

Technology Management Wireless

AN EXPLORATION OF NON-TERRESTRIAL NETWORK (NTN) FROM CURRENT CHALLENGES TO FUTURE EVOLUTION

Rohde & Schwarz Taiwan
Clark Lin
Application Team Manager
2024/05/31

ROHDE & SCHWARZ
Make ideas real



AGENDA

- Introduction and motivation
- Commercial NewSpace constellations
- NTN frequency and architecture aspects
- NTN RF aspects and challenges
- NTN evolution – outlook

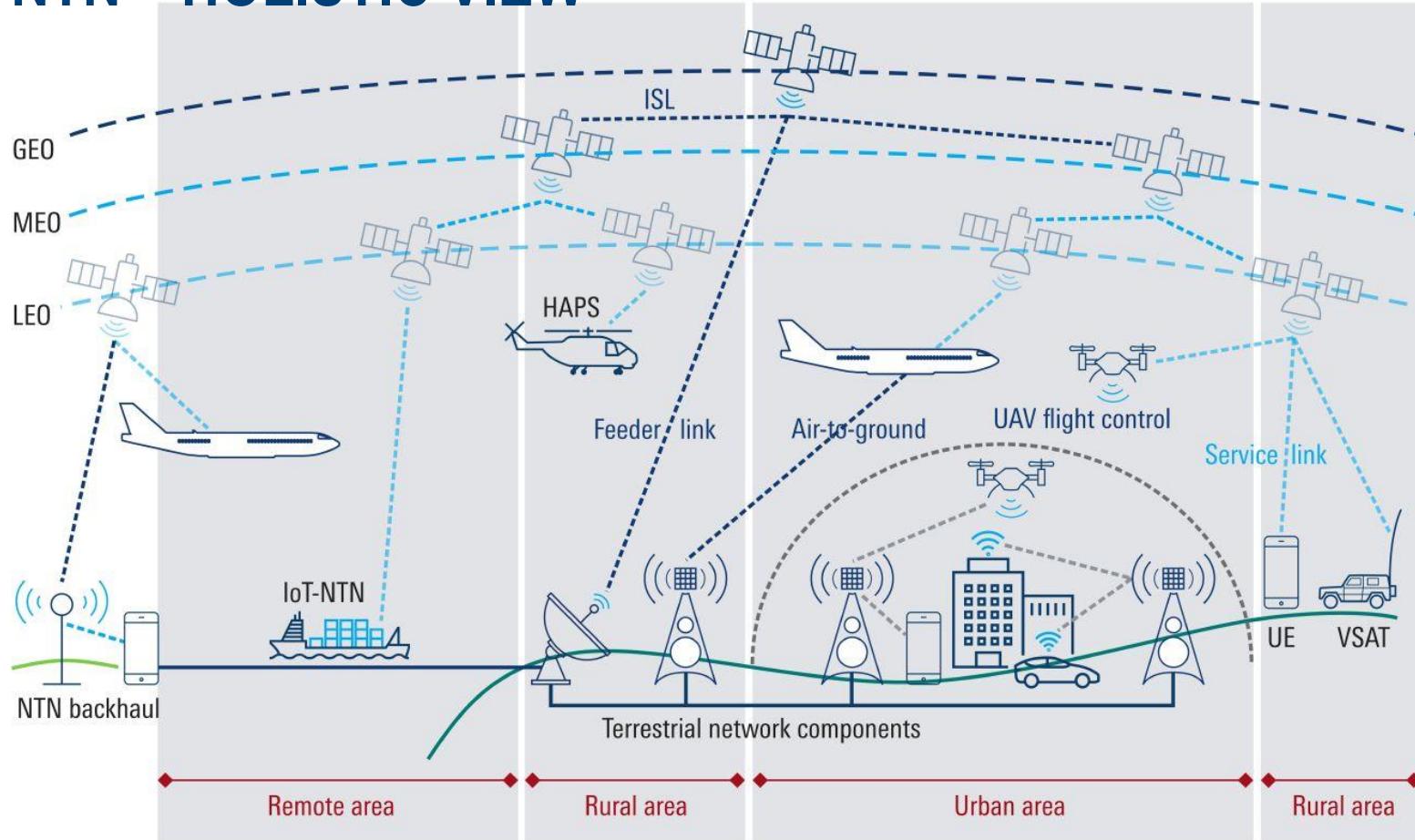




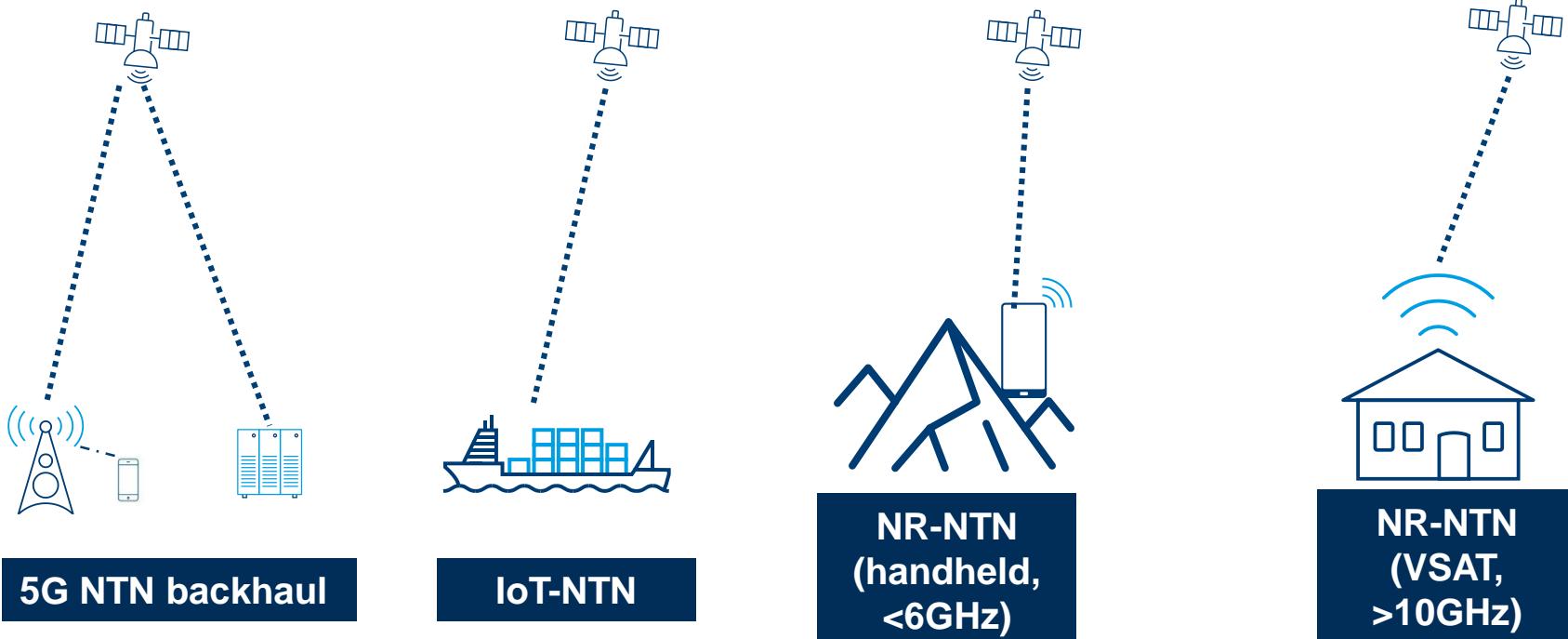
Non-terrestrial networks (NTN)

5G NTN INTRODUCTION AND MOTIVATION

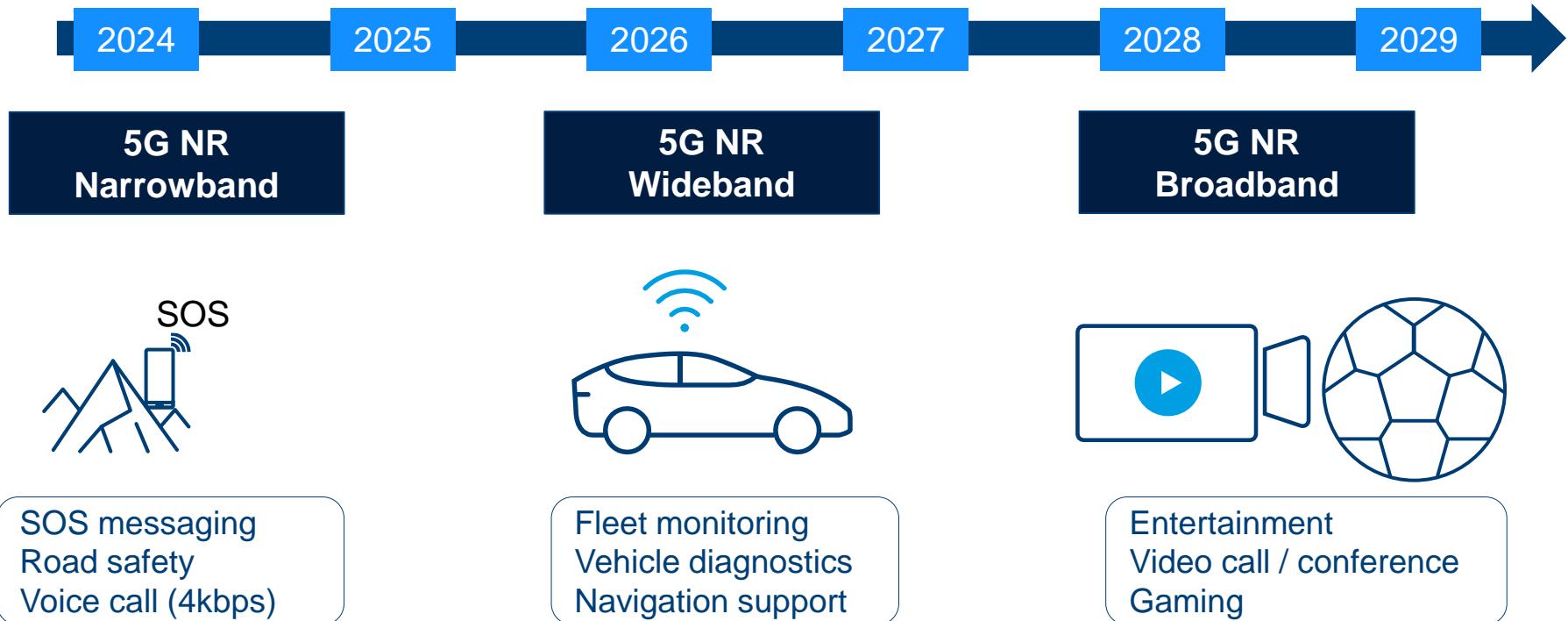
5G NTN – HOLISTIC VIEW



5G-NTN FOUR FACETS (PERSPECTIVE USE CASE)



5G-NTN DEPLOYMENT TIMELINE (E.G. AUTOMOTIVE)



NewSpace CONSTELLATIONS

Operator	Satellite system (deployed)	Spectrum	Technology	Operational	Services
Space X (Starlink)	12000+ (3580)	Ku-band	Proprietary	Yes	Broadband
OneWeb	648 (542)	Ku-band	Proprietary	TBD	Broadband
Kuiper	3236 (0)	Ka band	Proprietary	Estimated 2024	Broadband
Galaxy Space	1000 (7)	Q/V spectrum	Proprietary	TBD	Broadband
Boeing	147 NGSO (1)	V band	Proprietary	TBD	TBD
Inmarsat	14 GEO (14)	TBD	Proprietary	TBD	Broadband to IoT
Telesat	188 (2)	C, Ku, Ka bands	Proprietary	TBD	Broadband
Echostar	10 GEO (10)	Ku, Ka, S bands	Proprietary	Yes	Broadband
HughesNet	3 GEO (2)	Ka band	Proprietary	Yes	Broadband
Viasat	4 GEO (4)	Ka band	Proprietary	Yes	Broadband





Non-terrestrial networks (NTN)

5G NTN FREQUENCY ASPECTS & ARCHITECTURE

5G NTN SPECTRUM & UE ASPECTS

FR1: NTN bands

Band	Region	Related bands	Band type	UL low MHz	UL high MHz	DL low MHz	DL high MHz
n253	EU	L-ext	FDD	1668.0	1675.0	1518.0	1525.0
n254	EU	L+53	FDD	1610.0	1626.5	2483.5	2500.0
n255	EU	n65	FDD	1626.5	1660.5	1525.0	1559.0
n256	NA	n24	FDD	1980.0	2010.0	2170.0	2200.0

UE aspects for NTN

Link level assumptions	FR1 NTN-UE or IoT-UE	FR2-1N VSAT UE
TX power	23dBm ± 2dB (200mW) (note: more likely 23 dBm + 2dB)	33 dBm (2W)
Antenna type	Omnidirectional	60cm aperture diameter
Antenna gain	TX/RX 0dBi	TX: 43.2 dBi / RX: 39.7 dBi
Noise figure	9 dB	1.2 dB
Polarization	Linear (dual polarized possible)	Circular polarized phased array antenna

