**3GPP TSG RAN2 #121 R2-23xxxxx**

**Athens, Greece, 27th Feb – 3rd Mar, 2023**

**Agenda Item:**  **XX.YY**

**Source: Huawei (email rapporteur)**

**Title:** **Report of [Post120][313][UAV] Interference Control for UAVs (Huawei)**

**Document for: Discussion and Decision**

# 1 Introduction

This is the report of the email discussion[Post120][313]:

* [Post120][313][UAV] Interference Control for UAVs (Huawei)

Scope: Discuss the following aspects:

- Number of triggering cells: Scenarios (e.g. inter-RAT), possible modification compared to LTE baseline (need, motivation, option, benefit/drawback). Applicability to FR1/FR2 and need for ignoring mechanism (e.g. one cell is particularly strong). Discuss need for alternative mechanisms (number of changed cell, prohibit timer etc.

- CellsTriggeredList: possible modification compared to the LTE baseline (Motivation, options, claimed benefits and possible drawbacks). E.g. numberOfTriggeringCellsForLeaving.

Output: set of agreeable proposals

Deadline: Long - Kick off: Jan 9th, Deadline for company inputs Jan, 20th. Inactive Period January 23 to 27. Comments on rapporteur summary Jan. 30th to February 3rd

All the relevant documents from previous RAN2 meetings have been taken into account, nevertheless for the sake of progress we should focus a bit, and not all the proposals submitted in the past are in the scope of this email discussion. So please do not “expand” the scope of this email discussion. Please remember to justify your answer with clear motivations, expected gains/drawback, etc. Where applicable, rather than copying a lot of explanatory text, you can reference your (or somebody else) paper if needed.

Companies are invited to put their comment in the file and change the file name in the folder according to the convention below:

File\_v00\_Rapp

File\_v01\_company1

File\_v02\_company2

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File location:

hyperlink

PS: As a reminder, I copy here the latest agreement relevant to this email discussion. The purpose of *numberOfTriggeringCells* mechanism is to limit the interference caused by too many (measurement) reports.

Agreement in RAN2#119bis:

1. As in LTE, as a baseline, events A3, A4 and A5 can be configured with the configured number of cells (numberofTriggeringCells)

Companies providing input to this email discussion are invited to leave contact information below.

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# 2 Discussion

## 2.1 Applicability to the inter-RAT scenario

RAN2 should decide if the Number of triggering cells mechanism should be extended to apply to the inter-RAT scenario, i.e. event B1 and B2 triggering. How likely is that the UE will move at the border between LTE and NR? And what should we do in that case? If the Number of triggering cells mechanism is used, would this affect negatively the mobility, in particular the inter-RAT HO?

**Q1: Do you think that the Number of triggering cells mechanism should be extended to apply to the inter-RAT scenario, i.e. event B1 and B2 triggering?**

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| **Company** | **Short answer** | **Comments** |
| Huawei, HiSilicon | No | The inter-RAT scenario should not occur too frequently compared to the intra-RAT, but more importantly if we extend the *numberofTriggeringCells* mechanism to the inter-RAT scenario we see a risk for HO failure at the cross between the two different RAT, given by the UE withholding its measurement report in some cases.  |
| Ericsson | Yesyes | But we would like to clarify that the RSRP report triggering based on number of cells is not for mobility but for interference/flying mode detection.When triggering is based on N cells, all Ncells need to trigger before the measurement report is sent. Hence, the report is way delayed for mobility purposes! Actually, for mobility, short TTT is beneficial when UE is flying as the cell coverage gets scattered on higher altitudes.That, said, in our view taking into account LTE and NR cells in detecting interference and/or flying mode is important. |
| Qualcomm | No strong view |  |
| LGE | No strong view |  |
| NEC | No | Agree with Huawei. |
| Nokia, Nokia Shanghai Bell | No | The purpose of multi-cell triggering for events B1 and B2 needs to be explored, but only in the context of interference control. As multi-cell triggering was designed to help with interference detection, the topic of inter-RAT mobility should be discussed separately, if necessary. It isn’t clear whether there would be inter-RAT interference, as this would only be the case if the LTE and NR cells were on the same frequency. Additionally, DSS cells would be double counted in this scenario. |
| CATT | No strong view | If majority company support this function, we are fine. |
| Xiaomi | No strong view |  |
| vivo | No | Agree with HW and Nokia that inter-RAT interference may not occur frequently.  |
| Sharp | Yes | Inter-RAT interference is real case and extension of number of triggering cell to event B1 and B2 is simple. |
| Intel | No | Agree that it may impact HO performance. |
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## 2.2 Applicability to FR1/FR2

RAN2 should decide if the applicability of Number of triggering cells mechanism should be restricted to FR1 only.

