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Satellite Earth Stations and Systems (SES); Seamless integration of satellite and/or HAPS (High Altitude Platform Station) systems into 5G and related architecture options Reference DTR/SES-00405

2

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Satellite Earth Stations and Systems (SES).

Modal verbs terminology

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1 Scope

The present document identifies how to integrate satellite and/or HAPS communication systems in 5G system for relevant use cases. The report identifies the necessary standardization activity in relation to the integration of satellite or HAPS in the 5G system.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1]	ARIB 2020 and Beyond Ad Hoc Group White Paper, October 2014.
NOTE:	Available at https://www.arib.or.jp/english/image/committee/adwics/02-00_2020bah/20bah-wp-100.pdf.
[i.2]	NGMN 5G White Paper v1.0.
[i.3]	ESOA 5G White Paper, "Satellite Communications Services: An integral part of the 5G Ecosystem,", European and middle east Satellite Operator Association, 2017 (www.esoa.net).
NOTE:	Available at https://www.esoa.net/cms-data/positions/ESOA5G%20Ecosystem.pdf
[i.4]	European Commission H2020 5G PPP project "SaT5G" (Satellite and Terrestrial Network for 5G), 2017.
NOTE:	Available at: <u>http://sat5g-project.eu/</u> .
[i.5]	European Commission, "5G for Europe: An Action Plan,", 14 September 2016.
NOTE:	Available at http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=17131.
[i.6]	3GPP TR 38.811: "Study on New Radio (NR) to support non-terrestrial networks".
[i.7]	ETSI TS 123 501: "5G; System architecture for the 5G System (5GS) (3GPP TS 23.501 Release 15)".
[i.8]	ETSI TS 123 401: "LTE; General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access (3GPP TS 23.401 Release 15)".
[i.9]	3GPP TR 36.806: "Evolved Universal Terrestrial Radio Access (E-UTRA); Relay architectures for E-UTRA (LTE-Advanced) (Release 9)".
[i.10]	ETSI TS 123 502: "5G; Procedures for the 5G System (5GS) (3GPP TS 23.502 Release 15)".
[i.11]	IETF RFC 4555: "IKEv2 Mobility and Multi-homing Protocol (MOBIKE)".

- [i.12] Equivalent capacity and its application to bandwidth allocation in high-speed networks; R. Guerin, H. Ahmadi, M. Naghshineh ; IEEE Journal on Selected Areas in Communications (Volume: 9, Issue: 7, Sep 1991).
- [i.13]"Communicating Systems & Networks: Traffic & Performance". Georges Fiche, Gérard
Hébuterne; London; Sterling, VA : Kogan Page Science, 2004.
- [i.14] ETSI TS 138 470: "5G; NG-RAN; F1 general aspects and principles (3GPP TS 38.470 Release 15)".
- [i.15] ETSI TS 136 300: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (3GPP TS 36.300)".
- [i.16] ETSI TS 138 300: "5G; NR; Overall description; Stage-2 (3GPP TS 38.300 Release 15)".
- [i.17] ETSI TS 138 473: "5G; NG-RAN; F1 Application Protocol (F1AP) (3GPP TS 38.473 Release 15)".
- [i.18]3GPP TS 38.475: "Technical Specification Group Radio Access Network; NG Radio Access
Network (NG-RAN); F1 interface user plane protocol (Release 15)".
- [i.19] ETSI TS 132 240: "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; Telecommunication management; Charging management; Charging architecture and principles (3GPP TS 32.240)".
- [i.20] ETSI TS 133 501: "5G; Security architecture and procedures for 5G System (3GPP TS 33.501 Release 15)".
- [i.21] 3GPP TR 38.874: "Technical Specification Group Radio Access Network; Study on Integrated Access and Backhaul (Release 15)".
- [i.22] 3GPP TR 22.822: "Technical Specification Group Services and System Aspects; Study on using Satellite Access in 5G; Stage 1 (Release 16)".
- [i.23] ETSI TS 138 401: "5G; NG-RAN; Architecture description (3GPP TS 38.401 Release 15)".
- [i.24] ETSI TS 128 530: "5G; Management and orchestration; Concepts, use cases and requirements (3GPP TS 28.530 Release 15)".
- [i.25] ETSI TS 102 354: "Satellite Earth Stations and Systems (SES); Transparent Satellite Star B (TSS-B); IP over Satellite (IPoS) Air Interface Specification [TIA-1008-B (April 2012)]".
- [i.26] RESOLUTION 155 (WRC-15) "Regulatory provisions related to earth stations on board unmanned aircraft which operate with geostationary-satellite networks in the fixed-satellite service in certain frequency bands not subject to a Plan of Appendices 30, 30A and 30B for the control and non-payload communications of unmanned aircraft systems in non-segregated airspaces".
- NOTE: Available at https://www.itu.int/en/ITU-R/space/snl/Documents/RES-155.pdf
- [i.27] IEEE 802.1adTM-2005: "IEEE Standard for Local and Metropolitan Area Networks -- Virtual Bridged Local Area Networks -- Amendment 4: Provider Bridges".
- NOTE: Available at https://standards.ieee.org/standard/802_1ad-2005.html.
- [i.28] IEEE 802.1ahTM-2008: "IEEE Standard for Local and metropolitan area networks -- Virtual Bridged Local Area Networks Amendment 7: Provider Backbone Bridges".
- NOTE: Available at https://standards.ieee.org/standard/802_1ah-2008.html.

- [i.29] IEEE 802.11TM-2016: "IEEE Standard for Information technology -- Telecommunications and information exchange between systems Local and metropolitan area networks -- Specific requirements -- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".
- NOTE: Available at https://standards.ieee.org/standard/802_11-2016.html.
- [i.30] IEEE Std 1914.3TM (2018): "IEEE Standard for Radio over Ethernet Encapsulations and Mappings".

NOTE: Available at https://standards.ieee.org/standard/1914_3-2018.html.

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

3GPP defined NTN access network: NTN which implements a 3GPP Access Networks

5G Access Network: 3GPP Access Network (NR-RAN) connecting to a 5G Core Network

5G higher protocol layers: set of 5G protocols layers that include:

- In the control plane: NAS-MM, NAS-SM, NG-AP, RRC, SCTP over IP, IP
- In the user plane: PDU layer (e.g. IP), GTP-U, 5GUPE, UDP, IP
- NOTE 1: NAS-MM, NAS-SM, PDU layer are defined at the UE- 5G CN interface (in the control plane).
- NOTE 2: 5GUPE is defined at internal interface within the 5G CN (in the user plane).
- NOTE 3: NG-AP, SCTP are defined at the NG-C interface between the RAN and the 5G CN (in the control plane).
- NOTE 4: RRC is defined at the UE-gNB interface (both in the control and user planes). RRC is a cross-layer in the UE, interfacing both with PDCP, MAC and Physical local sub-layers.
- NOTE 5: GTP-U is defined at the NG-U interface between the RAN and the 5G CN (in the user plane).

5G Service Enablers: enabling features for the 5G service types including eMBB (Enhanced Mobile Broadband), mMTC (Massive Machine Type Communications), and URLLC (Ultra-Reliable and Low Latency Communications)

5G Use Case: particular case of how the 5G system is used

NOTE: See "Use case" definition.

access point: network entity providing an access to UEs or local RAN to the 5G CN, this access being either a 3GPP access or a non-3GPP access

NOTE: This definition conforms to the following ETSI terminology "device providing an interface between a Wide Area Network (WAN) and a local network".

aircraft: airborne vehicle including High Altitude Platforms (HAPs)

- NOTE 1: As part of wireless network, aircraft embarks relay nodes or base stations for connection with UE's. Aircraft may also be interconnected together by means of Inter-HAPS Links.
- NOTE 2: This may also refer to Unmanned Aircraft Systems (UAS) but preferably use HAPS in the present document.

bent-pipe vehicle: satellite or HAPS based on a transparent architecture

NOTE: Another wording is non-regenerative architecture.

feeder link: link between the vehicle (satellite or HAPS) and the Feeder Link terminal, at NTN Gateway side

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gNB: 5G Base station i.e. 5G Access Controller, serving the UE, local to the UE

HAPS access: access network using an HAPS embarking a transmission equipment relay node or base station and providing connectivity with user equipment

"Higher" NR Data Link Layers: link layers protocols such as SDAP, PDCP, RLC

L1 or Layer 1: physical layer

L2 or Layer 2: data Link layer

L3 or Layer 3: network layer

line termination gNB: gNB that serves a Relay UE or a network termination UE

mobile network operator: actor that operates the mobile cellular system (including UEs, RAN, CN)

NOTE: A company may or endorse both "NTN operator" and MNO roles or not.

multiplexer node: network entity that multiplexes single flows into aggregate flows and forwards them to the next network entity in the transmission chain

- NOTE: Endorses also the role of de-multiplexer node, which de-multiplexes aggregate flows into single flows and forwards them to next network entities or terminals, in the transmission chain, according to their destination.
- N3IWF: non-3GPP Interworking Function
 - NOTE: Non-3GPP access networks can be connected to the 5G Core Network via the Non-3GPP Interworking Function (N3IWF). The N3IWF interfaces the 5G Core Network CP and UP functions via N2 and N3 interfaces, respectively. In case of untrusted non-3GPP access, an IPSec tunnelling is setup between the UE with non 3GPP access and the 5G Core Network (see ETSI TS 123 501 [i.7]).

N3IWFg: extension of N3IWF

NOTE: Extension to enable establishment of IPsec tunnel(s) between the 5G CN and the local security gateway connected to the local gNB, over an untrusted Non-3GPP Access Network. At 5G CN side, N3IWFg relays signalling and data.

Nadir: point of the celestial sphere that is directly opposite the zenith and vertically downward from the observer

network termination UE: network termination for which UE management applies

non-3GPP layer: protocol layer not defined by 3GPP

NOTE: For example, layer of radio protocols not defined by 3GPP, such as specified by ETSI (DVB-S2X, DVB-RCS2). For the mixed 3GPP access, 5G higher protocol layers (see the definition) and "Higher" NR Data Link layers (see the definition) may be implemented onto this Non-3GPP layer, providing adaptations of these 5G and NR layers.

non-3GPP access network: access network which is not fully defined by 3GPP but may support an interface with the CN

NOTE: The "mixed 3GPP NTN access network" enters in this category but implements some 3GPP defined NR radio interface protocols.

Non-Access Stratum (NAS): signalling between the UE and the Core Network

non-GEO: non geostationary satellite systems such as LEO or MEO

NR: New Radio interface for 5G system

- NR data link layers: set of 5G protocol layers defined as: SDAP, PDCP, RLC, MAC
- NR-radio access: 5G Access Network based on NR interface

Non-Terrestrial Network (NTN): network, or segments of network, using an airborne or space-borne vehicle to embark transmission equipment, a relay node or base station

NOTE: See 3GPP TR 38.811 [i.6].

NTN Access: access that is provided by a NTN access network based on a satellite or a HAPS system

NTN enabled line termination gNB: function able to serve NTN enabled network termination UE, via an NTN infrastructure

NOTE: It is either centralized (located at core network side) or distributed over the NTN infrastructure. It may be either located in the ground segment or embedded in an OBP payload.

NTN enabled LT gNB: short name for NTN enabled line termination gNB

NTN enabled network termination UE: network termination UE that terminates a NTN Service Link

NOTE: It may be integrated in a NTN Relay UE or be a standalone equipment. The NTN enabled network termination UE interfaces a dedicated gNB, namely the NTN enabled line termination gNB and a Core Network, via satellite or HAPS link(s).

NTN enabled NT UE: NTN enabled network termination UE

NTN enabled relay UE: relay UE able to be served by a NTN access

NOTE: This NTN enabled relay UE implements local gNB function and NTN enabled network termination UE functions.

NTN Gateway: gateway located in the ground segment, linked to the Core Network and Feeder Link terminal(s)

NTN gNB-CU: short name for NTN enabled gNB Central Unit

NTN gNB-DU: short name for NTN enabled gNB Distributed Unit

NTN NT UE: NTN enabled network termination UE

NTN NT UE radio bearer: NR radio bearer associated with a NTN enabled network termination UE

NTN NT UE radio transport container: non-3GPP radio transport container associated with a NTN enabled network termination UE

NTN operator: actor that operates the NTN. A company may endorse both "NTN operator" and MNO roles or not

NTN radio transport container: generic term which stands for a radio transport container associated with NTN network termination

NTN relay UE: NTN enabled relay UE

NTN terminal radio transport container: non-3GPP radio transport container associated with a NTN enabled terminal

NTN UE: NTN enabled network termination UE

Radio Access Network (RAN): access network based on 5G radio interface, local to the UEs

relay UE: equipment that implements local gNB function and network termination UE functions

satellites: space borne vehicles including Low Earth Orbiting (LEO) satellites, Medium Earth Orbiting (MEO) satellites as well as Geostationary Earth Orbiting (GEO) satellites

NOTE: As part of a wireless network, satellites embark relay nodes or base stations for connection with UE's. Satellites can be interconnected together by means of Inter-Satellite Links.

satellite access: access network using a space borne vehicle embarking a transmission equipment relay node or base station and providing connectivity with user equipment

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NOTE: By extension, a satellite access may also rely on a multiplicity of satellites which relay nodes or base stations may or may not be interconnected with inter-satellite links.

satellite use cases: particular case of how the SatCom system is used in the 5G system to provide or to support the provisioning of a set of 5G services

scenario: instantiation of a Use Case for the accomplishment of a specific duty and driving the network topology and the architecture design

service link: link between the NTN terminal (NTN NT UE or VSAT) and the vehicle (satellite or HAPS)

trusted network: network or sub-network which are considered secured by the mobile network operator

NOTE: It depends on the commercial agreement between the MNO and the 3rd party operator (such as the Transport Network operator).

UE management: set of procedures and protocols over NR, N1 and NG interfaces to manage a UE

NOTE: Procedures (see ETSI TS 123 502 [i.10]).

EXAMPLE: Initial Access, Connection Management, PDU session management, Mobility Management, Radio resource Management.

UE mobility management: mobility management addresses the registration of an UE at a RAN, its location (how to keep track of an UE) and the handover (how to maintain service continuity following a mobility event)

NOTE: The mobility management and the afferent procedures are described in [i.7], [i.10] and [i.16] for the 5G and [i.8], [i.15] for LTE-A, updated for R15. In a 5G system, these mobility procedures are supported across several interfaces, such as NR, N1 and NG according to architectures specifications [i.16]. In the indirect scenarios, when embedded in a moving platform, the NTN NT UE may be considered as a mobile UE. In the Direct scenario, the NTN NT UE is mobile UE, as any handset.

untrusted network: network or sub-network which are considered unsecured by the Mobile Network Operator.

NOTE: It depends on the commercial agreement between the MNO and the 3rd party operator.

use case: particular example (a case) of how a system is used, literally a "case of system use", in order to achieve a specific goal

NOTE: The way a system is used corresponds to the interaction between a stakeholder and the system.

vehicle: satellite or HAPS

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

3GPP 3rd Generation Partnership Project

NOTE: See <u>https://www.3gpp.c</u>	org/.
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4G	4 th Generation
5G	5 th Generation
5G CN	5G Core Network (in the present document).
5G-EIR	5G Equipment Identity Register

5GMF	The fifth generation mobile communications promotion forum
NOTE:	See <u>https://5gmf.jp/en/</u> .
5G PPP	5G Infrastructure Public Private Partnership
NOTE:	See <u>https://5g-ppp.eu/</u>
5GUPE	5G User Plane Encapsulation
NOTE:	The wording is defined in 3GPP but not the acronym.
5QI AF AMF AN AP ARIB	5G QoS Identifier Application Function Access and Mobility management Function Access Network Access Point Association of Radio Industries and Businesses
NOTE:	See <u>https://arib.or.jp/english/</u> .
AUSF CA CN CoS CP CPRI CU DeNB DL DN DRB DSCP DU EMEA eMBB eNB ESOA	AUthentication Server Function Carrier Aggregation Core Network Class of Service Control Plane Common Public Radio Interface Central Unit Donor eNodeB Downlink Data Network Data Radio Bearer Differentiated Service Code Point Distributed Unit European, Middle East and Africa enhanced Mobile Broadband eNodeB European and middle east Satellite Operator Association
NOTE:	See <u>https://www.esoa.net/</u> .
F1AP F1-C F1-U FFS FOTA GBR GEO gNB	F1 Application Protocol F1 Control plane interface F1 User plane interface For Further Study Firmware Over-the-Air Guaranteed Bit Rate Geostationary Earth Orbit Next-Generation Node B
NOTE:	Alias 5G base station.
gNB-CU gNB-DU GPRS GTP GTP-U GW H2020 HAPS HPLMN	gNB Central Unit gNB Distributed Unit General Packet Radio Service GPRS Tunnelling Protocol GPRS Tunnelling Protocol, for the User Plane GateWay Horizon 2020 High Altitude Platform Station Home Public Land Mobile Network

IAB Integrated Access and Backhaul

IEEE TM	Institute of Electrical and Electronics Engineers

NOTE:	See <u>https://www.ieee.org/</u> .
IP	Internet Protocol
IPsec	Internet Protocol Security
IoT	Internet of Things
ISL	Inter-Satellite Link
LEO	Low Earth Orbit
LT	Line Termination
LT gNB	Line Termination gNB
M2M	Machine to Machine
MAC	Media Access Control
MEC	Multi-access Edge Computing
MEO	Medium Earth orbit
MNO	Mobile Network Operator
MOBIKE	MOBility and multihoming extension to Internet Key Exchange
MUX	MUltipleXing
N3IWF	Non-3GPP InterWorking Function
N/A	Not Applicable
NAS	Non-Access Stratum
NAS-MM	NAS, Mobility Management part
NAS-SM	NAS, Session Management part
NF	Network Function
NG	Next Generation
NG-AP	NG Application Protocol
NGMN	Next Generation Mobile Network alliance

NOTE: See <u>https://www.ngmn.org</u>.

Next Generation User plane
NTN enabled 5G Radio Access Network
Network Management System
Non-Guaranteed Bit Rate
5G New Radio interface
NF Repository Function
Network Slice Selection Function
Network Termination
Network Termination UE
Non-Terrestrial Network
NTN enabled line termination gNB
NTN enabled network termination UE
On-Board Processing
PHYsical layer
Policy Control Function
Packet Data Convergence Protocol
Packet Data Network
Protocol Data Unit
PDN GateWay
3GPP functional network entity.
Public Land Mobile Network
Public Private Partnership
QoS Flow Identifier
Quality of Service
Release 15 of 3GPP
Radio Access Network
Radio Resource Control
Radio Link Control
Relay Node
Radio Network Temporary Identifier
Remote Radio Head

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Service Architecture
Stream Control Transmission Protocol
Service Data Adaptation Protocol
SECurity gateway
Security Edge Protection Proxy
Session Management Function
Signalling Radio Bearer
Software Over-the-Air
Total Cost of Ownership
Transport Network
Transport Network Layer
Technical Specification
Unmanned Aircraft System
User Datagram Protocol
Unified Data Management
User Equipment
User Datagram Protocol/Internet Protocol
UpLink
User Plane
User Plane Function
Very High Throughput Satellite
Virtual Network Function
Very Small Aperture Terminal
Wireless Local Area Network
World Radiocommunication Conference

4 5G Connectivity using Satellites or HAPSs

4.1 Background

Several white papers among which, the ARIB's 5G white paper [i.1], the 5GMF's presentation at the 3GPP RAN 5G workshop referenced satellite-terrestrial cooperation as part of the mobile networks of 2020 and beyond. Similarly, the NGMN white paper [i.2], as part of its technology candidate analysis, has also listed satellites as an example of an emerging technology that could be relevant as part of 5G. Moreover, the EMEA Satellite Operators Association (ESOA) has recently published a 5G White Paper on the SatCom services' role as an integral part of the 5G ecosystem [i.3]. In addition, the European Commission funded H2020 5G PPP project "SaT5G" (Satellite and Terrestrial Network for 5G) has recently defined the Use Cases and Scenarios for satellite positioning into the eMBB (Enhanced Mobile Broadband) Service Enabler for 5G [i.4]. Furthermore, the European Commission [i.5] recognizes that satellite networks will be key element of the 5G infrastructure.

4.2 Roles of satellite and HAPS based access networks in 5G system

The roles of satellite AN and HAPS AN are discussed in this clause. HAPS AN has advantages similar to satellites in certain cases: ubiquity, broadcast, resiliency, as described below. Besides, the satellites can support any kind of moving platform while the HAPSs are designed to serve moving platforms on the ground. The area covered by a satellite is larger than the one served by an HAPS.

The consensus and wider agreement on the key advantages of satellite networks which can add value to the 5G ecosystem are:

- Ubiquity: Satellite provides high speed capacity across the globe using the following enablers: capacity in-fill inside geographic gaps, overspill to satellite when terrestrial links are over capacity, general global wide coverage, backup/resilience for network fallback and especially communication during emergency.
- Mobility: Satellite is the only readily available technology capable of providing connectivity anywhere on the ground, in sea or air for moving platforms, such as airplanes, ships and trains.

