3GPP TSG-RAN WG2 Meeting #123 draft-R2-230XXXX

Toulouse,France, 21 August – 25 August 2023

**Agenda item:** **7.17.4**

**Source: Nokia, Nokia Shanghai Bell**

**Title: [Post123][046][feMob] subsequent CPAC security (Nokia)**

**Document for: Discussion and Decision**

# 1 Introduction

Following post-e-mail discussion was approved in RAN2-123 to further progress on RAN2 aspects of security key management for subsequent CPAC.

* [Post123][046][feMob] subsequent CPAC security (Nokia)

Scope: Converge on detailed aspects of the security solution, Identify points for agreement and discussion (preferably such that we can have clear Stage-3 CR contents next meeting and can tell SA3 whether they need to capture anything in their security Stage-2). If further questions are needed towards SA3, identify those.

Intended outcome: Report, with agreeable proposals.

Deadline: long

In this discussion, we further analyze the required changes in the RAN2 signaling procedure and relevant UE behavior to implement the proposed SA3 solution. Any further clarifications needed from SA3 on specific scenarios that were not considered in the current SA3 solution are also discussed.

# 2 Contact Information

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# 3 Discussion

In current specifications, the security keys used for integrity protection and SCG bearers are generated from the master key (KgNB) and SK counter assigned by MN as part of the RRC Reconfiguration message. For every PSCell-change that involves a change of PDCP anchor point (Security anchor point), MN is expected to provide a new SK counter value. In order to avoid security re-keying issues within active connection the MN needs to ensure that SK counter values are not re-used across successive PSCell changes.

As part of the Rel-18 subsequent CPAC feature, the UE is preconfigured with multiple candidate PSCell configurations along with execution conditions. With this pre-configuration, the UE can execute subsequent PSCell changes without any RRC Reconfiguration message after the cell change. As the SK counter values for S-CPAC need to be pre-configured new solution is needed for SK counter change during PSCell-change that involves (security anchor point change (Inter-SN change). In this regard, SA3 has proposed a solution for SK counter management for the S-CPAC scenario. The solution proposes

* Pre-configuration of the list of SK counters for each SN at UE.
* UE is expected to use unused SK counter values from this list during Inter-SN mobility.

RAN2 has agreed to support the above solution in RAN2 signaling procedures.

## 3.1 Basic Signalling Procedure

**K-SN (S-KgNB) generation for Inter-SN S-CPAC**

Following is the rapporteur's understanding of SK counter selection and K-SN generation during subsequent CPAC as per the proposed solution from SA3. (From UE perspective). This forms the basis for further questions related to defining the RRC signalling aspects.

* A list of SK counter values per security anchor point(i.e SN ) is provided toward the UE when subsequent CPAC is configured with candidate cells belonging to different security anchor points.
* To enable the UE to identify changes of the security anchor point, each candidate configuration is assigned with group ID that points to the specific security anchor point. In other words, the each SK-counter list configured to UE includes Group ID. This group ID is referred in each of the candidate cells that uses the same SK-counter-list.
* During subsequent CPAC, if the UE identifies that the target cell belongs to a different Group-ID than the serving cell , UE selects the first unused entry in the SK-counter list that corresponds to this group-ID. K-SN and subsequent security keys are generated based on this selected SK-counter. The SK-counter is marked as used within the list.

**Q1 : Do companies agree to the above understanding on UE behaviour for SK-counter selection during subsequent CPAC? If not indicate the difference for specific steps.**

