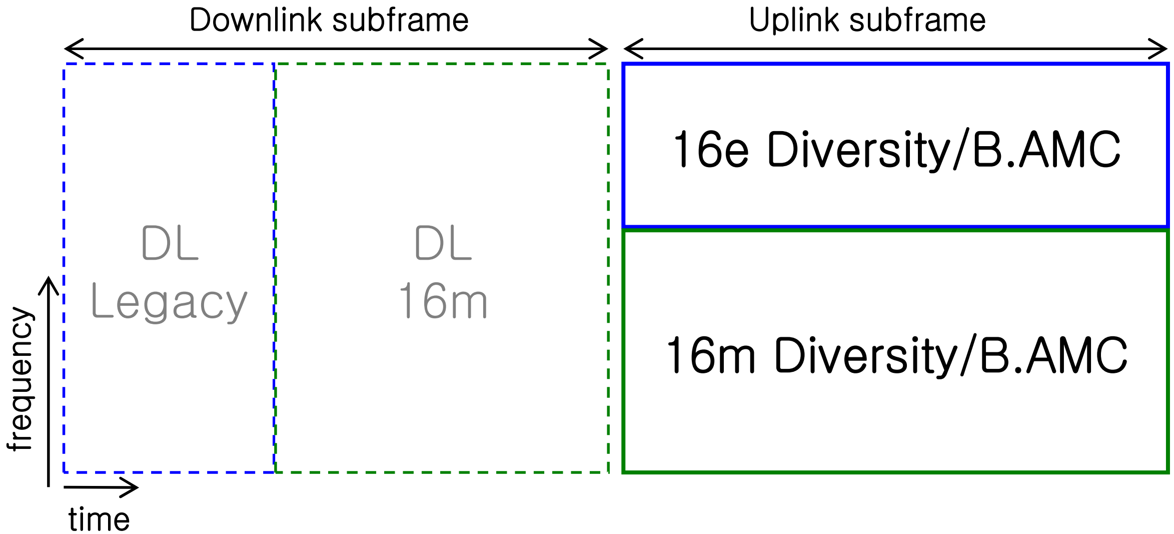
- Requirements
  - 16m should not give rise to constraint on 16e operation

- Proposed UL Diversity SubCH (DRU)
  - 'E-PUSC (Enhanced PUSC) ' represents proposed subchannel structure
  - A DRU is composed of five 4x6 tiles
  - 1 DRU : 120 tones (96 data, 24 pilots for 1Tx, 2Tx and CSM)

- Proposed UL B.AMC SubCH (LLRU)
  - A subchannel is 2×6 bins structures (18 subcarriers × 6 symbols)
  - 1 LLRU : 108 tones (96 data, 12 pilots for 1Tx, 2Tx and CSM)

Considerations

- UL Legacy Subchannel Types*
  - PUSC w/wo subchannel rotation
  - B. AMC of 2×3 bins
- Legacy and 16m coexistence in FDM manner
  - 16m diversity and B. AMC subchannel should be supported respectively
  - Legacy PUSC is mandatory because of Fast-feedback channels**

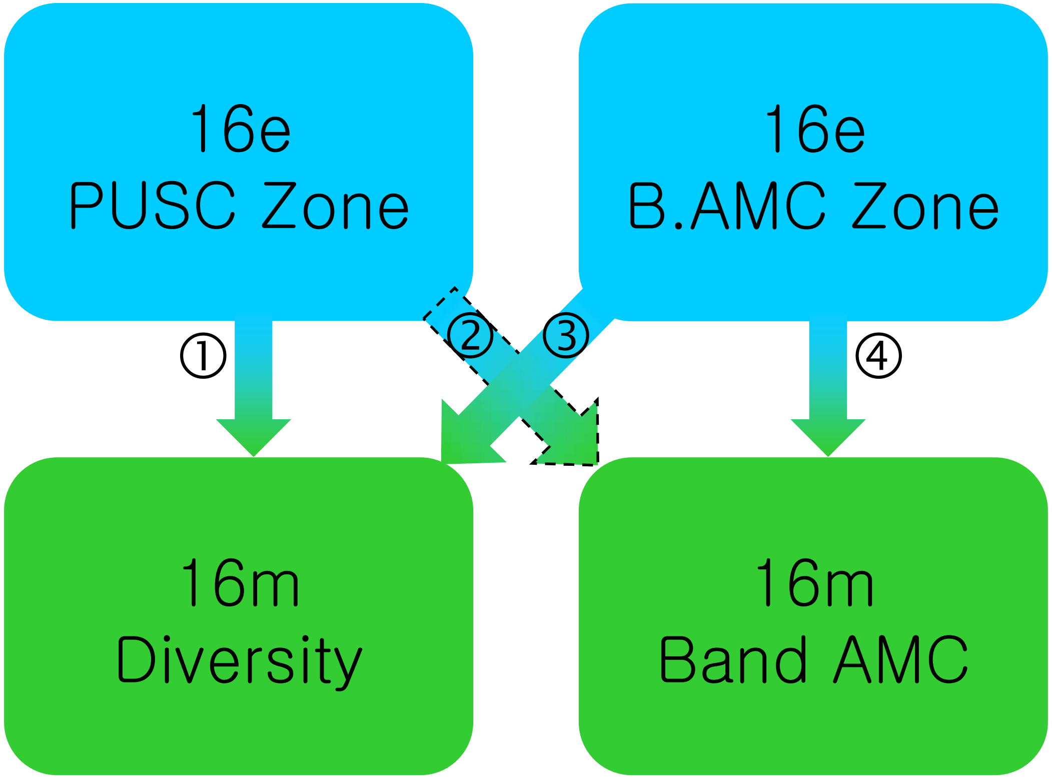


* WiMAX Forum™ Mobile System Profile Release 1.0 Approved Specification (4.1.2.2 of Revision 1.5.0: 2007-11-17)

