3GPP TSG-RAN WG2 Meeting #123 R2-230xxxx

Toulouse, France, August 21-25, 2023

Agenda Item: 7.7.4.2

Source: CMCC

Title: Report of [Post122][114][NR NTN Enh] Unchanged PCI (CMCC)

Document for: Discussion and Decision

# 1 Introduction

The HO signaling overhead reduction is one important topic of the R18 NR NTN due to the frequent (seconds, tens of seconds or hundreds seconds of HO frequency) and unavoidable handover for a large number of UEs. And PCI unchanged (i.e. no handover) is an effective solution to reduce signaling overhead. Further, in RAN2 121bis meeting, we have agreed that in quasi-earth fixed cell case, for hard satellite switch in the same SSB frequency and same gNB (no key change), satellite switching without PCI changing (not requiring L3 mobility) is supported.



Figure 1 PCI unchanged in quasi-earth fixed cell case

And in last meeting, RAN1 has also confirmed the feasibility about hard satellite switching in the reply LS R1-2306210, as follows:

***Question 1:*** *For**hard satellite switching without PCI change, if RAN1 identifies any major technical issues?*

***Reply:***

*RAN1 discussed the resynchronization of UE when hard switching, given that new common TA, K\_mac, ephemeris and cell-specific K-offset are applied during resynchronization to new satellite.*

*From RAN1 perspective, no feasibility issue is identified for hard satellite switching without PCI change.*

Hence, to progress the discussion on unchanged PCI, this offline discussion aims to address the left issue and reach some agreements for unchanged PCI in 7.7.4.2 as follows:

** [Post122][114][NR NTN Enh] Unchanged PCI (CMCC)**

Scope: Discuss aspects related to satellite switch with no PCI change. e.g. re-synchronization aspects

Intended outcome: Summary of the email discussion

Deadline: August 5th 10:00 UTC

# 2 Discussion

## How does UE re-sync to a new satellite

In the last RAN2 meeting, we have some discussions on how does UE re-sync to a new satellite, and reach the agreement as follows:

Agreements:

* t-Service in SIB19 can also be interpreted by Rel-18 UE in Connected mode to know that a satellite change or feeder link change happens
* In hard switch unchanged PCI scenario (i.e. no handover), the UE needs to know the time the UE attempts to re-synchronize. (FFS whether a new “t-Start” / a t-gap is needed or whether t-Service can be reused (i.e. no other IE) if the gap is very short/zero).

Therefore, for re-synchronize time, we could extract the following candidate solutions:

**Option 1:** Introduce a new “t-Start” (corresponding to incoming satellite starts providing coverage for the serving cell)

**Option 2:** Introduce a new t-gap (time duration between the current serving satellite and the incoming satellite starts providing coverage for the serving cell)

**Option 3:** reuse t-service (i.e. no other IE) with the condition that the gap is very short/zero

**Question 1: Please provide your preferred option listed. If you have any other preferred option, please provide it in the table and your argument.**