- Broadcast (Simultaneity): Satellite and HAPSs can efficiently deliver rich multimedia and other content across multiple sites simultaneously using broadcast and multicast streams with information centric networking and content caching for local distribution.
- Resiliency: A key component of 5G is network resiliency. As satellite and HAPS networks are not subject to the same weather and man-made disasters that happen to terrestrial communications systems, they bring to the network an important component of resiliency.

One may note that all four of the above roles are due to satellite's ability to serve coverage wider than those of most other wireless communications technologies and reduced vulnerability of space/airborne vehicles to physical attacks and natural disasters.

In other words, satellite or HAPS access networks are expected to:

- foster the roll out of 5G service in un-served areas that cannot be covered by terrestrial 5G network (isolated/remote areas, on board aircrafts or vessels) and underserved areas (e.g. sub-urban/rural areas) to upgrade the performance of limited terrestrial networks in a cost-effective manner;
- reinforce the 5G service reliability by providing service continuity for M2M/IoT devices or for passengers on board moving platforms (e.g. passenger vehicles-aircraft, ships, high speed trains, bus) or ensuring service availability anywhere especially for critical communications, future railway communications or maritime communications;
- enable 5G network scalability by providing efficient multicast/broadcast resources for data delivery towards the network edges.

The roles for satellite or HAPS access network elements in the 5G system are expected for the following application domains: Automotive and Road transport, Maritime, Aeronautics Transport, Public Safety, Media and Entertainment, eHealth, Energy, Agriculture, Finance.



Figure 1: Application domains typically addressed by Satellite Networks

The satellite and HAPS based access networks within the 5G system are expected to address also application domains among the one mentioned above.

This results in the following architecture concept supporting the integration scenarios of satellite and HAPS access networks in 5G system where, 5G user equipment can be served directly via the non-terrestrial platform or indirectly via a network node on the ground.



user equipment

Figure 2: Architecture concept supporting the integration scenarios of satellite and HAPS access network in 5G system

4.3 5G Use Cases wherein satellite or HAPS access networks have a role

There are several 5G use cases that can only be served by satellites:

- Broadband connectivity where it is difficult or not (yet) possible to deploy terrestrial communications to towers: For example, maritime services, coverage on lakes, islands, mountains, rural areas, isolated areas or other recreational areas that are best or only covered by satellites; across a wide geographic region.
- Disaster relief: During natural disasters or other unforeseen events that entirely disable the terrestrial network, satellites are the only option.
- Emergency response: Besides wide scale natural disasters, there are specific emergency situations in areas where there is no terrestrial coverage. For example, a public safety use case of an accident in a power plant. This can be achieved with tactical cells deployed and connected via satellite or with direct communications via satellite.
- Broadband connectivity to tactical cells for mission critical communications.
- Efficient broadcast service to end users, vehicles, etc. (e.g. video, software download), support of low bit-rate broadcast service e.g. for emergency messages and synchronization of remote sensors and actuators without significant latency requirements.
- Providing efficient multicast/broadcast delivery to network edges for content such as live broadcasts, ad-hoc broadcast/multicast streams, group communications, MEC VNF update distribution.
- Broadband connectivity to moving platforms, such as airplanes or vessels.
- Secondary/backup connection (limited in capability) in the event of the primary connection failure or for connected cars. Enabling Firmware/Software Over-the-Air (FOTA/SOTA) services to get information updates, such as information regarding Points of Interest (POIs), real-time traffic, and parking availability ("infotainment").

- Broadband Connectivity for network Head-Ends.

There are other 5G use cases for which satellites will augment terrestrial communications:

- Connectivity complementing terrestrial networks, such as broadband connectivity to home/office small cell in underserved areas in combination with terrestrial wireless or wireline.
- Connectivity for remotely deployed battery activated M2M/IoT sensors, or handset devices with messaging/voice capabilities via satellite (e.g. fleet management, asset tracking, livestock management, farms, substations, gas pipelines, digital signage, remote road alerts, emergency calls, mission critical/public safety communications, etc.).
- Two-way telematics capability enabling automotive diagnostic reporting on connected cars, user base insurance information, safety reporting (e.g. air-bag deployment reporting, advertising-based revenue, remote access functions e.g. remote door unlocking).
- Connectivity complementing terrestrial networks, such as broadband and content multicast connectivity to phased-array platforms on the move, in conjunction with a terrestrial based connectivity link to base stations or relay on board moving platforms such as high-speed trains/buses to ensure service reliability for major events in ad-hoc built-up facilities.
- Connectivity of IoT devices on containers (e.g. for tracking and tracing) connected via a Relay UE on a transport vehicle such as a ship, train or truck.
- Connectivity to Unmanned Aircraft Systems (UASs)/drones via satellite consistent with Resolution 155 WRC-15 [i.26].
- Connectivity of IoT devices and M2M that need wide area networks and/or resiliency and/or are located in remote areas.

HAPS access networks are well suited to provide:

- Broadband connectivity to cells or relay nodes to serve big events especially in un/underserved areas.
- Broadband connectivity to a User Equipment on board HAPS that operate over a restricted area (< 200 km diameter).
- Connectivity to User Equipment (handset or vehicle mounted) for public safety communications as part of a disaster relief mission.

4.4 Use Cases of satellite access in 5G

In the 3GPP TR 22.822 [i.22], a number of use cases have been identified for the purpose of 3GPP work. They are listed hereunder as examples:

- Roaming between terrestrial and satellite networks.
- Broadcast and multicast with a satellite overlay.
- Internet of Things with a satellite network.
- Temporary use of a satellite component.
- Optimal routing or steering over a satellite network.
- Satellite trans-border service continuity.
- Global satellite overlay.
- Indirect connection through a 5G satellite access network.
- 5G Fixed Backhaul between NR and the 5G Core.
- 5G Moving Platform Backhaul.

- 5G to Premises.
- Satellite connection of remote service centre to off-shore wind farm.

4.5 Satellite or HAPS access networks design principles for 5G

A high degree of operational integration of satellite or HAPS access networks into 5G system is required in order to maximize the benefits of satellite or HAPS access in the above mentioned 5G Use Cases. In addition, the use of radio interface commonalities between satellite or HAPS access networks and 5G radio access technologies is expected:

- to reduce satellite equipment cost (for instance, if 5G chipsets can be leveraged for that purpose); and/or
- to enable an efficient interoperability with the 5G Core Network and reduce its cost (for instance in supporting 5G higher protocols such as NG-AP and NAS).

5 Non-Terrestrial networks and 5G system

5.1 Non-terrestrial network types

The following type of Non-Terrestrial Network (NTN) is addressed in the present document:

• NTN encompassing vehicle with "Bent-pipe" payload: typically for use with a transparent GEO satellite, and also for transparent LEO, MEO, HAPS systems. By extension, it refers to satcom/HAPS system with signal processing also featuring some flexibility.

The following type of Non-Terrestrial Network (NTN) is FFS:

• NTN encompassing vehicle with "OBP payload hosting gNB functions" case: the satellite or HAPS has onboard processing capabilities (e.g. routing or switching) typically applies for LEO constellations with ISL. It covers base station functions hosted on-board. It enables, for example, to shorten the system response times and to better support the local traffic, at the UE side. The base station functions correspond to 3GPP "gNB" functions i.e. 5G access network functions.

5.2 Recall of 5G reference system architecture overview

The system architecture based on 5G non-roaming reference system architecture as defined in the ETSI TS 123 501 [i.7], clause 4.2.3, is considered in Figure 3.





Where:

- AUSF: Authentication Server Function.
- AMF: Core Access and Mobility Management Function.
- DN: Data Network, e.g. operator services, Internet access or 3rd party services.
- NSSF: Network Slice Selection Function.
- PCF: Policy Control Function.
- SMF: Session Management Function.
- UDM: Unified Data Management.
- UPF: User Plane Function.
- AF: Application Function.
- UE: User Equipment.
- RAN: Radio Access Network.

The 4G architecture for the Indirect access and the mapping with Radio Bearers, according to 3GPP relaying mechanisms of ETSI TS 123 401 [i.8] and of ETSI TS 136 300 [i.15] and 3GPP TR 36.806 [i.9] are recalled in Figure 4.



Figure 4: Indirect 3GPP 4G access architecture and mapping to Radio Bearers (recall)

UE are served by an access point 3GPP defined. This access point is served by a 3GPP defined Radio Access. UE management applies to the UE, obviously. In this way, UE has an indirect access to the 5G CN.

The Relay Node (RN) endorses a multiplexer node role and relays UE signalling flows (in the CP) and UE data flows (in the UP). The RN acts as user plane transport nodes from the UE signalling and data traffic point of view.

The Relay Node mobility management is not specified in 3GPP R15 when writing the present document.

5.3 Generic NTN Reference System Architecture

For the purpose of the integration of Non-Terrestrial networks in 5G systems, some existing interfaces may need to be adapted and new interfaces may need to be defined. In that perspective it is worth considering reference architectures for NTN.

Given the possible crossborder coverage of NTN systems, the resources of a NTN system could be shared between several 5G networks.

6 Integration scenarios of Non-Terrestrial Network in 5G system (Bent pipe)

6.1 Integration options and related architectures

Different integration scenarios of a NTN in the 5G system architecture can be considered depending on whether the NTN access network is 3GPP defined or not and whether it is trusted or not, according to operator's agreement. Only scenarios with bent-pipe payload on board of the satellite (GEO or Non-GEO) or the HAPS are considered in the present document:

- Scenario A1 Direct 3GPP access: The 5G UE are NTN enabled NT UE, that access the 5G Core Network via a 3GPP defined NTN NR-Radio Access. The 5G UE are directly linked to the satellite (respectively the HAPS). UE management applies to the NTN enabled NT UE.
- Scenario A2 Indirect 3GPP access: The 5G UE are served by an access point (see note 1). This access point is implemented by a gNB combined with a NTN enabled NT UE and is served by a 3GPP defined NTN NR-Radio Access. UE management applies to the NTN enabled NT UE. The NTN enabled NT UE endorses a multiplexer node role.
- Scenario A3 Indirect mixed 3GPP NTN access: The 5G UE are served by an access point (see note 1). This access point is implemented by a gNB combined with a NTN enabled NT UE and is served by a trusted mixed 3GPP NTN access network (see "Non-3GPP access network" definition). UE management applies to the NTN enabled NT UE. The NTN enabled NT UE endorses a multiplexer node role. Another wording for scenario A3 could be "Indirect 3GPP NTN access with non-3GPP L2, non-3GPP L1". The mixed 3GPP NTN access network is considered as trusted according to agreement between the operator of the UEs, the gNB and the 5G CN and the operator of the NTN (see note 2).
- Scenario A4 Indirect access via an NTN transport network: The 5G UE are served by an access point (see note 1). This access point is the NTN terminal and is linked to the 5G CN via a NTN transport network. The UE management does not apply to the NTN terminal. The NTN terminal may endorse a multiplexer node role. This NTN transport network is considered as **trusted** according to agreement between the operator of the UEs, the gNB and the 5G CN and the operator of the NTN (see note 2).
- Scenario A5 Indirect untrusted access: The 5G UE are served by an access point (see note 1). This access point is the NTN terminal and is served by an **untrusted** (see note 3) non-3GPP or a mixed 3GPP NTN access network. UE management does not apply to the NTN terminal. The NTN terminal endorses a multiplexer node role.
- NOTE 1: Only the 3GPP defined access type is described for these scenarios. But other scenarios with Non-3GPP defined access could be considered.
- NOTE 2: The concept of trusted network is reused and applied to the Non-3GPP NTN access/transport network and the mixed 3GPP NTN access network.

NOTE 3: ETSI TS 123 501 [i.7] only supports untrusted non-3GPP accesses, amongst possible non-3GPP accesses.

The architectures are described in the section "Principles" of the corresponding scenarios. They do not preclude implementing delocalised CN functions at the NTN terminal side (NTN enabled UE or VSAT).

A synthesis of the main characteristics of the scenarios is provided in Clause 7.

The scenarios of the present document refer to the scenarios of 3GPP TR 22.822 [i.22] according to table 1.

The present document - ETSI TR 103 611	3GPP TR 22.822 [i.22]
Scenario A1: The UE are standalone NTN enabled NT UE	 5.3 Internet of Things with a satellite network. 5.11 5G to Premises: There is a mapping provided: the NTN NT UE supports the terrestrial access and the 5G satellite access at the same time. Note that this dual mode of operation is out of the scope of the present document, and the NTN NT UE is the end user terminal.
Scenario A2	 5.8 Indirect connection through a 5G satellite access network (bent-pipe satellite case). 5.9 Fixed backhaul between NR and the 5G Core. 5.10 Moving platform Backhaul. Note that in scenario A2: A local gNB, linked to the NTN NT UE, serves the UE and not the NTN NT UE, that are served by a remote gNB, at gateway side. The UE indirectly access the satellite via the gNB combined to the NTN NT UE.
Scenario A3	Same mapping as for scenario A2. Unlike the scenario A2, the access type of the NTN NT UE is a mixed 3GPP NTN access, in scenario A3.
Scenario A4	No mapping.
Scenario A5	No mapping.

Table 1 Scenarios mapping to 3GPP TR 22.822 scenarios

Layout of the figures of the present document:

The NTN Gateway (respectively the VSAT/NTN Gateway in scenarios A4 and A5) is depicted by the following icon:



The satellite or the HAPS is depicted by the following icon:



6.2 Scenario A1 - Direct 3GPP access

6.2.1 Principles

This architecture targets an end-to-end system from the NTN NT UE perspective.

The related architecture is depicted in Figure 5.



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Figure 5: Scenario A1 - Option 1 - Direct 3GPP access with bent-pipe payload

Figure 5 entails:

- Data Network.
- 5G CN serving NTN enabled NT UEs (NTN NT UEs).
- Non-Terrestrial Network that transports encapsulated UP and CP of the UE and CP of the gNB. The NTN also encompasses a 5G RAN, named "NTN 5G RAN", encompassing one or several centralized NTN LT gNBs, each NTN LT gNB being linked to one or several NTN gateways and serving NTN enabled NT UEs. The number of gateways that are linked to NTN LT gNB(s) are not in the scope of the present document and needs further dimensioning analysis.
- Standalone NTN enabled NT UEs accessing 5G services.
- Integrated management systems (Orchestrator/NMS).

Different classes of NTN enabled NT UE may be defined, according to their telecommunication and multiplexing capabilities.

An alternative, named "scenario A1 option 2", which consists of splitting the New Radio (NR) between central and distributed units is described in Clause A.4.3. Both architectures options (Option 1 with centralized gNB and Option 2 based on gNB-DU/gNB-CU) are compared in Clause 6.2.4.

The scenario A1 can support the use case "5.3 Internet of Things with a satellite network" of 3GPP TR 22.822 [i.22].

In this scenario, the NTN enabled NT UE directly accesses the 5G Core Network via a 3GPP defined NTN NR-Radio Access.

In this case, the native 5G NR air interface is used with potential adaptations to take into account satellite/HAPS deployment specifics.

The NTN enabled NT UE is served by:

- a NTN 5G Radio Access Network (NTN 5G RAN);
- a 5G CN.

Within the NTN 5G RAN:

- A Feeder link is established over the air, between the satellite (in the space segment, depicted in blue) and the NTN gateway (in the ground segment, depicted with an antenna).
- For the bent-pipe case, the ground segment, at the NTN Gateway side, hosts gNB functions, named NTN LT gNB, that is remote to the NTN enabled NT UE and serves it.

• The NTN LT gNB and the Network functions serve the NTN enabled NT UE as a UE. The UP and CP transport of the NTN enabled are transparent for the UEs that are served by this NTN enabled NT UE.

6.2.2 Logical architecture

The logical architecture is depicted in the Figure 6. The messages at Ni reference points to be transported by the NTN are also depicted.



Figure 6: Scenario A1- Option 1 - Mapping of the 5G system reference points

The NTN encompasses:

• NTN 5G RAN. It is supported by the 5G Core Network. This RAN may include space/HAPS segment or ground segment.

The NTN endorses the roles of a 5G transport network for NTN enabled NT UEs, a 5G RAN with 3GPP access.

The figure above mainly depicts the control, user planes of the NTN NT UE.

The NTN supports interfaces to:

- 5G Orchestrator/NMS (Network Management Systems) of the 5G system including the NTN components.
- 5G Core Network, serving the NTN enabled NT UEs.

5G Interfaces are implemented with the following logic:

- NR (for NTN enabled NT UE) is used over the satellite or HAPS.
- N1 (for NTN enabled NT UE) is implemented between the NTN enabled NT UE and the AMF.
- N2 (for NTN enabled NT UE) is implemented between the NTN LT gNB and the AMF.
- N3 (for NTN enabled NT UE) is implemented between the NTN LT gNB and the UPF.
- Mngw: new reference point.

NTN NT UE radio bearers are created/removed between the NTN NT UE and the NTN LT gNB by appropriate signalling over the NR interface, according to ETSI TS 138 300 [i.16].

Considerations on protocol layers implementation are provided in clauses A.4.1 and A.7.

The principle of NTN NT UE Data Radio Bearers establishment is described in Clause A.4.1.1.

6.2.3 Considerations on 3GPP procedures implementation in NTN

6.2.3.1 Relaying

In this clause, relaying function/capacity mean transfer function/capacity, for both forward and return directions.

Depending on its terminal class, the NTN enabled NT UE may have **relaying capacity** for the benefits of UEs. If it is the case, refer to Clauses 6.3 and 6.4.

It is not applicable to Clause 6.2.

6.2.3.2 Transport of CP, UP of NTN NT UE

Data/Signalling Radio Bearers are used as is for the NTN enabled NT UE. They are defined between NTN enabled NT UE and NTN LT gNB.

3GPP tunnelling mechanisms on the terrestrial links are used as-is for the NTN enabled NT UE.

GTP-U tunnels are defined between NTN LT gNB and the 5G CN in the ground segment.

The contents of NTN enabled NT UE Signalling/Data Bearers are transported:

- over the air, by the space segment; then
- by the terrestrial segment, into GTP-U tunnels, towards the 5G CN, optimizing the time spent for routing.

The UP and the CP of the NTN enabled NT UEs are transported by the NTN, with an appropriate CoS (to be adapted) of NTN enabled NT UE Radio Bearer, that is characterized by parameters such as GBR or non GBR, with/without latency objective.

The CP between the 5G CN and the NTN enabled LT gNB serving the NTN enabled NT UEs, is transported by the ground segment.

Radio Bearers and tunnels between the NTN enabled LT gNB and the NTN enabled NT UE are further detailed in Clause A.4.1.

See Clause A.8 for further information related to the transport of CP, UP of UE and the transport of CP of the gNB, over dedicated protocol layers per scenario.

6.2.3.3 Multiplexing node

Depending on its terminal class, the NTN enabled NT UE may embed a multiplexing node function. In other words, the NTN enabled NT UE may have aggregating capacities: it could aggregate incoming traffic and signalling. If it is the case, refer to Clauses 6.3 and 6.4. It is not applicable to the Clause 6.2.

6.2.3.4 Access and Mobility managements

In the case of Non-GEO satellite, the NTN enabled NT UE may move from a beam to another beam (Inter-satellite or intra satellite), even though it could be earth-fixed. In the case of GEO satellite, the NTN enabled NT UE may move from a beam to another.

The UE management (such as connection, PDU session, mobility, radio resource) applies to the NTN enabled NT UE. Possible benefit is to re-use 3GPP procedures ETSI TS 123 502 [i.10], saving effort during the system specification, implementation and validation phases.

6.2.4 Performance considerations

Some performance considerations between the different architecture options of the scenario A1 are discussed below. When the NTN NT UE is connected to a local gNB and used as a component of the relaying mechanisms, for supporting Indirect UE, these considerations also apply to scenario A2.

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They also apply to scenario A3 except the considerations related to 3GPP F1 interface and 3GPP defined NTN NR-Radio Access (because these functions are not implemented in the mixed 3GPP NTN access network).

The NTN enabled LT gNB acts as an access controller serving the NTN enabled NT UE. It may be either centralized (option 1) or distributed (option 2).

At the local site, the local gNB (serving the UE) and the NTN enabled UE may be integrated into a single device/equipment, named NTN enabled Relay UE.

For the distributed NTN enabled gNB architecture, both interfacing following entities are involved:

- The NTN enabled gNB central unit (NTN gNB-CU), for handling the initial access, the main radio resource allocation scheme, the handover and the data transfer. The central unit controls the access of the distributed unit.
- The NTN enabled gNB distributed unit (NTN gNB-DU), acting as a moving or a fixed RRH:
 - in the UP, as the data, signalling flows are forwarded from/relayed to this unit;
 - in the CP, because this unit implements some functions that are delegated by the NTN gNB central unit, such as radio resource allocation refinement, admission control for congestion avoidance.

Latency range estimations are described in Clause A.10, per deployment scenario [i.6] and per scenario A1 architecture option.

Trends analysis based on latency estimations.

For all deployment scenarios, the following trends have been identified.

In the CP:

- For signalling exchanges such as Initial access, handover, radio resource allocation, both NTN gNB central and distributed units are involved. The signalling exchanges cannot be confined to the distributed unit.
- For signalling exchanges related to admission control/congestion prevention, radio resource re-allocation within a maximum provisioned envelop, the NTN gNB-DU (Distributed Unit) is involved while the NTN gNB-CU (Central Unit) may not be involved, as it delegates to the gNB-DU. In these cases, the scenario A1-Option 2 provides shorter response time for the access control, unless the NTN gNB DU moves or renegotiates the allocated radio resource beyond the provisioned envelop with the NTN gNB central unit.
- Most of the time, the distributed unit interworks with the central unit, that increases the latency, compared to a centralized NTN gNB equipment, localized at NTN gateway side.

