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

17th – 26th Apr. 2023

Source: Lenovo (Rapporteur)

Title: Summary of EMAIL DISC [121bis#xxx] on AI 7.3.5 Connected Mode Mobility

Agenda Item: 7.3.5

Document for: Discussion and Decision

# Introduction

This contribution is to check company views on different aspects of NES Connected Mode Mobility, and accordingly formulate agreeable proposals based on submitted contributions from agenda item 7.3.5.

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# Basic Understanding

We will first discuss some basic aspects that can help progress more technical issues later:

## NES Techniques for RRC Connected UEs for this email discussion

Following techniques are mentioned in the WID and company contributions:

1. Cell DTX/DRX mechanism
2. Cell switch-off
3. Spatial and power domain techniques

For Spatial and power domain techniques, RAN1 is the primary group (as shown below from an excerpt of RP-230566):

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| *Specify the following techniques in spatial and power domains*   * *Specify necessary enhancements on CSI and beam management related procedures including measurement and report, and signaling to enable efficient adaptation of spatial elements (e.g. antenna ports, active transceiver chains) [RAN1, RAN2]* * *Specify necessary enhancements on CSI related procedures including measurement and report, and signaling to enable efficient adaptation of power offset values between PDSCH and CSI-RS [RAN1, RAN2]* * *Note: Above objectives are only for UE specific channels/signals* * *Note: Legacy UE CSI/CSI-RS capabilities applies when considering total number of CSI reports and requirements* |

Some companies have made proposals in this sub-area as follows:

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| ***LG***  *Proposal 1: Do not pursue CHO enhancement (NW-triggered mobility to a preconfigured target) for spatial/power-domain NES technique and Cell DTX/DRX NES technique.*  ***CATT, Turkcell***  *Proposal 4: CHO with CondEvent A4 can also be used to offload UEs for spatial NES technique and no other enhancement for CHO is needed.* |

However, RAN2 has not received any conclusive LS so far which can be used as basis for our further work as far as this sub-area is concerned. So, Rapporteur devotes this email discussion primarily to first two techniques only.

Further, Rapporteur would further like to check company opinion to see if it is acceptable to consider cell switch-off as a special case of Cell DTX/ DRX mechanism. This simplification is used here to

- if the DTX/ DRX periodic sleep time is rather small (for smaller duty cycles) and UE would not be needed to be handed over to another cell to fulfill the QoS of the already running bearer, can be managed by network implementation using legacy principles

- if the cell’s sleep time would affect QoS fulfillment of the already running bearer, the network would rather prefer to handover the UE to a suitable candidate – for not only cell switch off case but also for Cell DTX/ DRX mechanism.

**Question 1: Is it acceptable (at least) for this email discussion to consider Cell DTX/ DRX as also representing cell switch off technique? If this is not so, please highlight here or in subsequent places the important differences leading to unique UE/ network behavior in each case.**

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| Company Name | Yes/ No | Comments |
| Xiaomi | No | 1. Only cell DTX/DRX is considered for now. 2. For cell switch-off, it is not in the scope of the WI. Furthermore, cell switch-off is not a special case of Cell DTX/ DRX mechanism. In my understanding, cell switch-off means that there is no paging, SSB, SIB transmission. 3. For Spatial and power domain techniques, it is up to RAN1. |
| Huawei, HiSilicon | No | Activating Cell DTX/DRX does not mean the NW intends to handover the UEs.  Rapp) Please see the yellow highlighted text. Rapporteur did not mean that Cell DTX/ DRX leads to a blanket handover for all UEs.  Legacy UEs and non-NES capable UEs cannot recognize the R18 CHO enhancements, the only targets for this enhancement are the NES capable UEs but these UEs are exactly what Cell DRX/DRX are designed for  Rapp) The legacy and non-NES capable UEs are not part of this discussions – RAN2 already discussed mechanism to restrict camping of NES capable (non-legacy) UEs, so the UEs transitioning to RRC Connected will naturally be only NES capable UEs.  If in the exceptional case some UE needs to be HO’ed to a non-NES cell to fulfill the QoS requirement, this should be managed by legacy HO.  **We think the discussion related to source cell NES mode should focus on the switching off case** (not including Cell DTX/DRX), because that scenario brings the largest gain (all UEs need to be HO’ed). The discussion related to target cell NES mode (i.e. selecting an appropriate target cell) can consider all NES techniques including Cell DTX/DRX. |
| Apple | Yes | In our understanding, there are at least below 2 cases target for CHO enhancement:   1. Source cell activates Cell DTX/DRX, and the activated Cell DTX/DRX will degrade QoS of served UEs (e.g. a long non-active duration) 2. Source cell turns off   We assume Rapporteur intends to include above 2 cases and avoid unnecessary discussion on clarification on what is “cell OFF mode” and whether to specify it. We agree this is a good way-forward. |
| Intel | See comments | We are not sure of the intention of the question. To us, both techniques target different scenarios to be considered for CHO enhancement. For the cell off case, all the UEs in the cell needs to be handover/CHO while for the application of the NES techniques case (e.g. application of Cell DTX/DRX and/or spatial/domain techniques), it may not be all the UEs in the cell.  Rapp) Since the specifications are written from a (per) UE perspective, the question is intended to see if the Cell DTX/ DRX and Cell switch off will impact the UE behavior differently? Since we are considering the mobility topic here, for both cases – when the need arises – the UE will be handed over to a target cell. |
| Vodafone | Yes | We agree manly with Apple. We should include both cases and also discuss both case where the outcome might be the same or different |
| Nokia | No | Turning cell of is quite different compared to activating cell DTX/DRX (which we don’t actually know what it will be in this WI)  and Generally what would be benefit of “generalizing” these? Anyway we need to consider whichever method is introduced in this WI for CHO as well.  Rapp) Hope the clarification provided to Intel explain the intention to generalize these two mechanisms. |
| Qualcomm | No | We already have a proposal in the [312] that specifies alignment requirement of UE CDRX and cell DTX. Cell DTX in general contains a periodicity which means that it follows a certain ON-OFF pattern. The rapporteurs suggestion seems to imply that UEs perform a CHO in the OFF period beginning, then what happens in the ON period?   * Option 1: UEs are offloaded and served by another serving cell, thus the cell is ON without serving any UEs and will start getting them gradually, which does not make sense in the realm of an ON-OFF cycle. Afterall, if this is the goal, why not simply switch OFF the cell then switch it back ON without a periodic pre-determined cycle. * Option 2: UEs go back to the gNB during the ON cycle. In this case we are on-purpose introducing a ping-pong behavior in the UE which is we always try to avoid due to UE power consumption, QoS,, UPT, Service continuity, backhaul signalling, etc.   Rapp) Not sure where’s this confusion coming from. In both cell switch off and cell DTX/ DRX cases, the UE might need to be handed over to another cell when/ before the source cell starts to sleep. There’s no further implication from this point.  Thus, we think CHO should be kept completely separate from Cell DTX/DRX.  Rapp) CHO is one potential solution which in my opinion almost all companies are considering to let the source cell enjoy some energy saving by using Cell DTX/ DRX. Not sure if by “separate” you mean that CHO is not used for Cell DTX/ DRX cases?  As for Apple’s comment that DTX/DRX can get too aggressive for UE QoS, then this would be no different from any energy saving measure gNB can take e.g., Reducing Tx power or completely switching off. The gNB can use whatever scheme we develop here to offload UEs for any reason, so explicitly spelling out cell DTX/DRX in not recommended.  Rapp) RAN2 is starting with cell DTX/ DRX and/ or cell switch off. The solution developed here can be used in another scenarios/ techniques, there’s no attempt to preclude anything yet. |
| OPPO | Yes | Per the Rapporteur clarification, I understand the question intends to figure out the suitable case(s) that would trigger the enhanced CHO as well as avoid the detailed discussion on cell off (e.g. what is the definition of the cell on/off, whether cell on/off is periodic, etc). We are fine to discuss the use case(s) and prefer a unified CHO enhancement mechanism if it can cover multiple use case(s).  With this in mind, we understand at least those two cases below can be considered for the enhanced CHO, i.e. 1) source cell off, 2) source cell applies cell DTX/DRX if it intolerantly degrades the UE’s performance. |

