802.16m Downlink Unicast Service Control Channel (USCCH) Transmission Format

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Re: Call for Contributions on Project 802.16m System Description Document (SDD)

Downlink control channel structure

Base Contribution:

Purpose: discussion and consideration for SDD

Outline

- Executive summary
- Downlink USCCH size analysis
  - Joint coding
  - Separate coding
- Downlink USCCH coverage analysis
- Downlink USCCH capacity analysis
- Summary and recommendations

Executive Summary

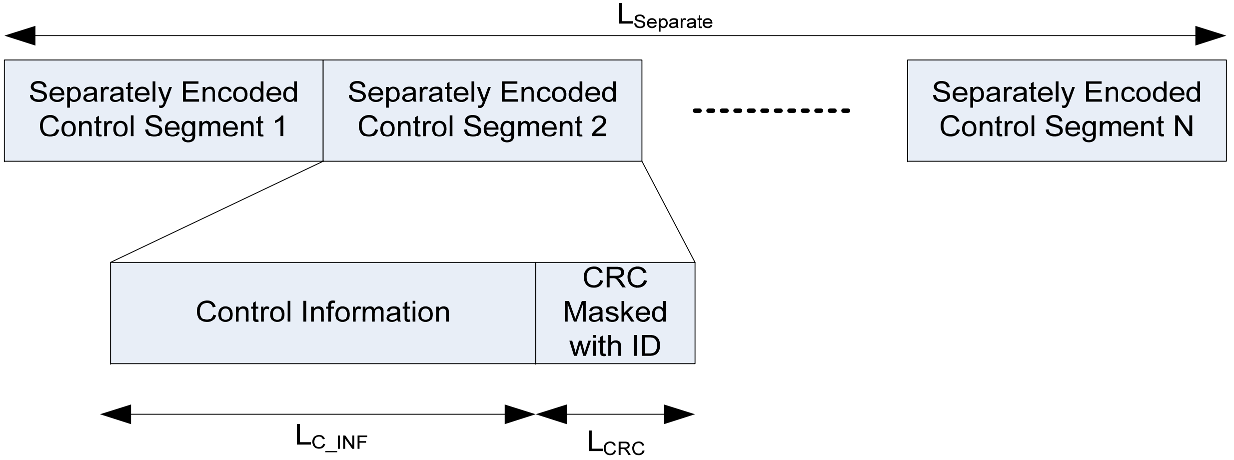
- Support sub-MAP with joint coding on DL USCCH
  - Apply MAP redundancy reduction
  - Support flexibly control information element design
  - Support dynamic group allocation (group persistent scheduling) and multiuser allocation (MU-MIMO)
- Support transmit diversity to improve link performance and cell coverage
- Support FFR and power boosting on DL USSCH to improve coverage and efficiency
- Support FDM between DL USSCH and data for better USCCH cell coverage and capacity

MAP Size Analysis – Separate Coding

- Each user has its own *MAP*, including user *ID*, controlling information and *CRC*
- Signaling overhead:

