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| 3GPP TR 28.808 V0.5.0 (2020-06) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Services and System Aspects  Study on management and orchestration aspects with integrated satellite components in a 5G network  (Release 16) | |
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Contents

Foreword 5

Introduction 6

1 Scope 6

2 References 6

3 Definitions and abbreviations 7

3.1 Definitions 7

3.2 Abbreviations 7

4 Concepts and Background 8

4.1 Reference management architecture for integrated satellite components 8

4.1.1 Management architecture for integrated satellite NR-RAT 8

4.1.2 Management architecture for integrated non-3GPP satellite RAN 8

4.2 Architecture scenarios for 5G networks with an integrated satellite component 9

4.2.1 Scenario #1: Satellite enabled 3GPP network as a roaming network for terrestrial network operators 9

4.2.2 Scenario #2: A 3GPP network with a satellite access network and a terrestrial access network 10

5 Use Cases 10

5.1 Use cases related to network slice management 10

5.1.1 Network slice instance(s) associated with a satellite RAN 10

5.1.1.1 Create a network slice instance associated with a satellite RAN 10

5.1.1.1.1 Pre-conditions 10

5.1.1.1.2 Description 10

5.1.1.1.3 Post-conditions 11

5.1.2 RAN sharing of a 5G network with satellite components 11

5.1.2.1 Pre-conditions 11

5.1.2.2 Description 11

5.1.2.3 Post-conditions 11

5.1.3 Handling of latencies associated with satellite components 11

5.1.3.1 Creating and managing sliced associated with satellite components 11

5.1.3.1.1 Pre-conditions 11

5.1.3.1.2 Description 11

5.1.3.1.3 Post-conditions 12

5.1.4 Network slice instance(s) associated with both a Satellite RAN and a Terrestrial RAN 12

5.1.4.1 Pre-conditions 12

5.1.4.2 Description 12

5.1.4.3 Post-conditions 12

5.2 Use cases for the management of satellite components 13

5.2.1 Use case for NGSO regenerative satellite components 13

5.2.1.1 Pre-conditions 13

5.2.1.2 Description 13

5.2.1.3 Post-description 13

5.2.2 Use case for NGSO transparent satellite components 13

5.2.2.1 Pre-conditions 13

5.2.2.2 Description 13

5.2.2.3 Post-description 13

5.3 Use cases for monitoring of satellite components 13

5.3.1 Use case for monitoring of performances of NGSO satellite components with split gNBs 13

5.3.1.1 Goal 13

5.3.1.2 Pre-conditions 13

5.3.1.3 Description 14

5.3.1.4 Post-description 14

5.3.2 Use case for monitoring of average delay on DL-Air Interface for MEO and GEO satellite components 14

5.3.2.1 Goal 14

5.3.2.2 Pre-conditions 14

5.3.2.3 Description 14

5.3.2.4 Post-description 14

5.3.3 Multi-RAT load-balancing associated with both a Satellite RAN and a Terrestrial RAN 14

5.3.3.1 Pre-conditions 14

5.3.3.2 Description 14

5.1.3.3 Post-conditions 15

6. Potential Requirements 16

6.1 Network slice management 16

6.1.1 Network slice instance(s) associated with a satellite RAN 16

6.1.2 Network slice instance(s) associated with satellite RAN sharing 16

6.1.3 Network slice instance(s) associated with satellite component latencies 16

6.1.4 Network slice instance(s) associated with both a Satellite RAN and a Terrestrial RAN 16

6.2 Management of satellite components 16

6.2.1 Management of NGSO regenerative satellite components 16

6.2.2 Management of NGSO transparent satellite components 16

6.3 Monitoring of satellite components 16

6.3.1 Monitoring of NGSO satellite component with split gNBs 16

6.3.2 Monitoring of average delay on DL-Air Interface with MEO or GEO satellite components 17

6.3.3 Multi-RAT load-balancing associated with both a Satellite RAN and a Terrestrial RAN 17

7 Potential Solutions 17

7.1 Potential solutions for the management of satellite components 17

7.1.1 Potential solutions to allow a network slice instance to be associated with both a Satellite RAN and a Terrestrial RAN 17

7.1.1.1 Solution #1: Extend SliceProfile to specify separate service requirements for Satellite RAN and Terrestrial RAN 17

8 Conclusions and Recommendations 17

8.1 Conclusions 17

8.2 Recommendations 17

Annex A: Characteristics of satellite systems 18

A.1 General 18

A.2 Class of orbit 18

A.3 Geometrical coverage of satellite and propagation delay 19

A.4 Type of satellite communication payloads 20

A.5 Air interfaces 21

A.6 General considerations on the use of satellite networks 21

Annex B: Reference Models for Satellite Components Integration in the 5G System 22

B.1 Elementary satellite network architecture 22

B.2 Reference architecture with satellite enabled NR-RAN 22

Annex C (informative): Change history 25

# 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.

In the present document, certain modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

NOTE 1: The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

NOTE 2: The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

NOTE 3: The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

NOTE 4: The constructions "can" and "cannot" shall not to be used as substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

NOTE 5: The constructions "is" and "is not" do not indicate requirements.

Satellite access has been included in the normative requirements for 5G (see [2]). Satellite components have specific characteristics that have been identified in [3]), in particular:

* The altitude of the spacecraft(s) (several hundred to several tens of thousands of kilometres), leading to a regional (multiple countries) or worldwide coverage by the satellite access network.
* The possibility to support end-to-end overlay access network, on a global scale basis, including with the possibility to embark gNBs, or parts of gNBs on board spacecraft.

# 1 Scope

The scope of this document is:

* to identify the main key issues associated with business roles, service and network management and orchestration of a 5G network with integrated satellite component(s) (whether as NG-RAN or non-3GPP access, or for transport), and
* to study the associated solutions.

This study aims at minimising the impacts and complexity of satellite integration in the existing business models and in management and orchestration aspects of the current 5G networks.

# 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".

[2] 3GPP TS 22.261: “Service requirements for next generation new services and markets.”

[3] 3GPP TR 22.822: “Study on using satellite access”

[4] 3GPP TR 38.811: “Study on New Radio (NR) to support non-terrestrial networks”

[5] 3GPP TR 23.737: “Study on architecture aspects for using satellite access”

[6] 3GPP TS 28.530: “Management and orchestration; Concepts, use cases and requirements”

[7] 3GPP TS 28.541: “5G Management and orchestration; 5G Network Resource Model (NRM), Stage 2 and Stage 3”

[8] 3GPP TS 28.522: “5G performance measurements”

[9] 3GPP TR 38.821: “Solutions for NR to support non-terrestrial networks (NTN)”

# 3 Definitions and abbreviations

## 3.1 Definitions

For the purposes of the present document, the terms and definitions 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].

**Geostationary (GEO) satellites**: located precisely in the plane of the Equator at an altitude of 35,786 km, these satellites rotate at the same rate as the Earth's rotation: a GEO satellite stands still with respect to Earth. Thanks to this property, a single GEO satellite is sufficient to create a continuous coverage.