## Definition of NES mode

Many companies expressed views on how to define “NES mode”:

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| *[Qualcomm] Proposal 1: Source cell NES mode means a cell that is observing low load and intends to offload all connected UEs and physically switch-off.*  *[Huawei] Proposal 1: “NES mode” means the cell is enabling an NES technique or turning off.*  *[Samsung] Proposal 2. RAN2 needs to discuss and determine the adequate NES modes for the CHO:*  *A. cell DTX/ DRX*  *B. spatial domain (e.g., adjustment of antenna ports, active transceiver chains)*  *C. power domain (e.g., adjustment of power offset values)*  *D. bandwidth domain (e.g., adjustment of bw, or BWP)*  *[Lenovo] Proposal 1: RAN2 discuss if one or more of the following terms are useful and should be defined in specification:*  *A cell in NES state*  *A cell not in NES state*  *A perfect target*  *An acceptable target*  *A sleeping target.* |

In the scope of this email discussion, we can limit the scope of “NES mode” to RRC Connected mobility. Later to include also the RRC Idle/ Inactive UEs, a more general definition can be agreed.

Coming to the definition itself, a definition should be meaningful from UE’s perspective and should differentiate between a cell in NES mode but in active time currently from cell not in NES mode or from a cell in NES mode and sleeping currently:

***A cell is in (or will enter) NES mode*** *means a NES cell is (or subsequently will be) saving energy but may or may not be in sleep (DTX/ DRX) “now”.*

***A cell is sleeping*** *if it is in NES mode and in DTX/ DRX idle/ sleep period “now”.*

Many companies have used phrases like “in NES mode, so above definitions are only used as a basis for driving this email discussion and companies may choose to use this for further work/ specification:

**Question 2: Are the following definitions acceptable to your company as way forward?**

***A cell is in (or will enter) NES mode*** *means a NES cell is (or subsequently will be) saving energy but may or may not be in sleep (DTX/ DRX) “now”.*

***A cell is sleeping*** *if it is in NES mode and in DTX/ DRX idle/ sleep period “now”.*

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| Company Name | Yes/ No | Comments |
| Xiaomi | With comments | The cell is in NES mode when the Cell DTX/DRX is configured and activated if the activation/deactivation mechanism is defined. |
| Huawei, HiSilicon | No | We don’t see the necessity to “differentiate between a cell in NES mode but in active time currently from cell not in NES mode or from a cell in NES mode and sleeping currently”. The “active time” and “sleeping” states of the NES techniques are switched quite dynamically, and could even be realized by L1/L2 signaling according to the discussion in Cell DTX/DRX, they should not affect the L3 mobility which is normally based on RRC message.  The definition of Nes mode should be simple and mean that the cell is enabling an NES technique or turning off.  Rapp) Then how to interpret someone saying that “cell is in NES mode”? What does it mean? |
| Apple | No | 1. We agree with Huawei that no need to define “A cell is sleeping”. 2. We are not sure whether it is really necessary to specify an official definition of “NES mode”. In our understanding, this discussion is because terminology of “NES cell” was captured in TR 38.864 and different company have different understanding on this terminology. However, since it is WI phase, we may avoid using terminology of “NES cell” in normative spec (e.g. we can just say “a cell which is adopting NES technology”). Then this issue doesn’t exist.   In summary, we suggest:  1. No need to capture “NES cell” or “NES mode” and its definition in normative spec.  2. In normative spec, if needed, we can just use “a cell which is adopting NES technology”, where NES technology can also be replaced by “Cell DTX/DRX” or others Rel-18 NES technology, depending on the text before and after the specification. |
| Intel | See comments | From the source cell pov, it would be good that CHO configuration is executed before the NES techniques are applied in the source cell so that the affected UEs are not impacted by the NES techniques. For the target cell pov, the UE should try to avoid selecting a target cell that has applied (or going to apply) a NES technique that may not be suitable to the UE. Hence we are not sure whether the above definitions are useful for the discussion. |
| Vodafone | No | It is for a reason we do not have official discussions during this meeting for NES definition and I think we should not have it here too. From our point of view, we should speak about Cell DRX/DTX capable UEs and in my view there is probably no need for NW definition.  Rapp) The main necessity from Rapp’s perspective is to ease our discussion. There’s no attempt here to force these definitions to specification. Rapp thinks that “cell is in NES mode” is not just one single scenario. |
| N*okia* | No | We don’t really see benefit of trying to decide definition now |
| Qualcomm | No | Unclear what any of these definitions achieve. These definitions lack specifics on what the UE is expecting and “now” emphasis seems to be an indirect agreement against introducing some CHO timer or some other proposals by companies. In this case, we can discuss timers’ proposals directly as we did in some questions below. In our view, Cell DTX/DRX applies for connected UEs and should stay this way. Source cell CHO implies that all UEs are asked to be offloaded from the cell; The exact reason the UEs are being offloaded via connected mode mobility does not need an airtight definition here. |
| OPPO | See comments | It may good to have a clear definition to understand what cell state would be considered for the enhanced CHO, e.g. the source cell is going to enter cell DTX/DRX non-active (or cell off), the target cell will enter or enters cell DTX/DRX non-active(or cell off). Considering there would be other cases applicable to the enhanced CHO, if we need to use a definition e.g. in the normative work, the definition would be future-proof. |

