**3GPP TSG RAN WG1 #113 R1-230xxxx**

**Incheon, Korea, May 22nd – May 26th, 2023**

**Agenda Item: 9.9**

**Source: CATT**

**Title: Discussion on RAN2 LS reply on unchanged PCI**

**Document for: Discussion and Decision**

# Introduction

RAN1 has received one LS from RAN2 about the unchanged PCI scenario in NTN [1]. With this LS, RAN2 informed the progress on unchanged PCI and ask for the reply from RAN1 on hard satellite switching (non-overlapping satellite coverage at switching time) and soft satellite switching (overlapping satellite coverage at switching time).

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| **To** **RAN1**  **ACTION:** RAN2 kindly requests RAN1 to take into account the above agreement on hard satellite switching without PCI change and provide feedback if RAN1 identifies any major technical issues, and also provide feedback on the feasibility to support soft satellite switching without PCI change. |

# First round discussion

## First question

**Q1: Is there any technical issue from RAN1 perspective on hard satellite switching without PCI change?**

**Moderator observations:**

From the companies’ contributions [2]-[9], for hard satellite switching, UE can switch to target satellite based on existed procedure. There is no technical issue identified from RAN1 perspective.

Companies are encouraged to provide the answers for above question and the conclusion is expected to derive based on company feedback.

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| **Company** | **Comment** |
| **CMCC** | No. we do not think there is any technical issue for the hard satellite switching without PCI change. Though there is a time gap without connection during the switching, it could be solved by using legacy mechanism, such as beam failure recovery. In addition, with the notification to re-acquire DL/UL synchronization with the serving cell, as mentioned in the LS, UE can access to the upcoming satellite without any issue.  So we see no technical issue for this problem. |
| **CATT** | No. We don’t find any technical issue for hard satellite switching without PCI change. |
| **QC** | **No, we don’t see any technique issues from RAN1 perspective.** |
| **Nokia, Nokia Shanghai Bell** | Yes, We find that there may be a number of issues with respect to the hard satellite switching. A number of these are:  **UEs in RRC\_IDLE may have trouble with the updated cell timing whenever a hard switch is performed**  **All UEs in a cell in RRC connected mode would have to re-acquire new cell timing. How would that be communicated to the devices?**  **How is system causality maintained when making an abrupt change in cell timing (SSB timing).**  **Will this be mandatory for all UEs to support?**  **How will Rel-17 UEs be supported?** |
| **Vivo** | **In our understanding, hard satellite switching would be triggered when the source satellite is turned off sometime up to network implementation and all UEs would have to switch to new satellite via beam failure recovery if the SSB beam has to be updated. So there seems no RAN1 impact.** |
| **Huawei, HiSilicon** | **No. We don’t see any technique issues from RAN1 perspective.** |

**Moderator summary for hard soft satellite switching:**

From the feedback of companies, it is observed that only one company raised there may be some issues on how to re-acquire the synchronization with new satellite, and all others companies have confirmed that there is no issue from RAN1 perspective.

Regarding the synchronization acquisition to new upcoming satellite, it is clarified that UE will read synchronization related information including cell specific K-offset, K-mac, common TA and ephemeris information for the new satellite. When UE switches to new satellite, UE shall apply the cell specific K-offset to access the new satellite until configured with new UE specific K-offset. With new satellite configuration, UE can access the new satellite without technical bottleneck.

## Second question

The second question is about that RAN2 asked for the feasibility check for soft satellite switching without PCI change. Then for the second question, RAN1 is responsible to feed back the feasibility of soft satellite switching for earth fixed cell case.

**Moderator observations:**

Based on the companies’ contributions [2]-[9], there are some discussions on technical issues from RAN1 aspects. VIVO and OPPO raised one issue that there is the interference between signals from 2 different satellites. CMCC thinks there are possible PCI collision and interference issue for two satellites, but they can be resolved by the implementation, which is supported by the ZTE，Huawei and CATT. In addition, CATT, CMCC and Huawei proposed that UE is required to connect only one satellite in soft satellite switching.

In order to make it clear for technical issues, more detailed discussions are needed. RAN1 needs to identity what is issue and if it can be resolved by the implementation or specification enhancement is needed.

**Q2.1: is there any issues identified from RAN1 perspective on soft satellite switching without PCI change?**

**[If yes, please list possible issues]**

Companies are encouraged to provide the answers for above question and conclusion are expected to derive based on company feedback.

