3GPP TSG-RAN WG2 Meeting#113-e Draft\_R2-2102017

Online, January 25th - February 5th 2021

Agenda Item: 8.12.2.2

Source: Huawei

Title: Summary of offline 107 - [REDCAP] L2 capabilities and UE types

Document for: Discussion and Decision

# Introduction

This document is for the following offline discussion on L2 capabilities and UE types:

* [AT113-e][107][REDCAP] L2 capabilities and UE types (Huawei)

 Scope: based on the proposals in [R2-2101255](file:///C%3A/Data/3GPP/Extracts/R2-2101255%20Higher%20layer%20capabilities%20and%20procedural%20impacts%20of%20RedCap%20UE.doc), [R2-2100310](file:///C%3A/Data/3GPP/Extracts/R2-2100310_Definition%20of%20RedCap%20UEs.docx) and [R2-2100460](file:///C%3A/Data/3GPP/Extracts/R2-2100460_UE%20type%20definition%20and%20constraining%20for%20RedCap%20UEs.doc), discuss:

1. which "reduced L2 capabilities" can be listed as possible enhancements in the TR
2. which impacts on procedures for RedCap UEs can be described in the TR
3. which pros and cons to have only one vs multiple RedCap UE types can be listed in the TR

For all the aspects (and namely for 3), the intention of this offline is to describe options and implications in the TR, not to down-select any alternatives

Initial intended outcome: Summary of the offline discussion with:

* + - List of proposals for agreement
		- List of proposals that require online discussions
		- Corresponding TP for the TR

Initial deadline (for companies' feedback): Monday 2021-02-01 11:00 UTC

Initial deadline (for rapporteur's summary in R2-2102017): Monday 2021-02-01 17:00 UTC

Proposals marked "for agreement" in R2-2102017 not challenged until Tuesday 2020-02-02 10:00 UTC will be declared as agreed by the session chair. For the rest the discussion will continue online.

This offline discussion is based on the proposals in the following contributions:

R2-2101255 Higher layer capabilities and procedural impacts of RedCap UE Huawei, HiSilicon

R2-2100310 Definition of RedCap UEs Qualcomm Incorporated

R2-2100460 UE type defination and constraining for RedCap UEs vivo, Guangdong Genius

# Discussion

The following issues will be discussed according to the scope of this offline discussion:

* Reduced L2 capabilities
* Impacts on procedures for RedCap UEs
* Pros/cons to have only one RedCap UE type v.s. multiple RedCap UE types

According to the chairman guidance, the intention of this offline is to describe options and implications in the TR.

## Reduced L2 capabilities

In RAN2#111e meeting, it was agreed that the reduction of upper layer capabilities is FFS:

FFS:

1. Whether reduction of upper layer capabilities should be considered is FFS (in any case no email discussion until the next meeting on this)

Regarding reduction of upper layer capabilities, proposals from above contributions are listed below:

|  |  |  |
| --- | --- | --- |
| **Tdoc number** | **Company name** | **Proposals** |
| R2-2100310 | Qualcomm Incorporated | Proposal 3. Make the following upper-layer UE capabilities optional for RedCap UEs:* Maximum number of DRBs;
* Total layer-2 buffer size;
* 18-bit sequence number field for PDCP and RLC AM;
* RRC processing delay.
 |
| R2-2101255 | Huawei, HiSilicon | Proposal 1: Consider to reduce the number of DRBs to be mandatorily supported for RedCap UE and allow the UE to report the number of supported DRBs.Proposal 2: Consider to reduce the length of PDCP and RLC AM SN to be mandatorily supported for RedCap UE (e.g. mandatory 12-bit SN). |

In summary, reduction for the following four higher layer capabilities are proposed:

* Maximum number of DRBs;
* Total layer-2 buffer size;
* 18-bit sequence number field for PDCP and RLC AM;
* RRC processing delay.

Companies are invited to provide comments on which the above four higher layer capabilities can be reduced.

**Question 1a.** Do you support reducing the maximum number of DRBs mandatory supported by RedCap UEs?

* Yes, how?
* No, why?