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| **Company** | **Answer (Yes/No)** | **Additional comments** |
| OPPO | Yes |  |
| Lenovo | Yes | If the UE identifies that the target cell belongs to same (as serving) SCG (group id), then no security update is required. For DRBs using RLC AM mode PDCP data recovery applies, and for DRBs using RLC UM no action is performed in PDCP. These are done by the UE on its own i.e., without explicit signalling. |
| ZTE | Yes, but | For the third bullet, we think the UE can remove the selected SK-counter from the corresponding SK-counter list after generation of K-SN and subsequent security keys, considering that the used SK-counter is invalid and shall not be used any more. Then the UE is not required to mark/record which SK-counter is used, and can always select the first SK-counter in the corresponding list upon subsequent CPAC execution. |
| vivo | Yes |  |
| Ericsson | Yes | Bullet 1: Change “is” to “can be”, A list of SK counter values … can be provided …, as it may not always have to be provided. |
| MediaTek | Yes in principle | We think in general this this approach is fine. How to capture this in SPEC could be further discussed in the CR.  On bullet 3, whether to remove used sk-counter or just mark the next sk-counter to be used is a stage-3 SPEC model issue. We could discuss based on the proposed TP. It should result in same behavior anyway. |
| Apple | Yes |  |
| Intel | Yes |  |
| Xiaomi | Yes, but | For bullet 3, we only need to specify “UE selects the first unused entry in the SK-counter list that corresponds to this group-ID.” And how to select the first unused SK-counter in SK-counter list can be up to UE implementation. |

**Signaling Procedure changes for Inter-SN S-CPAC**

For the above solution, the RRC Reconfiguration message that provides configuration for S-CPAC includes new information element that consists of multiple lists of SK-counters with each list assigned with Group ID. This information element is to be maintained across cell changes. So it is preferred to maintain this information outside the candidate configuration. Each candidate configuration also needs to have a new parameter to indicate its Group ID. As it is MN which is responsible for assigning SK-counter-list and group-ID, this parameter can be a parameter outside the RRC-configuration within the candidate-configuration. Based on the above we propose the following changes to RRC Reconfiguration message.

**Q2. Do companies agree to introduce the following changes in RRC-Reconfiguration**

1. **List of Group-ID and associated SK-Counter list in the RRC Reconfiguration as parameter outside candidate configuration.**
2. **Each candidate configuration includes the Group ID outside the RRC Configuration.**
3. **UE maintains new variable for SCPAC-SK-Counter-list which includes list of counters and index to last used SK-counter value. This variable is maintained until all the S-CPAC configurations are maintained.**

**If not, companies can indicate alternative signaling solutions and the advantages of the same.**

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| **Company** | **Answer (Yes/No)** | **Additional comments** |
| OPPO | See comments | 1. For the first bullet, we agree the “List of Group-ID and associated SK-Counter list” is provided outside candidate configuration since it is provided per SN. While it should be contained in the same message that provides subsequent CPAC configuration, i.e. within *ConditionalReconfiguration.* 2. Suggest to modify the second bullet as following to be more precise:   *“Each candidate configuration includes the Group ID outside the condRRCReconfig includes RRCReconfiguration.”*   1. We see no need to introduce new UE variable for SCPAC-SK-Counter-list configuration maintenance. As the SK counters will always be maintained/released along with subsequent CPAC configuration, single UE variable(i.e. *VarConditionalReconfig)* is sufficient to maintain the SK counter configuration as well as other subsequent CPAC configuration.   Furthermore, we wonder what does ”index to last used SK-counter value” mean. Upon inter-SN PScell change, the used SK-counter should be considered as invalid with no additional spec impact. |
