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Technical Report

**3rd Generation Partnership Project;
Technical Specification Group RAN;
NR;**

**Study on enhancement of Radio Access Network (RAN) slicing
(Release 17)**



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Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

- x the first digit:
 - 1 presented to TSG for information;
 - 2 presented to TSG for approval;
 - 3 or greater indicates TSG approved document under change control.
- y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.
- z the third digit is incremented when editorial only changes have been incorporated in the document.

1 Scope

The present document provides descriptions of use cases and solutions with regard to enhancement of Radio Access Network (RAN) slicing for NR.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

3 Definitions of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

4 General

The present document is organized as follows:

- Clause 5 is to address the objective of enabling UE fast access to the cell supporting the intended slice. Furthermore, clause 5.1 studies on slice based cell (re)selection under network control and clause 5.2 studies on slice based RACH configuration
- Clause 6 is to address the objective of supporting service continuity
- Clause 7 provides the conclusions

5 Study mechanisms to enable UE fast access to the cell supporting the intended slice

5.1 Slice based cell (re)selection under network control

5.1.1 Scenario and issue description

General description for the scenario:

- Multiple and different slices can be supported on different frequencies
- Multiple and different slices can be supported on the same frequency in different regions

For each scenario we study both IDLE and INACTIVE and determine whether there is need for solutions. Connected mode will also be considered but with a lower priority.

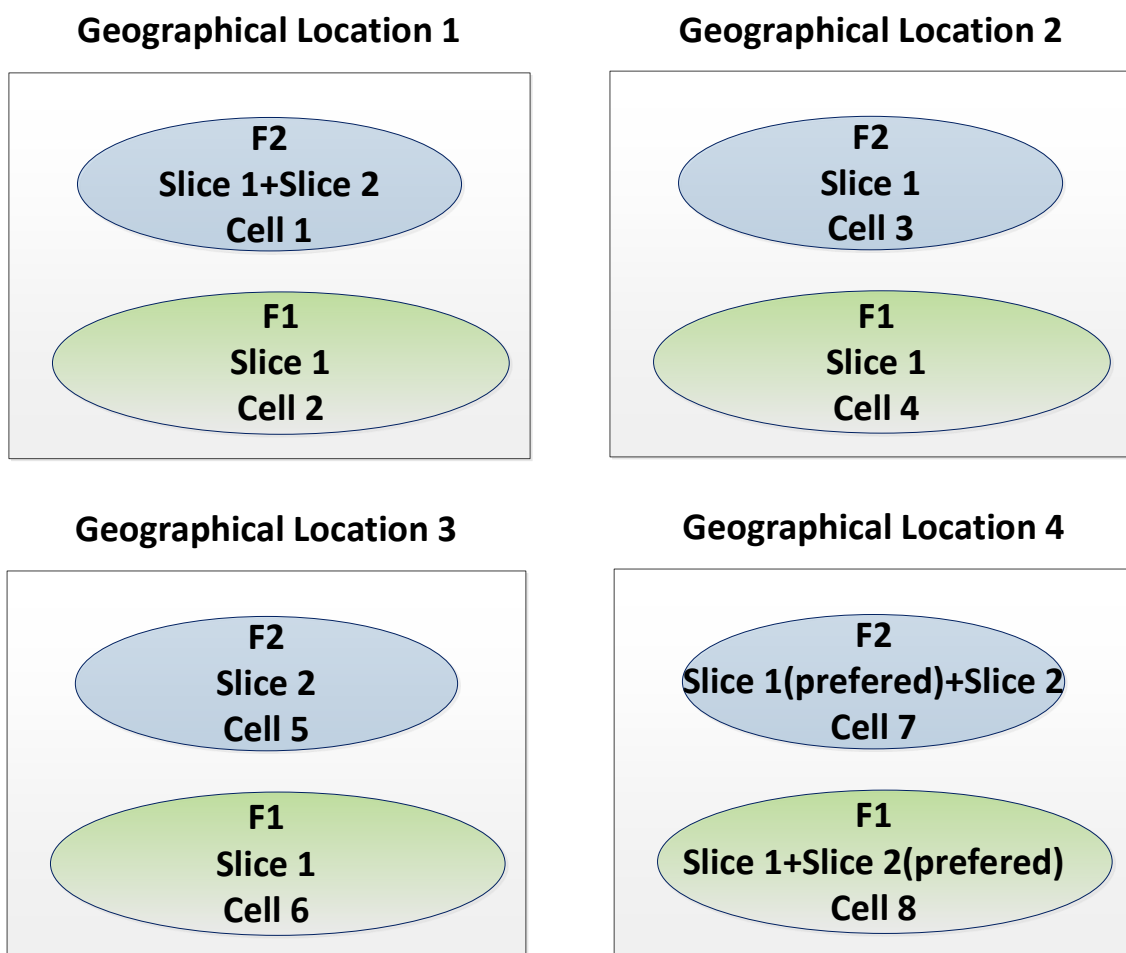


Figure 5.1.1-1: Examples for slice deployment scenarios

In the examples shown in Figure 5.1.1-1, slice 1 refers to e.g., eMBB, and slice 2 refers to e.g., URLLC. "Cell X" in the figures represent a set of cells.

Geographical Location 1 is deployed in the factory or hospital. In this location, F1 supports slice 1 (e.g., eMBB), while F2 supports both slice 1 and slice 2 (e.g. eMBB and URLLC).

Geographical Location 2 is the public area. F1 and F2 all supporting slice 1 (e.g., eMBB) for smart phone users, no slice 2 (e.g., URLLC) is supported in Geographical Location 2. And F2 is deployed as hotspot to provide wideband access.

Geographical Location 3 illustrates that different slices are supported on different frequencies. F1 only supports slice 1 and F2 only supports slice 2.

Geographical Location 4 illustrates a typical scenario that slices are available via multiple frequencies. And one or a set of frequencies are preferred for certain slice, e.g. F1 is preferred for slice 2 and F2 is preferred for slice 1 in Geographical Location 4.

eMBB and URLLC slices are used only as an example of various slices. The deployment of any slice on any frequency band is up to network implementation.

RAN2 common understanding is that intended slice is based on the information AS receives from NAS for the particular use case. This may be different in different cases:

- In case of cell selection and reselection, the intended slice means the allowed or requested S-NSSAI(s).
 - For the initial registration, and requesting new S-NSSAI(s): intended slices = Requested S-NSSAI(s)
 - For idle-mode mobility: intended slices = allowed S-NSSAI(s)
- In case of MO traffic, the intended slice means the S-NSSAI associated with MO traffic based on indication from NAS to AS. For MO service, UE is aware of the intended slice.
- In case of MT traffic, UE is unaware of the slice for the paged service in current NR specification.

The following issues are studied:

Issue 1: The UE is unaware of the slices supported on different cells or frequencies, which prevents UE from (re)select to the cell or frequency supporting the intended slice.

Issue 2: Dedicated priorities would not be available to the UE prior to first RRC connection establishment and only remain valid before T320 expires upon entering IDLE mode. In addition, dedicated priorities are discarded each time when UE entering CONNECTED mode and need to be configured again before UE leaving CONNECTED mode.

Issue 3: Operator may require different frequency priority configurations for the specific slice in different areas, however the dedicated priority always overwrites the broadcast priorities if configured.

