3GPP TSG-RAN WG2 Meeting #113bis-e R2-2104373

Elbonia, Online, 12 – 20th of April 2021

**Agenda item: 8.10.3.3**

**Source: Nokia, Nokia Shanghai Bell**

**Title: Report from [113bis-e][107][NTN] CHO aspects (Nokia) – Phase 2**

**WID/SID: NR\_NTN\_solutions-Core - Release 17**

**Document for: Discussion and Decision**

# 1 Brief scope of the paper

This document aims at collecting companies’ views regarding the Rel-17 NTN Conditional Handover (CHO):

* [AT113bis-e][107][NTN] CHO aspects (Nokia)

Initial scope: Discuss the proposals in [R2-2103335](file:///C%3A%5CData%5C3GPP%5CExtracts%5CR2-2103335%20On%20Connected%20mode%20mobility%20for%20NTN.docx)

Initial intended outcome: Summary of the offline discussion with e.g.:

* + - List of proposals for agreement (if any)
		- List of proposals that require online discussions
		- List of proposals that should not be pursued (if any)

Initial deadline (for companies' feedback): Thursday 2021-04-15 18:00 UTC

Initial deadline (for rapporteur's summary in R2-2104366): Thursday 2021-04-15 22:00 UTC

Proposals marked "for agreement" in R2-2104366 not challenged until Friday 2021-04-16 10:00 UTC will be declared as agreed via email by the session chair.

For the rest the discussion will continue in a second round of the offline discussion until Monday 2021-04-19. Further details on the scope/intended outcome/exact deadlines to be announced by the session chair after Friday 2021-04-16 10:00 UTC.

The following sections elaborate on the topics listed in the scope above.

# 2 Discussion – Phase 1

In this section we discuss the aspects described in [1], as instructed in the scope of this e-mail discussion.

## 2.1 Time related aspects

In various TDocs submitted to RAN2#113bis-e, including [1], one can find the issue of how to actually use the timing information for CHO/measurement report triggering. First aspect to discuss is what the time information should indicate. Among the options considered we have:

1. Time since when the UE can access the candidate CHO target cell
2. Time until when the UE can access the candidate CHO target cell
3. Time until when the source cell provides coverage
4. Other

Companies are asked to express their views how the time information shall be defined.

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| **Question 1: What does the timing information actually describe in CHO triggering condition for NTN?** |
| **Company** | **Option** | **Motivation** |
| Samsung | d- other | Time as a trigger (specified in RRC Configuration for measurement triggering)= time elapsed since the reception of the RRC Reconfiguration message. Example: When this time exceeds a time threshold/timer AND RSRP of a neighbor cell exceeds an RSRP threshold, the UE sends a measurement report. This approach will use for both quasi-Earth-fixed beams and Earth-moving beams. The time/timer is not needed for Earth-fixed beams. Since the gNB knows about time-based coverage of its cells, it can determine a good UE-specific timer/time threshold value to get an early report from the UE to determine a good CHO Candidate List.We do not recommend the use of time/timer as a standalone trigger for traditional handover and CHO. Time/timer should be combined with other triggers (especially, RSRP). |
| MediaTek | Either a) or c) | Time information was discussed with respect to feeder link switch. So, we think option b) does not serve this purpose. In addition, time information needs to be combined with measurement based triggers. |
| Huawei, HiSilicon | A or b  | If our understanding is correct, option a is timer based solution, i.e. timer is started when CHO command is received by UE, and it expires UE performs CHO execution; and option b is UTC based solution, then it reaches configured UTC time, UE performs CHO execution. |
| Qualcomm | (a) | Same as legacy, what we just need is earliest time for CHO execution. |
| Lenovo | d) | How to describe the time information depends on the different cases e.g time only or time in combination with other condition e.g A3.If time only is configured for CHO, the timer can be configured as trigger condition.If time condition in combination with measurement-based condition is configured, time duration associated with evaluating measurement condition should be configured because TTT is included in measurement-based condition. |
| OPPO | A or c | Depending on different scenarios (e.g. soft/hard feeder link switch), two timers may need to be configured for serving cell and CHO target cell. |
| CMCC | d | The time condition should consider in combination with RSRP-based solution |
| BT | a) Or b) for CHO measurementsd) for CHO trigger | In our understanding both a) and b) have the same fundamental meaning, a specific reference time when UE can start its CHO measurements, unless as pointed by Huawei, option a) is a timer and not a reference time.CHO report triggering is discussed below. |
| Sony | a) | A timer defined for when CHO will be executed. |
| Spreadtrum | a | We prefer the timer solution because it is not necessary to equip UE with GPS module.  |
| ZTE | A+B | We understand a candidate cell would not be available forever considering the satellite movement, thus we prefer to configure an absolute time range with the UTC time as reference, in which the start time and expire time of the candidate cell would both be aware to UE. |
| Vodafone  |  a or b | a or b indicate the transiting time either from the start or from the end!  |
| Apple | d | We feel the timer based solution works in conjunction with other triggers and not alone. At the minimum we want this identified in this discussion. Given another condition, we would need some form of (b+c => at the minimum) or (a+b+c) for the UE to be able to execute the CHO. |
| Intel | a)  | We share the same view as Qualcomm. |
| Xiaomi | a), c) | Time and timer based CHO triggering condition is suitable for feeder/service link switch. In these scenarios, option a) and c) are sufficient to configure proper CHO triggering condition. |
| Rakuten Mobile | d | We also think that RSRP measurement should be used along with timing information. |
| LG | A and B | The UE should know, for each neighbour cell, start time and end time to which the UE can access to the cell. Then the UE only needs to perform measurement and CHO evaluation only within the time duration, and avoid unnecessary measurement. If a) is not provided, then the UE may perform measurement and CHO evaluation too early, and if b) is not provided, the UE may perform it too long. It may bring unnecessary power consumption and wrong CHO.. |
| ETRI | a/b/c  | We think that what timing information What timing information to set for the trigger condition depends on the scenario. (earth fixed/moving cell and feeder/service link switch). For example, for option a, it can be useful in a service link switch of earth moving cell scenario, for option b in a service link switch of earth fixed cell scenario, for option c in a feeder link switch of earth fixed cell scenario. |
| Ericsson | A and c | Option a represent the earliest time in which the UE can perform CHO to a candidate target cell. But the UE also need to consider the remaining serving cell time (option c) as it will set the limit for when the CHO need to be performed at the latest.Both can be represented as UTC. Downside of timer in NTN is that there is RTT involved and with n of HARQ ack/nack it is not clear when UE has received the config.RSRP with time is needed. However, having option to configure it independently is needed as well. These are not exclusive. |
| CATT | c), together with RRM measurement. | We understand RRM measurement is the most essential condition for CHO. Time based condition should be used together with the RRM measurement event.Both a) and c) are feasible, however we understand that c) is more efficient than a).For a), UE may not aware of the stop time of the serving cell, RLF may be detected before access to the new target cell, this is likely to happen in case of hard feeder link switch. For c), UE knows the stop time of the serving cell, it could initiate the measurement towards the target cells before the stop time. Thus, when the target cell is ready, UE will aware of that via the RRM measurement, and then UE could access to the target cell.Above all, c) is essential for time information, and it should be used together with RRM measurement.  |
| Thales | a) | The time since when the neighbouring cells provide coverage should be indicated.In addition, time information needs to be combined with measurement based triggers. Note that Option c) may not be directly applicable to Measurement Reports. |
| China Telecom | a,b | Since the triggering condition is related to candidate cells, we prefer the time information is related to them. Option a) and b) is similar with the respect of candidate cells. |
| Nokia | a) or c) | We think the time since when the UE can access is the most sensible option. The time until when the source cell provides coverage is also reasonable, although a) is our primary choice. |
| InterDigital | a) or c) | Option a) is our default preference, but we think c) could be particularly useful in earth fixed and feeder-link switch scenarios. |