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | Yes | We are ok with reduction in number of DRBs, since some RedCap UEs like surveillance do not need many DRBs to support.This can be a capability at the UE. |
| Qualcomm | Yes | We notice that many use cases for RedCap UEs (e.g. sensors or low end wearables) do not need the current maximum number of DRBs (8), which was selected based on the need of premium eMBB UEs. Since maximum number of DRBs directly affects the buffer size requirement of a UE chip, smaller maximum number of DRBs can help reduce the buffer size and hence the cost of a RedCap UE.  |
| Ericsson | TBD | We can consider possible reduction in DRBs once it is clear what all functionality is supported by a RedCap UE, i.e., during the WI phase. However, even if for some use cases and UEs reduction in DRBs would be possible, we would like to avoid fragmentation and keep in mind forward compatibility with future features.  |
| Huawei, HiSilicon | Yes | The large number of DRBs to be mandatorily supported contributes to support multiple traffic types. However, according to the use cases of RedCap UE, the traffic types of RedCap UE will be limited. Moreover, the larger number of DRBs to be mandatorily supported will increase the cost of memory. So, the maximum number of DRB mandatorily supported by RedCap UE should be reduced.Thus, we propose to reduce the maximum number of DRBs mandatory supported by RedCap UEs to 8. |
| MediaTek | Yes | With limited traffic types defined for RedCap use cases and a goal to reduce complexity, a reduction in max number of DRBs is desirable. The details can be decided in the WI phase |
| Nokia, Nokia Shanghai Bell | Yes | RedCap use cases should suffice with less DRBs, however, the exact number can be discussed in the WI phase. |
| Futurewei | Yes | RedCap use cases may not need large number of DRBs. |
| Sierra Wireless | Yes | In principle the intent is to have a simpler device |
| vivo | Yes with comments | We agree that RedCap UEs may not need 8 DRBs for some use cases. But we need to first identify how much impact on the cost of the devices for this Max. number of DRBs first. After that, we could discuss what the exact number of DRBs is for RedCap UEs. |
| Samsung | Yes | We support the proposal in principle. |

**Question 1b.** Do you support reducing the total layer-2 buffer size for RedCap UEs compared with the value required by Section 4.1.4 in TS 38.306?

* Yes, how?
* No, why?

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | We are ok with this but | L2 buffer size is anyway something that the gNB can use as a parameter in scheduling. And since there is no CA or DC, it’s even simpler now and it’s transparent to how the UE implements this. So we are not sure what needs to be changed even with a reduction in DRBs. |
| Qualcomm | Yes | Total lay-2 buffer size is used by gNB for scheduling. What we have found in field studies is that for most applications, especially those do not have high data rates, do not need the entire L2 buffer specified in 38.306 to achieve good throughput. Relaxing this requirement hence can help reduce buffer size and hence cost of RedCap UEs. This reduction can be signalled as a fraction (e.g. 50%) of the “theoretical” total L2 buffer size as a UE capability to network.  |
| Ericsson | Yes, later | This sounds reasonable as maximum BW and MIMO layers are reduced (and no CA/DC support has been agreed). We can come back to the details once all options have been worked out related to the physical layer complexity reduction techniques.  |
| Huawei, HiSilicon | No | The current L2 buffer size is calculated based on UL/DL peak data rate and RTT time, and the UL/DL peak data is calculated based on bandwidth, modulation order, and numerology and so on. Since the bandwidth and maximum modulation order of RedCap UE has been reduced, the DL/UL peak data and the L2 buffer size of RedCap UE also will be reduced accordingly. The motivation of further reducing this value is not clear. Furthermore, it should be avoided to modify the basic logic of the current L2 buffer size definition in 38.306. |
| MediaTek | No | While a reduction in L2 buffer size is desirable for RedCap devices to lower its memory requirements, we agree with Huawei that with peak data rate reductions for RedCap, L2 buffer requirements of RedCap devices are implicitly reduced.A further reduction would imply changes to RLCRTT times (38.306, 4.1.4), which have not been modified for RedCap. We prefer to leave the L2 buffer requirements definition in 38.306 untouched. |
| Nokia, Nokia Shanghai Bell | Yes, but | The maximum data rate in both UL and DL used in the formula in TS 38.306 is what determines the buffer size. When these values are defined, the buffer size will be reduced as Huawei also explains. |
| Futurewei | No | L2 buffer requirement rule in 38.306 should be maintained. The actual L2 size would be adjusted as peak data rate is reduced in RedCap device. |
| Sierra Wireless | Yes | Agree with Ericsson |
| vivo | No? | As we understand, Layer-2 buffer size is calculated based on the bandwidth, MIMO layer and sequence numbers. While these capabilities have been reduced based on RAN1 discussion. So we understand that Layer-2 buffer size has been implicitly reduced naturally. In this way, we would like to check with proponent, what more is needed for specification? |
| Samsung | No | We share the view with Huawei and MediaTek that L2 buffer requirements of RedCap devices are implicitly reduced according to the existing equation, and thus we do not see the need of the change at the moment. |

