**3GPP TSG-SA5 Meeting #157 *S5-246092***

Hyderabad, India, 14 - 18 October 2024

**Source: CATT**

**Title: Rel-19 pCR TR 28.874 Rapporteur cleanup**

**Document for: Approval**

**Agenda Item: 6.19.15**

# 1 Decision/action requested

***Approval***

# 2 References

[1] 3GPP TR 28.874-101: " Study on management aspects of NTN – Phase 2"

[2] SP-231733: "New SID: Study on Management Aspects of NTN Phase 2"

# 3 Rationale

To fix the comments from EditHelp:

* The use of “shall” is not allowed in TRs outside the “Potential requirements” and “Potential solutions” clause.
* The use of “must” is not allowed in any TRs/TSs unless this is a quotation from another standard.
* Please be careful not to introduce a hanging paragraph (there should be no text between a clause and its subclause).

# 4 Detailed proposal

This contribution proposes to make the following changes in [1].

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| **1st change** |

# 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: "Technical Specification Group Services and System Aspects; Vocabulary for 3GPP Specifications".

[2] 3GPP TS 38.423: "Technical Specification Group Radio Access Network; NG-RAN; Xn application protocol (XnAP)".

[3] 3GPP TS 38.300: "Technical Specification Group Radio Access Network; NR; NR and NG-RAN Overall Description; Stage 2".

[4] 3GPP TR 38.821: "Technical Specification Group Radio Access Network; Solutions for NR to support non-terrestrial networks (NTN)".

[5] 3GPP TR 22.865: "Technical Specification Group Services and System Aspects; Study on satellite access Phase 3".

[6] 3GPP TS 23.501: " Technical Specification Group Services and System Aspects; System architecture for the 5G System (5GS); Stage 2".

[7] 3GPP TS 23.401: "Technical Specification Group Services and System Aspects; General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access".

[8] 3GPP TS 23.682: "Technical Specification Group Services and System Aspects; Architecture enhancements to facilitate communications with packet data networks and applications".

[9] 3GPP TS 28.530: "Technical Specification Group Services and System Aspects; Management and orchestration; Concepts, use cases and requirements".

[10] 3GPP TS 38.331: "Technical Specification Group Radio Access Network; NR; Radio Resource Control (RRC) protocol specification".

[11] 3GPP TS 22.261: " Technical Specification Group Services and System Aspects; Service requirements for the 5G system; Stage 1".

[12] 3GPP TR 23.700-29: "Technical Specification Group Services and System Aspects; Study on integration of satellite components in the 5G architecture; Phase 3".

[13] 3GPP TS 28.541: "Technical Specification Group Services and System Aspects; Management and orchestration; 5G Network Resource Model (NRM); Stage 2 and stage 3".

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## 3.1 Terms

For the purposes of the present document, the terms given in TR 21.905 [1], TS 22.261 [11] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

**Feeder link:** wireless link between the NTN Gateway and the NTN payload

NOTE: This definition is taken from TS 38.300 [3].

**Service link:** wireless link between the NTN payload and UE

NOTE: This definition is taken from TS 38.300 [3].

**Regenerative payload:** payload that transforms and amplifies an uplink RF signal before transmitting it on the downlink. The transformation of the signal refers to digital processing that may include demodulation, decoding, re-encoding, re-modulation and/or filtering

**Serving satellite:** satellite providing the satellite access to a UE (e.g. providing the serving cell(s)). Depending on the orbit, the serving satellite may cover a given geographic area for a limited period of time

**S&F Satellite operation:** operation mode providing communication service (in storing and forwarding information) to a UE in periods of time and/or geographical areas in which the serving satellite is not simultaneously connected to the ground network via feeder link or ISL. For the case of UL, "store" refers to on-board storage of UL information from UE and "forward" refers to forwarding of stored UL information to the ground network. For the case of DL, "store" refers to on-board storage of DL information from the ground network and "forward" refers to forwarding of stored DL information to the UE

**UE-Satellite-UE Communication:** refers to a communication between UEs under the coverage of one or more serving satellites, using satellite access without the user traffic transiting through the ground segment

**NTN Gateway**: earth station located at the surface of the earth, providing connectivity to the NTN payload using the feeder link. An NTN Gateway is a TNL node

NOTE: this definition is taken from TS 38.300 [3].

**NTN payload**: network node, embarked on board a satellite or high altitude platform station, providing connectivity functions, between the service link and the feeder link. In the current version of the present document, the NTN payload is a TNL node

NOTE: This definition is taken from TS 38.300 [3].

**On board NTN gNB:** gNB implemented in the regenerative payload on board a satellite

**On ground NTN gNB:** gNB of a transparent satellite payload implemented on ground

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## 4.1 Overview

The following management architecture assumptions of NTN are applied to the study:

- The 5GC architecture for satellite access for NR as defined in TS 23.501 [6] is used as a baseline.

- The EPC architecture for satellite access for IoT as defined in TS 23.401 [7] and the architecture enhancements to facilitate communications with packet data networks and applications as defined in TS 23.682 [8] are used as a baseline.

- The reference management scenario for NTN as defined in TS 28.530 [9] is used as a baseline.

- The management architecture will support Store and Forward (S&F) satellite operation.

- The management architecture will support UE-Satellite-UE communication, when UPF is present onboard of the satellites.

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### 5.1.1 Use case #1: Connections between RAN node on-board satellite and CN (regenerative mode)

#### 5.1.1.1 Description

When non-geo synchronized objects like LEO and MEO satellites are used for the NTN system, the satellites will not always be at the same position relative the earth's surface, and the coverage area on the earth surface for one satellite varies over time.

One consequence of non-geosynchronous satellites is that the associations between the entities on ground segment and entities in space segment are changing frequently, typically with a period of one to several minutes.



Figure 5.1.1.1-1 Non-geosynchronous satellites in NTN with regenerative gNB processed satellite payload

Fig. 5.1.1.1-1 illustrates this association change in an NTN system with regenerative gNB satellite payload. In this case, the ground segment Core Network (CN) will serve the same spotbeams all the time, while the space segment gNB on different satellites (satellite 1, 2 and 3) will serve the spotbeam in different time period as the satellites are approaching and leaving the coverage of the spotbeam over time. From management point of view, it will e.g. impact the association between GNBCUCPFunction and AMFFunction, and in case of regenerative payload with gNB onboard and quasi-earth fixed cell is applied, it will impact the cell configuration of NRCellCU in GNBCUCPFunction and cell configuration of NRCellDU in GNBDUFunction.

