**3GPP TSG RAN WG1 Meeting #106-E R1-210xxxx**

**e-Meeting, 16th – 27th August 2021**

**Source: Moderator (Intel Corporation)**

**Title: FL summary #1 on other aspects of UE complexity reduction for RedCap**

**Agenda item: 8.6.1.4**

**Document for:** **Discussion and Decision**

# Introduction

This document presents a summary of submitted contributions to AI 8.6.1.4 (Other aspects of RedCap complexity reduction), including considerations on maximum number of DL MIMO layers and relaxed maximum modulation order for RedCap devices.

[106-e-NR-R17-RedCap-04] Email discussion regarding other aspects of UE complexity reduction – Debdeep (Intel)

* 1st check point: August 19
* 2nd check point: August 24
* Final check: August 27

Based on the submitted contributions to RAN1 #106-E meeting, the discussion points are categorized into the following topics:

* Scaling factor for peak DL data rate for RedCap
* Max number of DL MIMO layers for RedCap
* Supported modulation orders for UL/DL and MCS tables for RedCap
* Miscellaneous including UE features

**Please provide your feedback to the “FL1 Question”s #1, #2, and #3 by August 17th, 23:59 UTC.**

To avoid excessive email load on the RAN1 email reflector, please note that there is NO need to send an info email to the reflector just to inform that you have uploaded a new version of this document.

# Scaling factor for DL peak data rate for RedCap

Contributions [1], [10], [11], [12] propose the consideration of DL peak rate scaling factor for RedCap UEs. The relevant proposals are presented below for convenience:

|  |  |
| --- | --- |
| **Tdoc ref.** | **Proposals** |
| [1] | [*Proposal 3 Support lower scalingFactor values for the RedCap UEs.*](#_Toc79162845)[* FFS: the new values for the scalingFactor.*](#_Toc79162846)[* FFS: how to relax the restriction “*$v\\_Layers\^((j))⋅Q\\_m\^((j) )⋅f\\_\^((j) )$ *is no smaller than 4”.*](#_Toc79162847)*Proposal 4 Discuss whether the RedCap WID should be updated to include lower values for the scalingFactor as one of the aspects for UE complexity reduction.* |
| [10]  | ***Proposal 1: Lower scalingFactor, e.g., 0.1, 0.2 shall be adopted for Rel-17 RedCap in order to relax HARQ and L2 buffer requirements for the industrial wireless sensor and the video surveillance use cases identified in [1].*** ***Proposal 2: Exclude RedCap UE from the minimum scalingFactor requirement in [5], Section 4.1.2.*** |
| [11] ***(submitted to AI 8.6.2)*** | 1. Send LS to RAN2 indicating RAN1 see value in specify support for early indication in Msg3 and for RAN2 to determine feasibility
* **FFS: how the UE is signaled to use Msg3 or Msg1 early indication or not**
1. The currently specified scaling factor of 0.4 is sufficient for RedCap, there is no need to specify any lower values.
 |
| [12] ***(submitted to AI 8.6.3)*** | ***Proposal 1: Reuse the current scaling factor, remove the restriction for RedCap, and introduce new value 0.1 for RedCap, e.g. the*** ***scaling factor values of RedCap are {0.1, 0.4, 0.8}.*** |

The primary motivation by the proponents of the above is to allow RedCap UEs to support DL peak data rates that are much lower than the corresponding achievable peak rates considering the agreed complexity reduction features (on BW, # of Rx branches, max modulation order, etc.) for RedCap. It is noted by the proponents that some of the RedCap use-cases (e.g., IWSN) may require much lower data rates than the min. peak rates achievable for currently-agreed capabilities for RedCap UEs.

As specified in TS 38.306, the peak rate scaling factor was introduced in Rel-15 based on the following motivations [13].

|  |
| --- |
| * *Scaling factor is used to reflect the association of capability mismatch between the baseband capability and RF capability for both SA UE and NSA UE.*
* *Scaling factor is used to scale down maximum throughput of NSA UEs operating in EN-DC scenario that share hardware resources between LTE and NR.*
 |

Clearly, neither of the above motivations apply for RedCap use-cases.

