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.

First, kindly fill in the contact information:

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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*
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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.
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## 2.2 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. |
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## 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 practicalObservation 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

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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. |
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# 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. |
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## 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. |
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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?**

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| Company Name | a/ b/ c/ d/ e | Comments |
| Xiaomi  | a | Same as legacy CHO. |
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## 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, 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?**

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| Company Name | Option(s) | Comments |
| Xiaomi  |  | Same as legacy CHO. |
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# 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]
* Choose candidate(s) with same NES mode as source cell [Fujitsu]
* Source Network provides NES state flag/ information of candidate cells [QC, Ericsson P2, HW, Sharp, Fujitsu, NEC, IDT, Lenovo, CMCC]
	+ DRX/ DTX configuration for each candidate cell in CHO command [Lenovo]

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| --- |
| ***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

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| --- | --- | --- |
| Company Name | a/ b/ c/ d/ e | 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. |
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## 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:

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| ***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**

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| Company Name | Option | Comments |
| Xiaomi  | 1. With comments
 | The UE can report the situation to the source cell. |
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# References

1. R2-2302764 CHO enhancement for NES CATT, Turkcell discussion Rel-18 Netw\_Energy\_NR-Core
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
5. R2-2303080 Handover enhancement for NES Sony discussion Rel-18 FS\_Netw\_Energy\_NR
6. R2-2303102 Discussion on CHO enhancement for NES Huawei, HiSilicon discussion Rel-18 Netw\_Energy\_NR
7. R2-2303128 CHO on NES Nokia, Nokia Shanghai Bell discussion Rel-18 FS\_Netw\_Energy\_NR
8. R2-2303146 Discussion on CHO enhancements for NES Sharp discussion
9. R2-2303161 Triggering conditions and other aspects of the Handover to/from DTX/DRX cells Vodafone España SA, Apple discussion Rel-18
10. R2-2303259 Discussion on Connected mode mobility for network energy savings Fujitsu Limited discussion Rel-18 Netw\_Energy\_NR-Core
11. R2-2303311 Discussion on connected mode mobility OPPO discussion Rel-18 Netw\_Energy\_NR
12. R2-2303317 CHO procedure enhancement to support NES mode NEC Telecom MODUS Ltd. discussion
13. R2-2303370 Discussion on CHO enhancement in NES Apple discussion Rel-18 Netw\_Energy\_NR-Core
14. R2-2303481 DRAFT LS for Enhanced handovers towards cells with activated cell DTX/DRX or cells which are going to be switched off Vodafone LS out Rel-18 To:RAN3
15. R2-2303512 CHO procedure enhancements for NES Intel Corporation discussion Rel-18 Netw\_Energy\_NR-Core
16. R2-2303602 NES mobility aspects InterDigital discussion Rel-18 Netw\_Energy\_NR-Core
17. R2-2303654 CHO Procedure in NES Mode Lenovo discussion Netw\_Energy\_NR-Core
18. R2-2303749 Discussion on Connected mode mobility for NES Samsung discussion Rel-18
19. R2-2303793 Discussion on Connected mode mobility enhancement for NES CMCC discussion Rel-18 Netw\_Energy\_NR-Core Late
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)