**3GPP TSG RAN WG1 #109-e R1-2204856**

**e-Meeting, May 9th – 20th, 2022**

**Agenda Item: 8.16.16**

**Source: Moderator (AT&T)**

**Title: Summary of UE features for DL 1024QAM for NR FR1**

**Document for:** **Discussion/Decision**

# Introduction

This document presents the summary of email discussion/approval [109-e-R17-UE-features-1024QAM-01] during RAN1 #109-e. According to the Chairman’s Notes:

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| [109-e-R17-UE-features-1024QAM-01] Email discussion on UE features for DL 1024QAM for NR FR1 – Ralf (AT&T)* 1st check point for LS to RAN2: May 13
* Final check point for any remaining issues: May 20
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The following was discussed and/or agreed during RAN1 #109-e within the scope of [109-e-R17-UE-features-1024QAM-01]. All proposals are based on the latest RAN1 UE features list for Rel-17 NR in [1].

# Summary of Contributions Submitted to RAN1 #109-e

The following is the moderator’s summary of contributions submitted to RAN1 #109-e in this agenda item.

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| 36. NR\_DL1024QAM\_FR1 | 36-1 | 1024QAM for PDSCH for FR1 | Support 1024QAM for PDSCH for FR1 including 1024QAM modulation scheme as defined in TS 38.211, MCS and CQI feedback tables based on 1024QAM modulation order as defined in TS 38.214. | pdsch-256QAM-FR1 | Yes | N/A | No support of 1024 QAM for PDSCH | Per Band | N/A | Applicable only to FR1 | N/A | Note from WI objective: DL PDSCH 1024QAM for FR1 should be defined as a per-band UE capability | Optional with capability signalling |

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| Company | Summary |
| MediaTek Inc. [2] | In the WID, it clearly states that 1024QAM is applicable scenarios with up to 2 layer DL MIMO.

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| The objective is to specify downlink 1024QAM for NR PDSCH operation in FR1, together with related procedures, signalling and necessary RF requirements. The main objectives are:* Specify high order modulation for PDSCH [RAN1]
	+ Specify 1024QAM constellation as specified in E-UTRA for DL PDSCH
	+ Specify corresponding 5-bit MCS table with 1024QAM entries as defined in E-UTRA, with 5 bit DCI overhead for MCS indication
	+ Specify corresponding CQI feedback with 1024QAM entries as defined in E-UTRA, with no changes to the CQI field and table sizes
* Specify corresponding RRC signalling and UE capabilities [RAN2]
	+ Note: DL PDSCH 1024QAM for FR1 should be defined as a per-band UE capability
* Specify corresponding UE and BS RF core requirements [RAN4]
	+ UE and BS RF core requirements are specified for stationary wireless scenarios **with up to 2 layer DL MIMO**
	+ The cell size(s) and type of stationary wireless scenarios for which UE and BS RF core requirements are defined will be studied and decided by RAN4.
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However, it is not captured in the description of FG 36-1.

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| **Index** | **Feature group** | **Components** |
| 36-1 | 1024QAM for PDSCH for FR1 | Support 1024QAM for PDSCH for FR1 including 1024QAM modulation scheme as defined in TS 38.211, MCS and CQI feedback tables based on 1024QAM modulation order as defined in TS 38.214. |

We propose the following changes to capture this restriction. Without this clarification, it is not clear up to how many DL MIMO layers UE should support when it wants to report this FG 36-1 capability.Proposal 1: Make the following changes highlighted in red to Components of FG 36-1: * **Support 1024QAM for PDSCH with up to 2 MIMO layers for FR1 including 1024QAM modulation scheme as defined in TS 38.211, MCS and CQI feedback tables based on 1024QAM modulation order as defined in TS 38.214.**
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# Discussion/Approval Items during RAN1 #109-e — First Checkpoint

After review of contributions submitted to RAN1 #109-e in this agenda item, the following topics were identified by the moderator for discussion/approval during RAN1 #109-e.

**General comments**

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| Company | Comments/Questions/Suggestions |
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# Issue 1: FG 36-1

After review of contributions submitted to RAN1 #109-e in this agenda item, the following is proposed by the moderator. Companies submitted the following views on the moderator’s proposals.