| Lenovo | Yes and… | 1. The last-used-index is incremented monotonically by 1 for inter-SN cases only. The counters in the SK-Counter list for the same group may be contiguous (e.g., 5, 6, 7…) but need not be (e.g., 5, 12, 20…) up to the network. 2. The counter values in two different SK-Counter lists for two different groups must be unique i.e., same counter values can’t be used in two SK-Counter lists. |
| ZTE | See comments | For the first and second bullets, we share the same view with OPPO.  For the third bullet, we also think the existing UE variable VarConditionalReconfig can be used to maintain the subsequent CPAC configuration, including SCPAC-SK-Counter-list, i.e. no need to introduce separate UE variables.  Besides, it seems no need to introduce the index to last used SK-counter value, if the UE removes the selected SK-counter from the corresponding SK-counter list each time after generation of K-SN and subsequent security keys. Please see our comments in Q1. |
| vivo | See comments | For the second bullet, we think it should be clarified whether each candidate configuration includes **only** the Group ID, or with the sk-counter list as well. It the sk-counter list is included in candidate configuration as well, then we are wondering whether it is possible that the sk-counter lists can be different for different PSCells, e.g.:  *RRC reconfiguration*:  {SN group ID-1, sk-counter 1,2,3,4,5,6}  *Conditional reconfiguration:*  {PSCell-1, SN group ID-1, sk-counter 1,2,3,4,5}  {PSCell-3, SN group ID-1, sk-counter 6}  And for the last bullet, we share the same view with ZTE. It is doubtful that this kind of index is needed. The UE can just delete the used SK-counter value in its variable, as we understand the used sk-counter cannot be used again. |
| Ericsson | See comments | We agree that it may not be needed introduce a new UE variable for this, the OPPO proposal seems to work. Also, an index to the last used counter value doesn’t seem to be needed.  We also need to consider the co-existence with existing Sk-counter. |
| MediaTek | See comments | On bullet 3, it is not clear to us whether reusing *VarConditionalReconfig* or a new UE variable will be result in better/simpler SPEC description. We are open for discussion. |
| Apple | Some comments (esp on bullet 3) | Bullet 3 : We do not want explicit procedures at the UE on handling used Sk counter. We could just say, UE uses the next un-used sk-counter and leave it to UE impl to ensure that, no need of extras variables etc. |
| Intel | Yes (with comments) | As also discussed in the next question, SK-counter is provided by the MN today and we expect to continue with that approach. Here, it will be the list of “Group ID and associated SK-Counter list” that will be provided by the MN.  The second bullet is not so clear to us – what is meant by “outside the RRC configuration”. But we agree with the general concept that the candidate configuration includes the Group ID. |
| Xiaomi | See comments | Yes for Bullet 1 and 2, and OPPO’s changes for bullet 1 and 2 are fine for us.  For Bullet 3, we also think a new UE variable for SCPAC-SK-Counter-list is not needed. And similar to our comments for Q1, UE use the first unused SK-counter in SK-counter list can be up to UE implementation. |

