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ROHDE & SCHWARZ TECHNOLOGY SYMPOSIUM 2024 JAPAN

3GPP規格における5G NTNの仕様

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Make ideas real



AGENDA

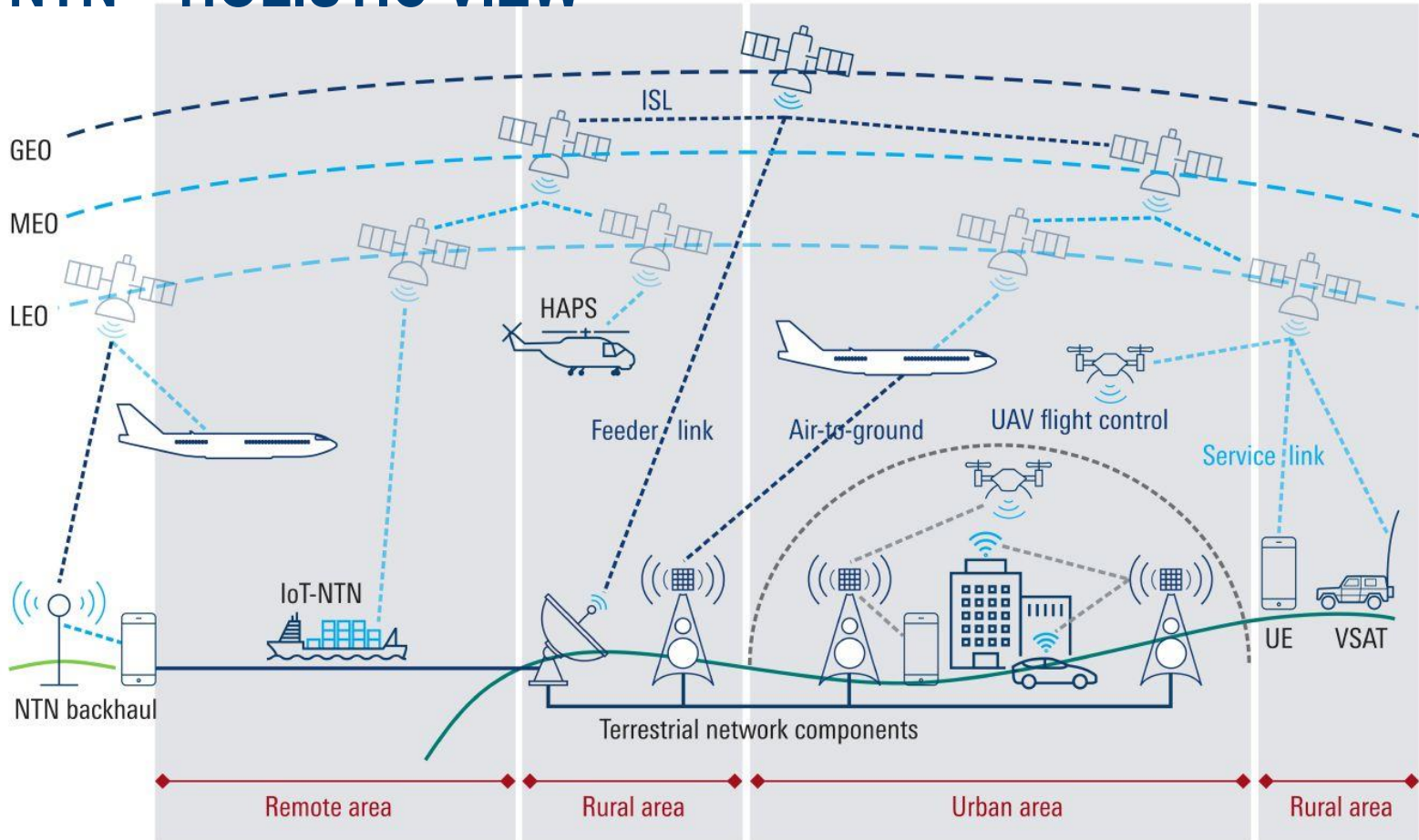
- Introduction and motivation
- Commercial NewSpace constellations
- NTN frequency and architecture aspects
- NTN RF aspects and challenges
- NTN procedures and protocol updates
- NTN evolution – outlook



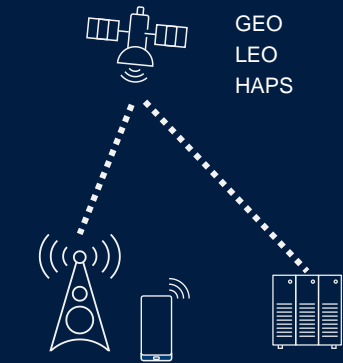
Non-terrestrial networks (NTN)

5G NTN INTRODUCTION AND MOTIVATION

5G NTN – HOLISTIC VIEW

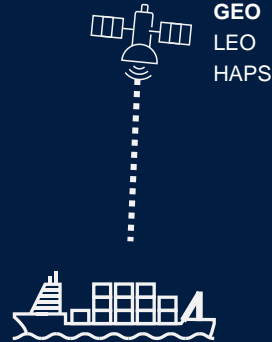


5G-NTN FOUR FACETS (PERSPECTIVE USE CASE)



5G NTN backhaul

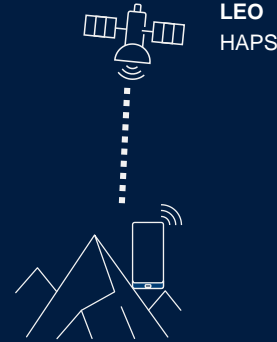
Mobile backhaul for terrestrial
NWs



**IoT-NTN
S/L Bands**

IoT devices 23 dBm
transmit power, omni
directional antenna (0dBi),
use smaller bandwidth
than handheld

Global IoT network



**NR-NTN
(direct handheld,
<6 GHz)**

Mobile service is provided to handheld
devices (e.g. omni directional antenna and
23 dBm transmit power)

Mobile coverage and resiliency
use cases




**NR-NTN
(VSAT, >10 GHz) Fixed**

wireless service with high gain ground
antenna, terminals use VSAT/phased array

Rural consumer and enterprise
broadband services

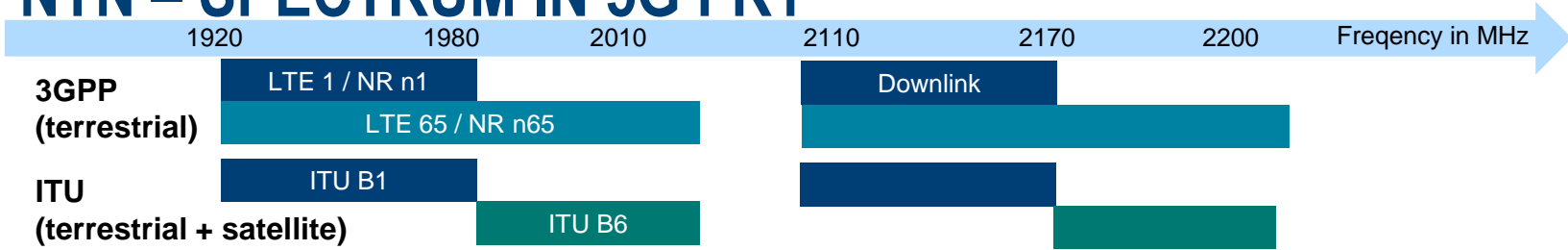
Emergency connectivity
(temporary networks)



Non-terrestrial networks (NTN)

5G NTN FREQUENCY ASPECTS & ARCHITECTURE

NTN – SPECTRUM IN 5G FR1



3GPP, first NTN bands for S and L-band

NTN band #	Uplink	Downlink	Duplex
n256	1980 – 2010 MHz	2170 – 2200 MHz	FDD
n255	1626.5 – 1660.5 MHz	1525 – 1559 MHz	FDD