**Non-Geostationary Orbiting (NGSO) satellites**: NGSO satellites do not stand still with respect to Earth. Should service continuity be required over time, a number of satellites (a constellation) is required to meet this requirement; the lower the altitude the higher the number of satellites.

**Low-Earth Orbiting (LEO) satellites**: with altitude ranging from 500 km to 2,000 km, and with inclination angle of the orbital plane ranging from 0 to more than 90 degrees. These constellations are placed above the International Space Station and debris, and below the first Van Allen belt.

**Medium-Earth Orbiting (MEO) satellites**: with altitude ranging from 8,000 to 20,000 km. The inclination angle of the orbital plane ranges from 0 to more than 90 degrees. These constellations are placed above the Van Allen belts.

**Highly-Eccentric Orbiting (HEO) satellites**: with a range of operational altitudes (the orbit of such satellites being designed for the spacecraft to be exploited when the vehicle is closer to its apogee - the higher part of the orbit -) between 7,000 km and more than 45,000 km. The inclination angle is selected so as to compensate, completely or partially, the relative motion of Earth with respect to the orbital plane, allowing the satellite to cover successively different parts of Northern land masses (e.g. Western Europe, North America, and Northern Asia).

## 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].

AN Access Network

5GC 5G Core Network

CN Core Network

GEO Geostationary satellites

gNB generic Node B

gNB-CU gNB-Central Unit

gNB-DU gNB-Distributed Unit

HEO Highly-Eccentric Orbiting satellites

LEO Low-Earth Orbiting satellites

MEO Medium-Earth Orbiting satellites

ms milli-second, a thousandth of a second.

NOP Network Operator

NS Network Slice

NSI Network Slice Instance

NSSI Network Slice Subnet Instance

QoS Quality of Service

RAN Radio Access Network

RAT Radio Access Technology

RU Radio Unit

TBD To Be Defined

# 4 Concepts and Background

## 4.1 Reference management architecture for integrated satellite components

### 4.1.1 Management architecture for integrated satellite NR-RAT

The reference architecture depicted in figure 4.4.1-1 considers the case of a 3GPP RAN integrating a satellite NR-RAT, possibly together with a Terrestrial RAT. The NOP operates the 5G network interfacing through API’s with Communication Service Customers or Verticals on the one hand and delivering services to UEs on the other hand. The 3GPP Management system manages the 3GPP RAN.



Figure 4.1.1-1: Reference architecture for the management of a satellite NR-RAT.

### 4.1.2 Management architecture for integrated non-3GPP satellite RAN

The reference architecture depicted in the following figure considers the case of a non-3GPP satellite RAN integrated in a 5G network. The NOP operates the 5G network interfacing through API’s with Communication Service Customers or Verticals on the one hand and delivering services to UEs on the other hand. The 3GPP management system manages the 3GPP RAN and the non-3GPP RAN.



Figure 4.1.2-1: Reference architecture for the management of a non-3GPP satellite RAN

## 4.2 Architecture scenarios for 5G networks with an integrated satellite component

### 4.2.1 Scenario #1: Satellite enabled 3GPP network as a roaming network for terrestrial network operators

Consider two separate 3GPP networks, one 3GPP network with a satellite access network and one 3GPP network with a terrestrial access network. Both networks have their own PLMN ID and have a roaming agreement in place with each other. Roaming is used by the terrestrial operator to use the 3GPP network with a satellite access. Both the satellite and terrestrial network have their own separate 3GPP management domain.

NOTE: This scenario follows the architecture identified in the Satellite access class scenario in section 4.1.3 from 3GPP TR 23.737 [5].

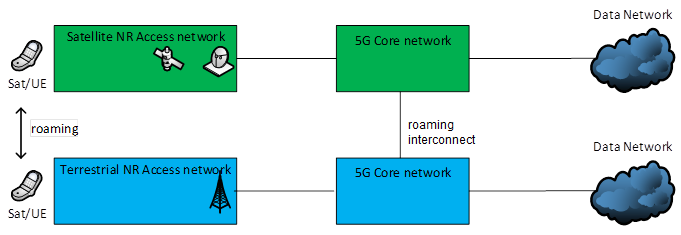


Figure 4.2.1-1: Architecture of satellite 3GPP network (green) as roaming network to a terrestrial 3GPP network (blue**)**

NOTE: The green and blue networks are separate management domains.

### 4.2.2 Scenario #2: A 3GPP network with a satellite access network and a terrestrial access network

In this scenario a 3GPP network is composed out of a 3GPP core network, a terrestrial 3GPP access network and a satellite 3GPP access network, where the satellite component is also integrated as a 3GPP access network. The satellite network and the terrestrial network both share the same PLMN and both access networks are managed by the same 3GPP management system. This architecture scenario follows the Satellite access class scenario in section 4.1.1 from 3GPP TR 23.737 [5].

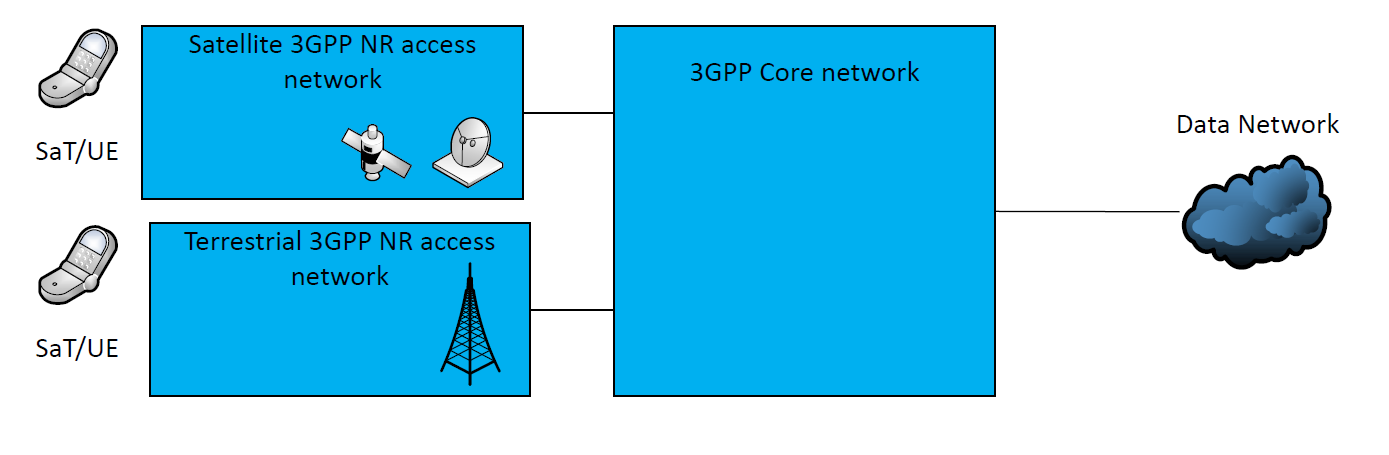


Figure 4.2.2-1 Architecture of 3GPP network with a satellite 3GPP access network and a terrestrial 3GPP access **network**

Note: Both access networks are in the same management domains

# 5 Use Cases

## 5.1 Use cases related to network slice management

### 5.1.1 Network slice instance(s) associated with a satellite RAN

#### 5.1.1.1 Create a network slice instance associated with a satellite RAN

##### 5.1.1.1.1 Pre-conditions

A NOP wants an NSI which includes a 5GC and a Satellite RAN. The Satellite RAN is associated with either a Satellite NR-RAT, or can be non-3GPP Satellite RAT.