As the UE is expected to select the next free available SK counter from the list of SK counters in orderly manner, the new SK counter value selected after the Inter-SN change can also be known to MN implicitly. In this case explicit signalling of selected SK counter to MN after the CPAC execution is not mandatory. It may be needed in some specific scenarios where there may be chances for mis-synchronization of the selected counter. There are different views expressed on the indication of selected SK counter value to MN on SCPAC execution.

**Q3: On execution of target configuration that changes SK counter value,**

1. **Do companies see need for including the selected SK counter value in RRC-Reconfiguration-complete considering the possibility that NW is aware of the selected SK counter value based on the defined UE behaviour?**
2. **If yes, please indicate the scenarios where such indication will be required.**

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| **Company** | **Answer (Yes/No)** | **Additional comments** |
| OPPO | See comments | In SA3 draftCR, they provide three options on the security info interaction among MN and SN as well as the corresponding interaction between UE and MN:  *Option 1: The MN derives the corresponding KSN as described in Annex A.16 based on the corresponding SN Counter values. The KSN keys and the corresponding SN Counter values are sent to the SN from the MN. The SN shall store the KSN keys and the corresponding SN Counter values in its security context.*  *Option 2: After the derivation of sequence of multiple distinct SN Counter values for each candidate SN, the SN Counter values are sent to the UE from the MN. The MN does not need to store the SN Counter values for each SNs after sending them.*  *Option 3: The MN derives the corresponding KSN as described in Annex A.16 based on the corresponding SN Counters values. The KSN keys are sent to the SN from the MN. The SN shall store the KSN keys in its security context.*  *Corresponding to the Option 1 in 6.10.2.X.1: The UE shall inform the MN which SN Counter value it used for KSN derivation when accessing the SCG of the target SN. The MN signals the received SN Counter value to the SN. The SN decides the KSN based on the received SN Counter value.*  *Corresponding to the Option 2 in 6.10.2.X.1 [Alt 1]: When the UE accesses an SCG of a target SN, the MN receives the SN Counter value from the UE. The MN derives KSN using the received SN Counter value. The KSN is sent to the target SN from the MN.*  *Corresponding to the Option 2 in 6.10.2.X.1 [Alt 2]: When the UE accesses an SCG of a target SN, the target SN receives the SN Counter value from the UE. The target SN uses the SN Counter value to request the Ksn derivation from MN.*  *Corresponding to the Option 3 in 6.10.2.X.1: The SN chooses the first unused Ksn key for that UE to establish the security with the UE.*  We understand whether UE shall indicate the selected SK counter rely on which option is selected by SA3. For option 1 and option2, including the selected SK counter in RRC reconfiguration complete message is required. While for option3, target SN may choose the unused Ksn with pre-defined order without the explicit indication from UE/MN. |
| Lenovo | Both alternatives work | Yes (**including the selected SK counter value in RRC-Reconfiguration-complete**): UE provides *next unused* SK-Counter in a **secured** RRC Reconfiguration complete message to the MN. MN generates S-KgNB and provides this to target SN, along with the SN Change complete from the UE. This does not require the MN or SN to remember the SK-Counter sequence/ list.  No (**not including the selected SK counter value in RRC-Reconfiguration-complete**): Since when the execution conditionof one (subsequent) candidate PSCell is satisfied, the UE applies *RRCReconfiguration\** message corresponding to the selected candidate PSCell, and sends an *RRCReconfigurationComplete\** message, including an *RRCReconfigurationComplete\*\** message for the selected candidate PSCell, and information enabling the MN to identify the SN of the selected candidate PSCell…MN can track UE’s movement and should be in a position to determine UE’s SK-Counter to be used for the target PSCell. Here, the MN need not remember the entire history but only the “last” occurrence of the UE in each candidate SN.  We do not see any security issue or race condition/ de-Sync between the UE and the MN/ SN from this aspect. |
| ZTE | No | In our understanding, the SK-counter list is provided by the MN, so the MN can maintain the SK-counter list corresponding to each candidate SN and perform the same handling for the SK-counter selection as the UE (i.e. select the first entry in the list and remove the used SK-counter after generation of the SN key) when knowing the target candidate SN selected by the UE. And then the MN can transfer the generated SN key to the target candidate SN.  Thus, the MN is only required to know which candidate SN is selected by the UE, which has been implemented by including the selected candidate PSCell information (i.e. condReconfigId) in the RRCReconfigurationComplete message to the MN upon CPAC execution. So there is no need to explicitly indicate the selected SK counter value to the NW. And no mis-synchronization will be caused if the MN and the UE handle the selected SK-counter with the same behaviour. |
| vivo | No | Our understanding is that the current multi-sk-counters mechanism can already work well and there is no misalignment between the UE and the NW about the sk-counter/ Ksn usage, which is, similar to the understanding of option-3 brought by SA3 as OPPO mentioned.  Although it is true that it is workable to include the selected SK counter value in the RRC complete message, we don’t see a strong motivation to spend more time with more RAN2 specification impact on that. |
| Ericsson | Maybe | We think both options 1 or 3 could work, but the UE sending the value in *RRCReconfigurationComplete* is more safe in case of misalignment between the UE and the network regarding number of executed procedures. |
| MediaTek | See comments | We agree the comment from OPPO regarding to SA3 discussion.  We think either approach (inform NW or not) should be fine. |
| Apple | Prefer UE reporting. | As Oppo has shown, 2 of the SA3 options already involve UE reporting the used sk\_counter.  Also in the case where the UE is configured with R17 CPAC and R18 S-CPAC, we do not see the need of a restriction on the NW to not have the same SN in both lists. In such a case, some form of indication is needed from the UE for the MN to know if SN changes is based on R17 or R18. We think we can run into situations like, esp with R17 and R18 mix of deployments, and it is better/safer for the UE to report. |
| Intel | No (see comments) | For network configuration, network should ensure that same SN-counter value is not re-used. The UE and SN selects the next available SK Counter value. Then the main motivation for including this would be to handle failure cases (as is done in NAS signalling). Such signalling can add additional delay to communicate the keys through the MN. With the current agreement that UE performs re-establishment on failure, there does not seem to be a scenario where the network and UE can go out of sync. If such a failure scenario is identified where a mismatch can happen, this can be considered. |
| Xiaomi | No | Because all SK-counter lists and the association between SK-counter lists and SCPAC configurations are always provided by the MN and MN can always know which candidates SN is selected by the UE via the RRCReconfigurationComplete message. Hence, network can always know which SK-counter has been used and the probability of mis-synchronization of the selected counter is very low. |