NTN band #	SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz (Rel.18)
256	15	Yes	Yes	Yes	Yes	Yes
	30		Yes	Yes	Yes	Yes
	60		Yes	Yes	Yes	Yes
255	15	Yes	Yes	Yes	Yes	Yes
	30		Yes	Yes	Yes	Yes
	60	N/A	Yes	Yes	Yes	Yes
		#RB	#RB	#RB	#RB	
Max. transmission bandwidth configuration	15	25	52	79	106	160
	30	11	24	38	51	78
	60	N/A	11	18	24	38

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

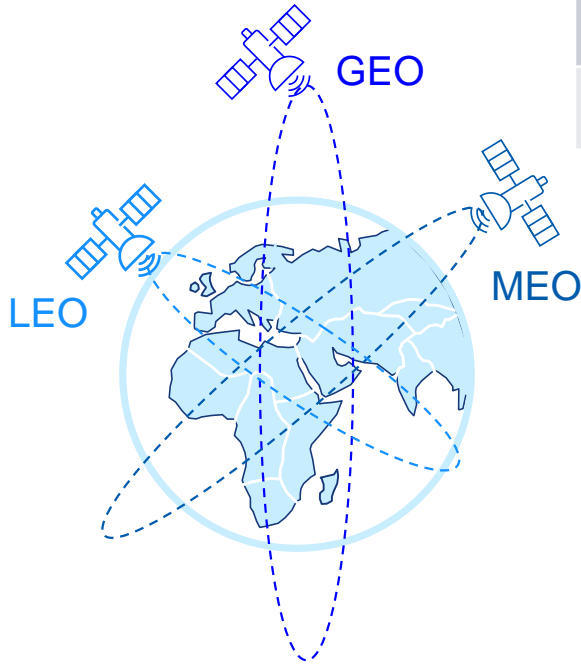
Band	Region	Band type	UL low MHz	UL high MHz	DL low MHz	DL high MHz
n510	US	FDD	27500	28350	17300	20200
n511	US	FDD	28350	30000	17300	20200
n512	EU	FDD	27500	30000	17300	20200

„FR3“ bands Ku: requested in R19

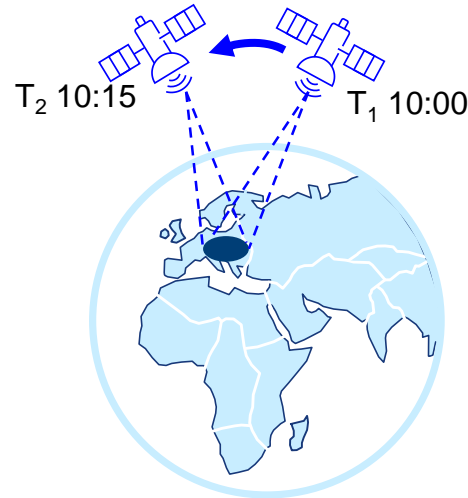
Band	Region	Band type	UL (Earth to space) GHz	DL (Space to Earth) MHz
Ku	Region 1	FDD	12.75 – 13.25 & 13.75 – 14.5	10.7 – 12.75
Ku	Region 2	FDD	12.75 – 13.25 & 13.75 – 14.5	10.7 – 12.7



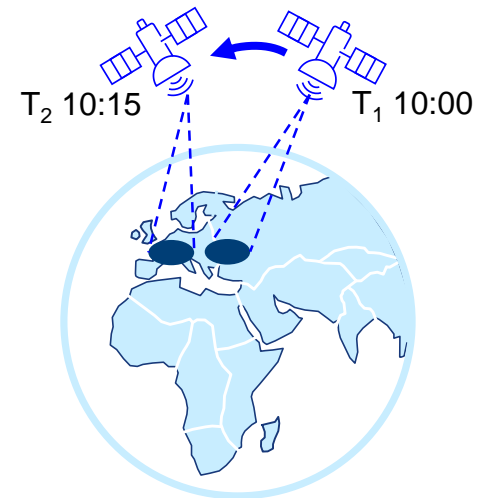
5G NTN: CONSTELLATIONS



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



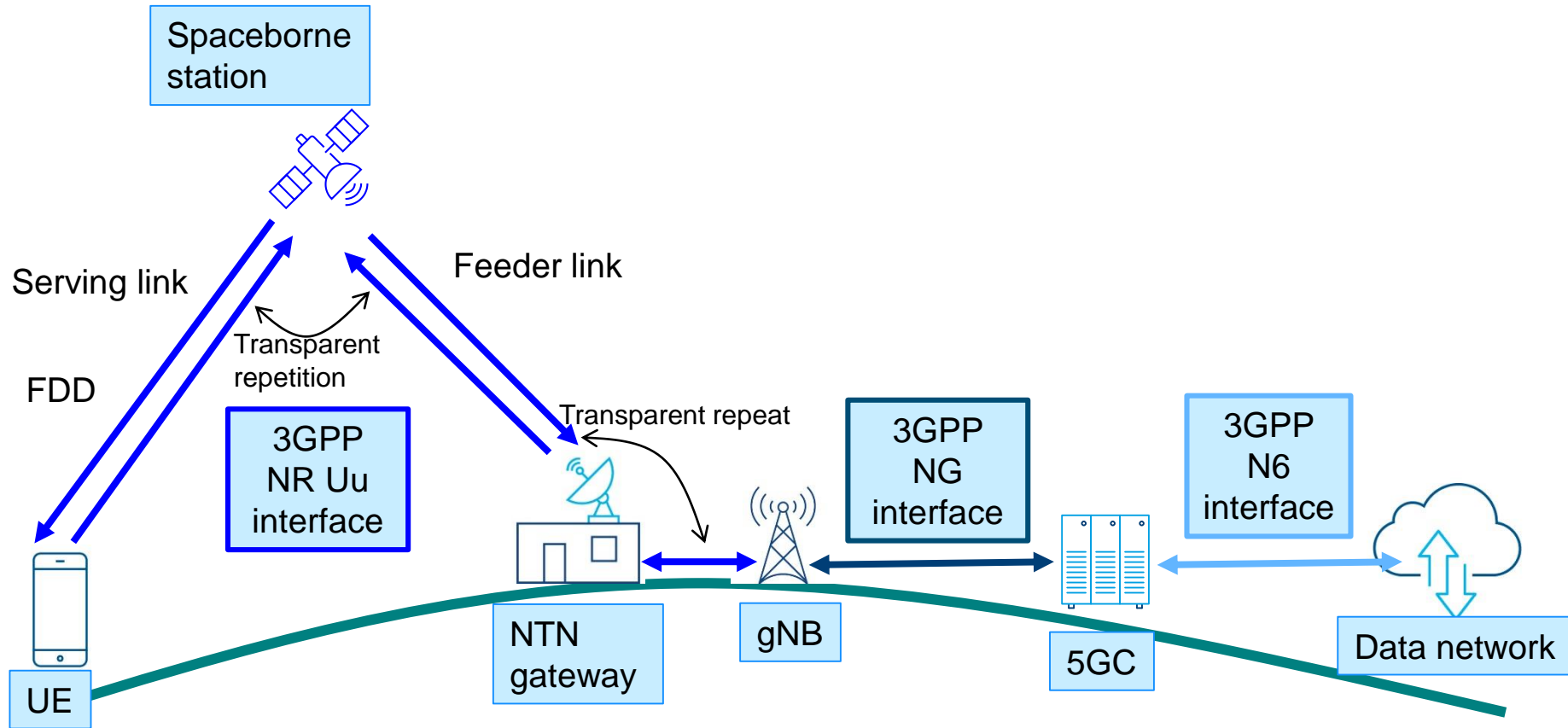
Fixed beams: Moving with respect to Earth's surface