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| --- | --- | --- |
| **Company** | **Preferred option** | **Comments** |
| OPPO | Revised option 2 | Introduce a new t-gap (time duration between the current serving satellite stopping providing coverage for the serving cell and the incoming satellite starting providing coverage for the serving cell)  Option 1 will consume more bits than option 2.  Option 3 does not indicate exact time when UE can re-synchronize with the new satellite, which may complicate UE’s implementation. |
| Huawei, HiSilicon | Option 3 | We think the unchanged PCI is mainly suitable for short/zero/negligible gap scenarios.  With Option 3, UE simply performs re-synchronization upon t-Service, there is nothing complicated.  NR NTN has never discussed discontinuous coverage case, and assuming a gap will complicate UE implementation from our perspective. |
| CATT | option 3 or Option 1 | For option 1, even though only hard satellite switch case has been confirmed by RAN1 to support PCI unchanged, but considering the future compatibility for soft satellite switch case, the option 1 is more flexible due to it is applicable for both hard and soft satellite switch case.  If only taking the hard satellite switch case into consideration. That depends on the gap length.  According to the analysis in contribution R1-2304756 submitted in RAN1#113, the gap is mainly caused by RF switching, which will be less than 1 ms in general. On this basis, with considering the propagation difference of the source satellite and target satellite, the interval before UE can search for SSB of the serving cell via target satellite will less than 10 ms. Hence, the interval can be omitted and t-Service can be used for re-sync indication. i.e. option 3 could work. |
| Fujitsu | Option 3 | If there is long gap between 2 cells in sequence, the NW should use legacy handover procedure. Hence, before introducing options 1 or 2, it should be discussed whether we should consider the long gap scenario as an applicable case. |
| vivo | Option 1 or 3 | Same view as Huawei to not couple the unchanged PCI mechanism with discontinuous coverage. They are not necessarily correlated with each other.  Between option 1 and option 3, we slightly prefer option 1 as a neater signaling design, since option 3 still needs additional signaling for the indication (as seen in Q4 later). |
| NEC | Option3 | Agree with Huawei and CATT regarding option3. |
| Qualcomm | Option 1/2, but see comments | The option 1 should not be viewed as allowing discontinuous coverage. We think it is just giving network a small time to prepare new satellite and switch.  It is possible network is able to set t-Start = t-Service and that is ok and even very good. But we want to be sure, there is SSB to detect at t-Start.  But we agree t-Start can be defined as delta time duration as t-Start = t-Service + delta, where delta = {0, x, y z, …). Therefore, the option 1 and option 2 are equivalent.  In our understanding, t-Start is not for resynchronizing as there is no signal to synchronize before t-Start. We should discuss whether/how to define synchronization gap (t-Sync). What happens if UE fails to synchronize within t-Sync.  So we have to be clear on two types of gap, see below.  So t-Start and t-gap is not same. We can make t-Service = t-Service, that is ok but it should be clear. |
| Xiaomi | Option 3 | For option 1 and option 2, UE may declare RLF during the t-gap or between the t-service and t-start, thus new UE behavior in this time should be defined, for example, UE don’t perform RLM or don’t declare RLF and only re-synchronize to the network.  For option 3, UE re-synchronize to the network and the legacy behavior on RLM and RLF can be reused. |
| Ericsson | Option 1/2 | This question is not exclusive to unchanged PCI and should be extended to cover the general service link hard switch case.  A minimum gap (order of milliseconds) may happen at the implementation level due to synchronism and propagation delay, as pointed out by CATT. However, it should not be confused with discontinuous coverage scenario which features gaps in the order of seconds.  It is beneficial to inform the UE of the length of this possible gap either with Option 1 or 2 so as to avoid unnecessary measurements and unwanted behavior (e.g., RLF or re-selection to a different cell). |
| Google | Option 1/2 | We share the same view as QC that option1/2 does not mean mixing up the unchanged PCI with discontinuous coverage. Since the unchanged PCI is now only supported in the hard satellite switch scenario, it is realistic to assume there is a small gap upon switching satellites. |
| Apple | Option 1/2 | For hard switching case, we share QC’s view that network needs some time to complete the satellite switching. Therefore, there will be gaps between the start time of the target satellite and the stop time of the source satellite.  => **t-Gap = t-Start** (of new SAT) **- t-Service** (of old SAT).  From UE perspective, UE can just suspend the operation in Uu interface (e.g. data reception/transmission, PDCCH monitoring, DL sync) during the **t-Gap**, and start to resync with new SAT from **t-Start**. |
| Panasonic | Option 1 | We widely agree with Qualcomm’s argumentation – with the following additions:  a) What we’re looking for is an indication of the point of time an RF signal becomes available from the respective neighbouring satellite (“UE attempts to re-synchronize”).  Should there be a need for indicating the time difference between “RF signal available” and “data exchange feasible”, that would be a separate discussion.  b) Very short/zero gap is feasible for electrical steering antenna (e.g. phased array) while may not be feasible for mechanical steering antenna (e.g. dish antenna) on the ground station. Therefore, indication of the gap or start is necessary.  c) We’re preferring option 1 over option 2, because option 1 might be applicable to soft switching case – as CATT explained it.  d) From the UE perspective, the period where DL is available and the period where UL is available may be different due to the long propagation delay. It should be clarified that t-service and t-start are the stop/start timing of DL transmission at gNB. |
| Samsung | Option 1/2 | NW can set t-start identical to t-service if there is no gap, Option 3 works only in this case. But we need a solution works for all cases.  Option 1 and 2 informs the time after which it can start synchronization with new satellite, that can work no matter if t-service = t-start or not. |
| LGE | See comments | We think that Option 1 or Option 2 can be applied limited with a maximum value of the time gap until the UE attempts to re-synchronize with the target satellite. The maximum value of the time gap can be less or equal to the interruption time of the legacy handover procedure. |