Further, to ensure that the scaling factor is utilized by UEs primarily for the originally intended use-cases, it is currently specified that for single carrier NR SA operation, a UE would need to ensure that any indicated value of scaling factor (default value = 1) is such that the product $v\_{Layers}^{(j)}⋅Q\_{m}^{\left(j\right)}⋅f\_{}^{\left(j\right)}$ is no less than 4.

Considering that RedCap UEs are limited to single carrier operations, allowing RedCap UEs to indicate scaling factors < 1 is effectively limiting one or more of: (i) max PDSCH TBS; and (ii) max # of HARQ processes, without actually relaxing them for PHY layer operations.

Thus, the primary benefits in allowing fractional DL peak rate scaling factors for RedCap would be in terms of reduction in L2 buffer size and possibly to soft-buffer requirements (depending on UE implementation). On the other hand, it should be noted that limiting max TBS sizes would have been more effective in this regard as it also allows the UE to take better advantage of the reduced peak rate support for PHY layers. However, RAN1 discussed these options in the past and did not agree to introducing limits on max PDSCH TBS or to limit max # of HARQ processes during past discussions since the Rel-17 SI on RedCap.

On L2 buffer sizes, it should be noted that RAN2 is also discussing this aspect. However, the benefit can be expected to be limited in terms of UE cost/complexity for the data rates under consideration for RedCap (the impact was much more pronounced for non-RedCap “eMBB” use-cases with peak rates of Gbps order).

Further, as noted in reference [1], it may also be necessary to update the scope of the WI to include L2 buffer size reduction and application of peak DL rate scaling factor as UE complexity reduction features.

However, further inputs from companies would be necessary to determine whether and how to optimize the support of scaling factor for RedCap in Rel-17 NR.

## FL1 Question 1

* *Please share your views on the following for handling of scaling factors for RedCap UEs:*
	+ ***Opt. 1:*** *Scaling factors for peak DL rates with existing values {0.4, 0.75, 0.8, 1} are available to RedCap UEs, with the same constraint on the minimum value of the product* $v\_{Layers}^{(j)}⋅Q\_{m}^{\left(j\right)}⋅f\_{}^{\left(j\right)}$*as applicable for single carrier NR SA operation.*
	+ ***Opt. 2:*** *Scaling factors for peak DL rates with existing values {0.4, 0.75, 0.8, 1} are available to RedCap UEs, with the removal of the constraint on the minimum value of the as applicable for single carrier NR SA operation.*
	+ ***Opt. 3:*** *Scaling factors for peak DL rates with existing values {0.4, 0.75, 0.8, 1} and new smaller values from one or more of: {0.1, 0.2} are available to RedCap UEs, with the removal of the constraint on the minimum value of the product* $v\_{Layers}^{(j)}⋅Q\_{m}^{\left(j\right)}⋅f\_{}^{\left(j\right)}$*as applicable for single carrier NR SA operation.*
	+ ***Opt. 4:*** *Scaling factors for peak DL rates are NOT available to RedCap UEs.*
	+ *Other options are not precluded.*

|  |  |  |
| --- | --- | --- |
| **Company** | **Preferred option** | **Comments** |
| Qualcomm | Opt. 4 | During SI phase of R17 RedCap UE, PDSCH TBS reduction and HARQ buffer size reduction have been evaluated for cost/complexity reduction. There was no consensus to support such complexity reduction features, and they have been excluded from the WI objectives of R17 RedCap device to avoid market segmentation.To ensure co-existence of R17 RedCap UE with R15/16 non-RedCap UE, shared CORESET0/SIB1 and qam64 MCS table (Table 5.1.3.1-1 in TS 38.214 for DL) should be supported. Therefore, we don’t think smaller scaling factors or relaxed constraint on the minimum value of the product $v\_{Layers}^{(j)}⋅Q\_{m}^{\left(j\right)}⋅f\_{}^{\left(j\right)}$ should be pursued in R17. |
| CATT |  | Current 38.306 spec states the following:

|  |
| --- |
| For single carrier NR SA operation, the UE shall support a data rate for the carrier that is no smaller than the data rate computed using the above formula, with $J=1 CC$ and component $v\_{Layers}^{(j)}⋅Q\_{m}^{\left(j\right)}⋅f\_{}^{\left(j\right)}$ is no smaller than 4. |

