Proposal for IEEE 802.16m SDMA and Beamforming

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*<http://standards.ieee.org/faqs/affiliationFAQ.html>

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

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

Scope

- This contribution presents a proposal for SDMA / beamforming for IEEE 802.16m

Introduction

- Beamforming on the DL is used to and maximize the SNR at the mobile
- Several user can be spatially multiplexed (SDMA) on the same resource by employing multiple beams
  - Closely spaced antenna elements are used to create multiple beams
  - Additional diversity antennas (e.g. cross-pole) can also be used for UL received diversity
- The SNR can be further enhanced by nulling the interference to other simultaneous scheduled users
- SDMA targets low mobility and nomadic users
- The system is further enhanced by using cross-polarization antennas to create 2-layer MIMO within each beam
  - Creates 2:N SDMA-MIMO system

IEEE 802.16m System Requirements

- The TGm SRD (IEEE 802.16m-07/002r4) specifies the following requirements:
  - Section 5.2 Complexity
    - IEEE 802.16m should minimize complexity of the architecture and protocols and avoid excessive system complexity. It should support low cost devices.
  - 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.
- The proposed DL SDMA / beamforming schemes target the above requirements.

SDMA Deployments and Beam Forming

- There are several deployment options in increasing complexity:
  - Fixed beam
  - Multi-beam steering
  - Adaptive beam forming
- This contribution proposes structures for support of these three deployment options.

SDMA Deployment	Performance	Feedback	Frequency of Feedback	Channel Information
Fixed beam	Fair	Beam index	Slow	Best Beam
Multi-beam steering	Good	UL Sounding or Beam position index	Medium	Best Beam position
Adaptive beam forming	Better	UL Sounding or Beamforming codebook vector (instantaneous or average)	Fast / Medium	Beam forming Vector

SDMA deployments and Beam forming

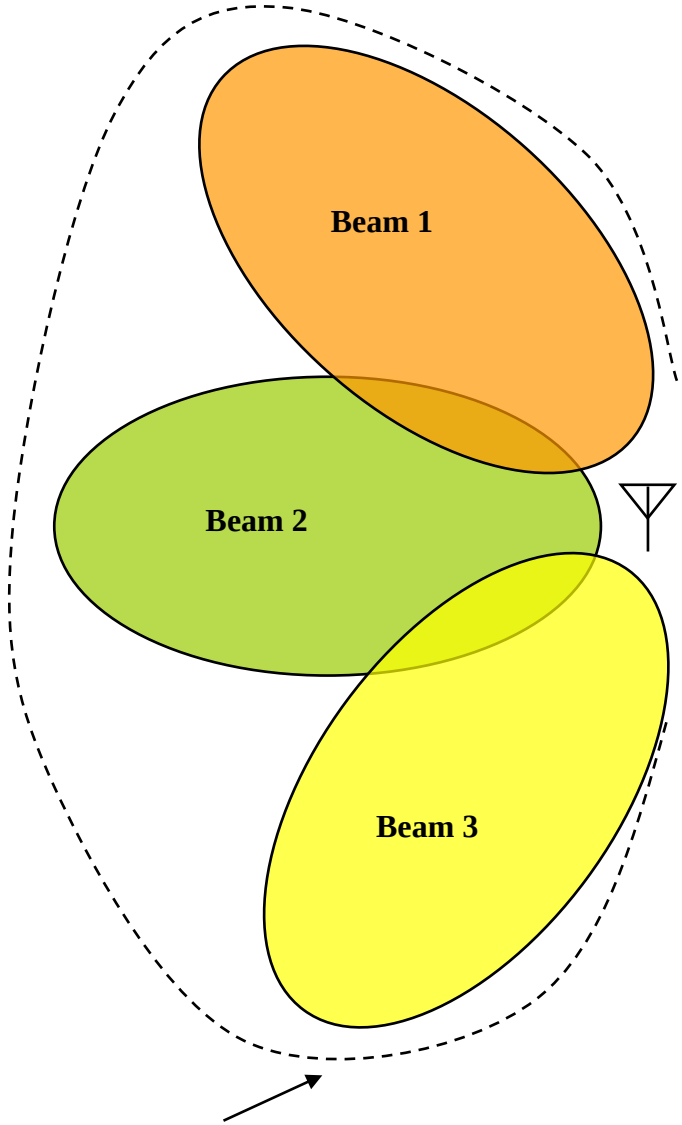
- In all deployment cases, the preamble and superframe broadcast information is sent on sector-wide beams
  - All users in sector aware of frame structure for each beam
  - Beam specific scrambling ID's used in traffic and subframe control known to all users
- Subframe resource allocations and control is per beam :
  - Sub-frame control information are sent on individual beams
    - Common control and MS-specific control/allocation messages
    - e.g. as proposed in C802.16m-08/176r1, multi-cast control segment (MCCS) and unicast/group control and traffic segments (UCTS &GCTS)
  - Beam forming control improves coverage

