Proposal for IEEE 802.16m Uplink Pilot Structures

Document Number: IEEE C802.16m-08/348r1

Date Submitted: 2008-05-05

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Re: IEEE 802.16m-08/016r1 – Call for Contributions on Project 802.16m System Description Document (SDD), on the topic of "UL Pilot Structures"

Purpose: Adopt the proposal into the IEEE 802.16m System Description Document

Scope

- This contribution presents the IEEE 802.16m Uplink MIMO pilot design
  - Unified pilot structures for diversity and localized RBs
  - Pilot structure for FDM legacy support
  - Uplink control tile and pilot structure

IEEE 802.16m System Requirements

- The TGm SRD (IEEE 802.16m-07/002r4) specifies the following requirements:
  - Section 5.7 Support of advanced antenna techniques:
    - “IEEE 802.16m shall support MIMO, beamforming operation or other advanced antenna techniques. IEEE 802.16m shall further support single-user and multi-user MIMO techniques.”
  - Section 6.10 System overhead:
    - “Overhead, including overhead for control signaling as well as overhead related to bearer data transfer, for all applications shall be reduced as far as feasible without compromising overall performance and ensuring proper support of systems features.”
  - Section 7.11 Relative Performance and Section 7.2.1 Relative sector throughput and VoIP capacity:
    - 2x performance gain over the legacy system is required
- The proposed pilot structure targets the above requirements by optimizing the pilot overhead for multi-antenna support

Background

- In the legacy 16e system, UL MIMO pilot allocation require large overhead (33% for PUSC, 11-22% for AMC).
- UL PUSC resource unit design is inefficient for both pilot and VoIP packet transmission
- As we consider a new frame structure for 802.16m, we should include a more optimum pilot design.
- With an optimal pilot design, reliable channel estimation should be achieved by using the minimum pilot overhead, under various channel conditions and mobility as required by 16m SRD and EVM:
  - Mobility: optimum performance for: 0-10 km/h; graceful degradation for: 10-120 km/h; connection maintained: 350 km/h
  - Baseline Channel models: ITU Pedestrian B, Vehicular A
- Uplink pilot design, as well as resource unit design, can be aligned with corresponding downlink designs (see C802.16m-08/172r1 and C802.16m-08/175r1)
  - Uplink pilots are MS specific pilots, similar to downlink dedicated pilot, which can only be used within MS allocated resource blocks.
  - In uplink MU-MIMO scenario, pilots for several MS can multiplexed onto the same resource blocks

Uplink Pilot Design Consideration

- Should support MS at various speed and channel conditions
- Enable BS to use pilot tones from available resource for interpolation to enhance the link performance and reduce overall pilot overhead
- Resource block size should align with basic pilot sub-carrier spacing
  - This can reduce signaling overhead and implementation complexity
- To support application like VoIP, diversity transmission for a MS has relatively small resource granularity. Pilot density and resource block size should adapt to such situation

Overview of uplink pilot design (1/2)

- Purpose of UL pilot
  - UL channel estimation for coherent demodulation/detection of data at the BS
  - UL control signal detection and demodulation
    - Most UL control signals are detected coherently.
    - Some UL control signals, e.g. ACK , have option to detect non-coherently.

Overview of uplink pilot design (2/2)

- The following pilot design principles, as described in C80216m-08_172r1, are also applied to UL pilot.
  - Pilot spacing constraint validated for downlink pilot should also be applied to UL pilot design, considering channels in both uplink and downlink share the same long term statistic properties, e.g. coherent time and coherent bandwidth
    - Maximum frequency spacing of 12 subcarriers and maximum time spacing of 3 OFDM symbols can be applied to UL
  - Scattered pilot design
  - Pilot design at resource boundaries
    - UL pilots are MS specific pilots, similar to downlink dedicated pilot, which can only be used within MS allocated resource blocks.
    - Channel estimation accuracy at resource boundaries plays an important role in overall system performance.
    - Allocate pilots at resource boundaries can enhance link performance without dramatically increasing pilot overhead
  - Unified pilot structures for diversity and localized RBs