**Question 1c.** Do you support to make support of 18-bit sequence number field for PDCP and RLC AM optional for RedCap UEs?

* Yes, how?
* No, why?

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | Yes | With no CA/DC, 18-bit is not necessary |
| Qualcomm | Yes | 18-bit SN is needed only by high data rate applications. The longer the SN is, the bigger buffer UE needs to have to support the sliding window operations in PDCP/RLC. Since RedCap UEs are not expected to have high data rates (e.g. no CA or DC), 18-bit SN field becomes unnecessary. RedCap can use the 12-bit SN instead (currently optional for R15/16). |
| Ericsson | TBD | We agree that the whole 18-bit space is not needed but wonder what would the actual gain be? We would like to avoid any changes to RLC and PDCP due to RedCap, but as brought up by QC this should be doable without changes to the existing specifications.  |
| Huawei, Hisilicon | Yes | Considering that the required peak data rate for RedCap UEs is lower, 18-bit SN is not needed for RedCap UE. We can consider 12-bit SN as mandatory capability. |
| MediaTek | No | Agree with Ericsson that while the whole 18-bit SN space may not be used for RedCap operation, we do not see a significant gain associated with removing this option. Where possible, we should avoid changes to the NR baseline unless absolutely necessary. |
| Nokia, Nokia Shanghai Bell | TBD | While the whole space is not required for 18-bit SN, we don’t see it would contribute too much to RedCap UE complexity. However, this can be discussed further. |
| Futurewei | Yes | 12-bit SN can be considered as mandatory instead. |
| Sierra Wireless | Yes | Agree with Huawei |
| vivo | Yes with comments | We agree that RedCap UEs may not need 18 bits SN due to less use cases. But we need to first identify how much impact on the cost of the devices for this SN number. After that, we could discuss what is the exact number should be supported for RedCap UEs. |
| Samsung | TBD | We tend to agree that 18-bit SN may not be required, but at the moment, do not see a significant gain either. RAN2 can discuss it later. |

**Question 1d.** Do you support relaxing the RRC processing delay for RedCap UEs?

* Yes, how?
* No, why?

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | Yes | We need to discuss the details but we agree with increased processing times. |
| Qualcomm | Yes | NR reduced RRC processing time (compared to LTE) to better support low latency applications such as URLLC. However, most RedCap use cases do not have low latency requirement. Reducing RRC processing time do not have much impact on UEs’ control-plane performance but can relax their requirement on processor. This relaxation can be signaled as a scaling factor (e.g. 1.25x) on top of R15’s mandatory RRC processing time, via UE capability signaling. |
| Ericsson | No | Not until we have discussed more details regarding this and whether there would be notable complexity gains. Also, we do not think latency should be increased from what it is now.  |
| Huawei, HiSilicon | No | The relaxation of RRC processing delay will lead to longer RRC configuration fuzzy time, which is not beneficial for the resource scheduling efficiency of the network. Moreover, the necessity to relax processing time is not clear, and the advantage on the cost saving arising from relaxed RRC processing delay seems trivial compared to other capability reductions. Note that if relaxation of RRC processing delay is allowed, identifying RedCap UE before Msg 4 is necessary because RedCap UE and non-RedCap UE have different processing time on Msg4.  |
| MediaTek | No | Agree with Huawei that the cost savings associated with relaxing the RRC processing delay are expected to be trivial. We prefer to avoid changes to the NR baseline unless absolutely necessary. |
| Nokia, Nokia Shanghai Bell | No | Agree with Ericsson and Huawei. |
| Futurewei | No | There’d be larger impact on network than potential saving on UE. |
| Sierra Wireless | Yes | From UE power consumption perspective, this may have some value. It would probably need to be signalled early as a capability, to enable the network to accommodate the delay. |
| vivo | No | As far as I know, RAN1 have made some quantified analysis on the PHY processing time, but there is no consensus on the cost reduction. Here, we also have the doubt for the impact on the cost. Besides, we donot see much motivation to relax the RRC processing delay.  |
| Samsung | - | We thought that 'relaxed UE processing time/capability' stated in the SID implies support of 'relaxed RRC processing delay', but we are also fine *not* to consider it to avoid fragmentation. |