Summary for Q1:

* 24 companies shared their view. Most supported multiple options
* 17 companies are OK with a (Time since when the UE can access the candidate CHO target cell)
* 7 companies are OK with b (Time until when the UE can access the candidate CHO target cell)
* 8 companies are OK with c (Time until when the source cell provides coverage)
* Some companies selected d (Other), but from the comment it is evident their intention was to ensure the timing event is always linked with RSRP/RSRQ-based. This is actually discussed later in this report

Thus, based on the majority view, we propose the following:

**Proposal 1: Timing information in CHO triggering for NTN describes the time since when the UE can access the candidate CHO target cell.**

If other options are desperately needed as well, we ask the companies to bring relevant paper to next meeting and justify.

Another related aspects is how such timing information is implemented. In [1] and other papers it is mentioned to use the timer (typical NR/LTE functionality), absolute time or timer range (e.g. implemented via two timers). Obviously, each of these options has its pros and cons. Thus, companies are asked to express their view how the timing-information is used for CHO/measurement reporting in NTN. Please motivate your answer.

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| **Question 2: How is the timing information implemented (i.e. timer/timers, absolute time, etc.)** |
| **Company** | **Answer** | **Motivation** |
| Samsung | timer | Same as Answer 1.Time as a trigger (specified in RRC Configuration for measurement triggering)= time elapsed since the reception of the RRC Reconfiguration message. Example: When this time exceeds a time threshold/timer AND RSRP of a neighbor cell exceeds an RSRP threshold, the UE sends a measurement report. This approach will use for both quasi-Earth-fixed beams and Earth-moving beams. The time/timer is not needed for Earth-fixed beams. Since the Gnb knows about time-based coverage of its cells, it can determine a good UE-specific timer/time threshold value to get an early report from the UE to determine a good CHO Candidate List.We do not recommend the use of time/timer as a standalone trigger for traditional handover and CHO. Time/timer should be combined with other triggers (especially, RSRP). |
| MediaTek |  | Use a timer and trigger the event once the timer expires. |
| Huawei, HiSilicon | Timer or UTC time are both OK | It can be configured per candidate target cell as different cell may have different arriving time for a UE. |
| Qualcomm | Timer |  |
| Lenovo | timer range (2 timers) | In the legacy specification, TTT will be configured for measurement-based condition. The condition can be considered as ‘fulfilled’ only if the entering condition of the event e.g CondEvent A3 is met within TTT. When the timer expires, UE determine whether the entry condition of the measurement-based condition can be met during TTT (if configured). UE only determines whether the measurement-based condition is met or not at the time point of the timer expiry. If the measurement-based condition is not met at the time point of the timer expiry, the combined condition will not ever be met because the timer will not be restarted. We think a timer range can provide more robustness to the evaluation for execution conditions. This can be implemented by 2 timers: The first timer is used to set the starting time. E.g. starting when UE receives the execution condition.The second timer is used to set the length of time range. E.g. UE starts the second timer once the first timer expires, and evaluates whether the measurement-based condition is met or not when the second timer is running. |
| Oppo | UTC time | UTC time is simple and sufficient. |
| CMCC | Both are fine |  |
| BT | Both are valid | In order to trigger the CHO event, both are valid. For a known constellation, the satellite time arrival pattern is known and therefore an absolute time might be enough. In that case, UE power consumption can be reduced. On the other hand, in order to reuse Rel-16, a timer base can be used.A hybrid solution is an alternative option where an absolute time (option a) or b) of previous question) plus a timer where CHO conditions need to meet in order to trigger the event. |
| Sony | Timer | Timer based solution is straightforward. |
| Spreadtrum | timer | Time solution is simple to UE. |
| ZTE | Time range expressed by UTC time | If a relative time as a timer is configured, the transmission delay between UE and the network should be taken into consideration at network side, which is quite challenging as we can see from the discussion on SMTC and gap.With the above concern in mind, we prefer to configure a time range expressed as UTC time to make our lives easier.The following options can be considered to configure the time range:Option 1: Two UTC time to indicate the start and expire time of the candidate cell.Option 2: A start UTC time with a duration to indicate the valid time range of the candidate cell. |
| Vodafone  | Timer | Timer is simple as stated above but equally absolute UTC could work  |
| Apple | Timer or UTC either are fine | Either of the ways to indicate are fine. The UTC can also be expressed using SIB9.  |
| Intel | Timer |  |
| Xiaomi | Timer or absolute time (eg: UTC time) are both OK | For feeder/service link switch, NW can configure an absolute time or timer based on the arriving time of the target cell and leaving time of the source cell. UE can trigger CHO according to the absolute time or timer. |
| Rakuten Mobile | Timer or UTC Timer | Both options can work. |
| LG | Timer and absolute time (e.g. UTC time) are both fine. | Timer can be used, but it may not accurate from UE perspective because of long propagation delay. (e.g. Network configures 5 seconds timer so UE applies CHO configuration 5 seconds later, but propagation delay is already 300~500ms). So absolute time is also fine. |
| ETRI | Timer and absolute time | It can be used for each purpose.  |
| Ericsson | UTC | Downside of timer in NTN is that there is RTT involved and with n of HARQ ack/nack it is not clear when UE has received the config. |
| CATT | **absolute time** is preferred | As different UEs may receive the CHO configuration at different time, time/timer based solution may be not so accurate if NG-RAN configures the same timer for all the UEs. Absolute time, e.g. UTC time or SFN could be used to definitely indicate the stop time of the serving cell, it is much easier. |
| Thales | Timer or absolute time (eg: UTC time) are both OK | For each serving cell, list of neighbouring cells can be provided One should distinguish between* Earth fixed cells: for each neighbouring cell, no need to provide any Time information. existing hand-over procedure applies.
* quasi Earth fixed cells: for each neighbouring cell, UTC Time for cell service start time should be provided