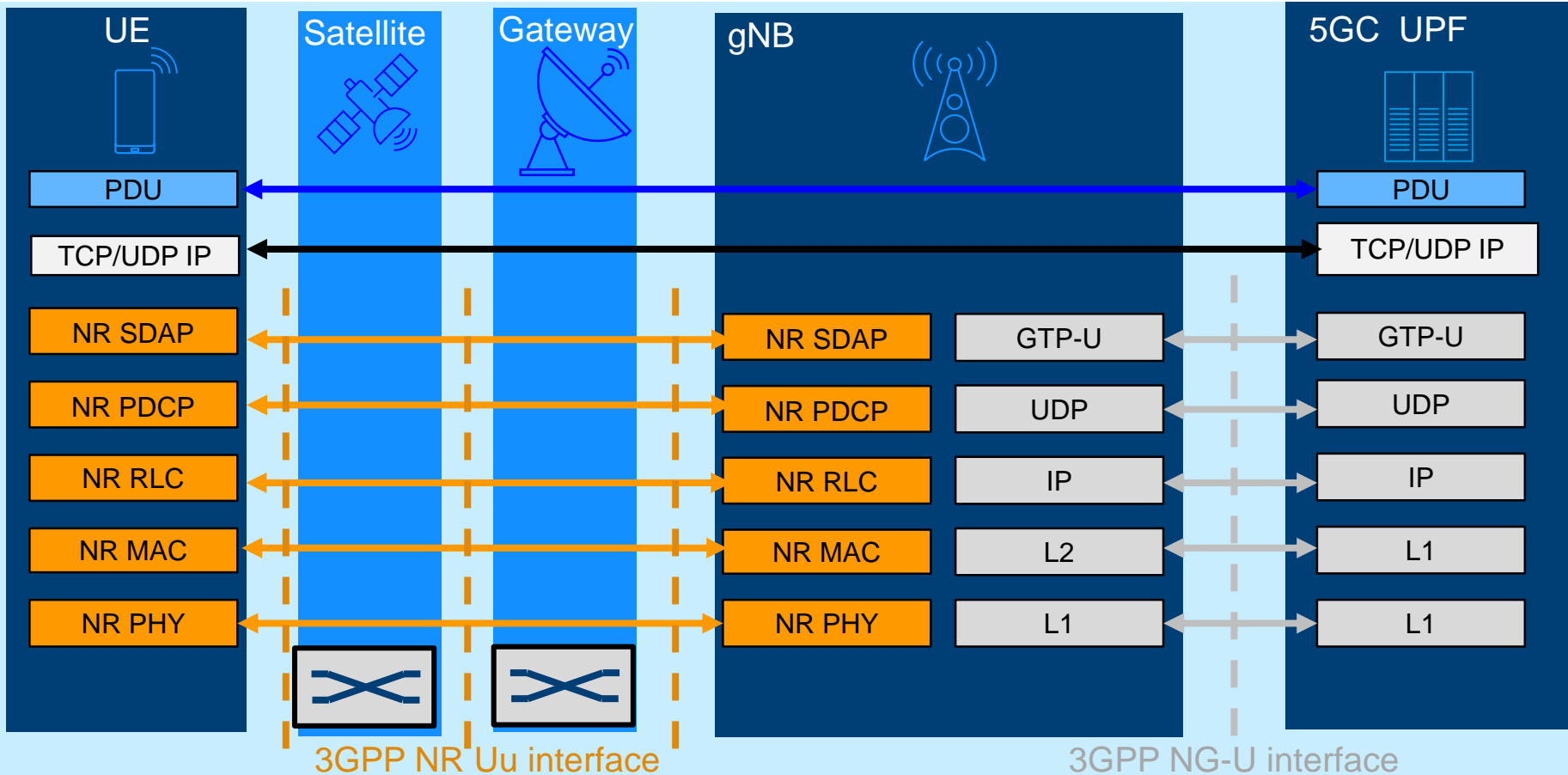
Non-terrestrial networks (NTN)