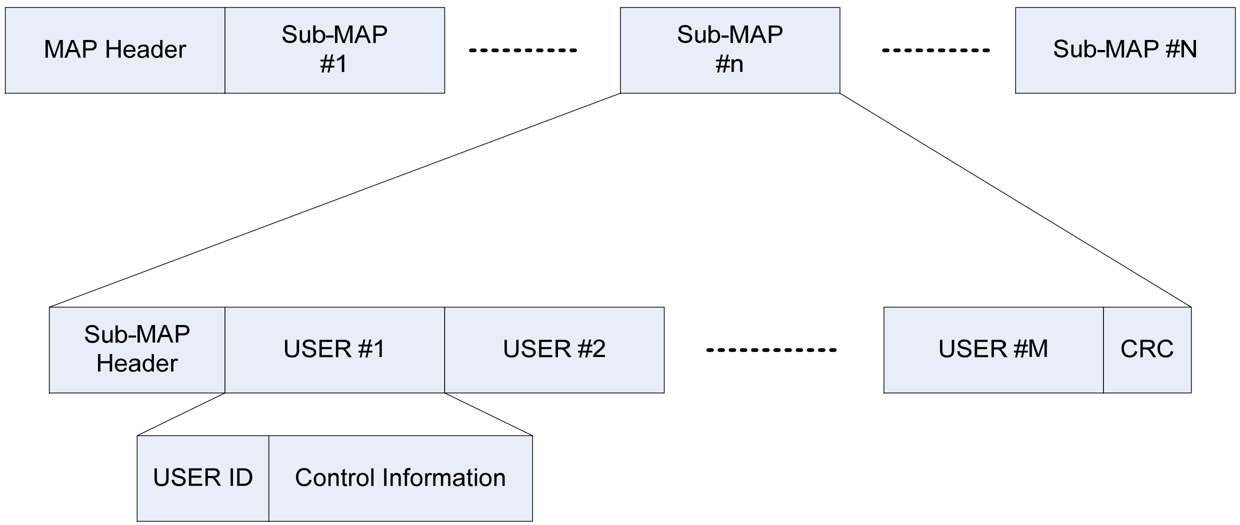
  - CRC Masked with ID: $L_{Separate} = N*(L_{C\_INF} + L_{CRC})$

  - CRC Masked without ID: $L_{Separate} = N*(L_{C\_INF} + L_{CRC} + L_{ID})$



MAP Size Analysis – Joint Coding with sub-MAP

- Scheduled users are partitioned into groups
- The control information for users in the same group is jointly coded as a sub-MAP
- The MAP contains one MAP header and multiple sub-MAPs



Sub-MAP Size Reduction

- Joint coding can support variable size control information element
  - Support more efficient control information element design
- Redundant fields can be omitted
  - HARQ retransmission with explicit NACK: transmission mode control and resource allocation information may be omitted
  - HARQ transmission after explicit ACK: transmission mode control and resource allocation information may be omitted
  - User ID can be further reduced
- Resource allocation (RA) and transmission mode ™ reduction in consecutive transmissions
  - L_r: RA bits
  - L_m: TM bits
  - p_r: probability of RA change
  - p_m: probability of TM change
  - $B\_OH_{RA\_TM}=L_r*p_r+L_m*p_m$
  - 50% reduction when p_r, p_m <0.5

MAP Size Example

- System bandwidth: 5MHz
- Size of control information element (L_{C_INF}): 26 bits
  - Size of Resource Allocation (L_r):9 bits
  - Size of Transmission Modes (L_m):5 bits
  - Probability of RA change: p_r=0.5
  - Probability of TM change: p_m=0.5
- Size of CRC (L_{CRC}): 16 bits
- Number of users (N): 32
- Size of user ID (L_{ID}):16 bits
- Signaling overhead of separate coded MAP
  - CRC Masked with ID: $L_{Sepatate} = N*(L_{C\_INF} + L_{CRC})$
  - CRC Masked without ID: $L_{Sepatate} = N*(L_{C\_INF} + L_{CRC} + L_{ID})$
- Signaling overhead of Sub-MAP
  - Number of Sub-MAPs (S): 4
  - Number of users in Sub-MAP(M): 8
  - RCID: 8 bits
  - $L_{Joint} = S*\{M*RCID + M*[L_{C\_INF} - (L_r+L_m) + B\_OH_{RA\_TM}] + L_{CRC}\}$
- The total size of sub-MAPs is 40% lower than separate coded MAP without CRC mask
- The total size of sub-MAPs is 20% lower than separate coded MAP with CRC mask

MAP Size Summary

- Jointly coded MAP can efficiently support variable size control information element
- Jointly coded MAP can efficiently reduce redundancy within one sub-MAP
- Jointly coded MAP can efficiently support multi-user MIMO allocation
- Jointly coded MAP can efficiently support allocation for a group of users (e.g. group based persistent scheduling)
- Jointly coded MAP allow better flexibility and scalability for information element design
- With simple MAP size reduction
  - Jointly coded MAP size can be 20% less than separate coded MAP with CRC masking
  - Jointly coded MAP size can be 40% less than separate coded MAP without CRC masking