Sector Wide Channelization

- Common pilot locations are aligned between beams of a sector
- FDM of sector wide beam zone is supported
  - the logical channels from each beam will be aligned

Fixed Multi-Beam Deployment

- Base station creates multiple fixed beams to cover sector
- Preamble and superframe broadcast information is sent on sector-wide beams
  - All users in sector aware of frame structure for each beam
  - Beam specific scrambling ID's known to all users
- FDM of sector wide beam zone is supported as channelization is the same for each beam
  - Dynamic FDM zones signaled in each sub-frame (see slide N for details)
- Sub-frame control information is sent on individual beams
- Common sub-frame control information is scrambled by sector and beam specific ID.
- MS provides beam selection in UL feedback
  - Beam selection is a slow process
- MS traffic scrambled by sector and MS specific IDs



Multi-Beam Steering Deployment

- Base station steers to each beam position per subframe
  - Beam positions are switched per subframe
  - FDM of zones for different beam positions within a subframe is also supported for cases of asymmetric loading
  - Broadcast information indicates which beam positions have resource zones in each
- Preamble and superframe broadcast information is sent on sector-wide beams
- FDM of sector wide beam zone is supported as channelization is the same for each beam
- Sub-frame control information is sent on individual beams
- Common sub-frame control information is scrambled by sector and beam specific ID.
- MS provides beam selection in UL feedback
  - Beam selection is a slow process
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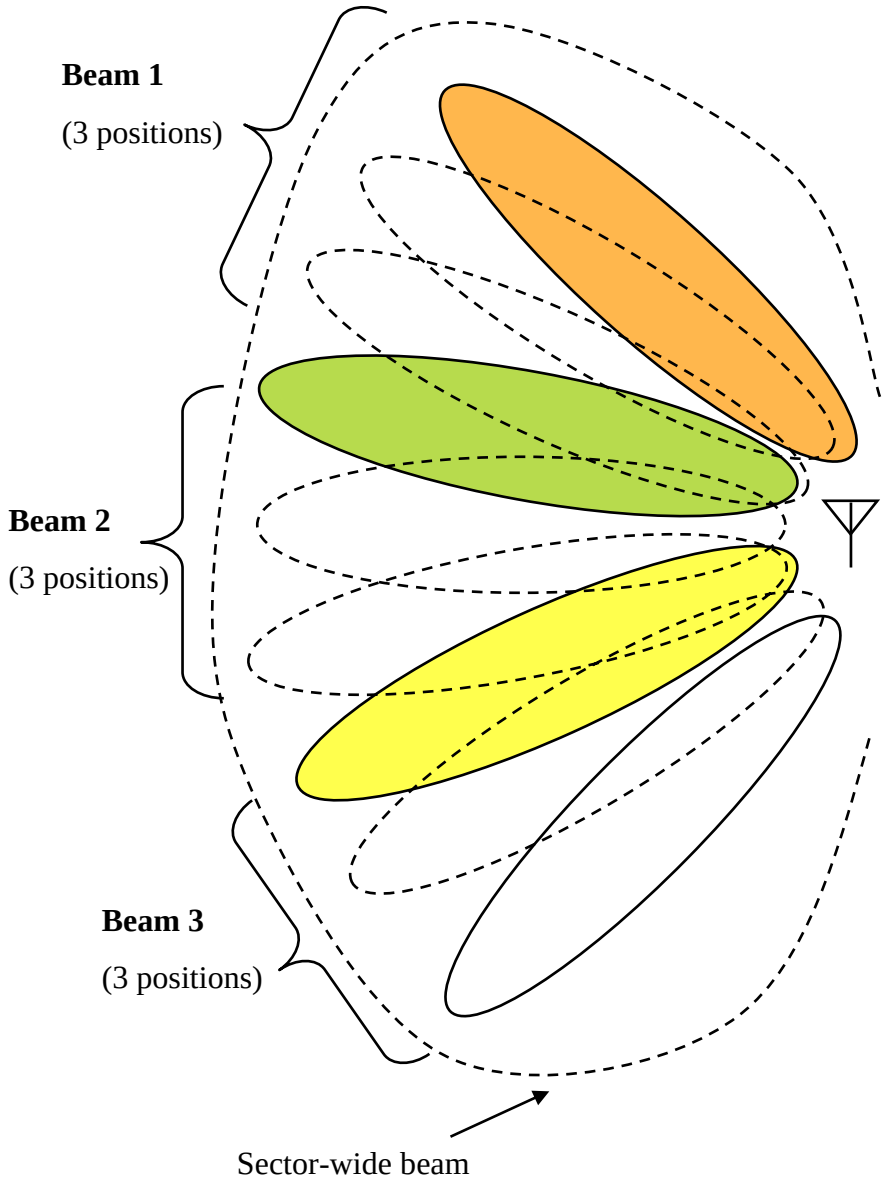
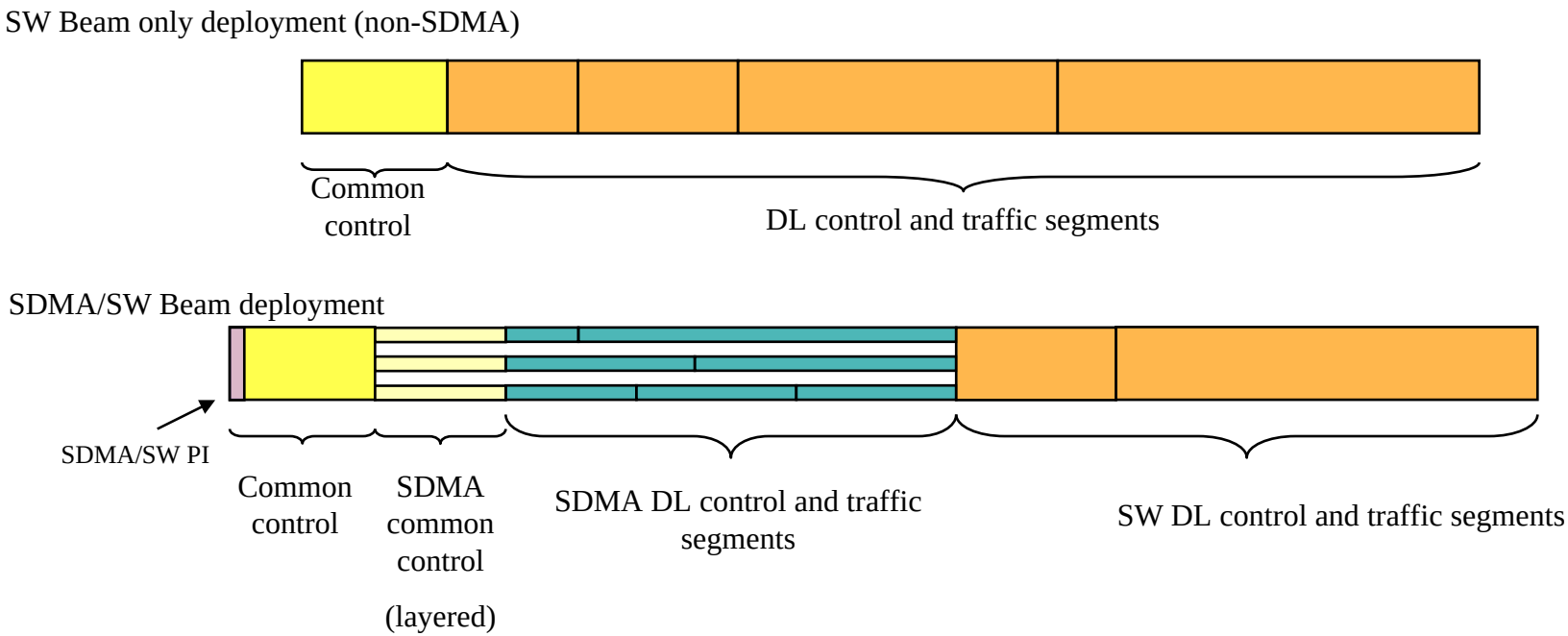