FR2-1N: new NTN bands (R18). FR2-1N range 17.3 – 52.6GHz

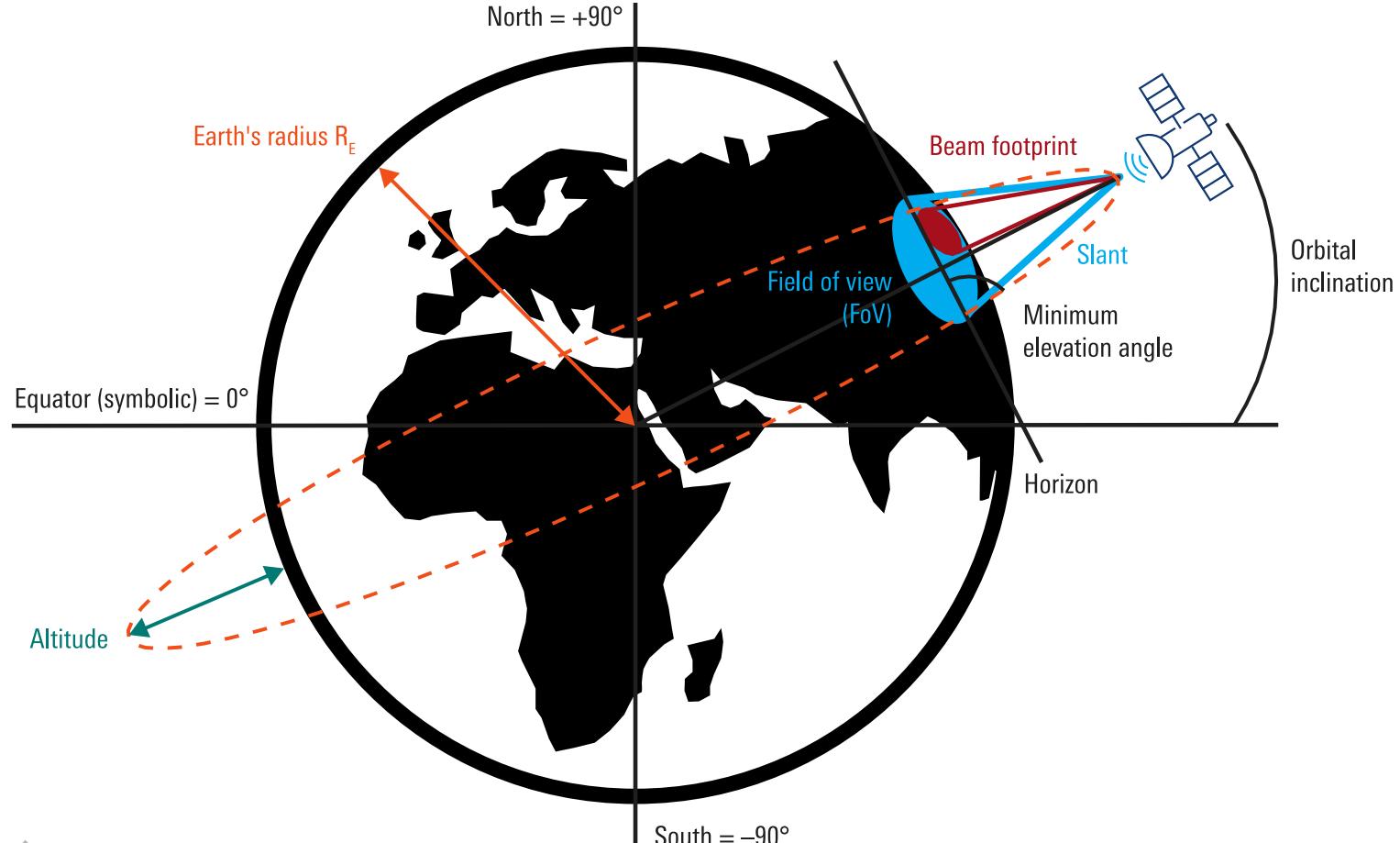
Band	Region	Band type	UL low MHz	UL high MHz	DL low MHz	DL high MHz
n510	US	FDD	27500	28350	17300	20200
n511	US	FDD	28350	30000	17300	20200
n512	EU	FDD	27500	30000	17300	20200

„FR3“ bands Ku: requested in R19

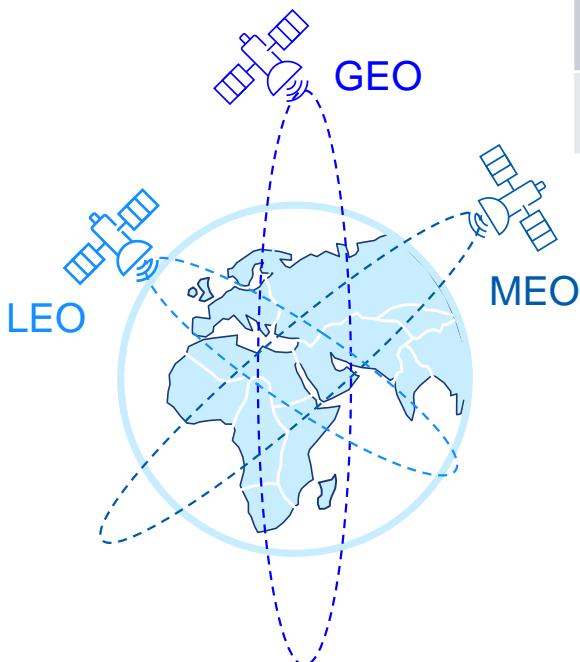
Band	Region	Band type	UL (Earth to space) GHz	DL (Space to Earth) MHz
Ku	Region 1	FDD	12.75 – 13.25 & 13.75 – 14.5	10.7 – 12.75
Ku	Region 2	FDD	12.75 – 13.25 & 13.75 – 14.5	10.7 – 12.7



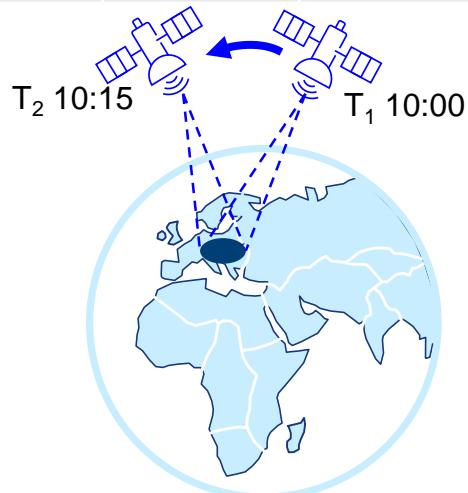
5G NTN: CONSTELLATIONS



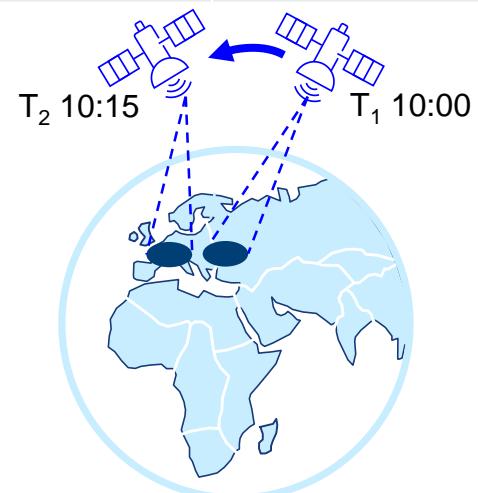
5G NTN: CONSTELLATIONS



Platform	Altitude	Orbit	Beam footprint
GEO	35786 km	Position fixed in elevation/azimuth to a given Earth point	200 – 3500 km
LEO	500-2000 km	Circular around the Earth. Not stationary to a given Earth point	100 – 1000 km