## 2.3 How often is a NES Mode changing (ON <-> OFF)?

Here are excerpts of what some companies think about NES mode/ status change (changing quickly or rather stable):

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| **Nokia**  Observation 1: NES mode changes can be frequent and relying on regular HO is not practical  Observation 4: In case NES mode of target cell is not frequently changing then NW can updates CHO configuration to UE based on neighbour cell information exchanged via gNBs.  Observation 5: If NES modes are very frequently changing exchanging this information between gNBs is not feasible.  **Intel**  Observation#8: The candidate PCells may apply the NES techniques at any time and this may change quite frequently (e.g. Cell DTX/DRX may be turned on and off dynamically). Hence Option 1 (target NES is indicated in CHO configuration) is not suitable.  **Sony**  Proposal 1: Network should notify the UE to start performing NES CHO execution conditions when the NES mode of source or candidate cells is going to change or has changed.  **NEC**  Proposal-5: Legacy CHO configuration update procedure is used to notify the UE the change of NES mode of the CHO candidate cell.  **Apple**  Observation 3: During discussion of study item phase, there were two concerns for the idea of CHO enhancement based on target cell NES mode:  The neighbor cell NES mode may change dynamically, and thereby the UE may need to read SIB of the neighbor cell to identify its NES mode.  **Interdigital**  Proposal 1: The change of the serving cell’s NES mode can be used as a new CHO trigger. FFS whether L1/L2 signalling indicating an upcoming NES mode change is needed for the trigger. |

The rate of change of NES mode (e.g., DRX/ DTX ON <-> DRX/ DTX OFF) may affect RAN2 solution design. If cell NES mode changes very often e.g., changes in milliseconds level or even 10s of milliseconds level is possible then RAN2 would look for a more dynamic signalling to inform UEs about the same but if a cell’s determination for power saving is based on more stable long term statistics then it is likely that once deciding to turn NES mode to ON/ OFF, the same will continue for longer time e.g., seconds or even minutes. Companies with former view may assume that energy saving can be done throughout the day/ night whereas companies with latter view may assume that energy saving mainly come from non-peak hour traffic when number of RRC Connected UEs is limited. In the below question, Rapporteur knowingly avoided a “middle-ground” option e.g., “every 100ms”, which may not help then which way to go for later discussions.

**Question 3: How dynamic is an NES mode change of a NES capable cell in your view?**

* Option 1: NES mode may change every 10s of milliseconds
* Option 2: NES mode may only change slower and once turned on/off remains so for seconds or longer (minutes/ hours)

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| Company Name | Option | Comments |
| Xiaomi | With comments | There is 2 option to explain the NES mode change:  Option a: from/to cell DTX/DRX active state to/from cell DTX/DRX non active state.  Option b: the cell DTX/DRX is configured/activated or the cell DRX/DRX is not configured/activated.  For option a, we think option 2 is reasonable. For option b, it may be several hours. |
| Huawei, HiSilicon | Option 2 | We think the discussion of “source cell NES mode” and “target cell NES mode” should be separated.  For source cell NES mode, we think the only beneficial scenario is the cell switching off (e.g., operator may want to switch off the cells during non-peak hours to achieve cost savings).  For target cell NES mode, we think it mainly includes the NES techniques that are being discussed in the WI, e.g. cell DTX/DRX. But the eventual (C)HO decision is up to source cell implementation. |
| Apple | Both are possible | Option 1 can't be precluded at this stage because dynamic L1/L2 cell common / UE specific signaling to activate/deactivate Cell DTX/DRX is still on the table. |
| Intel | Both | Both Option 1 and 2 look dynamic to us. In our understanding, the application of NES techniques duration can last for 10s of milliseconds or a few seconds (or longer) and both should be supported by specifications. |
| Vodafone | Option 2 | I would also agree that cells will not change their mode of operation very fast and once changed it will remain for a while. The main point if we consider Cell DTX/DTX is that the load is not changing very dynamically and in my assumption, there will be any way a timer/threshold to control it is not switched off/on in milliseconds.  For the case, the cell is going to be turned off, I think the cell will stay off at least for minutes |
| Nokia | Most likely option 2 | But it is not possible to omit option 1 now – RAN1 may come with some super frequent NES methods updates.  But e.g. turning of cell is not happening every few milliseconds but more or less minutes (at most). Cell DTX/DRX may change quite often depending on the load but even that does not seem necessary to change every few tens of milliseconds.  . |
| Qualcomm | 2 | CHO itself takes a while to complete including backhaul signalling so option 1 is unrealistic and generally RAN2 better stick to realistic mobility assumptions |
| OPPO | Option 2 | In our view, the change would be decided based on the statistics of system-level information or cell status, so the change may not be very frequent. |

# Source side

We start with a source side view where the source cell determines if it can save energy, and when so it starts handover preparation if otherwise the service maintenance to the UE will not be possible anymore without impacting the required QoS, eventually transmits a conditional RRC Reconfiguration message to a RRC Connected UE.