Issue 4: If the serving cell is unable to support the requested slices, the serving cell may need to perform handover to a cell supporting the requested slices or release the RRC connection. That may increase control plane signalling overhead as well as long control plane latency for the UE to access the network.

5.1.2 Solutions

The following solutions are studied:

Solution 1: Legacy dedicated priority via *RRCRelease* message.

Solution 1 (i.e., Legacy dedicated priority via *RRCRelease* message) cannot address issue 2 and issue 3.

Solution 2: Rel-15 mechanisms such as HO, CA, DC and redirection can be used to access the intended slice in different cell.

Solution 2 is legacy solution. With solution 2, the UE is still unaware of the slices supported in different cell or frequencies and the HO, CA, DC and redirection can be used to compensate for such loss with increased signalling overhead and latency. HO, CA, DC, redirection are applicable only for connected mode UE.

There is no complexity to support solution 2.

Solution 3: Slice related information for cell selection, e.g., the supported slice info of serving cell and neighboring cells, is provided in the system information.

Solution 3 can address issue 1, issue 2 and issue 4. There is benefit to broadcast slice related cell selection info in SIB.

The concerns on security and SIB payload size for broadcasting slice related cell selection info need to be resolved in WI phase (e.g., by providing only SST, on-demand SIB, SIB segmentation, slice grouping or slice associated UAC information).

For cell selection scenario, RAN2 may discuss during WI whether to broadcast supported slice of serving cell in SI message and how to solve SIB1 concerns.

The solution of adding the intended slice for MT access in slice specific cell selection is not pursued.

Solution 4: Slice related information for cell reselection is provided in the system information or *RRCRelease* message.

Solution 4 can address the issue 1, issue 2, issue 3 and issue 4. There is benefit to broadcast slice related cell reselection info in SIB. The slice info (with similar information as agreed slice info in SI message) can be added in RRC release message. Details can be discussed in WI phase.

The concerns on security and SIB payload size for broadcasting slice related cell reselection info need to be resolved in WI phase (e.g., providing only SST, on-demand SIB, SIB segmentation, slice grouping or slice associated UAC information).

To assist cell reselection, RAN can broadcast the supported slice info of the current cell and neighbour cells, and cell reselection priority per slice. The slice info may be: providing only SST, on-demand SIB, SIB segmentation, slice grouping (if any), or slice associated UAC information where other solutions are not precluded. Details can be discussed in WI phase. And, how to ensure UE doesn't lose coverage due to slice prioritization can be considered in WI phase.

The solution of adding the intended slice for MT access in slice specific cell reselection is not pursued.

Slice group is supported for both solution 3 and solution 4. Whether to define a new grouping mechanism or reusing UAC access category is left to WI phase.

5.2 Slice based RACH configuration

5.2.1 Scenario and issue description

The intentions for slice based RACH configuration are as follows:

Intention 1: RACH resource isolation. From marketing point of view, some of the industrial customers have the requirement for access resource isolation, in order to provide guaranteed RA resources for their sensitive slices.

Intention 2: Slice access prioritization. In R15 and R16, all slices are sharing the same RA resources and cannot be differentiated by network side. But some slices may need to be prioritized during the RA procedure.

5.2.2 Solutions

The following solutions are studied:

Solution 1: Slice-specific separate RACH resources pool can be configured per slice or per slice group, in addition to the existing common RACH resources.

The association between slices and slice-specific RACH resources can be configured and provided to UE in SIB and dedicated signalling. Separated PRACH configuration (e.g., transmission occasions of time-frequency domain and preambles) can be configured for slice or slice group. Separated PRACH configuration for slices does not imply PHY layer impacts.

Solution 2: Slice-specific RACH parameters prioritization can be configured per slice or per slice group.

Existing RACH parameters prioritization (i.e., *scalingFactorBI* and *powerRampingStepHighPriority*) can be supported as baseline for slices-specific RACH parameter prioritization.

Slice group is supported for solution 1 and solution 2. Whether to define a new grouping mechanism or reusing UAC access category is left to WI phase.

Slice based RACH configuration can be applied to idle and inactive UE. Solution 1 and Solution 2 can work independently in a complementary way. Neither solution 1 nor solution 2 may not be applicable to all possible slices.

The following open issues may be considered in WI phase:

- a) For slice specific RACH, how to perform RACH type selection (e.g., 2-step and 4-step).
- b) The fallback mechanism, e.g., whether to support 2 step slice-based RACH fallback to 4-step slice-based or common RACH.
- c) The collision in case that slice-specific RA prioritization is configured together with legacy RA prioritization (e.g., MPS and MCS UEs).

6 Study necessity and mechanisms to support service continuity

6.1 Scenario and issue description

Editor Note: capture the description of scenario and issue.

Editor Note: The proposed scenarios listed in this clause remain to be evaluated and updated.

The following two scenarios are considered to support service continuity.

Scenario 1: Slice resource shortage in case of Intra-RA mobility and Inter-RA mobility

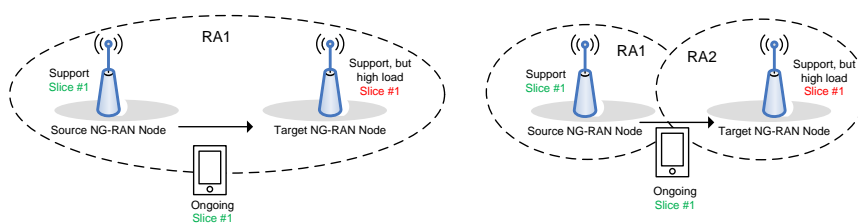


Figure 6.1-1: Service interruption due to slice resource shortage

As shown by Figure 6.1-1, the UE's ongoing slice(s) is/are supported by both the source and the target NG-RAN node. At the time of handover, the target node fails to accept the UE with at least one of the ongoing S-NSSAIs due to e.g. high slice-related load at the target node. Under such circumstance, the service(s) for failed ongoing slice(s) is/are interrupted for the UE.

It should be noted that remapping of traffic into the resource pool used by other slices requires a pre-configured policy allowing such action. The remapping should avoid overloading the resource pool of the target slice. Any solution to this issue should comply with the RRM policy model defined in TS 28.541 and be validated by SA5.

How to support the slice recovery (i.e., re-mapping of remapped slice to on-going slice) when the NG-RAN node recovers enough resources to serve the on-going slice(s) will be discussed in normative phase.

Scenario2: Non-supported slice in case of Inter-RA mobility

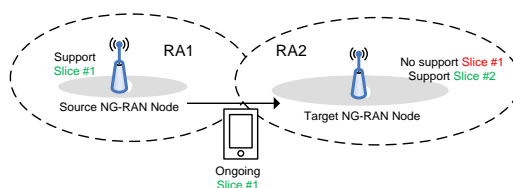


Figure 6.1-2: Service interruption due to slice not supported

As shown by Figure 6.1-2, the UE is moving towards an area that does not support at least one of UE's ongoing slices. The target node fails to accept the UE with at least one of the ongoing S-NSSAIs. Under such circumstance, the service(s) for failed ongoing slice(s) is/are interrupted for the UE.

This scenario is only valid if there is a specific SLAs, where the original slice is required to be available in a specific geographical area (TA/RA) and where services used on the original slice are also required to have continuity if moving outside the geographical area. It is also assumed that new PDU sessions of the same slice are not initiated in the new geographical area i.e., the SLA applies to connected mode mobility only.