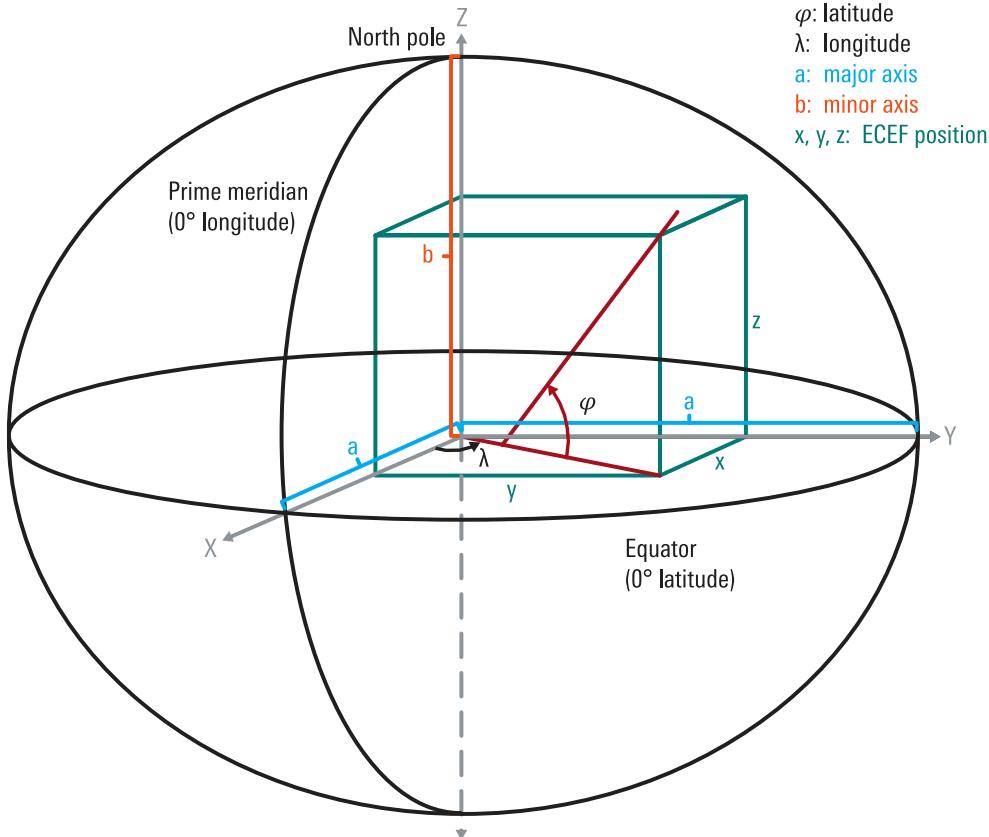


Steerable beams: Fixed with respect to Earth's surface



Fixed beams: Moving with respect to Earth's surface

5G NTN: EARTH-CENTERED, EARTH-FIXED (ECEF) COORDINATE

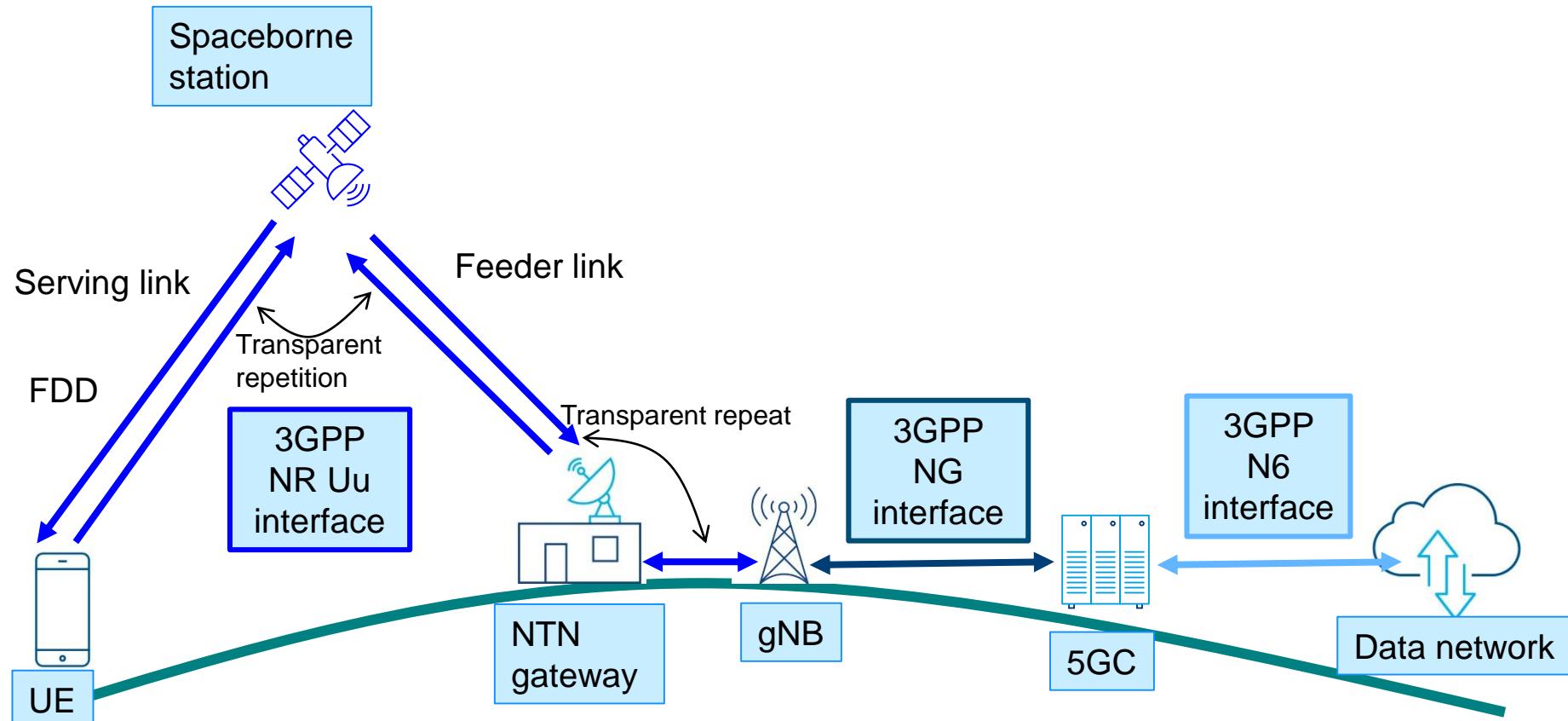




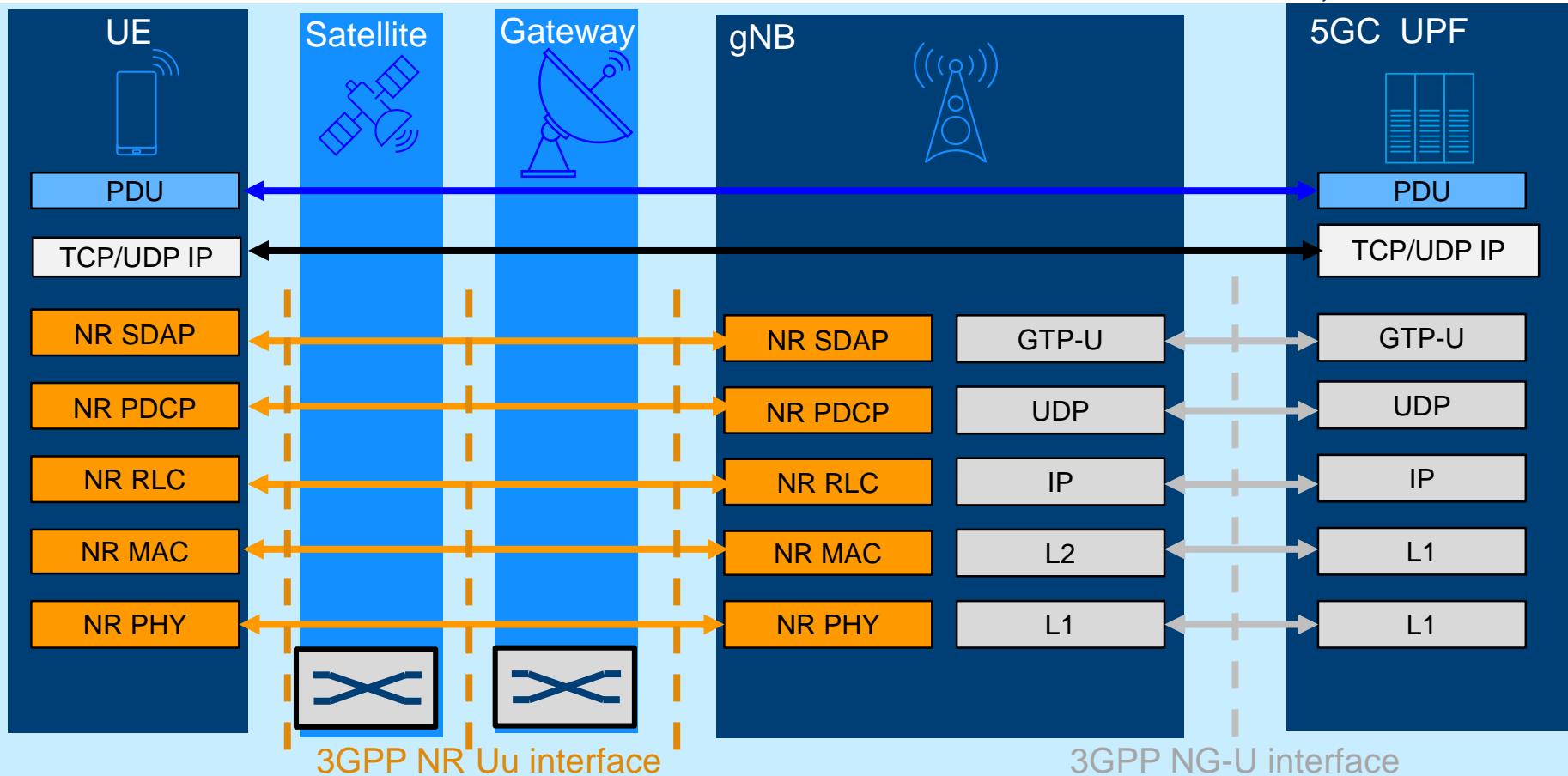
Non-terrestrial networks (NTN)