In this line, all companies agree to use CHO procedural framework for configuring one or more candidates, a vast majority of companies propose that some enhancement(s) for CHO procedure will be required, including likely new signalling – some companies [[1, 12, 21 and 23](#_References)] have concerns on pursuing enhancements. So, just to ensure that we are on the same page with respect to the work we need to do to fulfill parts of the WID, following question is being raised:

**Question 4: Do companies agree that some kind of enhancement in CHO procedure, including likely new signalling in conditional RRC Reconfiguration message would be required when either source cell or at least one of the candidate cell is in NES mode?**

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| Company Name | Yes/ No | Comments |
| Xiaomi | No | For Rel-18 NES capable CONNECTED UE(s), no matter the source gNB or targe gNB, the network can serve the UE with enhancements to ensure the performance. For legacy CONNECTED UE(s), no matter the source gNB or targe gNB, it is up to network implementation to serve the legacy UE with performance degradation. So it is not necessary to handover the UE from the cell even if the cell will enter NES mode.  Furthermore, when the network decides to configure the cell DTX/DRX for NEs purpose, there are no many active UEs on network and the service of the UEs is also not so active. So it is not urgent to handover the UEs to other non-NES cell and the group based handover is also not necessary. |
| Huawei, HiSilicon |  | It depends on the exact enhancement. We cannot have an agreement now without going to the details of the solution. Also, we have the following comments on the rapporteur descriptions:  1) “In this line, all companies agree to use CHO procedural framework for configuring one or more candidates” No we think legacy HO is also feasible when the source cells determines it can save energy and plans to handover some UEs.  2) This is under the discussion of source side, why “candidate cell” is mentioned in the question? |
| Apple | Yes | First, the benefit of CHO enhancement was extensively discussed in SI and the final conclusion is captured in TR 38.864. Not sure why repeating the same discussion in normative phase:  *During the switching of NES modes, it is possible to handover the UEs faster by enhancing the CHO framework with:*  *1. Evaluation of conditional handover conditions depending on the NES mode of source/target cell,*  *2. How to indicate to UE the triggering of the CHO evaluation is up to the WI phase.*    Secondly, we think RAN2 need to respect WID objective agreed in plenary:  *Specify CHO procedure enhancement(s) in case source/target cell is in NES mode [RAN2]*  Please note that it is NOT a conditional objective (i.e. without "if necessary"). So, more or less, RAN2 should do some work to fulfill this objective.  Finally, the use case of Rel-18 NES is "low load" rather than "low number of UE". It is a valid scenario that a large number of UEs are served by source cell but they have few traffic (e.g. midnight of community). |
| Intel | Yes |  |
| Vodafone | Yes | We believe the enhancements are needed for the source cell case. Then we are fine to discuss the case, the source cell is going to turn off and the source cell is going into cell DRX/DTX mode separately and see if the mechanisms applicable for one case, could be applicable for other. |
| Nokia | Yes | Agree with Vodafone comment. Most likely CHO source method needs to be discussed for each “NES method” separately in the end although the general principle is same e.g. trigger for event can be different. |
| Qualcomm | Yes | Obviously we have a decent baseline which is RRC unicast signalling and existing HO framework. However, we think that unicast RRC signalling takes too much time and causes too much overhead that the NW may prefer not to switch off to avoid the time delay and intensive RRC signalling.  To give an example of the benefit, this scheme is best understood as something that can be co-deployed with cell DTX/DRX. Consider the case where the NW starts deploying some form of cell DTX/DRX at 50% load and consistently sees less and less load until it decides to offload all UEs and enter “source cell CHO mode” where “source cell CHO mode” means the cell would physically be switched off, i.e., no UEs can camp or connect. In this case, we can assume the UE is applying a very aggressive cell DTX/DRX cycle right until CHO. Now to offload all UEs via L3 HO, the Cell needs to do one of two things:  1. Perform very slow RRC signalling over multiple cycles to offload all UEs via RRC signalling.  2. Deconfigure/deactivate Cell DTX/DRX to quickly perform L3 HOs for all UEs in the NW.  In this case, our argument is to bypass this L3 HO to every UE in-order to perform a HO operation by enhancing the CHO to allow for faster triggers. We understand that many companies have concerns over the perceived benefits and encroaching into the LTM territory, thus, it would be fair to use this email discussion to converge on a solution then we can rediscuss if the NES gains are worthwhile. |
| OPPO | Yes | It is a straightforward way to implement what we concluded during the SI phase and the objective approved in NESWID. |

## 3.1 When to start CHO condition evaluation

Going to the next logical part of the discussion, we will touch upon when to start CHO condition evaluation at the UE side when either source cell or at least one of the candidate cell is in NES mode. Some proposals have been made in this regard:

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| ***Apple***  *Observation 2: If UE group common L1/L2 signaling is introduced, RAN1 needs to design a new UE group common DCI, but RAN1 is not involved in the WID objective of CHO enhancement.*  *Proposal 5: The basic procedure of CHO enhancement based on source cell NES mode is described as below:*  *Source cell configures both legacy CHO condition and NES specific CHO condition to a group of Rel-18 NES capable UE(s) via legacy UE dedicated CHO command.*  *Upon reception of CHO command, the UE immediately starts to evaluate legacy CHO condition, and stores the NES specific CHO condition (i.e. not evaluation of NES specific CHO immediately).*  *Proposal 6: RAN2 discuss the following 2 alternatives on how the UE detects the source cell enters NES mode:*  *Alt-1: via detection of signaling to apply one or more NES technique(s), e.g. RRC signaling to apply Cell DTX/DRX or SIB to indicate legacy UE barring.*  *Alt-2: via reception of a UE group common L1/L2 signaling from gNB*  ***CMCC***  *Observation 4: Timer-based event for NES events is useful only if the gNB has accurate prediction/information of the cell load.*  *Proposal 5: If the CHO execution condition is not timer-based event, once UE is indicated the NES mode or cell on/off state switch, the indication can trigger the UE to perform handover immediately.*  ***Lenovo***  *Proposal 5: UE should start the evaluation of the candidate cell upon reception of CHO.*  ***NEC***  *Proposal-10: The CHO configuration for NES can include a timer-based condition, where the timer starts upon triggering the CHO condition evaluation.*  ***Intel***  *Observation#7: Using dedicated/group common L1 signalling (e.g. DCI) provides a fast and in timely manner for the indication to indicate NES technique(s) is to be applied or the source PCell is to be turned off.*  ***Vivo***  *Proposal 4: If T1 event is used as CHO execution condition for solving handover storm, the UE determines T1 event based on the preconfigured relative time offset and the reference time provided via the explicit trigger.*  ***ZTE Corporation, Sanechips***  *Observation 1: A time based CHO triggering event could be used for triggering handover before DTX/DRX in source cell would cause the large delay of transmission.*  ***Qualcomm***  *Proposal 2: To realize this source cell CHO, two aspects need to be enhanced over legacy CHO:*   * *RRC configuration of CHO is extended to include the required behaviour, i.e., allowing for CHO that is explicitly triggered by signalling.* * *L1/L2 trigger is introduced to invoke a preconfigured CHO procedure for NES purposes.* * *Possible introduction of a CHO time-to-execute T that can be used to instruct the UE to:*   + - 1. *Start evaluating CHO conditions after a time delay T.*       2. *Perform CHO to the best target cell after a time delay T.*   *Proposal 3: RRC CHO configuration is enhanced to include a new NES-CHO configuration that can be performed upon receiving an L1/L2 trigger from gNB and optionally after a time T*  ***Huawei, HiSilicon***  *Proposal 2: For L1/L2 triggered CHO, the benefits (e.g. faster HO) should be further justified, in the context of network energy saving.*  ***Oppo***  *Proposal 1: RAN2 considers either of the following on how to trigger CHO execution due to the cell off/NES of the source cell.*  *• Alt1: A UE executes the CHO once it is the time for the source cell to enter cell off/NES. The time information of the source cell can be pre-configured to the UE.*  *• Alt2: A UE executes the CHO once it receives a specific L1/L2 UE group common signalling.* |