## Impacts on procedures for RedCap UEs

In RAN2#111e meeting, the following agreement was made for the impacts on procedures for RedCap UEs:

Depending on RAN1 input, discussion is expected at least on the following impacts on RAN2 procedures:

 a. Impact on cell (re)selection

 b. Impact on initial access

 c. Impact on other idle mode procedures (i.e. SI acquisition, paging)

In above contributions, the following observations on procedural impacts were made and it was proposed to capture them in the TR:

|  |  |  |
| --- | --- | --- |
| **Tdoc number** | **Company name** | **Proposals** |
| R2-2101255 | Huawei, HiSilicon | Observation 1: RedCap UE may consume more power than non-RedCap UE during cell search and cell re-selection.Observation 2: If RedCap UEs share PO with non-RedCap UE, the power consumption of RedCap UEs may be impacted because of false probability and unnecessary SIB1 reading.Observation 3: RedCap UE needs measurement GAP for serving cell measurement with higher probability than non-RedCap UE.Proposal 3: Capture above observations into the TR. |

**Observation 1: RedCap UE may consume more power than non-RedCap UE during cell search and cell re-selection.**

**Question 2a. Do you agree with observation 1?**

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | yes | With reduced Rx/tx, more effort might be needed by redcap UEs to read broadcast info. |
| Qualcomm | Yes |  |
| Ericsson  |  | This doesn’t need to be always true. The observation sounds more like something to be discussed in RAN1/RAN4 and not directly related to impact on RAN2 procedures. Regarding P3 in R2-2101255, the original intention of the agreement seems to be to capture the possible impact on RAN2 procedures and not the possible impact on the lower layer procedures which may (or may not) impact the UE power consumption. Thus, we think it would be more appropriate for RAN1/RAN4 to come up with such concerns backed with analysis. Thus, we don’t think the observations are needed to be captured in the TR. |
| Huawei, HiSilicon | Yes | Agree with Apple.Besides, RedCap UE may select or reselect to a cell which does not support RedCap UE, which consumes additional energy. We think cell selection/reselection is RAN2 scope thus we need to capture potential impact if identified.We also agree with Ericsson that the observation only applies to some cases. |
| MediaTek | It depends on the WI discussion | The reasons provided in R2-2101255 for increased power consumption is due to the RedCap UE reselecting cells that may not support RedCap operation, requiring further cell search and reselection procedures to take place.However we have briefly discussed indications of RedCap support in relation with reselection and agreed to postpone this discussion to the WI phase (R2-2009936). We can discuss this topic alongside the expected discussion in the WI phase. |
| Nokia, Nokia Shanghai Bell |  | We are not sure how this observation would impact RAN2 procedures. |
| Futurewei | Yes | It “may” happen. |
| Sierra Wireless | Yes | It is true to say “may” but it does not have to be so. Indirectly this could affect RAN2 if it means accommodating more delay. |
| vivo |  | We agree “may consume more power”. But we wonder what is the impact on RAN2 here. Our understanding is that, we could keep this observation in mind, and further discuss any potential impact in WI phase based on contributions.  |
| Samsung | - | Same view as MediaTek. |

**Observation 2: If RedCap UEs share PO with non-RedCap UE, the power consumption of RedCap UEs may be impacted because of false probability and unnecessary SIB1 reading.**