ARCHITECTURE

NTN: TRANSPARENT PAYLOAD ARCHITECTURE

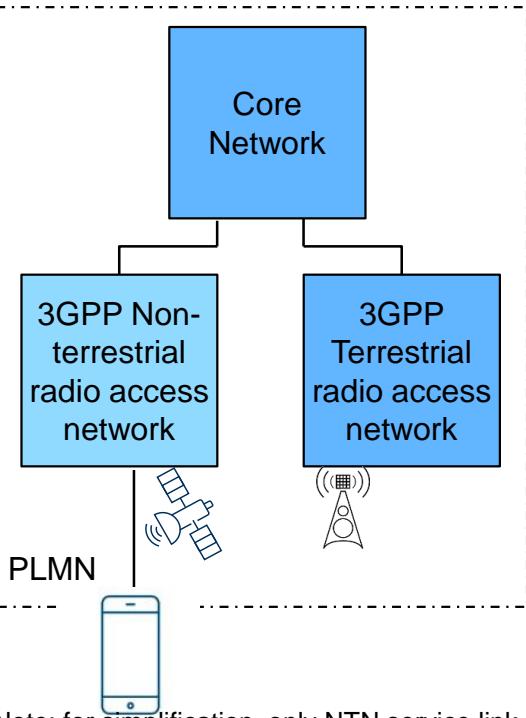


NTN: TRANSPARENT PAYLOAD - PROTOCOL STACK, U-PLANE

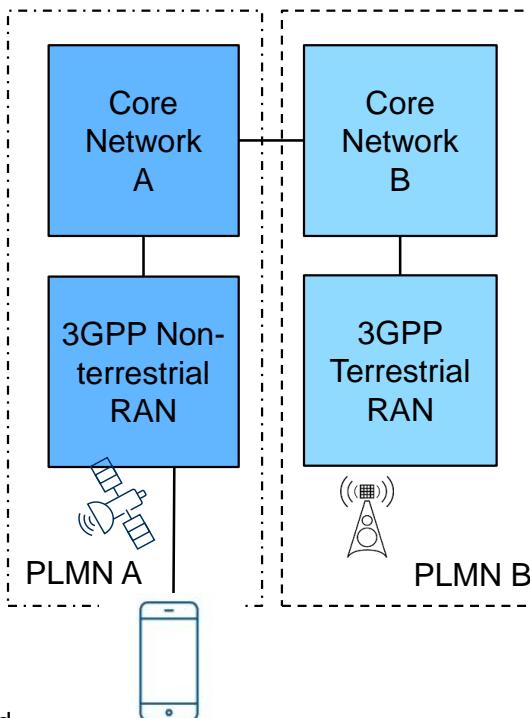


5G NTN INTEGRATION SCENARIOS WITH 5GC

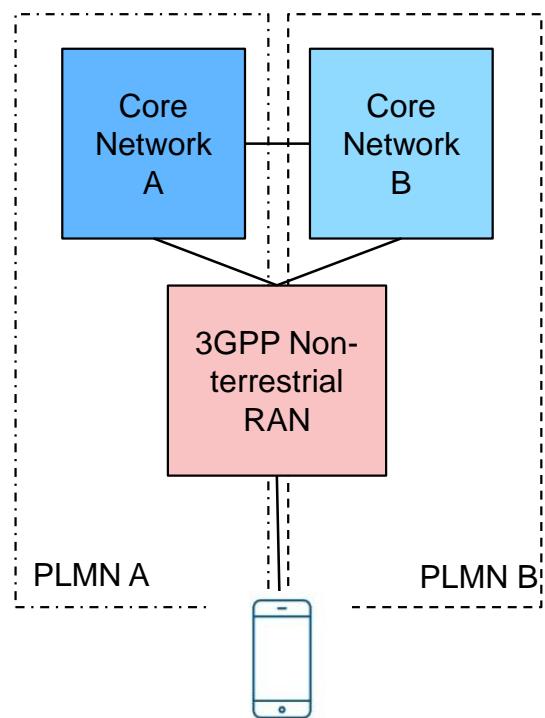
Same PLMN



Roaming

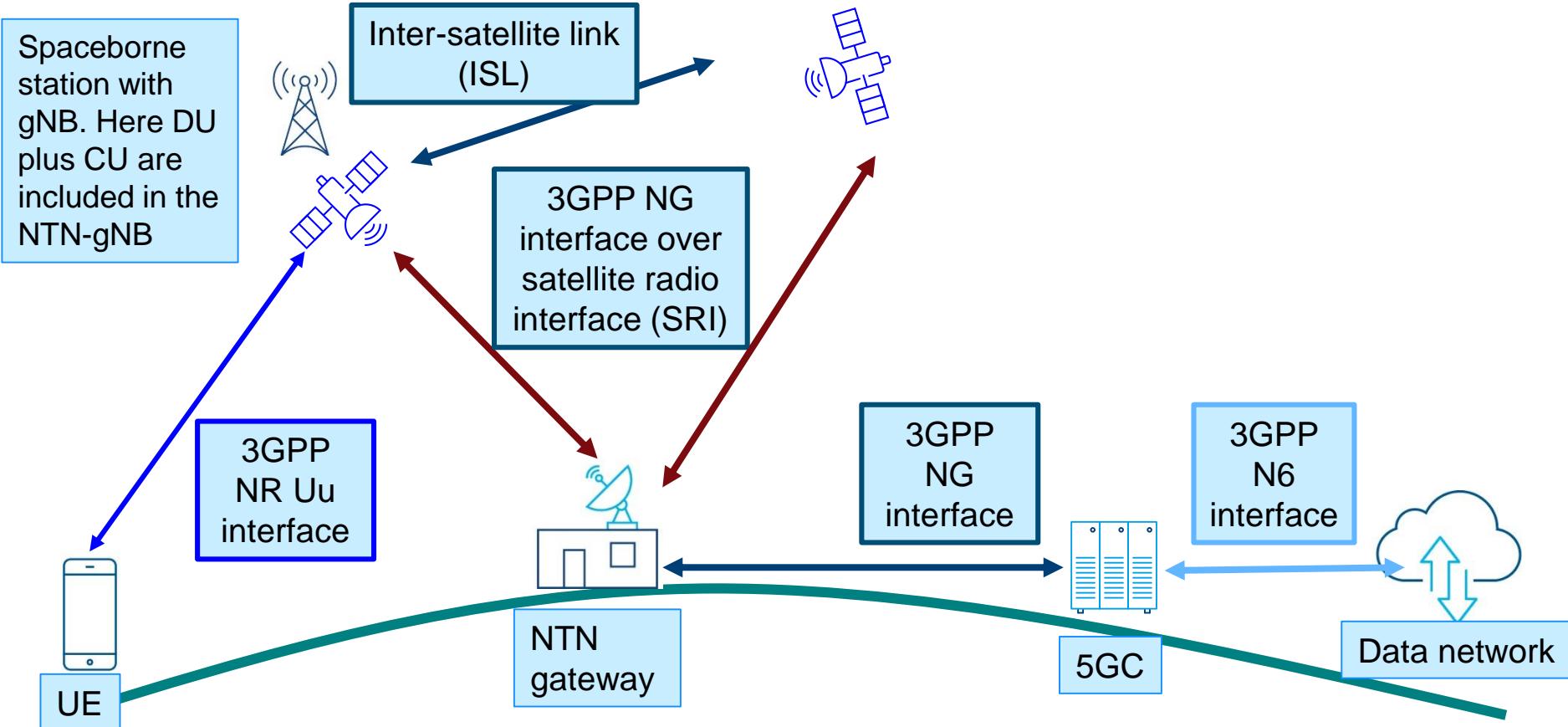


RAN sharing

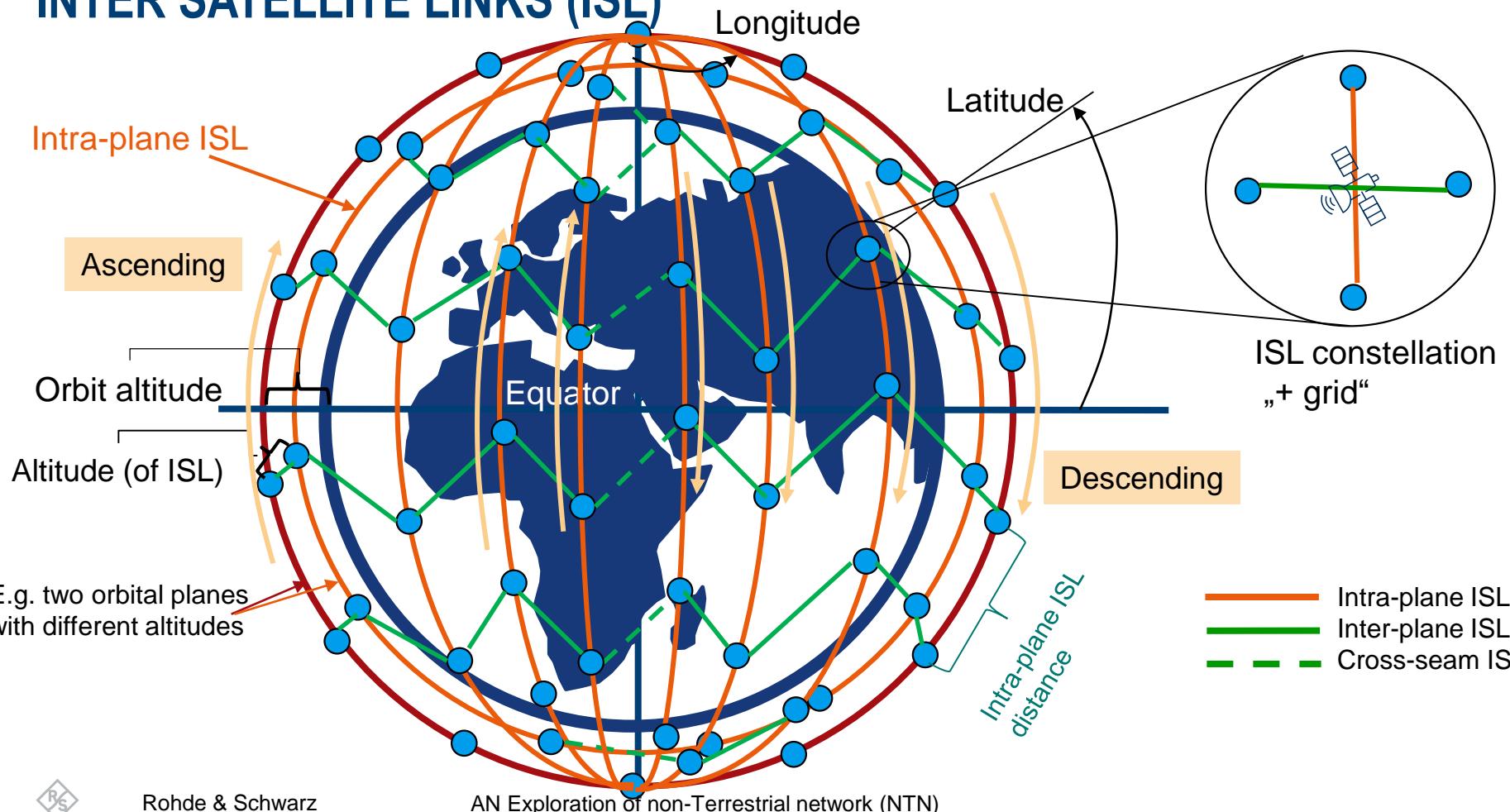


Note: for simplification, only NTN service link is depicted

NTN: REGENERATIVE PAYLOAD ARCHITECTURE



INTER SATELLITE LINKS (ISL)



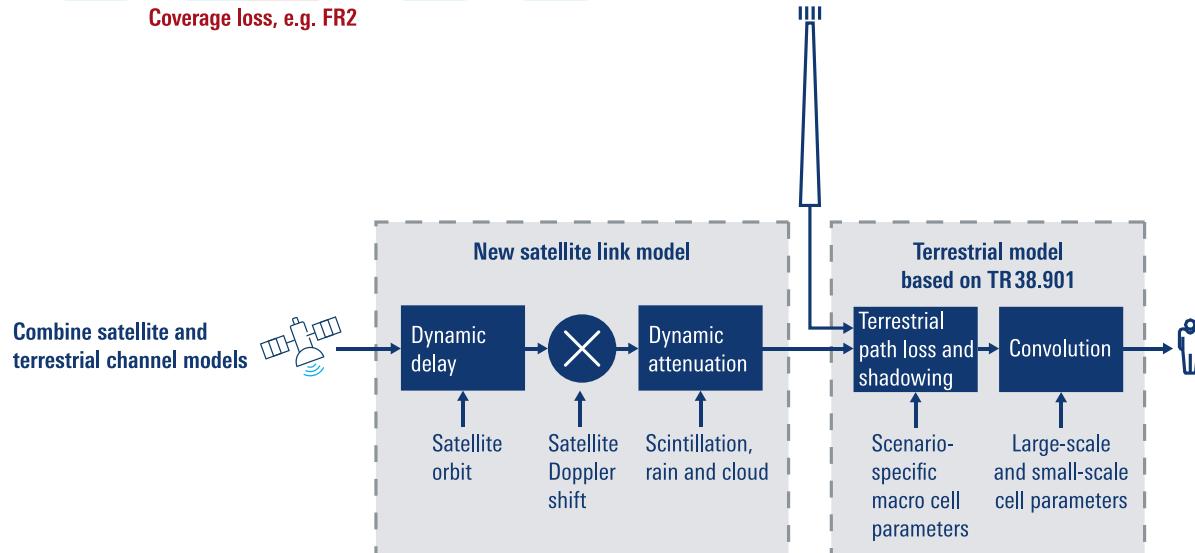
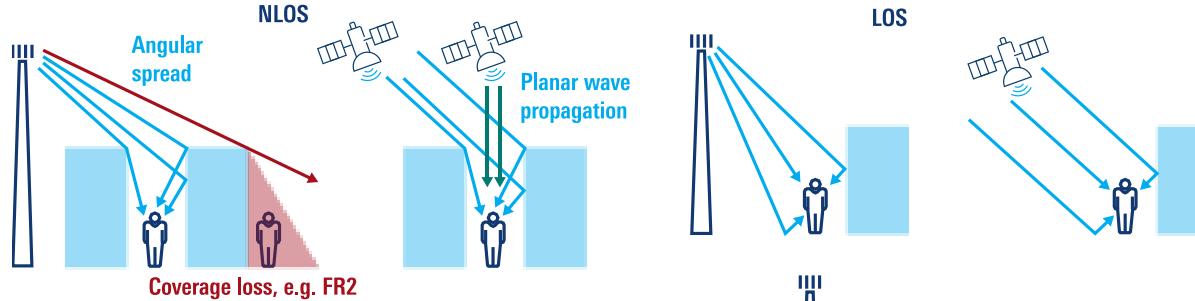


Non-terrestrial networks (NTN)

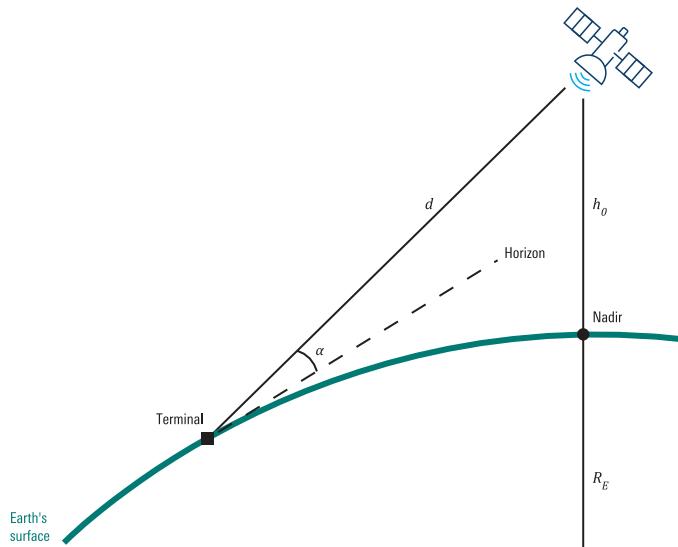
5G NTN RF ASPECTS AND SOME CHALLENGES

NTN: FADING ASPECTS

Propagation differences between terrestrial and non-terrestrial scenarios



NTN: FADING ASPECTS, PATHLOSS



$$d = \sqrt{R_E^2 \sin^2 \alpha + h_0^2 + 2h_0 R_E} - R_E \sin \alpha$$

α : elevation angle (angle at which the UE sees the satellite, e.g. minimum elevation, approx. 10°)