In the UP, the data flows may be transported:

- Towards the NTN gNB central unit and then straight forward to the 5G CN. In this case, the option 1 provides shorter latency.
- From the source NTN gNB to the target NTN gNB during a handover, over an X2n interface, when PDCP is duplicating PDUs, In this case, the X2n interface always operates between NTN gNB central units, and not distributed ones, according to ETSI TS 138 300 [i.16]. In this case, option 1 provides shorter latency, too.

For some traffic exchanges, such as local Push-To-Talk, the data plane flows may be confined to a given NTN gNB-DU (within the local radio loop), to shorten the paths and thus, reducing the perceived latency. But the data plane flows are always forwarded towards the NTN gNB-CU, according to ETSI TS 138 300 [i.16]. One enhancement would consist to establish logical connections for data plane exchanges between NTN NT UEs served by the same NTN gNB-DU and in that way, to further shortcut the path.

The one-way latency between the NTN NT UE and the 5G CN is smaller with the scenario A1-Option 1, for both CP and UP. The architecture option 1, as there is one hop less, better supports latency sensitive services such as voice or critical data services.

Conclusions for the scenario A1 architecture options:

- The option 1 provides shorter latency than option 2 for most of the data, signalling exchanges. Option 2 may be as efficient as option 1 when the NTN gNB-CU does not move (no handover occurrence) and does not negotiate allocated radio resource envelope on the service link, whatever the reason (bandwidth request beyond the initial envelope, preparation of handover).
- These latency constraints impact the timeouts related to system procedures ETSI TS 123 502 [i.10] and protocols exchanges, at different layers.

Other performance and dimensioning considerations are described in Clause A.11, per scenario A1 architecture option, regarding:

- The sharing of Bandwidth allocated to the NTN NT UE and the sharing of processing capacities.
- The dimensioning of the network.
- Complexity trends.

6.2.5 Potential areas of impact on 3GPP system architecture

Definition of a reference point "Mngw" between the NTN Gateway and the NTN enabled line termination gNB (NTN LT gNB). This reference point conveys:

- Downlink flows related to the NTN NT UE (both in user and control planes), received by the NTN LT gNB are transported to the NTN Gateway, over a wired link, encapsulated into NTN NT UE radio bearers (data and signalling bearers per NTN NT UE).
- Uplink flows related to the NTN NT UE (both in user and control planes), received by the NTN Gateway are transported to the NTN LT gNB, over a wired link, encapsulated into NTN NT UE radio bearers (data and signalling bearers per NTN NT UE).
- Each NTN NT UE radio bearer is associated with a relevant NTN NT UE CoS, for both directions.

While at the interface between the NTN LT gNB and the 5G CN:

- Downlink flows related to the NTN NT UE (both in user and control planes), received by the NTN LT gNB from the 5G CN. They are encapsulated into tunnels and transported over a terrestrial link.
- Uplink flows related to the NTN NT UE (both in user and control planes), received by the 5G CN from the NTN LT gNB, are encapsulated into tunnels and transported over a terrestrial link.
- The CoS of each tunnel is adapted to NTN NT UE CoS flows, in both directions.

Mobility management and Paging of NTN enabled NT UE (NTN NT UE) to manage NTN cell mobility & pattern.

Roaming of the moving NTN NT UE from one PLMN to another.

Define QoS provided to NTN NT UE services, especially in terms of latency and throughput, based on 5G QoS ETSI TS 123 501 [i.7].

The following is just a question of network engineering, without any impact on 3GPP: Define the NTN NT UE QoS flows mapping to NTN NT UE Radio Bearers, as UE management applies to NTN NT UE.

In addition, timers associated with messages at Ni reference points (i = 1, 2, 3) may be extended for data, signalling exchanges between the NTN NT UE and the NTN gNB, 5G CN, to face longer propagation delay.

To seamlessly integrate the NTN 5G RAN in the architecture:

- The NTN 5G RAN supports network slicing.
- These network slices are managed by the Orchestrator or the NMS component of the NTN that interfaces the Orchestrator.

6.3 Scenario A2 - Indirect 3GPP access

6.3.1 Principles

This architecture targets an end-to-end system from the UE perspective. It is considered that this scenario A2 includes the scenario A1 architecture. But in the scenario A2, the NTN NT UE is a UE acting as relay, between the local RAN and the NTN 5G RAN.



The related architecture is summarized in the Figure 7.

Figure 7: Scenario A2 - Option 1 - Indirect 3GPP Access with bent-pipe payload

Figure 7 entails:

- Data Network.
- 5G CN serving UEs and interworking with RANs (gNBs).
- 5G CN, serving the NTN NT UE and interworking with NTN 5G RANs.
- Non-Terrestrial Network that transports UP and CP of the UE passing through the gNB and CP of the gNB. The NTN also encompasses a 5G RAN, named "NTN 5G RAN", encompassing one or several centralized NTN LT gNBs, each NTN LT gNB being linked to one or several NTN gateways and serving the NTN enabled NT UEs.
- NTN enabled network termination UEs (NTN NT UEs).
- RAN serving UEs. In the scenario A2, the RAN is 3GPP defined.
- UEs accessing 5G services.
- Integrated management systems (Orchestrator/NMS).

An alternative "scenario A2 option 2", assumes a distributed architecture for the NTN enabled gNB with respectively CU (Central Unit) and DU (Distributed Unit) functions. It is described in Clause A.4.4.

The scenario A2 can support, amongst others, the use case "5.8 Indirect connection through a 5G satellite access network" of 3GPP TR 22.822 [i.22] (bent-pipe satellite case).

The 5G CN may be operated by either the MNO or the NTN operator. depending on business model that is outside the scope of the present document.

5G UE accesses the 5G Core Network via an access point (the NTN NT UE) which is served by an NTN implementing a 3GPP defined NR-Radio access (see note 1). The NTN NT UE provides a 5G CN access to the RAN and its 5G UEs.

In this scenario, the NTN NT UE is enhanced with capability to interwork with gNB(s). The NTN NT UE is still a NTN terminal.

In terms of implementation, the NTN NT UE is either standalone equipment connected to the RAN (gNB) serving the 5G UE or integrated with the gNB within the same equipment, named "NTN enabled Relay UE" (NTN relay UE).

NOTE: In this case, the native 5G NR radio interface is used between the NTN NT UE and the satellite, with potential adaptations to take into account satellite/HAPS deployment specifics.

The NTN of scenario A2 implements a 3GPP NR Radio Access and thus, all 5G protocol layers, with consideration of NTN constraints. The main characteristics of the scenario A2 are the following:

- the UE access is called "3GPP defined NTN NR-Radio Access";
- the NTN, as a 3GPP NR RAN, is trusted; and
- the UE management applies to the NTN terminal.

6.3.2 Logical architecture

The logical architecture with a remote gNB interworking with the 5G CN, is depicted in Figure 8.

The messages at Ni reference points to be transported by the NTN are also depicted.



Figure 8: Scenario A2 - Option 1 - Mapping of 5G system reference points onto the NTN

The NTN encompasses:

- NTN enabled network termination UEs (NTN NT UEs).
- NTN 5G RAN. It is supported by the 5G Core Network. This RAN includes both the space/HAPS segment and the ground segment.

The NTN endorses the roles of:

• a 5G transport network for UEs;

• a 5G RAN with 3GPP access.

Figure 8 mainly depicts the control and user planes of the UE.

In this approach, a single 5G CN serves both the UE and the NTN NT UE. The 5G CN also serves both the local gNBs and the NTN LT gNB.

In the scenario A2, the interface between NTN NT UE and the NTN LT gNB is NR, to re-use "UE management", applied to NTN NT UE. It is a major assumption for the scenario A2.

The control, user planes of the NTN NT UE are the same as for scenario A1 and not depicted here. The 5G Core Networks may be operated by either the MNO or the NTN operator, depending on business model that is outside the scope of the present document.

NTN NT UE radio bearers are created/removed as done for scenario A1.

The NTN supports interfaces to:

- 5G Orchestrator/NMS (Network Management Systems) of the 5G system including the NTN components.
- A 3GPP access network serving the UEs.
- 5G Core Network, serving the UEs and interworking with RANs (local gNBs).

5G Interfaces (reference points) are implemented with the following logic:

- NR (for UE service) is implemented in the local RAN (gNB), between the UE and the RAN (gNB).
- NR (for NTN NT UE service) is implemented over the satellite or HAPS links, between the NTN NT UE and the NTN LT gNB.
- N1 (for UE service) and N1 for NTN NT UE are implemented between the considered UE and the AMF.
- N2 (for RAN & UE service) is implemented between the gNB and the AMF.
- N2 (for NTN NT UE service) is implemented between the NTN LT gNB and the AMF.
- N3 (for NTN NT UE service) is implemented between the NTN LT gNB and the UPF.
- N3 (for RAN & UE service) is implemented between the gNB and the UPF.
- New Mnx reference point is implemented between the gNB and the NTN NT UE.
- New Mngw reference point is implemented between the NTN GW and the NTN LT gNB(s).

Considerations on protocol layers implementation are provided in Clauses A.4.2 and A.7.

For further details on UE Radio Bearers transport and their mapping to NTN UE Radio Bearers (over the air) and tunnels (in the ground segment), see Clause A.4.2.

Further considerations on NTN implementation are provided in Clause A.6.

6.3.3 Considerations on 3GPP procedures implementation in NTN

6.3.3.1 Relaying

In this clause, Relaying function/capacity mean transfer function/capacity, for both forward and return directions.

For the UE Indirect access, the relaying functions of UE signalling and UE data, starts in the local gNB. They are forwarded to the NTN NT UE.

UE signalling and UE data are then sent by the NTN NT UE, towards the 5G core network serving the NTN NT UE and the gNB, across the satellite service link, the satellite and the feeder link and is achieved upon received by the 5G Core Network.

The NTN NT UE has **relaying capacity** for the UEs and the gNB that it serves. The NTN NT UE relays the UP and the CP of the UEs, passing through the gNB, and the CP of the gNB.

The NTN NT UE Radio Bearers between NTN NT UE and NTN LT gNB are established/released by the NR Data Link (RLC for the CP Signalling Radio Bearer and PDCP for the UP Data Radio Bearers).

Mechanisms inherited from 3GPP 4G Relaying functions ETSI TS 123 401 [i.8] and 3GPP TR 36.806 [i.9] may be reused and adapted for 5G. See Clause 5.2 for an overview of the Indirect 3GPP access architecture based on 3GPP relaying.

As an alternative to this logical architecture and according to [i.8] and [i.9], a Relay Node (RN), at UEs side, could operate the UEs instead of the gNB, interworking with a remote DeNB (Donor eNodeB), at CN side. But these mechanisms need to be consolidated in 5G as:

- The Relaying framework [i.8] is based on 4G Network Entities and not so 5G NR oriented. Further changes are required to fully integrate 5G NR ETSI TS 123 501 [i.7] into a relaying framework.
- The mobility management of the RN (see note 1) is not currently specified in R15.
- The equivalent of the DeNB (Donor eNodeB) is not currently specified for the 5G CN.
- Note that a node type, performing relaying mechanisms and inherited from Relay Node (respectively from Donor eNB), named "IAB Node" (respectively "IAB Donor") is described in 3GPP TR 38.874 [i.21] Release 15. This document is under construction.

It is proposed to define a NTN enabled relay UE (see Clause 6.3.5).

The NTN enabled relay UE (see the definition of terms), when used, enables a high integration of both gNB and NTN enabled network termination UE (NTN NT UE) functions.

NOTE: See " UE mobility management" as defined in Clause 3.1.

6.3.3.2 Transport of CP, UP of UE and CP of the local gNB

Data and Signalling Radio Bearers per NTN NT UE are established and released by the Data Link layers, between the NTN NT UE and the NTN LT gNB, according to ETSI TS 138 300 [i.16]. They are established for the use of the NTN NT UE, prior to the UE Data Radio Bearers and UE Signalling Bearers establishment. See Clause A.4.1.1 for an overview of the NTN NT UE Data Radio Bearers.

QoS rules, UE QoS Flows encapsulation into NTN NT UE QoS flows and mapping NTN NT UE QoS flows to NTN NT UE Radio Bearers (signalling and data), need to be specified. It may have potential impact on 3GPP (see Clause 8).

3GPP tunnelling mechanisms over the terrestrial links are used as-is for UEs. UE Signalling/Data Bearers can be transported:

- into NTN Data Radio Bearers, over the air; and
- into GTP tunnels, over terrestrial links, from the NTN LT gNB to the 5G Core Network. The use of tunnels reduces the time for routing.

See protocol stacks instantiation in Clause A.4.2.1 for further details.

The UP and the CP of the UEs are transported in the UP of the NTN, with an appropriate CoS of NTN NT UE bearer that is characterized by parameters such as GBR or non GBR, with/without latency objective.

This solution better fits high density of UEs and huge traffic coming from/to UEs to serve, rather than the other one which consists of transporting CP of the UEs over the CP of the NTN NT UE.

Moreover, this solution, inherited from relaying mechanisms ETSI TS 123 401 [i.8] and 3GPP TR 36.806 [i.9] is then less disruptive in regards to 3GPP specifications.

The CP between the 5G CN and the gNB serving the UEs, is transported by the UP of the NTN: The messages/the PDUs of N2, N3 reference points are transported by the UP of the NTN 5G RAN.

For further considerations on Radio Bearers between the NTN NT UE and the NTN LT gNB and tunnels between the NTN LT gNB and the Core Network, see the Clause A.4.2.

6.3.3.3 Multiplexing node

In scenario A2, as multiplexer node, the NTN NT UE has aggregating capacities: it aggregates UE traffic and UE signalling coming from the gNB(s) linked to it, as multiple UEs may be served by a given gNB. Multiple gNBs can be connected to one NTN NT UE.

6.3.3.4 Access and Mobility managements

The UEs is moving from a cell to another, relatively to the serving NTN NT UE and gNB.

In the case of Non-GEO satellite, the NTN NT UE may move from a beam to another. The area where the NTN enabled NT UE is located/tracked by the gNB and the 5G CN.

The UE management (such as Connection, PDU session, mobility, radio resource) applies to the NTN NT UE. Possible benefit is to re-use 3GPP procedures ETSI TS 123 502 [i.10], saving effort during the system specification, implementation & validation phases.

6.3.4 Performance considerations

Performance considerations as described in Clause 6.2.4 for NTN 5G RAN apply to this clause too.

Furthermore, there is an opportunity to coordinate the Control Planes of the UEs, the gNBs, the NTN NT UE and the NTN LT gNB, especially in terms of Radio Resource Allocation, capacity sizing and mobility management.

To do so:

- The CP of the gNB is visible into the CP of the NTN NT UE and the CP of the NTN LT gNB.
- The gNB, the NTN NT UE and the NTN LT gNB may share spectrum, for a better use of the spectrum.

The expected benefits of a coordination at CP level are:

- An automatic, seamless frequency sharing between the ground segment and the space segment.
- Real time allocation of an amount of bandwidth on the satellite link (with a GBR scheme) that fits the required bandwidth for the set of served UEs. As the bandwidth is defined by the allocated radio resource, it may lead to reducing the amount of required resource and reduce the unused resource, in a GBR, resource sharing scheme.

The coordination between the gNB(s) and the NTN NT UE may be also operated at the management plane level, under the control of an orchestrator interfacing the NMS components of the gNB(s) and the NTN LT gNB.

Other performances considerations are discussed in Clause A.8, provided by the relaying and multiplexing functions in the NTN NT UE.

Note that a local Data Network (DN) may be optionally implemented at NTN NT UE side, for local traffic (data plane flows) exchanges.

6.3.5 Potential areas of impact on 3GPP system architecture

All the impacts below that apply to NTN NT UE also apply to the NTN Relay UE when present, as the NTN Relay UE integrates the NTN NT UE.

Definition of:

- "Relay UE" which endorses both roles of multiplexer node for the return direction & de-multiplexer node for the forward direction. This Relay UE implements local gNB function and network termination UE functions. Note that it also corresponds to the IAB-node (Integrated Access Backhaul node) being defined in 3GPP TR 38.874 [i.21].
- "Line termination gNB" (LT gNB) which serves a Relay UE or a network termination UE (NT UE). It corresponds to IAB-donor RAN node being defined in 3GPP TR 38.874 [i.21].

Definitions related to NTN:

- "NTN enabled relay UE" is a "Relay UE" able to be served by a NTN access. This NTN enabled relay UE implements a local gNB function and NTN enabled network termination UE functions.
- "NTN enabled network termination UE" (NTN NT UE) is a network termination UE that terminates a NTN Service Link. It may be integrated in a NTN enabled relay UE or be a standalone equipment. The NTN enabled network termination UE interfaces a dedicated gNB, namely the NTN enabled line termination gNB (NTN LT gNB) and a Core Network, via satellite or HAPS link(s).
- "NTN enabled line termination gNB" (NTN LT gNB) is a gNB able to serve NTN NT UE via NTN infrastructure.

Definition of a reference point "Mnx" between the local gNB and the NTN enabled network termination UE (NTN NT UE). This reference point conveys:

- Uplink flows related to UE and gNB (both in user and control planes), received by the NTN NT UE from the local gNB, are classified into NTN NT UE CoS and mapped to the relevant NTN NT UE radio bearers (data and signalling bearers per NTN NT UE) by the NTN NT UE, in order to transport them to the NTN LT gNB.
- Downlink flows related to UE and gNB (both in user and control planes) received by the NTN NT UE, are extracted from NTN NT UE radio bearers (data and signalling bearers per NTN NT UE) each associated with a NTN CoS, in order to transport them to the local gNB.
- Each NTN NT UE radio bearer is associated with a relevant NTN NT UE CoS, for both directions.

Definition of a reference point "Mngw" between the NTN Gateway and the NTN enabled line termination gNB (NTN LT gNB). This reference point conveys:

- Downlink flows related to UE and gNB (both in user and control planes) received by the NTN LT gNB from the 5G CN. They are encapsulated into NTN NT UE radio bearers (data and signalling bearers per NTN NT UE) and transported to the NTN Gateway, over a terrestrial link (wireless or wired link).
- Uplink flows related to UE and gNB (both in user and control planes), received by the NTN Gateway. They are transported to the NTN LT gNB, over a terrestrial link, encapsulated into NTN NT UE radio bearers (data and signalling bearers per NTN NT UE).
- Each NTN NT UE QoS flow is associated with the relevant NTN NT UE radio bearer CoS (type), for both directions.

Apart from its name and proposal positioning in the 3GPP System Architecture, the "Mngw" reference point is outside 3GPP, like the Y1, Y2, NWu reference points in the case of Non-3GPP Access Network, in ETSI TS 123 501 [i.7]. In other words, "Mngw" implementation is out of the scope of 3GPP.

While at the interface between the NTN LT gNB and the 5G CN:

- Downlink flows related to UE and gNB (both in user and control planes), received by the NTN LT gNB from the 5G CN. They are encapsulated into tunnels and transported over a terrestrial link to the NTN LT gNB.
- Uplink flows related to UE and gNB (both in user and control planes), received by the NTN LT gNB are encapsulated into tunnels and transported to the 5G CN, over a terrestrial link.
- The CoS of each tunnel is adapted to the NTN NT UE QoS flows, for both directions.

Mobility management and Paging of the moving UE and the moving NTN NT UE to take into account specifics of NTN cell mobility & pattern. Mobility management considerations are described in Clause 6.3.3.4.

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Roaming of the moving UE and the moving NTN NT UE from one PLMN to another one.

Logical synchronization between the 3GPP system procedures of each NTN NT UE and the UE connected to it:

- Initial access of each NTN NT UE and connected UE.
- Connection management of each NTN NT UE and connected UE.
- PDU session management of each NTN UE and connected UE.
- Mobility management of each NTN NT UE and connected UE:
 - Location/Tracking Area, Paging.
 - Handover.
- L2/L3 point of presence of each NTN NT UE and connected UE:
 - The point of presence is known by each entity along the chain (NTN RAN and 5G CN).
 - The point of presence of the NTN NT UE and UE may be linked to simplify 3GPP system procedures such as UE location, UE paging, UE Data and UE signalling transfer/routing tables to UE, NTN NT UE handover while the UE are connected to the NTN NT UE.

Define QoS provided to UE services, for UE that have an NTN indirect access, especially in terms of latency and throughput, based on 5G QoS [i.7].

Define encapsulation of UE QoS flows into NTN NT UE QoS flows, as the NTN NT UE endorses a multiplexer role, in terms of QoS rules and QoS flow mapping [i.7].

Define the NTN NT UE QoS flows mapping to NTN NT UE Radio Bearers, to transport UE QoS flows and NTN NT UE QoS flows with the appropriate QoS.

In addition, timers associated with messages at Ni reference points (i = 1, 2, 3) may be extended, to face longer propagation delay:

- For UE data, signalling exchanges with the 5G CN.
- For NTN NT UE data, signalling exchanges with the NTN gNB and the 5G CN.