Earth moving cells: for each neighbouring cell, UTC Time for cell service start time should be provided in association to reference points (Virtual cell centre) on the Earth |
| China Telecom | Both |  |
| Nokia | Timer | Timer is a typical implementation in 3GPP, so we think such approach should be reused. We understand the NW may take into account the propagation delay when setting the timer value. |
| InterDigital | Both | we think both are fine, however prefer that the time when the source cell will stop providing coverage (i.e. option c in Q1) is represented in UTC time. |

Summary for Q2:

* 24 companies have shared their views. 9 companies clearly prefer the timer approach. 3 companies clearly prefer UTC time. 11 companies are OK with both approaches
* It is evident timer is OK to the vast majority of companies (20 in total), but the final decision can be also postponed to Stage-3 phase of the WI. Thus, no proposal.

## 2.2 Location related aspects

Another metric to be used in for CHO triggering is location. It is however unknown what the term “location” actually implies. It can be at least one of the following:

1. Distance between the UE and the satellite
2. Distance between the UE and the cell center (of either the serving cell or the target cell)
3. Difference in the distance between the UE and its serving cell center and the UE and its target cell’s center
4. Other

Companies are encouraged to choose the definition of the distance which suits them most and justify the selection.

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| **Question 3: What does the location information actually describe in CHO triggering condition for NTN?** |
| **Company** | **Answer** | **Motivation** |
| Samsung | a and b | We see value in both a and b. Due to the novelty of NR-based NTN deployments, we like to have more flexibility at the Gnb so that one or multiple combination triggers can be explored by the Gnb. This will mitigate any risks. |
| MediaTek | a) | Distance between UE and satellite seems an easier choice, as UE can calculate it using satellite ephemeris (e.g. PV information). |
| Huawei, HiSilicon | b | Although the beam coverage may not be a regular shape, e.g. a circle, but a coarse distance between UE and cell center can also provide assistance. |
| Qualcomm | (a) | In (a), the condition can be configured per candidate cell. |
| Lenovo | a) | Distance between UE and satellite is easy for implementation and can reuse existing calculation/derivation results e.g. service link delay from UE location and ephemeris. It also somehow reflects the possible receiving power considering LOS propagation. B) or c) requires additional indication of cell center information, and a UE that is close to cell center may not be close to the LEO satellite (transmitter). |
| OPPO | b | Distance between UE and satellite may not represent the UE’s location in the cell coverage. It is more straightforward to use the distance between UE and cell center. |
| CMCC | a | Opt. A is simple to implement. |
| BT | neutral | Some thoughts:* Without knowing the cell radius, we don’t see a real point to trigger the CHO based on a)
* At least with b) the UE can guess the radius.

For option c), the UE will need to constantly measure the distance with the target(s) only to trigger the CHO event. |
| Sony | a) |  |
| Spreadtrum | a | Distance between UE and satellite is simple without extra indication of cell center in SIB. |
| ZTE | 1. Or b)
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| Vodafone | a | Option a is simple to implementOption b due to flatness and undefined cell coverage , cell centre is difficult to define |
| Apple | At least (a) but  | This question is heavily related on the ephemeris discussion. Option (a) needs satellite co-ordinates to the UE to constantly calculate the distance. Option (b) needs information on the “cell center” and identification of serving cell and target cell centers in earth moving satellites would be tricky. (c) is a complicated variant of (b).  |
| Intel  | (a) | Distance between the UE and the satellite should be more accurate to consider link budget and it is easy if the UE knows the location of satellite.  |
| Xiaomi | b) and d) | Option a) may only be feasible for inter-satellite handover because the distance between UE and satellite is the same for intra-satellite handover. Option b) are suitable for inter and intra satellite handover scenarios. But Option b) only can be used for satellite cells with regular shape, such as a circle. For cells with irregular shape, the distance between UE and cell center cannot be used to confirm whether the UE moves in (or moves out) the cell coverage. So, we can use option d) to define the location trigger for satellite cells with irregular shape.**Option d) a geographical area scope referring to the coverage information (of either the serving cell or the target cell).**Option c) is too complicated. |
| Rakuten Mobile | a | Option a) for simplicity, UE can calculate distance based on ephemeris information. |
| LG | None | We do not think such distance-based condition is needed. To achieve this, position of satellite or cell center should be provided by time, but it may bring too much signaling load. Already UE is aware of UE location, satellite location, and cell coverage trace, the network can expect when UE can access to each cell. Thus, based on the information, time condition is enough to provide appropriate CHO configuration. |
| ETRI  | a | We prefer option a for its simplicity. For option b and c, it seems complex to implement it.  |
| Ericsson | B or c | Distance between the UE and the cell centre (serving and/or target cell) may be sufficient. How to describe the cell area (circle, elliptical shape etc.) need further discussions.However, option c defines hexagons which would correspond to terrestrial cell modelling thus it should be discussed if that could actually be preferable even the standardization effect is bit larger.  |
| CATT | B and C | Option a) seems not workable for intra-satellite handover.Option b) and c) are both ok. |
| Thales | c) | One should distinguish between* Earth fixed cells: existing hand-over procedure applies.
* quasi Earth fixed cells: no extra location information is needed beyond the timing information discussed in question 2
* Earth moving cells: in line with the solution proposed by Thales in Q2, the solution c) could apply

Further considerations on earth moving cells:* The criteria of distance between UE and satellite is not usable because it depends on the position of the cell vs the nadir of the satellite. So the threshold will not be the same for all cells of the same satellite