**Q2: Do you think that the applicability of Number of triggering cells mechanism should be restricted to FR1 only? Why yes/why not?**

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| **Company** | **Short answer** | **Comments** |
| Huawei, HiSilicon | No | We do not see a reason why the *numberofTriggeringCells* mechanism should be restricted in FR1. Ultimately this is could be left to network configuration. |
| Ericsson | No | It would be important UE considers all cell in vicinity to trigger based on N cells. |
| Qualcomm | No | If we end up defining the mechanisms, we do not see a need to restrict it to FR1 only. It is up to the network to decide and configure accordingly. |
| LGE | No | We think there is no reason to restrict the mechanism by frequency range. The network can configure an appropriate *numberofTriggeringCells* according to the frequency range.  |
| NEC | No | It could be left to network configuration. On the other hand, any optimization for FR2 is not necessary, either. |
| Nokia, Nokia Shanghai Bell | No | Number of triggering cells should be an option in FR2, but it could be considered in combination with number of triggering beams. |
| CATT | No | This can be left to gNB configuration and there is no clear point to limit to FR1 only from our perspective. |
| Xiaomi | No | There is no reason to introduce the restriction. It is up to network configuration whether to configure *numberofTriggeringCells* for different frequency range. |
| vivo | No | We don’t see the need to have such restriction.  |
| Sharp | No | No reason to restrict. |
| Intel | No | No reason to add such restriction. |
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## 2.3 Need for ignoring or bypassing the Number of triggering cells mechanism

RAN2 should decide if there is a need for ignoring or bypassing the Number of triggering cells mechanism, once configured (e.g. for the case of strong DL interference from some neighbour cells, or the UE altitude is too high/not too high, or…).

**Q3: Do you think that the there is a need for the UE to ignore or bypass the Number of triggering cells mechanism, once configured, in some cases? If yes, in which cases and why?**

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| **Company** | **Short answer** | **Comments** |
| Huawei, HiSilicon | Yes | As we all know, introducing the number of triggering cells mechanism can result in late handover. Thus, in some scenarios we need to skip the number of triggering cells mechanism to ensure the network obtains the measurement report in time. For example, if the number of cells in the cellsTriggeredList is smaller than the *numberofTriggeringCells* when the UAV detects the DL interference of a certain cell as being very strong (i.e. signal level above a threshold), the UAV should send the measurement report to the network immediately, to ensure the network takes the appropriate actions on time. |
| Ericsson | No | Regular events need to be configured for the UE in addition to N of triggering cells for mobility support. This was the understanding already in LTE. (For the regular event, one can consider further enhancements mobility support) |
| Qualcomm | No | UE follows what network configures (including any new mechanism that may be introduced in R18). If there is desire and consensus for the UE to behave in a certain way, e.g. for the case of strong DL interference from some neighbour cells, then there should be corresponding procedure and configuration for that case, and UE again follows the configuration as specified (this is not same as UE ignoring or bypassing autonomously the configuration of number of triggering cells mechanism). |
| LGE | Yes  | If the DL interference by a few neighbor cell is too strong, UE may face problems before sending measurement reports such as decoding failure due to interference. Therefore, in the case of strong DL interference from neighbor cells, UE should be able to report strong DL interference even when the number of neighbour cells does not satisfy the *numberOfTriggeringCells*. |
| NEC | YES | Under sort of a circumstance that a strong cell enters, for example:- Before the number of cells in *cellsTriggeredList* is equal to or larger than *numberOfTriggeringCells*, if a new triggering cell quality is better than other cells included in the *cellsTriggeredList*,- After the number of cells in *cellsTriggeredList* is equal to or larger than *numberOfTriggeringCells*, if a new triggering cell quality is better than other cells included in the *cellsTriggeredList*,number of triggering cells mechanism could be ignored to avoid late measurement reporting. |
| Nokia, Nokia Shanghai Bell | Maybe | UE altitude could be used as a way to select between more than 1 number of triggering cells configuration since UEs at a high altitude will be in view of more cells than UEs at a low altitude. Whether the altitude dependency should only apply to the number of triggering cells or to an entire set of configurations, including the altitude trigger and one of A3, A4, or A5 is to be determined.In our paper R2-2212268 we showed that by “setting A4 threshold based on average LOS conditions for altitudes below 40m, it is possible to keep the number of triggering roughly in the same range as for altitudes above 40m. This as an alternative to a bypass would provide two options that can account for the conditions at different altitudes.  |
| CATT | No | The necessity to introduce this function is still unclear to us.  |
| Xiaomi | No | Agree with Qualcomm.For some case with strong DL interference or the UE altitude is too high, NW can configure measurement report without the Number of triggering cells. |
| vivo | No | If the network wants to know whether there are strong DL interference cells timely, the network can configure Ax events (e.g, A4 event with high quality threshold) in addition to N of triggering cells. So, we don’t see the need to introduce this mechanism.  |
| Sharp | No | Seems appropriate existing network configuration can solve the issue. |
| Intel | No | UE should follow NW configuration. If such bypass should happen, network should simply not configure it. |
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## 2.4 Need for introducing an alternative mechanism to the Number of triggering cells one.

