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

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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: $\quad L_{Separate} = N*(L_{C\_INF} + L_{CRC})$

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

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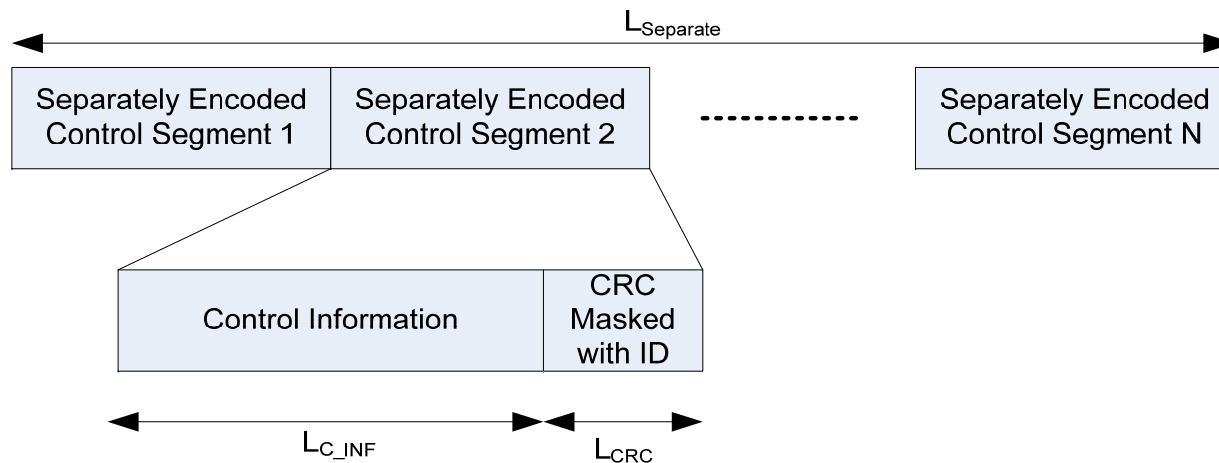
MAP Size Analysis – Joint Coding with sub-MAP

- 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

| MAP Header | Sub-MAP #1 | ---------- | Sub-MAP #n | ---------- | Sub-MAP #N |

| Sub-MAP Header | USER #1 | USER #2 | ----------- | USER #M | CRC |

| USER ID | Control Information |
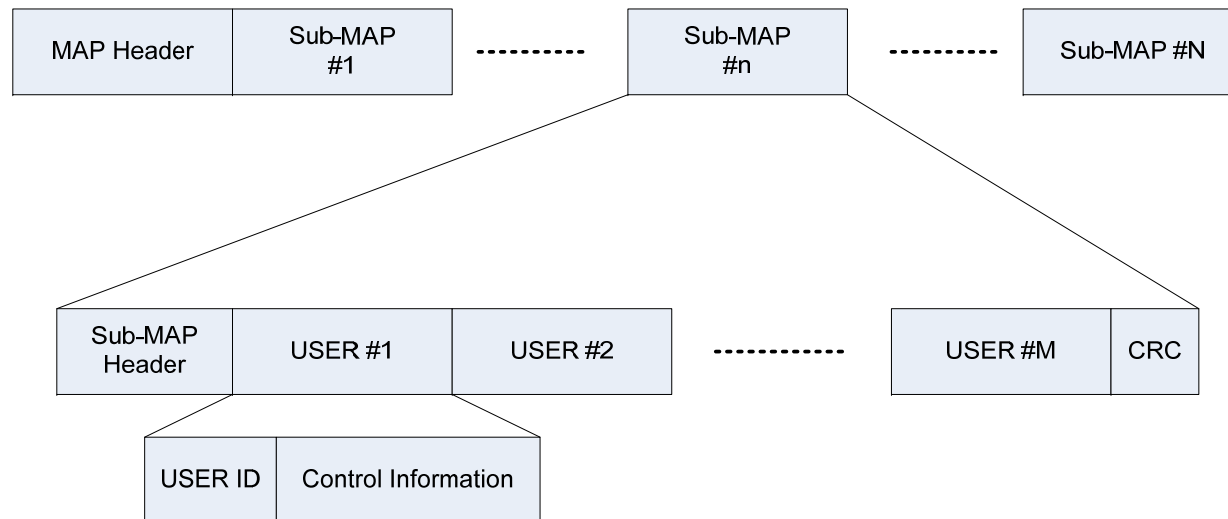
Sub-MAP Size Reduction