Another issue is the topology between space segment Managed Element (MnS producer) and the ground based Management System (MnS consumer): With long distances in between, disturbances (e.g. bad weather conditions), and partial reachability issues (when satellites fly over oceans with no gateway coverage), the latency, availability and reliability of the interface between them (feeder link + Inter-satellite link) are impacted.

Summary:

For the deployment scenario of RAN nodes on-board satellites, this would result in the following scenario: a LEO or MEO satellite with an onboard RAN node leaves the coverage area of a CN and then returns to the coverage area of that CN after cycling around the Earth.

From the operator's perspective, it's necessary to investigate how to efficiently manage the connections between RAN nodes and CN to avoid errors in CN due to stale connections, e.g. AMF/MME sending paging requests or AMF configuration updates to an unavailable RAN node. For example, 3GPP management system configures AMF/MME and/or gNB/eNB to add necessary information to support their awareness of when connectivity between a RAN node and a CN NF is available or unavailable.

#### 5.1.1.2 Potential requirements

**REQ-NTN-REGCON-1：**3GPP MnS producer should have the capability to configure the connections between RAN nodes on-board satellite and 5GC on an unreliable management interface.

**REQ-NTN-REGCON-2：**3GPP MnS producer should provide the capability to configure the continuously changing NRCellCU and NRCellDU configurations on RAN nodes on-board satellite due to NTN (quasi-earth-fixed) cells,on an unreliable management interface.

Editor's note: The need for this requirement, and related potential solutions (#<3.1> and #<3.2>), is FFS

#### 5.1.1.3 Potential solutions

##### 5.1.1.3.1 Potential solution #<1>: Batch pre-configuration of the eNB/MME gNB/AMF associations

For NTN with regenerative eNB/gNB processed satellite payload, it is assumed that the sector equipment and eNB/gNB are located at the satellites, while MME/AMF and ProvMnS consumer are located on ground according to figure below.

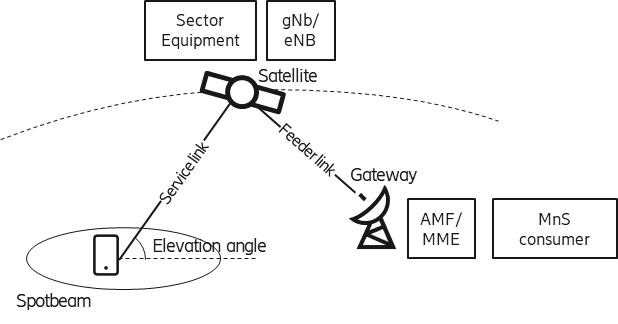


Figure 5.1.1.3.1-1 Location of NTN functions for regenerative eNB/gNB processed satellite payload.

As mentioned in the Use case #1 description, the interface between functions in the ground segment and space segment is unreliable, and the relationship between the eNB/gNB and MME/AMF is changing all the time, therefore there is a need to pre-configure the relation (association) between eNB/gNB and MME/AMF end points as a batch in advance.

For LTE/EPC, in order to realize batch configuration of the association, one possible solution is to modify the EP\_RP\_EPS (on eNB side) and EP\_RP\_EPS (on MME side) instances.

Attribute farEndNeIpAddr, which consists of an IP address of the remote MME/eNB, is replaced by attribute farEndNeIpAddrList, which is a list, where each list element consists of a timeWindow (start and end time when this association is valid), and IP address(es) of the remote MME/eNB. Further, the FarEndEntity attribute (inherited from EP\_RP) also needs to be replaced by a list where each list element consists of a FarEndEntity and a timeWindow.

For NR/5GC, in order to realize batch configuration of the association, one possible solution is to modify the EP\_NgC (on gNB side) and EP\_N2 (on AMF side) instances.

Attribute remoteAddress, which consists of an IP address of the remote AMF/gNB, is replaced by attribute remoteAddressList, which is a list, where each list element consists of a timeWindow (start and end time when this association is valid), and IP address of the remote AMF/gNB. Further, the FarEndEntity attribute (inherited from EP\_RP) also needs to be replaced by a list where each list element consists of a FarEndEntity and a timeWindow.

The sequence diagram for setup of the batch configuration in advance, and the results of the batch configuration for NR/5GC, is shown below.



Figure 5.1.1.3.1-2 Sequence diagram: Configuration of gNB/AMF endpoint as a batch (for NR/5GC)

1. For each gNB in space, the ProvMnS consumer requests the ProvMnS producer to create a number of EP\_NgC instances for the CUCPFunction through ProvMnS. The number of EP\_NgC instances shall be equal to the max number of simultaneous AMFs that the gNB will connect to during its movement in the satellite orbit.  
     
   For each AMF on ground, the ProvMnS consumer requests the ProvMnS producer to create a number of EP\_N2 instances for the AMFFunction through ProvMnS. The number of EP\_N2 instances shall be equal to the max number of simultaneous gNBs that the AMF will connect to.
2. The ProvMnS consumer receives, from an external entity, a list of the associations between all the gNBs in space and the AMFs on ground over a time period (and related time windows indicating when each association is valid). These associations and time windows are calculated based on e.g. position of the ground gateways, and possibility for the AMFs to connected to these ground gateways, the expected orbit position of the space gNBs over the time period, availability of the feeder link between the ground gateways and satellites over the time period (e.g. expected unavailability due to weather condition), the operation condition of the satellite gNB, ground gateways, ground AMF, transport over the time period, etc. Observe that the MnS consumer can receive new associations from the external entity before the previous time period ends due to unexpected changes in the NTN system.
3. The ProvMnS consumer sends, to each gNB in space, a batch of its associations to all AMFs during the time period by the ProvMnS service ModifyMOIAttributes() with the remoteAddressList for all the EP\_NgC instances in the gNB. FarEndEntity attribute (inherited from EP\_RP) also needs to be replaced by a list where each list element consists of a FarEndEntity and a timeWindow.
4. The ProvMnS consumer sends, to each AMF on ground, a batch of its associations to all gNBs during the time period by the ProvMnS service ModifyMOIAttributes() with the remoteAddressList for all the EP\_N2 in the AMFs. FarEndEntity attribute (inherited from EP\_RP) also needs to be replaced by a list where each list element consists of a FarEndEntity and a timeWindow.
5. The actual changes of all EP\_NgC associations to AMFs for all gNBs over the time period are continuously and timely executed by the gNBs according to the pre-defined time windows, and also logged and transferred back to the ProvMnS consumer through file data report service and/or notification service.
6. The actual changes of all EP\_N2 associations to gNB for all AMF over the time period are continuously and timely executed by the AMFs according to the pre-defined time windows, and also logged and transferred back to the ProvMnS consumer through file data report service and/or notification service.

