

Agenda Item: 6.2.6.1
Source: ZTE
Title: Evaluation and standard impact on EVM and receiver impairment for small cell 256QAM
Document for: Discussion & Decision

1 Introduction

At RAN4 #68, an LS reply to RAN1 on scope of feasible requirement of 256 QAM support was provided [1]. RAN4 observed that both Tx EVM and Rx impairments can be modelled as an AWGN component, meanwhile achievable values of Tx/Rx EVMs were fed back. At RAN1#74bis meeting, evaluations considering the impact of power back-off and relaxed clipping were recommended as well as investigation of specification impact for 256 QAM [2].

This contribution provides additional system evaluation on ranges of possible Tx/Rx EVMs for 256QAM given in RAN4's reply. The impact of power back-off is also taken into consideration. Further, the specification impacts for 256 QAM are discussed, mainly on the CQI/TBS/MCS tables.

2 System level simulation (SLS)

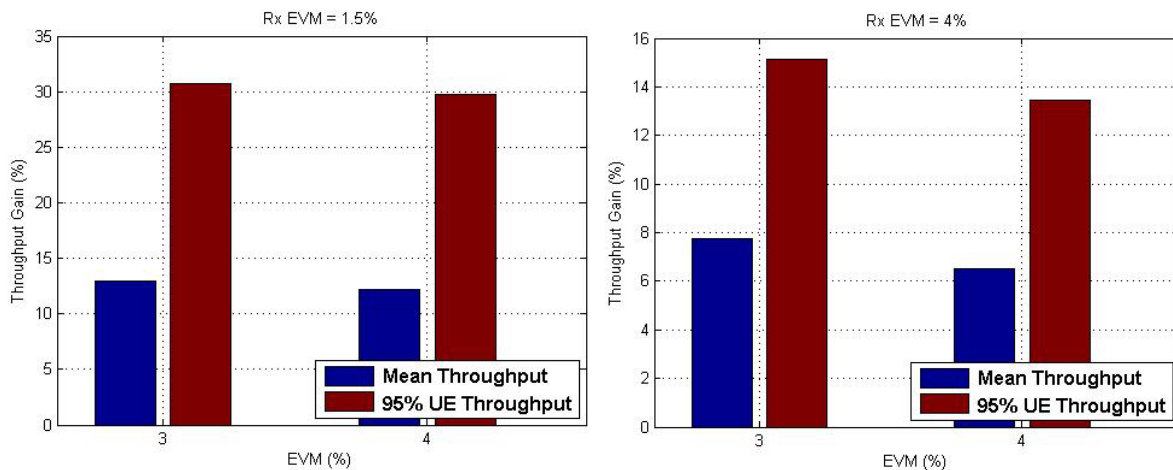


Figure.1. SLS results, scenario 2b (sparse), without power back-off

In the SLS, the modelling of EVM and the UE receiver impairments are modelled as equivalent additive Gaussian white noise, whose powers are characterized with Tx EVM and Rx EVM respectively. The simulation assumptions are given in Table A.2 in Appendix A. The CRS interference is modelled. The RU is 22.5 ~ 25 %. Figure.1 compares the mean UE throughput and 95% UE throughput gains by introducing 256QAM in conditions of different Tx EVMs, assuming 1.5% and 4% Rx EVMs.

It can be seen that the mean throughput gains is 6.5% for Rx EVM = 4%, Tx EVM = 4%. For Rx EVM = 1.5%, Tx EVM = 3%, the gain even reaches around 13%. Significant gains are achieved with values of TX/RX EVM recommended.

Observation 1: Significant gains by introducing 256 QAM are observed in the system level simulation with both EVM and the UE receiver impairments modelled. For the small cell scenario 2b (sparse):

- 13% UE throughput gain for Rx EVM = 1.5% and Tx EVM = 3%.

- 6.5% UE throughput gain for Rx EVM = 4% and Tx EVM = 4%.

3 Impact of power back-off and relaxed clipping

To achieve a better EVM such as 3~4% for 256 QAM, power amplifier with extended linear region and larger power can be adopted so that the transmission power of BS would not be necessarily reduced. If the transmission power of BS is kept, the coverage of small cells will not be impacted. The cost and size may be increased somehow for the larger power amplifier. However, a few more dBs power-back off does not induce much extra cost. Cell supporting 256QAM can be configurable to ease the concern of any vendor.