To seamlessly integrate the NTN 5G RAN in the architecture:

- The NTN 5G RAN supports network slicing.
- These network slices are managed by the Orchestrator or the NMS component of the NTN that interfaces the Orchestrator.

The justification, whether to define a new reference point "Mngw" between the NTN GW and the NTN line termination gNBs (NTN LT gNBs) and implementation aspects of Mngw are discussed hereafter.

In the case, the NTN GW and the NTN line termination gNB (NTN LT gNB) are merged/implemented into the same equipment, this reference point does not exist: the interface is internal to the NTN Relay UE. By convention the term "NTN line termination gNBs" stands both for NTN GW and the gNB.

A way to implement Mngw consists of using the 3GPP F1 interface, as following:

- The NTN LT gNB implements a gNB-CU (Central Unit), serving the gNB-DU(s) and the NTN NT UEs.
- The NTN GW implements a gNB-DU, serving the NTN NT UEs.

- The NTN LT gNB and the NTN GW interworks via a standardized interface.
- The NTN NT UE Bearers can be set up at the initiative of both NTN GW (as gNB-DU) and NTN LT gNB (as gNB-CU). An admission control is processed at each side, to check if the Radio Resources are available.

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Considerations on end-to-end protocols layers implementation, including F1 interface are given in Clause A.4.3.

According to ETSI TS 138 470 [i.14], the "F1 UE context management function" supports the establishment and modification of the necessary overall UE context. This is applicable to NTN NT UE context:

- DRBs and SRBs of an NTN NT UE can be managed i.e DRB and SRB radio resources can be established, modified, and released:
 - the establishment and modification of DRB resources are triggered by the NTN LT gNB (as gNB-CU); and
 - accepted/rejected by the NTN GW (as gNB-DU) based on resource reservation information and QoS information to be provided to the NTN GW (gNB-DU).
- The mapping between QoS flows and radio bearers is performed by the NTN LT gNB (as gNB-CU) and the granularity of bearer related management over F1 is radio bearer level:
 - In particular, to support packet duplication for intra-gNB-DU Carrier Aggregation (CA) as described in ETSI TS 136 300 [i.15], one data radio bearer is configured with two GTP-U tunnels between NTN LT gNB (gNB-CU) and a NTN GW (gNB-DU).

The benefits of Mngw implementation using the 3GPP F1 interface is discussed as following:

- "Mngw" may be fully implemented by an F1 interface implementation.
- Otherwise, without F1 interface implementation, apart from its name and proposal positioning in the 3GPP System Architecture, the "Mngw" reference point is outside 3GPP, like the Y1, Y2, NWu reference points in the case of Non-3GPP Access Network, in ETSI TS 123 501 [i.7]. In other words, in this case, "Mngw" implementation is out of the scope of 3GPP.
- According to ETSI TS 138 470 [i.14], the F1 interface is open and a gNB-CU may interwork with several gNB-Ds. The vendor of the gNB-CU may be different from this of the gNB-CU.
- Mobility inter NTN GW, for a given NTN LT gNB is handled, according to the "Inter-gNB-DU Mobility for intra-NR" principle as specified in [i.23]. As an application the SRB and the DRB of the NTN NT UE are automatically reconfigured and the continuity of user services is supported, when the Feeder Link switches from a NTN GW to another one, for any reason such as:
 - Predictable reasons:
 - In a Non-GEO vehicles constellation context, the moving vehicle serving the Feeder Links is planned to change.
 - The vehicle of the NTN GW serving the Feeder Link are planned to change, due to low budget link forecast.
 - Unpredictable reason: the vehicle serving or the NTN GW serving the Feeder Link fails.

6.4 Scenario A3 - Indirect mixed 3GPP NTN access

6.4.1 Principles

This architecture targets an end-to-end system from the UE perspective. It implements an Indirect UE access to the 5G CN with NR Data Link layers mapped to non-3GPP L2, L1 layers. This access is named "**mixed 3GPP access**" as this non 3GPP access supports the interface with the 5G CN and 3GPP system procedures and uses **5G higher protocol layers** (see Clause 3.1) mapped over **non-3GPP Layer 2, Layer 1**. It is the reason why the achieved NTN is named "mixed".

In the scenario A3, the NTN NT UE is a UE acting as relay, between the local RAN and the mixed 3GPP NTN Access Network.

The related architecture is summarized in Figure 9.



Figure 9: Scenario A3 - Indirect mixed 3GPP NTN access with bent-pipe payload

Figure 9 entails:

- Data Network.
- 5G CN serving UEs and interworking with RANs (gNBs).
- 5G CN, serving the NTN NT UE and interworking with NTN 5G RANs.
- Non-Terrestrial Network that transports UP and CP of the UE passing through the gNB and CP of the gNB. The NTN also encompasses a 5G RAN, named "NTN 5G RAN", encompassing one or several centralized NTN LT gNBs (for option 1), each NTN LT gNB being linked to one or several NTN gateways and serving the NTN enabled NT UEs.
- NTN enabled network termination UEs (NTN NT UEs).
- RAN serving UEs. In the scenario A3, the RAN is 3GPP defined.
- UEs accessing 5G services.
- Integrated management systems (Orchestrator/NMS).

The scenario A3 can support, amongst others, the use case "5.8 Indirect connection through a 5G satellite access network" of 3GPP TR 22.822 [i.22] (bent-pipe satellite case), but with a mixed 3GPP NTN access network instead of a 3GPP defined NTN NR-Radio Access network.

The 5G CN may be operated by either the MNO or the NTN operator, depending on business model that is outside the scope of the present document.

In this scenario, 5G UE accesses the 5G Core Network via an access (3GPP or non-3GPP defined) which is served by a NTN access network which supports 5G higher protocol layers (see Clause 3.1), 3GPP system procedures [i.10] and all RAN-5CN interfaces but makes use of a non-3GPP physical layer.

Considerations on protocol layers implementation:

The following protocol layers may be implemented in the NTN, both in UP and CP:

- In CP: 5G higher protocol layers (see the definition for the CP), adaptation of NR Data Link Layers (see the definition) over non-3GPP layer 2 and physical layer and support of NAS-SM, NAS-MM layers.
- In UP: 5G higher protocol layers (see the definition for the UP), adaptation of NR Data Link layers over non-3GPP Layer 2 and physical layer.
These layer adaptations need further study. They may be in the ETSI scope but are not in the scope of 3GPP.

In the scenario A3, this Indirect 3GPP like access is considered as trusted, by definition.

The 5G CN interworks with a remote gNB via a trusted mixed 3GPP NTN access network.

The **mixed 3GPP NTN access** is an intermediate solution laying between 3GPP access and Non-3GPP access. It is trusted and like in Scenario A2, it avoids implementing N3IWF [i.7] and mandatory security protocols (see note). Moreover, most of the 5G RAN protocols of the 3GPP radio access network can be re-used. This simplifies the 5G protocols stacks and the 5G procedures implementation.

NOTE: In the case the access is considered as an untrusted 3GPP access, a N3IWF [i.7] interworking proxy will be required, including IPSec tunnel establishment between N3IWF and the gNB serving the 5G UEs: see scenario A5.

Implementation of 3GPP mixed access is outside the scope of current 3GPP standardization, and therefore, implementation dependent.

In the scenario A3, the NTN NT UE is still a NTN terminal but enhanced with capability to interwork with gNB(s). As an alternative, a NTN enabled relay UE (respectively NTN relay UE) may be deployed instead of the NTN NT UE and the gNB, as a NTN relay UE endorses both roles.

The NTN of scenario A3 is agnostic of the Non-3GPP Data Link layers (L2) and the Non-3GPP physical layer (L1) but implements 5G higher protocol layers.

The main characteristics of the scenario A3 are following:

- the UE access is called "mixed 3GPP NTN access";
- the NTN is trusted, according to network operator's agreement; and
- the UE management applies to the NTN terminal.

6.4.2 Logical architecture

The logical architecture for Scenario A3 is depicted in the Figure 10. It is close to the architecture of the scenario A2, with a remote gNB interworking with the 5G CN but via a trusted mixed 3GPP NTN access network.

The messages at Ni reference points to be transported by the NTN are also depicted.



Figure 10: Scenario A3 - Option 1 - Mapping of 5G system reference points onto the NTN

The NTN encompasses:

- NTN enabled network termination UEs (NTN NT UEs).
- A mixed 3GPP NTN access network. It is supported by the 5G Core Network. This access network includes both the space/HAPS segment and the ground segment.

The NTN endorses the roles of a 5G transport network for UEs, an access network with a mixed 3GPP NTN access.

Figure 10 mainly depicts the control and user planes of the UE.

In this approach, a single 5G CN serves both the UE and the NTN NT UE. The 5G CN also serves both the local gNB and the NTN LT gNB.

In the scenario A3, the interface between NTN NT UE and the NTN LT gNB is mixed, inherited from NR, in order to re-use "UE management", applied to NTN NT UE. It is a major assumption for the scenario A3.

The CP and UP of the NTN NT UE in the scenario A3 is not depicted here, is close to the CP and UP of the NTN NT UE as described in the scenario A2 (see Clause 6.2), but with a mixed 3GPP NTN access for scenario A3. The creation and release of the NTN NT UE "radio transport containers" is implementation dependent and out of 3GPP scope because 3GPP specifies Radio Bearers and not "radio transport containers".

The 5G Core Networks may be operated by either the MNO or the NTN operator. depending on business model that is outside the scope of the present document.

The NTN supports interfaces:

- 5G Orchestrator/NMS (Network Management Systems) of the 5G system including the NTN components.
- A 3GPP access network (RAN) serving the UEs.
- 5G Core Network, serving the UEs and interworking with RANs.

5G Interfaces (reference points) are implemented with the following logic:

• NR (for UE service) is implemented in the local RAN, between the UE and the RAN (gNB).

• NR over non-3GPP Data Link and non-3GPP physical layer (for NTN NT UE service, as explained in Clause 6.4.1) is implemented over the satellite or HAPS links, between the NTN NT UE and the NTN LT gNB.

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- N1 (for UE service) and N1 for NTN NT UE are implemented between the considered UE and the AMF.
- N2 (for RAN & UE service) is implemented between the gNB and the AMF.
- N2 (for NTN NT UE service) is implemented between the NTN LT gNB and the AMF.
- N3 (for NTN NT UE service) is implemented between the NTN LT gNB and the UPF.
- N3 (for RAN & UE service) is implemented between the gNB and the UPF.
- New Mnx reference point is implemented between the gNB and the NTN NT UE.
- New Mngw reference point is implemented between the NTN GW and the NTN LT gNB(s).

Further considerations on NTN implementation are provided in Clause A.6.

6.4.3 Considerations on 3GPP procedures implementation in NTN

6.4.3.1 Relaying

Same as for scenario A2.

6.4.3.2 Transport of CP, UP of UE and CP of the local gNB

For the Scenario A3, the NTN NT UE Radio Bearers may be implemented as NTN NT UE Radio Transport Containers, between NTN NT UE and NTN LT gNB. These Radio Transport Containers could be established/configured/maintained/released by an adapted version of the RRC layer, taking into account the specificities of the non-3GPP physical layer and the non-3GPP layer 2. The Radio Transport Containers implementation depends on these non-3GPP layers.

Recall: In 3GPP R15, the RRC layer establishes, configures, maintains and releases the UE Signalling Radio Bearers of the CP and the UE Data Radio Bearers of the UP.

QoS rules, UE QoS Flows encapsulation into NTN NT UE QoS flows and mapping NTN NT UE QoS flows to NTN NT UE Data Radio Transport Containers (signalling and data) need to be studied. Their potential impacts on 3GPP is discussed in Clause 8.

3GPP tunnelling mechanisms over the terrestrial links are used as is for UEs. UE Signalling/Data Bearers are transported:

- into NTN Data Radio Transport Containers (depending on the NTN radio transport container technology), over the air; and
- into GTP tunnels, on terrestrial links, from the NTN LT gNB, to the 5G Core Network. The use of tunnels reduces the time for routing.

As with the scenario A2, the UP and the CP of the UEs are transported in the UP of the NTN, with an appropriate CoS (to be defined) of NTN NT UE Radio Transport Container that may be characterized by parameters such as GBR or non GBR, with/without latency objective. This solution better fits high density of UEs and huge traffic coming from/to UEs to serve, rather than the other one which consists of transporting CP of the UEs over the CP of the NTN NT UE.

Moreover, this solution, inherited from relaying mechanisms [i.8] and [i.9] is then less disruptive in regards to 3GPP specifications.

The CP between the 5G CN and the NTN LT gNB serving the UEs, is transported by the UP of the NTN: The messages/the PDUs of N2, N3 reference points are transported by the UP of the mixed 3GPP NTN access network.

See Clause A.8 for further information related to the transport of CP, UP of UE and the transport of CP of the gNB, over dedicated protocols layers per scenario.

In the scenario A3, an adaptation of NTN NT UE Radio Bearers is needed as non-3GPP Data Link layer and non-3GPP Physical layer are implemented, instead of the native NR Data Link and NR Physical layers. The wording "Radio Transport Container" for NTN NT UE is used instead of "Radio Bearer". These radio transport containers could be established/released by the Non-3GPP Data Link layers at higher NR Data Link layers demands, as close as it is done for NR Radio Bearers, in order to mitigate the effort adaptation. This adaptation needs further study.

For further considerations on UE Radio Transport Containers, see Clauses 6.4.5 and 8.

6.4.3.3 Multiplexing node

Same as for scenario A2.

6.4.3.4 Access and Mobility managements

The UEs is moving from a cell to another, relatively to the serving NTN NT UE and gNB.

In the case of Non-GEO satellite, the NTN NT UE may move from a beam to another. The area where the NTN NT UE is located/tracked by the local gNB and the 5G CN.

The access of the NTN NT UE to the 5G CN via the NTN needs to be adapted from UE 3GPP access management, to the Non-3GPP layer 2 and physical layer.

As with the scenario A2:

The UE management such as connection, PDU session, mobility, radio resource) applies to the NTN NT UE. Possible benefit is to re-use 3GPP procedures [i.10], saving effort during the system specification, implementation & validation phases.

6.4.4 Performance considerations

There is an opportunity to coordinate the Control Planes of the gNBs and the NTN NT UE, especially in terms of mobility management.

To do so, the CP of the gNB is partially visible into the CP of the NTN NT UE and the CP of the NTN LT gNB, in terms of mobility management.

Moreover, the expected benefits of a coordination between the gNB(s) and the NTN NT UE under the control of an orchestrator and the NMS components, in the management plane, are:

- frequency sharing between the ground segment and the space segment;
- capacity sizing: allocation of an amount of bandwidth on the satellite link (with a GBR scheme) that provisions the required bandwidth for the set of served UEs.

Other performances considerations are discussed in Clause A.8, provided by the relaying and multiplexing functions in the NTN NT UE.

Note that a local Data Network (DN) may be optionally implemented at NTN NT UE side, for local traffic (data plane flows) exchanges.

6.4.5 Potential areas of impact on 3GPP system architecture

All the impacts below that apply to NTN NT UE also apply to the NTN Relay UE when present, as the NTN Relay UE integrates the NTN NT UE.

As with scenario A2, definition of:

• "Relay UE" which endorses both roles of multiplexer node for the return direction & de-multiplexer node for the forward direction. This Relay UE implements local gNB function and network termination UE functions. Note that it also corresponds to the IAB-node (Integrated Access Backhaul node) being defined in 3GPP TR 38.874 [i.21].

• "Line termination gNB" (LT gNB) which serves a Relay UE or a network termination UE (NT UE). It corresponds to IAB-donor RAN node being defined in 3GPP TR 38.874 [i.21].

And NTN related definitions:

- "NTN enabled relay UE" is a "Relay UE" able to be served by a NTN access. This NTN enabled relay UE implements a local gNB function and NTN enabled network termination UE functions.
- "NTN enabled network termination UE" (NTN NT UE) is a network termination UE that terminates a NTN Service Link. It may be integrated in a NTN enabled relay UE or be a standalone equipment. The NTN enabled network termination UE interfaces a dedicated gNB, namely the NTN enabled line termination gNB (NTN LT gNB) and a Core Network, via satellite or HAPS link(s).
- "NTN enabled line termination gNB" (NTN LT gNB) is a gNB able to serve NTN enabled NT UE via NTN infrastructure.

Definition of a reference point "Mnx" between the local gNB and the NTN NT UE. This reference point conveys:

- Uplink flows related to UE and gNB (both in the user and control planes) received by the NTN NT UE from the local gNB are classified into NTN NT UE CoS and mapped to the relevant NTN NT UE radio transport containers (data and signalling containers per NTN NT UE) by the NTN NT UE, in order to transport them to the NTN LT gNB.
- Downlink flows related to UE and gNB (both in the user and control planes) received by the NTN NT UE, are extracted from NTN NT UE radio transport containers (data and signalling containers per NTN NT UE) each associated with a NTN CoS, in order to transported them to the local gNB.
- Each NTN NT UE radio transport container is associated with a relevant NTN NT UE CoS, for both directions.

Definition of a reference point "Mngw" between the NTN Gateway and the NTN enabled line termination gNB (NTN LT gNB). This reference point conveys:

- Downlink flows related to UE and gNB (both in user and control planes) received by the NTN LT gNB from the 5G CN. They are encapsulated into NTN NT UE radio transport containers (data and signalling containers per NTN NT UE) and transported to the NTN Gateway, over a terrestrial link (wireless or wired link) signalling.
- Uplink flows related to UE and gNB (both in user and control planes), received by the NTN Gateway. They are transported to the NTN LT gNB, over a terrestrial link, encapsulated into NTN NT UE radio transport containers (data and signalling containers per NTN NT UE).
- Each NTN NT UE QoS flow is associated with the relevant NTN NT UE radio transport container CoS, for both directions.

Apart from its name and proposal positioning in the 3GPP System Architecture, the "Mngw" reference point is outside 3GPP, like the Y1, Y2, NWu reference points in the case of Non-3GPP Access Network, in ETSI TS 123 501 [i.7]. In other words, "Mngw" implementation is out of the scope of 3GPP.

While at the interface between the NTN LT gNB and the 5G CN:

- Downlink flows related to UE and gNB (both in the user and control planes), received by the NTN LT gNB from the 5G CN. They are encapsulated into tunnels and transported over a terrestrial link to the NTN LT gNB.
- Uplink flows related to UE and gNB (both in the user and control planes), received by the NTN LT gNB are encapsulated into tunnels and transported to the 5G CN, over a terrestrial link.
- The CoS of each tunnel is adapted to NTN NT UE QoS flows, for both directions.

Mobility management and Paging of the moving UE and the moving NTN NT UE to take into account specifics of NTN cell mobility & pattern. Mobility management considerations are described in Clause 6.4.3.4.

Roaming of the moving UE and the moving NTN NT UE from one PLMN to another one.

Logical synchronization between the 3GPP system procedures of each NTN NT UE and the UE connected to it:

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- Initial access of each NTN NT UE and connected UE.
- Connection management of each NTN NT UE and connected UE.
- PDU session management of each NTN UE and connected UE.
- Mobility management of each NTN NT UE and connected UE:
 - Location/Tracking Area, Paging.
 - Handover.
- L2/L3 point of presence of each NTN NT UE and connected UE:
 - The point of presence is known by each entity along the chain (NTN RAN and 5G CN).
 - The points of presence of the NTN NT UE and UE may be linked to simplify 3GPP system procedures such as UE location, UE paging, UE Data and UE signalling transfer/routing tables to UE, NTN NT UE handover while the UE are connected to the NTN NT UE.

Define QoS provided to UE services, for UE that have an NTN indirect access, especially in terms of latency and throughput, based on 5G QoS [i.7].

Define encapsulation of UE QoS flows into NTN NT UE QoS flows, as the NTN NT UE endorses a multiplexer role, in terms of QoS rules and QoS flow mapping [i.7].

Define the NTN NT UE QoS flows mapping to NTN NT UE Radio Transport Containers, to transport UE QoS flows and NTN NT UE QoS flows with the appropriate QoS.

In addition, timers associated with messages at Ni reference points (i = 1, 2, 3) may be extended to face longer propagation delay:

- for UE data, signalling exchanges with the 5G CN;
- for NTN NT UE data, signalling exchanges with the NTN gNB and the 5G CN.

The following reference points have been identified. They depend on the adaptation of the mixed 3GPP NTN access to the non-3GPP layer 2 and physical layer. Apart from their name and respective positioning in the 3GPP system architecture, they are outside the 3GPP scope. However, they could be studied outside 3GPP.

Extend the "trusted network" definition to mixed 3GPP network, according to network operator's agreement.

In order to seamlessly integrate the mixed 3GPP NTN access network in the architecture:

- The mixed 3GPP NTN access network supports network slicing.
- These network slices are managed by the Orchestrator or the NMS component of the NTN that interfaces the Orchestrator.

Recommendations for further implementation:

• Adapt NR Data Link over Non-3GPP data link and Non-3GPP physical layers, both in CP and UP. Note that this study it is out of 3GPP scope.

6.5 Scenario A4 - Indirect access via transport network

6.5.1 Principles

This architecture targets an end-to-end system from the UE perspective.

The related architecture is summarized in the Figure 11.