** Refer to 8.4.5.4.10 Fast-feedback channels and 8.4.5.4.25 HARQ ACK Region Allocation IE in SPEC Rev2/D3

Coexistence Concept (1/4)

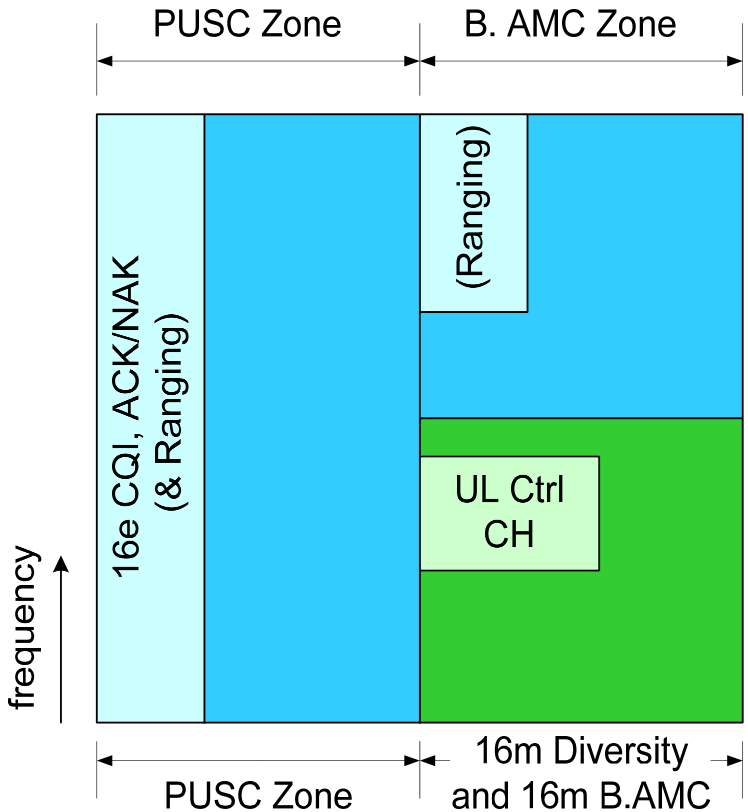
- Possible Ways to Support 16m Diversity and B.AMC



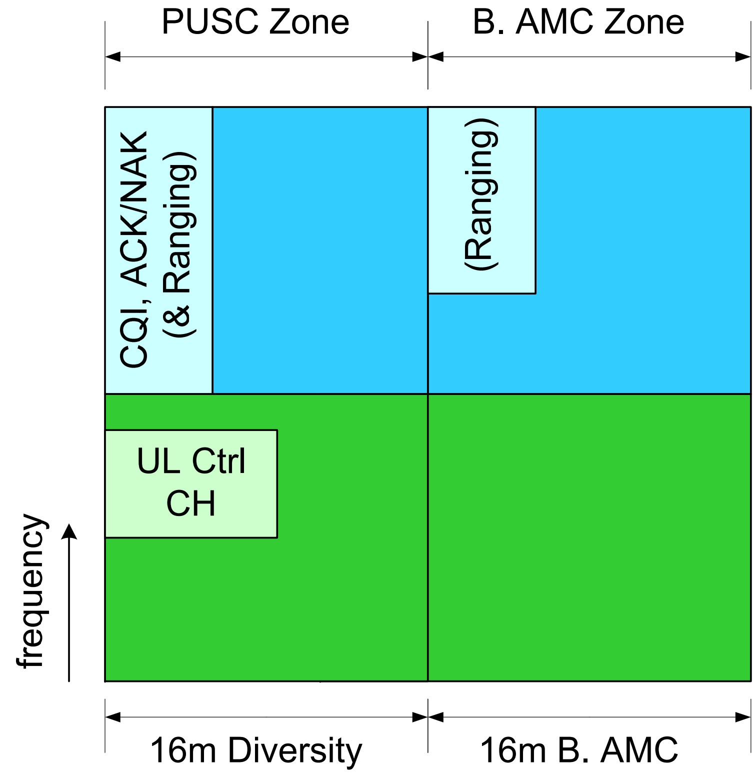
1	**Adequate**
2	**Inadequate**
3	**Possible**
4	**Adequate**

Coexistence Concept (2/4)

- Approach 1
  - ***Without*** New 16m Diversity Structure
  - Only 16e B.AMC zone supports 16m services