Scenario 3: Moving back for slice resource shortage in case of Intra-RA mobility and Inter-RA mobility

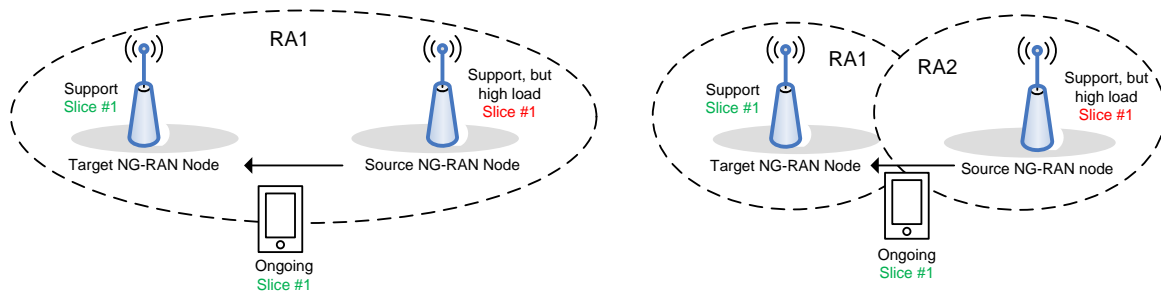


Figure 6.1-3: Moving back scenario due to slice resource shortage

This is a continuation scenario of scenario 1. As shown by Figure 6.1-3, the UE's ongoing slice(s) is/are supported by both the source and the target NG-RAN node. At the time of handover, the source node may serve at least one of the S-NSSAIs with degraded performance, or already rejects at least one of the S-NSSAIs, due to e.g., high slice-related load at the source node. Meanwhile the target node can fully support these S-NSSAIs.

Scenario 4: Moving back for non-supported slice in case of Inter-RA mobility

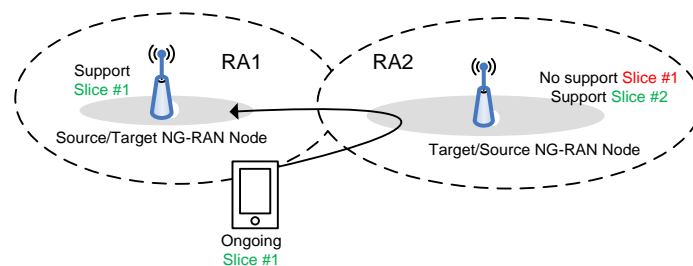


Figure 6.1-4: Moving back scenario due to slice not supported

This is a continuation scenario of scenario 2. As shown by Figure 6.1-4, at the time of handover, the source node may serve the UE with at least one of the S-NSSAIs not supported by the target node. The UE is moving towards an area that supports at least one of UE's these slices.

Scenario 5: Slice resource shortage for MR-DC

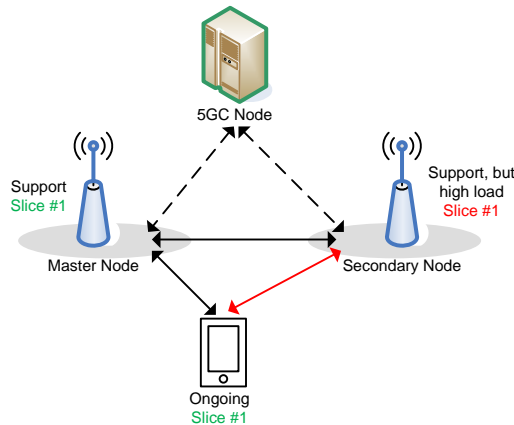


Figure 6.1-5: Service interruption due to slice resource shortage in SN

As shown by Figure 6.1-5, the UE's ongoing slice(s) is/are supported by both the MN and the SN. However, in case of SN addition or modification procedure, the SN fails to accept the UE with at least one of the ongoing S-NSSAIs due to e.g., high slice-related load at the SN. Under such circumstance, the services associated with these ongoing slices may be interrupted at the SN side.

Scenario 6: Slice overload in RAN node in absence of mobility

It is possible that resource shortage happens for a slice 1 as in scenario 1. In this case, some ongoing PDU sessions associated to this slice 1 may be offered degraded service even in the absence of mobility.

It is also possible that after taking an action to avoid resource shortage in slice 1, the resource shortage is resolved while the UE is still in the cell. In that case, any action taken can be reversed.

6.2 Solutions

NOTE: All solutions involving slice re-mapping do not work for legacy UEs when applied to scenario 2 and 4 because the UEs will release the PDU session when receiving the new Allowed NSSAI in the Register Update following the handover. Therefore, it is left to SA2 to investigate how to handle legacy UEs.

6.2.1 Re-mapping decision in NG-RAN node

Editor note: Feasibility of this solution at system level requires further work including checking with SA2.

In solutions where the target NG-RAN node decides the re-mapping at incoming handover, the target NG-RAN node should be aware of the re-mapping policy for the involved PDU session. The following options are available:

6.2.1.1 Slice Re-mapping policy generation

6.2.1.1.1 Slice Re-mapping policy configured by OAM

Configuration in target NG-RAN node

This option assumes that the remapping policy is rather static because it should have been validated by the tenant or the operator.

Therefore, the NG-RAN node is configured in advance with the re-mapping policy by the OAM.

In this option, the granularity of the re-mapping policy is per slice i.e. for each supported S-NSSAI, the target NG-RAN node is configured with a list of possible re-mapped S-NSSAI(s) as follows:

- S-NSSAI 1 \leftrightarrow re-mapped list (S-NSSAI 10, S-NSSAI 11)
- S-NSSAI 2 \leftrightarrow re-mapped list (S-NSSAI 12, S-NSSAI 13)

6.2.1.1.2 Slice Re-mapping policy configured by CN (during NG setup)

Signaling in NG Setup Response

The NG-RAN node has received in advance the re-mapping policy in the NG Setup Response message (or any update in the AMF configuration Update message) from the CN.

In this option the granularity of the re-mapping policy is the slice i.e. for each S-NSSAI supported by the target NG-RAN node, the CN includes in the NG Setup Response (respectively AMF Configuration Update) message an associated list of possible re-mapped S-NSSAI(s).

6.2.1.1.3 Slice Re-mapping policy configured by CN (during PDU session setup)

Signaling in NG Handover Request

At the time of handover, the CN includes in the NG Handover Request message the current PDU Session, the associated S-NSSAI and also the list of S-NSSAI(s) to which this PDU session can be re-mapped.

In this option the granularity of the re-mapping policy can be either:

- Per PDU session (using same principles as slice association in PDU Session Setup)
- Per UE: even though signaled for the involved PDU session, the choice of possible re-mapped slices for a given slice is a general policy for the UE.

Example of per UE policy:

UE 1, any PDU session of S-NSSAI 1 \leftrightarrow re-mapped list (S-NSSAI 10, S-NSSAI 11)

UE 2, any PDU session of S-NSSAI 1 \leftrightarrow re-mapped list (S-NSSAI 12, S-NSSAI 13)

Example of per PDU session policy:

UE 1, PDU Session 1, S-NSSAI 1 \leftrightarrow re-mapped list (S-NSSAI 10, S-NSSAI 11)

UE 1, PDU Session 2, S-NSSAI 1 \leftrightarrow re-mapped list (S-NSSAI 12, S-NSSAI 13)

UE 2, PDU Session 3, S-NSSAI 1 \leftrightarrow re-mapped list (S-NSSAI 14, S-NSSAI 15)

Signaling from Source NG-RAN node

When the PDU session is created in the source NG-RAN node, the CN includes in the NGAP PDU Session Resource Setup Request message (or the Initial Context Setup Request message or the NG Handover Request message) the S-NSSAI associated with the PDU session and also the list of S-NSSAI(s) to which this PDU session can be re-mapped.