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| **Company** | **Comment** |
| **CMCC** | No.  As we mentioned in our contribution, the PCI collision and the interference between two satellite with unchanged PCI, they could be solved through implementation such as sending different SSB with same PCI but different indexes and UE scheduled separately. |
| **OPPO** | Instead of discussing directly the issue, we suggest to first differentiate between hard switching and soft switching **from RAN1 point of view**, so that every RAN1 companies can be on the same page. Otherwise, it is hard to discuss the issue if we have different understandings in mind.  We would rather ask whether hard satellite switching or soft satellite switching is transparent to a UE? If it is transparent, then it is a pure network implementation and there is no difference in UE behavior. But if it is not transparent to a UE, what is the difference and what are the corresponding UE behavior in these two cases, respectively? Only after clarifying this, we can analyze whether there is any issue. |
| **Samsung** | We have a similar view with OPPO. Regarding soft satellite switching, many companies think that this can be handled by NW implementation e.g., proper scheduling or something else. However, we are wondering whether this can be seen as a kind of hard satellite switching or not since it means that a UE only connects one satellite at one time. |
| **CATT** | We would like to clarify a bit more. Based on RAN2 input, there is no requirement to do soft handover, this is to say, UE is NOT required to connect two satellites simultaneously.  For soft satellite switching, it is more related to network deployment. In this scenario, two satellites will cover same area and transmit the signals with same PCI configuration. From network perspective, no signal interruption between two satellites.  For hard satellite switching, there is one time gap between two satellites transmission. It means the serving satellite will stop the signal transmission firstly, and then upcoming satellite continues to serve the same area.  From UE perspective, UE will follow legacy UE behaviors for soft satellite switching when we take the assumption that UE is only required to connect one satellite at same time. For interference issue between two satellites, it can be handled by gNB with proper configuration and coordination.  **Based on above analysis, we think soft satellite switching is feasible.** |
| **LG** | According to Moderator’s updated comment, in the case of soft satellite switching, gNB can configure proper interference coordination, and if so, can UE distinguish between soft satellite switching and hard satellite switching? We think both cases will seems to be hard satellite switching from a UE perspective. |
| **Ericsson** | We agree with OPPO that it is hard to discuss the issue if we have different understanding. For soft switching, it is unclear what legacy UE behavior is used to make the UE switch to the new satellite, and whether scheduling/coordination can be used to avoid interference despite potential timing drift differences between the satellites. The LS from RAN2 does not give much information on technical solutions. Further discussion is needed to get better understanding. |
| **QC** | Further RAN1 discussions are needed. If the two cells are transmitting at the same time, the SSBs from the two cells may overlap in time and frequency. In such case, UE may lost the SSB of the serving cell. It’s unclear if this can be solved by NW implementation. |
| **CMCC2** | Thanks for companies’ question.  @OPPO  We cannot say hard switching and soft switching is completely transparent to UE and can be realized through the implementation, since RAN2 have the agreement on the hard switching and discussing on the details of the notification of re-acquiring of DL/UL synchronization.  For the hard switching, UE will try to re-acquire the DL and UL synchronization during the switching gap. For this, legacy mechanism can be reused, such as beam failure, or use the new indication from higher layer. For hard switching, there is no RAN1 impact.  For the soft satellite switching, first we want to confirm that UE will only connect to one of the two satellites in soft switching. Connecting to two satellites and maintain synchronization to two satellites is too complicated for UE.  @ companies  If the mechanism of hard satellite switching is reused in the soft satellite switching(which is also workable), UE will not distinguish hard switching and soft satellite switching. based on the implementation based solution as raised from our side, if SSBs with certain indexes is from satellite #1, and others are from the satellite #2, UE will be indicated to switch to another SSB of the 2nd satellite. Then, I think it is hard for UE to distinguish hard switching and soft satellite switching. |
| **Nokia, Nokia Shanghai Bell** | The two “soft cells” will not appear the same to the UEs, and SSBs may not be aligned. Hence, there is no smooth way of doing the transition. |
| **Vivo** | According to the current discussions, to move forward, probably more discussions are needed in RAN1 to understand the definition of soft satellite switching. So we’re fine to inform RAN2 that more discussions may be needed for RAN1 to understand the soft satellite switching, and if beneficial, we can list a couple of questions to RAN2 to ease the RAN1 further discussions in future. |
| **OPPO2** | According to CMCC’s explanation. It seems that the UE behavior for hard switching and soft switching are different. For hard switching the UE is given a switching gap but for soft switching the UE is expected to switch from one cell to the other cell immediately without gap including the synchronization. Could we confirm that this is the correct understanding? |
| **Huawei, HiSilicon** | 1. Our focus for the discussion here is regarding the reply LS to answer RAN2’s question. In LS from RAN2, it is explained clearly that “hard satellite switching (non-overlapping satellite coverage at switching time) and soft satellite switching (overlapping satellite coverage at switching time)”. Should we focus on answer from RAN1 perspective whether it is feasible to support soft switching, rather than the detailed UE behavior that could be discussed later. 2. In our view, there could be interference from two satellites’ signal in the overlapped coverage, but it can be handled by gNB scheduling. |