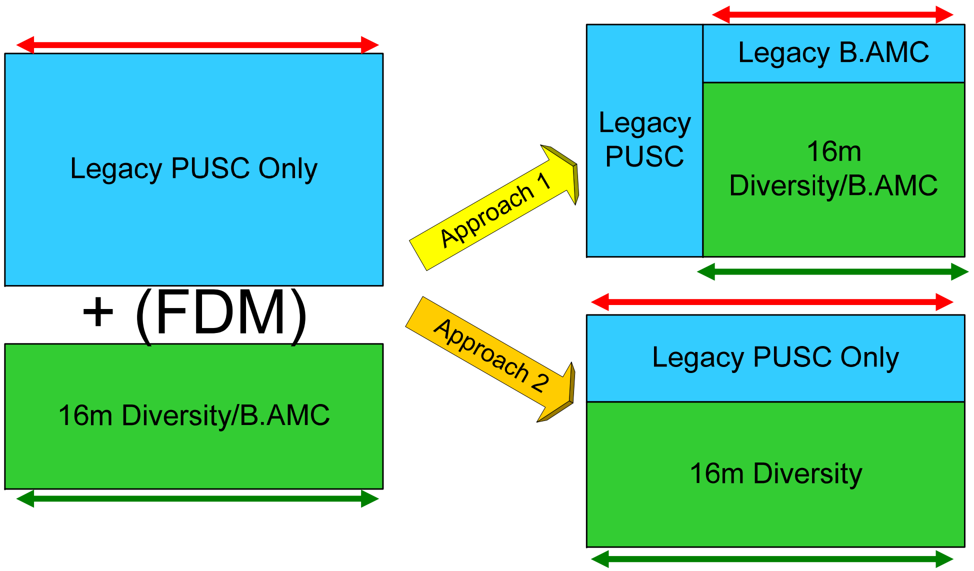


- Approach 2
  - ***With*** New 16m Diversity Structure
  - 16e PUSC and B.AMC zone support 16m services



Coexistence Concept (3/4)

- Case Study
  - When legacy system is operating with PUSC only

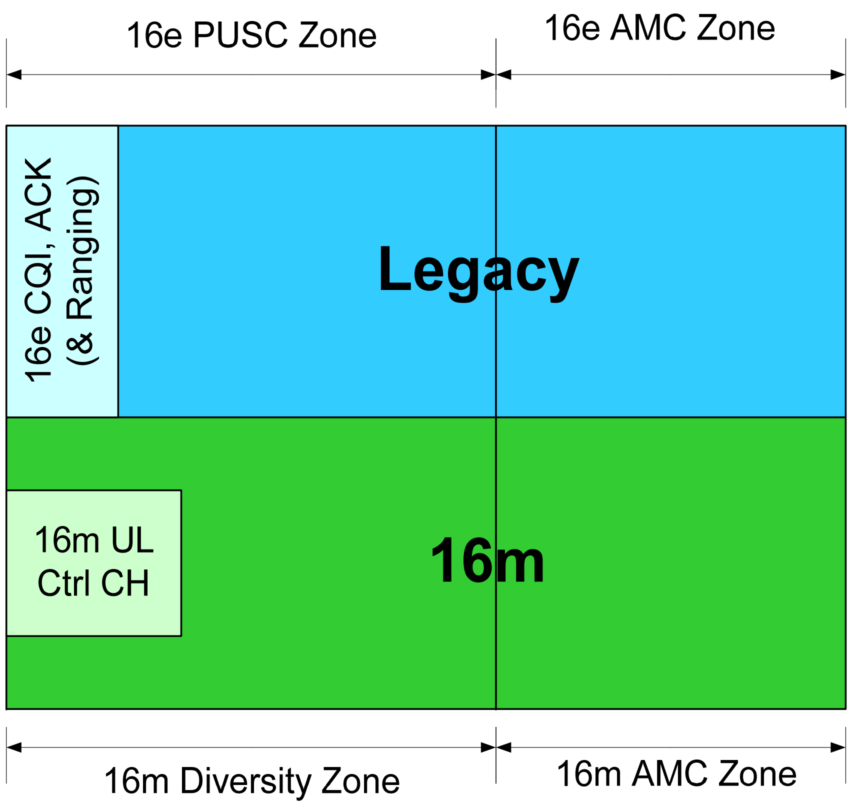


	Approach 1	Approach 2
Legacy view	- Need forced B.AMC zone - CSM not applicable in B.AMC zone - Concern about cell coverage	- CSM supportable in PUSC zone
16m view	- Lower hardware complexity - Shorter UL coverage	- Longer UL coverage - Higher hardware complexity

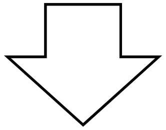
→ Taking everything into consideration, approach 2 is desirable.