Resource Block (RB) and Basic Channel Unit (BCU) for Data

- Resource block (RB) and Basic channel unit (BCU) definitions are the same for both DL and UL. Details on the proposed UL channelization can be found in C80216m-08/350.
- Two cases are considered: 1) TDM of legacy and 16m; 2) FDM of legacy and 16
- For the TDM case:
  - Pilot structure for RB sizes of 12 sub-carriers x 6 symbols is provided. Similar pilot structure can be applied to 18x6 RB.
- For FDM case:
  - Pilot structure for RB size of 4 sub-carrier x 6 symbols is proposed to align with legacy PUSC resource allocation

Pilot Design at Resource Boundaries: Considerations

- Pilot design at resource boundaries, as described in C802.16m-08_172r1, can also be applied to uplink pilot. Considerations of this design for uplink pilot are highlighted as following.
  - Extrapolation degrades channel estimation quality, as compared to interpolation. Extrapolation should be prevented as much as possible while keeping similar pilot structure and channel estimation complexity
  - Extrapolation can be prevented or limited by allocating extra pilot sub-carriers at the resource boundaries in time and frequency
    - In order to co-exist with legacy TDD system, user usually is assigned to a resource within one subframe (or 6 OFDM symbols). Sub-carriers at the sub-frame boundary which need extrapolation in **time direction** for channel estimation take a large portion of the total resource and should be prevented.
    - UL Pilots are always allocated within certain resource blocks. Extrapolation in **frequency direction** should also be prevented for sub-carriers located at frequency boundaries

Uplink pilot Design at Resource Boundaries: Solutions

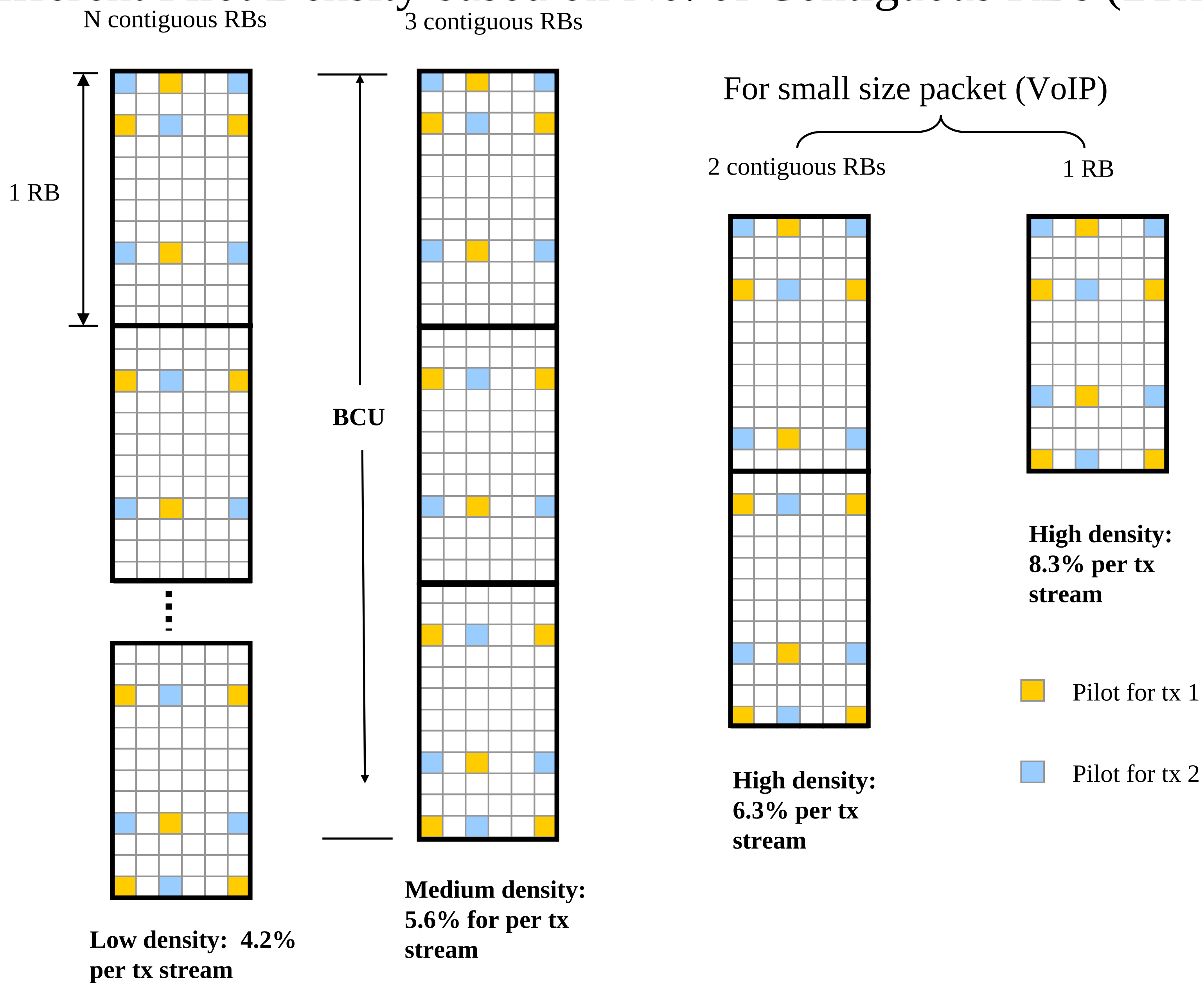
- Similar to DL pilot design in C80216m-08_172r1, solutions of UL boundary pilot design for uplink pilot are highlighted as following.
  - Extrapolation can be prevented or limited by allocating extra pilot sub-carriers at resource boundaries in time and frequency
  - These boundary pilots keep the basic scattered pilot structure in order to allow BS has the same channel estimation algorithm
  - Overall increase in overhead due to these extra pilots is limited
  - Uplink pilots are not boosted, so the collision between pilots in different sectors is not worse than collision with data tones.
  - In general, a boundary pilot is allocated when extrapolation distance in frequency direction is more than half of the maximum pilot spacing in frequency. In current design, boundary pilot is allocated when extrapolation distance is more than 6 sub-carriers.