##### 5.1.1.3.2 Potential solution #<2>: Pre-configuration of the gNB/eNB and AMF/MME before connections between them are established or lost

This is a candidate solution for Use case #1: Connections between RAN node on-board satellite and CN (regenerative mode).

As described in Use case #1, the connections between gNB/eNB on-board satellite and AMF/MME on the ground changes frequently, typically because the periodic connecting/disconnecting of the gNB/eNB on-board satellite to the gateways. Therefore, this solution proposes to take the connecting/disconnecting of the gNB/eNB on-board satellite to the gateways as an event or to periodically trigger the 3GPP management system to perform configuration operations on the gNB/eNB and AMF/MME based on pre-received information about the connection and disconnection time of satellites and gateways.

For example, an external entity (e.g. satellite management system) may provide the information on the connection and disconnection time of satellites and gateways over a period of time in the future. Then the 3GPP management system can determine when to trigger create/modify/delete operations on which interface instances, effectively avoiding delays in operations.

The solution addresses the scenario where the gNB/eNB on-board satellite is connected to one or more gateways simultaneously during a given period, and the AMF/MME on the ground associated with the gateway can be different or the same. Figure 5.1.1.3.2-1 shows an example deployment scenario.

- Case I: gNB/eNB connects to the same AMF/MME via a different gateway (e.g. gNB/eNB connects AMF/MME 3 via Gateway 2 or Gateway 3).

- Case II: gNB/eNB connects to a different AMF/MME via a different gateway (e.g. gNB/eNB connects AMF/MME 2 via Gateway 2).

The attribute localAddress in EP\_NgC/EP\_RP\_EPS instances will have the different value if the connection between gNB/eNB and AMF/MME is via the different gateway.



Figure 5.1.1.3.2-1 Example scenario of connections between RAN node on-board satellite and CN.

The 3GPP management system creates multiple EP\_NgC (on gNB side)/EP\_RP\_EPS (on the eNB side) and EP\_N2 (on AMF side)/ EP\_RP\_EPS (on MME side) instances to handle the multiple connectivity links between gNB/eNB on-board satellite and AMF/MME on the ground, and adds new attributes representing the connection availability duration information in EP\_NgC, EP\_N2 and EP\_RP\_EPS IOC.

Before the connection between gNB/eNB on-board satellite and gateway is lost or based on the information on satellite and gateway connection status, the 3GPP management system may create/remove/modify the EP\_NgC /EP\_RP\_EPS and EP\_N2/ EP\_RP\_EPS instances and removes/modifies the relevant connection availability duration information.

The connection availability duration information is a list that provides the time when the gNB/eNB has a connection to an AMF/MME and the time when the connection is disconnected.

Take the impacts on EP\_NgC as an example, the new attributes may be as follows:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute name | S | isReadable | isWritable | isInvariant | isNotifyable |
| localAddress | O | T | T | F | T |
| remoteAddress | O | T | T | F | T |
| AvaDurWindow | O | T | T | F | T |

| Attribute Name | Documentation and Allowed Values | Properties |
| --- | --- | --- |
| EP\_NgC.avaDurWindow | This provides the connection availability durations of the EP\_NgC | type: TimeWindow  multiplicity: \*  isOrdered: N/A  isUnique: N/A  defaultValue: None  isNullable: False |

##### 5.1.1.3.3 Potential solution #<3.1>: Batch pre-configuration of NRCellCU/NRCellDU over time in GNBCUCPFunction/GNBDUFunction

As mentioned in the problem description, the interface between functions in the ground segment and space segment is unreliable, and the relationships between the gNB and the NTN quasi-earth-fixed cells which the gNB is serving are changing all the time, therefore there is also (in addition to Potential solution #<1>) a need to pre-configure the relation (association) between gNB and NTN Cells as a batch in advance.

In order to realize batch configuration of the association, one possible solution is to create maximum number of NRCellCU instances and NRCellDU instances that the satellite gNB can handle simultaneously at the same time, and change the configuration of the NRCellCU and NRCellDU instance according to a list, where each list entry consist of information on time window when it is valid, and the valid configuration attribute for serving the NTN quasi-earth-fixed Cell during the time window.

The NRCellCU is modified so that all current attributes in NRCellCU are replaced by one single attribute NRCellCUInfoList, which is a list with entries consisting of a timeWindow, and NRCellCUInfo with the same attributes as the current attributes in NRCellCU.

The NRCellDU is also modified in a similar way, i.e. all current attributes in NRCellDU has been replaced by one single attribute NRCellDUInfoList, which is a list with entries consists of a timeWindow, and NRCellDUInfo with the same attributes as the current attributes in NRCellDU.

The sequence diagram for setup of the batch configuration in advance, and the results of the batch configuration, is shown below (the operations, e.g. CreateMOI and ModifyMOIAttributes), are defined in 3GPP TS 28.532).