**Q2.2: if the answer for Q2.1 is yes, whether the issues can be resolved by implementation or need RAN1 specification enhancement? Other critical comment can be also raised.**

Companies are encouraged to provide the answers for above question and conclusion are expected to derive based on company feedback.

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| **Company** | **Comment** |
| **OPPO** | See our above comment |
| **QC** | **It’s unclear if the issues can be solved by NW implementation.** |
| **Nokia, Nokia Shanghai Bell** | **See above. We do not find that this can be solved by network implementation, and if we need UE enhancements, it would need to be mandatory functionality.** |
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**Moderator summary for hard soft satellite switching:**

Based on the replies from companies, there are some technical points raised for soft satellite switching.

* **Point 1: what is the difference between soft satellite switching and hard satellite switching?**

The definition of RAN2 LS: hard satellite switching (non-overlapping satellite coverage at switching time) and soft satellite switching (overlapping satellite coverage at switching time).

This is the definition from network side. UE will follow network configuration to do satellite connection switching.

* **Point 2: whether it is assumed that UE is allowed to connect only one satellite?**

In order to simplify UE behavior, it is proposed from several companies that UE will connect only one satellite at switching stage.

* **Point 3: how to differentiate two satellites’ signals to help UE to acquire DL synchronization of new satellite?**

Due to same PCI configuration, there are possible different ways to resolve it. One way is to configure different SSB index for different satellite. Another way is to allow network configure different SSB timing offset and UE is informed that different timing is associated with different satellite.

* **Point4: how to resolve the interference for two satellites?**

Regarding the interference between two satellites, it is proposed by several companies to conduct the coordination between two satellites without specification change.

* **Point 5: what is the impact to UE behavior for soft satellite switching?**

If introduce new signaling or new configurations, UE supporting soft satellite switching would have different behaviors compared to legacy UE. The details can be discussed later when RAN2 has completed concrete mechanism design.

# Second round discussion

## Reply to hard satellite switching

Based on first round discussion, since no clear technical issue is found and will impact the feasibility of satellite switching, we tend to draft one answer to reply the RAN2 question.

*[Draft reply]:*

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

Companies are encouraged to provide the feedback for above reply for hard satellite switching.

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| **Company** | **Comment** |
| **CMCC** | Support. |
| **Xiaomi** | Support |
| **Huawei, HiSilicon** | Support |
| **ZTE** | Support |
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## Further discussion on soft satellite switching

Since there are some controversial points in the first round discussion, then it is needed to have further discussions for concrete questions and problems. Herein a few questions related to open issues are listed for deeper discussion.

**Question 1: What information is unclear and expected to acquire from RAN2 side?**

Companies are encouraged to provide the feedback to facilitate the reply to RAN2.

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| **Company** | **Comment** |
| **OPPO** | RAN2 definition: hard satellite switching (non-overlapping satellite coverage at switching time) and soft satellite switching (overlapping satellite coverage at switching time)  It is not clear the above RAN2 definition is from network viewpoint or from a single UE viewpoint |
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**Question 2: Can we assume UE is allowed to connect one satellite during soft satellite switching?**

Companies are encouraged to provide the feedback to facilitate the reply to RAN2.