##### 5.1.1.1.2 Description

In some cases, the satellite coverage can be as large as the whole world, or can be regional (i.e. covering several countries). In some cases, the latency of the satellite RAN can be significant, from few tens of ms (for LEO) to several hundreds of ms (see Informative Annex A). Further, the description of the Satellite RAN can vary according to its characteristics.

The NOP wants an NSI to support a communication service and the NSI to support to the description of the satellite RAN characteristics.

##### 5.1.1.1.3 Post-conditions

An NSI which includes CN part and RAN part is created, taking into account the specific characteristics of the satellite RAN.

### 5.1.2 RAN sharing of a 5G network with satellite components

##### 5.1.2.1 Pre-conditions

A 5G System is composed of a satellite component, that may include:

- A number of spacecraft, each composed of RUs, possibly gNB-DUs, gNB-CUs

- A number of Earth radio stations located on ground, interconnected with the spacecrafts, each composed of RUs and possibly connected to gNB-DUs and/or gNB-CUs.

The satellite component is interconnected with a 5GC.

It is specified in TS 22.261 that: “a 5G satellite access network shall support NG-RAN sharing”.

A number of NOPs want to share the 5G satellite access network and certain NOPs want to have Network Slicing enabled in the satellite components.

##### 5.1.2.2 Description

The satellite on-board resources are managed by a satellite NOP, to allow the distribution of the limited RF power and bandwidth resources (for a RU), as well as for the power consumption and network resources for the digital processing units. A satellite NOP can therefore act also as VISP (and/or a Data Center Service Provider (for the spaceborne part)). A NOP that is allowed access to the satellite components will be allowed to manage slice configurations in the shared satellite RAN.

##### 5.1.2.3 Post-conditions

The satellite components are configured to support multiple NOPs and NSIs are created for each NOP according to their requirements (bandwidth, connectivity, coverage, etc.) and according to the capabilities of each spacecraft and of the combined capabilities of the network.

### 5.1.3 Handling of latencies associated with satellite components

#### 5.1.3.1 Creating and managing sliced associated with satellite components

##### 5.1.3.1.1 Pre-conditions

A 5G System is composed of a satellite component, that may include:

- a Geostationary-satellite network on the Radio Access part,

- a global LEO access network on the Radio access part, creating potentially a global overlay.

Further, satellite backhaul can be used for transport between 5G-CN functions and RAN functions.

These conditions generate latencies between UEs and the 5G-CN that can be higher or lower than those that could be met if a terrestrial network (radio or fiber) would be used for access or transport.

##### 5.1.3.1.2 Description

In TS 22.261, it is specified that a 5G system with satellite access shall support different configurations where the radio access network is either a satellite NG-RAN or a non-3GPP satellite access network, or both.

It is further required that:

* The 5G system with satellite access shall support the use of satellite links between the radio access network and core network, by enhancing the 3GPP system to handle the latencies introduced by satellite backhaul.
* A 5G system with satellite access shall be able to support meshed connectivity between satellites interconnected with inter-satellite links.

For a 5G system with satellite access, the following requirement also applies:

* A 5G system with satellite access shall be able to select the communication link providing the UE with the connectivity that most closely fulfils the agreed QoS.

Operator wants an NSI to support a communication service and the associated Network Slice that offer the best service options.

##### 5.1.3.1.3 Post-conditions

An NSI which includes CN part and RAN part is created, taking into account the specific characteristics of the satellite RAN and backhaul characteristics.

The performances of the satellite components are monitored to ensure that the performances of the NSI can be delivered as planned.

### 5.1.4 Network slice instance(s) associated with both a Satellite RAN and a Terrestrial RAN

### 5.1.4.1 Pre-conditions

A NOP wants to instantiate an NSI which includes a 5GC, a 3GPP Satellite RAN and a 3GPP Terrestrial RAN. The Satellite RAN is connected to the 5GC with the use of RAN sharing.

### 5.1.4.2 Description

A satellite network could be used to the extend the coverage of an existing terrestrial 3GPP network. When the Satellite RAN is connected to a 5GC by using RAN sharing and therefore is connected to the same 5GC, the NOP may want to deploy a single NSI spanning the Satellite RAN, Terrestrial RAN and 5GC.

Moreover, a NOP may want to specify different network slice service requirements (data rate, latency, etc.) for the Satellite RAN and Terrestrial RAN in the same NSI, due to the specific Satellite RAN characteristics.



Figure 5.1.4-1: An NSI spanning both a Satellite RAN and a terrestrial RAN with two examples of network slice service requirements

Note: There may be more than one network slice service requirement for the Satellite RAN, terrestrial RAN and 5GC.

### 5.1.4.3 Post-conditions

An NSI is created which spans both the Satellite RAN and the terrestrial RAN, with specific network slice service requirements for Satellite RAN and Terrestrial RAN domains.

## 5.2 Use cases for the management of satellite components

### 5.2.1 Use case for NGSO regenerative satellite components

#### 5.2.1.1 Pre-conditions

A NOP operates a 5G network.

The NOP manages the 5G network in accordance with the 5G specifications.

#### 5.2.1.2 Description

The NOP integrates a satellite component based on NGSO regenerative satellites. NGSO regenerative satellites embark either gNBs or gNB-DUs.

The 5G network management is implemented in such a way that moving gNBs or gNB-DUs can be managed.

#### 5.2.1.3 Post-description

The NOP operates a 5G network that manages the satellite component.

### 5.2.2 Use case for NGSO transparent satellite components

#### 5.2.2.1 Pre-conditions

A NOP operates a 5G network.

The NOP manages the 5G network in accordance with the 5G specifications and wants to integrate one or multiple NGSO transparent satellites into a 5GS.

#### 5.2.2.2 Description

The NOP integrates a satellite component based on NGSO transparent satellites. A SaT/UE will connect to a 5GC via a NGSO regenerative satellite component. A gNB may use a special remote radio unit to connect via one or multiple regenerative satellite(s) to the SaT/UE, as illustrated in Annex B.2.

The 5G network management is implemented in such a way that moving regenerative satellite components could be managed.

#### 5.2.2.3 Post-description

The NOP operates a 5G network that manages a 5GS with transparent satellite component(s).

