3GPP TSG-RAN WG2 Meeting #121 R2-23xxxxx

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

**Agenda item: 8.8.2**

**Source: Nokia, Nokia Shanghai Bell**

**Title: Report from [Post120][312][UAV] Mobility Control for UAVs (Nokia)**

**WID/SID: NR\_UAV-Core – Rel-18**

**Document for: Discussion and Decision**

# 1 Introduction

This is to discuss the following:

* [Post120][312][UAV] Mobility Control for UAVs (Nokia)

Scope: Discuss aspects related to mobility control, including:

- Height dependent parameter/configuration adjustment or scaling (e.g. TTT, A4 threshold etc). Discuss which parameters/configuration, options, motivation, benefits/drawbacks.

- Event combination – discuss possible event combinations (e.g. height based event and signal strength events) and motivation/benefits

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

In the next section we elaborate on the open issues for Rel-18 UAV mobility control.

# 2 Discussion

## 2.1 Height-dependent Events

Here we consider how to make use of the height/altitude which is estimated by the UAV UE and in the basic approach – used to decide if LTE-like events H1 or H2 shall be triggered. In LTE Rel-15, when the triggering condition for H1 or H2 was met, the UE was supposed to send the measurement report which could contain the RSRP/RSRQ measurements as well as the UE’s location-related information (*LocationInfo* IE) and the height information. It would be good to confirm what is to be reported in NR when event H1 or H2 is triggered.