The information to be transmitted to the UE is the list of virtual cell centers. |
| China Telecom | a and b | Option a and b is the same in principle. However, it seems both a and b need additional information to work.  |
| Nokia | D or none | Regarding option a) – we completely agree with CATT, this does not work in intra-satellite cell scenarios. Overall, we do not think location-based triggering is needed, if we already decided to have time-based triggering. However, if pursued, we think the offsets used in legacy Ax events can be scaled in compliance with the distance change (option d).  |
| InterDigital | b) or c) | Agree with BT that option a) may need information regarding cell coverage/radius. Considering the curvature of the earth may deform these cells this may not be straightforward, and cell center distance may be more robust. |

Summary for Q3:

* 24 companies expressed their views. 14 companies are OK with option a (Distance between the UE and the satellite) 9 companies favour option b (Distance between the UE and the cell center (of either the serving cell or the target cell)). Option c is fine to 4 companies.
* Rapporteur’s concern, expressed by at least CATT, is that using distance between the UE and the satellite makes this mechanism unusable for intra-satellite handovers. Thus, we propose the following:

**Proposal 2: Discuss if location information in CHO triggering condition for NTN describes the distance between the UE and the satellite, considering it does not work in intra-satellite scenarios.**

In other papers, e.g. in [1], it is highlighted the use of instantaneous distance between the UE and cell center may lead to unnecessary HOs or RLFs. Instead, it is proposed to assess the distance change metric. One of the considered options is to use such distance change metric as an offset in radio measurement events (Ax). By doing so, the radio-based event has a notion of distance change and will be triggered sooner if the distance towards the target cell decreases.

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| **Question 4: Do you think the distance change should be considered in CHO/MR triggering, e.g. for modifying the offset used in Ax events?** |
| **Company** | **Answer** | **Motivation** |
| Samsung | No | Combination triggers (e.g., (distance AND RSRP) and (time AND RSRP)) would be more suitable in our view. |
| MediaTek | No |  |
| Huawei, HiSilicon | No | It’s a bit unnecessarily complicated, we prefer a straight solution. |
| Qualcomm | No | Agree with Samsung. |
| Lenovo | No | Combined triggers can handle. |
| OPPO | No |  |
| CMCC | No | Combination triggers are sufficient. |
| BT | No but | At this moment, it seems to overcomplicate the solution but we’re open to review it if someone presents a good justification.  |
| Sony | No |  |
| Spreadtrum | No | Agree with Samsung. |
| ZTE | No | Agree with Samsung |
| Vodafone  | No  |  |
| Apple  | No |  |
| Intel | No | The main motivation to use distance information is because the variance (difference) of RSRP is not big (i.e. between cell center UE and cell edge UE). Therefore, modifying offset doesn’t address this issue.  |
| Xiaomi | No |  |
| Rakuten Mobile | No | Agree with Samsung. |
| LG | No | Agree with Samsung. |
| ETRI | No |  |
| Ericsson | No | We understand the issue, but we also think it can be solved with a combination of triggers. |
| CATT | No | Agree with Samsung. |
| Thales | No | For Earth moving cell: Combination triggers (e.g., (distance AND RSRP) would be more suitable in our view.For (quasi) Earth fixed cell scenarios, this question doesn’t apply |
| China Telecom | No |  |
| Nokia | Yes | We think that would simplify the configuration and allow to use a single event only, which will simultaneously reflect the radio measurement conditions as well as the distance change. |
| InterDigital | No |  |

Summary for Q4:

* 24 companies expressed their views. 23 are against specifying such offsets reflecting the distance difference.
* This solution is not pursued, no resulting proposal.

## 2.3 Combination of events

During the discussion in [2] there were lots of controversies on how the different events (location-based, time-based, radio-based) can be linked and whether radio-based measurement event needs to be always configured – for either MR or CHO triggering. As the motivation and use case for applying the location-based or time-based event alone remains vague, companies supporting such option are given the chance to explain how it shall work and what is the use case they have in mind for such standalone event.

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| **Question 5: Should the time- or location-based event for CHO/MR triggering in NTN always need to be configured with radio-based measurement event (Ax)?** |
| **Company** | **Answer** | **Motivation/use case for standalone use** |
| Samsung | Yes | For reliable and robust handover, we prefer combination triggers. For flexibility, we can determine allowed ranges of thresholds to be sufficiently wide/flexible. The use of new standalone triggers such as timer or distance can be highly risky; at the minimum, RSRP should be used in conjunction with a new trigger. The use of RSRP by itself would not provide robust handover due to similar RSRPs in large NTN cells. There has been an agreement on combination triggers (instead of standalone triggers) per prior RAN2 agreements. |
| MediaTek | Yes | Combination of triggers is needed to make sure that the cell UE is handed over is sufficiently strong (enough RSRP or RSRQ) level. |
| Huawei, HiSilicon | No | It can be left up to network implementation, we can support this flexibility when network think it’s enough to only use time/location metric for CHO. |
| Qualcomm | Yes | At least with A4 event (meaning to meet minimum RSRP criteria). |
| Lenovo | Depends | Combination of triggers can be used for common CHO case and guarantees CHO performance. For the feeder/service link switching case where the switch time is certain, radio-based measurement could be unnecessary and we may consider “OR” association. |
| OPPO | Yes | To make CHO more robust and reliable, combination of triggers is needed. |
| CMCC | Yes |  |
| BT | No | It should be left to network implementation if CHO trigger is done by events, time/timer + events, time/timer + location, etc. |
| Sony | No | In our understanding we are discussing network restrictions which are not needed. We think standalone timer or location based CHO triggers can work and should be left to nw implementation.  |
| Spreadtrum | Yes | A4 event could guarantee the RSRP criteria. If only time- or location-based event is configured, the HO robustness could be risky in some cases, for example, UE in fading. |
| ZTE | No | We support to have such flexibility. For the case when more than one event is configured, the relationship (i.e. “and” or “or” ) among different CHO execution conditions, i.e. the R16 execution condition A3/A5, the newly introduced A4, location based condition, and time(r) based condition in NTN, can be configurable by the network and would be indicated to UE in CHO configuration.  |
| Vodafone  | No | Leave this to network implementation  |
| Apple | Yes |  |
| Intel | Yes | We prefer to combine location based CHO/MR triggering for A2 and A4.  |
| Xiaomi | No | Agree with Huawei, whether time/location based event should be always configured with radio measurement event can be decided by network implementation. Such as the following case, it may be enough to only use time based event for CHO:For the scenarios of feeder/service link switch, time and timer based CHO triggering event can be configured without radio measurement based events. The target cell and switch timing can be predicted by network. So, network can confirm whether the target cell can provide radio coverage at a certain time. Therefore, standalone time or timer based CHO triggering event is enough. |
| Rakuten Mobile | Yes | We believe that combination of events with “And” or OR can be defined for Handover robustness.  |
| LG | Yes | Even if time- or location-based condition is satisfied, radio quality condition must be satisfied to trigger CHO, because the radio quality may vary according to the weather condition. |
| ETRI | No | We think the combination of triggers would be beneficial, but it is better to leave it up to the network implementation. |
| Ericsson | No | We do not see benefits of limiting only to joint configuration(which will be supported). |
| CATT | No | We understand A4 should be the most essential event to trigger the CHO, while the time based info/location based info could be used as the assistance info. The simplest way is to broadcast the time/location based info in the SI of each serving cell. UE could initiate the RRM measurement of the candidate neighbour cells according to the assistance info. When the A4 event is satisfied, CHO will be triggered.That means, not necessary to define new triggering event, A4 is sufficient, and time/location based info could be broadcasted to UEs as the assistance info. |
| Thales | Yes | * Earth fixed cells: existing hand-over procedure applies.
* quasi Earth fixed cells: it should be possible to combine or not time and radio-based measurement information to trigger HO (up to network configuration)
* Earth moving cells: it should be possible to combine or not time, distance wrt virtual cell centre and radio-based measurement information to trigger HO (up to network configuration)
 |
| China Telecom | Yes | We think location or timer is assistant information for legacy metric of radio. Thus, they should work together for better performance. |
| Nokia | Yes for CHO triggering | We believe RSRP/RSRQ-based event is essential for CHO triggering. It can be potentially skipped for MR. Among the companies that responded ‘’No’’ there are not many solid answers regarding the use cases. So would e.g. the timing alone be used for FL switching? |
| InterDigital | Location – yesTime - No | For regular cases yes, but we see a strong motivation to have a time-only triggering criteria ONLY for the special case of soft feeder-link switch. |