## 5.3 Use cases for monitoring of satellite components

### 5.3.1 Use case for monitoring of performances of NGSO satellite components with split gNBs

#### 5.3.1.1 Goal

When considering an NGSO satellite component with split gNB, the goal is to allow the monitoring of average packet delays on the RAN, as delays would be varying between gNB-DUs and gNB-CUs.

#### 5.3.1.2 Pre-conditions

A NOP operates a 5G network.

The NOP monitors the 5G network performances in accordance with the 5G specifications.

The NOP integrates a satellite component. NGSO satellites embark gNB-DUs on board, gNB-CUs are located on ground (see Annex B of this document).

As the NGSO satellites move along their orbit, the distance between the gNB-DUs embarked on the satellites and the served CUs varies significantly.

#### 5.3.1.3 Description

The monitoring the packet delay is implemented in a such a way so that the varying distance between the gNB-DUs and the gNB-CUs are taken into account.

KPIs such as Average delay DL, CU-UP, Average delay on F1-U, Average delay DL in gNB-DU, are monitored.

#### 5.3.1.4 Post-description

The 5G network can monitor the performances of NGSO satellite components with split gNBs.

### 5.3.2 Use case for monitoring of average delay on DL-Air Interface for MEO and GEO satellite components

#### 5.3.2.1 Goal

The goal is to allow the monitoring of the delay on the DL-Air Interface when a MEO or GEO satellite component for which the HARQ process has been modified with respect to a terrestrial RAN.

#### 5.3.2.2 Pre-conditions

A NOP operates a 5G network.

The 5G network as operated by the NOP satellite RAN supporting NR

#### 5.3.2.3 Description

To cope with the effects of satellite delay and associated RTT, the HARQ operation is disabled or modified when compared to terrestrial RAN.

The management system of the 5G network is designed to provide a measured of the average delay on DL-Air Interface for MEO and GEO satellite components without an HARQ process.

#### 5.3.2.4 Post-description

The management system monitors the average delay on the DL-Air Interface for MEO and GEO satellite components.

### 5.3.3 Multi-RAT load-balancing associated with both a Satellite RAN and a Terrestrial RAN

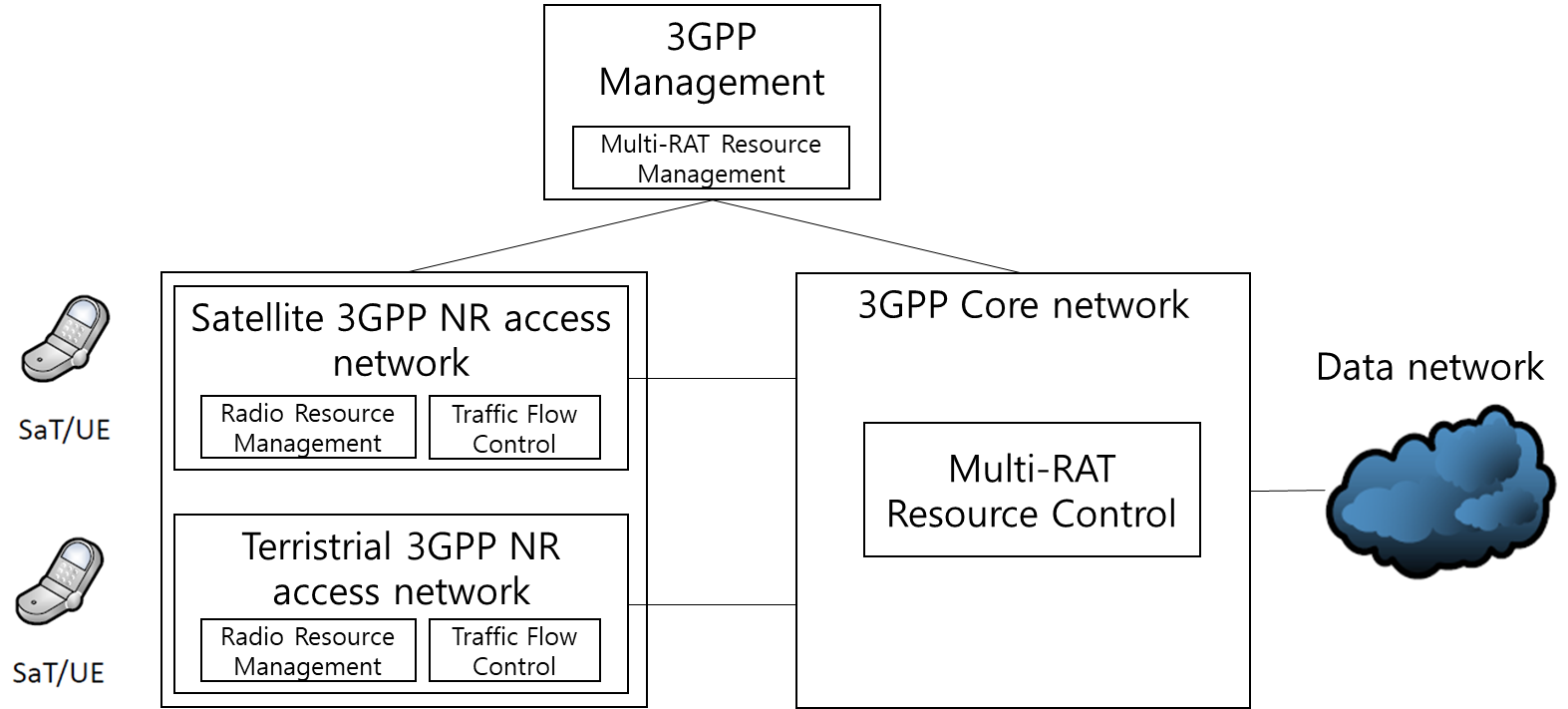
### 5.3.3.1 Pre-conditions

A NOP wants to optimize resource usage of multi-RATs by supporting load-balancing between satellite RANs and terrestrial RANs. The Satellite RAN and Terrestrial RAN are connected to the 5GC with the use of RAN sharing.

A NOP provides the following capabilities: radio resource management and traffic flow control in RAN, multi-RAT resource control in 5GC, and multi-RAT resource management in 3GPP Management.

### 5.3.3.2 Description

For efficient multi-RATs load balancing, the following capabilities and procedures are applied across different parts of 5GS. Figure 5.3.3-1 shows capabilities required for the load balancing.



**Figure 5.3.3-1: Capabilities for Multi-RATs load-balancing for Satellite and terrestrial RANs**

Both satellite and terrestrial 3GPP NR RANs have capabilities of its own radio resource management (e.g., dynamic selection of the appropriate radio bearers) and traffic flow control which dynamically decides, for each in progress connection, the traffic bit rates that have to be managed by each cell of the gNB. The 5GC has multi-RATs resource control capability which performs optimal load-balancing control of multi-RATs. 3GPP Management includes multi-RAT resource management capability which coordinates with multi-RAT resource control capability in 5GC for optimal multi-RAT load-balancing.