At the time of subsequent Xn handover, the source NG-RAN node includes in the Xn Handover Request message the current PDU Session, the associated S-NSSAI and also the list of S-NSSAI(s) to which this PDU session can be mapped.

In this option the granularity of the re-mapping policy can be either:

- Per PDU session (using same principles as slice association in PDU Session Setup)
- Per UE: even though signaled for the involved PDU session, the choice of possible re-mapped slices for a given slice is a general policy for the UE.

The above slice-remapping principle applicable to the handover case can be applied to MR-DC case.

6.2.1.2 Slice Re-mapping Message Sequence Charts

6.2.1.2.1 Slice Re-mapping for mobility case

Editor note: Feasibility of this solution at system level requires further work including checking with SA2.

6.2.1.2.1.1 Slice Remapping decision in target gNB at Xn based handover

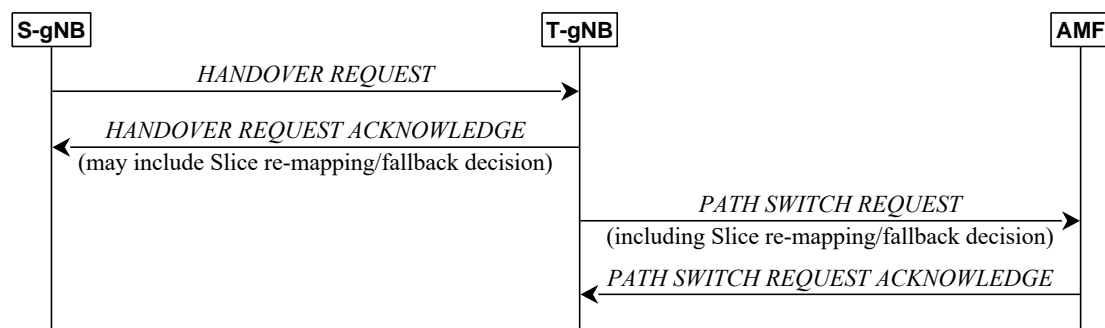
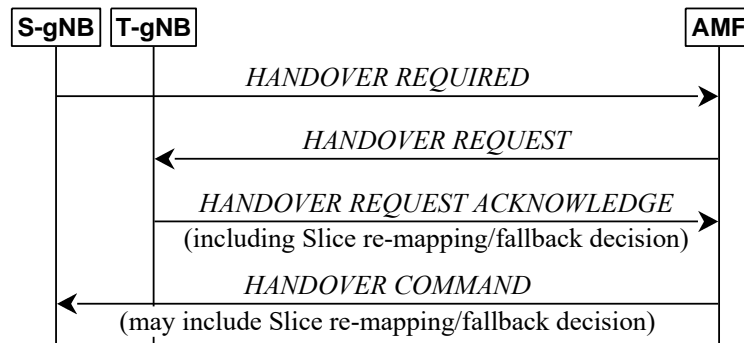


Figure 6.2.1.2.1.1-1: Slice re-mapping/fallback determined by the T-gNB

1. The S-gNB sends the *HANDOVER REQUEST* message to the T-gNB.
2. If the UE's ongoing slice(s) is rejected in the target gNB, based on the slice re-mapping policy described in section 6.2.1, the T-gNB makes the slice re-mapping/fallback decision. The T-gNB may send the slice re-mapping/fallback decision in the *HANDOVER REQUEST ACKNOWLEDGE* message to the S-gNB.
3. The T-gNB shall send the slice re-mapping/fallback decision to the AMF through the *PATH SWITCH REQUEST* message.
4. The AMF responds the *PATH SWITCH REQUEST ACKNOWLEDGE* message. The AMF may reject the PDU sessions in the *PDU Session Resource Released List IE*.

Editor Note: It is FFS whether and how the UE is aware of slice remapping.

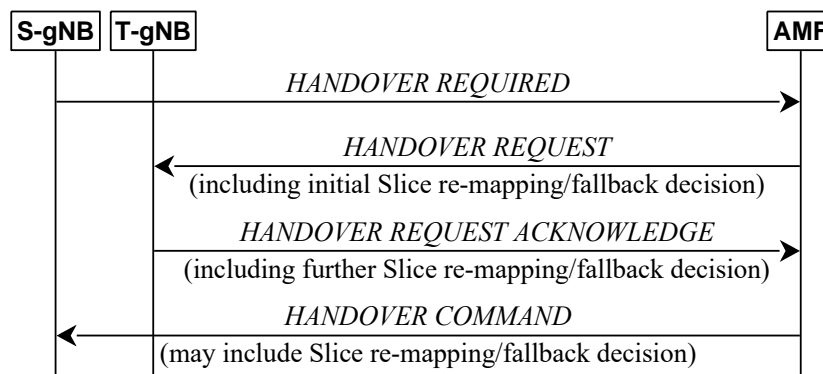
6.2.1.2.1.2 Slice Remapping decision in target gNB at NG based handover

**Figure 6.2.1.2.1-1: Slice re-mapping/fallback determined by the T-gNB**

1. The S-gNB sends the *HANDOVER REQUIRED* message to the AMF.
2. The AMF sends the *HANDOVER REQUEST* message to the T-gNB.
3. If the UE's ongoing slice(s) is rejected in the target gNB, based on the slice re-mapping policy described in section 6.2.1, the T-gNB shall include the re-mapped/fallback decision in the *HANDOVER REQUEST ACKNOWLEDGE* message to the AMF.
4. The AMF may send the slice re-mapping/fallback decision to the S-gNB through the *HANDOVER COMMAND* message.

Editor Note: It is FFS whether and how the UE is aware of slice remapping.

6.2.1.2.1.3 Slice Remapping decision in 5GC and target gNB at NG based handover

**Figure 6.2.1.2.1.3-1: Slice re-mapping/fallback determined by the AMF and T-gNB**

1. The S-gNB sends the *HANDOVER REQUIRED* message to the AMF.
2. If the UE's ongoing slice(s) is not supported by the T-gNB, the AMF may make the initial slice re-mapping/fallback decision and include the decision in the *HANDOVER REQUEST* message to the T-gNB.
3. If the UE's ongoing or re-mapped/fallback slice(s) is rejected in the target gNB, based on the slice re-mapping policy described in section 6.2.1, the T-gNB shall include the further re-mapped/fallback decision in the *HANDOVER REQUEST ACKNOWLEDGE* message to the AMF.

4. The AMF may send the slice re-mapping/fallback decision to the S-gNB through the HANDOVER COMMAND message.

Editor's note: The efficiency of the solution needs to be further evaluated.