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| **Company** | **Comment** |
| **CMCC** | Our understanding is that UE connecting to one satellite should be the baseline in the current stage, without increase the UE complexity. |
| **Xiaomi** | We understand now the soft satellite switch means the overlapped area between two satellites, UE is not required to maintain two connections. |
| **Huawei, HiSilicon** | The difference between hard switching and soft switching in RAN2 LS is just whether there is overlapped area of the two satellites.  In our view, single satellite is assumed to be used for a UE even when soft switching happens. |
| **ZTE** | Yes. The soft switch is referring to a case where different satellites provide overlapped area. UE should still connect to one satellite. |
| **OPPO** | Not only does a UE connect to a single satellite, but RAN1 needs to ask if the UE is required to perform the satellite switching instantaneously without any gap. This is important to a UE. So far it is clear that hard satellite switching does not have such demand, but what about the soft satellite switching? |
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**Question 3: Is it possible to differentiate SSB signals of two satellites without specification change or new enhancement is needed?**

Companies are encouraged to provide the feedback to facilitate the reply to RAN2.

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| **Company** | **Comment** |
| **CMCC** | As we comment in the last around, SSBs with different indexes can be sent from two satellites in the soft satellite switching. UE can distinguish two satellites through different SSB indexes and still knowing that it is under the same cell. |
| **Xiaomi** | It is possible if some kind of indication/notification is supplied. |
| **Huawei, HiSilicon** | Firstly, we think RAN2 didn’t ask question whether specification change is needed or not. This is not relevant with feasibility issue.  In our view, if some SSBs are sent from target satellite and some others are from source satellite. After the notification from gNB that soft satellite switching happens, the UE shall search and sync to the SSBs from the target satellite. |
| **ZTE** | Yes. Different SSBs can be associated with different satellites via implementation. |
| **OPPO** | It is too early to identify spec impact without having clear conclusion on the UE behavior. |
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**Question 4: For interference coordination, if it is feasible relying on network implementation?**

Companies are encouraged to provide the feedback to facilitate the reply to RAN2.

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| **Company** | **Comment** |
| **CMCC** | In our consideration, both two satellites are connected to one gNB serving gateway. gNB has the full knowledge that the UEs are served by which satellite. Then gNB can divide the UEs into two groups and serve them in TDM manner. Then, the interference can be avoided. |
| **Xiaomi** | Depending on the interference scenario, it is possible handle the interference problem by network implementation |
| **Huawei, HiSilicon** | gNB can do the scheduling to avoid the interference from the two satellites for PUSCH and PDSCH.  For SSB, there may be some time shift of the SSB from the target satellite in the time domain. But it can be still be handled by gNB, e.g. not to schedule PDSCH in the source satellite for some other UEs in the slots where overlaps with the SSB transmitted from the target satellite. |
| **ZTE** | Due to propagation delay difference between satellites, even if there is interference due to overlap, it can be regarded as background noise and soft switching is still feasible. |
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# References

1. R2-2304273, RAN2, LS on unchanged PCI
2. R1-2304449 Discussion on RAN2 LS on unchanged PCI vivo
3. R1-2304756 Discussion on RAN2 LS reply on unchanged PCI CATT
4. R1-2304757 Draft reply LS to RAN2 on unchanged PCI CATT
5. R1-2305075 Discussion on RAN2 LS on unchanged PCI CMCC
6. R1-2305924 Discussion on LS on unchanged PCI Huawei, HiSilicon
7. R1-2305440 Discussion RAN2 LS on unchanged PCI OPPO
8. R1-2305441 Draft reply LS on unchanged PCI OPPO
9. R1-2305565 Discussion on LS on the unchanged PCI ZTE

# Appendix

## RAN2 agreement

In RAN2 #121bis meeting, RAN2 has made the following agreements：

Agreements:

1. 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, unless major technical issues are identified by RAN1 (as usual RAN2 will aim at minimizing the specification impact so that it fits in Rel-18)
2. Remove the part in brackets “as usual RAN2 will aim at minimizing the specification impact so that it fits in Rel-18” in the LS to RAN1. The action to RAN1 will also ask for feedback for the hard satellite switch (not only the soft satellite switch case), e.g. action to RAN1 is to see if there are any major technical issues (as in the agreement).