Multi-RAT load-balancing procedure may follow the following steps:

1. UE connection procedure to the selected RAT is performed based on the connection profile information such as UE type, service type, and user’s connection preferences, etc.
2. When a connection is setup, uplink and downlink traffic is sent from/to the UE
3. UE sends measurement report about radio link periodically during the connection to the multi-RAT resource control module
4. The multi-RAT resource control module decides load-balancing policy based on the reports, the traffic is switched from the currently active RAT to another RAT by the traffic flow control when load-balancing is required

5. At the end of the connection, each UE sends feedback about the quality of connection and the connection profile information is updated accordingly. The same information is also sent to multi-RAT resource management module in 3GPP management system

### 5.1.3.3 Post-conditions

Optimal Multi-RAT load-balancing is completed across both the Satellite RAN and the terrestrial RAN, with specific multi-RAT resource usage requirements for Satellite RAN and Terrestrial RAN domains. As a result, the following improvement can be achieved:

* Improvement of the overall data rates (throughput) to mobile UEs in 5G networks for both DL and UL.
* Improvement of the optimal exploitation of 5G network resources while meeting the 5G KPIs.
* Guarantee of service continuity (reliability) in mobile UEs

# 6. Potential Requirements

## 6.1 Network slice management

### 6.1.1 Network slice instance(s) associated with a satellite RAN

[REQ-FS\_5GSAT\_MO-1.1.01] An NSI created for the management of services of a 5G system with satellite access, shall include parameters to describe the specific characteristics of the satellite access.

### 6.1.2 Network slice instance(s) associated with satellite RAN sharing

[REQ-FS\_5GSAT\_MO-1.2.01] In a 5G network with satellite access, the satellite components shall have the capability to provide NSIs and NSSIs for each of the NOP sharing the satellite access network.

[REQ-FS\_5GSAT\_MO-1.2.02] In a 5G network with satellite access, each of the NOPs sharing the satellite access shall have the capability to create, manage, monitor, activate, deactivate and terminate NSIs and NSSIs.

### 6.1.3 Network slice instance(s) associated with satellite component latencies

[REQ-FS\_5GSAT\_MO-1.3.01] A Network Slice created for the management of services of a 5G system with satellite access, shall include parameters to handle the latency associated with a satellite access.

[REQ-FS\_5GSAT\_MO-1.3.02] A Network Slice created for the management of services of a 5G system with satellite transport network, shall include parameters to handle the latency associated with the corresponding satellite network.

### 6.1.4 Network slice instance(s) associated with both a Satellite RAN and a Terrestrial RAN

[REQ-FS\_5GSAT\_MO-1.4.01] A single NSI created with both satellite access and terrestrial access, shall have the possibility to set separate network slice service requirements for the Satellite RAN and Terrestrial RAN domains.

## 6.2 Management of satellite components

### 6.2.1 Management of NGSO regenerative satellite components

[REQ-FS\_5GSAT\_MO-2.1-01] In a 5G network integrating an NGSO regenerative satellite RAT, the 5G network shall have the capability of managing moving gNBs or gNB-DUs.

### 6.2.2 Management of NGSO transparent satellite components

[REQ-FS\_5GSAT\_MO-2.2-01] In a 5G network integrating an NGSO transparent satellite RAT, the 5G network shall have the capability to manage one or multiple moving regenerative satellite component(s).

## 6.3 Monitoring of satellite components

### 6.3.1 Monitoring of NGSO satellite component with split gNBs

[REQ-FS\_5GSAT\_MO-3.1.01] In a 5G network integrating a NGSO component with split gNBs, it shall possible to monitor the packet delay KPIs.

### 6.3.2 Monitoring of average delay on DL-Air Interface with MEO or GEO satellite components

[REQ-FS\_5GSAT\_MO-3.2.01] In a 5G network integrating a MEO or GEO satellite components, it shall be possible to monitor the average delay on the DL-Air Interface.

### 6.3.3 Multi-RAT load-balancing associated with both a Satellite RAN and a Terrestrial RAN

[REQ-FS\_5GSAT\_MO-3.3.01] Multi-RAT load-balancing shall be provided to assure optimal resource usage of the Satellite RAN and Terrestrial RAN domains.

[REQ-FS\_5GSAT\_MO-3.3.02] Multi-RAT load-balancing shall be provided to guarantee service continuity (reliability) in mobile UEs.

# 7 Potential Solutions

## 7.1 Potential solutions for the management of satellite components

### 7.1.1 Potential solutions to allow a network slice instance to be associated with both a Satellite RAN and a Terrestrial RAN

#### 7.1.1.1 Solution #1: Extend SliceProfile to specify separate service requirements for Satellite RAN and Terrestrial RAN

The NOP can set specific service requirements for both the Terrestrial RAN and the Satellite RAN in the SliceProfile [7] to instantiate an NSSI which comprises a Terrestrial AN NSSI and Satellite AN NSSI.

To set separate performance requirements for the Terrestrial RAN and Satellite RAN the perfReq [7] attribute can be extended to allow distinct performance requirement entries for both RANs such as the experienced data rate, latency and coverage area.

# 8 Conclusions and Recommendations

## 8.1 Conclusions

TBD

## 8.2 Recommendations

TBD

Annex A:  
Characteristics of satellite systems

# A.1 General

This annex describes the main characteristics of satellite systems when considering their integration with the 5G system.

# A.2 Class of orbit

On the one hand, our planet attracts as a main body the much smaller satellite, which motion is dictated as a consequence by the laws of Kepler. On the other hand, the environment of Earth can be also constraining: the higher density of the atmosphere, debris from launchers and former satellites in the lower altitudes, as well as higher energy particles trapped in the Van Allen belts between 2,000 and 8,000 km's altitudes are to be avoided. These two constraints contribute to defining several classes of orbits that are used for communication satellites:

**- Geostationary** (GEO) satellites, located precisely in the plane of the Equator at an altitude of 35,786 km, these satellites rotate at the same rate as the Earth's rotation: a GEO satellite stands still with respect to Earth. Thanks to this property, a single GEO satellite is sufficient to create a continuous coverage.

**- Non-Geostationary Orbiting** (NGSO) satellites: NGSO satellites do not stand still with respect to Earth. Should service continuity be required over time, a number of satellites (a constellation) is required to meet this requirement; the lower the altitude the higher the number of satellites.

Different classes of NGSO satellites are listed below:

- **Low-Earth Orbiting** (LEO) satellites, with altitude ranging from 500 km to 2,000 km, and with inclination angle of the orbital plane ranging from 0 to more than 90 degrees. These constellations are placed above the International Space Station and debris, and below the first Van Allen belt.

- **Medium-Earth Orbiting** (MEO) satellites, with altitude ranging from 8,000 to 20,000 km. The inclination angle of the orbital plane ranges from 0 to more than 90 degrees. These constellations are placed above the Van Allen belts.