Summary for Q5:

* 24 companies provided their views. 13 companies want to always configure time/location-based event with radio-based event for NTN. 9 companies want to ensure time/location-based event can be used without radio-based event. One company wants to have such option of no radio-based event for time-triggering.
* Due to no clear majority, we suggest to discuss it further

**Proposal 3: Discuss/FFS if for NTN, the time/location-based event shall be always used with RSRP/RSRQ-based event (Ax) for CHO triggering or measurement report triggering.**

In [1][2] there were also considerations on using time-based event with location-based event. Please share your opinion whether such combination shall be allowed.

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| **Question 6a: Can the location-based event be combined/configured with time-based event for NTN Rel-17?**  |
| **Company** | **Answer** | **Motivation**  |
| Samsung | Yes/No | We suggest using RSRP of the neighbor in a combination trigger. Within a combination trigger, we prefer “AND.” Furthermore, there could be multiple combination triggers for a UE and these triggers can be combined using OR and AND per Gnb implementation. |
| MediaTek | No | We do not see a need to make such combination of location and time based trigger events. Combining only with measurement triggers seems enough. |
| Huawei, HiSilicon | Yes | If the detail above of both of them are agreed, we can allow to enable them together and it’s up to network implementation. |
| Qualcomm | No | We also see no need for this.  |
| Lenovo | No | We see no use case for combination of location and time. Combination of location-measurement or time-measurement is sufficient. |
| OPPO | No | We also don’t see the need for this. |
| CMCC | No | No benefit is identified for this combination. |
| BT | Yes | This should be left to network implementation. |
| Sony | Yes | We don’t need to restrict this configuration and could leave it to network implementation. |
| Spreadtrum | No | This combination is not needed. |
| ZTE | - | We support to have such flexibility. For the case when more than one event is configured, the relationship (i.e. “and” or “or” ) among different CHO execution conditions, i.e. the R16 execution condition A3/A5, the newly introduced A4, location based condition, and time(r) based condition in NTN, can be configurable by the network and would be indicated to UE in CHO configuration. |
| Vodafone  | Yes  | From operations perspective, we like to have the freedom to have both location and time base triggers |
| Apple | Yes |  |
| Intel | No | We are not sure if there is any additional gain.  |
| Xiaomi | Yes | It should be left to network implementation. |
| Rakuten Mobile | Yes | We don’t need to restrict the options (as of now) |
| LG | No | As we commented in Question 3, we do not think location-based condition is needed. |
| ETRI | - | We prefer to allow a combination of triggers and individual triggers depending on the network decision. |
| Ericsson | Yes/No | We do not see any obvious need (use cases) for combining the two trigger events. But on the other hand, we are open to a flexible framework where the different trigger events (i.e. not only the location and time-based events) can be combined. |
| CATT | Yes | We think this combination is needed.For example. In earth fixed cell, there are two reasons of service link switch (satellite movement and UE movement ). One is due to the satellite movement. Time-based are workable for satellite movement handover in earth fixed cell. Location-based cannot work in this scenario, because the cell coverage and UE location don’t change. In this case, UE will not initiate the corresponding measurement of neighbor cell. Another is due to the UE movement. In this case, time-based cannot work well. When UE is to move out of the cell, UE need to switch the target cell, even if the time-based event is not triggering. So, in earth fixed cell, UE location and stop time of serving cell can be used together. UE location can be used for mobility due to UE movement, and stop time can be used for mobility of satellite movement. |
| Thales | Yes | Same response as per question 5: flexibility in combination should be supported |
| China Telecom | No | Can not see any benefit. |
| Nokia | No strong view | We do not see any particular use case, so we would be OK not to allow that (extreme flexibility is not always the right path to follow). On the other hand, if this would be combined with radio-based event, then maybe it can work and ensure high reliability of triggering.  |
| InterDigital | No strong view | Agree with Nokia |

Summary for Q6a:

* 11 companies would like to allow such combination, while…11 companies do not think it shall be allowed.
* Thanks to this perfect split of views, we suggest to discuss this more and search for a solid use case where this would make sense

**Proposal 4: Discuss/FFS if there are any solid NTN use cases where combining the time-based triggering with location-based triggering would be relevant.**