Another way is to keep the current power amplifier unchanged which is designed for lower order modulation. Better EVM performance can be achieved with power back-off and relaxed clipping. It is reasonable to keep EVM less than 3% by 1~2dB power back-off [3] [4]. Table 1 shows the mean and 95% UE throughput gains with power back-off value of 2 dB over baseline for small cell scenario 3 (sparse) and 2b (sparse). The baseline is for no power back-off. The simulation assumptions are given in Table A.1 and Table A.2 in Appendix A. For scenario 2b, appropriate bias for small cell extension is used to keep the LPN UE ratio in the same level as that for the baseline, i.e., to keep the small cell coverage.

It can be seen from Table 1 that the maximum amplitude of negative gains due to power back-off is less than 2.5%, which is insignificant. The impact of power back-off is negligible.

Table.1 The mean and 95% UE throughput gains with power back-off value of 2 dB

Tx EVM/Rx EVM	3%/1.5%	4%/1.5%	3%/4%	4%/4%
Scenario 3 (sparse)	- 0.16% (0%)	-1.09% (0.52%)	-1.06% (-0.07%)	-0.49%(-1.41%)
Scenario 2b (sparse)	- 1.83% (0%)	-1.79% (- 0.21%)	-2.22% (-0.27%)	-2.20% (-0.15%)

Observation 2: The throughput losses due to 2 dB power back-off are less than 2.5%. The impact of power back-off and relaxed clipping is not significant.

4 CQI/MCS/TBS tables for 256 QAM

By introducing 256 QAM, the spectral efficiency is extended to about 7.44 (8 * 0.93), while the current CQI/MCS/TBS tables limit the maximum spectral efficiency at about 5.5547. To fully exploit the spectral efficiency of 256 QAM, it is necessary to introduce new MCS/TBS tables. Also, in order to make the scheduling of the eNodeB more effectively, new CQI table is desirable.

4.1 CQI table

The current CQI table includes 16 entries, and 4 bits are required for the CQI indices. There are two potential methods to define a new CQI table for 256QAM.

Method 1: 5-bit CQI table.

As a sub-method to design a 5-bit CQI table, new entries of 256 QAM are simply attached at the end of the current CQI table. It is expected not all 16 new added entries are utilized and most entries would be reserved. Another sub-method is to redesign a new table to fully use the new 16 entries, which covers the minimum spectral efficiency of QPSK to the maximum spectral efficiency of 256 QAM. In a 5-bit CQI table, sufficient items are provided to introduce 256 QAM with the current granularity kept or even more refined. Meanwhile, the UCI payload should increase, resulting in degeneration of the decoding performance of UCI. Then, CSI reporting may be reconsidered.

Method 2: 4-bit CQI table.

There are two sub-methods to design a 4-bit CQI table for 256 QAM. One is to replace some entries in the current CQI table (e.g. some QPSK entries) by new entries of 256QAM, which brings relatively small change of the current CQI table. The other is to redesign. Both sub-methods increase the granularity of code rate. However, a 4-bit CQI table for 256 QAM avoids the UCI payload impact. Although this method may cause some performance degeneration, the

degeneration is expected not to be low. Another issue is that due to the coexistence of the current and new 4-bit CQI tables, which CQI table is used should be made clear for the eNodeB and UE.

To design a CQI table for 256 QAM, the following considerations should be cover:

- 1) To fully exploit the efficiency, the maximum code rate for 256 QAM can be up to 0.93, corresponding to a SNR of about 25.5 dB [5].
- 2) Spectral efficiencies in CQI table are chosen such that mapping between CQI indices and SNR (e.g. targeting at 10% BLER) is evenly.

An example of CQI table with 256QAM is showed in Table B.1 in Appendix B.

Observation 3: It is necessary to introduce a new CQI table for 256 QAM. CQI table for 256 QAM could be 4-bit or 5-bit.

4.2 MCS/TBS tables

The current MCS table has 32 entries, which are denoted by 5 bits. Similar to the CQI table, there are two alternative to design a MCS table for 256 QAM, i.e. 5-bit and 6-bit tables.

Method 1: 6-bit MCS table.

In a 6-bit MCS table, 256 QAM entries are attached at the end of the current table, or a totally new table may be defined. The granularity remains refined while the DCI payload is increased and the DCI decoding performance would be degraded.

Method 2: 5-bit MCS table.