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| **Question 1: In NR Rel-18 when event H1 or event H2 is triggered, what shall be the content of the measurement report? Please choose from the following options:**   1. **Only the parameters from *CommonLocationInfo* IE** 2. **Only the RSRP/RSRQ/SINR measurement results** 3. **The content of the report fully configurable by the network (e.g. RSRP results + *CommonLocationInfo* components)** 4. **Other** | | |
| **Company** | **Answer** | **Comments** |
| Huawei, HiSilicon | c | We think the content of the Measurement Report should include the full report so the network can obtain more information to decide on, e.g., handover. This is the same as in LTE. In principle in NR we should do something different from LTE only if there is a good reason to do so. |
| Ericsson | d | The main goal of the H1/H2 measurements is for flying mode / interference detection. As such, the height information is of the highest interest to NW. Therefore, in our view, the height information must always be in the content of H1/H2 triggered measurement report. Whether to include ***CommonLocationInfo*** and/or**RSRP/RSRQ/SINR** should be configurable by the network. The configurability is important for interference control as it controls the size of the report. We are also fine if height is also optional but in our view it should be separate from the rest. |
| Nokia | c | We believe there is no need to restrict the content of the report to only location-related, height or RSRP/RSRQ. When H1/H2 triggers, the NW will have a rough understanding of the height at which the UAV UE is, so *heightUE* reporting is not essential, although we agree with Ericsson – this kind of information needs to be primarily known to the NW. However, there might be also other cases - where the NW is interested in obtaining UE’s location and/or RSRP/RSRQ/SINR measurement results, but that shall stay flexible. Thus, we prefer c). |
| Qualcomm | c/d | The question seems unclear. In our understanding, the main question is whether CommonLocationInfo alone without any RSRP/RSRQ/SINR measurement can be included. We think that should be possible.  It is unclear whether option c here includes that possibility. E.g., if the ‘+’ inside e.g. was changed to ‘and/or’, it would be clearer. |
| Vodafone | c | I think CommonLocationInfo has always to be configurable, also due to the “user consent” discussion, but I do not see any reasons not to include RSRP/RSRQ/SINR and Height into the measurement report. |
| LGE | c | We think that ‘option c’ is aligned with LTE and additional discussion will be necessary when other information is needed. The UE can optionally provide measurement results and location information. |
| NEC | c/d | We prefer to have configurable *CommonLocationInfo and heightUE* to allow flexibility for the network. |
| CATT | c | We share the same understanding that more information in measurement report is beneficial to the network to make suitable decision. And option C provides flexibility to the network decision. |
| Xiaomi | c/d | We think location information, measurement results and height can be included in the content of the measurement report.  In LTE, if the *triggerType* is set to *event* and *eventId* is set to *eventH1* or *eventH2*, UE shall set the *heightUE* to include the altitude of the UE in measurement report. Height information is always needed for measurement report triggered by event H1 and event H2. And, reporting of measurement results and/or location information are configurable by the network in the corresponding *reportConfig*.  For measurement report triggered by event H1/event H2 in R18 UAV, legacy LTE principle and procedure should be considered. Separate height reporting should be supported as in LTE. And reporting of location and/or RSRP/RSRQ/SINR can be configurable by the network via *reportConfig*. |
| vivo | c | We think height, location and RSRP can be optional. The network can configure the UE to report only those information interested in the network, to reduce the size of the report. |
| Sharp | c | We think ‘option c’ means NW can configure UE to report location information and/or RSRP results when event H1/H2 is triggered, and if both of them are not configured UE only reports height information. |
| Intel | c/d | We think that measurement result, height and location can be reported when network configured. In addition, if flight path change is available, it can also be indicated. |
| Samsung | c | We have similar views as other companies on option c. Hwoever, it would be good to discuss/clarify what contents of *CommonLocation* IE can be included into the measurement report i.e. whether all fields defined in this IE can be included for UAV UE. |
| Apple | d | Regarding how LTE framework works, seems the agreement in RAN2#101 was “UE location information are included in the measurement report for Aerial UE based on the existing location information IE and reporting mechanism.”.  Thus, our understanding is when event H1 or event H2 is triggered, UE only reports height info. But network is free to configure “*includeCommonLocationInfo*”, upon which UE reports *CommonLocationInfo.*  For RSRP, it is possible to carry as legacy. |
| DENSO | c | We think what (and how) information is used in the network is fully depending on the network implementation. Thus we think option c is optimal to reduce data size. |
| ZTE | c | We think the height information should be mandatory included in the measurement report triggered by height events, similar to LTE. Besides, the RSRP/RSRQ/SINR measurement results or/and location information could also be useful for the NW. So whether to include them in the measurement report could be flexibly configured by the NW. |
| AT&T | C | We don’t believe that the standard should impose restrictions on the UE reports. The network should be able to configure the needed report contents based on use case. |
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Staying still in the topic of H1/H2 events, it shall be discussed if those events can be combined/configured with Ax events (e.g. A3, A4 or A5 events) and the measurement reporting is triggered only if both events are fulfilled simultaneously. Such approach was suggested e.g. in [1] to handle vertical mobility. It would be also a similar principle as was defined for Rel-17 NTN (i.e. time or location based triggering).