If the answer to Question 6a is positive, companies are asked to express how such combination is used, i.e. with or without radio-based measurement:

1. Radio-based measurement event (Ax) always used in parallel to time and location events
2. Radio-based measurement event (Ax) used when other (time and/or location) event triggers
3. Radio-based measurement event (Ax) not used

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| **Question 6b: How the combination of location-based event and time-based event is configured? Please select one of the options listed above.**  |
| **Company** | **Answer** | **Motivation** |
| Samsung | Pl. see comments. | We suggest a flexible framework where multiple combination triggers are defined for a UE. RAN2 can first identify a set of quantity combinations that the contributors like. Then, define triggers for measurement reporting (and execution for CHO) using flexible OR and AND to combine trigger combinations. Define a single NTN event and include flexible combination triggers that companies prefer to cover all types of beams: Earth-fixed, quasi-Earth-fixed, and Earth-moving. |
| MediaTek | Not needed |  |
| Huawei, HiSilicon | c | We can have a separate indication to enable or disable measurement based CHO trigger.  |
| Lenovo | a) and b) | We prefer to keep the configuration flexible as both a) and b) could be used for time and location events. E.g. for combination of time and measurement events, as our comment for Q1, a first timer starts upon CHO configuration and expires when UE can initiate evaluation of measurement for a candidate cell, which is option b)-like. And the evaluation can be performed within a second timer running period, which is option a)-like. |
| BT |  | At this stage, we prefer to left this to network implementation where the network has the flexibility to configure a), b) or c) |
| Sony | c |  |
| Spreadtrum | b | Option a) means UE always performs radio-based measurement, which is power consuming for UE. So we prefer Option b). |
| Vodafone  |  | too early to discuss these as it should be left to the network implementation  |
| Apple |  | Agree with Samsung to have a flexible framework here for triggers.  |
| Xiaomi |  | Agree with Vodafone. Postpone the discussion and it can be left to the network implementation.  |
| Rakuten Mobile |  | Agree with Samsung. Also, this discussion can be postponed for now. |
| ETRI |  | We prefer to allow a combination of triggers and individual triggers depending on the network decision. |
| Ericsson | postpone | Can be stage 3 |
| CATT | See comments | Please refer to our view in question 6a.Generally, we believe the existing radio based measurement event is sufficient.If majority of the companies prefer to define the new time/location based events, we prefer Radio-based measurement event and other event (location or time) is ‘and’, time and location is ‘or’. e.g. ‘Ax and location’, ‘Ax and time’, ‘Ax and time and location’. Radio-based measurement event is more essential.  |
| Thales | a) and/or b) | We recommend to use radio based measurement as baseline, with the possibility to combine with an enhancement (time or distance). |
| Nokia | A or b | But we are also OK not to decide it now, as some companies imply. |

Summary for Q6b:

* 16 companies provided their views. Most would like to postpone the related decisions.
* As a result – no proposal is made. This can be rediscussed later, when directly preceding aspects are resolved.

## 2.4 Chain of Conditional Handovers

In [1], but also in some other papers submitted to RAN2#113 and RAN2#113bis, it is mentioned that the UE may retain the CHO configurations even after executing a CHO. The configurations to be kept are not the ones for other candidate cells evaluated in this CHO evaluation phase, but rather the configurations for future serving cells. As claimed in [1], in NTN the sequence of next serving cells can be predicted with high probability, which apparently may justify to equip the UE with the CHO configurations for future cells, i.e. not for the next handover execution only, but beyond that. Thus, companies are asked whether they see a benefit in enabling such option and would like to continue the related work.

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| **Question 7: Do you think providing the UE with CHO configurations for cells beyond the next cell change can be beneficial in NTN?** |
| **Company** | **Answer** | **Motivation** |
| Samsung | No | Since the measurement report needs to be obtained well in advance of an eventual handover, propagation delays are quite long, and RSRPs near the cell edge may be similar in an NTN, there would be a need for multiple CHO candidate cells. Note that resources in multiple CHO candidate cells are reserved but not actually used except by one cell at some point in future.In particular, we anticipate massive handover in an NTN due to movement of the NTN platforms. Hence, combination of a large number of handovers and need for CHO resource reservation in multiple cells mean that the resources available for user traffic can be significantly less. Because of these reasons, we think that RAN2 should try to accelerate CHO and reduce the resource reservation time.We suggest RAN2 to consider a UE indication of the selected CHO cell to the source cell before the UE leaves for the target CHO cell so that the resource reservation can be cancelled quickly, saving precious radio resources. |
| MediaTek | No | Such optimizations are not needed at this stage. We need to make a working solution first. |
| Huawei, HiSilicon | No | UE may move to another cell and even in the same cell different UEs may face different upcoming cells, so this solution may not work well in all cases. |
| Qualcomm | Yes | We think this is critical enhancement to reduce signaling overhead specially in case of handing over a large number of Ues from one cell to another and again to another. It is likely the predictable target cells are connected to same Gnb. Since time-based condition can be used for each candidate cell, resource utilization in candidate cells should not be issue. |
| Lenovo | No | This is an optimization that may not be necessary. We understand its intention of reducing signalling but as the time/location situation may change it is sufficient to let the current serving cell decide whether to configure CHO and the execution conditions. |
| OPPO | No | We should focus on the essential CHO features in NTN and not to do over-optimization. |
| CMCC | No | The cost is high due to large reserved resources of candidate target cells. |
| BT | Potentially  | In case the UE is restricted to a single satellite constellation, the fact that UE is configured with several neighbours will reduce the total overhead.  |
| Sony | Yes | Considering UE mobility is negligible compared to satellite movement, almost all UEs in the cell will need HO at the same time. Such pre-configuration of multiple potential target cells in future is needed in order to reduce the signalling overheads during handover preparation phase and receipts of HO commands in the UEs. We have already agreed timer based HO so target cells may reserve actual resources closer to the time when UEs will move in rather than well in advance and should be left to the node implementation. Relying on legacy HO mechanism will result in signalling storm. |
| Spreadtrum | Yes | For the UE with fixed location, the chain of conditional handover could be predicated actually. This mechanism could reduce a lot of signal, especially for large NTN cell. |
| ZTE | No | By configuring CHO, some resources would be reserved in the target side and wait for UE to use. With a CHO chain, more resources would be reserved and cannot be used by others. We do not see much benefits in having such enhancement. |
| Vodafone | no | In practice, the cells are 40-50 km wide and it is highly unlikely that the UE or the Network would handover to another cell further than the next cell.  |
| Apple | Maybe | This would help reduce some signaling load at the minimum. Also, this flexibility would help in the initial stages of LEO deployments where coverage would be primary concern.  |
| Intel | No | It was discussed in Rel-16 mobility WI, and has been excluded because the security and configuration (delta configuration) of CHO candidate cells are derived based on original source cell, and then security and configuration of CHO candidate cell cannot be used if source has been changed.  |
| Xiaomi | No | Considering the movement of UE, the CHO commands may become invalid as time goes on. And, if UE retains the CHO commands, system resources will be wasted. |
| Rakuten Mobile | Yes | We think this information can actually reduce amount of scheduling as multiple neighbours can be transferred at once. |
| LG | Yes | Providing the next serving cell list can reduce signalling load greatly. As UE’s mobility is ignorable compared with satellite mobility, CHO candidate cell list for a UE might change unfrequently. So the UE can keep the next serving cell list until the network updates. Based on this next cell list, the cell can avoid signalling storm to provide CHO configuration to all the connected UEs when the satellite is about to perform feeder link swtich. |
| ETRI | No | The probability of prediction in non-stationary satellite could be relatively higher than TN, but that’s a part of NTN scenario. We think it is unnecessary optimization. |
| Ericsson | Yes | We think this can be useful if designed properly. FFS for now |
| CATT | No | It is not essential part of CHO. R17 is an workable solution of NR NTN. Such optimization need deprioritize in this stage. |
| Thales | No | We don’t see the need. |
| China Telecom | Yes | It takes advantages of upcoming target cells are predictable in NTN. Radio overhead can be reduced by this method.  |
| Nokia | Yes | As argued in our paper, this can be helpful for signalling reduction in NTN as the sequence of cells is predictable.  |
| InterDigital | Yes | Agree with Ericsson |