Coexistence Concept (4/4)

- Proposed Scheme
  - 16m subchannel types synchronize with 16e subchannel types
  - 16m subchannel can be newly designed to enhance system performance



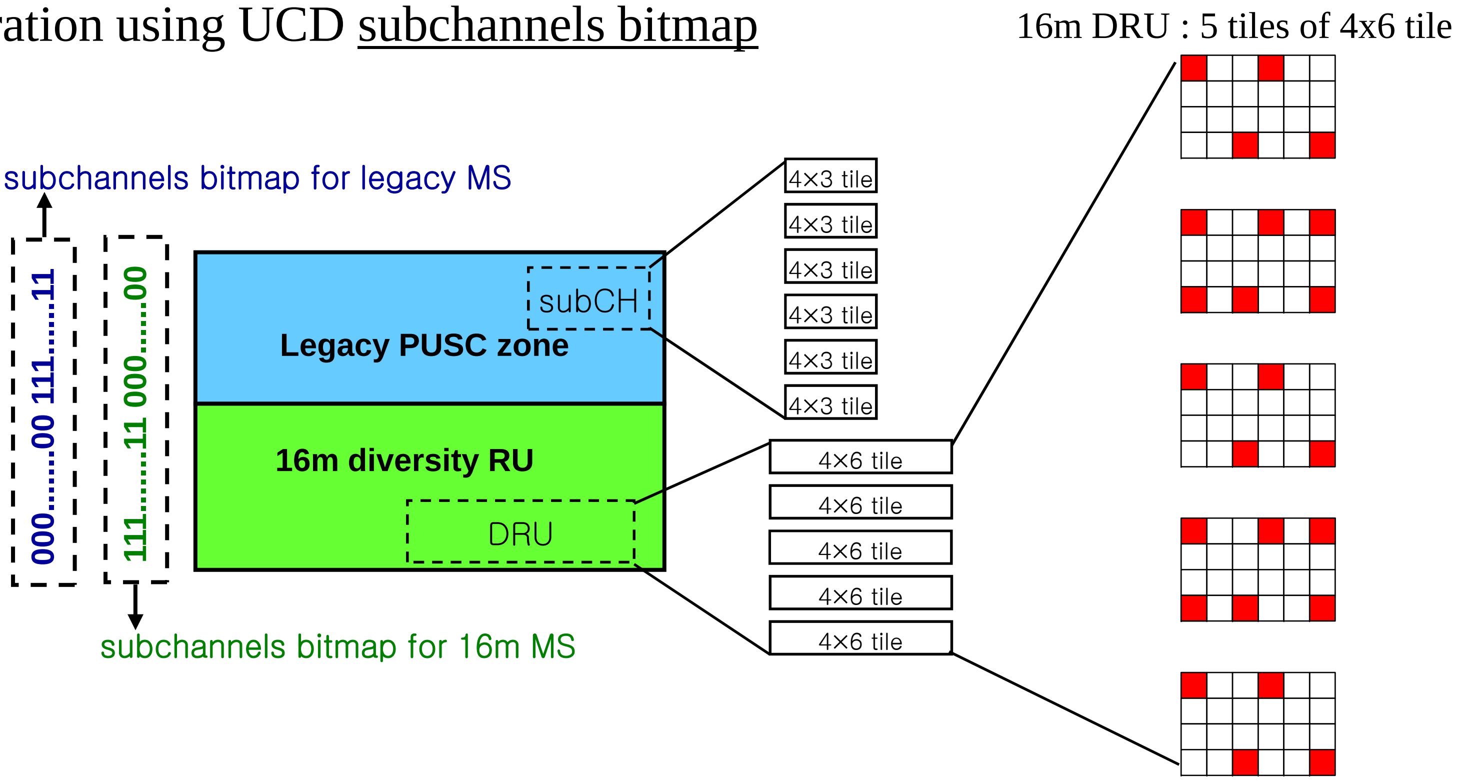
- Q) How to divide frequency domain resources into legacy and 16m ?