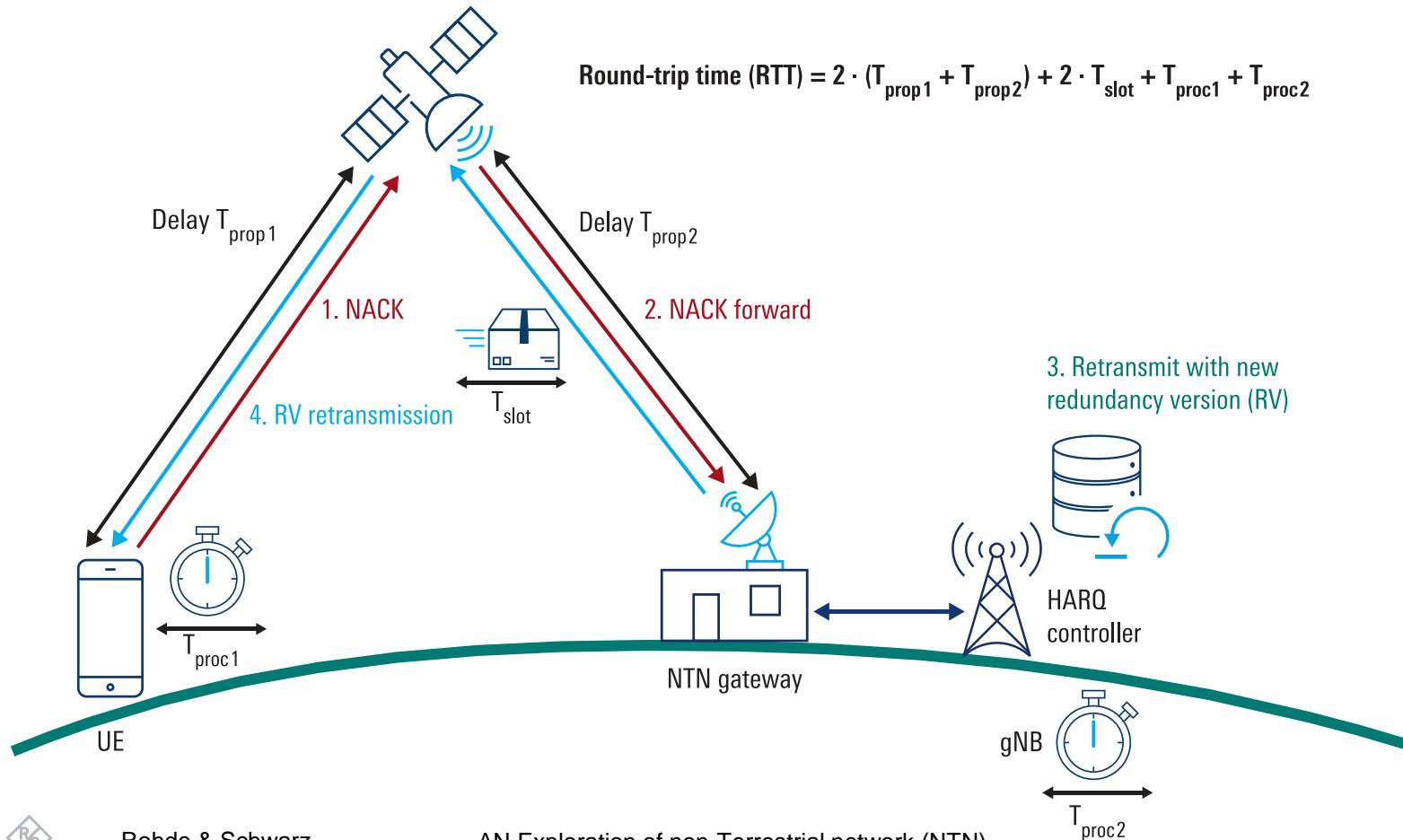
R_E : earth's radius = 6371 km

h_0 : satellite altitude

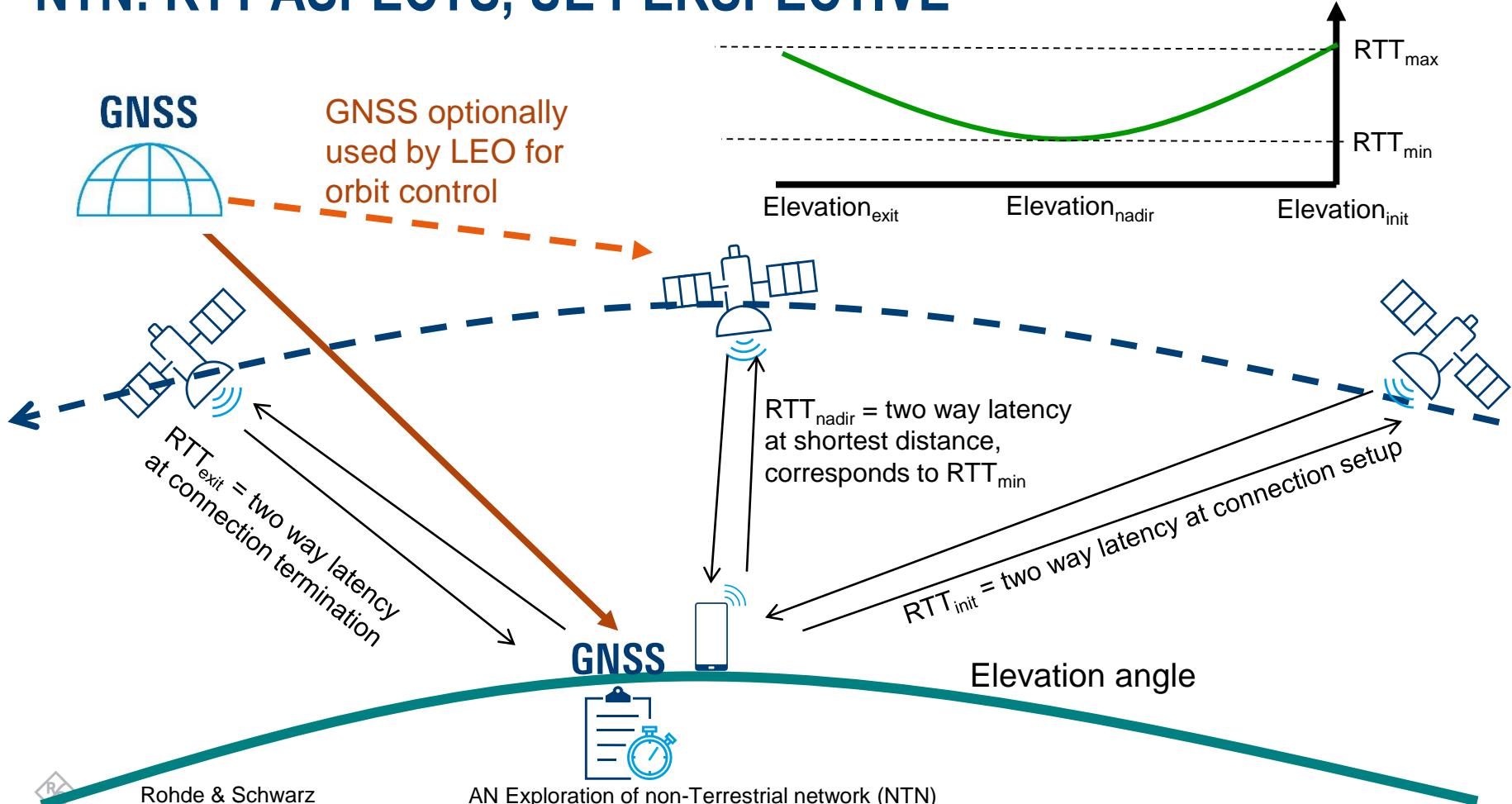
$$CNR = EIRP + G/T - k - FSPL - PL_g - PL_s - PL_e - PL_{AD} - B$$

Transmission mode	DL	UL
Frequency	2 GHz	2 GHz
TX: EIRP	78.8 dBm	23 dBm
RX: G/T	-31.6 dB · K ⁻¹	1.1 dB · K ⁻¹
Bandwidth	30 MHz	0.4 MHz
Free space path loss	159.1 dB	159.1 dB
Atmospheric loss	0.1 dB	0.1 dB
Shadow fading margin	3 dB	3 dB
Scintillation loss	2.2 dB	2.2 dB
Polarization loss	0 dB	0 dB
Additional losses	0 dB	0 dB
CNR	6.6 dB	2.8 dB

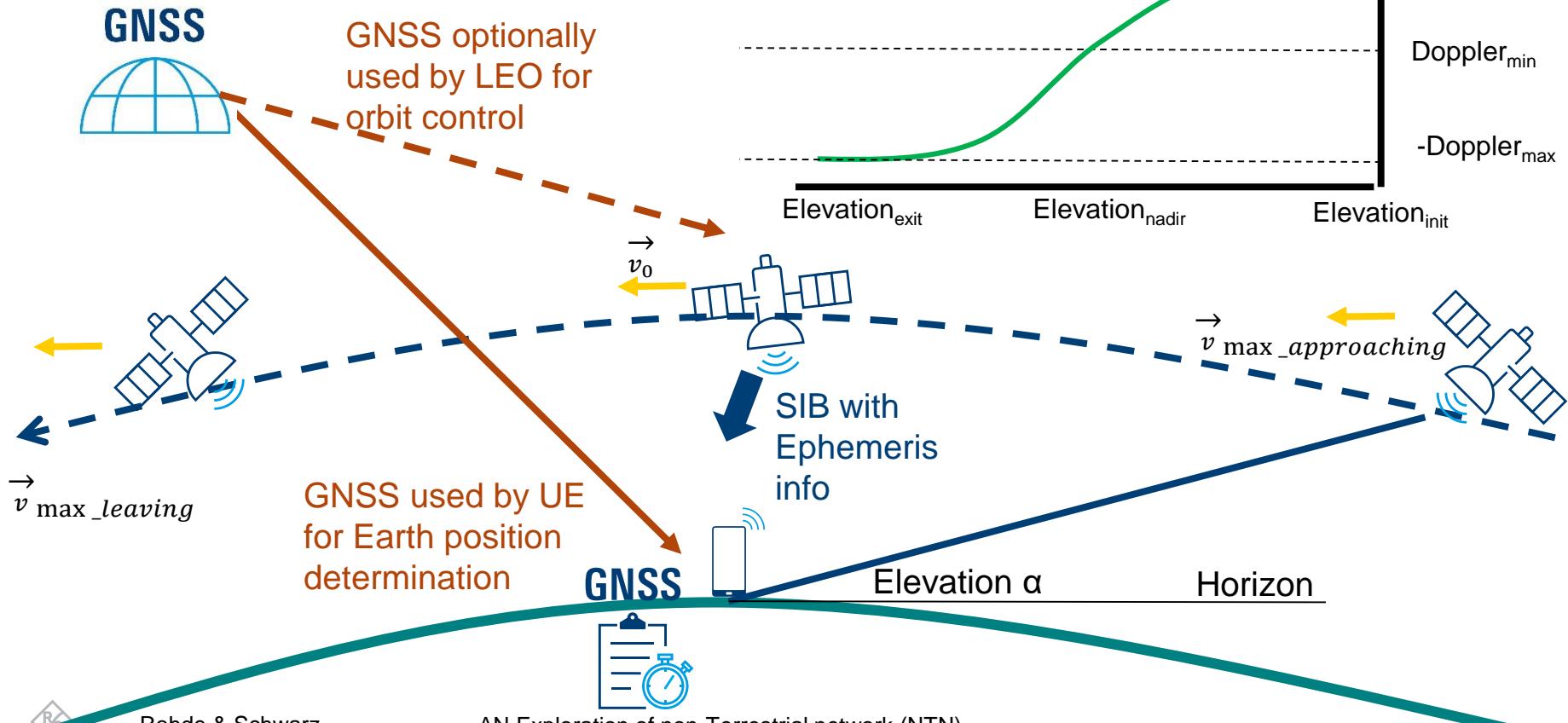
NTN: PATH DELAY, ROUND-TRIP TIME RTT



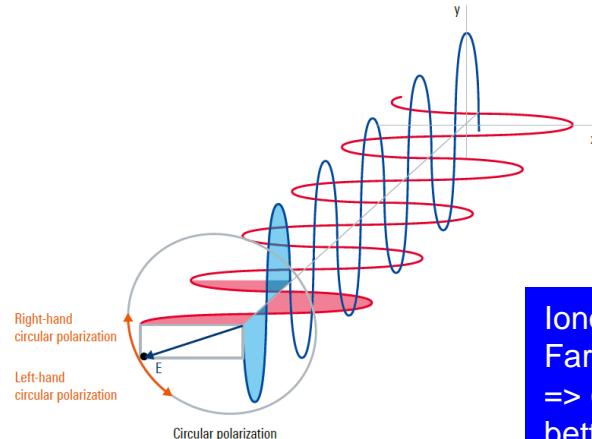
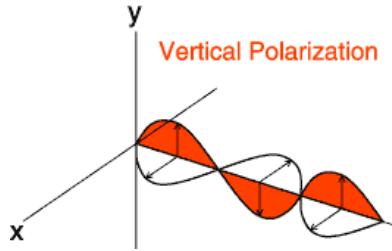
NTN: RTT ASPECTS, UE PERSPECTIVE



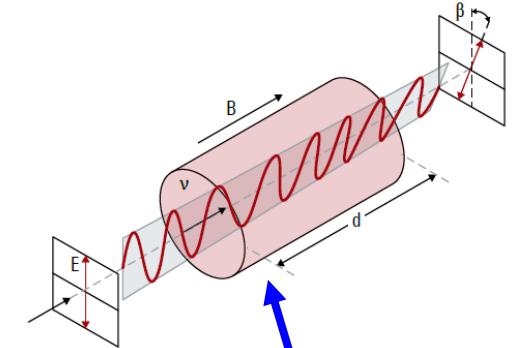
NTN: DOPPLER SHIFT RATE IN A LEO SCENARIO



REMINDER: ANTENNA POLARIZATION



Terrestrial communications often use vertical polarization.
Geometry of antennas is quasi-static

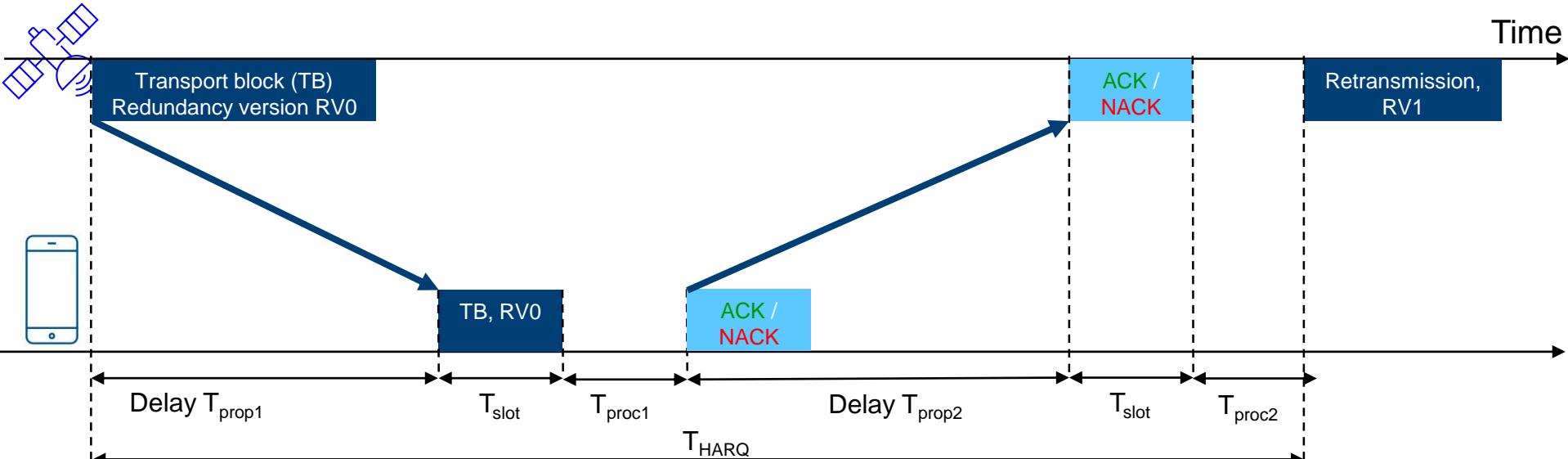


Ionosphere causes
Faraday rotation effect.
=> circular polarization is
better protected against
those anomalies