Before any selection, we would like to hear some clarification first. Is it the correct understanding that:For RedCap UEs, if nothing is changed, the above requirement can still be fulfilled by 1Rx RedCap UE, since v=1, Q=4 (by 64QAM), and f=1, and v\*Q\*f = 4? |
| Spreadtrum | Option 3 | Different from PDSCH TBS reduction and HARQ buffer size reduction, the motivation for scaling factor is mainly comes from L2 buffer size reduction which is under discussion in RAN2. As also mentioned in [1], scaling factor can be used to scale down the max data rate supported by the UE, and thereby reduce its memory size (L2 and HARQ buffers) and interface bandwidth requirements.Due to the restriction, 0.4 cannot be used for RedCap, then the benefits of reusing the current scaling factor are limited. Further, even the restriction can be removed (i.e. 0.4 can be used), the data rate in DL and UL are still very large for some use cases (e.g. sensors), so smaller values need to be introduced. Therefore, we prefer to reuse the current scaling factor, remove the restriction for RedCap, and introduce smaller value(s) for RedCap, i.e. option 3.Besides, it is noticed that the current restriction ($v\_{Layers}^{(j)}⋅Q\_{m}^{\left(j\right)}⋅f\_{}^{\left(j\right)}$ is no less than 4) is based on the originally intended use-cases(RF/BB mismatch, EN-DC) for scaling factor, however, the scaling factor for RedCap is a different use-case, then the restriction is not suitable for RedCap.We are open to other solutions which can reduce the L2 buffer size from RAN1 perspective. |
| LG | Option 4 | Our preference is Option 4. If we had the estimation of the amount of complexity reduction with the introduction of existing or even smaller scaling factor, we would be discussing this issue based on that, but unfortunately we don’t have it. If there is a strong needs, then Option 2 would be the next preference from our perspective. |
| vivo | Option 3 | We see the benefit of smaller scaling factor and have a preference to option. However, we prefer to leave this topic to RAN2 to decide, as far as we know, RAN2 will discuss this issue during this meeting. RAN1 can discuss the necessary spec update based on RAN2 input later |
| CMCC | If RAN2 agrees, Option 3 | Similar view as vivo, we can wait for RAN2 input. The benefit of smaller scaling factor is unclear for UE cost and complexity reduction, and the formula is used to calculate peak data rate, which is not always needed for data transmission. gNB can scheduling small amount of resources to meet low data rate requirement. If RAN2 agrees to introduce it, option 3 can be considered. |
| Nordic | Option 4 |  |
| DOCOMO | Opt. 1 (1st)Opt. 2 (2nd) | We think existing framework can be reused unless it is excluded by WID (such as CA/DC). In that sense, we are OK to support Opt.1 as 1st preference. Opt. 2 can be considered if there is a strong need from companies. |
| Huawei, HiSilicon | Option 4 | The motivation for scaling factor is due to support of CA and UE needs to share the resource inside. This does not apply to RedCap UEs.  |
| Lenovo, Motorola Mobility |  | Up to RAN2 decision. |
| Xiaomi | Opt.3 | We share the same view with Spreadtrum and vivo. We can wait for RAN2 input and then RAN1 could start the discussion if necessary.  |
| ZTE, Sanechips | Opt.3 | Introducing smaller scaling factor can be considered for the benefits of UE complexity reduction. Also, RAN2 decision need to be taken into consideration when we discuss the scaling factor issue. |
| Nokia, NSB | Option 4 | We are not keen to introduce smaller scaling factor for the purpose of UE complexity reduction. We discussed related issues of reducing maximum PDSCH TBS and number of HARQ processes in the SI but could not reached consensus. Therefore, we don’t see a strong motivation for smaller scaling factor. |
| FUTUREWEI | Opt. 4 | As the FL noted “RAN1 discussed these options in the past and did not agree to introducing limits on max PDSCH TBS or to limit max # of HARQ processes during past discussions since the Rel-17 SI on RedCap.” leads to opt. 4 |
| Sierra Wireless | Option 4 | There was no consensus to support this feature in the SI phase, hence, it was not included in the Rel-17 WID. If there is a need, then Option 1 can be considered using the existing framework. |
| Apple  | Opt.3 | Introducing smaller scaling factor has a clear benefit to reduce memory cost of industry sensor and video surveillance devices that has lower data rate requirement.  |
| Ericsson |  | The UE can indicate its max data rate capabilities using the scaling factor (*scalingFactor*) and using the maximum supported modulation order (*supportedModulationOrderDL*/*supportedModulationOrderUL*). The scaling factor can take the values 1, 0.8, 0.75, and 0.4, and the maximum supported modulation order can take values 1, 2, 4, 6, and 8, corresponding pi/2-BPSK/BPSK, QPSK, 16QAM, 64QAM, and 256QAM, respectively. In our understanding, the mentioned parameters for maximum supported modulation order concerns only the modulation order assumed in the maximum data rate calculations. The network may still use a modulation order higher than the value given by this field while scheduling the UE (see the definition of the parameter below).