Figure 11: Scenario A4 - Indirect access via an NTN transport network with bent-pipe payload

The figure above entails:

- Data Network.
- 5G CN serving UEs and interworking with RANs (gNBs).
- Non-Terrestrial Network that transports encapsulated flows between the 5G core network and the RAN (gNB), including UP and CP of the UE passing through the gNB and CP of the gNB.
- NTN terminals (or VSATs) which are NTN terminations.
- RAN serving UEs. In the scenario A4, the RAN is 3GPP defined.
- UE accessing 5G services.
- Integrated management systems (Orchestrator/NMS).

The 5G CN may be operated by either the MNO or the NTN operator, depending on business model that is outside the scope of the present document.

In the 11, it is assumed that the 3GPP management system of the MNO (typically managing the UE, the gNB and the 5G CN) and the NTN management system of the NTN operator, are integrated into a single management entity, depicted as "Orchestrator/NMS" in the figure. An alternative is to consider that they are not integrated but coordinated through dedicated interfaces, when the operators cannot share/merge the management systems, as specified in ETSI TS 128 530 [i.24] and shortly described in Clause A.12.

In the scenario A4, the 5G UE accesses the 5G Core Network via a trusted non-3GPP access network, supported by a NTN IP transport network.

In this scenario, the NTN terminal is a "VSAT", and not a "NTN NT UE" since:

• The UE management does not apply to this type of NTN terminal and thus, it cannot take any benefit for itself of 3GPP procedures such as Initial Access, Connection Management, PDU session management, Mobility Management, Radio Resource Management, through NR nor Ni interfaces (such as N1, N2, N3), as specified in ETSI TS 123 501 [i.7] and listed in Clause A.2.

• The Radio Resource allocated to the NTN terminal on the satellite service link, are managed by the Orchestrator & the NMS, at management plane only. This requires interface to the NTN terminal in order to properly operate it. When the management systems are not integrated, the radio resource allocation is more complex: coordination and interfaces are needed between the two NMS (the 3GPP management system and the TN management system) in order to allow indirect operation of the NTN terminal by the 3GPP management system.

In this scenario, it is is assumed that the NTN transport network provides a trusted Non-3GPP access network.

The main characteristics of the scenario A4 are following:

- The NTN is trusted, according to network operator's agreement.
- The UE management does not apply to the NTN terminal.
- Regarding the transport of the UP flows and the CP flows (such as N1, N2, N3 messages): The principle is to encapsulate them into IP packets (or into IEEE 802.1 ad [i.27] and IEEE 802.1 ah [i.28] frames) and transport them across the NTN. The choice of such encapsulation technology depends on NTN vendor solution and agreement with NTN operator.

6.5.2 Logical architecture

The logical architecture with a remote gNB interworking with the 5G CN, is depicted in Figure 12.

The messages at Ni reference points to be transported by the NTN are also depicted.



Figure 12: Scenario A4 - Mapping of 5G system reference points onto the NTN

The NTN encompasses:

- NTN terminal (or VSAT) as NTN network termination.
- The NTN access network. It is linked to the 5G Core Network, in this scenario. The access network includes both the space/HAPS segment and the ground segment.

The NTN endorses the roles of an NTN transport network for UEs and RANs and an NTN access network.

The figure above mainly depicts the control, user planes of the UE. The 5G CN serving the UE and the local RAN (gNB) serving the UE, is depicted in blue colour.

The control, user planes of the NTN terminal (VSAT) is out of the scope of the present document. The creation and release of NTN terminal radio transport containers are implementation dependant and out of 3GPP scope because 3GPP specifies Radio Bearers and not "radio transport containers".

The NTN supports interfaces to:

- 5G Orchestrator/NMS (Network Management Systems) of the 5G system including the NTN components.
- 5G Core Network, serving the UEs and interworking with RANs.

The NTN terminal endorses the role of node multiplexer.

It provides an access to the 5G CN, for the local RAN (gNB) and an indirect access for the UEs that are served by the RAN (gNB), via the NTN transport network.

The NTN transports both UP and CP of UEs passing through the gNB and CP of the gNB. The NTN is considered as trusted, according to network operator's agreement, in the scenario A4.

In this scenario, the NTN and the 5G Core networks are coordinated via a 5G Orchestrator and the 5G NMS (Network Management Systems), at management level. The UP & CP of the NTN and those of the 5G system are coordinated & configured via the management plane. In other words, there is no direct coordination between UP & CP of both systems, but User Planes interworking, configured by management plane.

An Orchestrator manages the resource (routing, computing, cloud in each nodes) of the 5G system virtualized network infrastructure. The orchestrator either directly manages the resource of the NTN network infrastructure or interfaces with the NMS of the NTN transparent network.

In this case, the virtualization of the resource of the NTN is optional. The 5G system supports network slicing of the resources. The NTN network implements network slicing and/or network partitioning. These partitions, when provided, are managed as network slices by the Orchestrator. The NTN supports network slices interface management.

Any access technology for the NTN can be implemented, such as DVB-S2(X), for the forward link and DVB-RCS(2), for the return link and additionally, IP over satellite return link, see ETSI TS 102 354 [i.25].

Note that the considered access does not currently conform to any R15 5G access network type, neither 3GPP nor Non-3GPP access and is currently considered as untrusted in ETSI TS 123 501 [i.7].

Assuming that ETSI TS 123 501[i.7] could change in order to let the NTN operator and the MNO to achieve an agreement, this Non-3GPP access type could be considered as trusted. With this assumption, the 3GPP procedures (as specified in ETSI TS 123 502 [i.10] for R15) could be implemented over the NTN and messages at Ni interfaces (such as N1, N2, N3, as specified in ETSI TS 123 501 [i.7] and listed in Clause A.2), could be transported over the NTN, without the use of any security proxy.

5G Interfaces (reference points) are implemented with the following logic:

- NR (for UE service) is implemented in the local RAN, between the UE and the RAN (gNB).
- N1 (for UE service) is implemented between the considered UE and the AMF.
- N2 (for RAN & UE service) is implemented between the gNB and the AMF.
- N3 (for RAN and UE service) is implemented between the gNB and the UPF.
- New Ymx is defined between the gNB and the NTN terminal.
- New Ygw is defined between the NTN Gateway and the 5G CN.

The Ygw is typically an IP interface so as Ymx.

6.5.3 Considerations on 3GPP procedures implementation in NTN

6.5.3.1 Transfer capacity

The NTN, as an autonomous transport network, supports the transport of the 3GPP procedures but does not implement them.

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This clause describes the transfer function/capacity, for both forward and return directions.

For the UE Indirect access, the relaying functions of UE signalling and UE data, starts in the local gNB. They are forwarded to the NTN terminal.

UE signalling and UE data are then sent by the NTN terminal on the satellite service link, to the satellite(s) within the space segment, the feeder link and is achieved upon received by the 5G core network, serving the gNB and the UEs.

In the scenario A4, the NTN terminal has **relaying capacity** for the UEs and the gNB that it serves. The NTN terminal relays the UP and the CP of the UEs, passing through the gNB, and the CP of the gNB.

The transfer capacity across the NTN is based on data and signalling encapsulation over transport technologies such as IP, IEEE 802.1ad [i.27] and IEEE 802.1ah [i.28].

6.5.3.2 Transport of CP, UP of UE and CP of the local gNB

3GPP tunnelling mechanisms on the terrestrial links are used as is for UEs.

The contents of UE Signalling/Data Bearers are transported:

- into IP flows, that are previously mapped to;
- NTN Data Radio Transport Containers (depending on the NTN radio transport technology), over the air; and
- into GTP tunnels, on terrestrial links, from the NTN Terminal, to the 5G Core Network. The use of tunnels reduces the time for routing.

Like for the scenario A2, the UP and the CP of the UEs are transported in the UP of the NTN, with an appropriate CoS (to be defined) of Radio Transport Container, that may be characterized by parameters such as GBR or non GBR, with/without latency objective, if implemented by the NTN.

The CP between the 5G CN and the gNB serving the UEs, is transported by the UP of the NTN: The information/the messages over N2, N3 reference points are transported by the UP of the NTN.

See Clause A.8 for further information related to the transport of CP, UP of UE and the transport of CP of the gNB, over dedicated protocol layers per scenario.

6.5.3.3 Multiplexing node

Same as for scenario A2.

Furthermore:

- The NTN terminal endorses both roles of multiplexer node for the return direction & de-multiplexer node for the forward direction.
- The NTN Gateway (respectively the Feeder Link terminal) endorses both roles of multiplexer node & demultiplexer node roles, for the return & forward directions.

6.5.3.4 Access and Mobility managements

The UEs is moving from a cell to another, relatively to the serving NTN terminal and the gNB. The area where the UE is located is tracked by the local gNB and the 5G CN.

In this scenario, the UE management (3GPP procedures such as connection, PDU session, mobility, radio resource) does not apply to the NTN terminal.

These procedures can be implemented by other frameworks than the 3GPP.

In the case of Non-GEO satellite, the NTN terminal may move from a beam to another. There is not any standardized facility to take into account such a mobility event in the 5G system, as UE mobility management does not apply to NTN terminal in this scenario.

6.5.4 Performance considerations

The expected benefits of a coordination between the gNB(s) and the NTN terminal under the control of an orchestrator and the NMS components, in the management plane, are:

- Frequency sharing between the ground segment and the space segment.
- Capacity sizing: Allocation of an amount of bandwidth on the satellite link (with a GBR scheme) that provisions the required bandwidth for the set of served UEs.

Note that a local Data Network (DN) may be optionally implemented at NTN terminal side, for local traffic (data plane flows) exchanges.

6.5.5 Potential areas of impact on 3GPP system architecture

Define QoS provided to UE services, for UE that have an NTN indirect access, especially in terms of latency and throughput, based on 5G QoS [i.7].

Define encapsulation of UE QoS flows into NTN terminal QoS flows, as the NTN terminal endorses a multiplexer role, in terms of QoS rules and QoS flow mapping [i.7].

Define the NTN Terminal QoS flows mapping to NTN Terminal Radio Transport Containers, in order to transport UE QoS flows and NTN Terminal flows with the appropriate QoS.

Extend timers associated with messages at Ni reference points (i = 1, 2, 3) for UE data, signalling exchanges with the 5G CN, to face longer propagation delay.

The following reference points have been identified. They depend on the radio access technologies used by the NTN. Apart from their name and respective positioning in the 3GPP system architecture, they are outside the 3GPP scope. However, they could be studied outside 3GPP.

Definition of a reference point "Ymx" between the local gNB and the NTN terminal. This reference point conveys:

- Uplink flows related to UE and gNB (both in user and control planes), received by NTN terminal from the local gNB are classified into NTN terminal CoS and mapped to the relevant NTN terminal radio transport containers (data and signalling containers per NTN terminal) by the NTN terminal, in order to transport them to the 5G CN (through the NTN Gateway).
- Downlink flows related to UE and gNB (both in user and control planes), received by the NTN terminal are extracted from the NTN terminal radio transport containers (data and signalling containers per NTN terminal), each associated with a NTN CoS, in order to transport them to the local gNB.
- Each NTN terminal radio transport container is associated with a relevant NTN terminal CoS, for both directions.

Definition of a reference point "Ygw" between the NTN Gateway and the 5G CN. This reference point conveys:

- Downlink flows related to UE and gNB (both in the user and control planes), received by the NTN Gateway from the 5G CN. They are classified into NTN terminal CoS, transported over tunnels to the NTN Gateway over a terrestrial link.
- Uplink flows related to UE and gNB (both in the user and control planes), received by the NTN Gateway. They are encapsulated into NTN terminal radio transport containers (data and signalling containers per NTN terminal) then, extracted by the NTN Gateway, mapped to tunnels and transported to the 5G CN, over a terrestrial link.

• Each NTN terminal radio transport container is associated with a relevant NTN terminal CoS, for both directions.

Mobility management and Paging of the moving UE to take into account specifics of NTN cell mobility & pattern. Mobility management considerations are described in Clause 6.5.3.4.

Extend the "trusted network" definition to non-3GPP network, according to network operator's agreement.

In order to seamlessly integrate the NTN network in the architecture:

- This NTN implements network slicing and/or network partitioning.
- These partitions, when provided, are managed as network slices by the Orchestrator interfacing the NMS component of the NTN to do so.

6.6 Scenario A5 - Indirect untrusted access

6.6.1 Principles

This architecture targets an end-to-end system from the UE perspective.

The related architecture is summarized in the Figure 13.



Figure 13: Scenario A5 - Indirect untrusted access with bent-pipe payload

Figure 13 entails:

- Data Network.
- 5G CN serving UEs and interworking with RANs (gNBs) via a N3IWF proxy.
- Untrusted Non-Terrestrial Network that transports encapsulated flows between the 5G core network and the RAN (gNB), including UP and CP of the UE passing through the gNB and CP of the gNB.
- NTN terminals (or VSATs) which are NTN terminations.
- A security entity, between the RAN and the NTN, that terminates the IPsec tunnels established by the peer N3IWFg proxy (see term in Clause 3.1).
- RAN serving UEs, which can be 3GPP or non-3GPP defined. In the scenario A5, it is 3GPP defined.
- UE accessing 5G services.
- Integrated management systems (Orchestrator/NMS).

The 5G CN may be operated by either the MNO or the NTN operator, depending on business model that is outside the scope of the present document.

In the Figure 13, it is assumed that the 3GPP management system of the MNO (typically managing the UE, the gNB and the 5G CN) and the TN management system of the NTN operator, are integrated into a single management entity, depicted as "Orchestrator/NMS" in the figure. An alternative is to consider that they are not integrated but coordinated through dedicated interfaces, when the operators cannot share/merge the management systems, as specified in ETSI TS 128 530 [i.24] and shortly described in Clause A.12.

In this scenario, the 5G UE accesses the 5G Core Network via an access technology (3GPP or non-3GPP defined) which is served by an NTN non-3GPP or a mixed 3GPP NTN access network, that is an untrusted one by definition of the scenario A5 (see note 1).

NOTE 1: For the terms of trusted network and untrusted network, see Clause 3.1.

NOTE 2: Another scenario could consist to provide to the UE a non-3GPP access (such as IP over IEEE 802.11 [i.29]) to the NTN terminal. It would be still an Indirect Access type to the 5G CN, across the untrusted NTN. This possible scenario is not studied in the present document.

In the scenario A5, like in scenario A4, the NTN terminal is a "VSAT", and not a "NTN NT UE" since:

- The UE management does not apply to this type of NTN network termination and thus, it cannot take any benefit for itself of 3GPP procedures such as Initial Access, Connection Management, PDU session management, Mobility Management, Radio Resource Management, through NR nor Ni interfaces (such as N1, N2, N3), as specified in ETSI TS 123 501 [i.7] and listed in Clause A.2.
- The Radio Resources allocated to the NTN terminal are managed by the Orchestrator & the NMS, at management plane only. This requires interface to NTN terminal in order to properly operate it.

In this scenario, the 5G network is agnostic of the NTN transport technology and the access type of the NTN terminal may be a 3GPP access or Non-3GPP access.

The main characteristics of the scenario A5 are following:

- the NTN is untrusted from the mobile network operator perspective; and
- the UE management does not apply to the NTN terminal;
- regarding the transport of the UP flows and the CP flows (such as N1, N2, N3 messages): The principle is to encapsulate into IP SEC tunnels packets and transport them across the NTN.

6.6.2 Logical architecture

The logical architecture with a remote gNB is depicted in Figure 14.

The messages at Ni reference points to be transported by the NTN are also depicted.



Figure 14: Scenario A5 - Mapping of 5G system reference points onto the NTN

The NTN encompasses:

- NTN terminal (or VSAT) as NTN network termination.
- The NTN access network. It is served by the 5G Core Network, in this scenario. The access network includes both the space/HAPS segment and the ground segment.

The NTN endorses the roles of an untrusted transport network for UEs and an untrusted NTN access network.

Figure 14 mainly depicts the control, user planes of the UE. The 5G CN serving the UE and the local RAN (gNB) serving the UE, is depicted in blue colour.

The control and user planes of the NTN terminal (VSAT) is out of the scope of the present document. The creation and release of NTN terminal radio transport containers are implementation dependent and out of 3GPP scope because 3GPP specifies Radio Bearers and not "radio transport containers".

The NTN supports interfaces to:

- 5G Orchestrator/NMS (Network Management Systems) of the 5G system including the NTN components.
- 5G Core Network, serving the UEs and interworking with RANs.

In the Scenario A5, like in Scenario A4:

- The NTN terminal endorses the role of multiplexer node.
- The NTN terminal provides an access to the 5G CN, for the local RAN (gNB) and an indirect access for the UEs that are served by the RAN (gNB), via the NTN transport network.
- The NTN transports both UP and CP of UEs passing through the gNB and CP of the gNB. The NTN is considered as untrusted from the MNO perspective, in the scenario A5.
- An Orchestrator manages the resources (routing, computing, cloud in each nodes) of the 5G system virtualized network infrastructure. The orchestrator either directly manages the resource of the NTN network infrastructure or interfaces with the NMS of the NTN transparent network. In this case, the virtualization of the resource of the NTN transparent network is optional. The 5G system supports network slicing of the resources. The NTN transparent network slicing or network slicing. Anyway, these partitions, when provided, are managed as network slices by the Orchestrator.

One of the interests of such case is:

• Security procedures deployment against threats coming from the untrusted NTN or whenever the NTN operators and MNO cannot achieve an agreement.

The considered access requires the implementation of an extension of the N3IWF security proxy, in order to conform to transfer information/messages over an untrusted 5G Non-3GPP access network in a secured way, between the 5G CN and the RAN (gNB), instead of 5G CN and UEs only, according to ETSI TS 123 501 [i.7].

The N3IWF extended security proxy, defined as N3IWFg in the present document, interworks with the RAN (gNB) serving the UEs.

5G Interfaces (reference points) are implemented with the following logic:

- NR (for UE service) is implemented in the local RAN, between the UE and the RAN (gNB).
- N1 (for UE service) is implemented between the considered UE and the AMF. The N1 messages are transported into secured transport containers, as NWg traffic.
- N2 (for RAN & UE service) is implemented between the gNB and the AMF. The N2 messages are transported into secured transport containers, as NWg traffic.
- N3 (for RAN and UE service) is implemented between the gNB and the UPF. The N3 messages are transported into secured transport containers, as NWg traffic.
- New Yg1 is defined between the security gateway connected to the gNB and the NTN terminal.
- New Yg2 is defined between the NTN Gateway and the N3IWFg that extends the N3IWF security proxy, in the 5G CN (see Clause 6.6.5).

The Yg2 is typically an IP interface or is IEEE 802.1ad [i.27] and IEEE 802.1ah [i.28] interface based.

6.6.3 Considerations on 3GPP procedures implementation in NTN

6.6.3.1 Transfer capacity

Same as for scenario A4.

6.6.3.2 Transport of CP, UP of UE and CP of the local gNB

Support of IPsec tunnel(s) establishment between each gNB and the 5G CN: The N3IWFg terminates the IKEv2/IPsec protocols with the gNB over NWg reference point and transports in a secured way the information over N1, N2, N3 interfaces.

3GPP tunnelling mechanisms on the terrestrial links are used as is for UEs.

The contents of UE Signalling/Data Bearers are transported:

- into IP sec tunnel between the security entity and the extended security proxy N3IWF, named N3IWFg; and
- into NTN Data Radio Transport Containers (depending on the NTN radio transport technology), over the air; and
- into GTP tunnels, on terrestrial links, between the N3IWFg and the NF of the 5G Core Network. The use of tunnels reduces the time for routing.

Like for the scenario A2, the UP and the CP of the UEs are transported in the UP of the NTN, with an appropriate CoS (to be defined) of Radio Transport Container, that may be characterized by parameters such as GBR or non GBR, with/without latency objective, if implemented by the NTN. The DSCP is used in the IPsec outer header. Otherwise, no IP packet processing per CoS could be done.

The CP between the 5G CN and the gNB serving the UEs, is transported by the UP of the NTN: The information/the messages over N2, N3 reference points are transported by the UP of the NTN.

See Clause A.8 for further information related to the transport of CP, UP of UE and the transport of CP of the gNB, over dedicated protocols layers per scenario.

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6.6.3.3 Multiplexing node

The NTN terminal endorses both roles of multiplexer node for the return direction & de-multiplexer node for the forward direction. A security entity, named security gateway, between the NTN terminal and the gNB is implemented, in order to extract the information encapsulated in IPsec tunnel(s) by the peer N3IWF security proxy. The interface between the NTN terminal and the gNB is not direct but passes through this security entity.

The NTN Gateway (respectively the Feeder Link terminal) endorses both roles of multiplexer node & de-multiplexer node roles, for the return & forward directions. The N3IWF security proxy is implemented at the interface between the Gateway and the 5G CN.

6.6.3.4 Access and Mobility managements

The UE is moving from a cell to another, relative to the serving NTN terminal and the gNB. The area where the UE is located is tracked by the local gNB and the 5G CN.

The UE management (such as connection, PDU session, mobility, radio resource) applies to the UEs but not to the NTN terminal.

In the case of Non-GEO satellite, the NTN terminal may move from a beam to another. There is not any standard facility to take into account such a mobility event in the 5G system, as UE mobility management does not apply to NTN terminal in this scenario.

6.6.4 Performance considerations

Same as for scenario A4.