Uplink Pilot Structure with Adaptive Density

- **General design of pilot based on adaptive density is described in C80216m-08_172r1.**
- **Pilot density is adapted based on number contiguous RBs used for channel estimation**
  - With boundary pilot design in uplink pilot structures, pilot density changes according to contiguous resource size in order to enable BS to have optimal pilot aided channel estimation under the uniformly designed pilot structure, while minimizing overall pilot overhead.
  - **Low density pilot pattern** (3.1% < density < 5.3% per Tx): when than 3 contiguous RBs (or one BCU), or extended subframe are allocated to a user
  - **Medium density pilot pattern** (density ~5.6% for 1 Tx): when one BCU or around 3 contiguous RBs are allocated to a user
  - **High density pilot pattern** (6.3% < density < 8.3%): when less than 3 RBs are assigned to a user. It is mainly used for VoIP transmission.

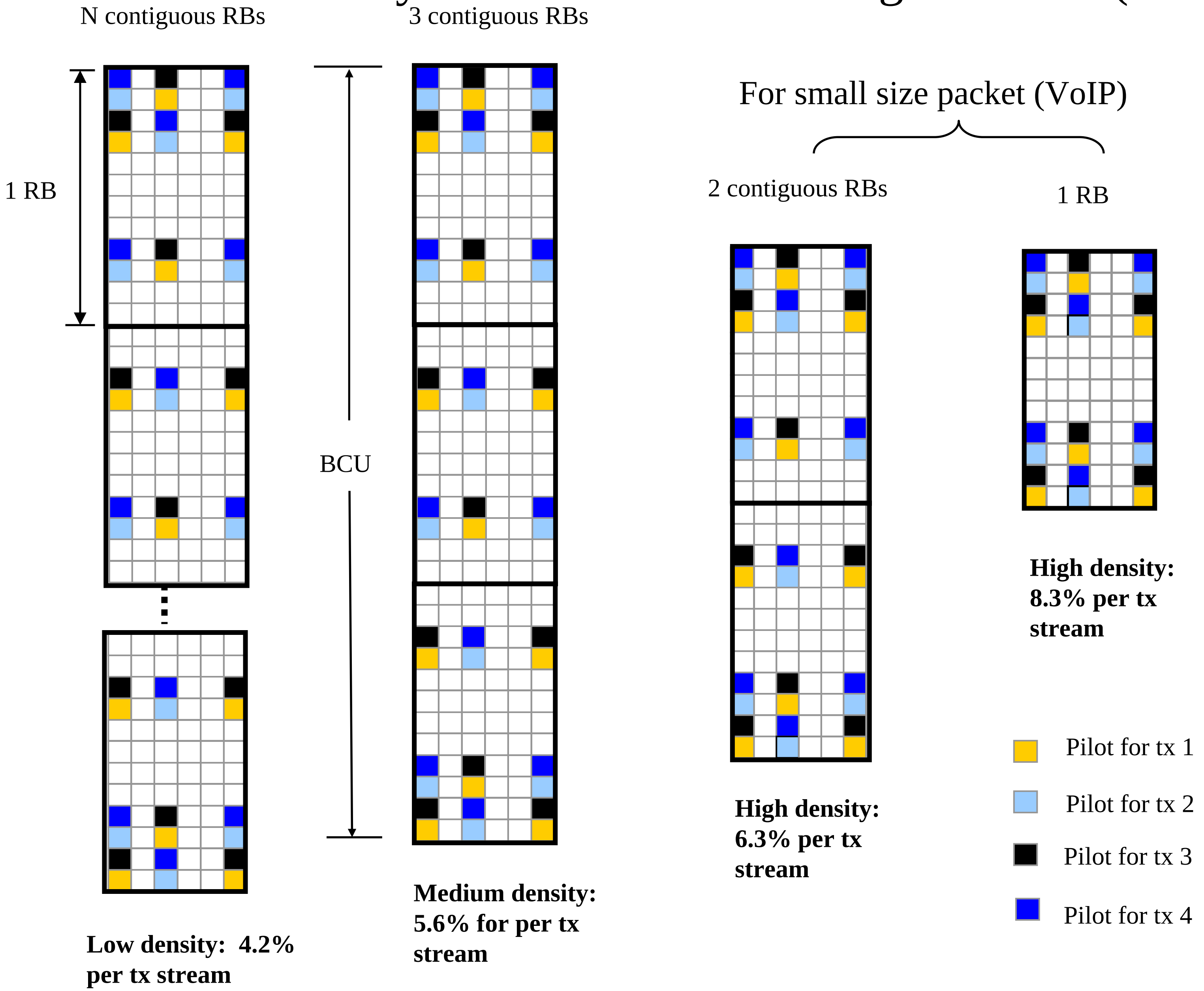
Pilot Structure for 12x6 RB

Different Pilot Density based on No. of Contiguous RBs (2Tx)