**Proposal: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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| 36. NR\_DL1024QAM\_FR1 | 36-1 | 1024QAM for PDSCH for FR1 | Support 1024QAM for PDSCH with up to 2 MIMO layers for FR1 including 1024QAM modulation scheme as defined in TS 38.211, MCS and CQI feedback tables based on 1024QAM modulation order as defined in TS 38.214. | pdsch-256QAM-FR1 | Yes | N/A | No support of 1024 QAM for PDSCH | Per Band | N/A | Applicable only to FR1 | N/A | Note from WI objective: DL PDSCH 1024QAM for FR1 should be defined as a per-band UE capability | Optional with capability signalling |

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| Company | Comments/Questions/Suggestions |
| MediaTek Inc.  | 1. With the current UE capability design, we don’t see how a UE that supports 1024QAM with up to only 2 MIMO layers but not 4 MIMO layers can report its capability in a distinguishing way so that NW can correctly understand its capability. More importantly, we don’t see how such a UE can be guaranteed not to be configured with a configuration (e.g. 1024 QAM with 4 DL MIMO layers) that is beyond its capability. Without this restriction (clarification), a UE that can support 1024QAM with 2 MIMO layers but not 4 layers can only choose not to report the support for 1024QAM at all which we believe is not a result that companies want to see.
2. Per WID, the requirements specified in RAN4 will only apply to 2 MIMO layers. Without the corresponding clarification (i.e. up to 2 MIMO layers) in anywhere in UE capability specification, it is not very confusing to the market that whether 4 layers is supported for 1024QAM or not.
3. If the majority sees the need for UE to report 1024QAM with 4 MIMO layers, we can leave FG 36-1 unchanged as it is. However, we would like to propose a new FG 36-1a to clearly capture the restriction of up to 2 MIMO layers.
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| QC | The WID doesn't limit 1024QAM for PDSCH to two layers only. The WID asks RAN4 for defining core and performance requirements for up to two layers only. However, we think that UE capability should be updated to provide some flexibility in terms of #DL MIMO layers for 024-QAM PDSCH. We propose on of the following two options:- Option 1: Add a new component within FG36-1 with candidate values {2, maxNumberMIMO-LayersPDSCH}- Option 2: Split FG36-1 into two, one is 1024-QAM with 2L and the other one is 1024QAM with the number of layers indicated by maxNumberMIMO-LayersPDSCH |
| Ericsson | The WID does not limit 1024QAM to PDSCH with up to 2 layers only. There are many features RAN4 does not have UE/BS RF core requirements, but that should not restrict the RAN1/RAN2 specifications. Regarding Qualcomm suggested options, it is a bit unclear how the linkage between this capability and maxNumberMIMO-LayersPDSCH would be applied since latter seems to be a per-FSPC capability. Our preference would be to go with simpler option for the capability description, if possible. Overall, for the issue that MTK raises, we would be OK to consider adding as components/separate capability: up to maximum 1/2/4/8 layers.  |
| Samsung | It is not clear whether “up to 2 layers” is only considered for RAN4 or RAN1. Anyhow, considering various DL layers might be meaningful in order to provide flexible UE implementation. In that sense, we are okay to consider new component in 36-1 such as {1, 2, 4} DL layers rather than introducing new UE capabilities for that.  |
| Nokia, NSB | There is no need to couple RAN1 FGs with RAN4 requirement availability. In fact we would need to remove several of the existing FGs, including Rel-15, if that was the case. We are not sure there is a need to define modulation-specific restriction on the number of layers, and why it would be done specifically for 1024QAM only. Such changes would require more discussion and they do not seem to be motivated from a RAN1 perspective, so perhaps it could be discussed in RAN4, if at all. |
| MediaTek | @Nokia, SNR and UE complexity requirements for supporting 1024QAM are higher than other modulation orders, and the more layers UE supports for 1024QAM, the higher requirements it demands UE to meet. In our view, it is hence not reasonable to ask UE to support up to 4 or even 8 MIMO layers if it plans to support 1024QAM. I hope you are not suggesting If a UE can’t support 1024QAM with 8 layers, it should just forget about 1024QAM. Hopefully, you can understand it is reasonable for the specification to provide some flexibility to UE to decide which level of complexity and capability it plans to support for 1024QAM. If you can agree with the above arguments, let me walk through the issues we have identified with the current specification. Let’s assume that a UE only plans to support 1024QAM with up to 2 MIMO layers in a band, say Band-A. Specifically, the UE plans to support 1024QAM with 2 layers for Band-A in its first Band combination, i.e. BC1, and to support 256QAM with 4 layers for Band-A in its second band combination, i.e. BC2. However, as highlighted in the following text from TS 38.306, the current specification does not prevent NW from configuring 1024QAM with 4 MIMO layers for the UE in BC2. This configuration is beyond UE’s capability and should not happen. Don’t you agree?