6.6.5 Potential areas of impact on 3GPP system architecture

Define QoS provided to UE services for UE that have NTN indirect access, especially in terms of latency and throughput, based on 5G QoS [i.7].

Extend timers associated with messages at Ni reference points (i = 1, 2, 3) for UE data, signalling exchanges with the 5G CN, to face longer propagation delay.

In order to enable N3IWF and RAN (gNB) interworking, the following requirements have been identified:

Extend the functionality of the N3IWF security proxy. The extended N3IWF, named "N3IWFg" and in case of Indirect untrusted access, includes the following:

- Support of IPsec tunnel establishment with the security gateway connected to the local gNB: The N3IWFg terminates the IKEv2/IPsec protocols with the security gateway connected to the gNB over NWg reference point and transports in a secured way the information over N1, N2, N3 interfaces. For example, for UE service, it relays over N2 the information needed to authenticate the UE and authorize its access to the 5G Core Network.
- 2) Termination & Relay (see 4), 7), 8) bullets below) of N2 and N3 interfaces to 5G Core Network for control plane and user plane respectively.
- 3) Relaying uplink and downlink control-plane NAS (N1) signalling between the UE and AMF.
- 4) Handling of N2 signalling from SMF (relayed by AMF) related to PDU Sessions and QoS.
- 5) Establishment of IPsec Security Association (IPsec SA) to support PDU Session traffic.
- 6) Relaying uplink and downlink user plane packets between the UE and UPF. This involves:
- 7) De-capsulation/encapsulation of packets for IPSec and N3 tunneling.

- 8) Enforcing QoS corresponding to N3 packet marking, taking into account QoS requirements associated with such marking received over N2.
- 9) N3 user plane packet marking in the uplink (return direction).
- 10) Local mobility anchor within untrusted non-3GPP access networks using MOBIKE per IETF RFC 4555 [i.11].
- 11) Supporting AMF selection.

The security gateway, at NTN terminal side, terminates the IKEv2/IPsec protocols, and establishes the IPsec Security Association(s), with the peer N3IWFg, for the benefits of the gNB and the UEs that it serves.

Definition of new reference points "Yg1", "Yg2" and "NWg".

The following reference points have been identified. They depend on the untrusted access technologies used by the NTN. Apart from their name and respective positioning in the 3GPP system architecture, they are outside the 3GPP scope. However, they could be studied outside 3GPP.

Yg1	Reference point between the local security gateway connected the RAN (gNB) and the untrusted access, provided by the NTN terminal. A security gateway may be integrated per gNB or implemented as a standalone equipment, connected both to the RAN and the NTN terminal.
Yg2	Reference point between the untrusted access, provided by the NTN GW, and the N3IWFg for the transport of NWg traffic.
NWg	Reference point between the security gateway connected the RAN (gNB) and the N3IWFg security proxy, for establishing secure IPsec tunnel(s), so that control-plane and user plane exchanged between each gNB and the 5G Core Network is transferred securely over the untrusted NTN access network.

The reference point Yg1, between the local security gateway and the NTN terminal conveys:

- Uplink flows related to UE and gNB (both in user and control planes), received by the security gateway (SEC) from the local gNB. Within the security gateway, they are:
 - Mapped to a NTN terminal CoS.
 - Encapsulated into IPsec tunnel, keeping the NTN terminal CoS ID in the tunnel header.
 - Sent to the NTN terminal.
- Downlink flows related to UE and gNB (both in user and control planes), received by the NTN terminal. Within the NTN terminal, these flows are:
 - Extracted from NTN terminal radio transport containers (data and signalling containers per NTN terminal), each associated with a NTN terminal CoS.
 - Sent to the local security gateway (SEC).

Once received, the security gateway extracts the flows from IPsec tunnel(s) and send them to the local gNB.

The reference point Yg2, between the NTN Gateway and the N3IWFg, conveys:

- Downlink flows related to UE and gNB (both in user and control planes), received by the N3IWFg from the 5G CN. Within the N3IWFg security proxy, these flows are:
 - Mapped to a NTN terminal CoS.
 - Encapsulated into IPsec tunnel, keeping the NTN terminal CoS ID in the tunnel header.
 - Sent to the NTN Gateway (i.e. to the untrusted NTN) over a terrestrial link.

Once received, the NTN Gateway encapsulates them into the relevant NTN terminal radio transport containers (data and signalling containers per NTN terminal).

- Uplink flows related to UE and gNB (both in user and control planes) received by the NTN Gateway from the NTN terminal. Within the NTN Gateway, these flows are:
 - Extracted from NTN terminal radio transport containers (data and signalling containers per NTN terminal), each associated with a NTN terminal CoS.
 - Sent to the N3IWFg security proxy over a terrestrial link.

Once received, the N3IWFg extracts the flows from IPsec tunnel(s), in order to:

- terminate the signalling and generate new signalling to the 5G CN, if needed;
- transport the signalling and data flows to the 5G CN

Mobility management and Paging of the moving UE to take into account specifics of NTN cell mobility & pattern. Mobility management considerations are described in Clause 6.6.3.4.

To seamlessly integrate the NTN transparent network in the architecture, even if it is untrusted:

- This NTN supports either network slicing or network partitioning.
- These partitions, when provided, are managed as network slices by the Orchestrator, interfacing the NMS component of the NTN to do so.

7 Comparison of the integration scenarios

The main characteristics of the integration scenarios are summarized hereafter.

Main characteristics of integration scenarios	Scenario A1	Scenario A2	Scenario A3	Scenario A4	Scenario A5	
The UE is operated by:	N/A	MNO	MNO	MNO	MNO	
NTN Radio Access technology	5G NR	5G NR	Mixed 3GPP NTN access (see note 1).	Any (agnostic about access technology).	Any (agnostic about access technology).	
NTN terminal is operated by:	MNO	MNO	NTN Operator or MNO.	NTN Operator or MNO.	NTN Operator.	
Functions to be supported by the NTN terminal	3GPP UE	3GPP UE, Relaying, MUX node, 3GPP Access Point for RAN.	3GPP UE, Relaying, MUX node, 3GPP mixed Access Point for RAN.	IP/frame Relaying, NTN Access Point for RAN.	IP/frame Relaying, NTN Access Point for RAN.	
5G CN is operated by	NTN Operator or MNO.	NTN Operator or MNO.	NTN Operator or MNO.	NTN Operator or MNO.	Typically MNO.	
Is UE management applied to NTN terminal?	Yes	Yes	Yes	No	No	
NTN trust ability	Trusted	Trusted	Trusted	Trusted	Untrusted. N3IWFg security proxy and a local security gateway are needed, to establish IPsec tunnel(s) between the 5G CN and the local gNB.	
Relaying capacity	N/A	As NTN Relay UE.	As NTN Relay UE.	As generic packet relay.	As generic packet relay.	
 Transport of: UP and CP of UEs, CP of gNB 	• N/A	• NTN NT UE Radio Bearer, + GTP-U Tunnels.	NTN NT UE Radio transport container s + GTP- U Tunnels.	NTN NT UE Radio transport container s + GTP- U Tunnels.	• Yes - Any radio container s and Secured IP Tunnels.	
Radio Resource Allocation coordination (see note 2)	N/A	Coordination at CP level and management level.	Implementation dependent. At least, coordination at management level.	Coordination at management level only.	Coordination at management level only.	
NTN Multiplexing nodes	N/A	Uplink: NTN NT UE Downlink: NTN LT gNB.	Uplink: NTN NT UE Downlink: NTN LT gNB.	Uplink: NTN terminal (VSAT) Downlink: NTN GW.	Uplink NTN terminal (VSAT) Downlink: N3IWFg.	
NOTE 1: Another wording may be 3GPP NTN access with non-3GPP L2, non-3GPP L1 layers. NOTE 2: Radio Resource Allocation is distributed over gNB, NTN terminal, and NTN gNB.						

Table 2: Main characteristics of integration scenarios

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8 Potential areas of impact on 3GPP standards

This clause entails a preliminary analysis of the different integration scenarios of satellite on 5G system and their potential areas of impact on 3GPP 5G system specification. It is a summary of the above clauses titled "Potential impacts on 3GPP system architecture" for each integration scenario considered.

All the impacts below that apply to NTN NT UE also apply to the NTN Relay UE when present, as the NTN Relay UE integrates the NTN NT UE.

NOTE: When stating the "attached UE", it means the "UE is attached to the gNB that is connected to/served by the NTN NT UE".

NTN equipment characteristics	Scenario A1	Scenario A2	Scenario A3	Scenario A4	Scenario A5	
NTN terminal	NTN NT UE as standalone equipment to be specified.	NTN NT UE standalone or integrated in NTN Relay UE, connected to a RAN, to specify.	NTN NT UE standalone or integrated in NTN Relay UE, connected to a RAN, to be defined (see note).	NTN Terminal (VSAT) connected to a RAN, to be defined (see note).	NTN terminal (VSAT) connected to a security gateway at RAN side, to be defined (see note).	
NTN Relay UE integrating the NTN NT UE function.	Network element to be specified.	Network element to be specified.	Network element to be defined.	N/A	N/A	
NTN LT gNB or NTN gNB-DU/CU	Network element to be specified.	Network element to be specified.	Network element to be specified.	N/A	N/A	
NOTE: The implementation is out of 3GPP scope.						

Table 3: NTN equipment characteristics

Table 4: 3GPP system procedures adaptation

3GPP system procedures adaptations	Scenario A1	Scenario A2	Scenario A3	Scenario A4	Scenario A5
Logical synchronization between the 3GPP system procedures of each NTN terminal and UE	N/A	Yes	Yes	N/A	N/A
3GPP system procedures adaptation	Mobility management and Paging of the NTN NT UE: few adaptations due to longer delay.	Mobility management and Paging of moving NTN NT UE and attached moving UE, and interworking between them.	Mobility management and Paging of moving NTN NT UE and attached moving UE, interworking between them.	Mobility management and Paging of UE: few adaptations due to longer delay.	Mobility management and Paging of UE: few adaptations due to longer delay.
	Roaming of NTN NT UE from one PLMN to another one.	Roaming of NTN NT UE and attached UE from one PLMN to another one.	Roaming of NTN NT UE and attached UE from one PLMN to another one.	Roaming of UE from one PLMN to another one.	Roaming of UE from one PLMN to another one.

New 3GPP reference points	Scenario A1	Scenario A2	Scenario A3	Scenario A4	Scenario A5
Reference points at GW side	Mngw between the NTN GW and the NTN LT gNB to be specified.	Mngw between the NTN GW and the NTN LT gNB to be specified.	Mngw between the NTN GW and the NTN LT gNB to be defined (see note 1).	Ygw between the NTN GW and the 5G CN to be defined (see notes 1 and 2).	Yg2 between the NTN GW and the N3IWFg to be defined (see note 1).
Reference points at NTN terminal side		Mnx between the local RAN (gNB) and the NTN NT UE to be specified.	Mnx between the local RAN (gNB) and the NTN NT UE to be defined (see note 1).	Ymx between the local RAN (gNB) and the NTN terminal to be defined (see note 1).	Yg1 between the local security gateway and the local RAN (gNB) to be defined (see note 1).
					NWg between the security gateway connected the RAN (gNB) and the N3IWFg, for establishing secure tunnel(s).
Possible implementation	For Mngw: The 3GPP F1 interface may be used (see Clause A.4.3).	For Mngw: The 3GPP F1 interface may be used (see Clause A.4.3).	Adapt 5G NR Data Link over Non-3GPP physical and data link layers, both in CP and UP (but it is out of 3GPP scope).		
NOTE 1: The imple NOTE 2: The Ygw	ementation is out of is typically an IP int	3GPP scope. erface.			

Table 5: New 3GPP reference points

Table 6: Security aspects

Adaptation of security framework							
Scenario A1	Scenario A2	Scenario A3	Scenario A4	Scenario A5			
		Extend "trusted network" definition to mixed 3GPP network, subject to operator's agreement.	Extend "trusted network" definition to non-3GPP network, subject to operator's agreement.	Extend N3IWF security proxy: N3IWFg, establishing IPsec tunnel between with the local RAN and relaying signalling from/to RAN.			

Flows encapsulation and QoS adaptation, timers' adaptation	Scenario A1	Scenario A2	Scenario A3	Scenario A4	Scenario A5
Flows encapsulation: bearers/container s aspects	Reuse of 3GPP mechanisms: NR Radio Bearers are implemented at the Service Link to encapsulate NTN NT UE QoS flows. Few adaptations are required for Radio Bearers establishment due to longer delay.	Mapping NTN NT UE QoS flows to NTN NT UE Radio Bearers (signalling and data): to be specified.	Mapping NTN NT UE QoS flows to NTN NT UE Data Radio Transport Containers: to be defined (see note).	Mapping NTN terminal transport layer to NTN terminal Radio Transport Containers: to be defined (see note).	Nesting IPsec tunnel in NTN terminal Radio Transport Containers, to transport contents of UE radio Bearers: to be defined (see note).
QoS rules adaptation	Define QoS provided to services for NTN NT UE.	Define QoS provided to services for NTN NT UE and UE.	Define QoS provided to services for NTN NT UE (see note) and UE.	Define QoS provided to services for NTN Terminal (see note) and UE.	Define QoS provided to services for NTN Terminal (see note) and UE.
Flows encapsulation: QoS aspects	Reuse NR QoS Radio Bearers, with few adaptations in terms of latency objective.	QoS rules, UE QoS flows encapsulation into NTN NT UE QoS flows to be specifiedin 3GPP.	QoS rules, UE QoS flows encapsulation NTN NT UE QoS flows: to be defined (see note).	QoS rules and QoS flows encapsulation into the provided transport PDUs: to be defined (see note).	QoS rules and QoS flows encapsulation into the provided transport PDUs: to be defined (see note).
Timers extension	Extend Timers associated with messages at Ni reference points (i = 1, 2, 3) for NTN NT UE.	Extend Timers associated with messages at Ni reference points (i = 1, 2, 3) for NTN NT UE and UE.	Extend Timers associated with messages at Ni reference points (i = 1, 2, 3) for NTN NT UE and UE.	Extend Timers associated with messages at Ni reference points (i = 1, 2, 3) for UE.	Extend Timers associated with messages at Ni reference points (i = 1, 2, 3) for UE.
NOTE: The implementation is out of 3GPP scope.					

Table 7: Flows encapsulation and QoS adaptation, timers' adaptation

Table 8: Support of network slicing

Support of network slicing							
Scenario A1	Scenario A2	Scenario A3	Scenario A4	Scenario A5			
Built-in. Interface	Built-in. Interface	May be based on	May be based on	May be based on			
with the	with the	network	network	network partitioning			
Orchestrator to	Orchestrator to	partitioning or	partitioning or	or network slicing.			
define.	define.	network slicing.	network slicing.	Interface with the			
		Interface with the	Interface with the	Orchestrator to			
		Orchestrator to	Orchestrator to	define.			
		define.	define.				

Annex A: Clarifications

A.1 N3IWF functions and Y1, Y2, NWu reference points

According to ETSI TS 123 501 [i.7], in the current Release 15:

Non-3GPP access networks may be connected to the 5G Core Network via a Non-3GPP Interworking Function (N3IWF). The N3IWF interfaces the 5G Core Network CP and UP functions via N2 and N3 interfaces, respectively.

The functionality of N3IWF in case of untrusted non-3GPP access includes the following:

- Support of IPsec tunnel establishment with the UE: The N3IWF terminates the IKEv2/IPsec protocols with the UE over NWu and relays over N2 the information needed to authenticate the UE and authorize its access to the 5G Core Network.
- Termination of N2 and N3 interfaces to 5G Core Network for control plane and user plane respectively.
- Relaying uplink and downlink control-plane NAS (N1) signalling between the UE and AMF.
- Handling of N2 signalling from SMF (relayed by AMF) related to PDU Sessions and QoS.
- Establishment of IPsec Security Association (IPsec SA) to support PDU Session traffic.
- Relaying uplink and downlink user plane packets between the UE and UPF. This involves:
 - De-capsulation/encapsulation of packets for IPSec and N3 tunnelling.
 - Enforcing QoS corresponding to N3 packet marking, taking into account QoS requirements associated with such marking received over N2.
 - N3 user plane packet marking in the uplink.
- Local mobility anchor within untrusted non-3GPP access networks using MOBIKE per IETF RFC 4555 [i.11].
- Supporting AMF selection.

In the Non-Roaming architecture, the role of the N3IWF is depicted by Figure A.1, as defined in Figure 4.2.8.2.1-1 of ETSI TS 123 501 [i.7].





Ni reference points: see Clause A2 and ETSI TS 123 501 [i.7].

- Y1 Reference point between the UE and the non-3GPP access (e.g. WLAN). This depends on the non-3GPP access technology and is outside the 3GPP scope.
- Y2 Reference point between the untrusted non-3GPP access and the N3IWF for the transport of NWu traffic.
- **NWu** Reference point between the UE and N3IWF for establishing secure tunnel(s) between the UE and N3IWF so that control-plane and user plane exchanged between the UE and the 5G Core Network are transferred securely over untrusted non-3GPP access.

Both in Non-roaming architecture and Roaming Architecture (see below), and according to ETSI TS 123 501 [i.7], Ni Interfaces may be transported over the Untrusted Network. N2, N3 interfaces, as all the so-named NWu traffic between the UE and N3IWF may be transported in a secure IPSec tunnel. ETSI TS 123 501 [i.7] specifies that N1 NAS signalling over standalone non-3GPP accesses are protected with the same security mechanism applied for N1 over a 3GPP access.



Figure A.2: Home-routed Roaming architecture for 5G Core Network with non-3GPP access - N3IWF in HPLMN and different PLMN in 3GPP access

A.2 Ni Reference Points (alias Ni interfaces)

Ni interfaces are listed in this clause.

According to ETSI TS 123 501 [i.7], the 5G System Architecture contains the following reference points:

- N1: Reference point between the UE and the AMF.
- N2: Reference point between the (R)AN and the AMF.
- N3: Reference point between the (R)AN and the UPF.
- N4: Reference point between the SMF and the UPF.
- **N6:** Reference point between the UPF and a Data Network.

- NOTE 1: The traffic forwarding details of N6 between a UPF acting as an uplink classifier and a local data network will not be specified in this release.
- **N9:** Reference point between two UPFs.

The following reference points show the interactions that exist between the NF services in the NFs (Network Functions). These reference points are realized by corresponding NF service-based interfaces and by specifying the identified consumer and producer NF service as well as their interaction in order to realize a particular system procedure.

N5: Reference point between the PCF and an AF. N7: Reference point between the SMF and the PCF. N24: Reference point between the PCF in the visited network and the PCF in the home network. N8: Reference point between the UDM and the AMF. N10: Reference point between the UDM and the SMF. N11: Reference point between the AMF and the SMF. N12: Reference point between AMF and AUSF. N13: Reference point between the UDM and Authentication Server function the AUSF. N14: Reference point between two AMFs. N15: Reference point between the PCF and the AMF in case of non-roaming scenario, PCF in the visited network and AMF in case of roaming scenario. N16: Reference point between two SMFs, (in roaming case between SMF in the visited network and the SMF in the home network). N17: Reference point between AMF and 5G-EIR. N18: Reference point between any NF and UDSF. N22: Reference point between AMF and NSSF. N27: Reference point between NRF in the visited network and the NRF in the home network. N31: Reference point between the NSSF in the visited network and the NSSF in the home network.

In addition to the reference points above, there are interfaces/reference point(s) between SMF and the charging system. The reference point(s) are not depicted in the architecture illustrations in the present document.

NOTE 2: The functionality of these interface/reference points are defined in ETSI TS 132 240 [i.19].

N32: Reference point between SEPP in the visited network and the SEPP in the home network.

NOTE 3: The functionality of N32 reference point is defined in ETSI TS 133 501 [i.20].

A.3 Distributed NTN enabled RAN architecture and 3GPP F1 interface principles

A.3.1 Distributed RAN architecture

This clause applies to the NTN LT gNB as defined in the scenarios A1, A2 and A3.

It is also applicable to the local gNB architecture, close to the UE, as defined in scenarios A2 to A5.

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With the development of Cloud based technologies that lowered the cost of computation power, most if not any digital processing tasks in telecom systems can be supported on software running on generic hardware platforms. This leads to make digital processing more centralized than before. This centralization also affected the 3GPP Radio Access Networks, to follow a "Cloud RAN" architecture. It consists of splitting the base station into a central and a remote (or "distributed") component (aka. Baseband Unit and Radio Remote Head).

Further, in current satcom trends, the same Cloud RAN concept is targeted for the implementation of large systems (i.e. in VHTS systems) comprising multiple Gateways. Centralizing some functions of the satellite Gateways (e.g. at Datacenters sites) contribute to reduce Total Cost of Ownerships (TCO), and provide more ease for frequent updates, by means of software-based rather than hardware-based management.

Figure A.3, taken from ETSI TS 138 401 [i.23] shows the overall architecture of the Cloud RAN as specified by 3GPP.



Figure A.3: Distributed RAN: overall architecture

The NTN 5G RAN may be viewed as a set of centralized gNBs (named NTN LT gNBs), or central and distributed ones, respectively gNB-CUs and gNB-DUs (named NTN gNB-CU and NTN gNB-DU).