Figure 5.1.1.3.3-1 Sequence diagram of potential solution 3.1

1. For each gNB in space, ProvMnS consumer request each ProvMnS producer (gNB) in space to create a number of Managed Object (MO) NRCellCU instances for the GNBCUCPFunction, and a number of Managed Object (MO) NRCellDU instances for the GNBDUFunction through NR NRM MnS The number of NRCellCU and NRCellDU instances shall be at least equal to the max number of NTN quasi-earth-fixed Cell that the gNB can serve simultaneously.
2. ProvMnS consumer receives, from an external entity, a list of the associations between all the gNBs in space and the NTN quasi-earth-fixed cells over a time period (and related time windows indicating when each association is valid). These associations and time windows are calculated based on e.g. minimum elevation angle between the NTN quasi-earth-fixed cell and space gNB, the expected orbit position of the space gNBs over the time period, availability of the feeder link between the ground gateways and satellites over the time period (e.g. expected unavailability due to weather condition), the operation condition of the satellite gNB, ground gateways, ground AMF, transport over the time period, etc. Observe that the ProvMnS consumer can receive new associations from the external entity before the previous time period ends due to unexpected changes in the NTN system.
3. ProvMnS consumer sends, to each ProvMnS producer (gNB) in space, a batch of its associations to all NTN quasi-earth-fixed cells (NTN cell configuration for the gNB-CU-CP part) during the time period by the NR NRM MnS service ModifyMOIAttributes() with the NRCellCUInfoList for all the NRCellCUInfo entries in the gNB. All remaining batch associations from the previous modification will be discarded when the new modification is received.
4. ProvMnS consumer sends, to each ProvMnS producer (gNB) in space, a batch of its associations to all NTN quasi-earth-fixed cells (NTN cell configuration for the gNB-DU part) during the time period by the NR NRM MnS service ModifyMOIAttributes() with the NRCellDUInfoList for all the NRCellDUInfo entries in the gNB. All remaining batch associations from the previous modification will be discarded when the new modification is received.
5. The actual changes of all NTN quasi-earth-fixed cells (gNB-CU-CP part) associations for all gNBs over the time period are continuously and timely executed by the gNBs according to the pre-defined time windows, and also logged and transferred back to the ProvMnS consumer through file data report service and/or notification service.
6. The actual changes of all NTN quasi-earth-fixed cells (gNB-DU part) associations for all gNBs over the time period are continuously and timely executed by the gNBs according to the pre-defined time windows, and also logged and transferred back to the ProvMnS consumer through file data report service and/or notification service.

##### 5.1.1.3.4 Potential solution #<3.2>: Batch pre-configuration of NRCellCU/NRCellDU over time in GNBCUCPFunction/GNBDUFunction (with multiple instances)

As mentioned in the problem description, the interface between functions in the ground segment and space segment is unreliable, and the relationships between the gNB and the NTN quasi-earth-fixed cells which the gNB is serving are changing all the time, therefore there is also (in addition to Potential solution #<1>) a need to pre-configure the relation (association) between gNB and NTN Cells as a batch in advance.

For realizing batch configuration of the association, one possible solution is to create NRCellCU instances and NRCellDU instances for all the ground fix NTN cells that the satellite gNB can serve, and provide validity of the NRCellCU and NRCellDU instances by a new attribute NRCellValidTimeWindowList, where each list entry consist of time window which indicates if the NRCellCU/NRCellDU instance is valid.

The sequence diagram for setup of the batch configuration in advance, and the results of the batch configuration is shown below.



Figure 5.1.1.3.4-1 Sequence diagram of potential solution 3.2

1. For each gNB in space, ProvMnS consumer requests each ProvMnS producer (gNB) in space to create a number of Managed Object (MO) NRCellCU instances for the GNBCUCPFunction, and a number of Managed Object (MO) NRCellDU instances for the GNBDUFunction through NR NRM MnS The number of NRCellCU and NRCellDU instances shall be equal to the all the NTN quasi-earth-fixed Cells that the gNB can serve.
2. ProvMnS consumer receives, from an external entity, a list of the associations between all the gNBs in space and the NTN quasi-earth-fixed cells over a time period (and related time windows indicating when each association is valid). These associations and time windows are calculated based on e.g. minimum elevation angle between the NTN quasi-earth-fixed cell and space gNB, the expected orbit position of the space gNBs over the time period, availability of the feeder link between the ground gateways and satellites over the time period (e.g. expected unavailability due to weather condition), the operation condition of the satellite gNB, ground gateways, ground AMF, transport over the time period, etc. Observe that the ProvMnS consumer can receive new associations from the external entity before the previous time period ends due to unexpected changes in the NTN system.
3. ProvMnS consumer updates all the NRCellCU instances in each ProvMnS producer (gNB) in space, the list indicating in which time periods the NRCellCU (configured to associated to a NTN quasi-earth-fixed Cell gNB-CU-CP part) instance wis valid. by the NR NRM MnS service ModifyMOIAttributes() with the NRCellValidTimeWindowList for all the TimeWindow entries in the gNB. All remaining timeWindow list from the previous modification will be discarded when the new modification is received.
4. ProvMnS consumer updates all the NRCellDU instance in each ProvMnS producer (gNB) in space, the list indicating in which time periods the NRCellDU (configured to associated to a NTN quasi-earth-fixed Cell gNB-DU part) instance wis valid. by the NR NRM MnS service ModifyMOIAttributes() with the NRCellValidTimeWindowList for all the TimeWindow entries in the gNB. All remaining timeWindow list from the previous modification will be discarded when the new modification is received.
5. The actual changes of all NRCellCU validity for all gNBs over the time period are continuously and timely executed by the gNBs according to the pre-defined time windows, and also logged and transferred back to the ProvMnS consumer through file data report service and/or notification service.
6. The actual changes of all NRCellDU validity for all gNBs over the time period are continuously and timely executed by the gNBs according to the pre-defined time windows, and also logged and transferred back to the ProvMnS consumer through file data report service and/or notification service.

#### 5.1.1.4 Evaluation of potential solutions

There are 2 potential solutions support the REQ-NTN-REGCON-1. It is proposed to evaluate them based on the following principles.

**Principle 1**: When regenerative mode is considered, the potential solution supports gNB/eNB and ground nodes to know in advance when the connections will be lost and need to be reconnected, without dependence of a working management interface. So that the N2/S1 connection setup/resume and disconnect/suspend can be triggered.

Both of the potential Solution #<1> and the potential Solution #<2> can support **Principle 1.** Moreover, both of them can be configured based on the pre-obtained information about the connection between the satellite and the gateway. Therefore, neither of them has the risk of N2/S1 connection update failure due to the configuration delay.