RAN2 should discuss if there is a need for an alternative mechanism to the Number of triggering cells one (need, motivation, options, benefit/drawback). In particular it has been mentioned as alternative a mechanism based on

“Number of changed cells”.

**Q4: Do you see the need for an alternative mechanism to the Number of triggering cells one? In particular what is your opinion on a mechanism based on “Number of changed cells”?**

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| **Company** | **Short answer** | **Comments** |
| Huawei, HiSilicon | No | For the entry condition, we think the number of changed cells is almost equivalent to the *numberofTriggeringCells*. RAN2 has been agreed to introduce the *numberofTriggeringCells* for LTE in the past and now that’s the baseline for NR*.* As a result, there is no reason to introduce the number of changed cells.For the leaving condition, using number of changed cells may cause the wrong HO. Assume the number of changed cells is two, and cells A, B, and C are in the cellsTriggeredList and has been reported to the network. When cell A leaves the list, the UE will not send measurement report, and if the network hands over the drone to cell A at this moment, this will result in handover failure. |
| Ericsson | No | Alternative mechanism for what use? For interference detection we have this and it seems enough. For flying mode detection we have this and H events. For mobility, we have the other email discussion to consider what is needed for that. |
| Qualcomm | No | RAN2 agreed to number of triggering cells mechanism after studying and analysing various simulation results for LTE in Rel-15 and recently agreed to re-use it for NR. We do not see need and motivation to introduce alternative mechanism based on number of changed cells. |
| LGE | Yes | In LTE, the UE cannot send another measurement for that measurement ID if the number of cells satisfies the number of triggering cells. We can discuss how to continuously and efficiently notify interference after the first measurement report. From this perspective, an alternative mechanism can be useful. Report restriction always has a trade-off relationship with handover failure. When the “number of change list” is applied to only one entry or leaving condition, the network can set an appropriate value according to the frequency characteristics or the situation the UE is in. Even, without limiting entry/leaving condition, if changes are counted by considering all added or removed cells from a list in the previous report, the environment the UE is in may be well reflected. |
| NEC | No | We do not see the need of the“Number of changed cells” mechanism as we already agreed to have “Number of triggering cells”.  |
| Nokia, Nokia Shanghai Bell | Yes | We support number of changed triggering cells. In our paper R2-2210356, it was shown that numberOfChangedTriggeringCells generates 50% fewer reports compared to the LTE multi-cell triggering mechanism, and with similar performance. Additionally, numberOfChangedTriggeringCells only requires one parameter compared to two in other methods. |
| CATT | No | For the current NR UAV first version, it is too premature to find an alternative mechanism right now (we treat it as one optimization with low priority). |
| Xiaomi | Yes | In LTE UAV, if *numberOfTriggeringCells* is configured, when the number of cell(s) in the *cellsTriggeredList* is larger than or equal to *numberOfTriggeringCells* for the first time, UE shall initiate the measurement reporting procedure. However, measurement reporting will not be triggered when the number of cells always satisfies the number of triggering cells. UE cannot report the latest interference to NW. The mechanism based on “Number of changed cells” can solve the issue without excessive measurement reports. When the number of cells added in *cellsTriggeredList* after the last measurement report is larger than or equal to *numberOfChangedCells*, UE can initiate the measurement reporting procedure.*“numberOfChangedCells”* and “*numberOfTriggeringCells”* can be configured simultaneously. And *numberOfTriggeringCells* can be configured for the first report and “*numberOfChangedCells”* can be used to trigger subsequent measurement report. |
| vivo | Yes | Firstly, we think “The number of changed cells” can be combined with “the number of triggering cells”, so “The number of changed cells” is not an alternative mechanism. From our understanding, introducing “The number of changed cells” can solve the below two issues. * **Issue 1:** When the number of triggering cells is equal to *numberofTriggeringCells*, the UE triggers measurement reporting. After that, the UE cannot trigger measurement reporting when new cells are added into *cellsTriggeredList* if periodic reporting is not configured. The network cannot obtain new cells timely to perform interference management and mobility management for the UAV, which may lead to RLF or HOF of the UAV.
* **Issue 2:** When *reportOnLeave* is set to true for the event (A3 or A4 or A5), the UE will trigger measurement report if each of the cells in *cellsTriggeredList* fulfills the leaving condition of the event. This is also not consistent with the motivation of introducing *numberofTriggeringCells*.