- A) By **<u>UCD bitmap</u>**

Resource Separation - for Diversity

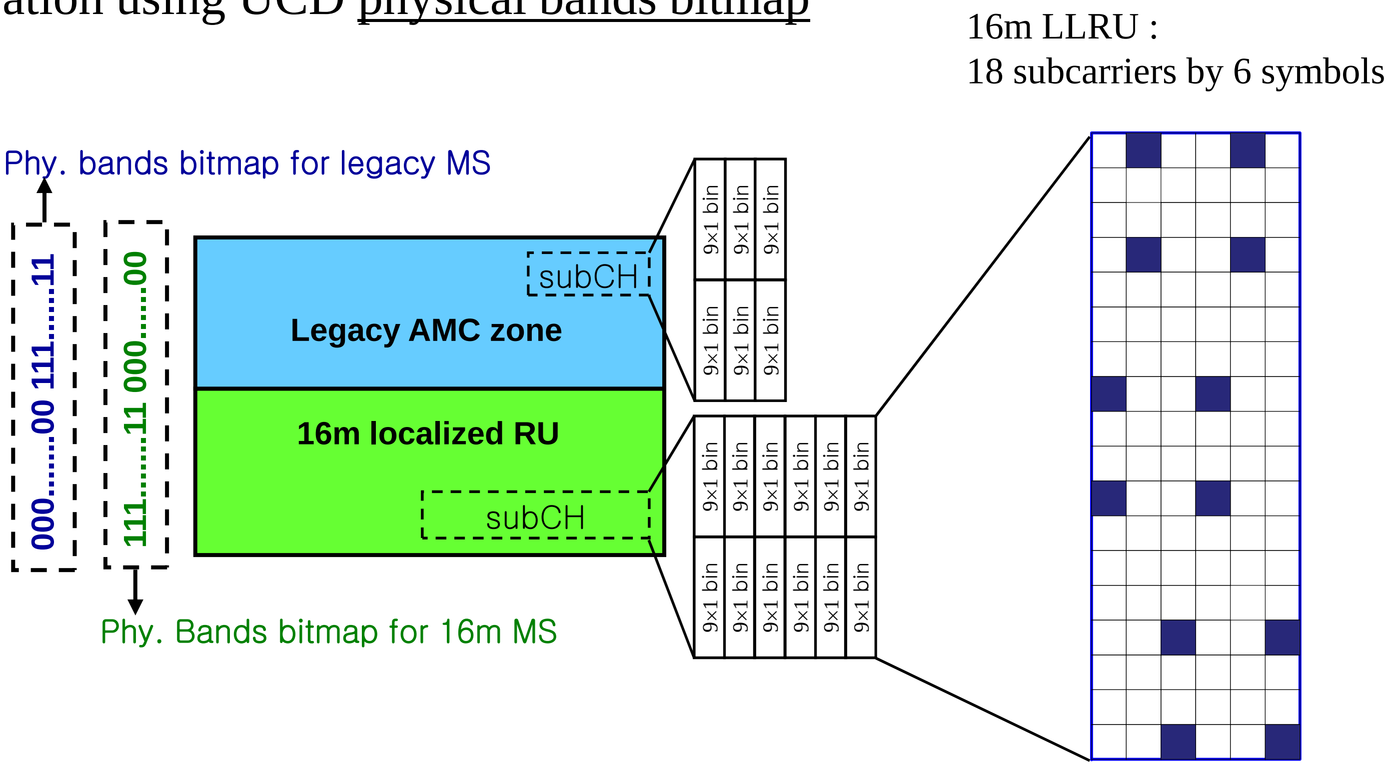
- Proposed Approach
  - Separation using UCD subchannels bitmap



  - Proposed approach can guarantee de-coupled subchannelization btw legacy and 16m
  - The only signaling newly required for 16m is a kind of legacy UCD subchannels bitmap

Resource Separation - for Band AMC

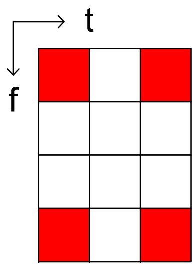
- Proposed Approach
  - Separation using UCD <u>physical bands bitmap</u>



  - The only signaling newly required for 16m is a kind of legacy UCD physical bands bitmap

E-PUSC – Tile for DRU

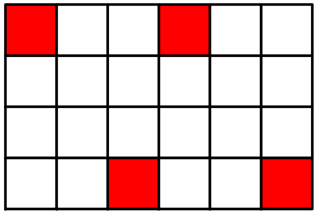
- Legacy 16e PUSC (4x3 tile)



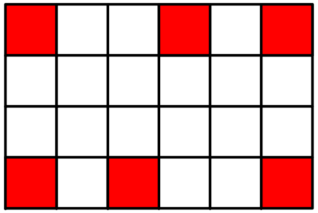
- Data tones / SubCH = 48
- Pilot OH = 4/12 = **33.3%**

- E-PUSC (4x6 tile-based)

A-tile



B-tile



Design Req : (1) Low Pilot OH (but more than 2 pilots in tile)

(2) PUSC compatible (extension of 4x3 tile structure)