Coverage Analysis

- Coverage improvement techniques
  - Tx diversity
  - Power loading
  - FFR
- Test scenarios considered
  - Different cell sizes
  - Different channel models
  - TDM/FDM of control channels and data traffic in a subframe

Coverage Analysis – Link Level Simulation Assumptions

- Two channel models in EMD
  - ITU Pedestrian B, 3km/h
  - ITU Vehicular A, 120km/h
- DL Tx schemes: STBC (2 antenna), SIMO (1 antenna)
- DL Rx antenna: 2
- MAP allocation size: 144 bits
- MCS: QPSK ½ with no rep., rep. 2, rep. 4, and rep. 6
- FDM allocation: 1 subchannel by 6 symbols for QPSK ½. 2, 4, and 6 subchannels for repetition 2, 4 and 6 respectively.
- TDM allocation: 3 subchannels by 2 symbols for QPSK ½. 6, 12, and 18 subchannels for repetition 2, 4 and 6 respectively.

Coverage Analysis – System Level Simulation Assumptions

- Cell size
  - 866 m cell radius, baseline test scenario in EMD.
  - 5000 m cell radius using the EMD open rural macrocell path loss model.
  - 1500 m cell radius using the baseline path loss model
  - 500 m cell radius using NGMN path loss model, which is also the baseline path loss model in EMD
- 4 FFR groups, 1 reuse one group, 3 reuse three group with 4.77 dB boosting
- Target PER 1%, target outage 5%.
- Based on the link level simulation results, the highest MCS level achieving <= 1% PER is chosen for each user.

866m Cell (EMD Baseline Configuration)

Test Scenarios		QPSK ½ coverage	QPSK ¼ coverage	QPSK 1/8 coverage	QPSK 1/12 coverage	Outage
FDM, Ped B	Reuse 1, SIMO	44.3%	64.3%	90.5%	97.5%	2.5%
	Reuse 1, STBC	54.8%	77.4%	96.6%	99.5%	0.5%
	FFR, STBC	74.1%	98.2%	99.9%	100%	0
TDM, Ped B	Reuse 1, SIMO	42.3%	61.3%	84.1%	94.7%	5.3%
	Reuse 1, STBC	51.2%	68.7%	91.6%	97.3	2.7%
	FFR, STBC	78.4%	98.3%	100%	100%	0
FDM, Veh A	Reuse 1, SIMO	42.4%	61.3%	87.6%	96.5%	3.5%
	Reuse 1, STBC	53.2%	73.9%	95.9%	99.1%	0.9%
	FFR, STBC	75.8%	98.2%	100%	100%	0
TDM, Veh A	Reuse 1, SIMO	37.2%	56.5%	79.1%	90.8%	9.2%
	Reuse 1, STBC	48.6%	65.7%	90.3%	96.5%	3.5%
	FFR, STBC	77.6%	97.6%	99.9%	100%	0

500m Cell

Test Scenarios		QPSK ½ coverage	QPSK ¼ coverage	QPSK 1/8 coverage	QPSK 1/12 coverage	Outage
FDM, Ped B	Reuse 1, SIMO	44.6%	69.2%	90.3%	98.2%	1.8%
	Reuse 1, STBC	58.7%	79.8%	96.7%	99.7%	0.3%
	FFR, STBC	75.6%	97.9%	99.7%	100%	0
TDM, Ped B	Reuse 1, SIMO	43.3%	64.4%	85.9%	94.3%	5.7%
	Reuse 1, STBC	53.8%	72.9%	91.9%	97.5%	2.5%
	FFR, STBC	76.7%	98.6%	99.8%	100%	0
FDM, Veh A	Reuse 1, SIMO	43.5%	64.5%	87.4%	96.2%	3.8%
	Reuse 1, STBC	56.9%	77%	95.4%	99%	1%
	FFR, STBC	76.1%	97.9%	99.7%	100%	0
TDM, Veh A	Reuse 1, SIMO	39.5%	59.7%	81.6%	90.9%	9.1%
	Reuse 1, STBC	50.6%	70.5%	90.1%	96.3%	3.7%
	FFR, STBC	74.8%	98%	99.9%	100%	0