- 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
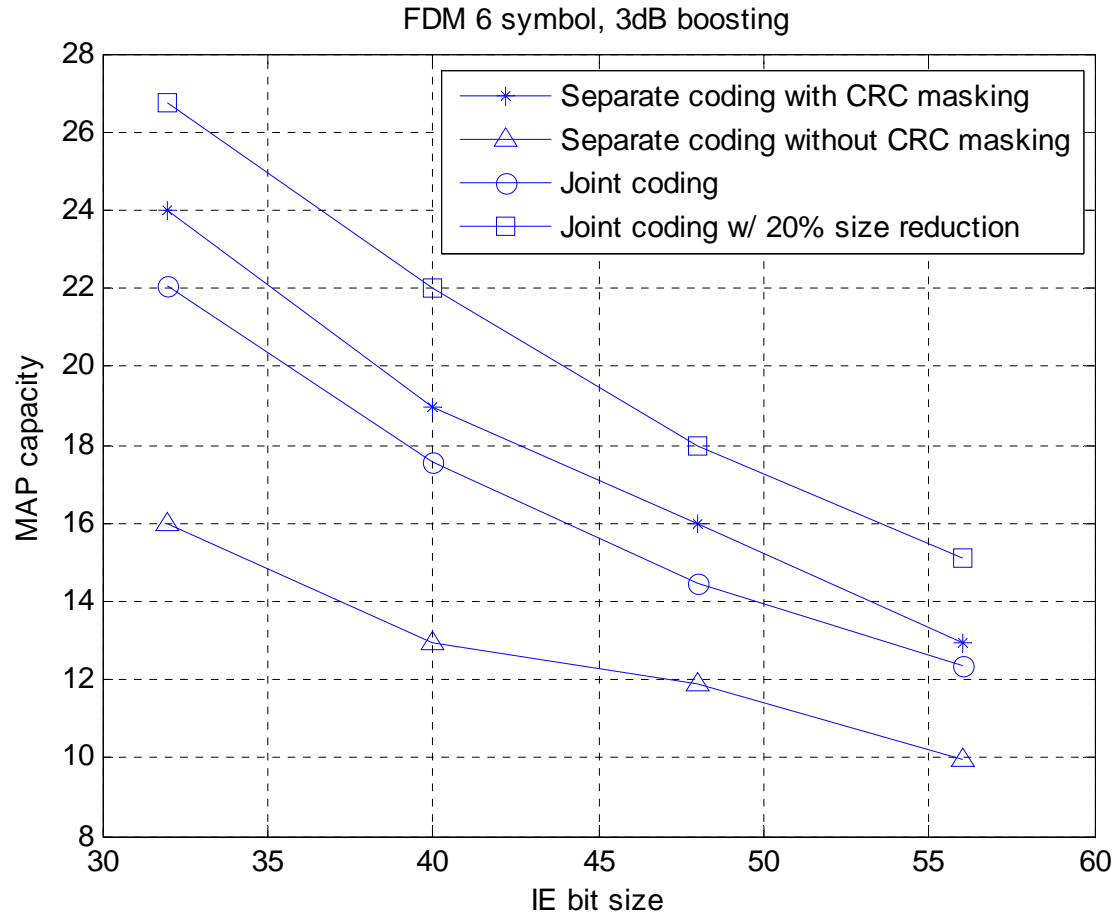 - The capacity is mean(max(n)).

TDM MAP Capacity

TDM 1 symbol, 0dB boosting
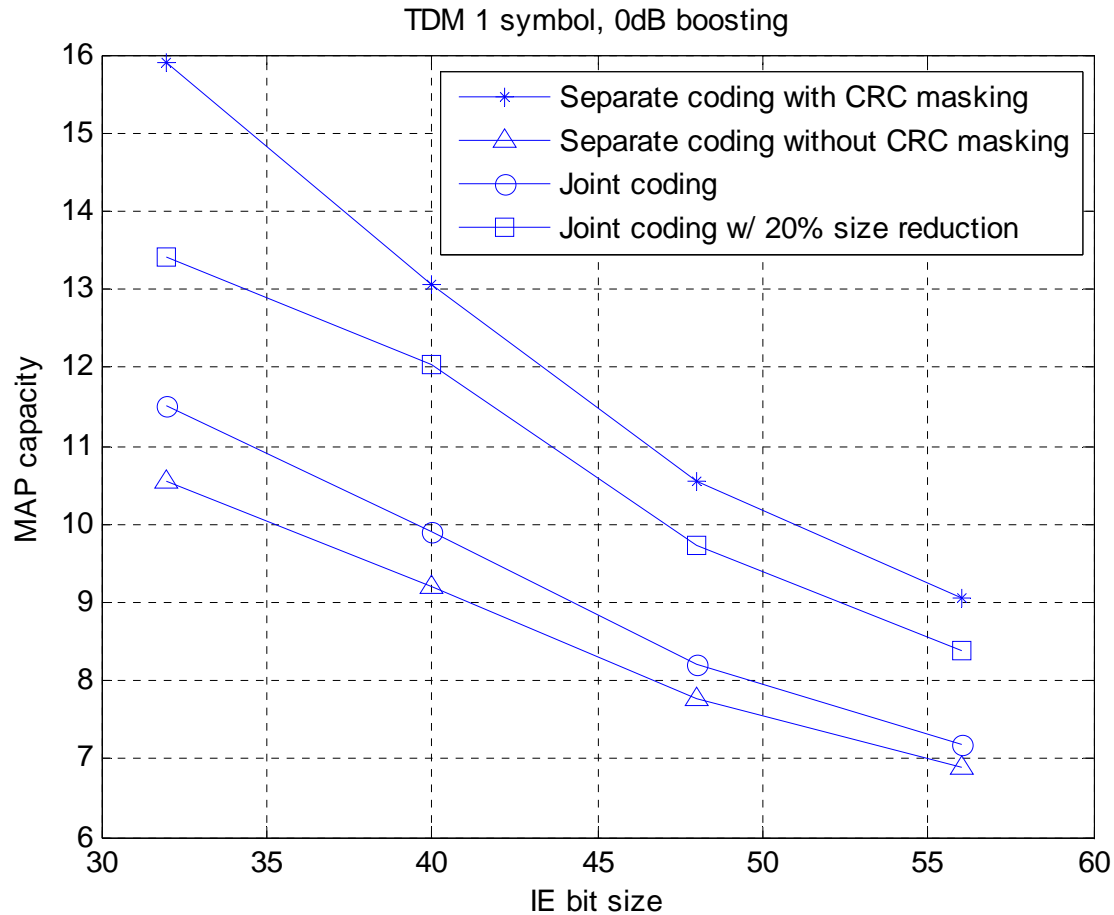
MAP capacity as function of IE play load