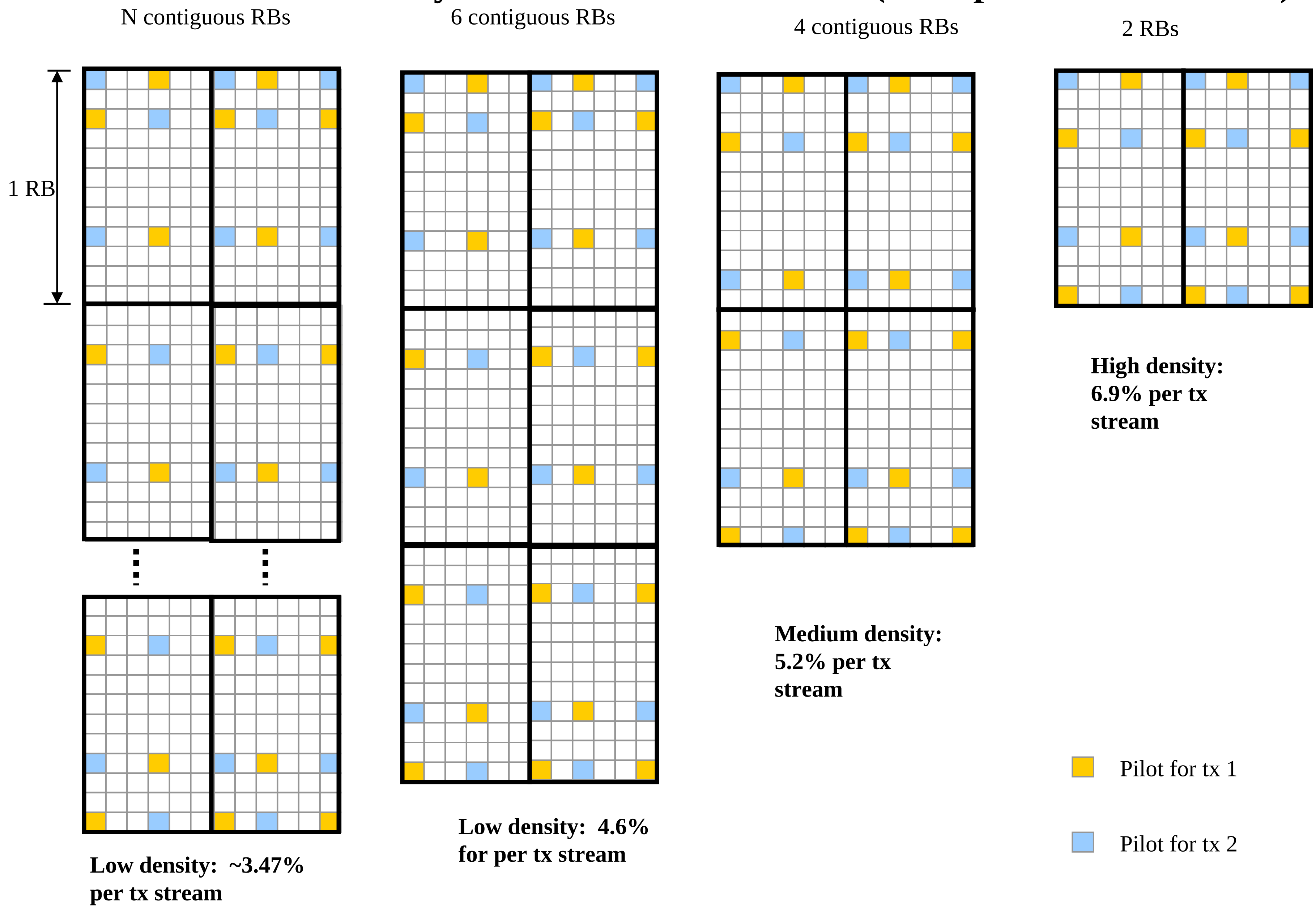
Pilot Structure for 12x6 RB

Different Pilot Density based on No. of Contiguous RBs (4Tx)



Pilot Structure for 12x6 RB

Different Pilot Density for Extended Sub-frame (example shown for 2 Tx)



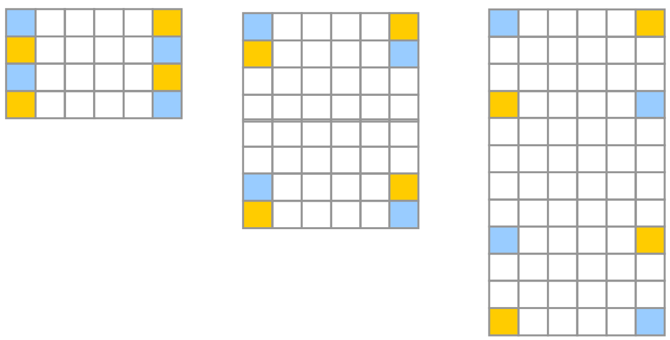
Resource block for FDM legacy PUSC support

- Mini-RB is defined as a 4x6 tile (4 subcarriers by 6 OFDM symbols), and pilots are allocated correspondingly.
  - As in the case of pilot structure for 12x6 RB, pilot structure for the mini-RB adapts to contiguous mini-RB available for one MS, so as to minimize the pilot overhead.
  - To further reduce pilot overhead, pilot structures adapt to low mobile speed and high mobile speed are also presented
  - Pilot structure also adapt to normal subframe and extended subframe