**Question 2b. Do you agree with observation 2?**

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | Yes |  |
| Qualcomm | Yes | This issue is not necessarily specific to RedCap. The paging enhancements discussed in R17 Power saving are applicable to RedCap too.  |
| Ericsson | Maybe with changes | This would mainly concern RedCap UEs which are in bad reception conditions. Without further analysis (e.g. link budget) it is not clear how significant this concern is in practice.  |
| Huawei, HiSilicon | Yes | Agree with Qualcomm. Frequent paging of non-RedCap UEs will impact RedCap UEs regardless the reception conditions. But the impact on RedCap UEs that are in bad reception conditions will be larger. |
| MediaTek | Depends on NW implementation | Agree with Qualcomm that this is not a RedCap specific issue. POs are a function of the network assigned UE\_ID, and we expect that PO sharing and load management can be controlled by NW implementation. |
| Nokia, Nokia Shanghai Bell | Maybe | The impact would similarly exist for non-RedCap UEs. |
| Futurewei | Yes | This is a downside of sharing PO. |
| Sierra Wireless | Yes |  |
| vivo |  | We agree with Qualcomm that this is not RedCap specific issue, and this could be considered in R17 PowerSaving WI.  |
| Samsung | Yes but | We have same view with as Qualcomm that the issue is discussing in R17 power saving. |
|  |  |  |

**Observation 3: RedCap UE needs measurement GAP for serving cell measurement with higher probability than non-RedCap UE.**

**Question 2c. Do you agree with observation 3?**

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Yes/No*** | ***Comments*** |
| Apple | Yes | 1Tx/1Rx results in this for eg. |
| Qualcomm | Yes |  |
| Ericsson |  | Again, without analysis / link budget results it is hard to assess the full situation, but this is likely true. Again, this sounds more like a RAN4 discussion topic.  |
| Huawei, HiSilicon | Yes | Due to the limited bandwidth of RedCap UE, it is difficult to configure the active BWP of all RedCap UEs covering CD-SSB since it will degrade network performance to centralize too many RedCap UE working near CD-SSB.  |
| MediaTek | Potentially yes | Limited RedCap bandwidth may result in a higher need for measurement gaps to measure the CD-SSB, when the network is trying to avoid crowding in the BW around the CD-SSB. However, agree with Ericsson that this is more of a RAN4 discussion. |
| Nokia, Nokia Shanghai Bell |  | Agree with Ericsson |
| Futurewei | Yes | This may be caused by reduced BW and UE Rx capability. |
| Sierra Wireless  | Yes |  |
| vivo |  | Based on the limited conclusions for RedCap UEs, we are not sure whether it is true. This needs some quantified analysis in RAN4.  |
| Samsung | - | Agree with Ericsson |

## One v.s. multiple RedCap UE type(s) (Pros/Cons)

Regarding how many type(s) should be defined for RedCap UEs, proposals from above contributions are listed below:

|  |  |  |
| --- | --- | --- |
| **Tdoc number** | **Company name** | **Proposals** |
| R2-2100310 | Qualcomm Incorporated | Proposal 1. Only a single RedCap UE type (per FR) is defined. |
| R2-2100460 | vivo, Guangdong Genius | Proposal 1: Two UE types/categories should be defined for RedCap devices to cover various use cases: high-end and low-end devices.Proposal 2: Two UE types/categories for RedCap devices can be defined based on the UE features (e.g. Bandwidth, antenna number, etc.). Detailed reduced capability could be discussed and decided in WI. |

The number of RedCap UE type(s) has been discussed in the previous RAN2 meetings and the following principle has been agreed in RAN2#111e:

1. The number of device types should be minimised, to reduce market fragmentation, and introduced only where essential to control UE accesses and differentiate them from legacy R15/R16 and non-Redcap R17 UEs, (e.g. number of Tx/Rx antennas, maximum supportable BW, etc.). The exact composition of the set of L1 capabilities of the device type can be discussed by RAN1

The discussion here is not for down-selection but for elaborating pros/cons for both options, i.e. only one UE type v.s. multiple UE types.