We can carry this discussion in two parts:

First, a UE may need time to evaluate HO condition(s) for included candidates, attempt to execute handover and even to possibly fallback (to source or reestablish connection) before the source cell would/ should actually start to sleep. So, CHO evaluation should start at Point A (somewhat before point B) in the below figure. In a first option, Point A can be chosen by the network and coincides with reception of CHO reconfiguration at the UE. On the other hand, if CHO evaluation is triggered at point B when the source cell is about to enter sleep then there will be time period until which the UE will not have service due to impending condition evaluation, handover execution etc.

**Question 5: Do you think that handover condition evaluation for any candidate cell starts *sometime* before source cell enters sleep/ inactive time?**

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| Company Name | Yes (= Point A[[1]](#footnote-1))/ No (= Point B) | Comments |
| Xiaomi | Yes | The UE evaluate the candidate cells after the reception of the conditional RRC Reconfiguration message, i.e., no enhancement on CHO for NES. |
| Huawei, HiSilicon | Yes, but | Yes but we don’t think source cell DTX/DRX is a target scenario, we prefer to change “Cell DRX/DTX” in the figure to “Cell switching off”. |
| Apple | Yes | We think that the UE shall follow legacy CHO behavior before entering NES mode (i.e. start evaluation of the candidate cells upon reception of CHO config). And if CHO condition is satisfied, the UE shall handover to another cell (i.e. follow legacy behavior).  However, this doesn't preclude enhancement for below new NES specific CHO scenario:   * The source cell enter NES mode (e.g. turn off) but there is no candidate cell satisfying CHO condition   For this scenario, we think a simple enhancement is that the UE can apply a relaxed condition of CHO evaluation (e.g. an offset of threshold for configured CHO A3/A5 event), so that the CHO condition can be easily satisfied. |
| Nokia | Yes | Agree with Xiaomi (and we don’t follow rapporteur “sleep” reference? Is it generally any NES mode) |
| Intel | Yes (Point A), but see comments | Firstly, we note there are two ways to model this. In our understanding, the model used in this email discussion is to do the evaluation only at that the time of the trigger in Q6. Another model (that we were using in our contribution) would be to do the evaluation from the time of reception of the CHO configuration but only perform the execution at the time of reception of the trigger. Both models are OK but it would be good to understand the model being used in relation to the comments. Our comments below are based on the assumption that the model used in this email discussion is as described above.  While we don’t think evaluation and HO execution takes very long, using point A to be a little earlier than the actual ctivating of the NES will be useful to ensure all the UEs have been handed over.  We also believe that CHO configuration needs to be sent in advance for the following reasons:   1. Prevent surge in sending CHO configuration at the point where network decide to perform NES technique (this can be avoided via sending the CHO configuration in advance and spread over time)   ii. Avoid delay in the preparation of the handover (sending the CHO configuration in advance) if decided at the point where network decide to perform NES technique  iii. Avoid delay in the sending of the CHO configuration due to sending at the same time, not just UE RRC processing |
| Vodafone | See R2-2303161 | We are not sure, why our document is not listed here. In our understanding the additional conditions (in our view, it is just the best RSRP level of the cells configured for CHO) associated with NES mode (switched off or entering Cell DRX/DTX mode) are evaluated once RRC message is received. |
| Qualcomm | Yes | In our view, after point B (at which the cell should just sleep as there is no point to this ON-OFF cycle except confusing UEs) does not make sense, so point A is the better option. The more interesting question, if a trigger is agreed, whether the UE needs to evaluate CHO conditions before the trigger is received. The question depends on whether an NES CHO configuration doubles as a normal CHO configuration that the UE is evaluating anyway. |
| OPPO | Yes | In our view, the UE can evaluate the candidate target cells upon receiving the enhanced CHO configuration, i.e. Point A. The UE would execute the CHO once the source cell is judged to enter cell off/NES mode (i.e. based on a T1-like event but which is associated with the source cell NES/off time duration) or the additional triggering signalling).  One follow-up question: if there is a long gap between Point A and Point B and if a suitable target cell has been evaluated/found before Point B, e.g. based on RSRP-related CHO execution condition contained in the enhanced CHO configuration, whether the UE needs to hand over to that suitable target cell directly? |



Figure 1: Point A appears sometime before cell starts to sleep (Point B)

Second, if you chose point A for the above question, a second option to define Point A is by using a later trigger after the reception of the conditional RRC Reconfiguration message e.g., timer based (where timer value is signalled in CHO i.e., in conditional RRC Reconfiguration message) or L1 L2 signalling or broadcast signalling. In this option, the conditional RRC Reconfiguration has been sent to the UE sometime before point A. While generally network can choose a “right time” to transmit conditional RRC Reconfiguration to the UE, a separate point A would mean that there’s value in triggering CHO evaluation (i.e., point A) more dynamically – this may depend on your views on Question 3, discussed previously.