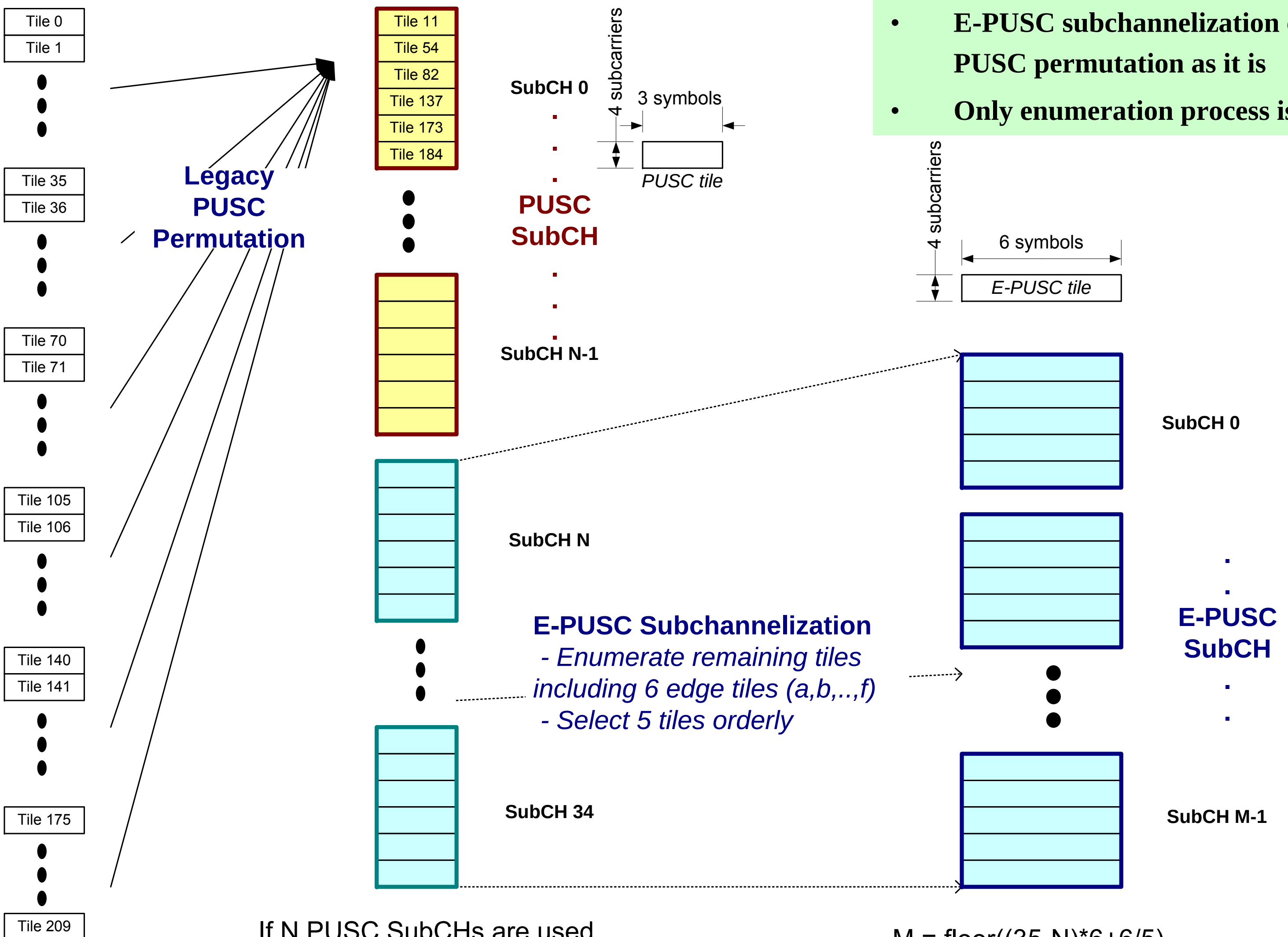
(3) 96 data tones per subchannel

- 1 SubCH = 3 × A-tiles + 2 × B-tile
- Data tones = 96
- Pilot density = (4/24) × 3/5 + (6/24) × 2/5 = **20% (1Tx, 2Tx and CSM)**

DRU – Subchannelization Procedure

Maximize Commonality

- E-PUSC subchannelization can use legacy PUSC permutation as it is
- Only enumeration process is newly required