**Question 3.** Companies are invited to provide comments on pros/cons to have only one v.s. multiple RedCap UE type(s).

|  |  |  |
| --- | --- | --- |
| ***Company name*** | ***Only one RedCap UE type*** | ***Multiple RedCap UE types*** |
|  | * Pros:
* Cons:
 | * Pros:
* Cons:
 |
| Apple | We prefer to not fragment. Anyway the capabilities would be exchanged to know the different “types” of RedCap, and for initial access, all RedCapUEs are required to support a min BW. We do not see the need to define more types. Also, RAN1 is also discussing this, and their input needs to be considered. |  |
| Qualcomm | For access, we think a single UE type is sufficient for network to enforce access restriction (ensure RedCap is used only for its intended use cases). Once UE is connected, network can learn different capability levels of RedCap UEs from capability signaling.Have a single UE type is simple, avoid market segmentation. Although a single UE type is defined, one can still potentially support an infinite number of feature permutations in the market, through NR’s capability framework.  | Defining multiple UE types means that 3GPP would have to take on the role of product management and identify specific product segments to determine where to draw the line between different UE types. In our view, that’s outside 3GPP’s scope. |
| Ericsson | We would like to note that “RedCap UE type” has not been defined yet so it is strange to discuss number of RedCap UE types before the definition is clarified.Pros: * No fragmentation of “types”
* Simpler specification-wise
* Re-uses existing functionality (e.g. capability signaling)
* Not going back to “UE categories” like in LTE.
 | Pros: * More fine-grained control from NW side potentially possible

Cons: * It is not straightforward to map use cases to “UE types”.
* Requires more changes to specifications.
* Results in more resource use (e.g. PRACH resources, Mgs3 bits)
* Effectively bringing back “UE categories” from LTE which were deliberately avoided in NR.

Agree with QC on the discussion going out of 3GPP scope.  |
| Huawei, HiSilicon | Pros:* Avoid market fragmentation.
* Only one type is enough for the network to control the access of RedCap UEs. Redcap UEs can still report different capabilities for different use cases.
* Simpler specification, e.g. easy early identification

Cons:No obvious cons is observed | Pros:No clear pros is observed.Cons: * Market fragmentation, which has been agreed to be avoided
* Early identification will be complex.
* Larger spec impact to define access restriction and identify capabilities/features supported for each type.
* Agree with QC and Ericsson that defining multiple device types are out of 3GPP scope.
 |
| MediaTek | Pros:* Avoids market fragmentation
* Simple specification
* Easy early identification

Cons:* No obvious issues identified
 | Pros:* No obvious advantages identified

Cons:* Market fragmentation
* Complex early identification
* Specification complexity

The criteria we have agreed on to define a device type are:* to control UE access
* to differentiate from legacy (eMBB) UEs.

We see no reason to justify defining more than one RedCap UE based on the criteria we’ve agreed upon. |
| Nokia, Nokia Shanghai Bell | Agree with above. |  |
| Futurewei  | Agree with above comments. | Agree with above comments. |
| Sierra Wireless | There may be many different sets of capabilities for RedCap devices. Reporting one type implies treating all as the least capable. More capability information should be reported by the UE before potentially barring all. | There may be value to having at least two types based on distinguishing the most limiting capabilities, e.g. 1Rx and 2Rx. Other capabilities still need to be reported. |
| vivo | Pros:* No obvious advantages identified

Cons:* it will be challenging to achieve the targets on data rate/power efficiency for different use cases, e.g. sensor/low-end wearable vs. video surveillances
* The capabilities set cannot be differentiated by use cases
* Vast of low end sensors will impacts on the performance of high end devices
 | Pros:* It is hard to define a common set of capabilities for different use cases.
* Good for NW to control/offload different types of RedCap UEs
* Good to meet the requirements for various use cases
* Optimize the tradeoff between the economics of scale and cost/power efficiency

Cons:* No obvious issues identified
 |
| Samsung | Just to give rapporteur a short answer, we prefer to have a single type to avoid market fragmentation. | - |

# Summary

TBD

# Conclusion

This offline discussion focused on L2 capabilities and UE types for REDCAP:

**TBD**

# Contact delegates

|  |  |  |
| --- | --- | --- |
| **Delegate** | **Company name** | **Email** |
| Linhai He | Qualcomm | linhaihe@qti.qualcomm.com |
| Tuomas Tirronen | Ericsson | tuomas.tirronen@ericsson.com |
| Baokun Shan | Huawei, HiSilicon | baokun.shan@huawei.com |
| Pradeep Jose | MediaTek | pradeep[dot]jose[at]mediatek[dot]com |
| Samuli Turtinen | Nokia, Nokia Shanghai Bell | samuli.turtinen@nokia-bell-labs.com |
| Steve Bennett | Sierra Wireless | sbennett@sierrawireless.com |
| Chenli | vivo | Chenli5g@vivo.com |
|  |  |  |
|  |  |  |
|  |  |  |