- **Highly-Eccentric Orbiting** (HEO) satellites, with a range of operational altitudes (the orbit of such satellites being designed for the spacecraft to be exploited when the vehicle is closer to its apogee - the higher part of the orbit -) between 7,000 km and more than 45,000 km. The inclination angle is selected so as to compensate, completely or partially, the relative motion of Earth with respect to the orbital plane, allowing the satellite to cover successively different parts of Northern land masses (e.g. Western Europe, North America, and Northern Asia).

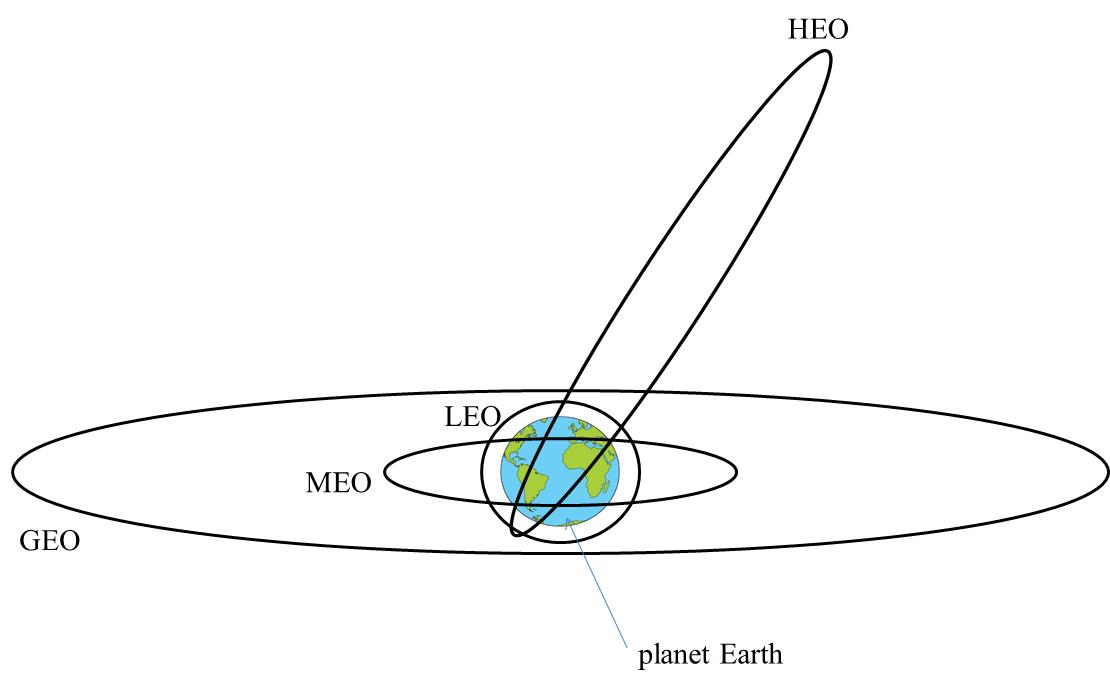


Figure A.2-1: Illustration of the classes of orbits of satellites

# A.3 Geometrical coverage of satellite and propagation delay

As depicted in the following figure, the theoretical geometrical coverage of a satellite is associated to its altitude and the minimum elevation angle under which the satellite is seen by the UE above the horizon.

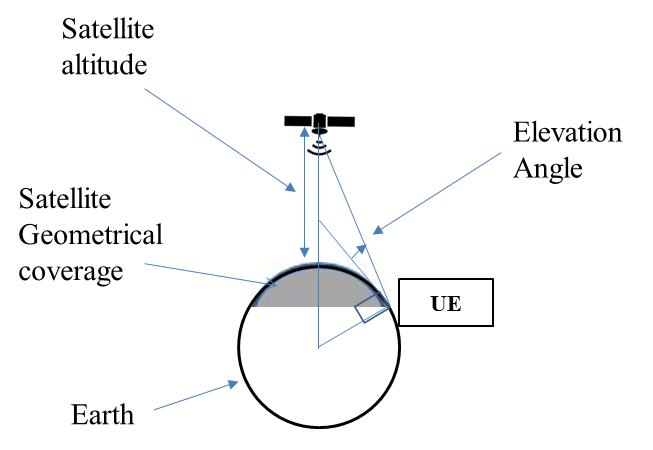


Figure A.3-1: Illustration of the geometrical coverage of a satellite

The following figure illustrates the geometrical coverage for a LEO satellite and for geostationary-satellites:

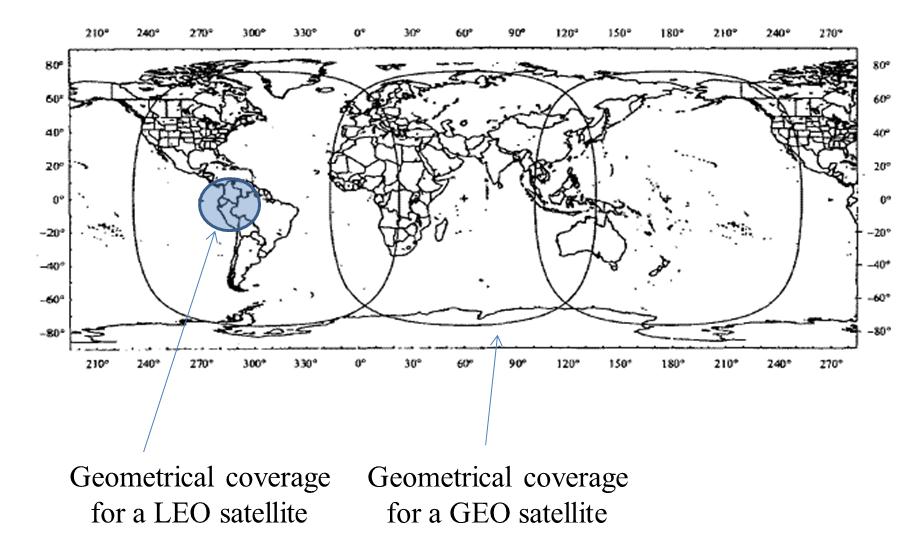


Figure A.3-2: Illustration of the geometrical coverage of a LEO satellite and of GEO satellites

The following tables provide elevation, distance and geometrical coverage related figures for different classes of satellites:

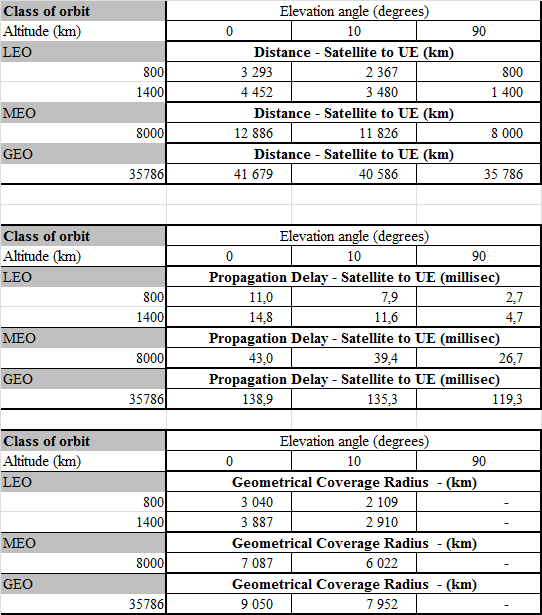


Figure A.3-3: Geometrical coverage radius, propagation distance and delay for different orbits

NOTE: The above figure provides only examples, some designers may decide to select lower altitudes as this contribute lowering the propagation delay.