6.2.1.2.1.4 5GC Solution based on SSC-mode 3

The call flow below uses SSC mode 3 in 5GC as the service continuity solution:

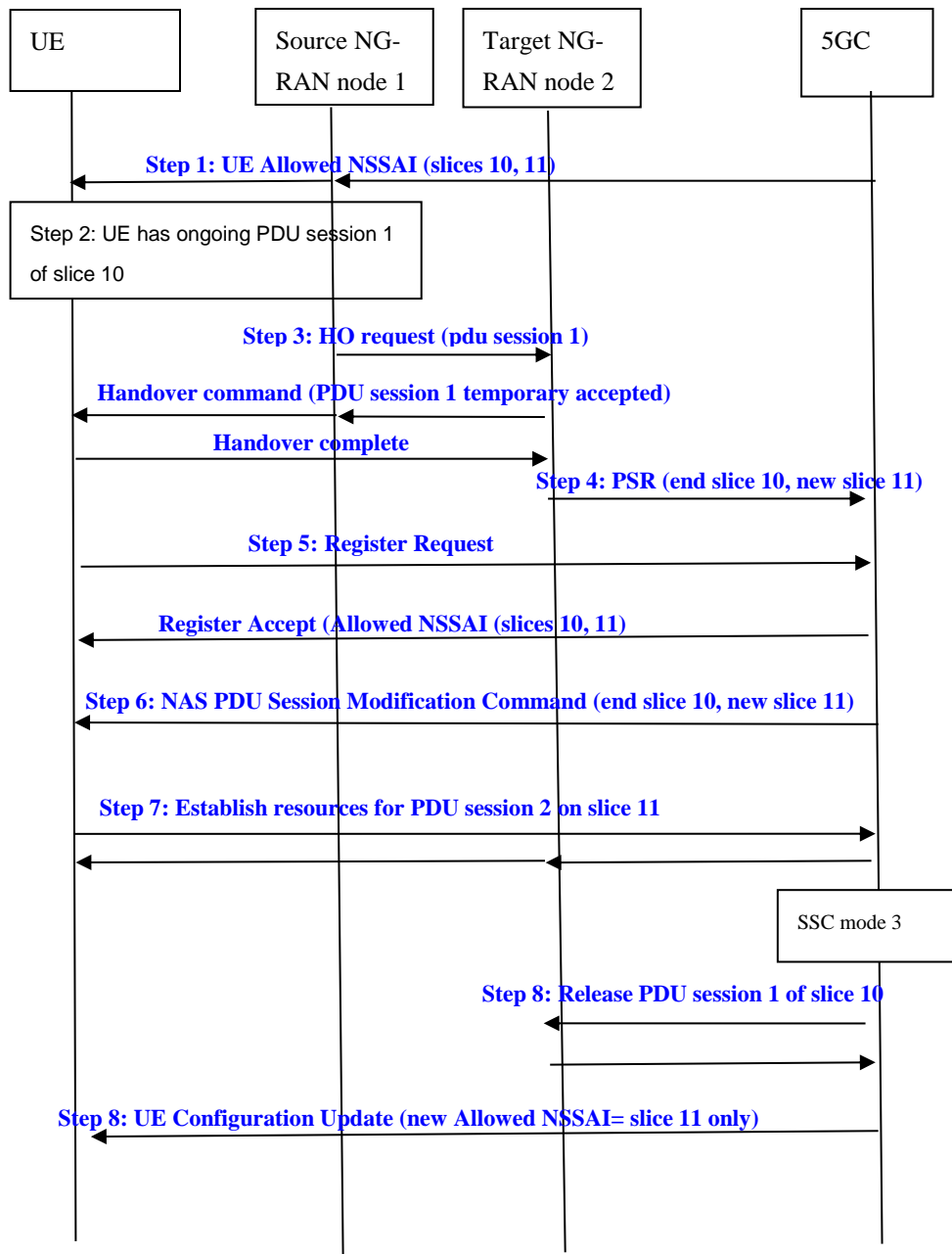


Figure 6.2.1.2.1.4-1 Re-mapping based on SSC mode 3

Step 0: NG-RAN nodes have been configured with slice re-mapping slice 10 to 11.

Step1: 5GC has sent the UE Allowed NSSAI to the serving NG-RAN node and to the UE per existing procedures

Step 2: UE has ongoing PDU session 1 of slice 10.

Step 3: Source NG-RAN triggers Handover to target NG-RAN. The target NG-RAN node 2 informs during the HO procedure the source NG-RAN node 1 that it accepts the PDU session 1 of slice 10 temporarily due to slice re-mapping action.

Step 4: at handover completion, the target NG-RAN indicates to 5GC in Path Switch Request that PDU session 1 of slice 10 needs to be terminated and a new PDU session is to be setup with slice 11.

Step 5: The UE performs the post-handover registration (as Source and Target NG RAN nodes have different slice support, they don't belong to the same registration area for the UE). Because 5GC received (end slice 10) at step 4, the 5GC still includes the slice 10 in the Allowed NSSAI towards the UE at this step (the slice is indeed still temporarily available until it receives from 5GC notification of the final release of PDU session 1 of slice 10 at step 9).

Step 6: In reaction to step 4, the 5GC triggers towards the UE the NAS PDU Session Modification Command to invoke SSC mode 3. The (end slice 10, new 11) may be included towards the UE to prompt the UE to setup the new PDU session 2 with slice 11 even if the URSP in the UE would indicate slice 10 as higher priority.

Step 7: the UE triggers the setup of PDU session 2 with slice 11 according to SSC mode 3 procedure as per existing procedures described in 23.502 § 4.3.2.2.1.

Step 8: at the expiry of SSC mode 3 timer, the 5GC triggers the release of the PDU session 1 of slice 10 according to SSC mode 3 procedures (existing procedures described in 23.502 § 4.3.2.2.1). The 5GC sends a final the UCU (UE Configuration Update) message in order to update the Allowed NSSAI towards the NG-RAN and the UE. In this example, the new Allowed NSSAI is slice 11.

Editor note: This solution is CN-centric and requires confirmation from SA2.

6.2.1.2.2 Slice Remapping for non-mobility case

6.2.1.2.2.1 Slice Remapping decision in SN for MR-DC case

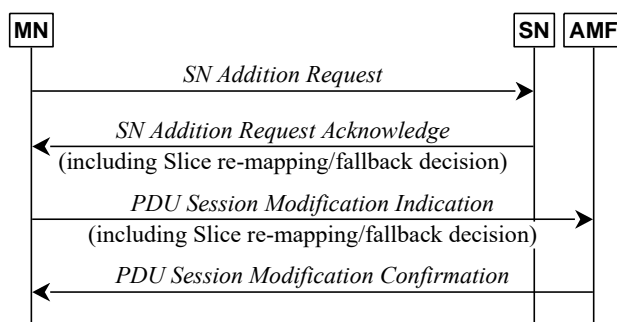


Figure 6.2.1.2.2.1-1: Slice re-mapping/fallback determined by the SN

This flow chart applies to the scenario of resource shortage only.

1. The MN sends the *SN Addition Request* message to the SN.
2. If the UE's ongoing slice(s) is rejected by the SN, based on the slice re-mapping policy described in section 6.2.1, the SN makes the slice re-mapping/fallback decision. The SN shall include the slice re-mapping/fallback decision in the *SN Addition Request Acknowledge* message to the MN.
3. The MN may send the slice re-mapping/fallback decision to the AMF through the *PDU Session Modification Indication* message.