Depending on the usage of the SK-counter list for a given SN, MN can update the SK-counter list for specific SN via a dedicated RRC signaling message that can update the SK-counter list. It is possible to include additional counter entries via update operation or the complete list can be replaced whenever MN intends to update the list.

## 3.2 Additional Scenarios

RAN2 has agreed that the SCPAC configurations are maintained at UE during Pcell-change /PSCell change and SCG release scenarios unless explicitly specified by NW to release the SK-Counter list. In such scenarios, the SK-counter list along with the current information of unused counters per SN also needs to be maintained UE in similar manner. However, in this case there could be some security concerns for each of the scenarios. Hence RAN2 needs to conclude on the UE behaviour on these scenarios.

**Q4. For Pcell-change /PSCell-change /SCG Release scenarios, if the SCPAC configuration is maintained what is the expected UE behavior on maintaining the SK-counter list.**

1. **UE maintains the current status of the SK-counter list along with used counter status corresponding to the maintained configuration.**
2. **UE releases the SK-counter list by default. If the SCPAC is maintained, NW is expected to provide new SK-counter list to be used after the RRC Reconfiguration in these scenarios.**
3. **Indicate the scenario to SA3 and ask SA3 opinion for any preferred UE action.**
4. **Other Means.**

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| **Company** | **Option** | **Additional comments** |
| OPPO | Option A | The SK-counter list should follow the same behaviour as SCPAC configuration, i.e. rely on NW on release/maintenance/modification. |
| Lenovo | Option A | Seems to work. |
| ZTE | Option A, but | For option A, we think the UE just needs to maintain the current status of the SK-counter list, no need to record the used counter status (see our comments in Q1/2). |
| vivo | A | B is not preferable as it requires more signalling between NW and UE, which is not aligned with the spirit to introduce subsequent CPAC.  We think A would be enough. We are also fine if the majority thinks it should be informed to SA3. |
| Ericsson | A | The same behaviour as for S-CPAC should be applied. |
| MediaTek | Option A | We assume maintain the SK counter list is okay and NW could reconfigure it explicitly if needed. |
| Apple | A | But, we assume that ASN.1 need codes can ensure this. |
| Intel | A with comments | We suggest to split the discussion into the functionality and signalling aspects. In terms of signalling, we prefer to keep to the general principle that network should signal the release of a configuration explicitly where possible rather than implicit release in the procedural section. That is, option A.  In terms of functionality, the discussion is on whether the previously signalled SK-counter will be valid for the scenarios. The different scenarios have to discussed separately. For PCell change, there could be a change of KgNB and that can invalidate the SK counter values sent with the previous KgNB. Hence it is safer to release them. For SCG release, we don’t normally leave hanging configurations in the UE and it is also cleaner to release them explictly. The PSCell change scenario mentioned here is not clear to us – what exactly this is addressing where there is a need to release the SK counter? In any case, as mentioned in the previous para, we prefer network to explicitly release the SK counter when it should not be maintained. |
| Xiaomi | Option A | Based on network configuration, network can update SK-counter list when Pcell-change /PSCell-change /SCG Release, if needed. (similar to maintain SCAPC configuration) |

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It is possible that conditional configurations provided to UE may include some configurations which are not to be maintained for SCPAC. For these candidate configurations when MN provides explicit SK counter value, it is possible to assign uniquely different value from the SK-counter-list given to SCPAC OR it can be one of values assigned for SCPAC. Because the UE is expected to release SCPAC when UE execute these normal CPAC or CHO configurations. To decide on specific NW and UE behaviour for this scenario following discussion will be beneficial.