FDM MAP Capacity Without Power Boosting
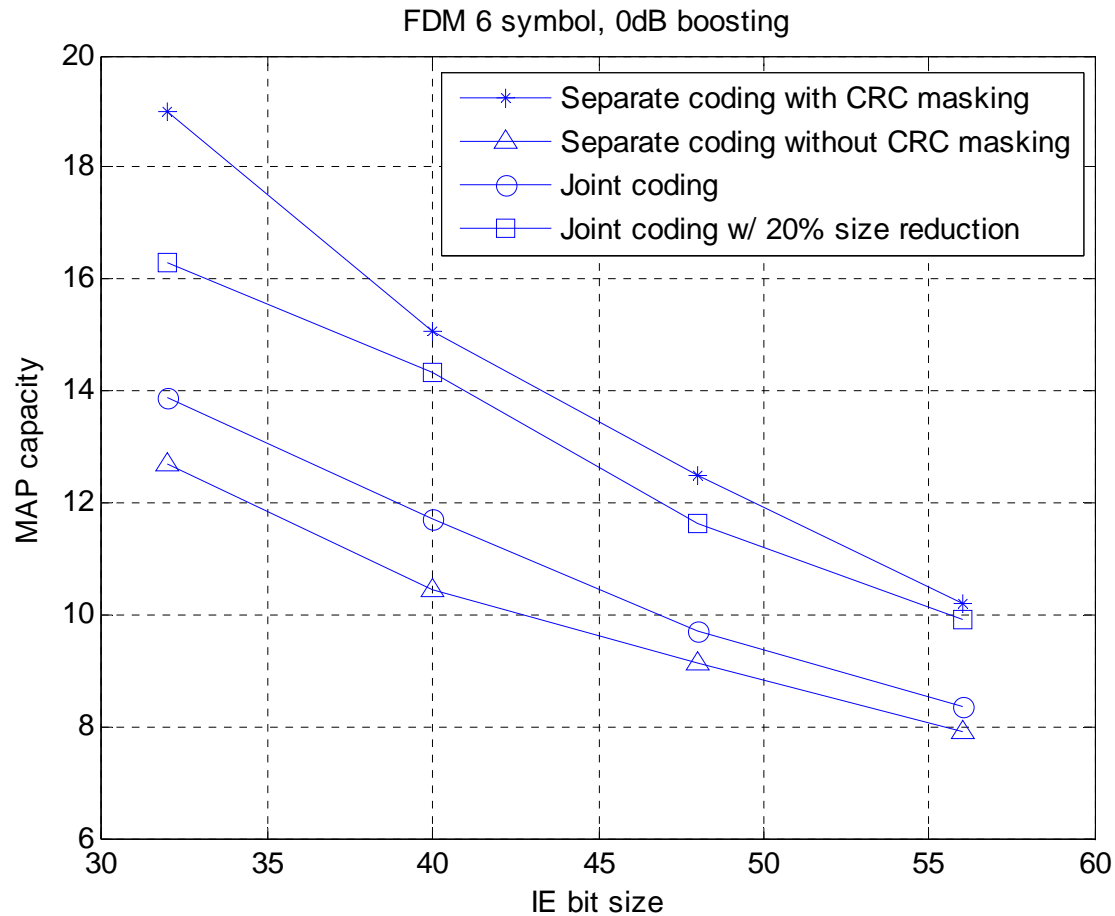
MAP capacity as function of IE payload

FDM MAP Capacity With 3 dB Power Boosting

FDM 6 symbol, 3dB boosting

MAP capacity as IE payload

MAP Capacity - Summary

- MAP capacity without power boosting has following order:
  - Separate coding with CRC mask~> Joint coding with size reduction (20%) > 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
- Support FDM between DL USSCH and data for better USCCH cell coverage and capacity