1500m Cell

Test Scenarios		QPSK ½ coverage	QPSK ¼ coverage	QPSK 1/8 coverage	QPSK 1/12 coverage	Outage
FDM, Ped B	Reuse 1, SIMO	42.6%	62.5%	88.8%	96.5%	3.5%
	Reuse 1, STBC	53.2%	75%	95.6%	98.6%	1.4%
	FFR, STBC	74.1%	97.7%	99.8%	100%	0
TDM, Ped B	Reuse 1, SIMO	41%	59.2%	82.7%	93%	7%
	Reuse 1, STBC	49.5%	66.8%	90.1%	96.2%	3.8%
	FFR, STBC	76.7%	96.9%	100%	100%	0
FDM, Veh A	Reuse 1, SIMO	41.2%	59.2%	85.1%	95.6%	4.4%
	Reuse 1, STBC	52.1%	71.8%	94.7%	97.9%	2.1%
	FFR, STBC	75.8%	97.6%	100%	100%	0
TDM, Veh A	Reuse 1, SIMO	36.5%	54.1%	77.4%	88.8%	11.2%
	Reuse 1, STBC	47.5%	64.2%	88.3%	95.6%	4.4%
	FFR, STBC	76.8%	96.8%	99.9%	100%	0

5000m Cell

Test Scenarios		QPSK ½ coverage	QPSK ¼ coverage	QPSK 1/8 coverage	QPSK 1/12 coverage	Outage
FDM, Ped B	Reuse 1, SIMO	19.1%	40.6%	68.6%	84.9%	15.1%
	Reuse 1, STBC	30.3%	51.4%	81.8%	93.8%	6.2%
	FFR, STBC	56.9%	86.7%	97.8%	100%	0
TDM, Ped B	Reuse 1, SIMO	18.1%	35.6%	59%	76.5%	23.5%
	Reuse 1, STBC	25.3%	45.4%	71.9%	83.1%	16.9%
	FFR, STBC	53%	84.2%	97.1%	100%	0
FDM, Veh A	Reuse 1, SIMO	18.4%	35.9%	62.5%	80.9%	19.1%
	Reuse 1, STBC	28.8%	48.7%	79.1%	91.1%	8.9%
	FFR, STBC	56.5%	85.5%	97%	100%	0
TDM, Veh A	Reuse 1, SIMO	15.5%	31%	52.5%	69.1%	30.9%
	Reuse 1, STBC	23.3%	42.6%	68.2%	81.3%	18.7%
	FFR, STBC	51%	83.1%	97%	99.7%	0.3%

Coverage Summary

- DL Tx diversity is required to achieve the target coverage in most cases.
- With FDM and STBC, QPSK ½ repetition 4 can meet the requirement in most scenarios
  - 5% outage target can be achieved with QPSK ½ repetition 4 in all cells except the 5000m radius cell and 1500m cell with the Vehicular A channel.
- FDM has better coverage than TDM
  - QPSK ½ repetition 6 is always required to achieve 5% target outage
  - The inferior performance is due to the fact that channel estimates for TDM are based on 2 symbols instead of 6 symbols in the FDM case.
- FFR with power boosting improves coverage significantly in all cell sizes
  - Required to achieve 5% target outage for the 5000m cell. With FFR, 5% outage target can be met with QPSK ½ repetition 4
  - QPSK ½ with repetition 2 is sufficient for smaller cell sizes