Mini-RB for FDM legacy support

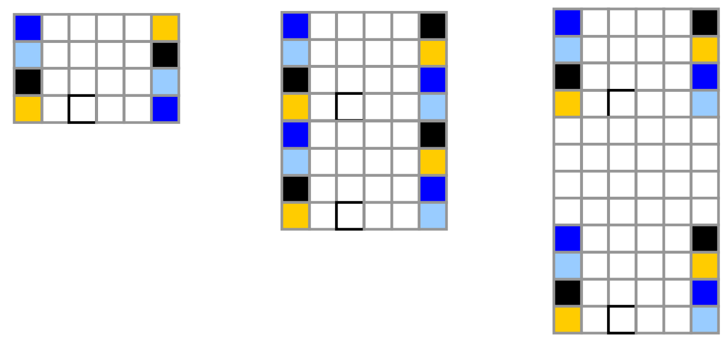
Low/Moderate MS speed

1 mini-RB | 2 mini-RBs | 1 RB = 3 mini-RBs



16.7% per Tx stream | **8.3% per Tx stream** | **5.6% per Tx stream**

1 mini-RB | 2 mini-RBs | 1 RB = 3 mini-RBs



8.3% per Tx stream | **8.3% per Tx stream** | **5.6% per tx stream**

Pilot for tx 1

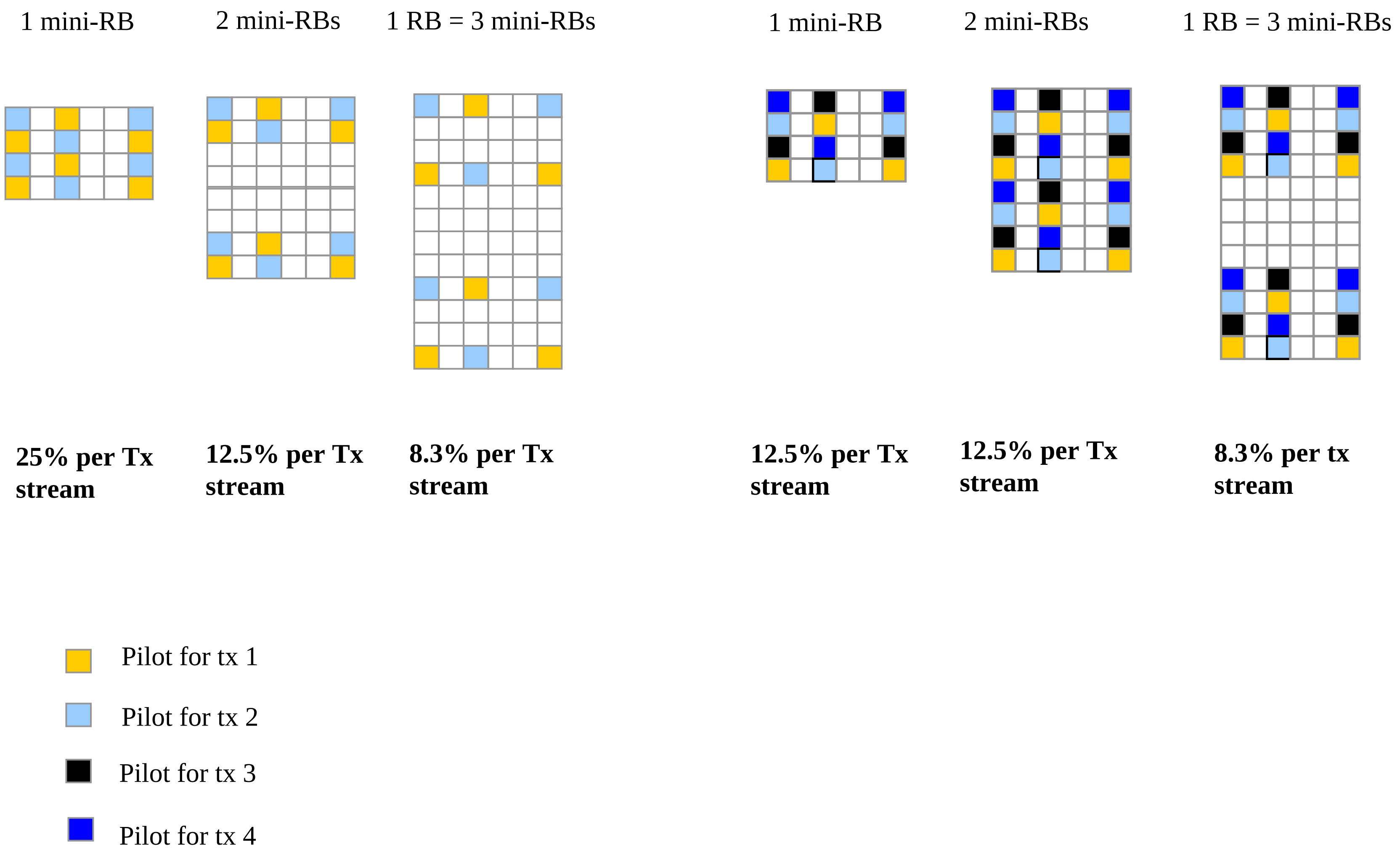
Pilot for tx 2

Pilot for tx 3

Pilot for tx 4

Mini-RB for FDM legacy support

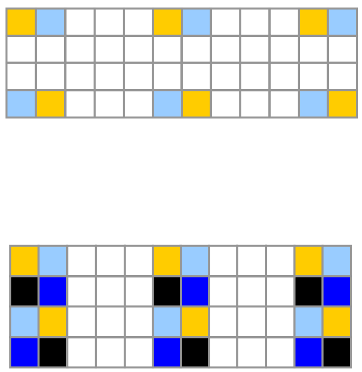