The following table illustrates the number of satellites that are necessary for a constellation of satellites to provide continuous coverage for an elevation angle ranging from 5 to 10 degrees. Global coverage may not be fully achieved for MEO or GEO satellite, however in this case the vast majority of the world population is covered.



Figure A.3-4: Illustration of number satellites in a constellation for continuous Earth coverage

# A.4 Type of satellite communication payloads

Communication payloads embarked on-board a satellite are of two main categories, for any type of satellite (whether GEO or NGSO):

**- Transparent payloads**: the electromagnetic waves that are transmitted from the Earth’s surface are converted by a satellite receive antenna into an electric signal which is channel filtered and amplified by a low-noise amplifier (LNA). The signal is then frequency converted. A high-power amplifier (HPA) delivers finally the signal to a transmitting antenna generating a reconditioned electromagnetic wave towards the Earth surface where receive station are located.

**- Regenerative payloads:** an On-Board Processor (OBP), is inserted between the LNA and the HPA. This OBP allows to convert the air interface between the uplink (from Earth to satellite) and the down link (from satellite to Earth). It allows to correct bits or packet in errors before retransmitting them, or to route packets between beams. Ultimately any network function can be implemented, at the expense of power and mass, thanks to an OBP (including gNB CU's or DU's, or any function attached to a CN).

**- Inter-Satellite Links (ISL):** can also interconnect regenerative satellite payloads. Through ISL's satellites can be interconnected through a dedicated mesh-network.

# A.5 Air interfaces

Air interfaces can include:

- 3GPP defined air interfaces, such as the New Radio;

- Non-3GPP defined air interfaces

Unless otherwise indicated, 3GPP NR will be assumed in this document.

# A.6 General considerations on the use of satellite networks

In relation to the coverage associated with Non-Geostationary Satellite Networks, or Geostationary-Satellite ones, the use of satellite networks is related to:

- The complement of terrestrial networks where these terrestrial networks are not available, permanently for physically (maritime or aeronautical constraints) or economic reasons, or for temporary reasons associated to local unavailability of a terrestrial of network (drought, Earth quake) or local overload of the demand;

- Satellite networks can be used for broadcast over large areas of a same content, for multicast (with acknowledge of delivery of content), for unicast;

- Use cases are related to the actual of altitude of the satellite platforms and the associated delay of propagation.

Annex B:  
Reference Models for Satellite Components Integration in the 5G System

# B.1 Elementary satellite network architecture

The physical implementation of a satellite network architecture can always be sketched as displayed in the following figure:

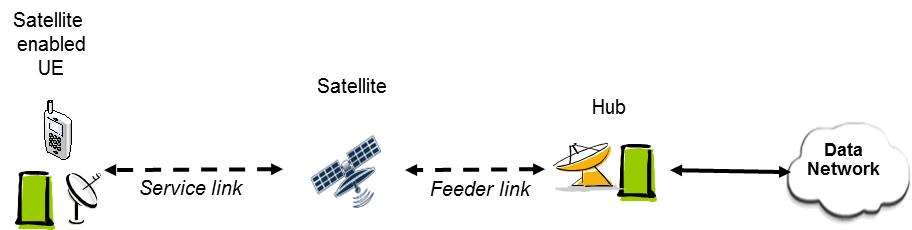


Figure B.1-1: Reference Satellite Access Network Architecture

A satellite network is always composed of:

- One, or more, satellite(s), embarking a telecommunication payload.

- Satellite enabled UEs, such as IoT devices, broadband vehicular or fixed terminals.

- A Hub, including an RF Earth station, and a data centre including (co-located or not) RAN and CN related functions. The hub is also interconnected to (a) data network(s).

- UEs interconnected to the hub through the satellite.

## B.2 Reference architecture with satellite enabled NR-RAN

The following figure depicts a reference architecture for a direct access with a satellite enabled NR-RAN (see below):

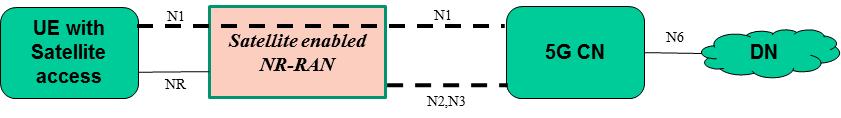


Figure B.2-1: 5GS with Satellite enabled NR-RAN

Knowing the possible nature of satellite payloads (transparent or re-generative), the instantiation of this architecture can have several forms:

In a first implementation, the satellite is transparent, the NR signals are generated from gNB's from a satellite enabled NR-RAN that are located on ground. The satellite is equivalent to a Radio Frequency (RF) Remote Unit, and is full transparent to the New Radio protocols, including the physical layer (see below).

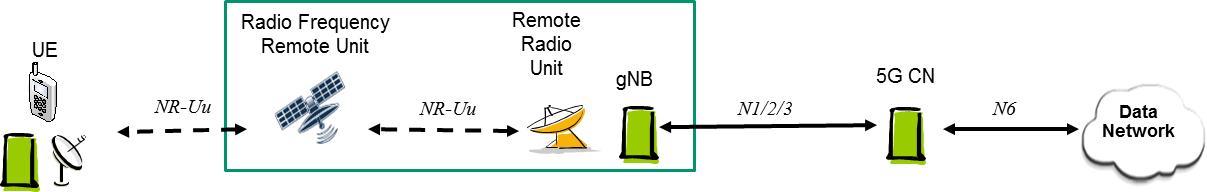


Figure B.2-2: 5GS with transparent satellite enabled NR-RAN

In a second implementation, the satellite is regenerative. The satellite payload implements a gNB-DU as part of a satellite enabled NR-RAN. Some of the protocols of the NR are processed by the satellite. A Satellite Radio Interface (SRI) transports the F1 protocol between the on-ground CU and the on-board DU (it can be the NR (see below)).