4. The AMF responds the *PDU Session Modification Confirmation* message.

6.2.1.2.2.2 Slice Remapping decision in MN for MR-DC case

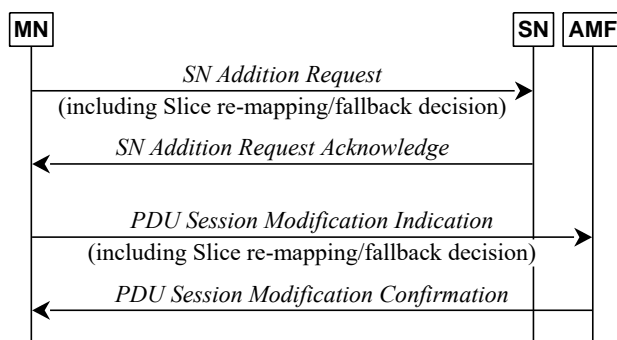


Figure 6.2.1.2.2.2-1: Slice re-mapping/fallback determined by the MN

This flow chart applies to the scenario of resource shortage only.

1. The MN makes the slice re-mapping/fallback decision and include the decision in the *SN Addition Request* message to the SN.
2. The SN confirms the slice re-mapping/fallback decision made by the MN in the *SN Addition Request Acknowledge* message.
3. The MN may send the slice re-mapping/fallback decision to the AMF through the *PDU Session Modification Indication* message.
4. The AMF responds the *PDU Session Modification Confirmation* message.

6.2.1.2.2.3 Slice Remapping Solution for Scenario 6

At the same time the NG-RAN node may notice that another slice 2 which is not overloaded has resources available and is still compatible with the SLA of slice 1.

In short, there is a potential that some unloaded but "good enough or better" alternative slices in the RAN could be used for the subscriber to continue to receive service.

6.2.2 Partially slice re-mapping in NG-RAN

6.2.2.1 Candidate solutions with/without CN involvement

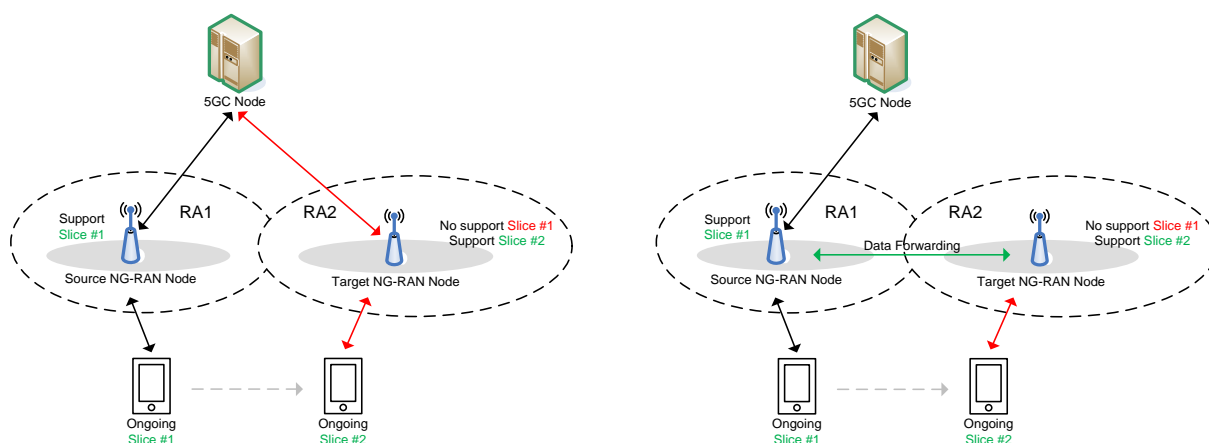


Figure 6.2.2.1-1: Slice re-mapping solutions: (a) with CN impact; (b) without CN impact

This solution is applicable to scenario 2, where there are two possible slice re-mapping solutions depending on whether the CN is involved.

Figure 6.2.4-1 (a) shows the re-mapping solution where both the RAN and CN parts are involved. In this case, the CN procedure is involved.

Figure 6.2.4-1 (b) shows the re-mapping solution where the CN part of the slice is not changed while the RAN part of the slice is remapped. The UL/DL traffics are relayed between the S-gNB and the T-gNB via the Xn tunnel.

Editor's note: The handling of the UE at the target node needs to be clarified.

Editor's note: Whether CN involvement is required, needs to be evaluated.

Editor's note: Slice remapping needs to be defined in line with SA2 definitions.

6.2.3 Resource management in NG-RAN node

6.2.3.1 Configuration Based Solution

The solution builds on the resource modelling described in TS 28.541. The following analysis is provided for the scenario 1 and scenario 2 respectively:

- Scenario 1: Slice resource shortage in case of Intra-RA mobility and Inter-RA mobility

As specified in TS 28.541, the slice re-mapping between different S-NSSAIs can be achieved via the prioritized resource modeling. For example, suppose UE's ongoing slice is S-NSSAI 1 configured with *rRMPolicyMaxRatio* policy, which can use at least one of the shared resources, prioritized resources and dedicated resources. If the dedicated resources are not available, it can use other un-used prioritized and shared resources.

But the following needs to be further studied, e.g., for the S-NSSAI 1,

- it can explicitly use resources belonging to which S-NSSAIs;
- it can use the dedicated but not used resources of other S-NSSAIs;
- it can preempt the used prioritized and/or shared resources from other S-NSSAIs.

In this case, further involvement with SA5 is required.

- Scenario 2: Non-supported slice in case of Inter-RA mobility

In this case, if the T-gNB does not support certain S-NSSAIs, these S-NSSAIs will not be included in the *RRMPolicyMemberList*, thus no resource will be planned by the T-gNB, as specified in TS 28.541.

For example, suppose UE's ongoing slice is S-NSSAI 1, it will not be included in the *RRMPolicyMemberList* of the T-gNB. Thus the re-mapping of S-NSSAI 1 to the supported S-NSSAI(s) of T-gNB is not supported.

In this case, slice re-mapping is not supported yet by the prioritized resource modeling defined in SA5. And further involvement with SA5 is required.

6.2.3.2 Slice resource re-partitioning

Editor note: Feasibility of this solution at system level requires further work including checking with SA5.

This solution is applicable to scenario 1. In this solution, the resource limits for a particular slice in the RAN are relaxed (possibly for a limited time period). This is applicable for resource types which have been hard-partitioned between slices, or where a limit per slice has been defined according to the SLA. For example, such an approach could be applied individually (or jointly) to the following:

- spectrum resource (e.g. slots, beams, carriers etc)
- transport resources (e.g. backhaul capacity)
- hardware resources (e.g. specific processors, processing load, intra-RAN logical nodes such as a gNB-CU-UP)

To solve this problem, the system can allow a slice to use another slice's resources on a temporary basis i.e. making the partition soft. The RAN may allow such temporary overflow while keeping some form of accounting of resources used which may be used to modify the existing SLA, or provide reporting.

Re-partitioning policy may be configured in the RAN.

The solution may have impacts in metric collection and OAM requirements, but does not impact the core network or the UE.