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| **Question 2: Do you support combining event H1 or H2 with event Ax to ensure the measurement reporting is triggered only if both events are fulfilled simultaneously? Please note, this does not remove the support for ‘standalone’ use of H1 or H2.** | | |
| **Company** | **Answer** | **Comments** |
| Huawei, HiSilicon | Yes | We think the combination of Hx and Ax can handle the vertical mobility well. Having only the Ax event makes it harder for the network to ensure the handover of the UAV UE to the target cell timely and correctly. For example, because the signal quality may decrease dramatically at the edge of the serving cell in a vertical direction (the distance between the drone and the gNB may not change or change a little when the drone moves vertically), it is hard to handover the drone to the neighboring cell in time just according to the Ax event because the signal quality is strong before the drone crosses the cell’s edge. However, if the drone considers the combination of the Ax and Hx, it can handover to the neighboring cell timely, according to the height and the quality of the cell. More details can be found in R2-2212638. |
| Ericsson | yes | In case there is consensus for the use case on combining Hn and An events, then also Hn and inter-RAT Bn events should be supported.  We could discuss also other combinations and see which ones have good use cases. For example, combining location and height might be useful for network to know if UE is approaching a no-fly zone. Or, per network implementation an area where drone UL interference causes issues for BS. In that case network can at least refrain from scheduling UL for the UE.  Finally, how the triggering is combined should be discussed. Should the condition combination H and A/B be both fulfilled during TTT, or should UE evaluate the events independently and triggering is similar to NTN CHO. |
| Nokia | Yes | We think such combination could be defined as the NW could expect the UE to send the reports just at certain heights or make the UE not to send the reports at certain other heights. Scenarios described by Huawei are also valid to consider. Of course, this does not exclude the option of having standalone H1 and H2 events, where just the height above the reference level is considered in report triggering.  Agree with Ericsson that we should discuss how this combining is done. However, we wanted to first agree in RAN2 that we pursue this kind of combination of events as a part of this WI.  We are not sure if combining other events, e.g. location and height is needed as addressing the no-fly zones may not be in the scope of the WI. |
| Qualcomm | Yes | This should be made possible (in addition to standalone H1/H2) |
| Vodafone | Yes | We also like to idea to combine the triggering evens and we also like to highlight we agree with E///, that Inter-RAT Bn events need to be considered once the design is made. |
| LGE | Yes | We agree with Ericsson that we need to discuss how the triggering is combined. |
| NEC | See in comment | We wonder how this combining is done. Maybe the question should be whether to associate triggering of event Ax with height event H1/H2. |
| CATT | See comments | We are not against the proposal. Just wondering if the combination of Hx and Ax is accepted, the relationship between the standalone H1/H2 and combination should be further discussed. For example, if both standalone and combination are all configured by the gNB, then the gNB will receive two sets of measurement report in parallel, how to handle/distinguish is one question to gNB. |
| Xiaomi | Yes | We think the combination of event H1/H2 and event Ax for measurement reporting can be considered. Height-depending combination can reduce measurement reporting and increase the flexibility of measurement configuration. How to trigger measurement report based on the combination of multiple events can be discussed. |
| vivo | See comments | If this is for vertical mobility, we think H1/2 event triggered RRM report is sufficient. If the intention is to avoid triggering RRM report from signalling overhead perspective, then we don’t see the need. If H1 combined with Ax is configured, whether Ax event can also be separately configured? If Ax event is configured, then the UE may trigger measurement report twice. If Ax event is not configured, the NW may not be able to get the horizontal mobility of the UAV |
| Sharp | Yes | The details of combination need to be further discussed. |
| Intel | See comments | We see benefit of combining the event rather than height depending configuration within the Ax event. |
| Samsung | Yes | We are fine with combining multiple events, but this should be done based on currently defined events i.e. we should not pursue introducing additional new events for this. |
| Apple | See comments | In NTN CHO, network does always configure condEventD1 and condEventAx together for conditional handover. But for normal measurement reporting, the EventD1 and EventAx are independent, meaning UE does not need to wait for both events to be met. I thought CHO case is not what we are discussing here?  For UAV, we are wondering for normal HO, what can not be handled if UE follows legacy behaviour and report height and Ax triggered results at different time instances. As long as UE does not report “leave” for first event, network would know the two events are met when receiving the second event triggered report. |
| DENSO | Yes | We agree with Ericsson. We see benefit of combining the events, but details need to be discussed. |
| ZTE | Yes | We see some benefits to combine H events with A/B events, e.g. to help handle the vertical mobility well. Besides, considering that the measurement report triggered by height events may also include the RSRP/RSRQ/SINR measurement results or/and location information (as discussed in Q1), we think the standalone H events with multiple height thresholds could also be considered, to decide the vertical mobility. E.g., the NW can combine RSRP/RSRQ/SINR measurement results (may also include neighbour cell results, if reportAddNeighMeas is configured) and height information by itself to decide whether the vertical mobility is to be required in the concerned height range. |
| AT&T | Yes | We don’t see a reason to exclude any combinations. |
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## 2.2 Height-dependent Adjustments

As the UAV UE can fly high above the ground level (up to 300 meters was supported in LTE Rel-15) it can experience largely varying radio conditions. This effect is especially pronounced when the UAV UE is ascending in NLOS conditions, below the rooftops. When the UAV UE flies higher, above the rooftops (in LOS conditions), it can monitor secondary lobes of distant base station’s antennas [2]. This can result in the UE attempting to HO not to the closest available cell. These circumstances have been used in several RAN2 papers to propose height-dependent actions to be taken for UAV UEs. Those include for example: parameter (e.g. TTT) scaling or using different configuration sets, depending on the altitude. Below we would like to ask the companies to express their support for such adaptations and provide additional information how these could be used and implemented.