High MS speed



Mini RB for FDM legacy support and extended sub-frame

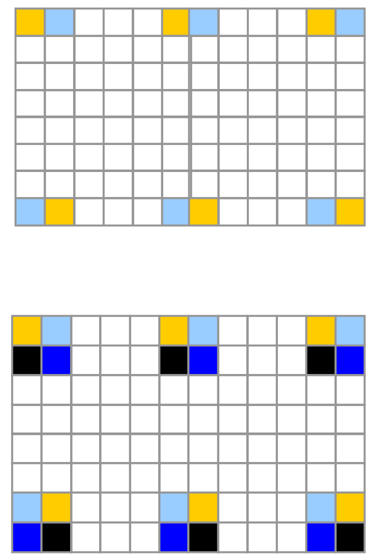
Low/moderate MS speed support

1 extended mini-RB



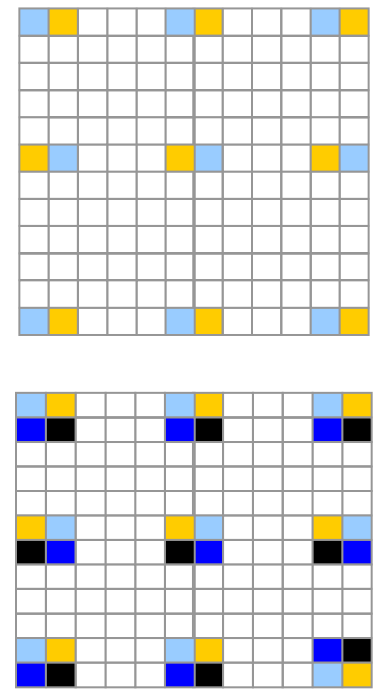
12.5% per Tx stream

2 extended mini-RBs



6.25% per Tx stream

Extended RB



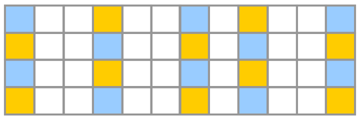
6.25% per Tx stream

- Pilot for tx 1
- Pilot for tx 2
- Pilot for tx 3
- Pilot for tx 4

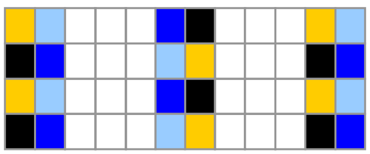
Mini RB for FDM legacy support within extended sub-frame