So far, no interoperable and open solution exists for supporting this splitting (in case for example of different vendors for each component). 5G addresses this issue through the definition of a higher 3GPP interface and layer called F1 and F1AP. Its specification is found in ETSI TS 138 470 [i.14].

NOTE: Physical and Data link layer technologies remain out of the scope of this specification. Different technologies compete here (such as (e) CPRI, Radio over Ethernet [i.30].

According to ETSI TS 138 470 [i.14], the NTN gNB architecture may be split into a Central Unit, NTN LT gNB-CU, connected to the Core Network and one or several distributed units, NTN LT gNB-DU, closer to the terminal. The NTN LT gNB-CU and the NTN LT gNB-DUs exchanges are supported through F1-C interface for the control plane and F1-U interface for the user plane. Figure A.3 shows the protocol structure.



Interface protocol structure for F1-C

Interface protocol structure for F1-U

Figure A.4: Interface protocol structure on F1-C and F1-U

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In the CP, the Transport Network Layer (TNL) is based on IP transport, comprising SCTP on top of IP.

In the UP, the TNL is based on IP transport, comprising GTP-U and UDP on top of IP.

According to 3GPP TS 38.475 [i.18], the F1 user plane (F1-U) protocol is located in the User Plane of the Radio Network layer over the F1 interface. The F1AP protocol layer uses services of the Transport Network Layer in order to allow flow control of user data packets transferred over the F1 interface.

In view of integrating NTN in the 5G RAN, there might be opportunities in the business models on the satcom (or HAPS) ground segment through the support of this interface, and this may impact both ground segment vendors and operators.

For instance, a 5G NTN RAN could be under the global management and supervision of the MNO, while the specific clause from the gNB-DU to the NTN NT UE would be left to the NTN operator.

A.3.2 3GPP F1 interface principles

The F1 UP protocol is used to convey control information related to the user data flow management of bearers. The gNB-DU flow control feedback may support indication of successful transmission towards a UE, or successful delivery to the UE, as defined in ETSI TS 138 300 [i.16].

Each F1 UP protocol instance is associated with one data radio bearer only.

When configured, F1 UP protocol instances exist at the gNB-CU and the gNB-DU between which the F1 user data bearers are setup.

According to ETSI TS 138 473 [i.17], F1AP consists of Elementary Procedures (EPs). An Elementary Procedure is a unit of interaction between gNB-CU and gNB-DU. The usage of several F1AP EPs together is specified in stage 2 specifications (e.g. ETSI TS 138 470 [i.14]).

The F1AP layer is mainly in charge of the following procedures:

- F1 Setup/Reset/Error Indication.
- gNB-DU/gNB-CU Configuration Update.
- UE Context Management procedures:
 - UE Context Setup/Release (gNB-CU initiated).
 - UE Context Modification (gNB-CU initiated), UE Context Modification Required (gNB-DU initiated).
 - UE Context Release Request (gNB-DU initiated).
- DL/UL RRC Messages Transfer.

The purpose of the F1 Setup procedure is to exchange application level data needed for the gNB-DU and the gNB-CU to correctly interoperate on the F1 interface. This procedure is the first F1AP procedure triggered after the TNL association has become operational. The procedure uses non-UE associated signalling.

The purpose of the Reset procedure is to initialize or re-initialize the F1AP UE-related contexts, in the event of a failure in the gNB-CU or gNB-DU. This procedure does not affect the application level configuration data exchanged during, e.g. the F1 Setup procedure.

The Error Indication procedure is initiated by a node in order to report detected errors in one incoming message, provided they cannot be reported by an appropriate failure message.

The purpose of the gNB-DU Configuration Update procedure is to update application level configuration data needed for the gNB-DU and the gNB-CU to interoperate correctly on the F1 interface. This procedure does not affect existing UE-related contexts, if any.

The purpose of the gNB-CU Configuration Update procedure is to update application level configuration data needed for the gNB-DU and gNB-CU to interoperate correctly on the F1 interface. This procedure does not affect existing UE-related contexts, if any.

The purpose of the UE Context management procedure is to establish and release the necessary UE Context over F1. C-RNTI is allocated by gNB-DU during this procedure when UE initially accesses to the gNB.

The establishment of the F1 UE context is initiated by the gNB-CU and accepted or rejected by the gNB-DU based on admission control criteria (e.g. resource not available).

The gNB-CU decides to which Bearer each QoS flow are mapped.

The purpose of the DL RRC Message Transfer procedure is to transfer an RRC message as a DL PDCP-PDU to the gNB-DU.

The purpose of the UL RRC Message Transfer procedure is to transfer an RRC message as an UL PDCP-PDU to the gNB-CU.

As defined in ETSI TS 138 401 [i.23]:

- **gNB Central Unit** (**gNB-CU**) is a logical node hosting RRC, SDAP and PDCP protocols of the gNB or RRC and PDCP protocols of the en-gNB that controls the operation of one or more gNB-DUs. The gNB-CU terminates the F1 interface connected with the gNB-DU.
- **gNB Distributed Unit (gNB-DU)** is a logical node hosting RLC, MAC and PHY layers of the gNB or engNB, and its operation is partly controlled by gNB-CU. One gNB-DU supports one or multiple cells. One cell is supported by only one gNB-DU. The gNB-DU terminates the F1 interface connected with the gNB-CU.

A.4 Protocols layers instantiation - Examples

A.4.1 Scenario A1, Option 1 - Direct 3GPP access

A.4.1.1 NTN NT UE User plane for a PDU session

This clause depicts the protocols stacks from the NTN NT UE user plane perspective.

The 3GPP protocol layers in the user plane, are instantiated according to ETSI TS 123 501 [i.7] with a bent-pipe architecture.

Instantiation on the NTN Radio Interfaces

The application layer and the PDU layer (e.g. IP) of the NTN NT UE are transported by the 5G Data Link layers (orange coloured) and the NR Layer 1 (physical layer) on the service link and the feeder link.

This is applicable for both directions.



Figure A.5: Scenario A1 - Option 1 - Transport of NTN NT UE UP layers on service link and feeder link, with bent-pipe payload

End-to-end instantiation

The application layer and the PDU layer (e.g. IP) are transported towards the 5G CN.

This is applicable for both directions.



Figure A.6: Scenario A1 - Option 1 - End-to-end transport of NTN NT UE UP layers, for Direct 3GPP access, with bent-pipe payload

NTN NT UE Data Radio Bearers, GTP-U tunnels and N9 transport containers mapping

As specified in ETSI TS 123 501 [i.7]:

- The 5G QoS model is based on QoS Flows. The 5G QoS model supports both QoS Flows that require guaranteed flow bit rate (GBR QoS Flows) and QoS Flows that do not require guaranteed flow bit rate (non-GBR QoS Flows). The 5G QoS model also supports reflective QoS.
- The QoS Flow is the finest granularity of QoS differentiation in the PDU Session. A QoS Flow ID (QFI) is used to identify a QoS Flow in the 5G System. User Plane traffic with the same QFI within a PDU Session receives the same traffic forwarding treatment (e.g. scheduling, admission threshold). The QFI is carried in an encapsulation header on N3 (and N9) i.e. without any changes to the e2e packet header. QFI should be used for all PDU Session Types. The QFI is unique within a PDU Session. The QFI may be dynamically assigned or may be equal to the 5QI (5G QoS Identifier).

- PDU layer: This layer corresponds to the PDU carried between the UE and the DN over the PDU Session. When the PDU Session Type is IPV6, it corresponds to IPv6 packets; When the PDU Session Type is Ethernet, it corresponds to Ethernet frames; etc.
- GPRS Tunnelling Protocol for the user plane (GTP-U): This protocol supports multiplexing traffic of different PDU Sessions (possibly corresponding to different PDU Session Types) by tunnelling user data over N3 (i.e. between the 5G-AN node and the UPF) in the backbone network. The GTP encapsulates all end user PDUs. It provides encapsulation on a per PDU Session level. This layer carries also the marking associated with a QoS Flow defined in Clause 5.7.
- 5G Encapsulation (5GUPE): This layer supports multiplexing traffic of different PDU Sessions (possibly corresponding to different PDU Session Types) over N9 (i.e. between different UPF of the 5G CN). It provides encapsulation on a per PDU Session level. This layer carries also the marking associated with a QoS Flow defined in clause "QoS model" of ETSI TS 123 501 [i.7].

See clause "QoS model" of ETSI TS 123 501 [i.7] for further details.

In this scenario, after classification according to TFTs, the User Data (NTN NT UE QoS flows) are transported by dedicated NTN NT UE Radio Bearers, Data NG-U tunnels (such as GTP-U tunnels) and Data encapsulating containers. This is applicable for both directions. PDUs session are encapsulated within the 5G CN using the most appropriate encapsulation mechanism, depending on the PDU session type, such as IP packet, Ethernet frame.

The classification is processed by SDAP within the NTN NT UE for the uplink direction and by the UPF (P-GW) for the forward direction.

The Figure A.7 below depicts the mapping between the Data Radio Bearers, in the RAN, and the end-to-end QoS flows, both in RAN and 5G CN. The Radio Bearers objects are not used anymore in 5G CN, but in RAN. QoS flows are used instead, in 5G CN. For simplification purposes, in this figure:

- QoS flows related to NTN NT UE #1 are implemented but they are almost masked behind its Data Radio Bearers.
- Data Radio Bearers related to NTN NT UE #2 are implemented but they are not depicted. Only its QoS flows are figured



Figure A.7: Scenario A1 - Option 1 - End-to-end NTN NT UE Data Radio Bearers, GTP-U tunnels and N9 transport containers mapping for Direct 3GPP access, with bent-pipe payload

NTN NT UE Data Radio Bearers establishment

The Figure A.8, inherited from ETSI TS 138 300 [i.16], instantiates a NTN NT UE (instead of UE), a NTN LT gNB (instead of gNB), a NTN 5G RAN (instead of NG-RAN).

For each NTN NT UE, the NTN 5G RAN establishes one or more Data Radio Bearers (DRB) per PDU Session. The NTN 5G RAN maps packets belonging to different PDU sessions to different DRBs. Hence, the NTN 5G RAN establishes at least one default DRB for each PDU Session.



Figure A.8: NTN NT UE Data Radio Bearers establishment, according to ETSI TS 138 300 [i.16]

In the figure above, the NG-U is the interface between a 5G RAN a 5G core Network. The N3 reference point, between the 5G RAN and the UPF network function is mapped to this NG-U.

A.4.1.2 NTN NT UE Control plane

This clause depicts the protocols stacks from the NTN NT UE control plane perspective.

The 3GPP protocol layers in the control plane, are instantiated according to ETSI TS 123 501 [i.7] and the bent-pipe architecture, which is transparent to 5G higher protocol layers (see the definition), NR Data Link Layers (see the definition).

Instantiation on the NTN Radio Interfaces

The NAS-SM, NAS-MM, RRC layers are transported by the NR Data Link layers (orange coloured) and the NR Layer 1 (physical layer) on the service link and the feeder link. This is applicable for both directions.



Figure A.9: Scenario A1 - Option 1 - Transport of NTN NT UE CP layers on service link and feeder link, for Direct 3GPP access, with bent-pipe payload

End-to-end instantiation

The NAS-SM, NAS-MM are transported towards the 5G CN. This is applicable for both directions.

The RRC and the NG-AP protocols are processed as signalling in the NTN LT gNB serving the NTN NT UE.



Figure A.10: Scenario A1 - Option 1 - End-to-end transport of NTN NT UE CP layers for Direct 3GPP access, with bent-pipe payload

NTN NT UE Signalling Radio Bearers and N11 transport containers mapping

The NTN NT UE radio signalling and connections signalling are transported by dedicated Signalling Radio Bearers and tunnels. This is applicable for both directions.

The classification is processed by the NTN NT UE for the uplink direction and by the P-GW for the forward direction.

The Figure A.11 below depicts the mapping between the Signalling Radio Bearers, in the RAN, and the end-to-end QoS flows, both in RAN and 5G CN. The Radio Bearers objects are not used anymore in 5G CN, but in RAN. QoS flows are used instead, in 5G CN. For simplification purposes, in this figure:

- QoS flows related to NTN NT UE #1 are implemented but they are almost masked behind its Signalling Radio Bearers.
- Signalling Radio Bearers related to NTN NT UE #2 are implemented but they are not depicted. Only its QoS flows are figured.



Figure A.11: Scenario A1 - Option 1 - NTN NT UE Signalling Radio Bearers and N11 transport containers mapping, for Direct 3GPP Access, with bent-pipe payload

A.4.2 Scenario A2 - Option 1 - Indirect 3GPP Access

A.4.2.1 UE User plane for a PDU session

This clause depicts the protocols stacks from the UE user plane perspective.

According to 3GPP TR 36.806 [i.9] principle, the user plane of the scenario A1 (for NTN NT UE) is re-used to transport the UP of the UE.

Justification of the instantiation:

The 3GPP protocol layers in the user plane, are instantiated according to ETSI TS 123 501 [i.7], the relaying framework as described in ETSI TS 123 401 [i.8] and 3GPP TR 36.806 [i.9] but with Network Function as specified in ETSI TS 123 501 [i.7], and the bent-pipe architecture, which is transparent to 5G higher protocol layers, NR Data Link Layers (see the definitions of terms in Clause 3.1).

Instantiation on the UE-gNB interfaces and the NTN Radio Interfaces

The application layer and the PDU layer (e.g. IP) of the UE are transported:

- First, from the UE to the RAN (gNB) over the NR Radio Interface. The RAN (gNB) multiplexes flows coming from the UE.
- Then by the NTN NT UE user plane (as described in Clause A.4.1.1). from the gNB to the NTN LT gNB, in GTP-U tunnels. The NTN NT UE multiplexes flows coming from the RANs (gNBs), through the Mnx reference point (see below).

The layers at the Mnx reference point between the gNB(s) and the NTN NT UE are not specified. Mnx is defined in Clause 6.3.5.

NR is the New Radio interface as defined in 3GPP TS series 38.

Note that name of the 4G interfaces are no more used, but 5G ones.

Any technology that supports flows classification into CoS is proposed, in order to multiplex flows with same characteristics and same destination into NTN NT UE Bearers.

This is applicable for both directions.



Figure A.12: Scenario A2 - Option 1 - Transport of UE UP layers on service link and feeder link, for Indirect 3GPP access, with bent-pipe payload

End-to-end instantiation:

The application layer and the PDU layer (e.g. IP) of the UE are transported towards the 5G CN. This is applicable for both directions.



Figure A.13: Scenario A2 - Option 1 - End-to-end transport of UE UP layers, for Indirect 3GPP access, with bent-pipe payload

Figure A.13 depicts both:

- a NTN enabled Relay UE, which integrates gNB and NTN NT UE functions; or
- gNB, NTN NT UE standalone equipment. In this case, these equipments are connected through an interface which is not depicted.

UE Data Radio Bearers, GTP-U tunnels and "transport containers over N9" mapping

According to ETSI TS 123 501 [i.7], the 5G QoS model is based on QoS Flows. See clause "QoS model" of ETSI TS 123 501 [i.7] for further details.

In this scenario, after classification according to TFTs, the User Data (UE QoS flows) are transported by dedicated UE Data Radio Bearers, then multiplexed NTN NT UE Radio Bearer and tunnelled, in the 5G CN. This is applicable for both directions. PDUs session are encapsulated within the 5G CN using the most appropriate encapsulation mechanism, depending on the PDU session type, such as IP packet, Ethernet frame.

The NTN NT UE Data Radio Bearers are established prior to the UE data radio Bearers. NTN NT UE Data Bearers are established according to scenario A1 (see Clause A.4.1.1).

The classification of flows coming/from/to UE is processed:

- by SDAP layer within the UE and then by SDAP within the NTN NT UE, for the uplink direction and
- by the UPF (P-GW) then by the NTN LT gNB as multiplexer node, for the forward direction.



Figure A.14: Scenario A2 - Option 1 - UE Data Radio Bearers, GTP-U tunnels and N9 transport containers mapping, for Indirect 3GPP access, with bent-pipe payload

A.4.2.2 UE Control plane

This clause depicts the protocols stacks from the UE control plane perspective.

According to 3GPP TR 36.806 [i.9] principle, the user plane of the scenario A1 (for NTN NT UE) is re-used to transport the CP of the UE.

The 3GPP protocol layers in the control plane, are instantiated according to ETSI TS 123 501 [i.7], the relaying framework as described in ETSI TS 123 401 [i.8] and 3GPP TR 36.806 [i.9] but with Network Functions as specified in [i.7] and the bent-pipe architecture, which is transparent to 5G higher protocol layers (see the definition), NR Data Link Layers (see the definition).

Instantiation on the UE-gNB interfaces and the NTN Radio Interfaces

The NAS-SM and the NAS-MM layers of the UE are transported:

- first, from the UE to the RAN (gNB) over the NR Radio Interface;
- then by the NG-AP layer from the gNB to the NTN LT gNB.

The NG-AP layer is transported over SCTP:

• by the NTN NT UE user plane (as described in Clause A.4.1.1). from the gNB to the NTN LT gNB.

For the CP, like for the UP:

The layers at the Mnx interface between the gNB(s) and the NTN NT UE are not specified. Any technology that supports flows classification into CoS is proposed, in order to multiplex flows with same characteristics and same destination into NTN NT UE Bearers.

This is applicable for both directions.



Figure A.15: Scenario A2 - Option 1 - Transport of UE CP layers on service link and feeder link, for Indirect 3GPP access, with bent-pipe payload

End-to-end instantiation

The NAS-SM, NAS-MM of the UE and the NG-AP of the gNB are transported towards the 5G CN.

This is applicable for both directions.


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Figure A.16: Scenario A2 - Option 1 - End-to-end transport of UE CP layers, for Indirect 3GPP access, with bent-pipe payload

UE Signalling Radio Bearers, tunnels and N11 transport containers mapping

After classification, the signalling flows are transported by dedicated UE Signalling Radio Bearers, then multiplexed into NTN NT UE Radio Bearer and tunnelled, in the 5G CN. This is applicable for both directions.

The NTN NT UE Data Radio Bearers are established prior to the UE signalling radio Bearers. NTN NT UE Data Bearers are established according to scenario A1 (see Clause A.4.1.1).

The classification of signalling flows coming from/to UE is processed:

- by the UE and then by SDAP layer within the NTN NT UE, for the uplink direction; and
- by the P-GW (UPF) then by the NTN LT gNB as multiplexer node, for the forward direction.

The signalling from/to the gNB is also classified in the NTN NT UE for the return direction (respect. the NTN LT gNB for the forward direction) and multiplexed into NTN NT UE signalling Radio Bearers and tunnelled, in the 5G CN.



Figure A.17: Scenario A2 - Option 1 - UE Signalling Radio Bearers, tunnels and N11 transport containers mapping for Indirect 3GPP access and with bent-pipe payload

A.4.3 Scenario A1, Option 2 - Direct 3GPP acces with distributed NTN enabled gNB, F1 interface between NTN GW and NTN LT gNB

A.4.3.1 Principles

An alternative architecture to scenario A1, with a distributed NTN gNB between a central NTN gNB-CU and a NTN gNB-DU per gateway is depicted in Figure A.18.



Figure A.18: Scenario A1 - Option 2 - End-to-end transport of NTN NT UE UP, CP layers with bentpipe payload and F1 interface

Figure A.18 entails:

- Data Network.
- 5G CN serving NTN enabled NT UEs (NTN NT UEs).
- Non-Terrestrial Network that transports UP and CP of the NTN NT UE and CP of the 5G RAN. The NTN encompasses a distributed 5G RAN, named "NTN 5G RAN", encompassing one or several NTN gNB-CUs and NTN gNB-DUs, each NTN gNB-CU being linked to one or several gateways and serving NTN enabled NT UEs.
- Standalone NTN enabled NT UEs accessing 5G services.

The NTN gNB-DU acts as a RRH (Remote Radio Head).

A.4.3.2 NTN NT UE User plane for a PDU session

This clause depicts the protocols stacks from the NTN NT UE user plane perspective when:

- The NTN GW hosts an NTN gNB-DU.
- The 5G NTN RAN implement (at least) one NTN gNB-CU.
- The NTN gNB-DU and the gNB-CU interface via F1 interface (F1-U in the UP), in a distributed gNB architecture approach.



End-to-end instantiation

Figure A.19: Scenario A1 - Option 2 - End-to-end transport of NTN NT UE UP layers, for Direct 3GPP access, with bent-pipe payload and F1 interface

NTN NT UE Data Radio Bearers and tunnels mapping



Figure A.20: Scenario A1 - Option 2 - NTN NT UE Data Radio Bearers and tunnels mapping with bentpipe payload and F1 interface

A.4.3.3 NTN NT UE Control plane

This clause depicts the protocols stacks from the NTN NT UE control plane perspective when:

- The NTN GW hosts an NTN gNB-DU.
- The 5G NTN RAN implement (at least) one NTN gNB-CU.
- The NTN gNB-DU and the gNB-CU interface via F1 interface (F1-C in the CP), in a distributed gNB architecture approach.