A 5-bit MCS table avoids the DCI payload problem. An example is to replace some entries in the current CQI table by new entries of 256QAM, e.g. some QPSK entries, overlap entries (i.e. $I_{MCS} = 9/10/16/17$) or reserved entries. Totally redesign of table is also possible. For 5-bit MCS table, it is necessary for the eNodeB and UE to make it configurable for the new table.

No matter which method is adopted, the standard should keep the MCS table and CQI table matched. The occupation proportion of a modulation scheme and also the SNR range covered should be kept constant in the CQI/MCS tables. If some entries in the current CQI table are removed, corresponding MCS entries should be removed. New entries for CQI table will need corresponding MCS entries. Spectral efficiencies in MCS table should be chosen such that mapping between MCS indices and SNR (e.g. Targeting at 10% BLER) is evenly. An example of MCS table with 256QAM is showed in Table B.2 in Appendix B.

TBS table should be finally defined after the MCS/CQI tables have been decided. It is noted the case of 136 RE per PRB needed to be considered to fully explore the throughput. TBSs for 256 QAM can mostly reuse the sizes in current TBS table.

Observation 4: Candidate MCS tables for 256 QAM could be 5-bit or 6-bit. MCS table and CQI table should be kept matched.

5 Conclusions

In this contribution, evaluation on EVM and the UE receiver impairments for 256QAM. More system-level simulations are presented to help better understand the performance gain of 256QAM. Observations and proposal are as follows:

Observation 1: Significant gains by introducing 256 QAM are observed in the system level simulation with both EVM and the UE receiver impairments modelled. For the small cell scenario 2b (sparse):

- 13% mean UE throughput gain for Rx EVM = 1.5% and Tx EVM = 3%.
- 6.5% mean throughput gain for Rx EVM = 4% and Tx EVM = 4%.

Observation 2: The throughput losses due to 2 dB power back-off are less than 2.5%. The impact of power back-off and relaxed clipping is not significant.

We also made analysis on the potential standard impact on the case if LTE introduce 256QAM. Here we focus on the CQI/MCS/TBS design for 256QAM. Our further related observations on standard impact are:

Observation 3: It is necessary to introduce a new CQI table for 256 QAM. CQI table for 256 QAM could be 4-bit or 5-bit.

Observation 4: Candidate MCS tables for 256 QAM could be 5-bit or 6-bit. MCS table and CQI table should be kept matched.

We see the implication of RF can be mostly alleviated by careful setting of system parameters, e.g. bias value. And we also note that 256QAM can be fully configurable and can be enabled/disabled depending on cell planing. At this stage of small cell study phase, we propose:

Proposal: RAN1 introduces 256QAM into small cell operation to further enhance small cell performance. Required Tx/Rx EVM need to be further decided in RAN4. Specification impact will be taken in the discussion of standardization phase.

6 Reference

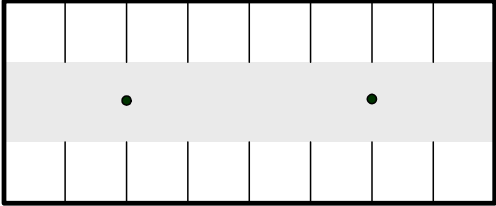
- [1] R4-134571, [Draft] Reply LS on Higher Order Modulation Evaluation Assumptions
- [2] 3GPP TSG RAN WG1 Meeting #74bis, RAN1 Chairman's Notes
- [3] R4-131091, On support of 256QAM, Huawei
- [4] R4-132671, BS EVM for DL 256QAM, Nokia Siemens Networks, Nokia Corporation
- [5] R1-132091, On EVM and UE receiver impairment for 256QAM, ZTE

Appendix A

Table A.1. System-level simulation assumptions for Scenario 3 (sparse)

Deployment scenarios	Indoor Hotspot
Carrier configuration	1 carrier @ 3.5GHz
System bandwidth	10 MHz
Simulation case	ITU-InH 2 indoor small cells
Number of UEs	10 UE
Outdoor/Indoor UE ratio	100% Indoor
DL transmission scheme and coordination scheme	SU-MIMO with rank adaptation
UE speed	3km/h
Tx power (Ptotal)	Small cell:24dBm(baseline), 22dBm(power back-off)
Traffic model	FTP 1
Number of TX and RX antennas	2x2
Antenna configuration	XPOL
Antenna gain + connector loss	5dBi
UE receiver	MMSE
Network synchronization	Synchronized
Scheduler	Proportional Fair
Feedback scheme	Rel-8 RI/CQI/PMI based on Rel-8 2Tx codebook
Tx EVM	3%, 4%
Rx EVM	1.5%, 4%