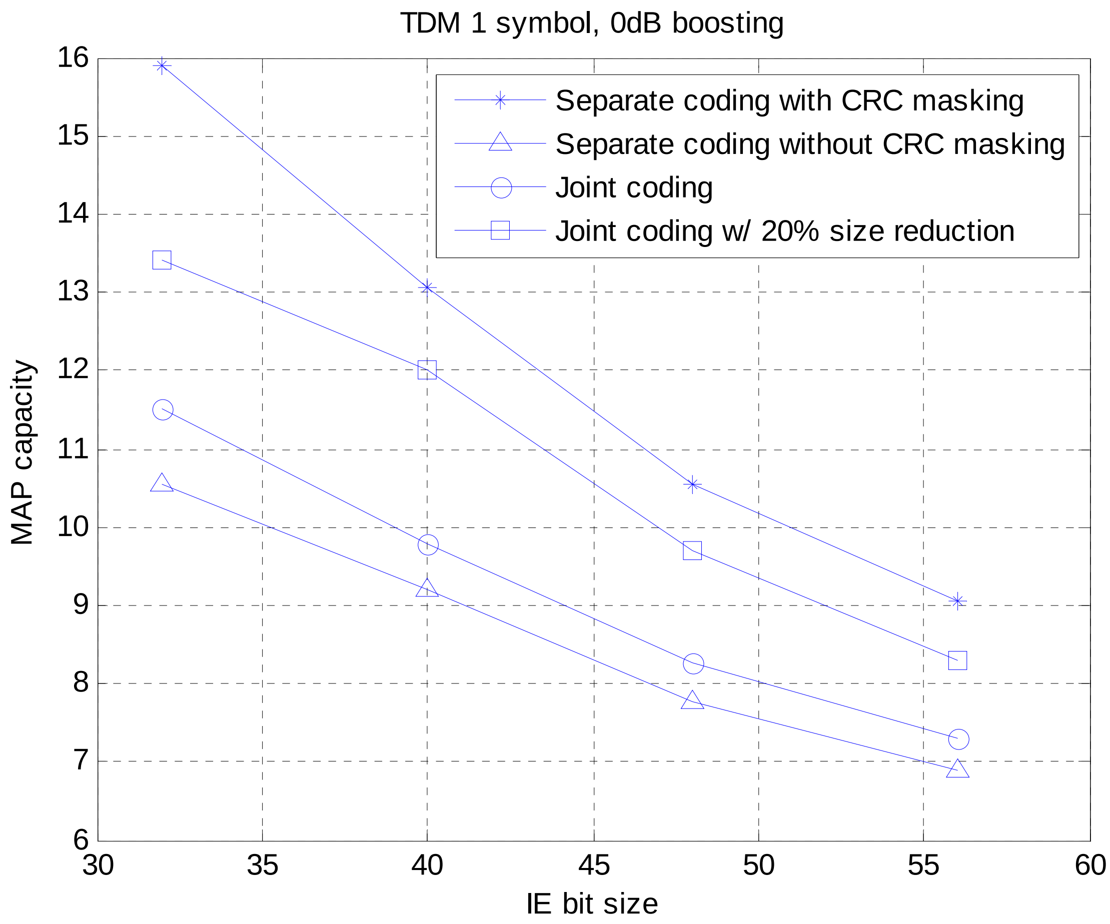
MAP Capacity – Simulation Assumptions

- Compare the MAP capacity with different configuration
  - Joint coding and separate coding
  - TDM and FDM
  - FDM with and without 3dB power boosting
- Link level simulation results with TDM and FDM, Pedestrian B channel, and STBC are used to define target SINR.
- System level simulation results with baseline EMD configuration are used to obtain the SINR distribution for users in the cell.
- For TDM, the MAP region is 744 data tones by 1 symbol.
- For FDM, the MAP region is 128 data tones by 6 symbols