End-to-end instantiation

Figure A.21: Scenario A1 - Option 2 - End-to-end transport of NTN NT UE CP layers for Direct 3GPP access with bent-pipe payload and F1 interface

NTN NT UE Signalling Radio Bearers and tunnels mapping



Figure A.22: Scenario A1 - Option 2 - NTN NT UE Signalling Radio Bearers and tunnels mapping with bent-pipe payload and F1 interface

A.4.4 Scenario A2, Option 2 – Indirect 3GPP acces with distributed NTN enabled gNB, F1 interface between NTN GW and NTN LT gNB

A.4.4.1 Principles

An alternative architecture to scenario A2, with a distributed NTN gNB between a central NTN gNB-CU and a NTN gNB-DU per gateway is depicted in the Figure A.23.



Figure A.23: Scenario A2 - Option 2 - End-to-end transport of UE UP, CP layers with bent-pipe payload and F1 interface

Figure A.23 entails:

- data Network;
- 5G CN serving NTN enabled NT UEs (NTN NT UEs); and
- 5G CN serving UEs. These 5G core Networks may be merged, as a subset or all their NF may be implemented in the same VMs;
- Non-Terrestrial Network that transports UP and CP of the UE and CP of the local RAN. The NTN also encompasses a distributed 5G RAN, named "NTN 5G RAN", encompassing one or several NTN gNB-CUs and NTN gNB-DUs, each NTN gNB-CU being linked to one or several NTN gateways and serving NTN enabled NT UEs;
- NTN enabled NT UEs accessing 5G services and being a component of the relaying mechanism;
- A local RAN, which encompasses at least a gNB;
- UE accessing 5G services.

The NTN gNB-DU acts as a RRH (Remote Radio Head).

The NTN enabled relay UE, when present, may integrate either:

- a gNB and a NTN enabled NT UE; or
- a gNB central unit (gNB-CU) and a NTN enabled NT UE (NTN NT UE).

The interest of such distributed gNB architecture is discussed in Clause A3.1 and Clause A.10. The interface between gNB-DU and gNB-CU is described in Clause A3.2.

A.4.4.2 UE User plane for a PDU session

It includes the protocol layers architecture as described in Clause A.4.3.2.

The difference between the scenario A2 architecture option 2 remains in the protocol layers at the interface between the NTN gNB-DU, hosted by the NTN GW and the NTN gNB-CU per NTN 5G RAN.

End-to-end instantiation



Figure A.24: Scenario A2 - Option 2 - End-to-end transport of UE UP layers with bent-pipe payload and F1 interface

A.4.4.3 UE Control plane

It includes the protocol layers architecture instantiation as described in Clause A.4.3.3.

As for the UE user plane, the difference between the scenario A2 architecture option 2 remains in the protocol layers at the interface between the NTN gNB-DU, hosted by the NTN GW and the NTN gNB-CU per NTN 5G RAN.

End-to-end instantiation



Figure A.25: Scenario A2 - Option 2 - End-to-end transport of UE CP layers for Indirect 3GPP Access with bent-pipe payload and F1 interface

A.5 Statistical multiplexing gain principle

Generally speaking, several solutions may be used by operators to size a shared link/channel, when a GBR scheme is applicable to the users sharing this link/channel. It needs to analyse the required bandwidth (bit/s) and the amount of associated resource on this link. Some operators may size the links according to an estimated average rate, other ones use an estimated peak rate. The 1st solution may lead to congestion, due to lack of bandwidth, in a contention scheme, and the 2nd one leads to over-sizing the link due to unused but allocated bandwidth.

It has been demonstrated with [i.12] and [i.13] that an aggregate flow, multiplexing single flows according to the equivalent capacity (or equivalent bandwidth) principle, consumes less rate than the sum of the peak rates of its single flows, and moreover, it can aggregate each single flow in an efficient way (according to a configurable blocking factor), avoiding both congestion and reducing the unused bandwidth. The amount of the required resource on the link/channel is therefore, reduced.

Furthermore, when applied to admission control as a threshold to avoid congestion, the equivalent capacity (equivalent bandwidth) may lead to admit and serve more users or in other words, to aggregate single flows for a given link/channel capacity. It is more efficient, for a given capacity.

A.6 Considerations on NTN implementation

As already mentioned, the NTN encompasses the role of a 5G transport network for UEs, a 5G RAN with 3GPP access.

If the NTN operator and the MNO are different, the NTN may encompass the role of Visited PLMN (5G RAN and 5G Core Network) providing the MNO is the Home PLMN, for serving the NTN NT UEs as UEs.

Otherwise, if the NTN operator and the MNO are the same or if they achieve an agreement, they can share the same 5G RAN. When the 5G RAN is shared, it can be distributed between distributed units located near the NTN gateways and a central unit located near the 5G CN (see Clause A.3.1).

A.7 Considerations on protocol layers implementation in the NTN

The following protocol layers may be implemented, both in UP and CP, according to each scenario.

Overview of the protocols layers	Scenario A1 (for NTN NT UE)	Scenario A2 (for NTN NT UE, otherwise for UE if mentioned)	Scenario A3 (for the NTN NT UE, otherwise for UE if mentioned)	Scenario A4 (for the NTN terminal, otherwise for UE if mentioned)	Scenario A5 (for the NTN terminal, otherwise for UE if mentioned)
Control Plane					
	NAS-SM, NAS- MM Over NG-AP	For the UE: NAS-SM, NAS- MM Over NG-AP	For UE: NAS-SM, NAS-MM Over NG-AP	For UE: NAS-SM, NAS-MM Over NG-AP	For UE: NAS-SM, NAS-MM Over NG-AP
	RRC over NR Data Link layers	For UE: RRC over NR Data Link layers	For UE: RRC over NR Data Link layers	For UE: RRC over NR Data Link layers	For UE: RRC over NR Data Link layers
	NG-AP over SCTP	For UE: NG-AP over SCTP	For UE: NG-AP over SCTP	For UE: NG-AP over SCTP	For UE: NG-AP over SCTP
	SCTP over IP	SCTP over IP over NR Data Link layers, over the air	SCTP over IP over Higher NR Data Link layers over Non-3GPP Data Link layers	SCTP over IP over Non-3GPP Data Link layers	SCTP over IP over IPSec tunnel over Non-3GPP Data Link layers

 Table A.1: Overview of the protocol layers to be implemented

Overview of the protocols layers	Scenario A1 (for NTN NT UE)	Scenario A2 (for NTN NT UE, otherwise for UE if mentioned)	Scenario A3 (for the NTN NT UE, otherwise for UE if mentioned)	Scenario A4 (for the NTN terminal, otherwise for UE if mentioned)	Scenario A5 (for the NTN terminal, otherwise for UE if mentioned)
	NR Data Link layers: PDCP, RLC, MAC	NR Data Link layers: PDCP, RLC, MAC	Higher NR Data Link layers over Non-3GPP Data Link layers		
			Non-3GPP Data Link layers over Non-3GPP physical layer	Non-3GPP Data Link layers over Non- 3GPP physical layer	Non-3GPP Data Link layers over Non-3GPP physical layer
	NR Physical layer	NR Physical layer	Non-3GPP Physical layer	Non-3GPP physical layer	Non-3GPP physical layer
User Plane	For UE: PDU layer (e.g. IP) over NR Data Link layers	For UE: PDU layer (e.g. IP) over GTP- U/UDP/IP	For UE: PDU layer (e.g. IP) over GTP- U/UDP/IP	For UE: PDU layer (e.g. IP) over GTP-U/UDP/IP	For UE: PDU layer (e.g. IP) over GTP- U/UDP/IP
	For UE: GTP-U over UDP/IP	For UE: GTP-U over UDP/IP	For UE: GTP-U over UDP/IP	For UE: GTP-U over UDP/IP	For UE: GTP-U over UDP/IP
	UDP/IP over NR Data Link layers over NR Physical layer	UDP/IP over NR Data Link layers over NR Physical layers	UDP/IP over Higher NR Data Link layers, over Non-3GPP Data Link layers	Between NTN terminal and NTN Gateway: UDP/IP over Non-3GPP Data Link layers	Between NTN terminal and NTN Gateway: UDP/IP over IPsec tunnel over Non-3GPP Data Link layers
		UDP/IP over Layer 2 (e.g. Ethernet), in the terrestrial segment	UDP/IP over Layer 2 (e.g. Ethernet), in the terrestrial segment	UDP/IP over Layer 2 (e.g. Ethernet), in the terrestrial segment	UDP/IP over Layer 2 (e.g. Ethernet), within the 5G CN. At Yg1 and Yg2 interfaces: UDP/IP over IPsec tunnels over Layer 2 (e.g. Ethernet).
	NR Data Link layers: SDAP, PDCP, RLC, MAC	NR Data Link layers: SDAP, PDCP, RLC, MAC	Higher NR Data Link layers: SDAP, PDCP, RLC, over Non-3GPP Data Link layers		
			Non-3GPP Data Link layers over Non-3GPP physical layer	Non-3GPP Data Link layers over Non- 3GPP physical layer	Non-3GPP Data Link layers over Non-3GPP physical layer
	NR Physical layer	NR Physical layer	Non-3GPP Physical laver	Non-3GPP Physical	Non-3GPP Physical

A.8 Performance considerations provided by the relaying & multiplexing functions in the NTN NT UE

The NTN NT UE endorses both the roles of a relay, multiplexer node and NTN terminal. The amount of Radio Resources allocated to the NTN NT UE for the benefits of the relayed 5G UEs could be smaller than the amount of Radio Resource allocated to each UE, if they were equipped with satellite connection, in a one to one scheme, as explained in the following.

The NTN NT UE aggregates the traffic from/to multiple local UEs via their gNBs, and linked them to the centralized 5G CN through the satellite link. Such traffic multiplex ensures smoother variations load (i.e. higher predictable load) than a single UE traffic (respectively traffic forwarded by a single gNB), making the satellite radio resource allocation process more efficient, compared to a Direct access scheme. It is more efficient in terms of higher radio resource usage, according to statistical multiplexing gain principle (see Clause A.5) and into lower access delays for user services (see note).

NOTE: The NTN NT UE as NTN terminal, can negotiate the satellite radio resource for all UEs, within a given envelope of resource, when accessing the satellite link and further, if needed. This mechanism may lead to gain in terms of allocated satellite radio resource, for the UEs. The gain in allocated resource will increase as the number of multiplexed UE flows grows and as the UE flows rates are varying [i.12] and [i.13].

The NTN NT UE will also demand the access to the Core Network via the NTN, initially and furthermore at each NTN NT UE mobility event, making the system access to the satellite link(s) transparent for all the UEs served by the same NTN NT UE and same NTN gateway. But the characteristics of the satellite link could have implications on system procedures ETSI TS 123 502 [i.10] in terms of timeouts and logical synchronization between the sequencing of moving NTN NT UE related procedures and the sequencing of UE related procedures, while the UE is attached to the gNB served by the NTN NT UE (respect. while the UE is attached to the NTN Relay UE). Nevertheless, gains in terms of time are expected, as discussed below.

Once the access for NTN NT UE has been established, the UEs will access the system via satellite links that are already set up. The UE Radio Bearers are set up and transferred on NTN NT UE Data Radio Bearer(s) and GTP tunnels that are already established. This mechanism may lead to gain in terms of access response time and transfer delay, for the benefits of UEs, as the numbers of UEs and multiplexed UE flows grow.

A.9 Performance considerations provided by the relaying & multiplexing functions in the VSAT

The VSAT endorses both the roles of relay (at IP level), multiplexer node and satellite/HAPS terminal. The amount of Radio Resources allocated to the VSAT for the benefits of the relayed 5G UEs could be smaller than the amount of Radio Resource allocated to each UE, if they were equipped with satellite connection, in a one to one scheme, as explained in the following.

Unlike the NTN NT UE, the UE access management is not applicable to the VSAT. The VSAT cannot negotiate directly the radio resource with a NTN LT gNB.

The radio resources are scheduled at management level, then requested by the Resource Manager to a local agent within the VSAT.

Furthermore, the UE mobility management is not applicable to the VSAT. The radio resource cannot be requested to a NTN LT gNB in order to prepare a handover, to prevent from service, connectivity discontinuity. Unlike for the scenario A2, for which there is an opportunity to design a Radio Resource coordination between UE, NTN UE and NTN LT gNB, as discussed in Clause 6.3.4.

Nevertheless, the VSAT may provide benefits to the UEs as a multiplexer node, as explained below.

The VSAT aggregates the traffic from/to multiple local UEs via their gNBs, and linked them to the centralized 5G CN through the satellite link. Such traffic multiplex ensures smoother variations load (i.e. higher predictable load) than a single UE traffic (respectively traffic forwarded by a single gNB), making the satellite radio resource allocation process more efficient, compared to a Direct access scheme. It is more efficient in terms of higher radio resource usage, according to statistical multiplexing gain principle (see Clause A.5) and into lower access delays for user services (see note).

NOTE: The VSAT as NTN terminal, can provision the satellite radio resource for all UEs, within a given envelope of resource, when accessing the satellite link and further, if needed. This mechanism may lead to gain in terms of allocated satellite radio resource, for the UEs. The gain in allocated resource will increase as the number of multiplexed UE flows grows and as the UE flows rates are varying [i.12] and [i.13].

The VSAT will also demand the access to the Core Network via the NTN, initially making the system access to the satellite link(s) transparent for all the UEs served by the same VSAT and same NTN gateway. But the characteristics of the satellite link could have implications on system procedures in terms of timeouts. Nevertheless, gains in terms of time are expected, as discussed below.

Once the access for VSAT has been established, the UEs may access the system via satellite links that are already set up. The UE Radio Bearers are set up and transferred on NTN NT UE Data Radio Containers(s) in the space segment, depending on the used NTN access technology and GTP tunnels that are already established, in the 5G CN. This mechanism may lead to gain in terms of access response time and transfer delay, for the benefits of UEs, as the numbers of UEs and multiplexed UE flows grow.

A.10 Latency estimations, per deployment scenario and per scenario A1 architecture option

A.10.1 Methodology for latency estimations

Latency range estimations are computed per deployment scenario and scenario A1 architecture option. They are based on hop counts considerations and propagation delays computation per scenario deployment 3GPP TR 38.811 [i.6].

The hops are counted as following, per scenario A1 architecture option.

Scenario A1 - Option 1:

- NTN NT UE satellite: 1 hop (user link).
- Satellite gateway: 1 hop (feeder link).
- Gateway NTN LT gNB: 1 hop (wired link).
- NTN LT gNB 5G CN: 1 hop (wired link).

Scenario A1 - Option 2:

- NTN NT UE satellite: 1 hop (user link).
- Satellite gateway: 1 hop (feeder link).
- Gateway NTN gNB-DU: 1 hop (wired link).
- NTN gNB-DU NTN gNB-CU: 1 hop (wired link).
- NTN gNB-CU 5G CN: 1 hop (wired link).

The latency due to one hop between the NTN NT UE and the bent-pipe satellite and the latency between the bent-pipe satellite and the gateway are computed according to 3GPP TR 38.811 [i.6].

Two elevation angles are considered for the NTN terminal:

- Terminal at the edge of the satellite coverage: 10° (leads to longer delay).
- Terminal at NADIR: 90° (leads to shorter delay).

While the elevation angle for the gateway is set to 5° (worst case).

The main component of the latency is produced by the space segment, which is much longer than the latency on the ground segment. Nevertheless, the latency component produced by the ground segment is taken into account. It is assumed that within the ground segment, a hop over a wired link between two equipment takes 50 ms time.

A.10.2 Latency for GEO deployment scenario

The latency estimations for the GEO scenario deployment, are described in table A.2.

Performance Indicator	Scenario deployment	Scenario A1 - Option 1	Scenario A1 - Option 2
One-way latency range estimation (ms) between the NTN NT UE and the NTN enabled gNB distributed unit.	GEO at 35 786 km, NTN terminal at 10°	N/A	322, 4
	GEO at 35 786 km, NTN terminal at 90° (nadir)	N/A	306, 4
One-way latency range estimation (ms) between the NTN NT UE and the NTN enabled gNB central unit.	GEO at 35 786 km,	322, 4	372, 4
	GEO at 35 786 km, NTN terminal at 90° (nadir)	306, 4	356, 4
One-way latency range estimation (ms) between the NTN NT UE and the Core Network.	GEO at 35 786 km, NTN terminal at 10°	372, 4	422, 4
	GEO at 35 786 km, NTN terminal at 90° (nadir)	356, 4	406, 4

TableA.2: Worst case one way Latency estimations for the GEO scenario deployment

A.10.3 Latency for MEO at 10 000 km scenario deployment

The latency estimations for the MEO scenario deployment, are described in table A.3.

able A.3: Worst case one way،	Latency estimations for the MEO	scenario deployment
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Performance Indicator	Scenario deployment	Scenario A1 - Option 1	Scenario A1 - Option 2
One-way latency range estimation (ms) between the NTN NT UE and the NTN enabled gNB distributed unit.	MEO at 10 000 km NTN terminal at 10°	N/A	145,2
	MEO at 10 000 km NTN terminal at 90° (nadir)	N/A	131,8
One-way latency range estimation (ms) between the NTN NT UE and the NTN enabled gNB central unit.	MEO at 10 000 km	145,2	195,2
	MEO at 10000 km NTN terminal at 90° (nadir)	131,8	181,8
One-way latency range estimation (ms) between the NTN NT UE and the Core Network.	MEO at 10 000 km NTN terminal at 10°	195,2	245,2
	MEO at 10 000 km NTN terminal at 90° (nadir)	181,8	231,8

A.10.4 Latency for LEO at 600 km deployment scenarios

The latency estimations for the LEO scenario deployment, are described in table A.4.

Performance Indicator	Scenario deployment	Scenario A1 - Option 1	Scenario A1 - Option 2
One-way latency range estimation (ms) between the NTN NT UE and the NTN enabled gNB distributed unit.	LEO at 600 km NTN terminal at 10°	N/A	64,2
	LEO at 600 km NTN terminal at 90° (nadir)	N/A	59,8
One-way latency range estimation (ms) between the NTN NT UE and the NTN enabled gNB central unit.	LEO at 600 km	64,2	114,2
	NIN terminal at 10°		
	LEO at 600 km NTN terminal at 90° (nadir)	59,8	109,8
One-way latency range estimation (ms) between the NTN NT UE and the Core Network.	LEO at 600 km NTN terminal at 10°	114,2	164,2
	LEO at 600 km NTN terminal at 90° (nadir)	109,8	159,8

Table A 4. Worst case one way	I stancy actimations for	or tha LEO cooporid	o donlovmont
TADIE A.4. WUISI LASE UNE WA	y Latency estimations it	JI LITE LEU SCETIATIO	o deployment

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A.11 Other performance and dimensioning considerations

Other performance and dimensioning considerations per scenario A1 architecture are discussed in table A.5.

option 1. Thus, the same NTN NT UE cost is expected as for option 1.

Performance indicator	Scenario A1 architecture option 1	Scenario A1 architecture option 2
3GPP access type of the NTN NT UE (recall)	Direct Access for NTN enabled NT UE and for NTN enabled Relay UE, when implemented. The Access controller serving the NTN NT UE is remote and centralized.	Direct Access for NTN enabled NT UE and for NTN enabled Relay UE, when implemented. The Access controller serving the NTN NT UE is remote and distributed.
Sharing of Bandwidth allocated to the NTN NT UE and Sharing of processing capacities	The NTN NT UE has its own user channel on the NR interface, for a given served area and will not to share it with other terminals (once the Data transfer mode is established). Nevertheless, the amount of radio resource is shared by all terminals on a given served area. The Access Controller processing capacities are dedicated to the NTN UEs served by same gateway.	Same as for option 1 on the NR interface. On the ground segment, these flows are processed by the same NTN gNB- CU, per RAN. The processing capacities of the NTN gNB-CU and its links towards the 5G CN are shared by the NTN UEs served by all the gateways.
Dimensioning	A co-located NTN LT gNB is required per hosting gateway.	A NTN gNB distributed unit is required per hosting gateway. A NTN gNB central unit is required, at least, per NTN 5G RAN.
Complexity trends	Reference model. The global complexity depends on the nr of NTN gNB, distributed and central units, the nr of gateway to implement.	The global complexity depends on the Nr of NTN gNB, distributed and central units, the nr of gateway to implement. There is no expected gain if only one NTN gNB-DU is implemented. A distributed unit NTN gNB-DU per gateway is less expensive than a centralized NTN LT gNB per gateway. The global cost will decrease as the ratio Nr of NTN gNB- DU vs. Nr of NTN gNB-CU increases. When the NTN NT UE interworks with the local gNB, for supporting Indirect UE, its architecture is the same as for

Table A.5: Other performance and dimensioning considerations

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A.12 Coordination with management systems

When the NTN management system (acting as a Transport Network) and the 3GPP management system of the MNO (3GPP management system) are not integrated into a single management entity, coordination between 3GPP and Transport Network managements systems is needed.

As depicted in "Figure 4.7.1: Example of coordination between 3GPP and TN management systems" in ETSI TS 128 530 [i.24] represented below, an advanced interface between the NTN Management System should be implemented in order to allow some advanced feature such as ensuring the support of End to End QoS, coordinated resources allocation.



Figure A.26: Example of coordination between 3GPP and TN Management systems (ETSI TS 128 530 [i.24])

To allow proper functioning of such system, agreement is established between the 3GPP management system and the TN management system in order to exchange required information such as flow details and non-usage of encryption around the NTN system.

History

Document history			
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