Summary:

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If new parameter (t-star or t-gap) is supported, we need to discuss how to provide it to UE, simply, both system information and dedicated signaling could be considered.

**Question 2: If new parameter (t-star or t-gap) is supported, which option is companies’ preference to provide the time information?**

**Option 1: System information (e.g. SIB1, SIB19)**

**Option 2: Dedicated signaling (e.g. *RRCReconfiguration* )**

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| **Company** | **Preferred option** | **Comments** |
| OPPO | Option 1 | System information is sufficient as the time when the new satellite starts providing coverage for the serving cell is common for all UEs. |
| Huawei, HiSilicon | Option 1 |  |
| CATT | Option 1 | The start coverage time of the serving cell via target satellite is common to all the UE in the cell, the time information can broadcast in system information. |
| Fujitsu | Option 1 | If new parameter is introduced in Q1, it is enough to provide it by system information. |
| vivo | Option 1 |  |
| NEC | Option1 |  |
| Qualcomm | Option 1 |  |
| Xiaomi | Option 1 |  |
| Ericsson | Option 1 |  |
| Google | Option 1 |  |
| Apple | Option 1 |  |
| Panasonic | Option 1 | Same argument as OPPO and CATT. |
| Samsung | Option 1 |  |
| LGE | Option 1 |  |

Summary:

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As mentioned in some companies’ contribution, UE needs to know that it is in a scenario where PCI does not change after satellite switch, and additional indication (explicit or implicit) from network is needed. However, considering we have discussed the re-synchronize time, the exact indication manner (i.e. explicit or implicit) may be depend on the final solution in Q1. For example, if new parameter(t-start or t-gap) is supported, implicit manner may be enough while explicit manner is needed if we reuse the t-service, because UE maybe still not clear whether the current scenario is PCI unchanged scenario only with the t-service.

**Question 3: Do companies agree that if new parameter (t-start or t-gap) is supported, implicit indication manner is enough?**

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| **Company** | **Yes/No** | **Comments** |
| OPPO | Yes |  |
| Huawei, HiSilicon | Yes |  |
| CATT | Yes |  |
| Fujitsu | Yes |  |
| vivo | Yes |  |
| NEC | Yes |  |
| Qualcomm | Yes |  |
| Xiaomi | Yes |  |
| Ericsson | No | RAN2 should discuss first whether the new parameters can also be used for the regular service link hard switch scenario, i.e., with PCI change. |
| Google | Yes |  |
| Apple | Yes |  |
| Panasonic | Yes |  |
| Samsung | Yes |  |
| LGE | Yes |  |

**Question 4: Do companies agree that if t-service is reused, explicit indication manner is needed?**

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| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| OPPO | Yes |  |
| Huawei, HiSilicon | Yes |  |
| CATT | Yes | Additional new parameter is needed to assistant the UE to identify the PCI unchanged case, so that the UE could be aware to perform re-sync to the new satellite after t-service. |
| Fujitsu | Yes | Also, it is preferred to add the indication in SIB19. |
| vivo | Yes | This is needed for an RRC\_CONNECTED UE to distinguish the purpose of the t-service. |
| NEC | Yes |  |
| Xiaomi | Yes |  |
| Google | Yes |  |
| Panasonic | Yes | Same argument as CATT. |
| LGE | See comments | We prefer to introduce a new t-Service implicitly indicating that the PCI will be not changed if Option 3 is the majority view of Q1. |

Summary:

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To synchronize to the new satellite after switch, for RACH-based solution, both 2-step RA and 4-step RA could be considered. Then considering the long RTT in NTN system, maybe 2-step RA should have a higher priority.