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| **Question 3: Do you support allowing the UAV UE to perform height-dependent parameter scaling? If yes, please provide the details on which parameters can be scaled and in what kind of scenarios.** | | |
| **Company** | **Answer** | **Comments** |
| Huawei, HiSilicon | Maybe | We think a height-dependent TTT autonomous scaling by the UAV UE could be considered for NR UAVs. Speed-dependent TTT has been specified in LTE. When the speed of UE changes, the TTT will be scaled accordingly to adjust the reporting delay. Similarly, when the UAV UE moves vertically, the drone could adjust the TTT to ensure that it sends Measurement Reports on time, as the communication environment can change dramatically in the vertical direction. If we follow the legacy mechanism, i.e., reconfiguring the TTT when the aerial UE exceeds a certain height, the configured TTT may not be suitable due to the communication delay and the drone’s high mobility. If the TTT is running at the time UE is crossing a threshold that would trigger scaling, it could anyway conclude the ongoing operation and use the different TTT the next time a condition is triggered. Nevertheless, rather than autonomous scaling by the UE (based on some pre-configuration from the network of a scaling factor or similar), it could be more straightforward to use multiple configuration as in the following question, so we prefer the solution mentioned in Q4 instead. |
| Ericsson | yes | In our view, TTT can be scaled with height. This could be simpler option than Q4 |
| Nokia | No/not necessary | If scaling is understood as multiplying the parameter’s value by factor proportional to/directly dependent on the instantaneous height value then we do not see such need.  The existence of speed-dependent TTT scaling (in LTE) does not mean that height-dependent TTT (or other parameter) scaling for UAVs is automatically justified.  Please note that in the results shown in multiple papers (including Nokia’s TDocs) it is visible the is no consistent trend (e.g. in terms of received signal level versus height) with increasing/decreasing height. Instead, there is a big change of conditions when the UAV crosses the border between NLOS and LOS conditions (usually associated with below/above rooftops). Thus, continuous scaling, depending on the height, may lead to erroneous decisions. |
| Qualcomm | No | ‘Scaling’ of parameters based on height can have multiple issues without clear gain, as explained by Nokia. |
| Vodafone | Rather no | The TTT scaling depended on the height seems interesting, but I agree with Nokia explanation, so it would be good to have more discussions about the need or leave it for now. |
| LGE | Yes | We think the Height-dependent solution is beneficial to adjust the suitable parameter for the height timely. In terms of scaling, as speed dependent TTT scaling, we think TTT is applicable for height dependent scaling. |
| NEC | No | We share the same view with Nokia. |
| CATT | No | Actually, we think the height-dependent TTT has no obvious benefits on handover decision. The trend for signal strength does not show its consistency. Hence, it is difficult to make suitable handover decision. |
| Xiaomi | No | According to Nokia’s explanation, the gain of height-dependent parameter scaling is unclear. And height reporting has been supported, so network can configure appropriate measurement configurations based on UE’s height. Height-depending scaling is not needed. |
| vivo | No | In LTE, the number of triggering cells was introduced, and the motivation is to avoid frequent measurement reporting, but short TTT seems against with this motivation. In our view, reducing the signaling overhead of measurement reporting and pursing timely measurement reporting are contradictory, and the compromise can be left to network, that is, the network can configure proper TTT based on network strategy. So, we don’t prefer to scale the TTT parameter by UE itself. |
| Sharp | No | Based on Nokia’s explanation, the gain of automatic parameter scaling is unclear so far. |
| Intel | No | We don’t see the need or benefit from height scaling on parameter such as TTT. It seems to us that it is independent to height. |
| Samsung | No | We think that network can simply configure shorter TTT or lower altitude threshold if it wants to make aerial UE to send the measurement report faster. Also, if network cares about higher HOF or RLF ratios, network can configure multiple instances of the same configured event with different configurations. Having said that, we think it can be left to network implementation and there seems to be no need to introduce any kind of height-dependent scaling mechanism. |
| Apple | See comments | We are open to discuss this but for now, the TTT scaling is not very convincing. Probably proponents can provide more data to justify. |
| DENSO | No | We agree with Nokia’s view. |
| ZTE | No | We share the same view with Nokia. The correspondence between the TTT scaling and the height seems not have definitive trend. The autonomous TTT scaling by height-dependent factor may cause more issues but without obvious benefit. |
| AT&T | See comments | We understand the issue. However, our interpretation of TTT scaling just implies TTT multiplication by one factor versus another factor based on height, and we don’t see how that addresses the issue. |
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If you do not think height-dependent parameter scaling is beneficial/feasible then another question is whether the UE could be configured with more than a single configuration (e.g. RRM configuration) – each to be used within certain height region.