6.2.3.3 Multi-carrier radio resource sharing

This solution is applicable to scenario 1. In this solution, it is assumed that radio resources are primarily assigned to a slice (or slice sets) on a frequency, or cell, basis. For example, a RAN node may host two layers as shown below:

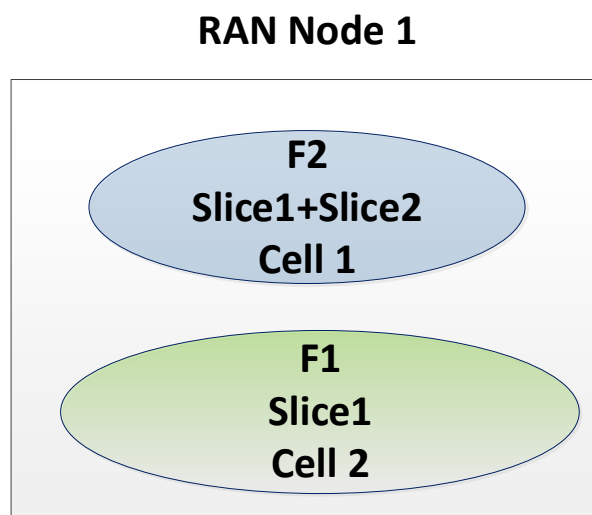


Figure 6.2.3.3-1: RAN node supporting two layers

The solution addresses temporary resource shortage in one cell as per scenario 1, and where the RAN node hosts another cell with different frequency and overlapping coverage where the same slice is available.

In above, this could be the case for slice 1 and cell 1/F2 (or also slice 1 and cell 2/F1).

The solution consists of setting up DC or CA using user plane resources of F1 (or F2), for some or all UEs with slice1 PDU sessions. This action can be wholly decided by the RAN node, without referring to the CN or other nodes. This solution can be seen as fallback planning in the RAN.

6.2.4 Slice Remapping decision in 5GC

This solution is applicable for scenario 2, when a UE with bearers associated to a given slice, e.g. S-NSSAI1, wants to be handed over to a target cell and where S-NSSAI1 is not supported in the target cell. It is also applicable for scenario 4, when the UE later returns to the cell supporting the slice. At NG based HO, the AMF will detect that the target cell is not supporting S-NSSAI1 or that the Allowed NSSAI in the target cell for the UE does not include S-NSSAI1. The 5GC will then decide if the PDU sessions associated to S-NSSAI1 can be re-mapped to another slice. The new S-NSSAI is signalled with the HO Request, using legacy signalling, and there is no impact to the target gNB.

When Xn HO can be used, but the target gNB does not support all slices of an UE, the source gNB will use NG based HO instead, so that 5GC may re-map the slice.

At the end of the HO the UE will be updated with the new Allowed NSSAI through legacy NAS procedures. The original slice will be included in the Rejected NSSAI, and the UE will not be allowed to access it as long as it stays in the current RA. Once the UE returns to the old RA, it may request to add the original slice to the Allowed NSSAI, and the PDU sessions may be re-assigned to the original S-NSSAI1.

The granularity of slice remapping in this solution is per PDU session. The re-mapping decision can be based on slice awareness in availability in registration area, operator policy for slice re-mapping as well as the subscription of the UE.

System Impact

No impact on signalling protocols. gNB should be aware that re-mapping may be used, and select NG based HO when needed.

6.2.4.1 Slice Remapping decision in 5GC at NG based handover

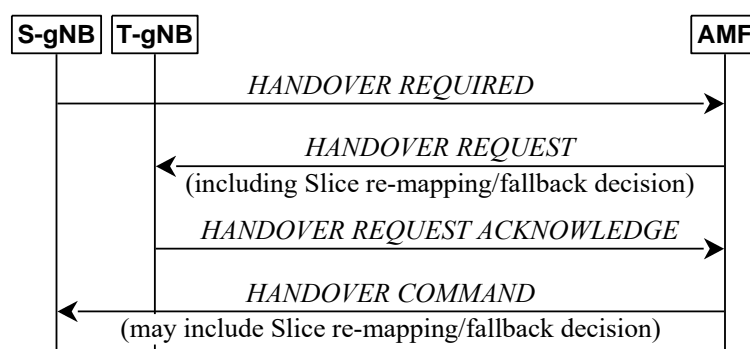


Figure 6.2.4.1-1: Slice re-mapping/fallback determined by the AMF

1. The S-gNB sends the *HANDOVER REQUIRED* message to the AMF.
2. If the UE's ongoing slice(s) is not supported by the T-gNB, the AMF may make the slice re-mapping/fallback decision and include the decision in the *HANDOVER REQUEST* message to the T-gNB.
3. The T-gNB responds to the AMF through the *HANDOVER REQUEST ACKNOWLEDGE* message.

4. The AMF may send the slice re-mapping/fallback decision to the S-gNB through the *HANDOVER COMMAND* message.

Editor Note: It is FFS whether and how the UE is aware of slice remapping.

6.3 Solution evaluation

The evaluation criteria are as follows:

- **RAN impact**

The point here is to analyze RAN impact of the solution (standardization and node behaviour), for example what signalling procedures may be affected and at what extent.

- **Core impact**

The point here is to analyze Core impact of the solution (standardization and node behaviour), for example what signalling procedures may be affected and at what extent. Such analysis needs to be carried out together with SA2 and CT groups.

- **OAM impact**

The point here is to analyze operator and maintenance effort, for example how many network elements (e.g. gNB, NF) should be configured and managed by OAM. Such analysis may need to involve SA5.

- **UE Impact**

This is to analyse the impact at NAS and AS level on the UE. Such analysis needs to be carried out together with RAN2, SA2 and CT groups.

- **Effectiveness of solution**

The point here is to analyse the effectiveness after applying the solution, for example the UE's service experience after applying the solution.

- **Applicable scenarios**

The point here is to list the applicable scenarios which the corresponding solution targets.

NOTE: All solutions involving re-mapping do not work for legacy UEs when applied to scenario 2 and 4 because the UEs will release the PDU session when receiving the new *Allowed NSSAI* in the Register Update following the handover. Therefore, it is left to SA2 to investigate how to handle legacy UEs.

Table 6.3-1: Evaluation of the solutions

<div>Criteria</div> <div>Solution</div>		RAN impact	Core impact	OAM impact	UE impact	Effectiveness	Applicable scenarios
6.2.1: Re-mapping decision in NG-RAN node	6.2.1.1.1: Policy configured by OAM	<p>RAN is configured with re-mapping policy from the OAM.</p> <p>FFS if RAN needs to signal the slice remapping decision to CN.</p>	<p>CN is configured with re-mapping policy from the OAM.</p> <p>FFS if the CN needs to be notified in case of any slice-remapping, e.g. for charging purpose.</p> <p>CN reconfigures UE with NAS signalling to associate an ongoing PDU Session to a new S-NSSAI. Pending SA2 decisions.</p> <p>How the slice remapping is done in 5GC is pending to SA2.</p>	OAM configures slice re-mapping policy to the NG-RAN, CN (if verification is needed).	UE needs to be reconfigured at NAS level to associate an ongoing PDU Session to a new S-NSSAI. Pending SA2 decisions.	Solution at the cost of CN, OAM, RAN and UE impact	1, 2, 3, 4, 5, 6
	6.2.1.1.2/6.2.1.1.3: Policy configured by CN	RAN is signalled with the remapping policy from CN/the source RAN node.	CN is configured with remapping policy from the OAM, and signals the re-mapping policy to the NG-RAN.	OAM configures slice re-mapping policy to the CN.	UE needs to be reconfigured at NAS level to associate an ongoing PDU Session to a new	Solution at the cost of CN, OAM, RAN and UE impact	1, 2, 3, 4, 5, 6