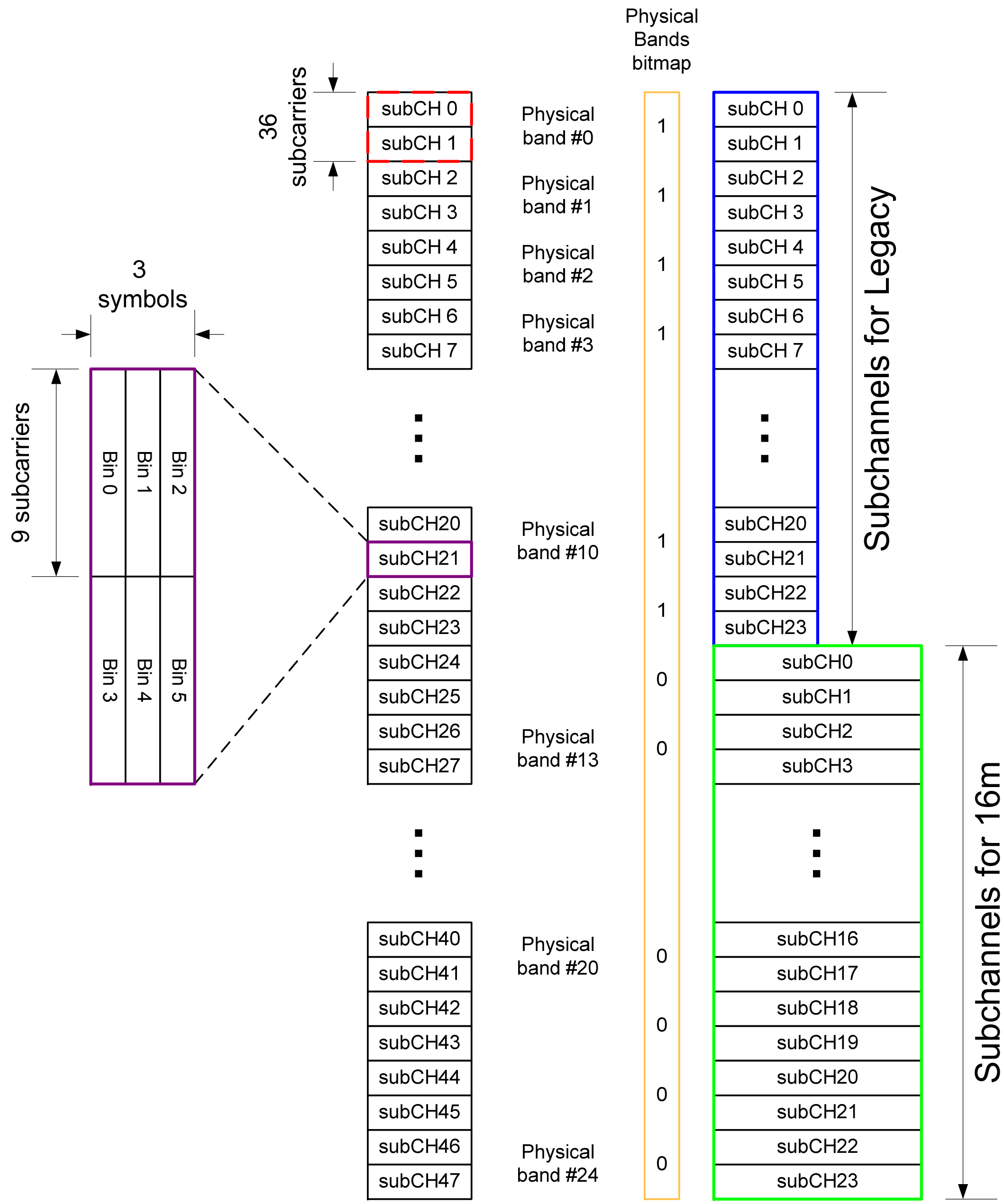


If N PUSC SubCHs are used, (35-N)*6 tiles will be left.

M = floor((35-N)*6+6/5)

LLRU – Subchannelization Procedure

- LLRU Subchannelization
  - By using physical bands bitmap
  - 1 physical band
    = 2 subchannels in B.AMC
    = 4 bins
    = 2 LLRUs in 16m



Proposed Text

Insert the following text into SDD Section 11 in IEEE 802.16m-08/003r1

Section 11.6 Uplink Physical Structure for 16m Green Field

Section 11.6.1 Physical and Logical Resource Unit

A physical resource unit (PRU) is the basic physical unit for resource allocation that comprises Psc consecutive subcarriers by Nsym consecutive OFDMA symbols. For uplink PRU, Psc equals to 18. Nsym equals to 6 for regular subframes and equals to 5 for irregular subframes.

A logical resource unit (LRU) is the basic logical unit for resource allocation that comprises Lsc subcarriers by Nsym consecutive OFDMA symbols. In the case of localized allocations, Lsc is equal either to 18 or 9. Therefore, one LRU should contain 108 tones for 18 Lsc, or 54 tones for 9 Lsc.

Section 11.6.1.1 Distributed Resource Unit

The distributed resource unit (DRU) can be used to achieve frequency diversity gain. The minimum unit for forming the uplink DRU can be equal to three tile types. The first one (tile type A) is 18 subcarriers by 6 symbols, the second one (tile type B) is 6subcarriers by 6 symbols and the third one (tile type C) is 3 subcarriers by 6 symbols.

Section 11.6.1.2 Localized Resource Unit

The localized resource unit (LLRU) can be used to achieve frequency-selective scheduling gain. The LLRU contains a group of subcarriers which are contiguous across the localized resource allocations. The size of the uplink LLRU equals to PRU.

Proposed Text

Insert the following text into SDD Section 11 in IEEE 802.16m-08/003r1

11.6.2 Subchannelization and Resource Unit Mapping

11.6.2.1 Basic DRU and LLRU Structure

DRU can be made up by three kinds of ways as shown in the figure 11.6.2.1-1, figure 11.6.2.1-2 and figure 11.6.2.1-3.

LLRU can be made up based on the figure 11.6.2.1-1.