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| **Question 4: Do you support the option where the UE can be configured with more than a single configuration (e.g. RRM configuration) – each to be used within certain height region? Please provide the details which part of the configuration can be subject to such height-dependence and how the switching between the configurations looks like.** | | |
| **Company** | **Answer** | **Comments** |
| Huawei, HiSilicon | Yes | We think this could be useful and we prefer this solution compared to the UE “autonomous” scaling (see our answer to Q3 above). |
| Ericsson | No | This may be rather complicated to implement in specs and the complexity of the solution should be evaluated against the benefits before final decision in case there is support enough to start inspecting this option.  Another point is that the functionality will need to be discussed, that is the UE action when the switch happens. First option is that UE drops all filters(L3) and TTT and starts over when threshold to apply the second configuration is fulfilled. Hence, UE starts over all the filters and TTT. Now, how to prevent ping pong and/or delayed reporting? |
| Nokia | Yes | We believe this approach is simpler than scaling (Q3) and more justified. As we have shown in section 2.2 of R2-2212268, the A4 threshold (RSRP-based) can vary a lot, especially when the UAV is in NLOS conditions. Thus, at least having two separate sets of conditions for triggering Ax event reporting, each set being height-dependent, is desirable in our opinion. Naturally, the UE would use event H1 or H2 to detect when a new set of parameters (e.g. A4 threshold) is to be applied.  When it comes to the concerns raised by Ericsson, defining requirements for transition period is nothing new. Those exist, e.g. for the case of switching between ‘normal’ measurements and relaxed measurements (for reselection) or for the DRX/eDRX case. We also do not think the UE needs to suddenly clear all the measurements it has conducted in the previous height range (e.g. cellsTriggeredList) when the switching occurs. |
| Qualcomm | Yes | Cleaner approach is to have more than one configuration each to be used within certain height regions (or above/below certain height threshold(s)).  One example of such height-dependent configuration is explained in R2-2211305. To reduce the amount of measurements (and therefore measurement reporting) performed by the UE, height threshold(s) for measurement of a subset of beams can be introduced. |
| Vodafone | Rather no | We are (still) wondering how the height thresholds would be configured to apply different RRM measurements. Especially looking on the paper highlighted by Nokia we noted a sentence: “it is not possible to determine the exact LOS/NLOS radio conditions of the UAV”. If this assumption is correct we feel that correct settings of different RRM configurations might be difficult. Also reading contribution highlighted by Qualcomm, I am not 100% sure if LOS and NLOS conditions are considered within the measurement simulation shown. I think, whatever we agree for this part, it has to be controlled by the Network.  *[NOKIA]: Yes, this setting would be entirely up to the network. We assume the network will know that the cell is e.g. in dense urban environment, where the boundary between NLOS and LOS can be assessed and configured appropriately. Then it should be possible to control when the UE shall switch between LOS and NLOS parameters. Please also note that the time spent below rooftops (in NLOS) would be typically relatively short, compared to the entire UAV flight path/duration. The excerpt from our paper you have mentioned was in fact on the multi-cell triggering for interference detection and considered a wider scale, while the aim there was to check if a single value of A4 threshold is possible for NLOS and LOS, to keep the same number of cells for multi-cell triggering.* |