While “timer-based” may not allow such dynamic nature, as (and if) the timer value is to be included in conditional RRC Reconfiguration, L1 L2 based dynamic signaling can overcome this demerit. A broadcast based approach may need to overcome new hurdles to ensure SI changes are seen as-and-when and before modification boundary changes.

Accordingly, following broad options on “when to start CHO condition evaluation for NES triggering” can be seen:

* 1. Immediately upon receiving CHO configuration like in legacy
  2. A timer based approach (in this case please also indicate how the timer value is signalled to the UE)
  3. L1 L2 signalling
  4. Broadcast signalling approach
  5. Others (please clarify)

**Question 6: Which of the above option on “when to start CHO condition evaluation** **for NES triggering” do you find as most sensible?**

|  |  |  |
| --- | --- | --- |
| Company Name | a/ b/ c/ d/ e | Comments |
| Xiaomi | A | Same as legacy CHO. |
| Huawei, HiSilicon | A, B | Legacy scheme (a) is of course feasible. Time-based CHO (b) is also in legacy spec. But before going for time-based CHO, we would like to check if companies have the same understanding that this applies mainly to the case when the source cell plans to switch off (e.g. during non-peak hours). |
| Apple | b, c, d  (down-selection can be in future meeting) | We think b, c, d are solutions on the table, and RAN2 can further down-select among them. It is no hurry to make decision now because there are 5 remaining RAN2 meetings for NES.  Please note that timer based approach (i.e. option b) also needs spec change at least for below highlighted part in TS 38.306:  ***timeBasedCondHandover-r17***  Indicates whether the UE supports time based conditional handover, i.e., *CondEvent T1* as specified in TS 38.331 [9]. A UE supporting this feature shall also indicate the support of *condHandover-r16* for NTN bands and the support of *nonTerrestrialNetwork-r17*. UE shall set the capability value consistently for all FDD-FR1 NTN bands.  And below issue needs further discussion:  1) Whether a UE which doesn’t support NTN can use event T1.  2) Event T1 is based on absolute UTC time. This is always feasible for NTN UE because they are always equipped with GNSS. However, if a NES UE doesn’t equip GNSS, whether such UE can apply event T1? |
| Intel | c (please also see comments) | Please also refer to our comments on Q5 on the modelling.  In terms of final execution, we believe that L1/L2 trigger and the RF conditions of the CHO has to be met. Whether the RF evaluation starts at the time of the reception of L1L2 signal or from the time of reception of CHO command is a modelling aspect. |
| Vodafone | d | At least for the case cell switched off, the broadcast signaling is fully sufficient. We also do not think, there is any specific enhanced NES CHO configuration (and therefore we do not think Option A is applicable). The UE executes once of the CHO configurations received before once it receives the RRC message, choosing the best cell. For Cell DRX/DTX case, we should discuss it more, but also here, the RRC broadcast signaling should be sufficient. |
| Nokia | A | Quite confusing discussion. Why would we change legacy CHO evaluation. Only thing we need is to have additional trigger (in addition to radio condition) to trigger event in case “NES mode” is entered (I guess that is “sleep” mode mentioned by rapporteur?) |
| Qualcomm | a/c | Option a, if the configuration doubles as a normal CHO configuration, e.g., target cell is configured A3/A5 as a legacy CHO, but may apply a relaxed A3/A5 condition upon receiving an L1/L2 trigger. Option c, if the CHO configuration is only for NES-triggered CHO, i.e., UE does not need to evaluate target cell before the trigger.  For the timer, we think it can be introduced (if need) between receiving the trigger and executing the CHO, so in this case the evaluation is done during the time the timer is running, not wait for timer expiry to start evaluation. |
| OPPO | a for evaluation,  b/c for execution triggering | We may need to distinguish the CHO evaluation and CHO execution. In our view, the UE evaluates the candidate target cells upon receiving the enhanced CHO configuration, which is the same as the legacy. The CHO enhancement focuses on the new execution triggering, including e.g. time-based and signaling-based triggering.   * If we apply time-based CHO execution triggering, which we understand is categorized into option b, the time duration is associated with the source cell. Such time duration reflects the time duration of the source cell NES/off and is contained in the enhanced CHO configuration. * If we apply signalling-based CHO execution triggering, the signaling is sent before the source cell is about to apply NES/off   Answer to Apple:  Generally, we agree that spec change is needed but its impact is limited.   1. No, we do not intend to require the UE to support NTN. That is why we think the time-based method is similar to *CondEvent T1* but not the same. 2. It is correct, not all UEs support GNSS. We think we can use reference SFN to indicate the start time of the source cell applying NES/off. But, we are also open to other solutions. |

## 3.2 Measurement Events

Which events are used as conditions in a CHO configuration? Following events have been mentioned:

1. A3 [7, 11]
2. A4 [1, 7, 11, 13, 20]
3. A5 [7, 13]
4. A new condition “NES trigger” attached to these events [7]
5. A new trigger [2]: “*off duration of DTX/DRX configuration in the NR PCell is higher than a threshold1 and off duration of DTX/DRX configuration in the neighbor Cell is lower than a threshold2*”

**Question 7: Which of the above event(s)/ condition(s) can be used in your opinion as conditions in a CHO configuration for each/ some of the candidate cells included?**

|  |  |  |
| --- | --- | --- |
| Company Name | Option(s) | Comments |
| Xiaomi |  | Same as legacy CHO. |
| Huawei, HiSilicon | A3, A4, A5 | condEvent A3 and condEvent A5 are already in the current spec.  condEvent A4 is also in current spec with the restriction that it applies only to NTN or CPA and MN-initiated inter-SN CPC in terrestrial network. |
| Apple | A3, A4, A5 | See no reason to preclude any existing CHO event. |
| Intel | b)+ d). That is, A4 and new NES trigger condition | As mentioned in our response to Q5, we believe CHO configuration has to be provided in advance of the cell activating the NES technique or Cell off. As it is related to inter-frequency CHO and the serving cell may still be in good radio condition, Event A4 is needed to allow the UE to move other cell. But we also need d) to time the execution of the CHO with the cell turning on NES. |
| Vodafone | A3,A5 | We do not propose to enhance trigger events for CHO, but we need a trigger from the NW (see my previous comments) |
| Nokia | Any | We are fine to have any event – Unless there is issue for some specific event to introduce it but we don’t see now. So basically we would question that if source cell based CHO NES mode is specified why would we not allow it for any event (if it comes for free)? |
| Qualcomm | d | A cell switching off would inform the UEs via some L1/L2 trigger to execute one of the CHO configurations available. UE can perform a step of evaluation of A3-A5 before executing CHO, but our view is that the trigger would be the enhancement over legacy |
| OPPO | A3, A4 | A3/4 if we are talking about radio link-related measurement. If the question also covers other aspects to be measured, e.g. measure whether it is the time to enter source cell NES/off, we would also like to include time measure, and are open to discuss others. |