**Question 5: Do companies agree that to perform synchronization to the new satellite after switch, 2-step RA could be supported firstly considering the long RTT in NTN system?**

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| **Company** | **Yes/No** | **Comments** |
| OPPO | No need for any prioritization | Whether 4-step RACH or 2-step RACH can be up to network’s configuration. |
| Huawei, HiSilicon |  | Agree with OPPO |
| CATT | See the comment | In Rel-17 NTN, both 2-step RA and 4-step RA are supported, and the RA type selection is based on RSRP threshold. Since the RA type is not a special issue for unchanged PCI scenario, we can follow the Rel-17 mechanism and support both RA types, no specific enhancement is needed. |
| Fujitsu | No | Agree with OPPO and CATT, it would be up to NW implementation then there is no need to prioritize the 2-step RA. |
| vivo | See comments | Same view as OPPO and CATT. This is up to NW configuration, and legacy RA type selection procedure applies. |
| NEC |  | Agree with OPPO and CATT， no need of enhancement and up to configuration |
| Qualcomm |  | Agree with OPPO. But this should not mean network only configures 2 step RACH. |
| Xiaomi |  | It is up to network configuration, and both 2 step and 4 step RACH can be configured. |
| Ericsson |  | Agree with OPPO and CATT. |
| Google |  | Agree with OPPO and CATT. |
| Apple |  | Agree with OPPO and CATT that it can be up to network configuration.  Furthermore, 2-step RACH is optional UE feature, so network should not only configure 2-step RACH for this purpose. |
| Panasonic |  | Agree with OPPO and CATT. |
| Samsung | Support both 4-step and 2-step | Agree with OPPO and CATT.  Follow existing RA, no need of enhancement |
| LGE |  | Agree with OPPO. |

Summary:

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Further, for selection of CBRA and CFRA, CFRA could also be prioritized due to the long propagation delay characteristic in NTN system.

**Question 6: Do companies agree that CFRA could be supported firstly due to the long propagation delay characteristic in NTN system?**

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| **Company** | **Yes/No** | **Comments** |
| OPPO | No need for any prioritization | In some cases, CFRA may not even be affordable for so many UEs to switch satellite within short period.  Whether CFRA or CBRA can be up to network’s configuration. |
| Huawei, HiSilicon |  | Agree with OPPO |
| CATT | See the comment | Both CBRA and CFRA are legacy mechanism and can be supported, we don’t need to limit on that. It is up to NW implementation. For example, the network can configure CFRA for some Ues, but configure no CFRA for the remaining Ues, considering the different delay requirement of the ongoing traffic. |
| Fujitsu | No | Agree with OPPO and CATT, it would be up to NW implementation then there is no need to prioritize the CFRA. |
| Vivo | See comments | Same view as OPPO and CATT. |
| NEC | no further enhancement to support CFRA | Agree with OPPO that “ CFRA may not even be affordable for so many Ues to switch satellite within short period.”  Not sure how to support CFRA since we avoid dedicate signaling during cell switch with unchanged PCI. Considering RACH-less solution can be used together. We do not want to do any further enhancement to support CFRA |
| Qualcomm |  | Agree with OPPO. |
| Xiaomi |  | Both CFRA and CBRA can be configured, it is up to network implementation. |
| Ericsson | No | Agree with OPPO and CATT. |
| Google | Yes (CFRA can be supported), but no prioritization is needed | CFRA (i.e., PDCCH order) can be supported for sure, like in legacy. But it is up to network whether to configure a UE with the CFRA resource or not. For those Ues not configured with the CFRA resource, they can only perform CBRA to regain the UL synchronization and TA upon the arrival of any UL traffic. |
| Apple |  | Agree with OPPO and CATT. |
| Panasonic |  | Agree with OPPO and CATT. |
| Samsung | Support both CBRA and CFRA | Follow existing RA, no need of enhancement |
| LGE |  | Agree with OPPO. |

Summary:

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On the other hand, some companies propose to combine the RACH-less procedure with PCI unchanged solution in NTN system.