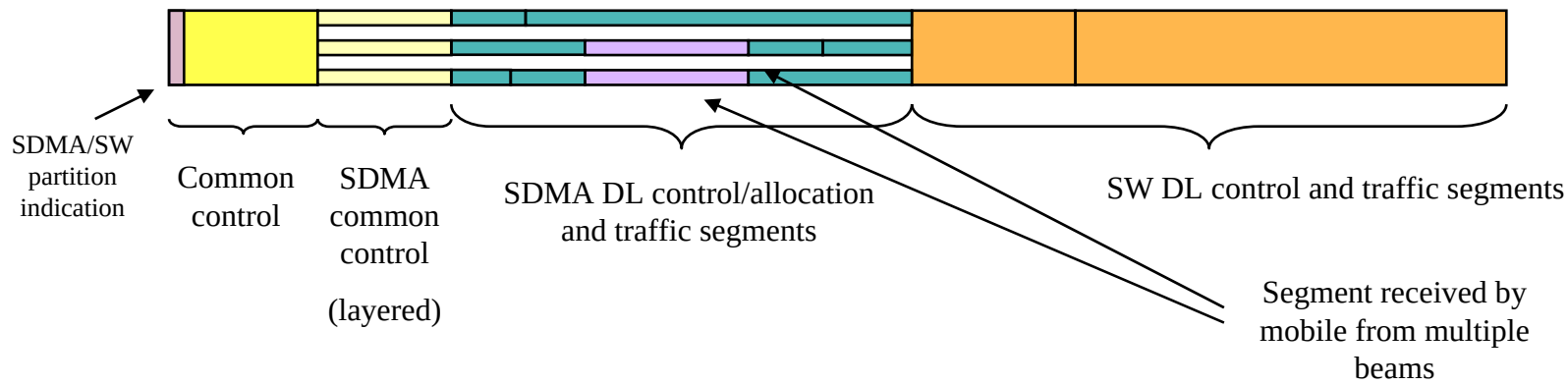
Multiplexing of SDMA and Sector-Wide (SW) Beam Allocations (Fixed beam and Multi-Beam steering)



- Common DL sub-frame control information is sent on individual beams
- SW common control and SDMA common control are in known locations signaled in superframe header (they can be located in different locations for different beams)
- SDMA users need to read only the SDMA common control which contains information on SDMA unicast assignments
- The resource partitioning between SDMA and SW resources (logical partition) is indicated. Sent only to sector wide beam users.