| ***supportedModulationOrderDL***Indicates the maximum supported modulation order to be applied for downlink in the carrier in the max data rate calculation as defined in 4.1.2. If included, the network may use a modulation order on this serving cell which is higher than the value indicated in this field as long as UE supports the modulation of higher value for downlink. If not included:- for FR1, the network uses the modulation order signalled per band i.e. [pdsch-1024QAM-FR1] when [pdsch-1024QAM-FR1] is signalled for the band , otherwise the network uses the modulation order signalled in *pdsch-256QAM-FR1*.- for FR2, the network uses the modulation order signalled per band i.e. *pdsch-256QAM-FR2* if signalled. If not signalled in a given band, the network shall use the modulation order 64QAM.In all the cases, it shall be ensured that the data rate does not exceed the max data rate (*DataRate*) and max data rate per CC (*DataRateCC*) according to TS 38.214 [12]. | FSPC | No | N/A | N/A |
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Taking companies’ feedbacks into consideration, we propose the following changes to FG 36-1* **Support 1024QAM for PDSCH with maximum *K* MIMO layers for FR1 including 1024QAM modulation scheme as defined in TS 38.211, MCS and CQI feedback tables based on 1024QAM modulation order as defined in TS 38.214 where *K* is indicated as one of {1, 2, 4, 8}.**

Hopefully, this is acceptable to everyone.  |
| Huawei, HiSilicon | We share similar view that the WID does not limit PDSCH with 1024QAM to up to 2 layers. In fact, from our understanding, 1024QAM with high ranks is very useful in scenarios where high SNR can be achieved. The data rate can be effectively improved.The intention of this WID is to improve the peak data rates, however data rate of 1024QAM with 2 layers would have less data rate than 256QAM with 4 layers, which is against the WID intension.Despite all that, we can understand the concern from MTK, and would be fine to consider a component with candidate values to resolve it. But we are not sure whether maximum layer 1 is needed or not. As in Rel-15, the UE capability maxNumberMIMO-LayersPDSCH has candidate values of 2, 4 and 8. We can reuse that as the candidate values for 1024QAM as {2, 4, 8}. |
| ZTE, Sanechips | We also agree that according to WID, only RAN4 needs to consider the “2 layers” restriction, while for other WGs there is no need to introduce such a limitation. Therefore, we think it doesn’t make sense to couple it with RAN1/2 capability. Since it is RAN4 requirement, if there is any need, we think it can be discussed in RAN4. |
| MediaTek | @ZTE, Let’s forget about what the WID says for a second. Could you please kindly answer the following questions?1. Do you agree that UE complexities are different for 1024QAM with 2 layers and for 1024QAM with 4 (or 8) layers?
2. If your answer to 1 is yes, what is your concern with having corresponding UE capabilities for UE to differentially report its capability? Or would you rather see UE not reporting this capability at all?
3. Which feature group(s) in RAN4 do you suggest that we add this restriction to? FG36-1 is a basic feature group for 1024QAM. Since FG36-1 is defined by RAN1, in our opinion, it is RAN1’s responsibility to clarify it and make it work properly.
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# Discussion/Approval Items during RAN1 #109-e — Second Checkpoint

Based on the comments/questions/suggestions received by the first checkpoint, the following are the revised proposals and/or proposed agreements by the moderator. Companies submitted the following views on the moderator’s proposals.

***[Please submit all comments/questions/suggestions here, late comments/questions/suggestions submitted in Section 3 will not be considered]***

**General comments**

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| Company | Comments/Questions/Suggestions |
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# Issue 1: FG

**Proposal: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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| Company | Comments/Questions/Suggestions |
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# Discussion/Approval Items during RAN1 #109-e — Third Checkpoint

Based on the comments/questions/suggestions received by the second checkpoint, the following are the revised proposals and/or proposed agreements by the moderator. Companies submitted the following views on the moderator’s proposals.

***[Please submit all comments/questions/suggestions here, late comments/questions/suggestions submitted in Section 4 will not be considered]***

**General comments**

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| Company | Comments/Questions/Suggestions |
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# Issue 1: FG

**Proposal: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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| Company | Comments/Questions/Suggestions |
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# Summary of Final Proposals for Agreements

This Section summarizes the final proposals for agreement in RAN1 #109-e by email. There are no tables for comments.

***[All comments must be directly made on the RAN1 email reflector]***

Companies can continue to update their comments in the previous Sections, however, these are no longer monitored by the moderator. Any such comments will be for archival purposes only and will not influence the outcome of this email discussion. Any objection to any of the proposals in this Section must be voiced directly on the RAN1 email reflector.

## Final Proposals for Agreement by the First Check Point

**Possible Agreement: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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## Final Proposals for Agreement by the Second Check Point

**Possible Agreement: Adopt the following changes highlighted in chromatic fonts, while keeping the yellow highlighting, if any, as shown**

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# Conclusion

In addition to the agreements in Section 6, that were reached by email during RAN1 #109-e, the following was agreed by GTW during RAN1 #109-e:

# References

1. R1-2202929, Updated RAN1 UE features list for Rel-17 NR after RAN1 #108-e including remaining RAN1 issues, Moderators (AT&T, NTT DOCOMO, INC.)
2. R1-2204713, UE features DL 1024QAM for NR FR1, MediaTek Inc.