Algorithms in Capacity Simulation

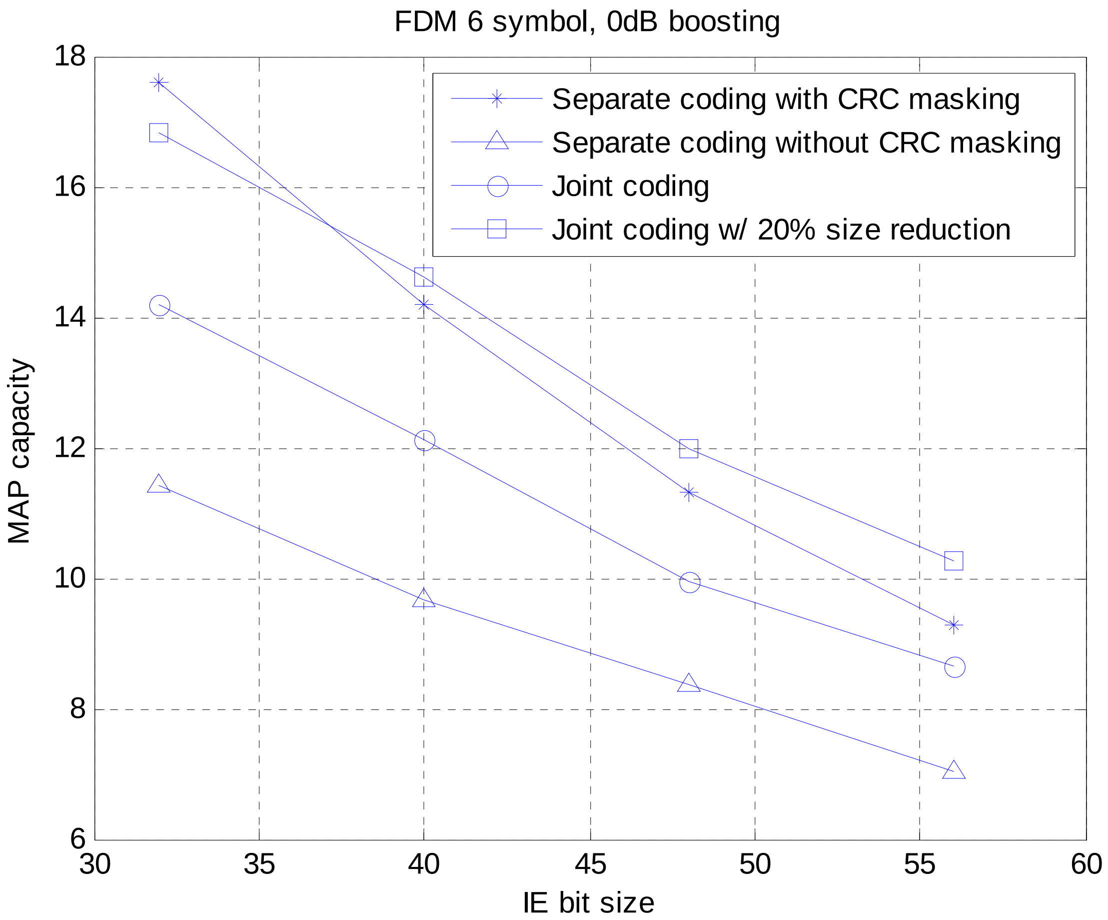
- Total power budget and bandwidth budget are fixed for a particular MAP region
- Separate coding
  - Randomly select n users
  - Based on the required SINR of each MCS, adjust the power and MCS of each user to fit into the power and bandwidth budgets of the MAP region
  - The capacity is mean(max(n)).
- Joint coding
  - Randomly select n users
  - Sort users by SINR and partition into 4 groups
  - The lowest SINR in each group represents the group SINR
  - Different groups are coded by different MCS
  - Adjust the group sizes so that MAP IE from all users can fit into the power and bandwidth budgets of the MAP region
  - The capacity is mean(max(n)).