MS Served by Multiple Beam (Fixed beam and Multi-Beam steering)

SDMA/SW Beam deployment



- An MS can be sent information on multiple beams. This common control information can be sent separately on each beam. The mobile can attempt to access the common control of one or more beams. Common control is scrambled by a sector /beam ID.
- The base station can schedule the traffic information on the same set of resources on multiple beams, scrambled by the MS and sector ID (not beam ID). The combined signal on both beams will be received at the mobile, improving detection for the mobile over using one beam.
  - If the control/allocation message is sent in the partition over both beams with the data, the control message detection will also be improved

Channel Information for Beam forming

Channel information for SDMA feedback:

- Angle of Arrival
  - Determined at BS from UL transmissions
- Channel estimates can be measured at:
    - at the mobile and sent as beamforming (codebook) vector to BS
    - at the BS through UL channel sounding
  - Can use average or ‘instantaneous’ feedback depending on mobile speed / feedback delay / frequency of feedback

Beam selection and CQI feedback (1/2)

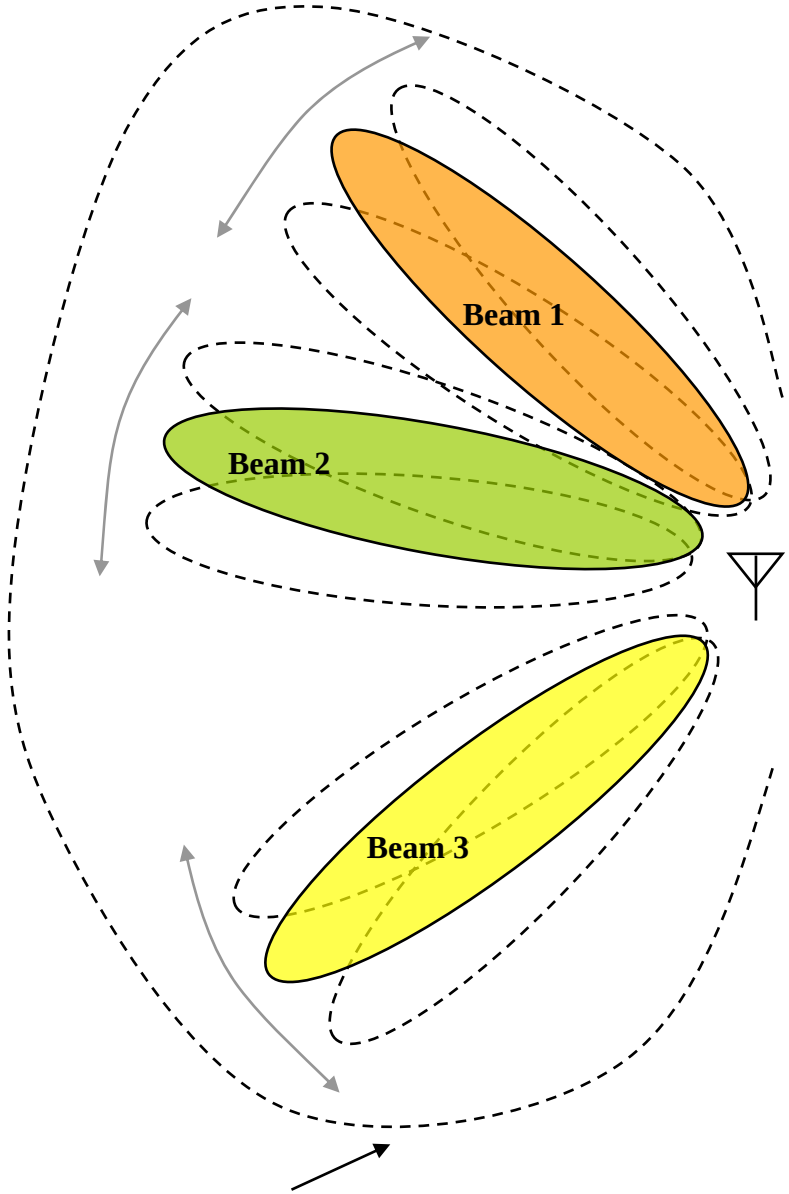
- Beam selection can be done at the mobile or at the base station.
- At the base station, UL channel sounding is used to identify the approximate AoA of the UL sounding pilots from each mobile
  - UL sounding send pilots from each mobile antenna to the base station so that the base station can determine AoA, and other channel information
  - Details on the UL Sounding Pilot channel are given in contribution IEEE C802.16m-08/349
- At the mobile station, for fixed beams and beam positions the desired beam index is determined and feedback to the base station
  - Beam specific MIMO channel measurements pilots used (see contribution IEEE C802.16m-08/343)
  - Additional details on next slide