Summary for Q7:

* 24 companies provided their views.
* 9 companies clearly support such configuration possibility. 2 companies say ‘maybe/potentially’, the remainder responded No.
* Among those who said No, there are opinions this is not an essential mechanism for Rel-17 NTN. We agree and, considering noticeable interest level, suggest to return to the discussion when more basic aspects of Rel-17 NTN mobility are addressed.

**Proposal 5: Providing the UE with CHO configurations for cells beyond the next cell change (chain of CHOs) can be considered in NTN Rel-17 once basic NTN mobility aspects are addressed.**

# 3 Conclusions – Phase 1

Based on the views expressed in the previous sections, we propose the following:

For e-mail agreement:

**Proposal 1: Timing information in CHO triggering for NTN describes the time since when the UE can access the candidate CHO target cell.**

**Proposal 5: Providing the UE with CHO configurations for cells beyond the next cell change (chain of CHOs) can be considered in NTN Rel-17 once basic NTN mobility aspects are addressed.**

For online discussion:

**Proposal 2: Discuss if location information in CHO triggering condition for NTN describes the distance between the UE and the satellite, considering it does not work in intra-satellite scenarios.**

Postpone to next meeting:

**Proposal 3: Discuss/FFS if for NTN, the time/location-based event shall be always used with RSRP/RSRQ-based event (Ax) for CHO triggering or measurement report triggering.**

**Proposal 4: Discuss/FFS if there are any solid NTN use cases where combining the time-based triggering with location-based triggering would be relevant.**

# 4 Discussion – Phase 2

This is to kick-off the second phase of the discussion, as instructed by the Chairman:

**[AT113bis-e][107][NTN] CHO aspects (Nokia)**

Final scope: Discuss a revision of proposals from [R2-2104366](file:///C%3A%5C%5CData%5C%5C3GPP%5C%5CRAN2%5C%5CInbox%5C%5CR2-2104366.zip%22%20%5Co%20%22C%3AData3GPPRAN2InboxR2-2104366.zip)

Final intended outcome: Summary of the offline discussion with e.g.:

  List of proposals for agreement (if any)

  List of proposals that require online discussions

  List of proposals that should not be pursued (if any)

Final deadline (for companies' feedback): **Monday 2021-04-19 18:00 UTC**

Final deadline (for rapporteur's summary in R2-2104373): Monday 2021-04-19 22:00 UTC

Proposals marked "for agreement" in R2-2104373 not challenged until Tuesday 2021-04-20 10:00 UTC will be declared as agreed via email by the session chair.

For the rest the discussion will continue online in the Tuesday CB session

Companies are asked to share their brief opinion below.

## 4.1 Time-related proposals

After several comments to the summary of Phase-1, submitted in [3], the revised version of Proposal 1 is as follows:

**Proposal 1\_revised: Timing information in CHO triggering for NTN describes at least the time after which the UE can access the candidate CHO target cell. FFS on whether the timing information can also describe** **the time after which UE cannot access the candidate CHO target cell.**

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| **Question 4-1: Is Proposal 1\_revised acceptable to you? Please answer yes/no and suggest what should be changed.** |
| **Company** | **Answer** | **Motivation** |
| Samsung | No | **In our understanding, since the question is discussing CHO triggering (and NOT CHO execution), the UE should not be trying to “access a candidate CHO target cell” but should be sending a Measurement Report to the gNB.** |
| Lenovo | Yes with comments | **If the time based condition is combined with measurement-based condition, our understanding is that “the time after which the UE can access the candidate CHO target cell” refers to the time after which the UE checks combined measurement-based condition. And “the time after which UE cannot access the candidate CHO target cell” refers to the time before which the UE checks measurement based condition.** |
| Xiaomi | Partially Yes | We support that “**Timing information in CHO triggering for NTN describes at least the time after which the UE can access the candidate CHO target cell.**” But we don't agree to introduce “**the time after which UE cannot access the candidate CHO target cell**”, which is not an essential info for time based CHO. |
| OPPO | Yes with comments | Since this is not talking about CHO execution and to avoid confusion that CHO execution (i.e. UE access) is not based on this timing information only, we propose the following wording:**Timing information in CHO triggering for NTN describes at least the time after the candidate CHO target cell is considered as available.**For the FFS part, no strong view to keep it. Maybe we can focus on the first part. |
| Huawei, HiSilicon | Yes | We hope to make it clear, “**the time after which the UE can access the candidate CHO target cell**” means the candidate cell is available.So we suggest to change the wording to “**the time after which the candidate CHO target cell is available**”. As “UE can” doesn’t mean UE must do it. |
| Turkcell | Yes with commnets | We agree OPPO’s wording. We don’t need to introduce the second part of the Proposal 1 related with access limitation.  |
| ETRI | Yes |  |
| Thales | Yes | Agree with Oppo’s wording  |
| Lockheed Martin | Yes with comments | It needs rewording to clarify the meaning of “access”. We agree with OPPO’s wording. |
| LG | Yes | We think both time condition should be considered, because the UE should know until when the UE can access the candidate cell. This is essential information. |