|  |
| --- |
| ***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 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]. |

Therefore, when we combine the two capabilities, the effective scaling factor can already be low. For example, if a RedCap UE (20 MHz BW, 30 kHz SCS, 1 MIMO layer and 64QAM modulation order) reports *scalingFactor* = 0.4 and *supportedModulationOrderDL/UL* = bpsk:* w/ constraint on $v\_{Layers}^{(j)}⋅Q\_{m}^{\left(j\right)}⋅f\_{}^{\left(j\right)}$, max data rate would be ~ 55 Mbps.
* w/o constraint on $v\_{Layers}^{(j)}⋅Q\_{m}^{\left(j\right)}⋅f\_{}^{\left(j\right)}$, max data rate would be ~ 5 Mbps.

It may seem reasonable to remove the constraint to achieve further cost reduction for IWSN use cases. However, we also need to take into account that the max TBS may also be restricted (as also highlighted by the FL). For example, the max data in the case above (w/o constraint) would be ~2500 bits. This may impact reception of SI/paging messages. This aspect needs to be studied further. We are also interested in knowing if the FL/other companies share similar understanding as us on this matter.Therefore, it may not be suitable to completely remove the constraint on $v\_{Layers}^{(j)}⋅Q\_{m}^{\left(j\right)}⋅f\_{}^{\left(j\right)}$. However, there is potential for the relaxation of the constraint. We are OK with Option 2 if it is updated as follows:* + ***Opt. 2:*** *Scaling factors for peak DL rates with existing values {0.4, 0.75, 0.8, 1} are available to RedCap UEs, with the removal/relaxation of the constraint on the minimum value of the product* $v\_{Layers}^{(j)}⋅Q\_{m}^{\left(j\right)}⋅f\_{}^{\left(j\right)}$*as applicable for single carrier NR SA operation.*

We are also open to discuss other options achieving similar results.It would be also interesting to know whether reduced scaling factor for UL would bring significant complexity reduction. |
| IDCC | Option 4 | It is not clear if this will reduce UE complexity. |
| u-blox | Option 3 | Per discussed in [10], we see clear benefit of smaller scaling factor values in reducing memory size for lower data rate use cases as promised in the RedCap WID.  |

**Summary of views:**

Company preferences:

* **Opt. 1:** DCM (1st preference), Sierra W. (2nd preference), Intel **(3)**
* **Opt. 2:** DCM (2nd preference), Ericsson (w/ “relaxation” in addition to “removal” of the existing constraint) **(2)**
* **Opt. 3:** SPRD, vivo, CMCC (subject to RAN2 decision), Xiaomi, ZTE/Sanechips, Apple **(6)**
* **Opt. 4:** QC, LG, Nordic, HW-HiSi, Nokia/NSB, FTW, Sierra W., IDCC, Intel (2nd preference) **(9)**
* **Up to RAN2:** Lenovo, CMCC (w/ Option 3 being their preference), vivo (w/ Option 3 being their preference) **(3)**
* **No opinion** expressed on identified Options: CATT **(1)**

Considering the situation above, and taking into account the justifications provided by companies, it does not appear that there is agreement in RAN1 on need to support scaling factor for DL peak rate for RedCap UEs.