| LGE | Yes | We don’t think Q3 and Q4 are opposed. Other parameters for which scaling is not suitable may be set separately to reduce unnecessary measurements/measurement reports. For example, we believe that a certain subset of beams or a certain cell list(allowed/not allowed) can be configured for the associated height for measurement/measurement reports. |
| NEC | Yes | We prefer to have more than one configurations for different height ranges. In our view, at least following parameters can be considered:   * Exclude-listed cells and allow-listed cells * Measurement report triggering parameters (e.g., A4 threshold, NumberOfTriggeringCells) |
| CATT | No | The necessity and generality to support this function is still not clear to us. |
| Xiaomi | Not necessary | The solution in Q4 is not necessary. The combination of event H1 or H2 and event Ax can be an alternative.  For the solution in Q4, each RRM configuration can be considered as a configuration for event Ax, and the certain height region can be configured by event H1/H2. Each RRM configuration to be used within certain height region can be achieved by combining event H1 or H2 with event Ax. Hence, if RAN2 support the combination of event H1 or H2 and event Ax, the solution in Q4 is not necessary. |
| vivo | Yes | In our view, the network can reconfigure RRM configuration. But we are fine with multiple RRM configurations for different height regions. |
| Sharp | Yes | It is possible. If this option is agreed, the number of RRM configuration sets should be limited. |
| Intel | No | UE already can trigger report by height and network can reconfigured when UE reports to the UE. If the UE applies to different configuration based on height, network may not know the same configuration is used. |
| Samsung | No | Our understanding is that if combination of event H1 or H2 and event Ax is supported, then the concern raised in R2-2212268 can be addrsssed based on network implementation/configuration. Also, it is not clear to us for now whether network really knows the boundary beetween NLOS and LOS if UAV altitudes are relatively low. Even if it is the case, it is still not clear why having more than one configuration per each height is beneficial for the network i.e. do we really need to apply multi-cell triggering mechanism in the concerned scenario or not? As expressed by Ericsson, we think the benefit of the proposed solution should be more justified/evaluated. |
| Apple | No | In general, we think the justification should be elaborated more. We can see the reason for A4 since the signal quality changes at different heights. But we also feel network can re-configure UE in this case. So probably we should not complex the UE operation as pointed out by Ericsson. |
| DENSO | Yes | To support at least LOS and NLOS situation, supporting multiple conditions seems to be beneficial and relatively simper than Q3 approach. |
| ZTE | Yes | Agree with QC. We think at least a separate set of RRM measurement parameters (e.g. SSB-ToMeasure) associated with height threshold can be considered, to avoid unnecessary RRM measurement on the beams not intended for UAV UE and side lobes from far away cells. |
| AT&T | Yes | We tend to believe that the altitude dependencies in propagation environments may be significant, and that may justify different RRM approaches. |
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# 3 Conclusion

This report has collected inputs on mobility enhancements for UAVs. As a result the following proposals are made:

# References

1. R2-2212638 *Further discussion on UAV measurement enhancements* 3GPP TSG-RAN WG2 Meeting #120 Toulouse, France, November 14-18, 2022
2. J. Stanczak, D. Kozioł, I. Z. Kovács, J. Wigard, M. Wimmer and R. Amorim, "*Enhanced Unmanned Aerial Vehicle Communication Support in LTE-Advanced*," 2018 IEEE Conference on Standards for Communications and Networking (CSCN), 2018, pp. 1-6, doi: 10.1109/CSCN.2018.8581827.
3. RP-223545 *Revised WID: NR Support for UAV (Uncrewed Aerial Vehicles)* 3GPP TSG RAN Meeting #98e Electronic Meeting, Dec 12 - 16, 2022