## Companies’ proposals and observations

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| Contributions number | Company | Proposal and observations |
| R1-2304449 | VIVO | ***Observations 1 to 2:***   * ***Soft satellite switching would introduce interference between signals from 2 different satellites and it’s hard to introduce additional mechanism to mitigate the interference.*** * ***Hard satellite switching can be supported without any RAN1 impact.***   ***Proposal 1:***   * ***RAN1 sends an LS reply to RAN2 based on the draft reply provided in Table 1.*** |
| R1-2305075 | CMCC | **Observation 1:**  **Whether hard satellite switching or soft satellite switching is used is more dependent on the deployment of satellites.**  **Observation 2:**  **With the ephemeris information of new satellite, UE can access to the new satellite reusing the legacy mechanisms in the hard satellite switching.**  **Observation 3:**  **Both satellites can be observed by UE in the soft satellite switching. Connecting both satellites and compensating the transmission delay and frequency drift from two satellites will increase UE complexity tremendously.**  **Observation 4:**   * **The PCI collision issue can be solved through grouping the SSBs to two sets and different satellite can transmit different set of SSBs, which is an implementation solution.** * **Or the same SSBs can be transmitted by the two satellites, but different CSI-RS/TRS can be transmitted through each satellite. UE can connect the satellite following one SSB with specific delay and frequency drift.**   **Proposal 1:**  **From RAN1’s perspective, no major technical issue is observed for the hard satellite switching without PCI change.**  **Proposal 2:**  **In the soft satellite switching, only UE connecting to one satellite should be discussed.**  **Proposal 3:**  **The PCI collision issue in soft satellite switching can be solved through implementation.**  **Proposal 4:**  **The ephemeris of two satellites in soft switching can be informed to UE. This can be realized through implementation or discussed by other working groups**  **Proposal 5:**  **The interference between the UEs under different satellites in the soft satellite switch can be solved though the scheduling of gNB.**  **Proposal 6:**  **From RAN1’s perspective, no major technical issue for soft satellite switching without PCI change is observed. The interference issue can be solved through scheduling of gNB.** |
| R1-2305440 | OPPO | **Proposal 1: For hard satellite switching, it is feasible as long as the UE can determine when to perform DL/UL synchronization to the upcoming satellite.**  **Proposal 2: For soft satellite switching, there are many issues that may cause interference issue, UE uplink synchronization issue, and ambiguous applicable ephemeris information issue. Thus, it seems not feasible.** |
| R1-2305565 | ZTE | ***Observation 1:*** *Due to the different location of satellite which provide the same coverage with unchanged PCI, the DL synchronization procedure (e.g., monitoring the DL signal) and updates of UL timing (e.g., re-acquisition SIB for satellite ephemeris, common TA parameters, etc), should be implemented at UE side.*  ***Proposal 1:*** *For the hard switching, it’s feasible from RAN1 perspective to support satellite switching without PCI changing.*  ***Proposal 2:*** *For the soft switching, it’s feasible from RAN1 perspective support satellite switching without PCI changing. And same enhancement for hard switching can be considered.* |
| R1-2305924 | Huawei | ***Observation 1: From RAN1 perspective, there is no issue identified to support hard switching.***  ***Observation 2: The gNB can mitigate the interference between signals of the two satellites by scheduling and transmitting different SSBs in SS burst from different satellites.***  ***Observation 3: UE does not need to maintain the timing and frequency synchronization simultaneously with two satellites, considering only one satellite is used for the UE on a time occasion in the overlapped coverage.***  ***Proposal 1: Inform RAN2 that hard switching is feasible from RAN1 perspective.***  ***Proposal 2: RAN1 informs RAN2 that interference could happen between the signals relayed by the source satellite and the destination satellite, however, it is feasible to resolve/mitigate the interference issue from RAN1 perspective.*** |
| R1-2304756 | CATT | **Observation 1: Inter-satellite coordination for same gNB for PCI unchanged usage is easily implemented.**  **Observation 2: The time gap length of signal interruption between two adjacent satellites is up to network implementation and propagation delay, which is less than 10ms in most of cases from UE reception point of view.**  **Observation 3: In order to help UE to fast access the upcoming satellite, common TA and ephemeris information can be informed to UE before satellite switching.**  **Observation 4: Connecting two satellites simultaneously for signal transmission will increase UE complexity.**  **Observation 5: When same PCI is used for two adjacent satellites, there exists possible interference for two satellites in DL and UL.**  **Observation 6: With resource separation for two neighboring satellites, the interference issue can be resolved through network implementation. For cell specific signal and resource allocation including SSB, SIB and PRACH, TDM based resource isolation can be used for two satellites. For UE specific signal and resource allocation, FDM based resource isolation can be used.**  **Proposal 1: From RAN1 perspective, no major technical issue is observed for hard satellite switching on unchanged PCI scenario.**  **Proposal 2: For sake of UE implementation simplicity, UE can connect to only one satellite during soft satellite switching period.**  **Proposal 3: From RAN1 perspective, with proper resource coordination between serving satellite and upcoming satellite and no spec change, soft satellite switching without PCI change is feasible.** |