# Target side

On legacy handover condition(s) fulfillment towards a candidate cell for conditional handover, there’s no visible difference of opinion among companies. However, for new NES state related enhancement/ aspect, following options are brought forward by companies:

* UE implementation [Nokia]
* Network provides additional prioritization for candidate cells [Fujitsu, Apple, OPPO]
* Choose candidate(s) with same NES mode as source cell [Fujitsu]
* Source cell obtains the candidate cell NES state and source cell implementation to utilize the candidate cell NES state to configure suitable candidate cells to the UE [HW]
* Source Network provides NES state flag/ information of candidate cells [QC, Ericsson P2, Sharp, Fujitsu, NEC, IDT, Lenovo, CMCC, OPPO]
  + DRX/ DTX configuration for each candidate cell in CHO command [Lenovo]

|  |
| --- |
| ***NOKIA***  *Proposal 1: Add for events A3, A4 and A5 a additional parameter that indicates that event is triggered only if “NES trigger” is active for the source cell.*  *Proposal 2: “The NES trigger” would be at least for the use case of turning off the cell (whether other triggers are enabled is FFS and need to wait that WI progresses on other aspects of the WI).*  *Proposal 3: It can be left up to UE implementation to select target cell out of multiple candidate CHO cells.*  ***Fujitsu***  *Observation 7: It is useful to select the target cell as the same cell mode as the source cell.*  *Proposal 5: For target cell case, the priority information is additionally provided by the source cell.*  ***Apple***  *Proposal 7: For CHO enhancement based on target cell NES mode, introduce a gNB configured priority value for each candidate cell based on their NES mode. The UE is not required to detect NES mode change of the candidate cell(s).*  ***Ericsson***  *Proposal 2: Enhance CHO procedure to enable priorization of candidate target cells by the UE based on NES mode.* |

## 4.1 Finding right target cell

There was some initial online discussion on this from the last [#121] meeting. From some of the contributions it is not fully clear how a sensible UE implementation makes consistent decision on mobility without any information provided by the source and/ or reading system information from the candidate cell – which is generally avoided for handover execution.

Further, it seems a majority of companies believe that some sort of information/ aid from the source cell needs to be provided to the UE to help it decide on a target cell among candidate cell(s) that have fulfilled handover condition(s) included in conditional RRC Reconfiguration message.

While additional prioritization per candidate cell can be easy from UE implementation perspective, it is unclear how network would prioritize e.g., two cells on the same frequency that are in NES mode but have very different duty cycle and/ or how would network prioritize among cells where some of the cell is/ are in “active” time but the others are sleeping – at the time of sending the conditional RRC Reconfiguration message to the UE!

As another option brought forward by some company “Choose candidate(s) with same NES mode as source cell”, is simple and requires only a Boolean indication per candidate cell but suffers from the same demerits as for the previous option. The same is perhaps also true of “NES state flag” like proposals.

However, if the UE were to be provided with DRX/ DTX configuration of each candidate cells, where the offset is aligned with the source cell’s downlink timeline, UE itself can plot the DRX/ DTX cycle of a candidate cell and see if the cell is sleeping or active “now”.

**Question 8: Which of the following option do you think will ensure better chances of UE finding service immediately after executing conditional handover?**

1. UE implementation
2. Network provides additional prioritization for candidate cells
3. Choose candidate(s) with same NES mode as source cell / Source Network provides NES state flag of candidate cells
4. DRX/ DTX configuration for each candidate cell in CHO command and implicitly/ explicitly NES mode of source as well as included candidate cells
5. Network can provide a subset of CHO candidates as part of the CHO trigger
6. Network implementation to (re)configure the candidate cells

|  |  |  |
| --- | --- | --- |
| Company Name | a/ b/ c/ d/ e/ f | Comments |
| Xiaomi | a) with comments | If the question 8 is based on CHO case, then I think it is not possible to configure the NES mode of target cell in CHO if the NES mode changes frequently. So option a) is feasible.  For legacy HO case, it is up to RAN3.  Anyway, the target can serve the UE no matter the UE is NES capable UE or legacy UE. If the target cell think it cannot meet the Qos of the UE , the network can leave the NES mode. |
| Huawei, HiSilicon | f | As indicated in our paper R2-2303102, we think it’s better to leave it to NW implementation. If the source cell does not filter the candidate cells by the NES mode and configure more candidates cells for UEs to choose from, all the configured candidate cells need to reserve resources, especially considering the candidate cells may be an NES cell whose main motivation is to save power and avoid excessive wireless resources consumption. |
| Apple | a) | We can leave it to UE implementation. |
| Intel | e) | If multiple candidate cells satisfied the execution condition for NES, it can be left to the UE implementation, but we are also fine if some priority is provided for this case. |
| Vodafone |  | NW should ensure the Handovers do not take place to the cell going to be switched off or where cell DRX/DTX is switched on. No enhancements for this case are needed in RAN2. Moreover the target NW should not configure CHOs once in Cell DRX/DTX mode or going to be switched off. |
| Nokia | a/f | A might be needed if there is possibility to have multiple candidate target cells in CHO events. We are also OK to limit only to one. Then no need to have A => then it means network needs to apply f) solution in some scenarios |
| Qualcomm | a+b | When CHO conditions are true for multiple cells, the UE can leverage information from source cell about the NES mode of the target cell to select a target cell. We don’t think this should be hard-coded into CHO configuration so as to not to complicate UE implementation of CHO evaluation by enforcing too many checks before/during CHO, but we foresee this as useful information for UE implementation in target cell selection. |
| OPPO | b/d/a | b/d has a benefit if more than one cell fulfils the CHO execution condition. But a is also acceptable to us. |