**Question 7: Do companies agree that the RACH-less procedure can be combined with PCI unchanged solution in NTN system?**

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| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| OPPO |  | Not sure about this. This PCI unchanged solution (not requiring L3 mobility as agreed by RAN2) seems to have something different from RACH-less HO’s design in which RRC handover command will carry target cell’s NTA information and other CG/DG-related configurations. For PCI unchanged solution, we seems not to rely on RRC signaling that much. |
| Huawei, HiSilicon | Yes | We don’t see an issue here.  1) NTA is assumed to be zero, which is the same with the NTA for inter-satellite RACH-less HO with changed PCI;  2) UE monitors the PDCCH of target cell for UL grant;  3) After t-Service, the UE performs downlink synchronization with the new satellite, and T304 is stopped if MAC indicates the successful reception of a PDCCH with UE C-RNTI from the target cell. |
| CATT | Depends on the RACH-less topic | On topic of RACH-less handover, inter-satellite handover with same gateway/gNB is supported. It means UE could have valid TA of the target cell after inter-satellite switch without RACH. In unchanged PCI scenario, the way to get sync to the serving cell via the target satellite after satellite switch is same as the scenario of inter-satellite handover with same gateway/gNB. We can wait for the progress of RACH-less handover and reuse the mechanism of getting TA. |
| Fujitsu | See comments | It could be combined if the valid TA of target cell can be provided before satellite switching. However, it is not clear whether the RACH-less HO is just reused, or some considerations is needed for the PCI unchanged scenario. Thus, we should wait for progress of RACH-less HO. |
| Vivo | No | RACH-less HO is basically still a L3 mobility mechanism, which is actually what unchanged PCI mechanism intends to avoid. On the other hand, if the two are combined, it is not actually to support the real “RACH-less HO” being discussed, but to support a potentially new mechanism which requires no RACH in the unchanged PCI scenario. |
| NEC | Yes | Agree with Huawei, 0 NTA can be assumed. |
| Qualcomm | Yes | We think RACH-less operation should be possible.  We agree with Vivo that we should not mix it up with RACH-less HO as this whole solution is not about handover but rather how to avoid handover. T304 has nothing to do here.  Simply we need to define a time window where UE finishes synchronizing to new satellite and resumes normal UL/DL operation. But we agree, the initial UL transmission can borrow the solution of initial UL transmission defined for RACH-less HO, e.g., N\_TA = 0 or continue using same N\_TA |
| Xiaomi | See comment | The PCI unchanged solution does not require L3 mobility, but the RACH-less HO is still L3 mobility, so we suggest don’t mix them. However, we think the intention for the question is whether the RACH can be skipped or not during the re- synchronize to the network, from this point, the RACH could be skipped in some case. |
| Ericsson | Yes | Agree with Huawei and Qualcomm. In addition, we think that this should be the only scenario supported. We see the usefulness of the unchanged PCI scenario without RACH-less access to be very limited.  Note that the use of RACH-less access principles should not be confused with RACH-less HO (L3 mobility procedure). |
| Google | Yes | The provision of the TA can reuse the same mechanism as in RACH-less HO, but the UE does not need any other things from the RACH-less HO (e.g., starts/stop T304, transmits L3 message after switching to the new cell). |
| Apple | Yes | It’s possible to support RAC-less SAT switching with unchanged PCI.  As Huawei indicated, we can always assume NTA=0 for Tta value calculation, and rely on the dynamic UL grant for the 1st UL transmission to the new SAT. |
| Panasonic | See comment | Agree with Xiaomi. |
| Samsung | See comment | RACH-less HO procedure is different and is not applicable here. PCI unchanged satellite switch is not a HO, no RRC reconfiguration, no initial UL transmission, but only requires re-synchronization with the serving cell.  The issue here is whether RA is required or not for PCI unchanged satellite switch. If we consider legacy procedure when UE is out of synchronization, RA is always required for re-synchronization with serving cell, to skip RACH a new procedure is needed. We see benefit of RACH-less resynchronization and also see additional work to support this. For RACH-less resynchronization, both N\_TA =0 or N\_TA = source can work. |
| LGE | Yes with comment | We agree with Huawei with some comments. The unchanged PCI scenario assumes that the handover is not conducted. Therefore, there is no case to start T304. |

Summary:

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## Backward compatibility issue

In addition, backward compatibility issue should also be considered as companies mentioned. If current scenario is PCI unchanged case, the legacy UEs who are not able to identify the indication mentioned above form NW, they might still perform handover procedure(i.e. L3 mobility), or leverage BFR procedure.