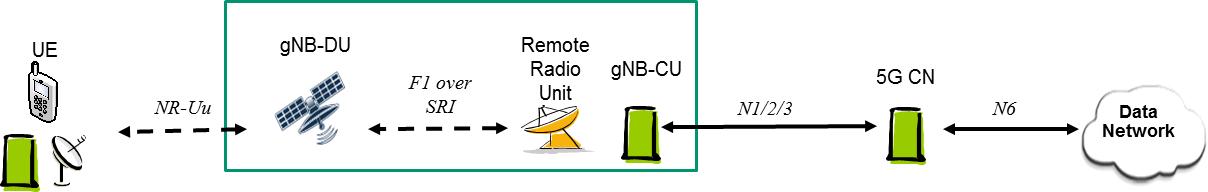


Figure B.2-3: 5GS with regenerative satellite enabled NR-RAN and distributed gNB

In a third implementation, the satellite is regenerative. The satellite payload implements a full gNB supporting a satellite enabled NR-RAN. A Satellite Radio Interface (SRI) transports the N1/N2/N3 interfaces between the on-ground 5G CN and the on-board gNB-CU (see below).

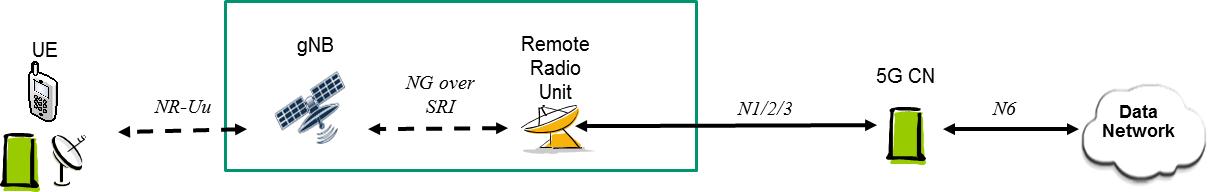


Figure B.2-4: 5GS with regenerative satellite enabled NR-RAN and on-board gNB

One can note that with a regenerative implementation (either with distributed gNB or not) a 5GS can have a global coverage, providing a single 5G CN with global or regional (continental or sub-continental) coverage as well. This is valid for GEO or LEO (see below):

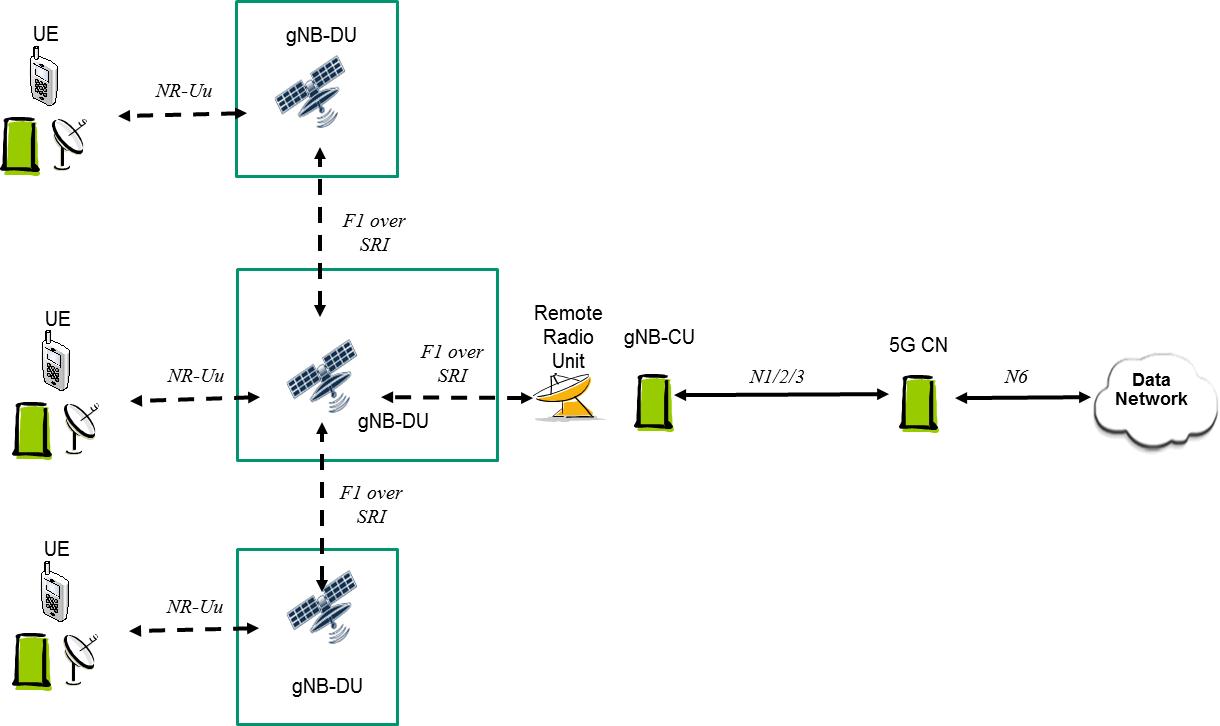


Figure B.2-5: 5GS with regenerative satellite enabled NR-RAN, with ISL for regional or global coverage

Another configuration (see below) may consist in satellites each embarking a gNB supporting a satellite enabled NR-RAN, and 5G CN's accessing these gNB's, as described in the following figure, where specific (or not) satellite radio interfaces are used to handle control and user planes:

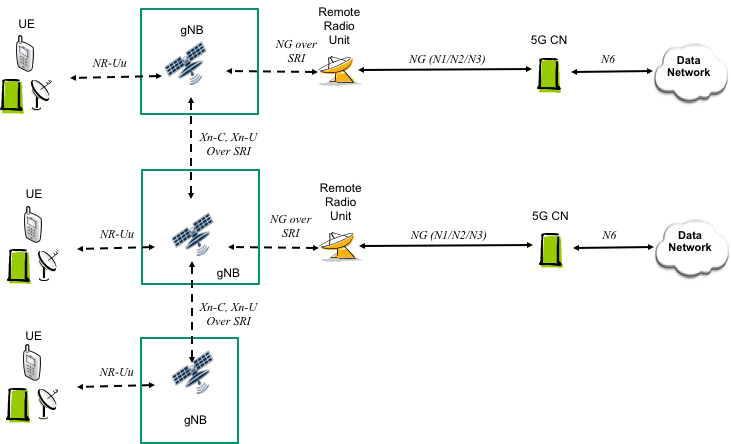


Figure B.2-6: 5GS with regenerative satellite enabled NR-RAN, with ISL & multiple 5G CN connectivity

Annex C (informative):  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2019-04 | SA5#125 | S5-193525 |  |  |  | Implemented S5-193123, S5-193522, S5-193523, S5-193526, S5-193527, S5-193237, S5-193524, S5-193127 | 0.1.0 |
| 2019-08 | SA5#126 |  |  |  |  | Implemented S5-195867, S5-195867, S5-195872, S5-195873, S5-195874, S5-195874, S5-195876 | 0.2.0 |
| 2019-10 | SA5#127 | S5-196874 |  |  |  | Implemented S5-196664, S5-196665 | 0.3.0 |
| 2019-11 | SA5#127 | S5- 197850 |  |  |  | Implemented S5-197242, S5-197326, S5-197579 | 0.4.0 |
| 2020-06 | SA5#131E | S5-203321 |  |  |  | Implemented S5-203018, S5-203019, S5-203020 | 0.5.0 |