ARCHITECTURE

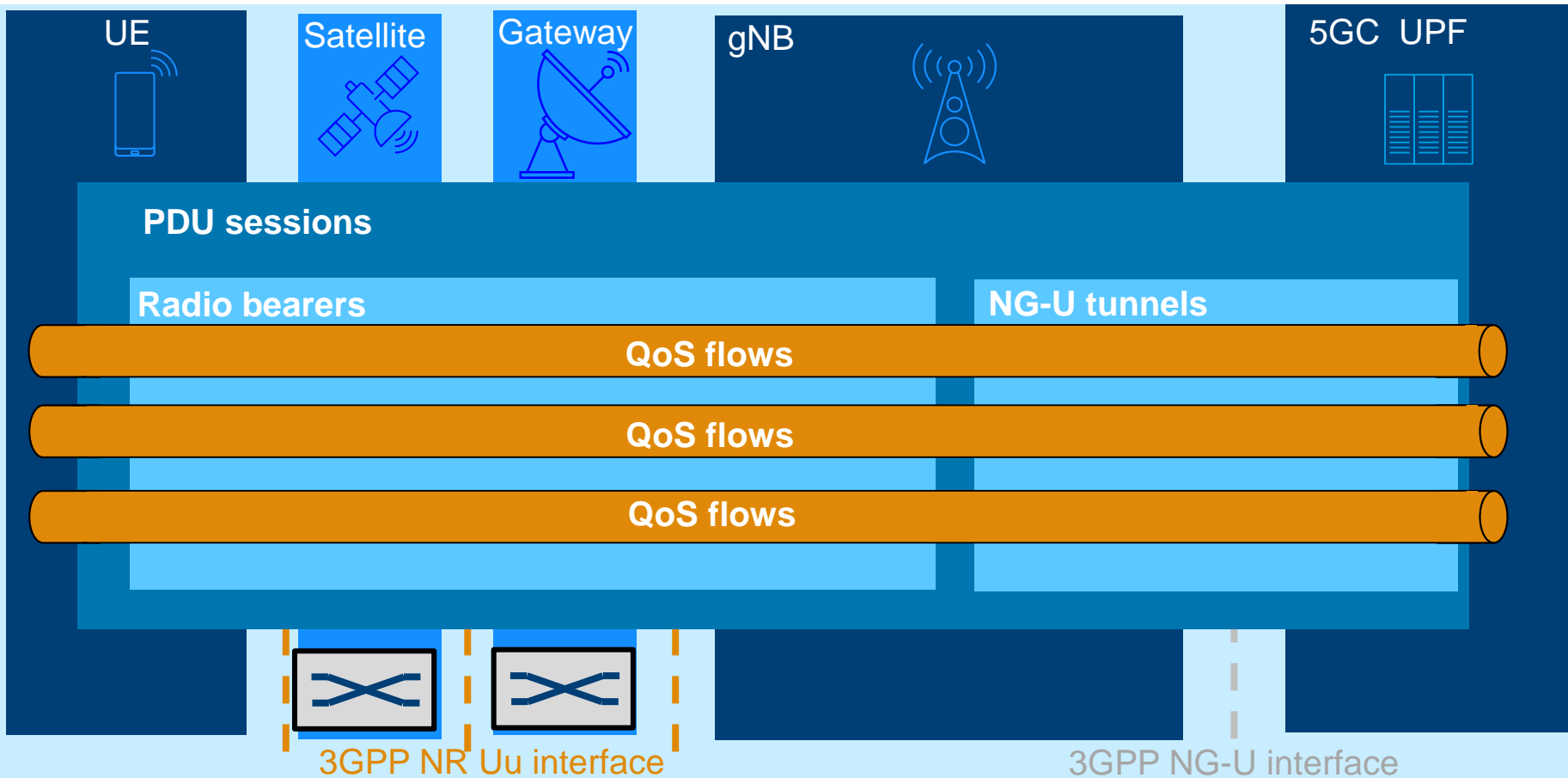
NTN: TRANSPARENT PAYLOAD ARCHITECTURE



NTN: TRANSPARENT PAYLOAD - PROTOCOL STACK, U-PLANE

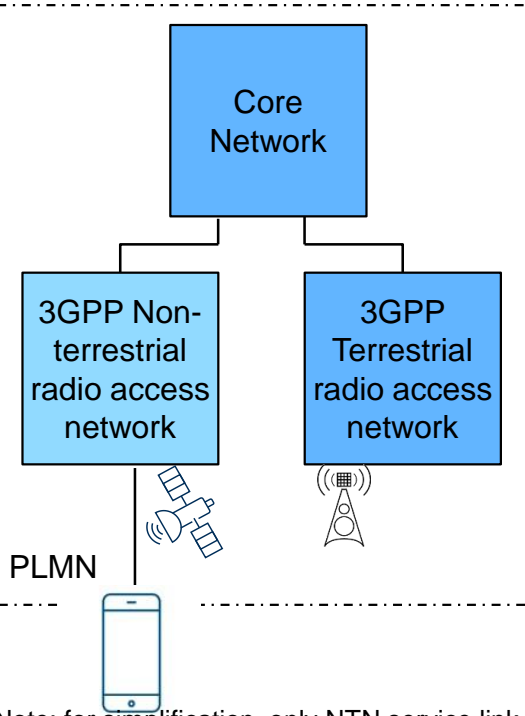


NTN: TRANSPARENT PAYLOAD - BEARER & QoS FLOWS

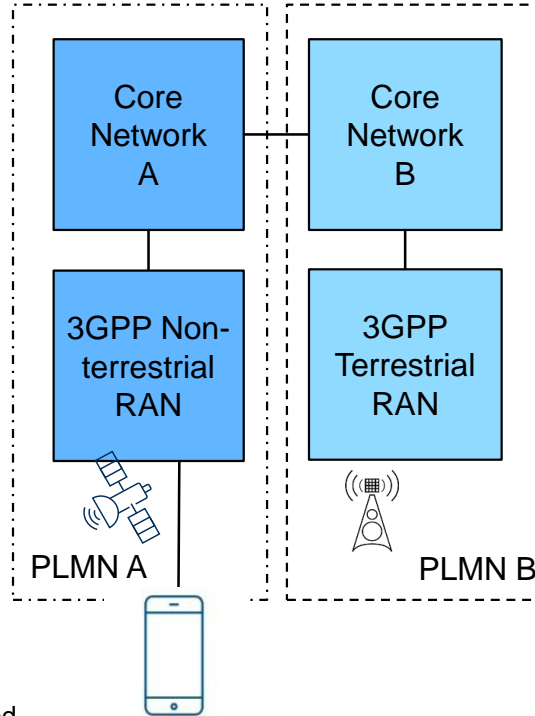


5G NTN INTEGRATION SCENARIOS WITH 5GC

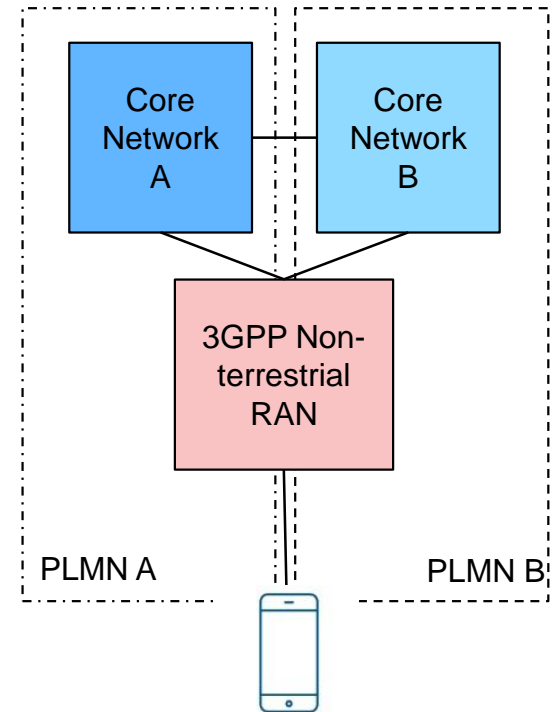
Same PLMN



Roaming

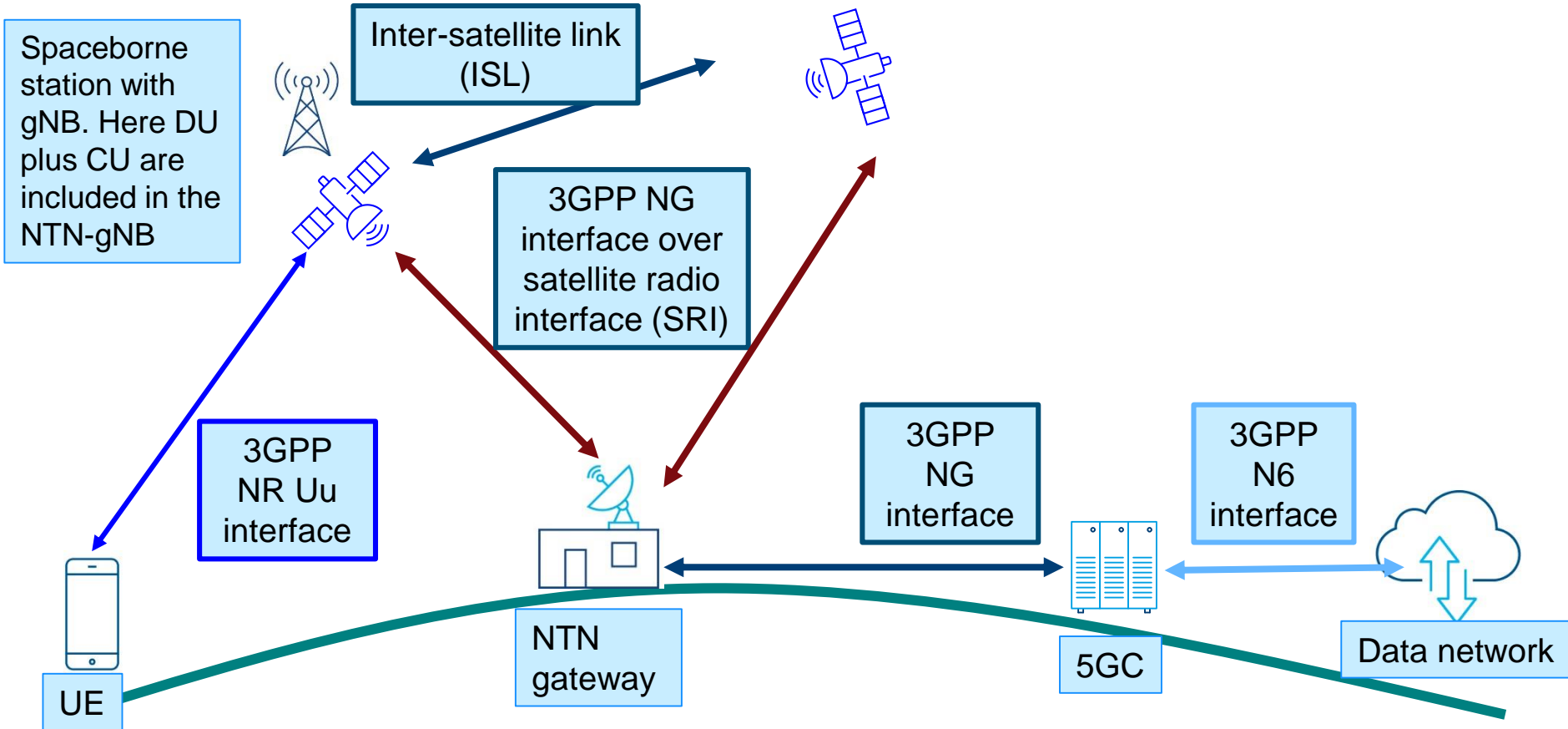


RAN sharing