High MS speed support

1 mini-RB

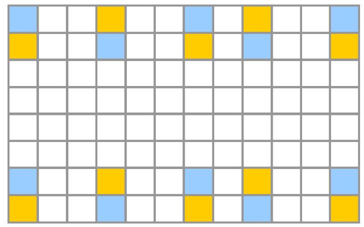


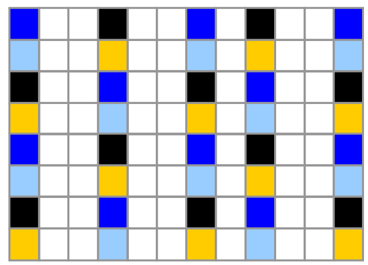
20.8% per Tx stream



12.5% per Tx stream

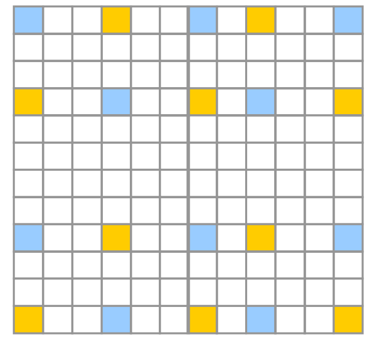
2 extended mini-RBs

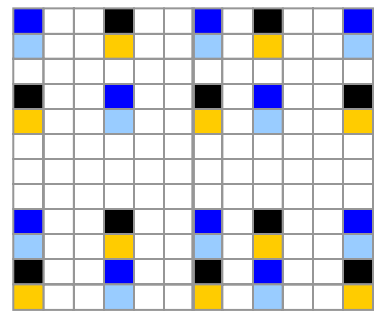




10.4% per Tx stream

Extended RB





6.9% per Tx stream

Pilot for tx 1

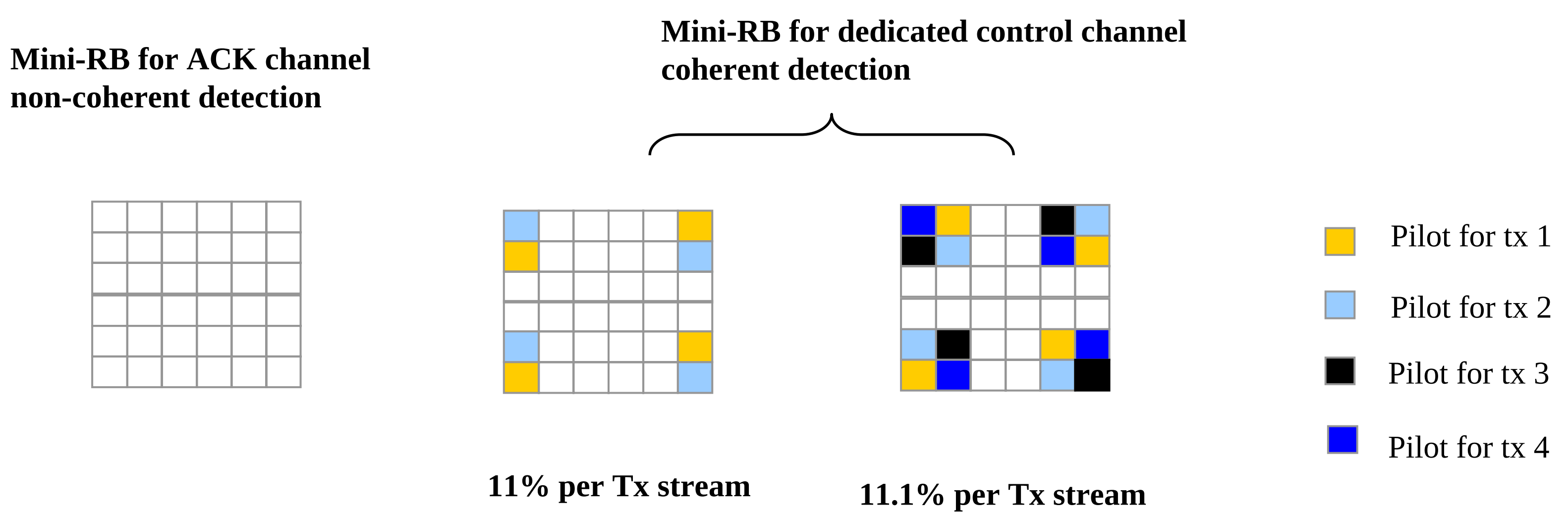
Pilot for tx 2

Pilot for tx 3

Pilot for tx 4

Uplink Control RB and Pilot Structure

- Considerations on control resource and pilot design
  - Control signal packet is usually small
  - Control signal need be transmitted with more reliability
    - Diversity transmission is applied
  - Control signal need be detected coherently or non-coherently
- ACK channel: smaller tile is required
  - Non-coherent detection is preferred for ACK channel, no pilots are allocated
  - Coherent detection is optional
- Dedicated control channel (CQI, PMI, rank, bandwidth request) are coded together and fit into smaller tiles
  - Coherent detection is used
  - 4x6, or 6x6 tile size is recommended.
- Control resource unit is defined as mini-RB which can be 4 subcarriers by 6 OFDM symbols. Other sizes is FFS.



Proposed Text for SDD
Section 11 Physical Layer

- Section 11.x UL Pilot structure
  - Unified pilot structures for diversity and localized uplink channelization
  - General pilot structure for different number of contiguous RBs allocated to a user
  - Resource block definition and pilot allocation for FDM legacy support
  - Control tile definition and pilot structure