		FFS if RAN needs to signal the slice remapping decision to CN.	FFS if the CN needs to be notified in case of any slice-remapping, e.g. for charging purpose. CN reconfigures UE with NAS signalling to associate an ongoing PDU Session to a new S-NSSAI. Pending SA2 decisions. How the slice remapping is done in 5GC is pending to SA2.		S-NSSAI. Pending SA2 decisions.		
	6.2.1.2.1.4: 5GC Solution based on SSC-mode 3	RAN is signalled with the remapping policy from CN/the source RAN node if this option is used. It requires support of updated “SSC-mode 3”, e.g., the target node needs to temporarily accept the PDU session even if slice is not supported in the cell.	CN is configured with remapping policy from the OAM, and signals the re-mapping policy to the NG-RAN if this option is used. It requires modification of the “SSC mode 3” procedure in CN. Pending SA2 decisions. .	OAM configures slice re-mapping policy to the RAN if this option is used.	The update of “SSC-mode 3”. Pending SA2 decisions.	Solution with OAM, CN, RAN and UE impact	2, 4
6.2.2: Partially slice re-mapping in NG-RAN	Solution with CN involvement	Same as 6.2.1: Signalled from 5GC/source RAN node	Same as 6.2.1: Signalled from 5GC/source RAN node	Same as 6.2.1: : Signalled from 5GC/source RAN node	Same as 6.2.1: Signalled from 5GC/source RAN node	Same as 6.2.1: Signalled from 5GC/source RAN node	Same as 6.2.1: Signalled from 5GC/source RAN node

	Solution without CN involvement	<p>RAN is configured with re-mapping policy from the OAM.</p> <p>New functionality to support semi-handover case.</p> <p>New behaviour in new gNB (allow usage by non-supported slice).</p> <p>Requires Xn support from inside old RA to any node inside new RA (unless continuity is broken later)</p>	<p>New functionality to support the new handover case, where the UE is connected to target but source maintains UE signalling connection with CN.</p>	<p>OAM configures slice re-mapping policy to the NG-RAN.</p>	<p>New functionality to support the new handover case, where the UE is connected to target but source maintains UE signalling connection with CN.</p> <p>Pending SA2 decisions.</p>	<p>Solution at the cost of CN, OAM, RAN and UE impact.</p>	2, 4
6.2.3: Resource management in NG-RAN node	6.2.3.1: Configuration based Solution	<p>RAN is configured with re-mapping policy from the OAM.</p> <p>RAN may possibly signal the RAN-internal slice resource change to CN.</p>	<p>FFS if the CN needs to be notified in case of any RAN-internal slice resource change e.g., for charging purpose.</p>	<p>OAM configures slice resource policy to the NG-RAN.</p> <p>Pending SA5 feedback</p>	No impact	Simple and effective solution at the main cost of the OAM impact.	1, 3, 5, 6.
	6.2.3.2: Slice resource re-partitioning	<p>RAN is configured with re-mapping policy from the OAM.</p> <p>RAN may possibly signal the RAN-internal slice resource change to CN</p>	<p>FFS if the CN needs to be notified in case of any RAN-internal slice resource change e.g., for charging purpose.</p>	<p>OAM configures slice resource re-mapping policy to the NG-RAN.</p> <p>Pending SA5 feedback</p>	No impact	Simple and effective solution at the main cost of the OAM impact	1, 3, 5, 6

	6.2.3.3: Multi-carrier radio resource sharing	No impact.	No impact	No impact	No impact	Simple and effective solution. It requires the same slice coverage across different frequencies.	1, 3, 5, 6
6.2.4: Slice Remapping decision in 5GC		No impact	CN is configured with remapping policy from the OAM. New intra-CN procedure is needed to change the slice for an ongoing PDU session. Pending SA2 decisions.	OAM configures slice re-mapping policy to the CN.	UE needs to be reconfigured at NAS level to associate an ongoing PDU Session to a new S-NSSAI. Pending SA2 decisions.	Solution with OAM, CN and UE impact Loss of efficiency due to target gNB may refuse the re-mapping decision of 5GC due to resource shortage.	2, 4

7 Conclusion

7.1 Conclusions on slice based cell reselection, cell selection and RACH configuration

For slice based cell reselection, the following solutions are recommended for normative work:

- To assist cell reselection, RAN can broadcast the supported slice info of the current cell and neighbour cells, and cell reselection priority per slice in SI message. And RAN can also include the slice info (with similar information as agreed slice info in SI message) in *RRCRelease* message

For slice based cell selection, the following solutions may be discussed during WI in RAN2:

- To assist cell selection, whether to broadcast supported slice of serving cell in SI message and how to solve SIB1 concerns

For slice based RACH configuration, the following solutions are recommended for normative work:

- Separated PRACH configuration (e.g., transmission occasions of time-frequency domain and preambles) can be configured for slice or slice group
- RACH parameters prioritization (e.g., *scalingFactorBI* and *powerRampingStepHighPriority*) can be configured for slice or slice group

7.2 Conclusion on service continuity

Conclusions on Scenarios:

Scenario 3-6 can be regarded as the extension of Scenario 1-2, where Scenario 1,3,5,6 are caused by slice resource shortage, while Scenario 2 and 4 are caused by non-supported slice.

For those scenarios caused by slice resource shortage, the situations of resource shortage or overload may exist in RAN, provided that pre-configured policies allow serving this slice even when slice resources are exhausted, under such conditions, Scenario 1,3,5,6 are valid scenarios.

For those scenarios caused by non-supported slice, scenarios 2 and 4 are valid if there is a specific pre-configured policy, where the original slice is required to be available in a specific geographical area and its slice services are required to have continuity even outside of such geographical area.

Conclusions on Solutions for Scenarios 1, 3, 5, 6:

The solutions to support following RAN slicing scenarios are recommended by RAN3 to be specified in normative phase:

- Resource shortage in case of Intra-RA mobility
- Slice resource shortage for MR-DC
- Slice overload in RAN node in absence of mobility

Solutions are expected to be refined during normative phase after feedback from SA2 and SA5.

Conclusions on Solutions for Scenarios 2, 4:

RAN3 is not able to make any recommendations on solutions to support scenario 2 and 4 during the Study Item. RAN3 would like to postpone the feasibility of addressing scenario 2 and 4, including potential solution selection, until SA2's feedback.

Annex <A> (informative):

Change history

Change history							
Date	Meeting	TDoc	C R	Rev	Cat	Subject/Comment	New version
2020-08	RAN2#111-e	R2-2007419	-	-	-	Draft skeleton	0.0.0
2020-08	RAN2#111-e	R2-2008549	-	-	-	Capture the agreements in RAN2#111-e	0.1.0
2020-09	RAN3#109-e	R3-205815	-	-	-	Capture the agreed TPs in R3-205626, R3-205729, R3-205783	0.2.0
2020-11	RAN3#110-e	R3-207235	-	-	-	Capture the agreed TPs in R3-206807, R3-207106, R3-207107, R3-207124, R3-207136, R3-207193, R3-207194, R3-207195, R3-207197,	0.3.0
2021-1	RAN2#113-e	R2-2101801	-	-	-	Capture the agreements in RAN2#112-e	0.4.0
2021-2	RAN2#113-e	R2-2102059	-	-	-	Capture the agreements in RAN2#113-e and RAN3#111-e	0.5.0