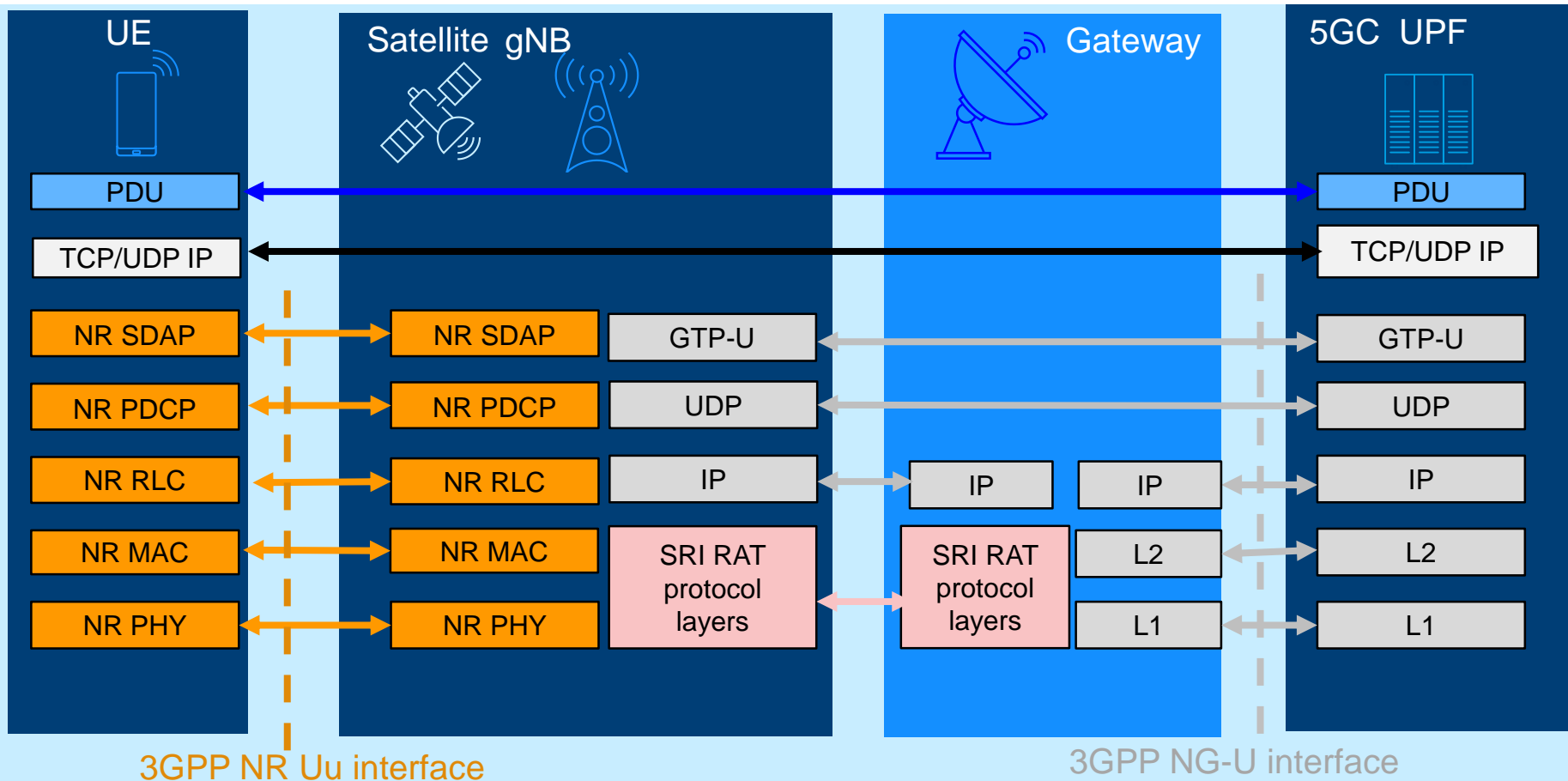


Note: for simplification, only NTN service link is depicted

NTN: REGENERATIVE PAYLOAD ARCHITECTURE

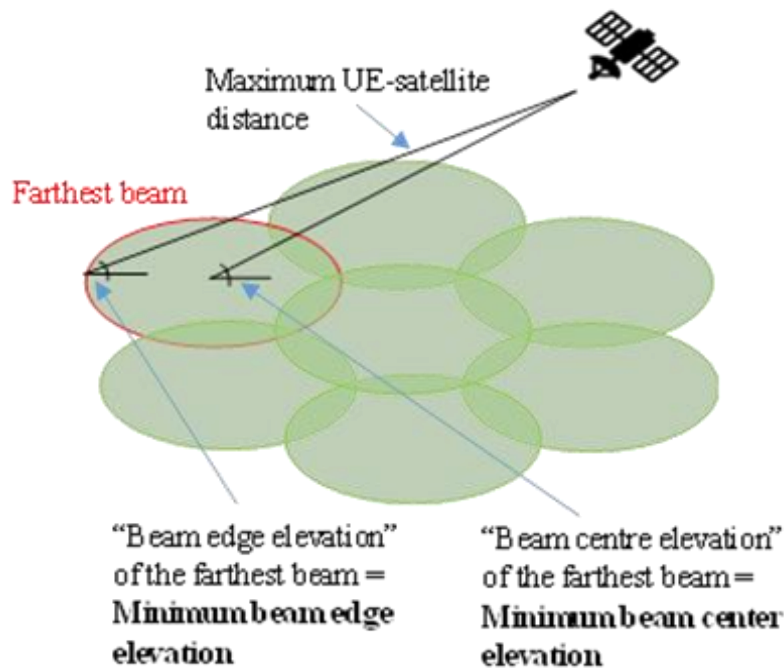
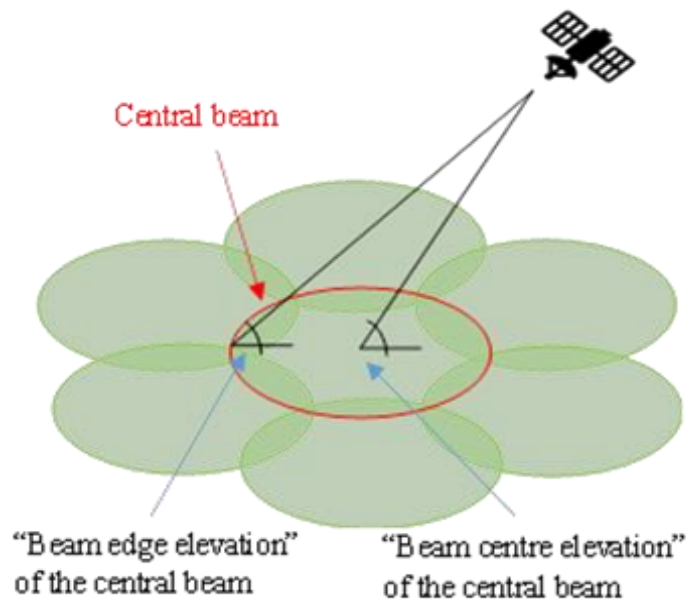


NTN: REGENERATIVE PAYLOAD - PROTOCOL STACK, U-PLANE



NTN: DEPLOYMENT ASPECTS – BEAM LAYOUT

- Satellite with multiple beams
- Each beam can be a “different cell” e.g. PCI or via SSB_Indices with same PCI
- Spectrum re-using or clustering possible