## 4.2 Failure case

Some companies mentioned that it may not always be possible to find perfect target cells, fulfilling not only handover condition(s) but also one that is in active time when the UE is about to execute handover. What can be done in such situation? Some proposals were made as follows:

|  |
| --- |
| ***Ericsson***  *Proposal 1: Network needs to know if there are no good enough candidate target cells for CHO at the time cell is going to deactivate or enter cell DTX/DRX.*  *Proposal 3 If the UE is performing HO or CHO and experiences HO failure due to cell being in NES mode, UE should inform the network about the HO failure cause.*  ***Lenovo***  *Proposal 7: RAN2 kindly discuss further how to handle cases when there’s still no perfect target or an acceptable target when the source cell is about to enter sleep.*  ***Vivo***  *Proposal 5: After receiving the explicit signaling to trigger CHO, if the UE cannot find a candidate cell satisfies the execution condition (e.g., A4 event), the UE should notify the source cell within a certain time.*  ***Oppo***  *Proposal 2: If CHO execution is triggered due to the cell off/NES of the source cell and if the network also configures the UE with the CHO execution event (e.g. A3 or A4), the UE needs to select the target cell from candidates for which the CHO execution event related to channel quality is satisfied. If such a CHO execution event cannot be satisfied for any of the candidate cells, the UE needs to choose the candidate cell with a better channel quality.* |

So, mainly two options emerge from the proposals made by companies:

1. UE reports to source cell if there are no good enough candidate target cells for CHO at the time cell is going to deactivate or enter cell DTX/DRX. Rapporteur thinks that the source cell may possibly stretch its active time (i.e., postpone sleep when e.g., user is on a voice call with you know who…) or may just ignore the UE’s situation (e.g., if user is surfing 6G videos).
2. UE chooses a candidate cell with best radio quality among all candidates evaluated even if the said cell has not fulfilled the stipulated radio condition(s). Rapporteur thinks that this may not avoid choosing a sleeping target though.

**Question 9: If there are no good enough candidate target cells for CHO at the time cell is going to deactivate or enter cell DTX/DRX, the UE shall:**

1. **Report the situation to source cell**
2. **Choose the best among worst candidate cells**
3. **The UE applies a relaxed condition of CHO evaluation (e.g. a threshold offset for configured CHO A3/A5 event). If still no candidate target cell satisfies the condition, follow legacy procedure.**

|  |  |  |
| --- | --- | --- |
| Company Name | Option | Comments |
| Xiaomi | 1. With comments | The UE can report the situation to the source cell. |
| Huawei, HiSilicon | None | We think in this case, the legacy behavior should apply, e.g. UE triggers RRC re-establishment. Alternatively, the NW can configure RRM measurements to UE (this is common practice for RRC\_CONNECTED mode UEs) and know there is no good enough candidate via the measurement report by the UE, and NW uses legacy HO command to handover the UE to a relatively good target cell. |
| Apple | c),  b) can be further considered | We disagree a) because it can be achieved by NW implementation. Note that in legacy CHO, source cell can still configure measurements towards candidate target cells after CHO is configured. Therefore, based on UE measurement reporting, the source cell can always know the radio condition of candidate cells, and can do anything accordingly (e.g. postpone cell sleep).  We have sympathy with intention of b), but it has 2 issues:   1. The best candidate cell may still have poor radio condition, so the mandating UE to choose such cell will result in RLF. 2. If source cell just activates Cell DTX/DRX with a long non-active duration, the UE can still stay in source cell if no candidate cell with good radio condition is available.   Thus, we are fine to continue discuss b) and improve it.  For c), we think it can resolve the issues with minor spec change:   * It can resolve issue 1) of b), i.e. we still have a RSRP/RSRQ threshold to restrict UE to select candidate cell with poor radio condition. * It can also resolve issue 2) of b), i.e. source cell can (by its implementation) configure different threshold offset depending on whether it plans to tun off or activate cell DTX/DRX. * It is on top of existing CHO framework with minor spec change. |
| Intel | None | We think this will not be a normal case but a corner case. We can leave this to existing RLF handling. |
| Vodafone | See my previous comment | Happy R2-2303161 is also included into this summery as we clearly propose not to introduce any new mechanism for the target cell case |
| Nokia | None of proposed solutions | We tend to agree with Intel i.e. if no candidate cell fulfills condition then we can rely on basic RLF handling |
| Qualcomm | A | Obviously, we would like to avoid RLF for the UE based on that so we can discuss how the gNB can confirm that the UE has performed a successful CHO, e.g., either via UE signalling or legacy backhaul HANDOVER SUCCESS message from target cell |
| OPPO | b | The intention of option b is to provide an additional chance to switch the UE when the source cell is about to enter NES/off. In our view, sometimes the best cell among the worst candidates can serve the UE (temperately) and may hand over that UE to a more suitable cell if needed. If the best cell among the worst candidates is not good enough, the UE would trigger RRC re-establishment.  On option c, we are open to further discussing it. |

# References

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2. R2-2302837 Further discussion on connected mode mobility ZTE Corporation, Sanechips discussion Rel-18 Netw\_Energy\_NR-Core Late
3. R2-2302925 NES Connected mode mobility Qualcomm Incorporated discussion Rel-18
4. R2-2303077 CHO for NES Ericsson discussion Rel-18 Netw\_Energy\_NR-Core
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11. R2-2303311 Discussion on connected mode mobility OPPO discussion Rel-18 Netw\_Energy\_NR
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13. R2-2303370 Discussion on CHO enhancement in NES Apple discussion Rel-18 Netw\_Energy\_NR-Core
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20. R2-2303824 Conditional handover enhancement for network energy saving vivo discussion Rel-18
21. R2-2303853 Discussion on UE mobility due to NES cell Xiaomi discussion
22. R2-2304155 Discussion on CHO procedure enhancements in case source/target cell is in NES mode Turkcell discussion Rel-18
23. R2-2304180 Connected Mode Mobility LG Electronics Inc. discussion Rel-18 Netw\_Energy\_NR-Core

# Conclusion

1. Point A and B are drawn in Figure 1 [↑](#footnote-ref-1)