Beam selection and CQI feedback (2/2)

- Mobile needs to be able to identify each beam or beam position, and determine strength of beams.
  - DL channel measurement pilot sent periodically (see contribution IEEE802.16m-08/343 for details)
  - Each beam or beam position is sent on a separate subcarrier
    - Each beam/beam position may not need to be sent in every frame
    - One subcarrier can be used for multiple beams that are spatially separated such that interference between the beams is negligible
      - Same beam index applies to beams with co-located pilots
      - Base station can infer which beam the mobile has feedback by roughly estimating AoA
  - Boosting of the channel measurement pilots is FFS.
- Mobiles can identify their best beam by pilot position in DL channel measurement pilot
  - MSs feedback best beam index and also feedback beam CQI

Adaptive Beam forming Deployment (1/2)

- Beams adaptively formed to target individual users
- Preamble and superframe broadcast information is sent on sector-wide beams
- FDM of sector wide beam zone is supported as channelization is the same for each beam
  - Dynamic FDM zones signaled in each sub-frame (see slide 10 for details)
- Sub-frame control information is sent on individual beams
- Common sub-frame control information is scrambled by sector and beam specific ID.
- MS provides beam selection in UL feedback
  - Beam selection is a slow process
- MS traffic scrambled by sector and MS specific IDs
- Location of UL control in either SDMA/beam specific zone or sector-wide beam zone is semi-static, and signaled in broadcast information for each sub-frame



Adaptive Beam Forming Deployment (2/2)

- Beam forming can be codebook based or make use UL channel sounding.
- Mobile uses UL control resources on for periodic CQI feedback
  - Beamformed CQI is also indicated
  - SDMA feedback on the UL control is specified by the UL control message type
- Codebook based:
  - Codebook vector feedback indicated in UL control resource
  - Frequency of the feedback will depend on mobile speed.
  - Best vector and/or best nulling vector sent
  - DL channel measurement pilot (see contribution IEEE802.16m-08/343 for details) is used for codebook vector selection
  - Codebook and codebook size are FFS.
    - Codebook book contains *N* codes, where *N* is the number of possible beams in the array space
- UL channel sounding
  - Sounding sent from mobile. Each antennas sent on different subcarriers.
  - FDD system may also use UL channel to determine average beam forming values for DL through transformation

Summary

- This contribution proposes structures to support SDMA/beamforming operation
- Multi-cast and unicast control information is sent with beam specific scrambling in each beam.
- Sector-wide and beamformed /SDMA resource segments can be multiplexed (FDM) in the same subframe
  - Users receiving SDMA transmission do not need to receive sector-wide control information
- UL control and resource allocation sent using SDMA is FFS.

Proposed SDD Text

11.x.x. DL MIMO

11.x.x.x. SDMA beamforming

IEEE 802.16m will support DL SDMA. The sector may use one of three SDMA modes: fixed beam pattern, multi-beam steering or adaptive beamforming. Subframe control and resource allocation are sent using beamforming.

Preamble and superframe broadcast headers are sent with a sector wide beam.

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11.x.x.1 Fixed beam modes

[*Add content of slide 8 to this section*]

11.x.x.2 Multi-beam steering

[*Add content of slide 9 to this section*]

11.x.x.3. Adaptive beamforming

[*Add content of slide 17 to this section*]

11.x.y UL feedback

11.x.y.x DL MIMO feedback

11.x.y.x.x. SDMA feedback

To support SDMA on the DL, an IEEE 802.16m mobile will feedback its best beam or codebook vector on UL control resources. The IEEE 802.16 mobile determines its best beam or codebook vector from DL MIMO channel measurement pilots.

UL sounding may also be used for SDMA/beamforming feedback..