Geometric differences if satellite
moves with respect to the fixed Earth-
bound station => linear polarization
may lose alignment

NTN: ROUND-TRIP-TIME ASPECTS AND HARQ

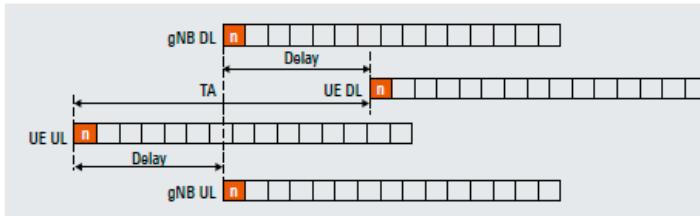


Constellation	T_{HARQ} max	#HARQ processes	UE side feasibility
Terrestrial	16 ms	16	Rel. 15
LEO	50 ms	50 theoretical 3GPP agrees to 32	HARQ extension
GEO	600 ms	600	For future study

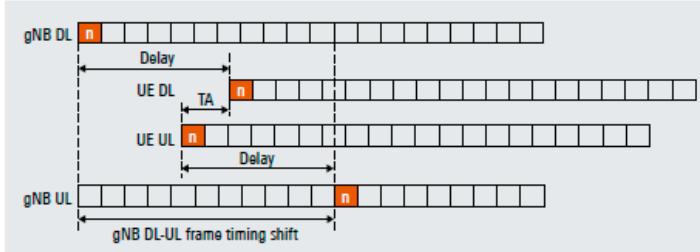
Assumption: 15 kHz
SCS and 1 ms slot duration (TR 38.811)



NON TERRESTRIAL NETWORK CHALLENGES



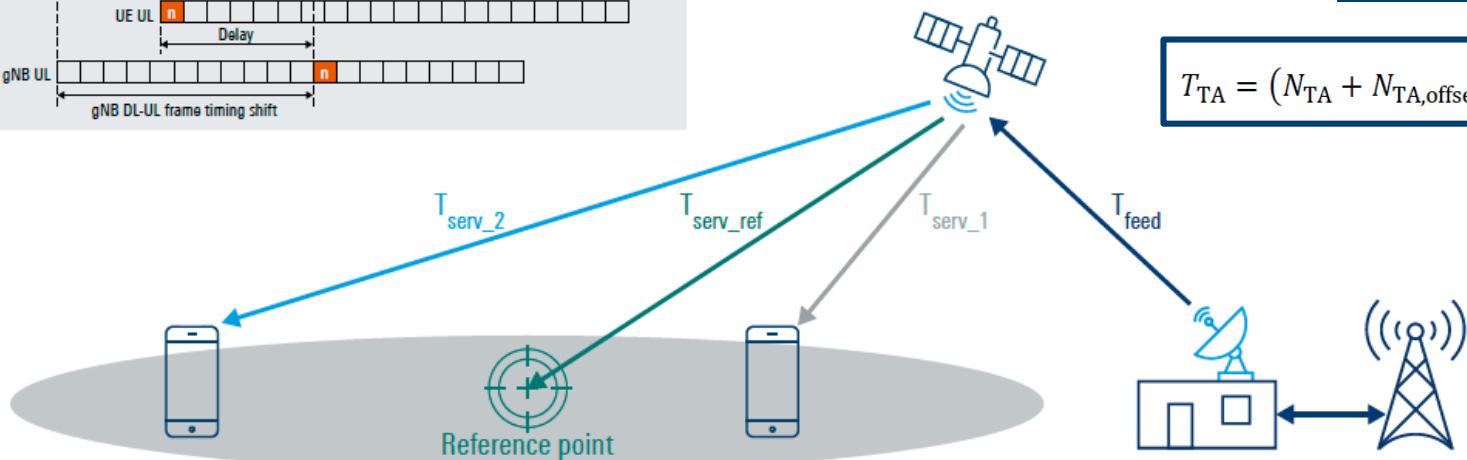
Idea to adjust large timing advance values:
⇒ large TX – RX offset in the UE



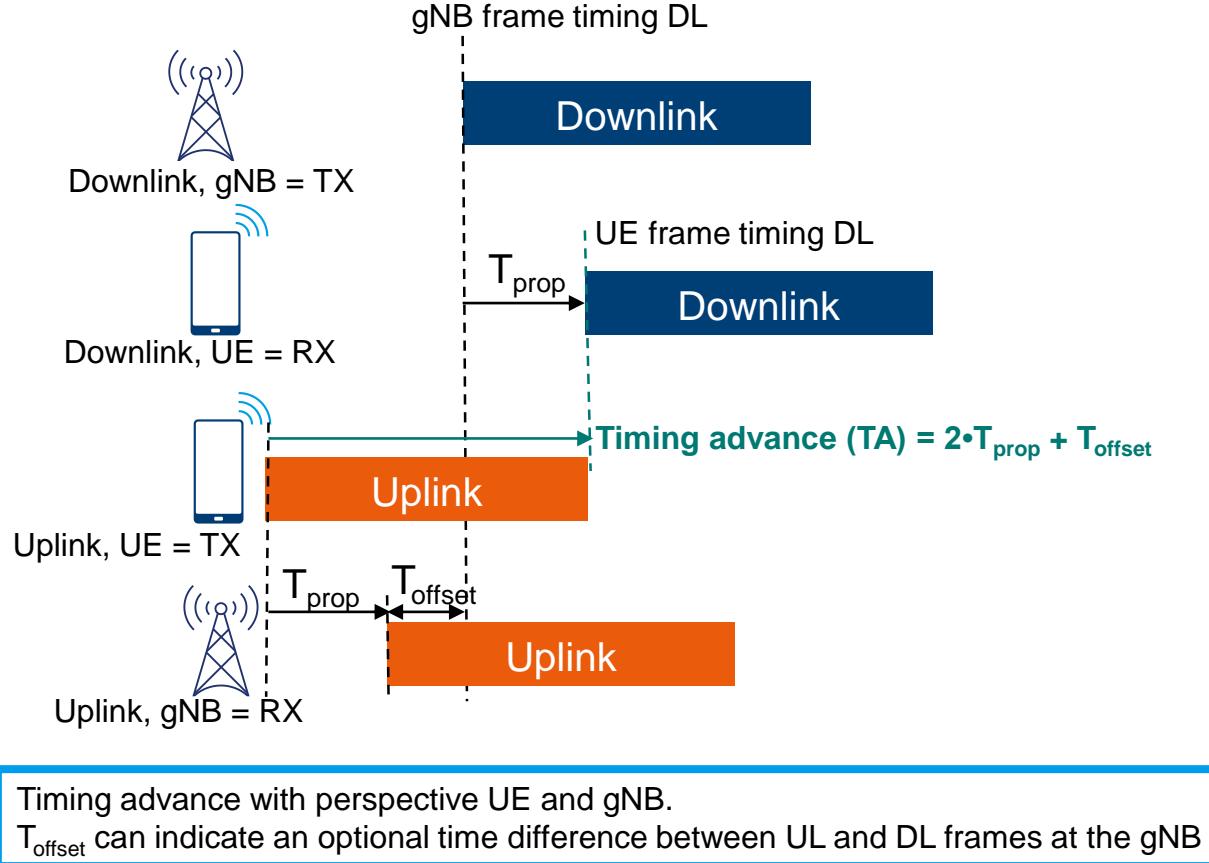
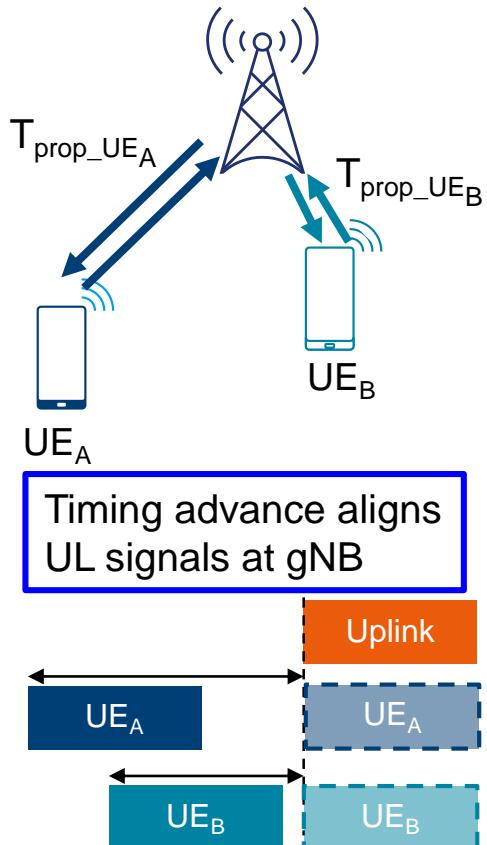
Idea to adjust shorter timing advance values:
⇒ large TX – RX offset in the gNB
⇒ possible SFN shift in gNB for UL/DL

Timing advance depends
on UE and cell specific
values + TA control

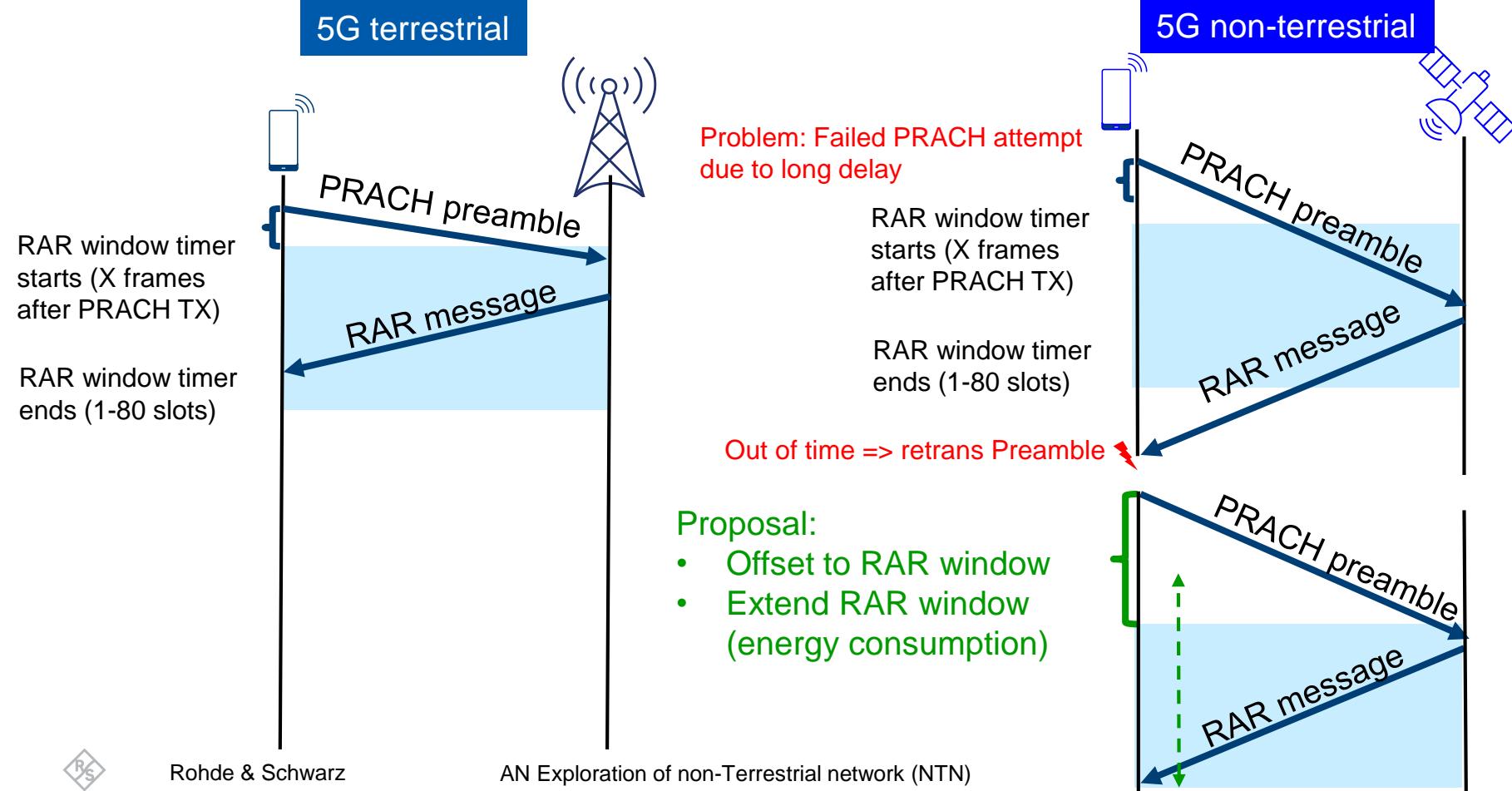
$$T_{TA} = (N_{TA} + N_{TA,\text{offset}} + N_{TA,\text{common}} + N_{TA,\text{adj}}^{\text{UE}})T_c$$