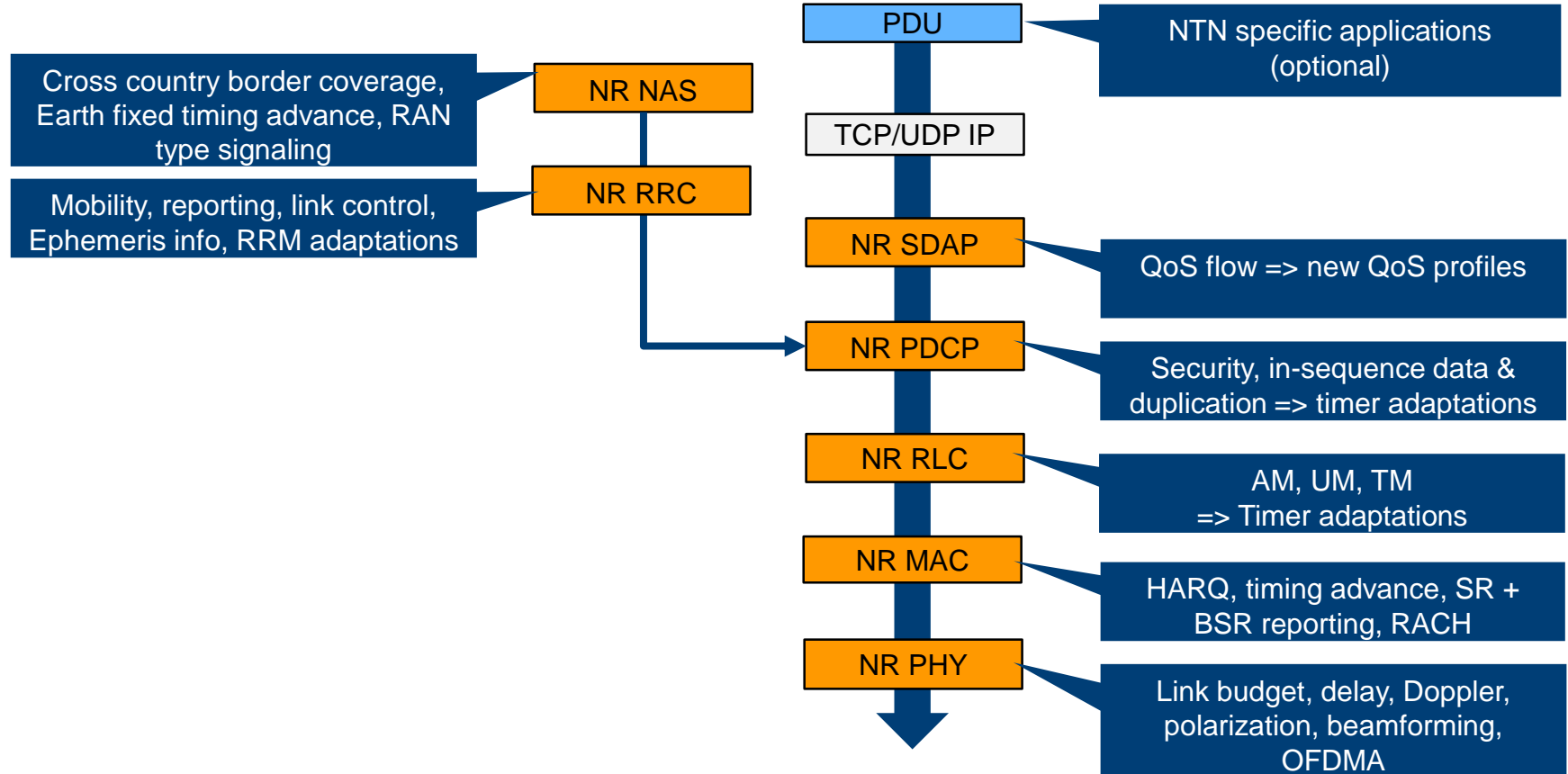




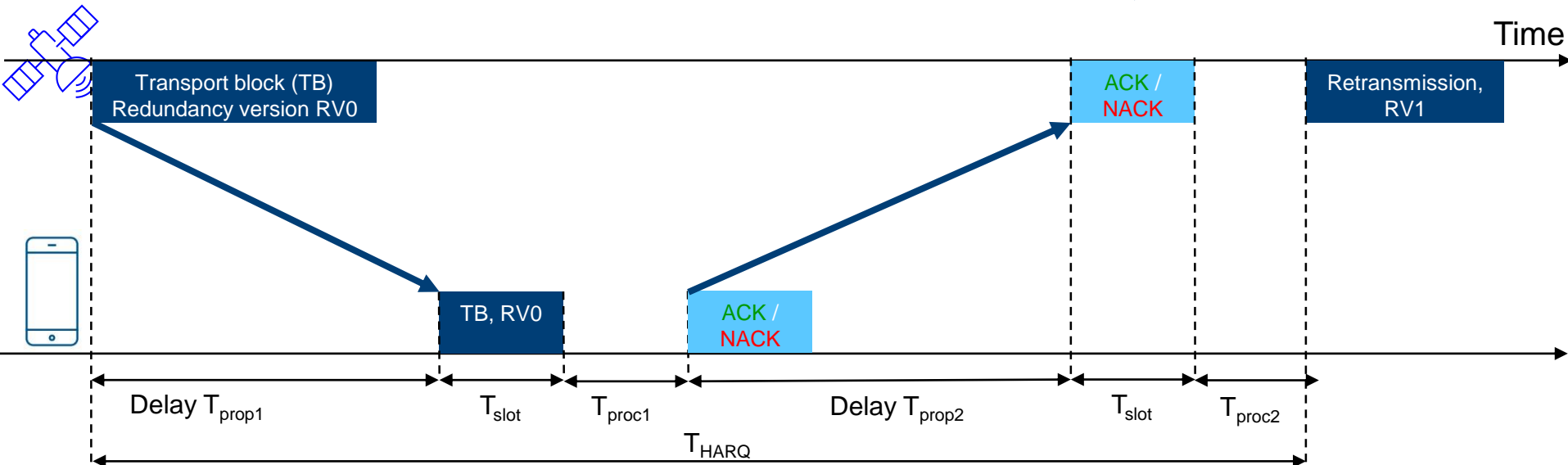
Non-terrestrial networks (NTN)