The common part of two issues is the number of changed cells compared to the cells included in the *cellsTriggeredList.* So, it seems straightforward to introduce a new parameter *numberofChangedCells* to trigger RRM report.  |
| Sharp | No | Enhancements to reduce measurement reports can be discussed based on the current “Number of triggering cells”. |
| Intel | No | We prefer using LTE as a baseline. If there is other enhancement, we can discuss separately. |
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## 2.5 Need for introducing a prohibit timer.

RAN2 should discuss if there is a need for a prohibit timer mechanism. What would be the motivation, the expected gains and drawbacks. Should this be introduced in coexistence or as an alternative to the baseline CellsTriggered mechanism?

**Q5: Do you see the need for introducing a prohibit timer mechanism?**

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| **Company** | **Short answer** | **Comments** |
| Huawei, HiSilicon | Yes | We believe that the cellsTriggered mechanism and the prohibit timer can coexist. Using the prohibit timer mechanism in combination with the cell Triggered mechanism can reduce the measurement reports even further.For example, if the prohibit timer expires but the number of cells is less than the *numberOfTriggeringCells*, the UAV will continue to refrain from sending reports*.* Otherwise, it will send the reports. Also the other way around works, i.e. the UE can follow the most restrictive conditions of the two.  |
| Ericsson | Yes | This is proposed for regular mobility events originally!This method can control the amount of measurement reporting, also at the same time it enables timely reporting when the event is triggered first time.Preventing certain measurement results may result in a worry on decreasing mobility performance, but we have results in R2-1807257 to prove that it is not a problem. |
| Qualcomm | No | If there are too many measurement reports triggered due to certain network configuration, the correct approach is to adjust the configuration by the network instead of ‘*prohibit*’ing the reports by yet another new configuration (which are legitimately triggered by the network configuration). Prohibiting the reports also does not solve the issue of UE having to perform the measurements in the first place.  |
| LGE | No | We think the prohibit timer is not suitable for reporting interference. Even the configured timer may not be suitable depending on the speed of the UE. |
| Ericsson2 |  | To QC: for mobility events, as same event is going to be triggered by new cell consecutively as UE starts to fly, it is difficult to impact that by RRC reconfiguring as that is slow. The prohibit timer would indeed be the way to impact the configuration to not trigger this way. We would be happy to elaborate better the proposal e.g. in Athens.  |
| NEC | No | At least for cell entering case, we think “prohibiting” the report by a timer is not as reasonable as the *numberOfTriggeringCells* mechanism and we do not know how the network should determine the length of the timer. |
| Nokia, Nokia Shanghai Bell | No | When properly tuned, the number of changed triggering cells mechanism that has been suggested should provide a sufficient time between reports such that a prohibit timer would not be necessary. As stated in Q4, our paper showed that a prohibit timer was not needed to reduce the number of reports by 50%. |
| CATT | No | If the numberOfTriggeringCells can not be used correctly to control the amount of measurement reporting, just wondering the necessity to further introduce the prohibit timer mechanism. We think with the proposed proposal, the cost is to introduce more limitation and complexity to gNB. |
| Xiaomi | No | The CellsTriggered mechanism is enough to reduce the measurement report. The prohibit timer mechanism is not needed. |
| vivo | No | Prohibit timer is not flexible, which may lead to untimely RRM report and handover failure.  |
| Sharp | No | Number of triggering cells is enough, and prohibit timer may delay measurement reports further. |
| Intel | May be | We see benefit on prohibit timer. However, the downside of prohibit timer is missing measurement report and hence delay HO resulting RLF. Therefore, adding timer stop condition in such cases will avoid that and make prohibit timer useful. |
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## 2.6 reportOnLeave.