NON TERRESTRIAL NETWORK TIMING ADVANCE



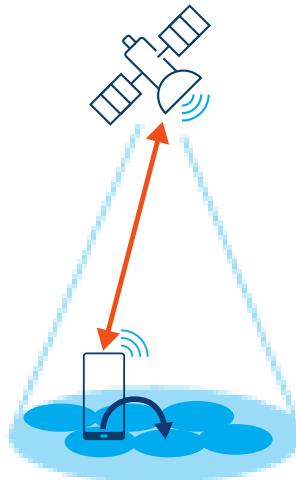
NTN: RANDOM ACCESS PROCEDURE WHEN LARGE RTT



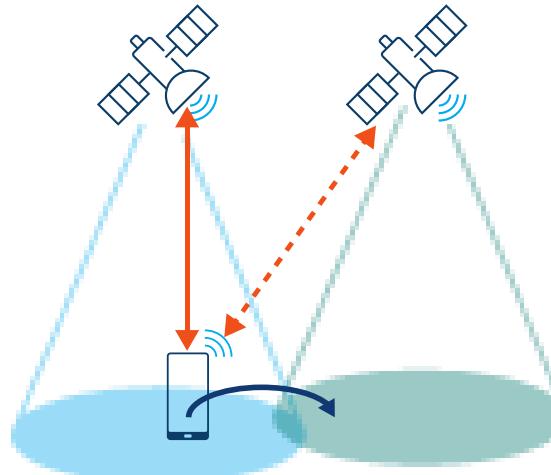
5G NTN MOBILITY SCENARIOS - EXAMPLES



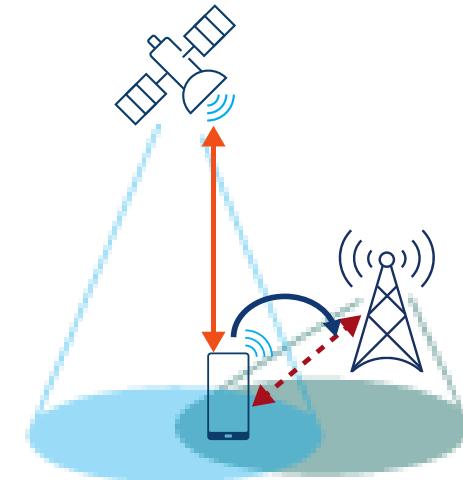
Cell selection/
cell reselection



Intra-satellite/
inter-beam handover



Inter-satellite handover/
inter-satellite dual connectivity (DC)



NTN – terrestrial
handover/DC

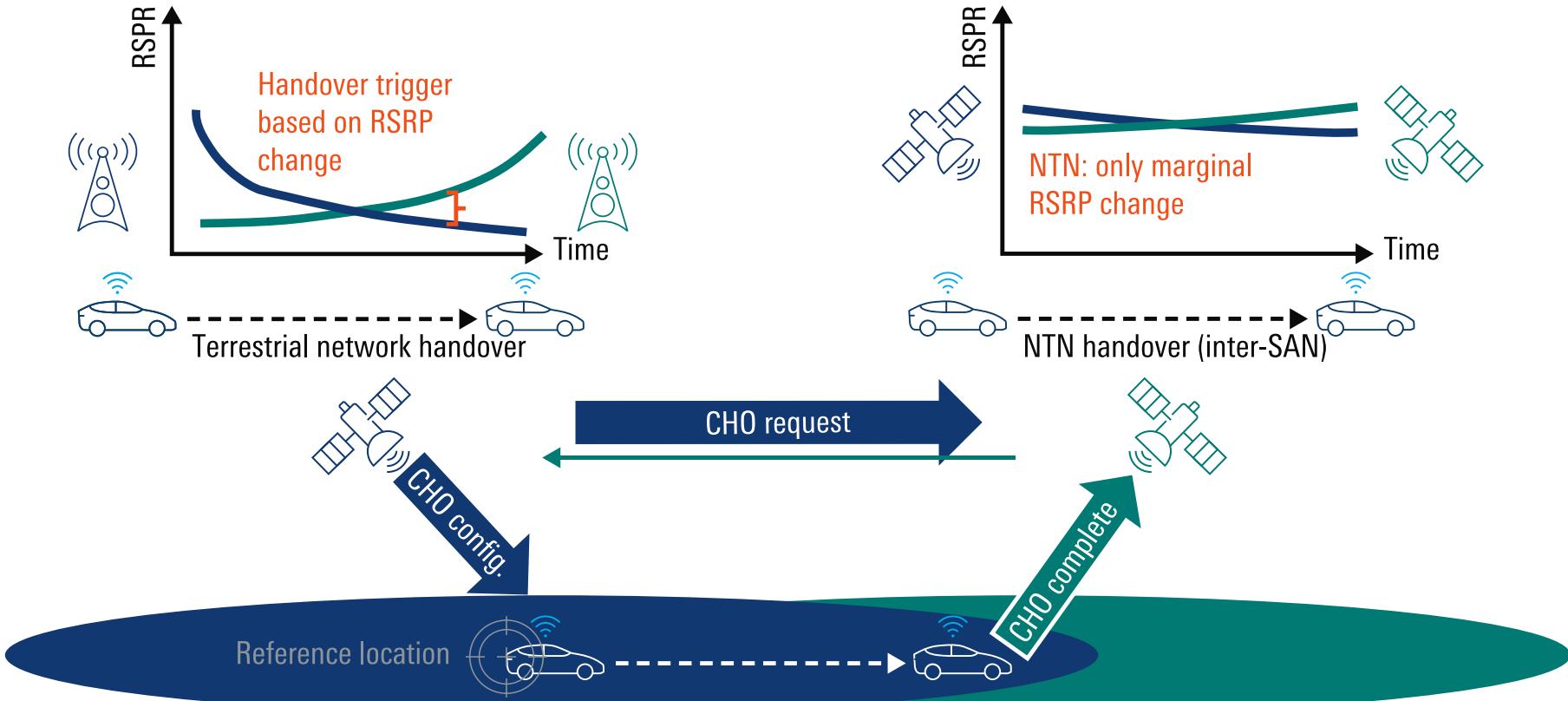
↔ NR-NTN connection

↔ Target or simultaneous dual connectivity NR-NTN connection

↔ Target or simultaneous dual connectivity terrestrial connection



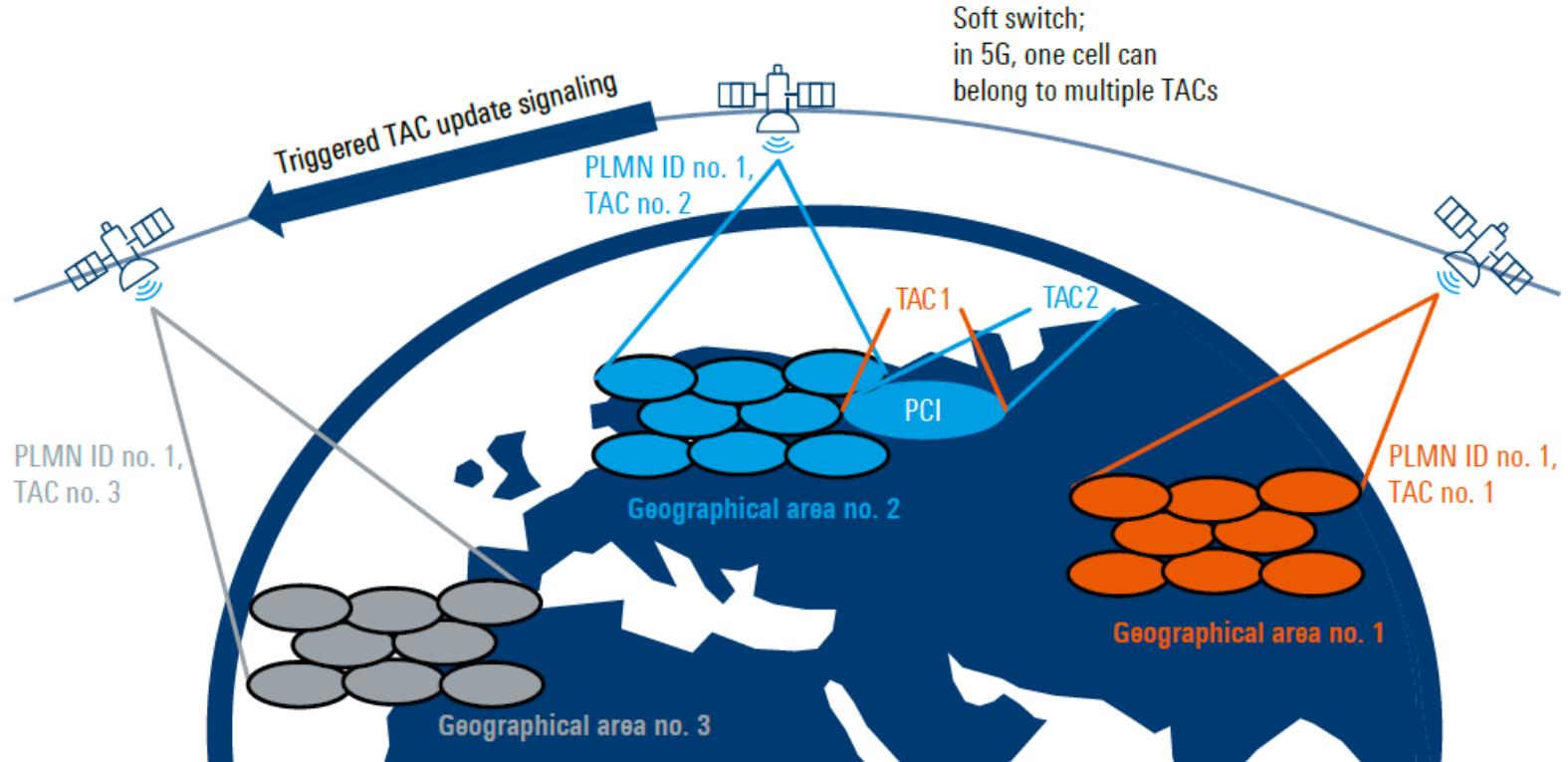
5G NTN HANDOVER EXAMPLE (CHO)



Conditional handover (CHO): network configures UE with triggering condition; e.g. distance between UE and reference location