5G NTN PROTOCOL ASPECTS AND PROCEDURES

5G-NTN: PROTOCOL STACK



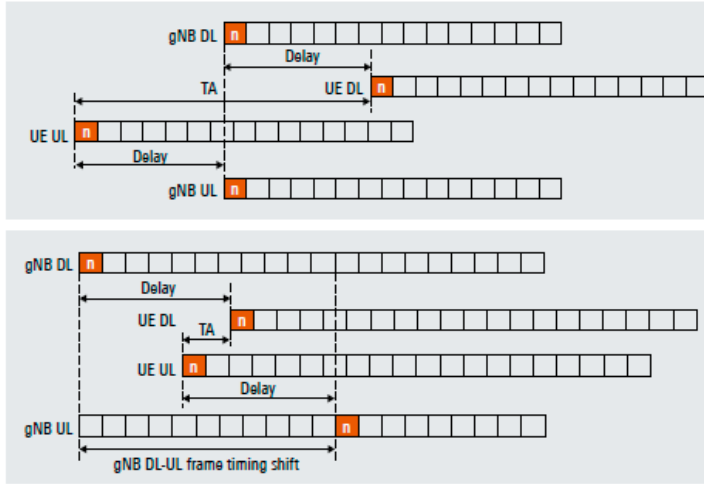
NTN: ROUND-TRIP-TIME ASPECTS AND HARQ



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

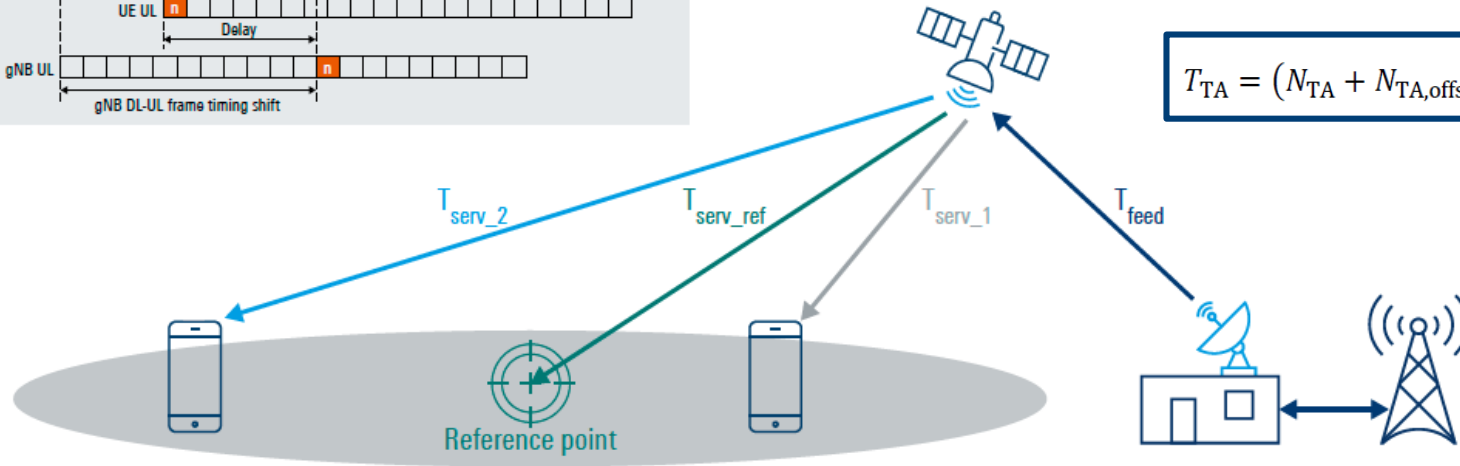


Idea to adjust large timing advance values:
 ⇒ large TX – RX offset in the UE

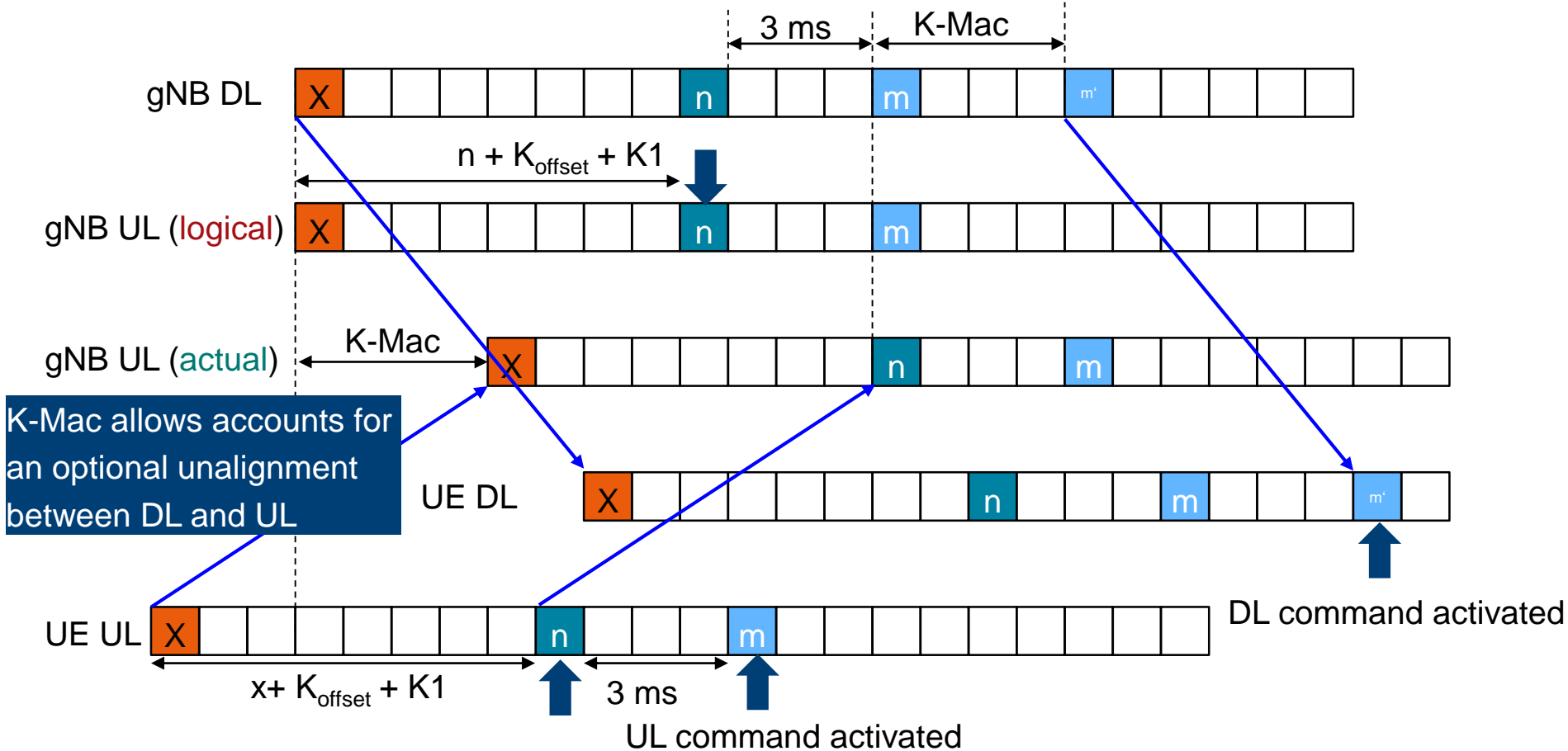
Idea to adjust shorter timing advance values:
 ⇒ large TX – RX offset in the gNB
 ⇒ possible SFN shift in gNB for UL/DL

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

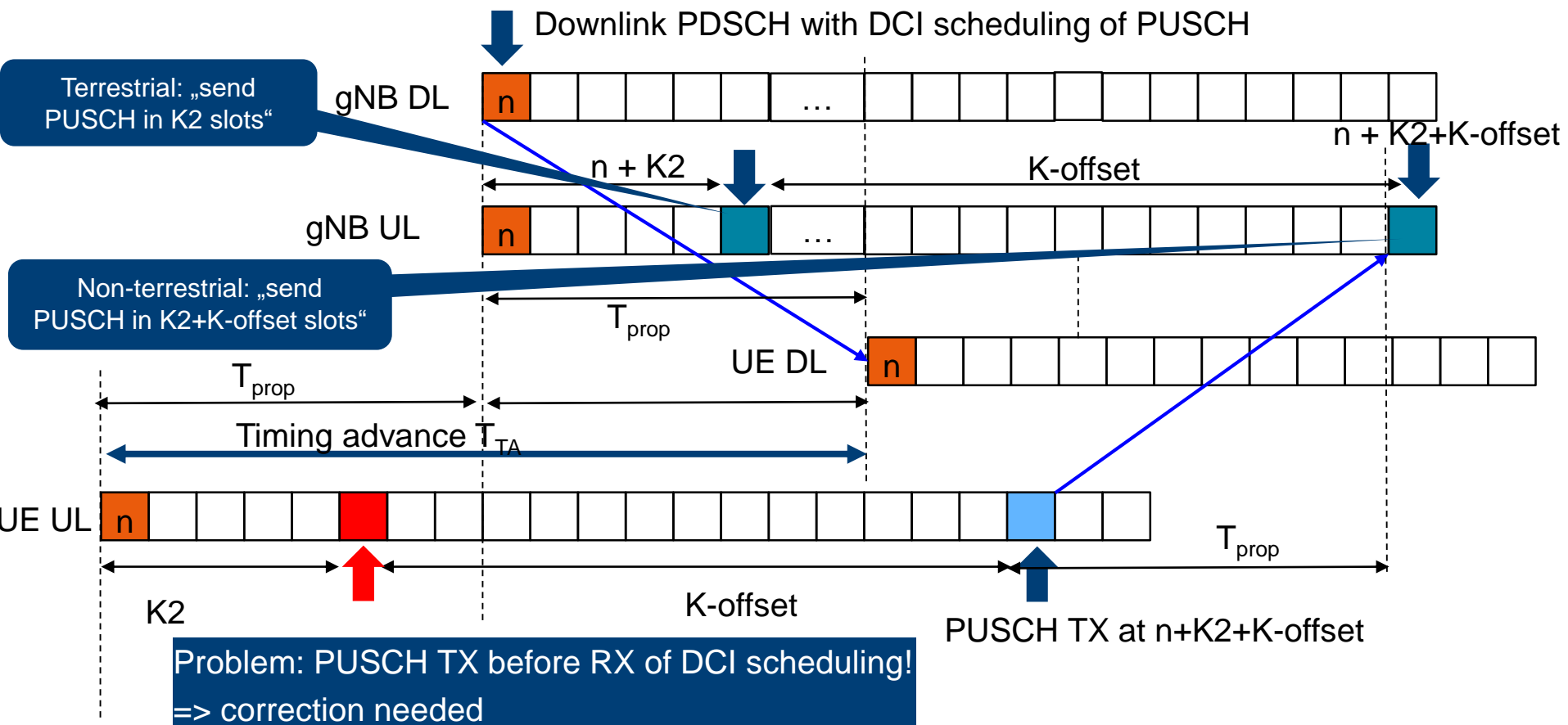
$$T_{TA} = (N_{TA} + N_{TA,offset} + N_{TA,adj}^{common} + N_{TA,adj}^{UE})T_c$$