In Phase-1 it was also debated whether the time can be expressed in the form of a timer (or timers) or absolute UTC time. Many companies said both are OK, while there was also a clear preference towards the timer approach. Thus, we suggest to check once again companies views and whether you prefer to:

1. Implement the timing information for CHO-triggering in NTN in the form of a timer/timers
2. Postpone the decision to Stage-3 discussion

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| **Question 4-2: Should the timing information for CHO-triggering in NTN be in the form of a timer/timers (a) or do you prefer to postpone the decision to Stage-3 (b)?** |
| **Company** | **Answer** | **Motivation** |
| Samsung | Timer preferred, absolute time acceptable | The timer would likely simplify the UE implementation instead of frequently comparing absolute times. |
| Lenovo | a) with comments | **“The time after which the UE can access the candidate CHO target cell” as in Proposal 1 can be easily implemented by a timer since the form of ‘timer’ is extensively used in RRC specification.** |
| Xiaomi | a)But, absolute UTC time should not be precluded | Whether the time information for CHO triggering can also be expressed in the form of absolute UTC time can be FFS. |
| OPPO | b) |  |
| Huawei, HiSilicon |  | Both timer and UTC should be supported. |
| Turkcell | a) |  |
| ETRI | - | We support in the form of timer and UTC time. It’s ok to postpone the decision to Stage-3 discussion. |
| Thales | a) |  |
| Lockheed Martin |  | Timer implementation is simpler |
| LG | Both | For network’s flexibility, both way should be supported. |

## 4.2 Location-related proposals

Based on the concerns expressed via e-mail after Phase-1, we want to rediscuss Proposal 2 from [3]. To refresh everyone’s memory, Proposal 2 was as follows:

**Proposal 2: Discuss if location information in CHO triggering condition for NTN describes the distance between the UE and the satellite, considering it does not work in intra-satellite scenarios.**

Companies are asked to share their further view on P2 and related aspects.

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| **Question 4-3: Do you agree location information in CHO triggering condition defined as the distance between the UE and the satellite does not work in intra-satellite handover scenarios?** |
| **Company** | **Answer** | **Comments** |
| Samsung | Yes with comment | **Yes- if we simply observe the UE-satellite distance where a neighbor cell belongs to the same satellite as the serving cell, such distance would be unhelpful as a trigger. The NTN solution should work for all scenario: intra-satellite and inter-satellite. All types of beams: Earth-fixed, quasi-Earth-fixed, and Earth-moving beams. For the location-based trigger, we prefer distance between the UE and the center of the serving cell as one of the useful triggers.**  |
| Lenovo | No | **For the combination of location and measurement conditions, the distance between the UE and the satellite can be used to trigger evaluation and CHO execution is based on distance and measurement results, and this can work for intra-satellite HO scenarios. This distance may not work in intra-satellite scenarios only if configured alone (without measurement conditions).** |
| Xiaomi | Yes  | The distance between UE and satellite is the same for intra-satellite handover. Agree with Samsung, location info in CHO triggering should can be used for all scenarios in NTN. So, we prefer the distance between UE and cell center.  |
| OPPO | Yes with comments | We share the same comments as Samsung. Distance between UE and cell center is more useful for CHO triggering condition. |
| Huawei, HiSilicon | Yes | Same view as Oppo. |
| Turkcell | Yes with comments | We agree with Samsung |
| ETRI | Yes |  |
| Thales | Yes |  |
| Lockheed Martin | Yes with comments | The solution should work for both intra-satellite (inter-beam) and inter-satellite scenarios. Provision should be given for using either the distance between the UE and the satellite or distance between the UE and the center of the serving cell.  |
| LG | Yes | We do not think distance between UE and satellite is feasible. |

Assuming a single location-based triggering definition for all NTN mobility scenarios should be our goal, which of the following options you prefer:

1. Distance between the UE and the satellite
2. Distance between the UE and the cell center (of either the serving cell or the target cell)
3. Difference in the distance between the UE and its serving cell center and the UE and its target cell’s center

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| **Question 4-4: What does the location describe in location-based CHO triggering for NTN? Choose from a), b), c) listed above.** |
| **Company** | **Answer** | **Comments** |
| Samsung | b most useful | **In our view, “b” would be most useful and “a” could be useful in some cases. In general, we prefer a combination trigger such that the neighbor cell can provide at least a target RSRP value.** |
| Lenovo | a) | **As our comments for Q4-3, a) can work for intra-satellite HO scenarios unless location-only CHO condition is considered.** |
| Xiaomi | b)  | b) is suitable for inter and intra satellite handover scenarios. |
| OPPO | b) |  |
| Huawei, HiSilicon | b) |  |
| Turkcell | b) |  |
| ETRI | b) | Option b can support both intra and inter-satellite scenario.  |
| Thales | b) |  |
| Lockheed Martin | a) | If only one option can be supported in R17, then we prefer a. Perhaps b can be added in R18. |
| LG | Slightly b) | We are opponent of introducing location-based triggering condition, but if we should introduce one, we think option b) is most feasible solution. |

# 5 Conclusions – Phase 2

Based on the views expressed in the previous section, we propose the following as a Phase-2 outcome:

For e-mail agreement:

For online discussion:

Postpone to next meeting:

# 6 List of referenced documents

[1] R2-2103335 *On connected mode mobility for NTN* 3GPP TSG-RAN WG2 Meeting #113bis Electronic Elbonia, 12 – 20 of April 2021

[2] R2-2102016 *Report of [AT113-e][106][NTN] CHO aspects (Ericsson)* 3GPP TSG-RAN WG2 Meeting #113 electronic Online, January 25th - February 5th, 2021

[3] R2-2104366 *Report from [113bis-e][107][NTN] CHO aspects (Nokia)* 3GPP TSG-RAN WG2 Meeting #113bis-e Elbonia, Online, 12 – 20th of April 2021

# Contact information

|  |  |
| --- | --- |
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