**Q5. Should the SK-counter lists configured for SCPAC purpose and explicit SK-counter configured for Rel-17 CPAC be uniquely different?**

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| **Company** | **Answer (Yes/No)** | **Additional comments** |
| OPPO | Yes | According to current agreements, the SCPAC configuration may be maintained if NW does not explicitly indicate UE to release upon the execution of normal CPAC or CHO. To avoid frequently RRC reconfiguration of SK counter list after CPAC or CHO, uniquely different values should be assigned for the SK-counter-list given to SCPAC. |
| Lenovo | Yes | This is anyway in network’s implementation and unique values (like a SK-counter value not included in any SK-counter-list) can save any potential rekeying issues. This way UE implementation can be simplified. |
| ZTE | Yes | We think it can be up to the NW implementation to ensure unique SK-counter value(s) is provided for each conditional configuration. |
| vivo | Yes | It is up to NW implementation to ensure that.  Otherwise, if a same SK-counter is provided to UE for Rel-17 CPAC (compared to R18 S-CPAC), it must need to be deleted from UE’s variable as the same sk-counter cannot be used more than once, thus introducing more spec impact. |
| Ericsson | Yes | This can be up to network implementation, no need to specify anything. |
| MediaTek | Yes | We understand each sk-counter value should be unique in the R18 S-CPAC sk-counter list or in R17 explicit IE contained in candidate configuration (i.e. *RRCReconfiguration* in *condRRCReconfig-r16*.)  BTW, we expect explicit SK-counter (the one in *RRCReconfiguration* within container *condRRCReconfig-r16*) should NOT be used for Rel-18 S-CPAC candidates. Otherwise, it would be confusing. |
| Apple | Yes |  |
| Intel | Yes with comments | Agree in principle, but this can be left to network implementation. The basic security requirement is clear that the same SK counter value should not be reused. Whether we capture any network requirements as a guidance can be discussed later. |
| Xiaomi | Yes | It can be up to network implementation to ensure that. |

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RAN2 is yet to conclude on the failure scenarios related to subsequent CPAC changes as PS-Cell change failure and S-RLF scenario. In such cases depending on the specified UE behaviour there can be additional impacts related to SK-counter management. In the rapporteur view impact to SK-counter management for failure scenario can be revisited once RAN2 concludes on the same. If companies think some failure scenarios require early attention for SK-counter management, it can be indicated here.

**Q6. Do companies think some additional changes or issues to be addressed related to SK-counter management for failure scenarios (S-RLF and SCG-change failure) ? If yes, the issues can be captured here.**

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| **Company** | **Answer (Yes/No)** | **Additional comments** |
| OPPO |  | This can be discussed after we have progress on failure cases. |
| ZTE |  | This can be discussed later after we conclude on failure cases. |
| vivo | No | We can wait for more progress on failure scenarios for general S-CPAC configurations. |
| Ericsson |  | Agree that it can be discussed later. |
| MediaTek |  | We expect S-CPAC evaluation is stopped after SCG failure, in this case, there should be no issue. |
| Apple |  | As the case with others, UE will release the counter list at RLF/SCG failure. |
| Intel | See comments | Agree with the rapporteur that failure scenario handling for SK-counter can be revisited once RAN2 concludes the details of failure handling itself. |
| Xiaomi |  | We also prefer to discuss the issue later after we conclude on failure cases. |

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If any specific scenario /issue not handled in the above list of questions can be provided as part of the below question.

**Q7. Any additional issues /scenarios impacted due to subsequent CPAC for security key management and specific comments for the same.**

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| **Company** | **Answer (Yes/No)** | **Additional comments** |
| MediaTek |  | What is the UE behavior if all the configured sk-counters has been used out? We assume that the UE simply stop S-CPAC evaluation for the corresponding SN. Not sure if any different understanding. |
| Apple |  | For the MediaTek situation, we assume the NW configuration does not result in such scenario. |
| Intel |  | We also have the same view as Apple that this should not happen with proper network implementation. We don’t think it is necessary to specify a UE behaviour for this case. W |
| Xiaomi |  | For the MediaTek situation, we share the same view with Apple and Intel. |

# 4 Conclusion