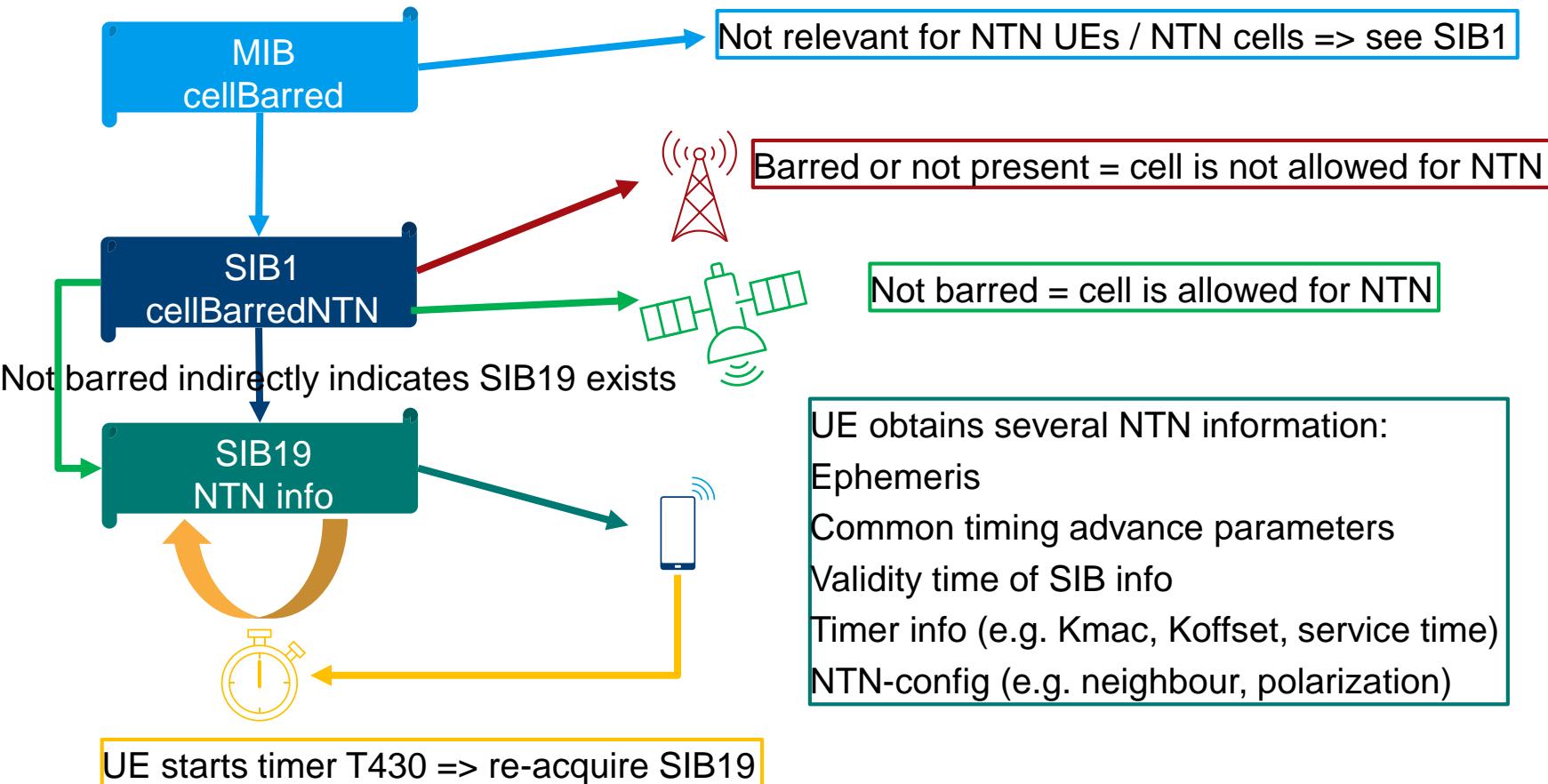
NTN: TRACKING AREA ASPECTS



5G NTN supports Earth-fixed tracking area codes (TAC) and multi-TAC signaling



NTN: CELL ACQUISITION



NTN: SYSTEM INFORMATION



SIB1: cellBarredNTN means, that the cell is barred for connectivity to NTN

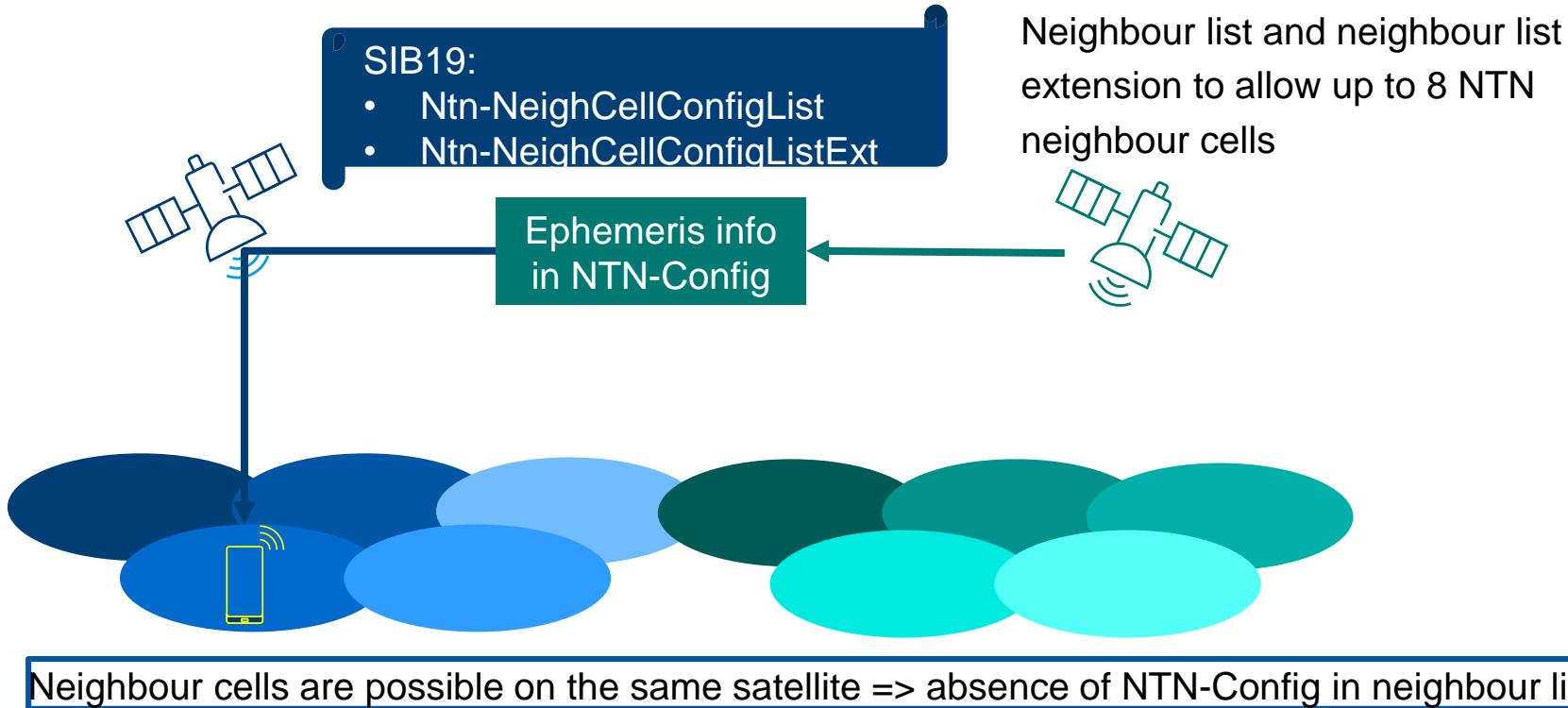
SIB2 and SIB4: SSB-based RRM Measurement Timing Configuration window (SMTC), generic parameter, but has an important effect in NTN constellations, as the SMTC window should coincide with neighbor satellite availability

SIB2 allows the configuration of RRM relaxed measurements. In NTN only applicable for GEO satellite neighbour cells

SIB19 with NTN specific system information



NTN: NEIGHBOUR CELL INFORMATION IN SIB19



5G NTN – SERVICE TIME INDICATION VIA SIB19

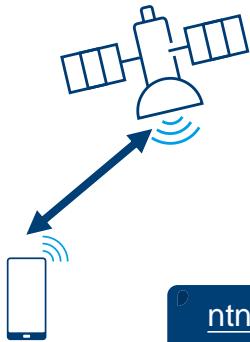


t-Service

Indicates the time information on when a cell provided via NTN quasi-Earth fixed system is going to stop serving the area it is currently covering. The field indicates a time in multiples of 10 ms after 00:00:00 on Gregorian calendar date 1 January, 1900 (midnight between Sunday, December 31, 1899 and Monday, January 1, 1900). The exact stop time is between the time indicated by the value of this field minus 1 and the time indicated by the value of this field.



NTN: UE CAPABILITY INFORMATION SIGNALING



nonTerrestrialNetwork-r17 = indicates supports for NR NTN access, i.e. essential features:

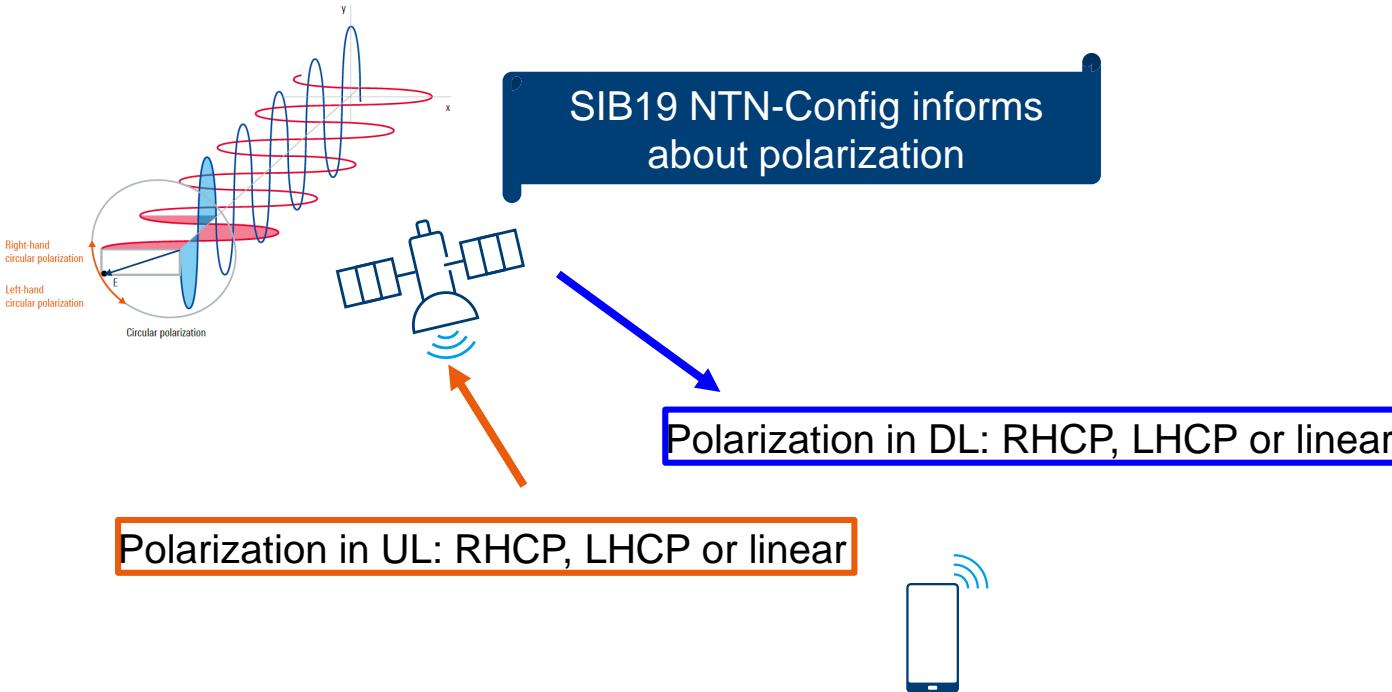
- timer extension in MAC/RLC/PDCP layers and RACH adaptation to handle long RTT
- acquiring NTN specific SIB
- more than one TAC per PLMN broadcast in one cell.

ntn-ScenarioSupport-r17 = indicates whether UE supports NTN features either in GSO or NGSO scenarios. If not included, UE supports both GSO + NGSO and mobility between both.

condHandover-r16 / condHandoverFailure-r16 / condHandoverTwoTrigger Events-r16 = shall be set by UE consistently for all FDD-FR1 NTN bands (i.e. TDD-FR1 and FR2 are excluded).
Indicates whether the UE supports CHO, CHO during re-establishment and 2 trigger events for same condition.

cqi-4BitsSubbandNTN-SharedSpectrumChAccess-r17 = indicates support for CQI reporting with 4 bits per subband for NTN and shared spectrum channel access

NTN: POLARIZATION INDICATION



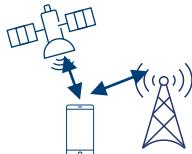
If UL polarization info is not present, but DL polarization info is present
=> UE assumes same polarization in both directions



Non-terrestrial networks (NTN) **OUTLOOK**

NTN REL. 18 TOPICS OVERVIEW

5G NR-NTN enhancements in Rel. 18 (overview)



Mobility & service continuity

- Same PCI SAN switch
- NTN-NTN Handover
- Reduced signaling
- Terrestrial coverage area



Coverage extension & power aspects

- PUCCH repetition (Msg4, HARQ)
- PUSCH DMRS bundling
- TN-NTN cell reselection signaling
- UE power class, e.g. PC1.5



NW estimated UE location



New spectrum

- FR2-0-NTN
- 17.3-30GHz
- VSAT/ESIM UE type

5G IoT-NTN enhancements in Rel. 18 (overview)



Performance

- Disable HARQ
- GNSS operation



Mobility

- Conditional handover for eMTC
- Time-based triggering of neighbour cell measurements
- RRM measurements location based



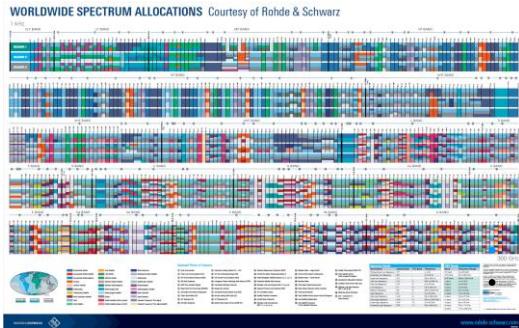
Discontinuous coverage

- Mobility management
- Power saving enhancements



ADDITIONAL RESOURCES

5G technology book online version
(>1000 pages on 5G technology):
www.rohde-schwarz.com/5G-ebook



[Worldwide Spectrum Allocation Poster \(2020\)](#)
[Free "Demystifying 5G NR" poster | Rohde & Schwarz \(rohde-schwarz.com\)](#)

5G NTN TAKES FLIGHT:
TECHNICAL OVERVIEW OF 5G
NON-TERRESTRIAL NETWORKS



Whitepaper

https://www.rohde-schwarz.com/solutions/test-and-measurement/aerospace-defense/satellite-test/white-paper-5g-ntn-takes-flight-technical-overview-of-5g-non-terrestrial-networks_255919.html



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AN Exploration of non-Terrestrial network (NTN)

THANK YOU



Future networks: Fiber to the space (FTTS)



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