**Principle 2**: Less configuration complexity.

Solution #<1> proposes to change the attribute of the existing EP\_RP IOC. It requires that the existing standard definition of the FarEndEntity attribute changes from a DN type attribute allowing only one value, to the FarEndEntityList attribute which is a list attribute and each list element of this attribute consists of a FarEndEntity and a timeWindow describing the valid time of the connection.

Because of this change, the associations represented by EP\_RP IOC may need to change from one-to-one association to one-to-many association. Considering that many IOCs inherit from the EP\_RP IOC, such change may lead to impact on other IOCs.

Solution #<2> adds a new attribute or IOC in the existing interface instances. The new attribute or IOC is a list describing the available time window for the instance.

Potential solution#<1>:

* Pros:
  + Supports gNB/eNB and ground nodes to know in advance when the connections will be lost and need to be reconnected, without dependence of a working management interface. So that the N2/S1 connection setup/resume and disconnect/suspend can be triggered.
  + Since the association between the local address and the remote address is changed, the complexity and overhead when configuring all association time windows is reduced, as only one instance per association needs to be updated.
* Cons:
  + Since the definition of the attribute in EP\_RP is changed, the impact on the current NRM needs to be carefully evaluated, e.g. whether it will have an impact on other IOCs inheriting from EP\_RP.
  + Leads to potential backward compatibility issues.

Potential solution#<2>:

* Pros:
  + Supports gNB/eNB and ground nodes to know in advance when the connections will be lost and need to be reconnected, without dependence of a working management interface. So that the N2/S1 connection setup/resume and disconnect/suspend can be triggered.
  + No changes to EP\_RP, minimizing the impact on inheritance relationships and reducing unexpected backward compatibility issues.
* Cons:
  + When the satellite constellation is large, many instances need to be created and updated, resulting in more overhead cost and potential misalignment needs to be handled.

Potential solution #<3.1>

Editor's note: This clause should be aligned with the format and contents of 5.1.1.4 in S5-244799

* Pros:
  + Minimizes the complexity and overhead when configuring all association time windows, as only one instance per association needs to be updated. Also minimizes feeder link load as well as satellite CPU load and memory usage.
* Cons:
  + May lead to a potential backward compatibility issue. This could however be avoided with the following approach: Instead of modifying the existing association attributes to a list of associations with time stamps, the new list of association with timestamps can be introduced in a new additional attribute, with a "CO" (Conditional Optional) support qualifier constraint meaning that the new attribute may be supported when the NTN system is supported.

Potential solution #<3.2>

Editor's note: This clause should be aligned with the format and contents of 5.1.1.4 in S5-244799

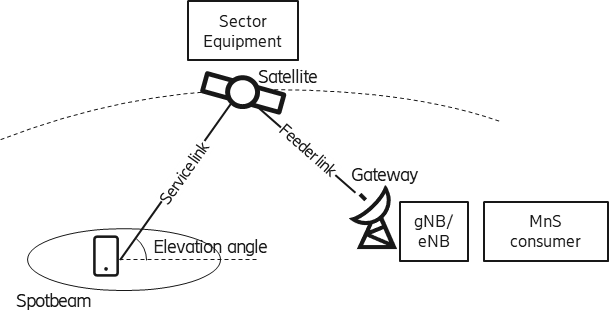
* Pros:
  + Avoids potential backward compatibility issue with the above Potential solutions 1 and 3.1.
* Cons:
  + As in gNB in space are non-geo synchronized, each space gNB needs to serve all the quasi-earth fixed cells on the entire earth, and the association updates need to be made with a period of approximately every minute, this solution has the drawback of managing a huge number of instances for all the connections (hundreds or even thousands) with the high system load for creation and updates, and related risk of delays and inconsistency in the creation/updates due to loss of feeder link between the management system and satellites, or alternatively a huge overhead and memory cost if all instances should be created in advance. In the latter case there is also a risk for inconsistent configuration in case some of all the sub-operations cannot be successfully executed for various reasons, causing a "PARTIALLY\_FAILED" response.

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| **Next change** |

#### 5.1.2.3 Potential solutions

##### 5.1.2.3.1 Potential solution #<1>: Batch pre-configuration of the NRSectorCarrier/ sectorEquipmentFunction associations

For NTN with transparent satellite payload, it is assumed that the sector equipment is located at the satellites, while eNB/gNB, MME/AMF (not shown in the figure) and the ProvMnS consumer are located on ground according to figure below.



**Figure 5.1.2.3.1-1 Location of NTN functions for transparent satellite payload according to 3GPP architecture**

As mentioned in the Use case #2 description, the interface between functions in the ground segment and space segment is unreliable, and the relationships between the eNB/gNB and SectorEquipment are changing all the time, therefore there is a need to pre-configure the relation (association)between eNB/gNB and SectorEquipment end points as a batch in advance.

In order to realize batch configuration of the association, one possible solution is to modify EUtranGenericCell/NRSectorCarrier (on eNB/gNB side) and SectorEquipmentFunction (on sector Equipment side) instances.

For EUtranGenericCell on eNB side, attribute relatedSector, which consists of Distinguished Name (DN) of the remote Sector Equipment, is replaced by attribute relatedSectorList, which is a list, where each list element consists of a timeWindow (start and end time when this association is valid), and DN of the remote Sector Equipment.

For NRSectorCarrier on gNB side, attribute sectorEquipmentFunctionRef, which consists of Distinguished Name (DN) of the remote Sector Equipment, is replaced by attribute sectorEquipmentFunctionRefList, which is a list, where each list element consists of a timeWindow (start and end time when this association is valid), and DN of the remote Sector Equipment.

For SectorEquipmentFunction on Sector Equipment side, in case of LTE, attribute theCellList, which consists of Distinguished Name (DN) of a list of remote eNB E-UTRAN cell, is replaced by attribute theCellListList, which is a list, where each list element consists of a timeWindow (start and end time when this association is valid), and a list of DN of remote eNB E-UTRAN cell.