RAN2 should discuss the reportOnLeave mechanism.

Is the LTE baseline suitable/sufficient? If not, which of the following enhancements will make sense to introduce and why? Indicate possible gains and drawbacks in your view. In particular your opinion is welcome on the following:

1. Introduce a numberOfTriggeringCellsForLeaving
2. The UE should not report a cell leaving if that cell was not reported joining previously.
3. Measurement report when the number of cells in *cellsTriggeredList* becomes smaller than a threshold

**Q6: Do you see the need to enhance the reportOnLeave mechanism? Please comment on the possible enhancements listed above.**

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| **Company** | **Short answer** | **Comments** |
| Huawei, HiSilicon | b | Solutions a) and c) may cause the wrong HO, like the number of changed cells. See for example our comments in the papers that we submitted in Q4 for more details.For solution b), we think this mechanism should work (i.e. be introduced) only when the number of cells in the CellsTriggereddList is greater than *numberOfTriggeringCells.* When the number of cells is smaller than *numberOfTriggeringCells* should follow the current mechanism, i.e., the UAV sends a report to the network when a cell leaves. In this way we do not see any technical drawbacks and some useless measurement reports can be avoided. |
| Ericsson | See comment | If numberOfTriggeringCellsForLeaving means a measurement report is triggered when the number of cells in the list goes below this value it seems ok to consider. |
| Qualcomm | b + c | Motivation for a) is not convincing enough to justify the additional complexity/work to introduce the new procedures. |
| LGE | a | For option b, if the leaving condition is applied only to the cells included in the previous measurement reports, it is difficult to notify the interference continuously. The leaving condition can be a complement to sending measurement reports when measurement reports cannot be sent due to the number of triggering cells condition. Therefore, to inform the interference continuously, the UE must be able to report the interference regardless of whether the cell has been previously reported. For option c, we think, even if there are more cells than a certain threshold, a report is required if large interference is measured or there is a large change in the list.Therefore, we think ‘option a’ seems to be reasonable to report the interference continuously while preventing an excessive report. |
| NEC | Slightly prefer b |  |
| Nokia, Nokia Shanghai Bell | a | If the number of changed triggering cells mechanism, which we prefer, from Q4 is adopted, the report on leave mechanism would be redundant since the list of triggering cells can change by having cells leave condition, which would trigger a report.a) Based on our simulations, out of the three choices, this option produced the best accuracy (percentage of cells report which receive UAV interference of at least 3dB above noise) while reducing the number of reports compared to LTE.b, c) These options produced fewer reports compared to LTE, but with a lower accuracy than both numberOfChangedTriggeringCells and option a. |
| CATT | b | We reckon that the reportOnLeave mechanism introduced in LTE is not appropriate, hence the first step for NR UAV is to fix this issue firstly.  |
| Xiaomi | b | Solution b) can update the interference and measurement results in time, thus avoiding the wrong HO. |
| vivo | See comments | See our comments in Q4, we prefer to introduce the number of changed cells. |
| Sharp | b | This option is based on existing method and is simpler. |
| Intel | b |  |
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## 2.7 Use of “beams” vs “cells” for interference control.