## Proposed Observation 1:

* *There is no consensus in RAN1 on the need to introduce new smaller values of scaling factor for DL peak rate for RedCap UEs.*
* *There is no consensus in RAN1 on the need to remove or relax the Rel-15 constraint on minimum value of the product* $v\_{Layers}^{(j)}⋅Q\_{m}^{\left(j\right)}⋅f\_{}^{\left(j\right)}$ *for single carrier SA operation.*

# Max number of DL MIMO layers for RedCap

Contributions [1], [3], [4], [5], [7] discuss various aspects related to potential updates to DCI formats and higher layer parameter configurations motivated by the limited support of max # of DL MIMO layers by RedCap UEs.

Most of these proposals are already under discussion as part of AI 8.6.1.2 and can continue there.

In light of the reduced max # of DL MIMO layers for RedCap, certain updates to TS 38.306 to for RedCap has been proposed in [5], but this should be handled in RAN2 rather than RAN1.

## FL1 Question 2

* *Please indicate below* ***if you think*** *there are any aspects related to max # of DL MIMO layers for RedCap that should be discussed in AI 8.6.1.4.*
* ***NOTE: No explicit conclusions are intended to be captured for the above.***

|  |  |
| --- | --- |
| **Company** | **Comments** |
| CATT | OK to handle the update of higher layer parameter definition (in 38.306 or 38.822) in RAN2. |
| Nordic | RAN2 discussion, no need to discuss here |
| Huawei, HiSilicon | RAN1 can decide candidate values to be 1 or 2 for MIMO layers |
| ZTE,Sanechips | RAN1 should discuss which higher layer parameters are affected on MIMO layers for RedCap Ues. Whether/ how to optimize these parameters is determined by RAN2.Additionally, for 1Rx RedCap Ues, antenna ports field can be reduced by 1 bit in DCI format 1\_1/1\_2 after the capability on maximum number of MIMO layers is reported. This issue can be discussed in 8.6.1.2. |
| FUTUEWEI | This is a RAN2 discussion |

**Summary of views:**

Based on feedback above, it can be concluded that at this point there is no specific issue related to max # of DL MIMO layers for discussion within this agenda. Some of the aspects are for RAN2 while some others, relevant to RAN1, are already under discussion in AI 8.6.1.2.

# Supported modulation orders for UL/DL and MCS tables for RedCap

**Support of 256-QAM in the UL** ([2], [4])

Couple contributions propose that 256-QAM for UL is available as an optional feature for RedCap Ues.

Unless explicitly prohibited, this feature would be available to RedCap Ues as an optional feature. If sufficiently motivated to explicitly preclude support of 256-QAM in the UL for RedCap Ues, this can be revisited as part of UE capability discussions.

**1024-QAM in the DL** ([8])

Unless explicitly prohibited, 1024-QAM would be available to RedCap Ues as an optional feature. Similar to the case of 256-QAM in the UL, if sufficiently motivated to explicitly preclude support of 1024-QAM in the DL for RedCap Ues, this can be revisited as part of UE capability discussions.

**Dynamic indication to switch between MCS tables** ([8])

Reference [8] makes the following proposal:

|  |
| --- |
| ***Proposal 1:******The dynamic indication of MCS table with MCS-C-RNTI for PDSCH or PUSCH shall continue to be optional for RedCap Ues.*** |

As such, this feature is associated with support of low-SE MCS table and would be available to RedCap Ues as optional feature unless explicitly precluded. This can be discussed further if necessary, as part of UE capability discussions.

Thus, for all of the above already-optional features, while they could all be left as optional for RedCap Ues, it is suggested not to discuss them one by one. Instead, they can be discussed as part of UE features discussions, including if some of these may be explicitly prohibited for RedCap.