For SectorEquipmentFunction on Sector Equipment side, in case of NR, attribute theNRSectorCarrierList, which consists of Distinguished Name (DN) of a list of remote gNB sector carrier, is replaced by attribute theNRSectorCarrierListList, which is a list, where each list element consists of a timeWindow (start and end time when this association is valid), and a list of DN of remote gNB sector carrier.

The sequence diagram for setup of the batch configuration in advance, and the results of the batch configuration for NR is shown below.



Figure 5.1.2.3.1-2 Sequence diagram: Configuration of Sector Carrier / Sector Equipment function associations as a batch (for NR)

1. For each Sector Equipment in space, the ProvMnS consumer requests the ProvMnS producer to create SectorEquipmentFunction instances through the ProvMnS.  
     
   For each gNB on ground, the ProvMnS consumer requests the ProvMnS producer to create a number of NRSectorCarrier instances for the GNBDUFunction through the ProvMnS. The number of NRSectorCarrier instances shall be equal to the max number of sector Carriers that the gNB will handle.
2. The ProvMnS consumer receives, from an external entity, a list of the associations between all the sector equipments in space and the gNBs on ground over a time period (and related time windows indicating when each association is valid). These associations and time windows are calculated based on e.g. position of the ground gateways, and possibility for the gNBs to connected to these ground gateways, the expected orbit position of the space sector equipment over the time period, availability of the feeder link between the ground gateways and satellites over the time period (e.g. expected unavailability due to weather condition), the operation condition of the satellite sector equipment, ground gateways, ground gNB, transport over the time period, etc. Observe that the MnS consumer can receive new associations from the external entity before the previous time period ends due to unexpected changes in the NTN system.
3. The ProvMnS consumer sends, to each sector equipment in space, a batch of its associations to all sector carriers in one or several specific gNBs during the time period through the ProvMnS ModifyMOIAttributes() with the theNRSectorCarrierListList for all the sectorEquipmentFunctions.
4. The ProvMnS consumer sends, to each gNB on ground, a batch of its associations to all sector equipment in space for all sector carriers in all gNBs during the time period through the ProvMnS service ModifyMOIAttributes() with the sectorEquipmentFunctionRefList for all the NRSectorCarrier in the gNBs.
5. The actual changes of the associations to all sector carriers in different gNBs over the time period are continuously and timely executed by the sector equipment according to the pre-defined time windows, and also logged and transferred back to the ProvMnS consumer through file data report service and/or notificationservice.
6. The actual changes of the associations to all sector equipment for all sector carriers in all gNBs over the time period are continuously and timely executed by the gNB according to the pre-defined time windows, and also logged and transferred back to the ProvMnS consumer through file data report service and/or notificationservice.

##### 5.1.2.3.2 Potential solution #<2> Batch pre-configuration of the NRSectorCarrier/ SectorEquipmentFunction associations (with multiple instances)

An alternative potential solution may also be considered, where each gNBDUFunction for each NRCellDU creates individual NRSectorCarrier associated to sectorEquipmentFunction on each satellite in the constellation, and for each SectorEquipmentFunction located in space, attribute theNRSectorCarrierList consists of reference of NRCSectorCarrier for all NTN cells in all GNBDUFunction.

For NRSectorCarrier, a new attribute, validTimeWindows, as a list of TimeWindow datatype, indicates when the NRSectorCarrier (and it associated SectorEquipmentFunction) is active.

For SectorEquipmentFunction, a new attribute ValidTimeWindowsList is added, consisting of a list where each list item maps to the elements in theNRSectorCarrierList, and the item in ValidTimeWindowsList consist of a list of TimeWindow datatype, indicating when the associated NRSectorCarrier is active.

The sequence diagram for setup of the batch configuration in advance, and the results of the batch configuration for NR is shown below.



Figure 5.1.2.3.2-1 Sequence diagram: Batch configuration of Sector Carrier / Sector Equipment function associations with multiple instances

1. For each Sector Equipment in space, the ProvMnS consumer requests the ProvMnS producer to create SectorEquipmentFunction instances through the ProvMnS, with attribute theNRSectorCarrierList consists of reference of NRCSectorCarrier for all NTN cells in all GNBDUFunction.   
     
   For each gNB on ground, the ProvMnS consumer requests the ProvMnS producer to create a number of NRSectorCarrier instances for the GNBDUFunction through the ProvMnS. Each NRSectorCarrier instances is associated to one sectorEquipmentFunction on one satellite, and the total number of NRSectorCarrier shall cover associated to sectorEquipmentFunction on each satellite in the constellation.
2. The ProvMnS consumer receives, from an external entity, a list of the associations between all the sector equipments in space and the gNBs on ground over a time period (and related time windows indicating when each association is valid). These associations and time windows are calculated based on e.g. position of the ground gateways, and possibility for the gNBs to connected to these ground gateways, the expected orbit position of the space sector equipment over the time period, availability of the feeder link between the ground gateways and satellites over the time period (e.g. expected unavailability due to weather condition), the operation condition of the satellite sector equipment, ground gateways, ground gNB, transport over the time period, etc. Observe that the MnS consumer can receive new associations from the external entity before the previous time period ends due to unexpected changes in the NTN system.
3. The ProvMnS consumer sends, to each sector equipment in space, a batch of its associations to all sector carriers in one or several specific gNBs during the time period through the ProvMnS ModifyMOIAttributes() with the theNRSectorCarrierValidtimeListList for all the sectorEquipmentFunctions.
4. The ProvMnS consumer sends, to each gNB on ground, a batch of its associations to all sector equipment in space for all sector carriers in all gNBs during the time period through the ProvMnS service ModifyMOIAttributes() with the validTimeList for all the NRSectorCarrier in the gNBs.

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### 5.1.4 Use case #4: NRM extension to support re-generative mode of operations.

#### 5.1.4.1 Description

The current NR-NRM definitions do not support NTN function in regenerative mode. It only support transparent mode of operation. In case of regenerative mode of operation the attribute nTNpLMNInfoList (in NTNFunction IOC) will overlap with the attribute pLMNId (in GNBCUCPFunction IOC).