RAN2 should discuss the possible use of “beams” vs “cells” for interference control. Will this increase the number of reports, and therefore the interference, or rather the opposite? How would that work? What are the possible gains and drawbacks?

**Q7: Do you see the need to use of “beams” instead of “cells” for interference control?**

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| **Company** | **Short answer** | **Comments** |
| Huawei, HiSilicon | No | In NR, the measurement report is still based on the measurement result at the cell level, even for the beamforming cell. Thus, using beams for interference control cannot improve the performance of interference control. We see that this could cause additional work in RAN2 for no real benefit. |
| Ericsson | No | It’s a bit unclear what is meant by “interference control”. In general, in NR the measurements are done at beam level and the measurements can be used to calculate a cell-level quantities. In our view, using cell-level RSRP is appropriate for the event of numberOfTriggeringCells.  |
| Qualcomm | See comments | The question is a bit confusing. The beam level measurements can be used to calculate cell-level quantities, and such cell-level value is appropriate for the evaluation of event trigger conditions for numberOfTriggeringCells. However, if beam level reporting is considered, then separate trigger condition e.g. numberOfTriggeringBeams would be needed. Note that we showed previously that naturally there will be more measurements when there is more than one beam per cell (compared to one beam per cell). So, if report trigger mechanisms depend on number of ‘beams’, for example, instead of number of ‘cells’, there will be more reports triggered. We observed that measuring only a subset of beams based on height can save on number of measurements without significant performance degradation. Consequently, we propose that to reduce the number of beam measurements (and measurement reporting), RAN2 should introduce height threshold for measurement of a subset of beams. See R2-2211305 [1] for details. |
| LGE | No | We can consider two scenarios:Scenario 1. A Cell quality does not satisfy the report condition, but some beams exceed the threshold of the report condition.Scenario 2. A Cell quality satisfies the report condition, but some beams are weak.In the case of scenario 1, if the target cell is a neighbor cell, the UE will not perform a handover to the corresponding cell. Even if one or two beams are good, if the cell quality is not satisfied, it cannot be considered a good cell. So, the UE does not need to send a measurement report for mobility. If the target cell is a serving cell, the purpose of the measurement report may be beam control. However, the beam can be controlled by the existing procedure such as CSI-RS report. So, the UE does not need to send a measurement report for beam control. In the case of scenario 2, if the cell quality satisfies the report condition, it means that there are beams that satisfy the threshold and can be considered as a good cell. Thus, the weak beams should not affect the measurement report. If the cell quality based on beams (whose beam quantity is higher than absThreshSS-BlocksConsolidation or absThreshCSI-RS-Consolidation) satisfies the report condition, the UE should send the measurement report for mobility.  |
| NEC | No | In NR, the triggering of the measurement report is still based on cell-level measurements, so in our view this “beam-level interference control” requires at least beam-level triggering of the measurement report, which may bring much higher burden for RAN2 works. |
| Nokia, Nokia Shanghai Bell | See Comments | Beams could be reported when a multi-cell report is triggered. Or the cell and beam level measurements could be used in combination. We do not support triggering on beams only. |
| CATT | No | We share the same view as Huawei. |
| Xiaomi | No | Because cell-level measurement results are calculated based on beam-level measurement results, the signal strength of beam can indirectly affect the measurement results of cell-level. Hence, using cell-level measurement results is enough for NR UAV and using beam-level measurement results for interference control is not needed. |
| vivo | No | Agree with Huawei.  |
| Sharp | No | Agree with Huawei. |
| Intel | No | We don’t see the benefit using beam instead of cell. Beams can be reported to the NW but for triggering condition, it is still unclear to us how it is benefit.  |
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# 3 Conclusions and Proposals

[To be added later by the rapporteur]

# 4 References

[you can add if needed]

[1] R2-2211305, Measurement and reporting enhancements, Qualcomm Incorporated, RAN2#120, Toulouse, France, Nov 14-18, 2022