## FL1 Question 3

* *Please indicate below* ***if you disagree*** *that the following features related to support of modulation orders in the UL or DL or MCS tables are not discussed in isolation but can be considered as part of discussions on UE features for RedCap:*
	+ *256-QAM in the UL*
	+ *1024-QAM in the DL*
	+ *Dynamic indication to switch between MCS tables for PDSCH/PUSCH*
* ***NOTE: No explicit conclusions are intended to be captured (to avoid case-by-case decisions).***

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Qualcomm | We don’t see a need to support 256-QAM in UL or 1024 QAM in DL as optional UE features for R17 RedCap devices.Based on capability signaling, dynamic indication of MCS table with MCS-C-RNTI for PDSCH or PUSCH can be supported as optional UE feature for R17 RedCap devices. |
| CATT | Fine with the handling of FL. The listed features can be discussed during UE feature discussion. |
| LG | We support the FL’s handling on this topic. |
| Vivo | We think this can be discuss later in UE feature session, where we can still discuss optionally support for UL 256QAM and DL 1024QAM, or do not support them at all for RedCap by specification.  |
| CMCC | OK with FL’s handling. |
| Nordic | Agree with FL direction |
| DOCOMO | Agree with FL |
| Lenovo, Motorola Mobility | Agree with the proposal. |
| ZTE, Sanechips | Agree with FL’s proposal.  |
| Nokia, NSB | We support FL’s proposal. |
| FUTUREWEI | OK with FL suggestion |
| Apple  | Agree with FL handing.  |
| Ericsson | Agree with the FL. |
| IDCC | Agree. |

**Summary of views:**

Based on feedback above, it seems companies are in general agreement that the support of optional features for RedCap UEs would be discussed as part of UE feature discussions for RedCap.

# Miscellaneous including UE features

In contribution [6], it is proposed to further study compact CSI reporting in Idle/Inactive modes, in view of support of RACH- or CG-PUSCH-based SDT in Inactive mode.

Further, it is also proposed that SRS transmissions outside of active UL BWP are not supported by RedCap UEs and details of frequency selective scheduling outside of active DL BWP of a RedCap UE are studied further in view of the complexities involved with accurate CSI measurements and feedback outside of the active DL BWP.

Considering that some of these considerations have some correlation to the discussions in AI 8.6.1.1 on reduced BW support for RedCap UEs and already being considered as part of discussions in AI 8.6.1.2 (compact CSI feedback in Idle/Inactive modes), it is suggested to consider these proposals therein.

In contribution [9] an overview of UE optional features that may be available to RedCap UEs is presented. This is expected to be handled as part of discussions on UE features for RedCap.

# References

1. R1-2106566, Other UE complexity reduction aspects for RedCap, Ericsson

1. R1-2106652, Other UE Complexity Reduction Aspects, Nokia, Nokia Shanghai Bell
2. [R1-2106844](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_106e_review%5CallTdocs_R1-106e%5CR1-2106844.zip), Discussion on DL MIMO layers for RedCap UEs, ZTE, Sanechips

1. R1-2106980, Discussion on other aspects related to complexity reduction, CATT

1. R1-2107301, MIMO aspects for RedCap, NEC

1. R1-2107354, Other Aspects of UE Complexity Reduction, Qualcomm Incorporated
2. [R1-2107411](file:///C%3A%5CUsers%5Cdchatt2%5COneDrive%20-%20Intel%20Corporation%5CDocuments%5Cwork%5C3gpp%5CRAN1%5CContribution%20reviews%5CRAN1_106e_review%5CallTdocs_R1-106e%5CR1-2107411.zip), Discussion on potential modification of existing DCI formats, CMCC

1. R1-2107668, Reduced maximum MIMO layers and reduced maximum modulation order for RedCap, Huawei, HiSilicon

1. R1-2107929, Discussion on the UE features for RedCap, Xiaomi

1. R1-2108088, RedCap UE Further Complexity Reduction Considerations, u-blox AG
2. R1-2107077, Design consideration for Higher layer support of RedCap, Sierra Wireless, S.A.
3. R1-2107385, Discussion on scaling factor for RedCap, Spreadtrum Communications, Apple, CEPRI
4. R1-1807651, Reply LS on formula or table for L1 data rate, RAN1

# Appendix: Companies’ point of contact

**FL1 Question: Please consider entering contact info below for the points of contact for this email discussion.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Point of contact** | **Email address** |
| vivo | Xueming Pan | panxueming@vivo.com |
| DOCOMO | Shinya Kumagai | shinya.kumagai@docomo-lab.com |
| Ericsson | Sandeep Narayanan Kadan Veedu | sandeep.narayanan.kadan.veedu@ericsson.com |