#### 5.1.4.2 Potential requirements

**REQ-NTN-FUN-0X:** The MnS Producer should have the capability to manage re-generative mode of satellite operation.

#### 5.1.4.3 Potential solutions

##### 5.1.4.3.1 Potential solution #1: Basic NRM extensions to support re-generative mode of operations.

This solution proposes the following options to update NTNFunction NRM fragment to support re-generative mode of satellite operations.

1. Option 1

The GNBCUCPFunction should have direct association (represented by an attribute nTNFunctionRef) with the NTNFunction with 1..0..1 relation. That imply that a gNB will have a single NTNFunction configuration available to it. In other words, it will show that a particular gNB is supporting NR NTN. The attribute nTNpLMNInfoList attribute in NTNFunction IOC is to be made CM (condition mandatory) with the condition of "transparent mode of satellite communication is used." That would imply that the attribute nTNpLMNInfoList shall only be present in case of transparent mode. In this case the attribute pLMNId (in GNBCUCPFunction IOC) will indicate non-NTN PLMN and the attribute nTNpLMNInfoList attribute (in NTNFunction IOC) will indicate NTN PLMN. This is due to the fact that in case of regenerative mode of operation the NTN specific PLMN information provided by the attribute pLMNId in GNBCUCPFunction IOC applies.

A new IOC (SatelliteInfo) is to be introduced to contain all the satellite related configuration. This IOC will be in composition relation with NTNFunction IOC with 1…\* relation. The existing EphemerisInfos attribute (part of SatelliteInfo information related with generic configuration for the satellite IOC) is added directly to the SatelliteInfo IOC making the existing EphemerisInfoSet IOC obsolete.



1. Option 2

The GNBCUCPFunction should have direct association (represented by an attribute nTNFunctionRef) with the NTNFunction with 1..0..1 relation. That imply that a gNB will have a single NTNFunction configuration available to it. In other words, it will show that a particular gNB is supporting NR NTN. The attribute nTNpLMNInfoList attribute in NTNFunction IOC is to be made CM (condition mandatory) with the condition of "transparent mode of satellite communication is used." In other words the attribute nTNpLMNInfoList shall only be present in case of transparent mode. In this case the attribute pLMNId (in GNBCUCPFunction IOC) will indicate non-NTN PLMN and the attribute nTNpLMNInfoList attribute (in NTNFunction IOC) will indicate NTN PLMN. This is due to the fact that in case of regenerative mode of operation the NTN specific PLMN information provided by the attribute pLMNId in GNBCUCPFunction IOC applies.

The existing EphemerisInfoSet IOC stays and will have direct association with SatelliteInfo IOC. A new IOC (SatelliteInfo) is to be introduced to contain all the satellite related configuration except Ephemeris information. This IOC will be in composition relation with NTNFunction IOC with 1…\* relation.



1. Option 3

The attribute nTNpLMNInfoList attribute in NTNFunction IOC is to be made CM (condition mandatory) with the condition of "transparent mode of satellite communication is used." In other words the attribute nTNpLMNInfoList shall only be present in case of transparent mode. In this case the attribute pLMNId (in GNBCUCPFunction IOC) will indicate non-NTN PLMN and the attribute nTNpLMNInfoList attribute (in NTNFunction IOC) will indicate NTN PLMN. This is due to the fact that in case of regenerative mode of operation the NTN specific PLMN information provided by the attribute pLMNId in GNBCUCPFunction IOC applies.

The GNBCUCPFunction should also have direct association (represented by an attribute satelliteInfoRef) with the SatelliteInfo with 1..1 relation.

A new IOC (SatelliteInfo) is to be introduced to contain all the satellite related configuration except Ephemeris information. This IOC will be in composition relation with NTNFunction IOC with 1…\* relation. The solution proposes new S&FConfigInfo to contain information related with generic configuration for the satellite.



#### 5.1.4.4 Evaluation of potential solutions

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#### 5.4.2.4 Evaluation of potential solutions

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### 5.5.1 Use case #1: Connectivity between non-terrestrial network node and security gateway

#### 5.5.1.1 Description

In a 3GPP network Radio Access Network (RAN) nodes such as eNodeB and gNodeB are deployed in cell sites which are typically part of an untrusted network domain. By contrast, core network (CN) nodes are deployed in a trusted domain. These two network domains are logically and physically separated by means of Security Gateways (SEG) as defined in [x]. The communication between the domains, including the network management traffic, should be secured and is carried over a logical connection referred to as the 'backhaul'.

In ground based terrestrial networks the connectivity between RAN nodes and SEG is based on physical connectivity. As a result the underlying IP network design seldom changes, and the logical connectivity between the RAN nodes and SEG remains relatively stable.

However, in airborne Non-Terrestrial Networks (NTN) the connectivity between RAN nodes and SEG is not stable since the RAN nodes are moving. E.g. a satellite in LEO, MEO or GEO orbit. A non-terrestrial node provides a service link and relies on a feeder link to communicate with other nodes comprising the NTN, including the SEG.

As NTN nodes move the availability of terrestrial connectivity is subject to change. This has potential impact to the security associations between the NTN node, SEG and CN.