TDM MAP Capacity



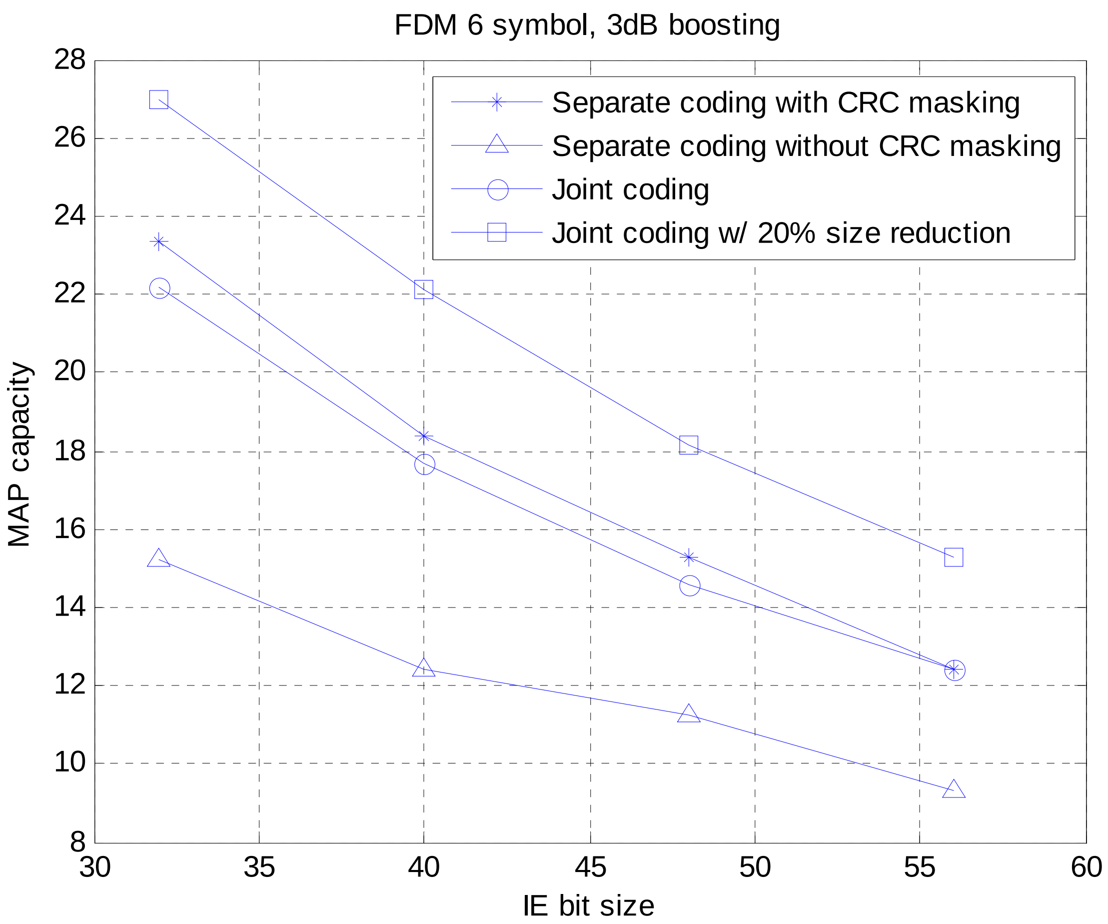
MAP capacity as function of IE play load

FDM MAP Capacity Without Power Boosting



MAP capacity as function of IE payload

FDM MAP Capacity With 3 dB Power Boosting



MAP capacity as IE payload

MAP Capacity - Summary

- MAP capacity without power boosting has following order:
  - Joint coding with size reduction (20%) ~ Separate coding with CRC mask> Joint coding > Separate coding without CRC mask
- Power boosting in FDM provide significant gain on MAP capacity.
  - At least 30% gain with 3 dB power boosting
  - Joint coding with size reduction has better performance than separate coding with CRC mask

Summary and Recommendation

- Support sub-MAP with joint coding on DL USCCH
  - Support MAP redundancy reduction
  - Support flexibly and scalable control information element design
  - Support dynamic group allocation (group persistent scheduling) and multiuser allocation (MU-MIMO)
- Support transmit diversity to improve link performance and cell coverage
- Support FFR and power boosting on DL USSCH to improve coverage and efficiency
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