Table A.2. System-level simulation assumptions for Scenario 2b (sparse)

Scenario #2b		
	Macro cell	Small cell
Layout	<p>Hexagonal grid, 3 sectors per site, case 1 7 Macro sites used.</p>	 <p>ITU Indoor Hotspots, the hotspots are uniformly random within macro geographical area. The detailed parameters setting for an indoor hotspot can refer to A.2.1.1.5 in TR36.814.</p>
System bandwidth per carrier	10MHz	10MHz
Carrier frequency	2.0GHz	3.5GHz
Carrier number	1	1
Total BS TX power (P_{total} per carrier)	46dBm	24 dBm,
Antenna configuration	2Tx2Rx in DL, 1Tx2Rx in UL, Cross-polarized	
Number of UEs	60 UEs per macro cell geographical area are recommended (FTP model 3 is used)	
Traffic model	FTP Model 3	

Other system-level simulation assumptions not listed in Table A.1/A.2 is following TR36.872, Scenario #3 (sparse) and Scenario 2b (sparse).

Appendix B

Table B.1 An example of CQI table for 256 QAM

CQI index	modulation	code rate x 1024	efficiency
1(4)*	QPSK	308	0.6016
2(5)	QPSK	449	0.8770
3(6)	QPSK	602	1.1758
4(7)	16QAM	378	1.4766
5(8)	16QAM	490	1.9141
6(9)	16QAM	616	2.4063
7(10)	64QAM	466	2.7305
8(11)	64QAM	567	3.3223
9(12)	64QAM	666	3.9023
10(13)	64QAM	772	4.5234
11(14)	64QAM	873	5.1152
12(15)	64QAM	948	5.5547
13(new)	256QAM	803	6.2734
14(new)	256QAM	889	6.9453
15(new)	256QAM	952	7.4375

* The number in parenthesis denotes the entries in the current CQI table in Rel-11

Figure B.1 shows the SNR and CQI indices are evenly mapped.

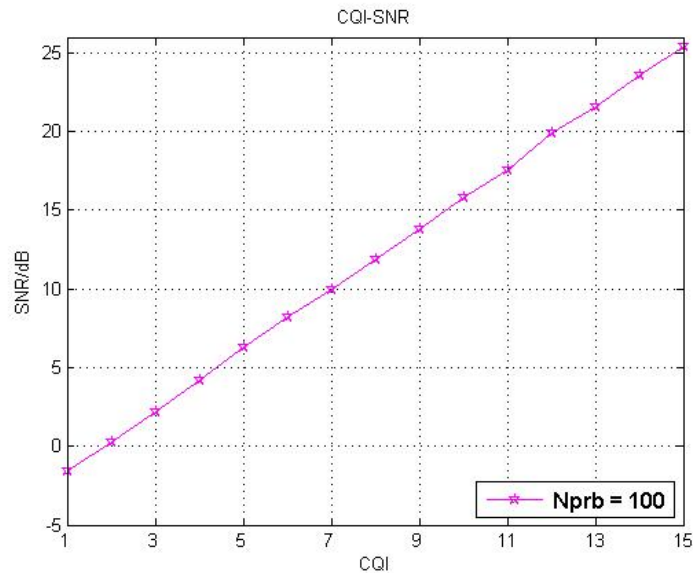


Figure B.1

Table B.2 An example of MCS table for 256 QAM

MCS Index I_{MCS}	Modulation Order Q_m	TBS Index I_{TBS}	MCS Index(in Rel-11) I_{MCS}	Efficiency
0	2	0	5	
1	2	1	6	
2	2	2	7	
3	2	3	8	
4	2	4	9	
5	4	5	11	
6	4	6	12	
7	4	7	13	
8	4	8	14	
9	4	9	15	
10	4	10	16	
11	6	11	18	
12	6	12	19	
13	6	13	20	
14	6	14	21	
15	6	15	22	
16	6	16	23	
17	6	17	24	
18	6	18	25	
19	6	19	26	
20	6	20	27	
21	6	21	28	
22	8	22	—	CQI = average of 12&13
23	8	23	—	CQI = 13
24	8	24	—	CQI = average of 13&14
25	8	25	—	CQI = 14
26	8	26	—	CQI = average of 14&15
27	8	27	—	CQI = 15
28	2	Reserved	29	
29	4		30	
30	6		31	
31	8		—	