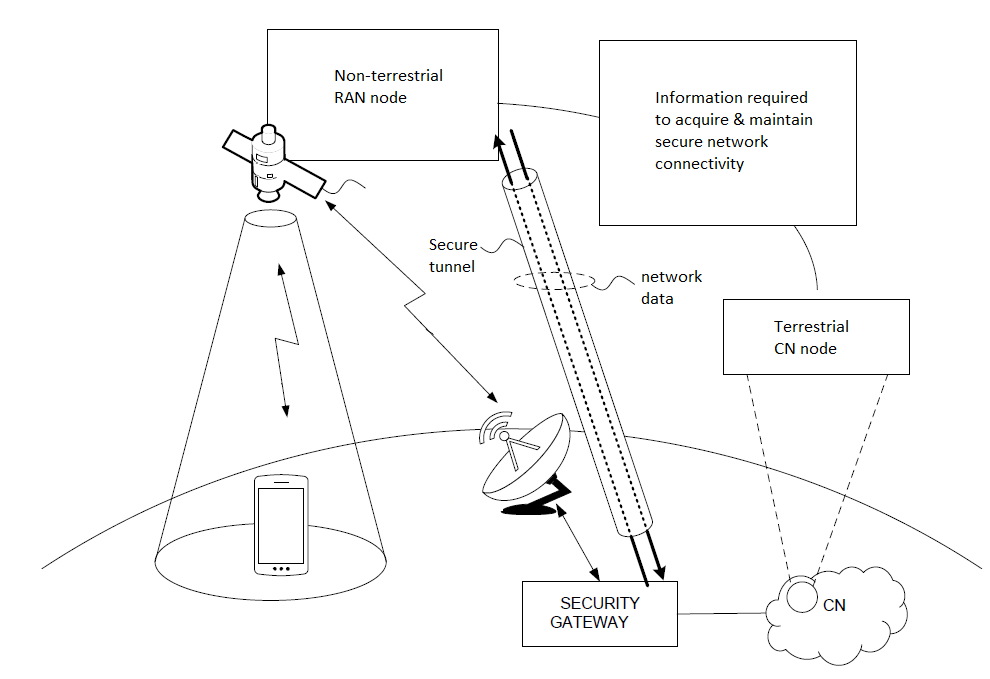


Figure 5.5.1.1-1 Secure connectivity between non-terrestrial RAN node and terrestrial CN node(s)

As NTN nodes move their security associations should be updated subject to the availability of new terrestrial connectivity to a new SEG. In some cases, such SEG transitions may be able to be performed in anticipation of the upcoming feeder link update (i.e. "make then break") whereas in others the new connectivity may not be available in advance (i.e. "break then make"). Both scenarios should be supported, and different information may be required to setup and maintain the secure associations subject to which security protocols and features are configured.

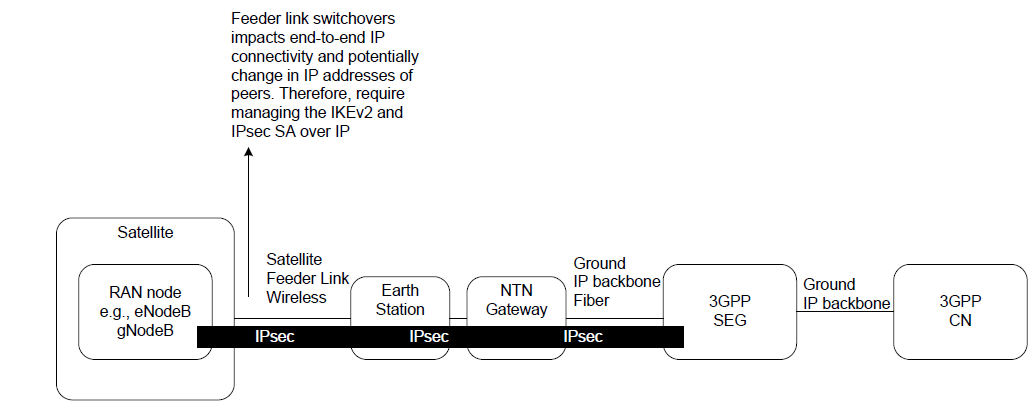


Figure 5.5.1.1-2 Impact of feeder link switchover between NTN node, SEG and CN

The IP configuration requires correlation with the state of connect/disconnect of the IP link itself. For example, for satellite based NTN node the following may need to be considered:

* + satellite may only ever connect to ground stations allowed by policy. As a result, when the satellite moves out of ground station's catchment location, it loses the ground connectivity via the feeder link and the IP transport during such period, and then reestablishes the IP connectivity.
  + when the satellite orbit is passing over the earth surface (e.g. oceans, mountains, deserts, forests etc.) where there is no ground station and supporting infrastructure, the satellite may by-design route data over to Inter Satellite Link (ISL) to other satellites that may have connectivity with the ground infrastructure over a feeder link, but the ground infrastructure may reside in jurisdiction not permitted by regulations.

To further ensure the security associations are maintained, additional information should also be made available to the NTN node about the anticipated terrestrial connectivity based on criteria such as flight path and/or time windows.

Summary: Movement of the NTN nodes means the backhaul connection should traverse multiple feeder links and its security associations should be maintained throughout lifecycle phases of IP connectivity. As a result, NTN nodes require information not only to setup the initial secure communications channel, but to maintain such communications as the NTN moves.

#### 5.5.1.2 Potential requirements

**REQ-NTN-PnC-1：**IP configuration data shall be configured for the secure communications channel association between RAN nodes on-board satellite and SEG.

**REQ-NTN-PnC-2：**IP configuration data shall be updated when transitioning between terrestrial networks, to ensure the secure association between NTN node and SEG.

**REQ-NTN-PnC-3：**IP configuration data shall be maintained at NTN node independent of feeder link availability.

#### 5.5.1.3 Potential solutions

##### 5.5.1.3.1 Potential solution #1: Pre-configure security association data in NTN satellite node

Pre-configure the anticipated feeder link switchovers and satellite handovers in advance based on the 'flight path'.

Flight path information can be used as input to the network management system to create configuration data for the RAN nodes hosted on-board satellites. Specifically, time windows can be derived that provide the anticipated connectivity between each NTN node and ground infrastructure via feeder link(s).

Each time window includes start time, end time, and the configuration required to establish/maintain secure communications with SEG during that period. Time windows may overlap in the event multiple connectivity options exist for a given period. Such overlaps can be leveraged to help ensure seamless connectivity.

At least 1 entry needs to be provided to allow each NTN node to perform initial connection to terrestrial network.

Once configured, the appropriate data is applied to its respective NTN node.

Within each NTN node the information is used to define triggers to automate the setup and maintenance of the secure connectivity, including:

* time window start: trigger for IP configuration each time IP connection is available.
* time window end: trigger to anticipate when the IP connection is about to disconnect.
* time window overlaps: trigger to allow configuring the new IP configuration in advance of losing the current connection.
* time window gaps: trigger to adjust secure IP connection configuration before potential disruption to IP connectivity.

Changes to terrestrial network may require the NTN data also be updated. Periodic checks for such changes could also occur as triggered events based on the NTN data, however it may be better to perform such maintenance from the network management system to minimize disruptions to terrestrial connectivity.

#### 5.5.1.4 Evaluation of potential solutions

TBD

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