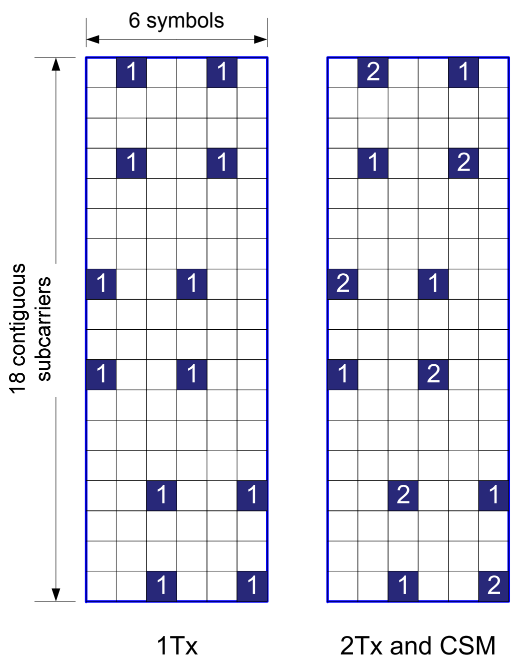


figure 11.6.2.1-1

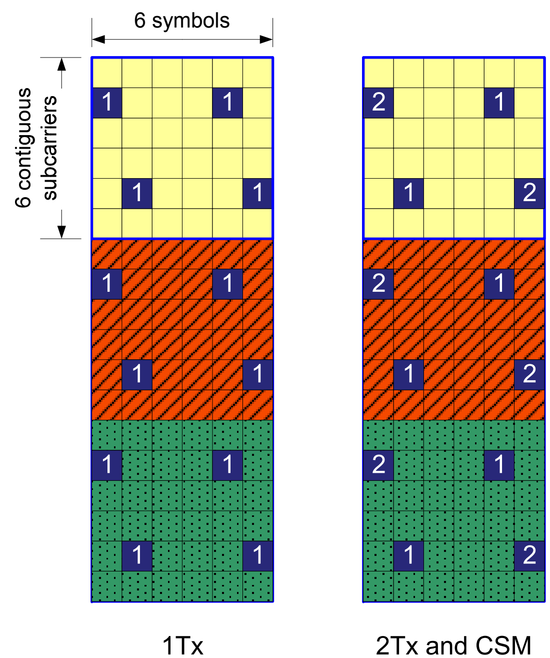


figure 11.6.2.1-2

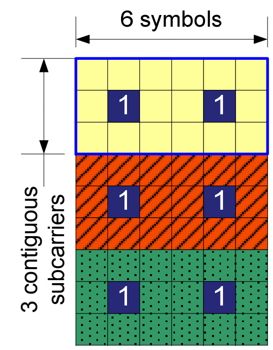


figure 11.6.2.1-3

Proposed Text

Insert the following text into SDD Section 11 in IEEE 802.16m-08/003r1

11.6.2.2 Resource Unit Mapping

Overall procedure of downlink subcarrier mapping to resource unit should be like below:

1. Outer permutation with cluster (A cluster can one or the multiples of PRU)
2. Divide total clusters into N groups which are separated exclusively in frequency domain
3. Reserve required clusters for LLRU in each group
4. Inner permutation in terms of type B and type C tile
5. Logical indexing for all DRU and LLRU

Proposed Text

Insert the following text into SDD Section 11 in IEEE 802.16m-08/003r1

11.7 Uplink Physical Structure for FDM based Legacy Support

16m should be able to coexist with legacy system in FDM manner.

11.7.1 Physical and Logical Resource Unit

A physical resource unit (PRU) is the basic physical unit for resource allocation that comprises Psc consecutive subcarriers by Nsym consecutive OFDMA symbols. For uplink PRU in FDM based legacy support mode, two kinds of Psc are used. The first one is 4 and the second one is 18.

A logical resource unit (LRU) is the basic logical unit for resource allocation that comprises Lsc subcarriers by Nsym consecutive OFDMA symbols. In the case of localized allocations, Lsc is equal either to 20 or 18. Therefore, one LRU should contain 120 tones for 20 Psc or 108 tones for 18 Psc.

Section 11.7.1.1 Distributed Resource Unit

The distributed resource unit (DRU) can be used to achieve frequency diversity gain. The minimum unit for forming the uplink DRU is equal to the tile size of 4 subcarriers by 6 symbols.

Section 11.7.1.2 Localized Resource Unit

The localized resource unit (LLRU) can be used to achieve frequency-selective scheduling gain. The LLRU contains a group of subcarriers which are contiguous across the localized resource allocations. The size of the uplink LLRU equals to the tile of 18 subcarriers by 6 symbols.

Proposed Text

Insert the following text into SDD Section 11 in IEEE 802.16m-08/003r1

11.7.2 Subchannelization and Resource Unit Mapping

11.7.2.1 DRU and LLRU Structure

DRU structure is shown in 11.7.2.1-1 and LLRU structure is shown in figure 11.7.2.1-2.

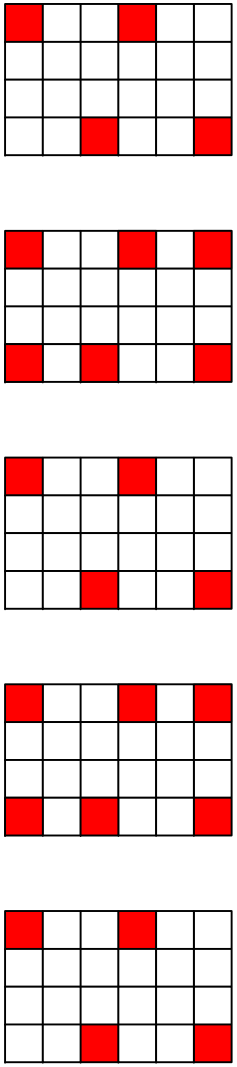


figure 11.7.2.1-1

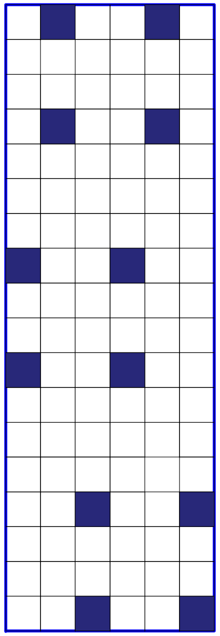


figure 11.7.2.1-2