**Question 8: For back-ward compatibility, which option is companies’ preference?**

**Option 1: Perform intra-cell handover procedure (i.e. L3 mobility)**

**Option 2: Reuse BFR procedure**

**Option 3: other solution**

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| **Company** | **Preferred option** | **Comments** |
| OPPO |  | No sure about the question. It seems there is nothing we can do to optimize for legacy UEs other than using existing procedures, e.g. intra-cell HO, RLF and re-establishment, etc. In any case, there is no standard impact. |
| Huawei, HiSilicon | Option 1 |  |
| CATT | Option 1 | For option 1, it is legacy behavior, after identifying the UE doesn’t support unchanged PCI, e.g. based on the UE capability, the NW can configure HO or CHO for these UEs at suitable time. It will not impact the experience for legacy UE.  For option 2, we wonder whether the legacy UE will reacquire DL timing when BFD occurs. If the UE only perform beam recovery based on the timing of the source satellite, the UE may never detect the SSB from the target satellite. Additionally, the BFR will not trigger the application of ephemeris and TA common info, which is needed for UE access to the target satellite. |
| Fujitsu | Option 1 | Option 1 is simpler solution, and it is already supported. The NW can handle the legacy UEs based on the UE capability information. |
| vivo | Option 1 | NW can handle this well. |
| NEC |  | Agree with OPPO. And believe handover will happen if NW take care, otherwise UE probably will experience RLF |
| Qualcomm | See comments | For legacy UEs, network has to use available tools to handle it such as time-based CHO where legacy UE can execute the HO after t-Service, RLF, HO command right before t-Service or SI update procedure at/after t-Service etc. |
| Xiaomi | See comment | We think there is no impact on legacy UE. |
| Ericsson | Option 3 | Regarding Option 1, given the target cell is not yet available (until t-service expires) and it has the very same configuration as the serving cell (same PCI), it is unclear to us how a Release 17 UE can be handed over. R2-2304147 expands on this issue.  Given CHO is an optional feature, RLF and RRC Re-establishment might be the only option for Rel-17 UEs. |
| Google | Option 1 | Which means there is no spec impact (option 1 is anyway available to all UEs including legacy ones). |
| Apple | Option 1 | Network should handle the legacy UE using the legacy method, e.g., L3 mobility. |
| Panasonic | See comment | We agree with OPPO in so far as there is no specification impact. Apart from that, we’re in agreement with Qualcomm, i.e. the available tools of the Release the UE corresponds to can be used. |
| Samsung | See comment | Legacy UE replies on legacy procedures, e.g., HO (including intra-cell HO) and RLF. |
| LGE |  | We do not see any issues for this question. The network will handle this well. |

Summary:

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# **3 Summary**

Summary:

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# **4 Conclusion**

**List of proposals for agreement (if any):**

**List of proposals that require online discussions:**

# 5 References

1. R2-2304836 Further discusison on service link switching with unchanged PCI vivo discussion Rel-18
2. R2-2304899 Discussion on unchanged PCI scenario CATT discussion Rel-18 NR\_NTN\_enh-Core
3. R2-2305152 Satellite switch\_PCI change without L3 handover NEC discussion Rel-18 NR\_NTN\_enh-Core
4. R2-2305197 Satellite switch enhancements for NTN Qualcomm Incorporated discussion Rel-18 NR\_NTN\_enh-Core
5. R2-2305599 Discussion on handover enhancements for NTN CMCC discussion Rel-18 NR\_NTN\_enh-Core
6. R2-2305676 Discussion on handover enhancements for NTN-NTN mobility Xiaomi discussion
7. R2-2305937 Satellite switching without PCI change InterDigital discussion Rel-18 NR\_NTN\_enh-Core
8. R2-2306156 NTN specific handover enhancement Apple discussion Rel-18 DUMMY
9. R2-2306296 Consideration on HO enhancements in NTN ZTE corporation, Sanechips discussion Rel-18 NR\_NTN\_enh-Core

# 6 Contact information

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