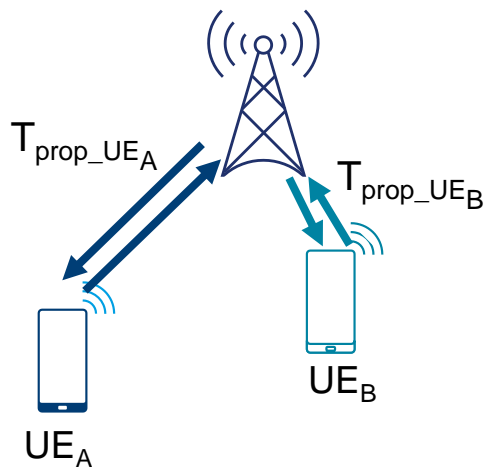
NON TERRESTRIAL NETWORK PARAMETER K-Mac



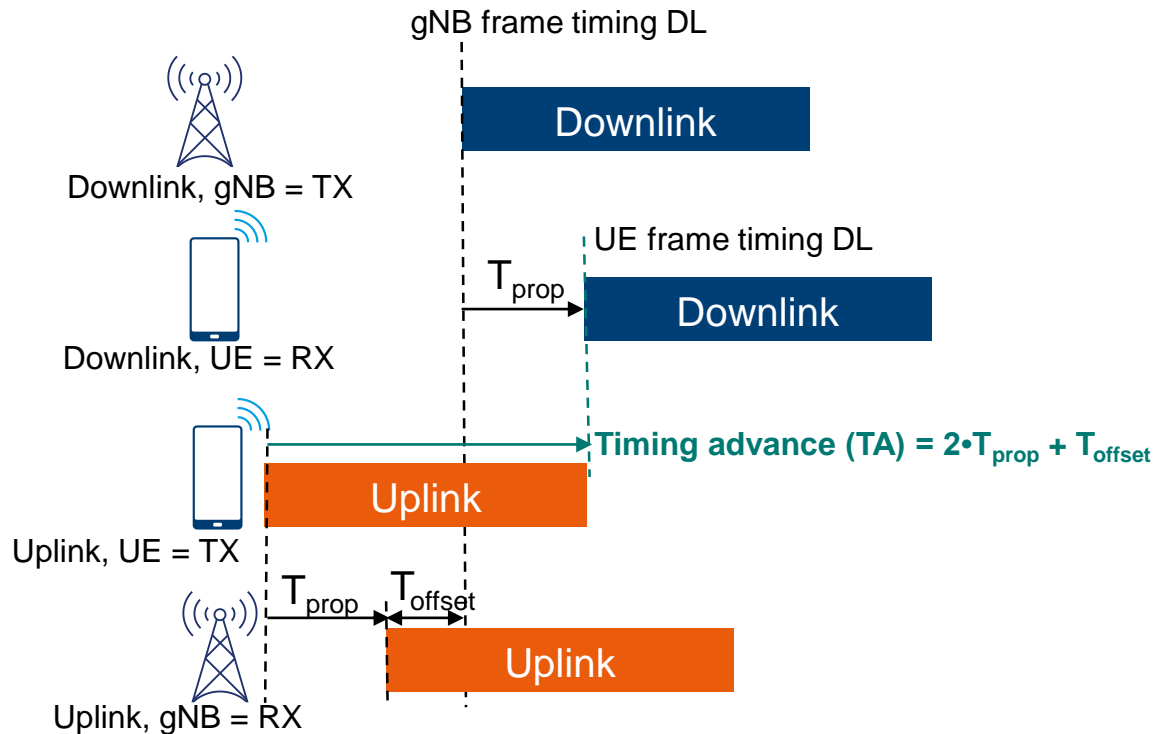
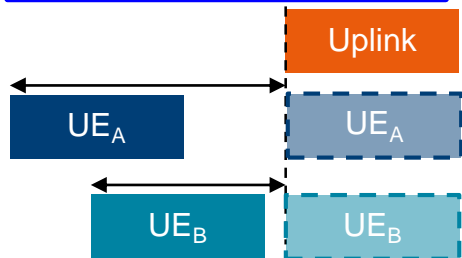
NON TERRESTRIAL NETWORK PARAMETER K-OFFSET



NON TERRESTRIAL NETWORK TIMING ADVANCE



Timing advance aligns UL signals at gNB

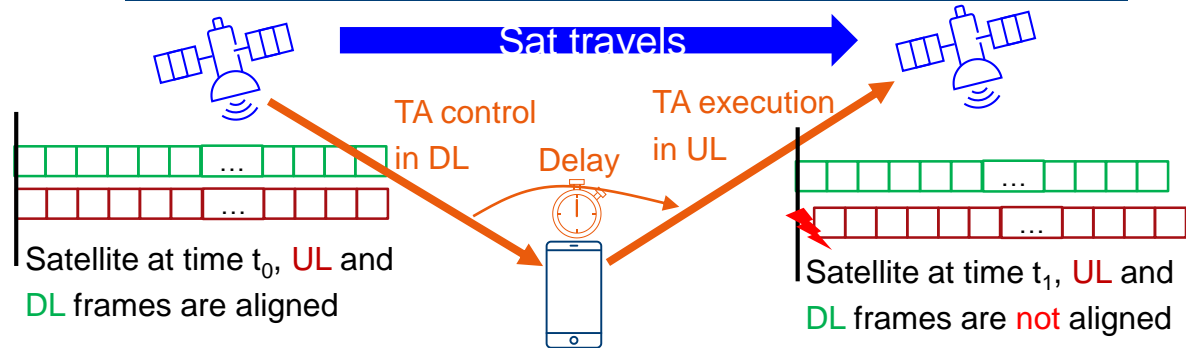
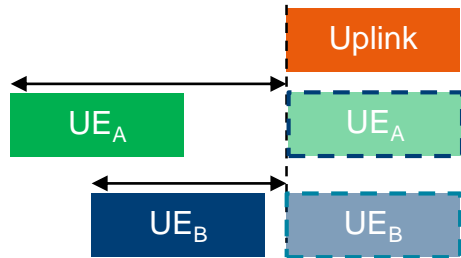
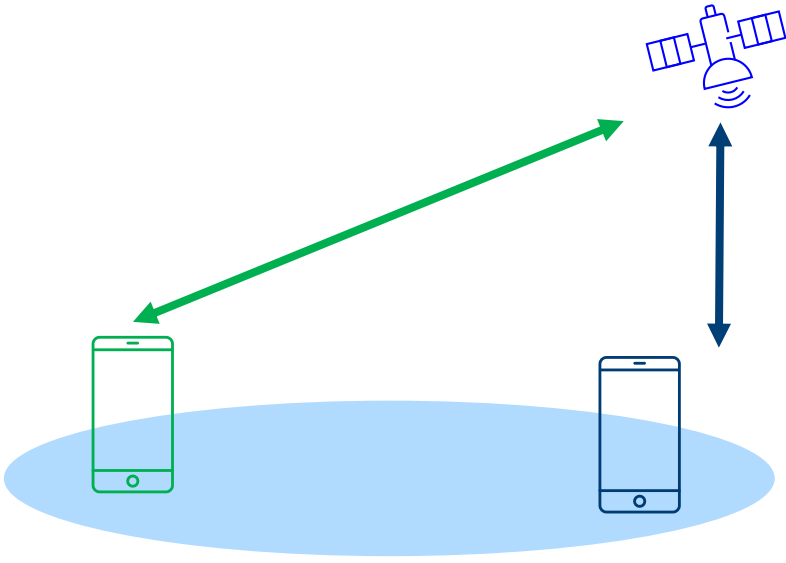


Timing advance with perspective UE and gNB.
 T_{offset} can indicate an optional time difference between UL and DL frames at the gNB

NTN – TIMING ADVANCE SERVING LINK

The situation of the serving link timing advance is similar between NTN and TN. Need for individual TA settings for every UE.

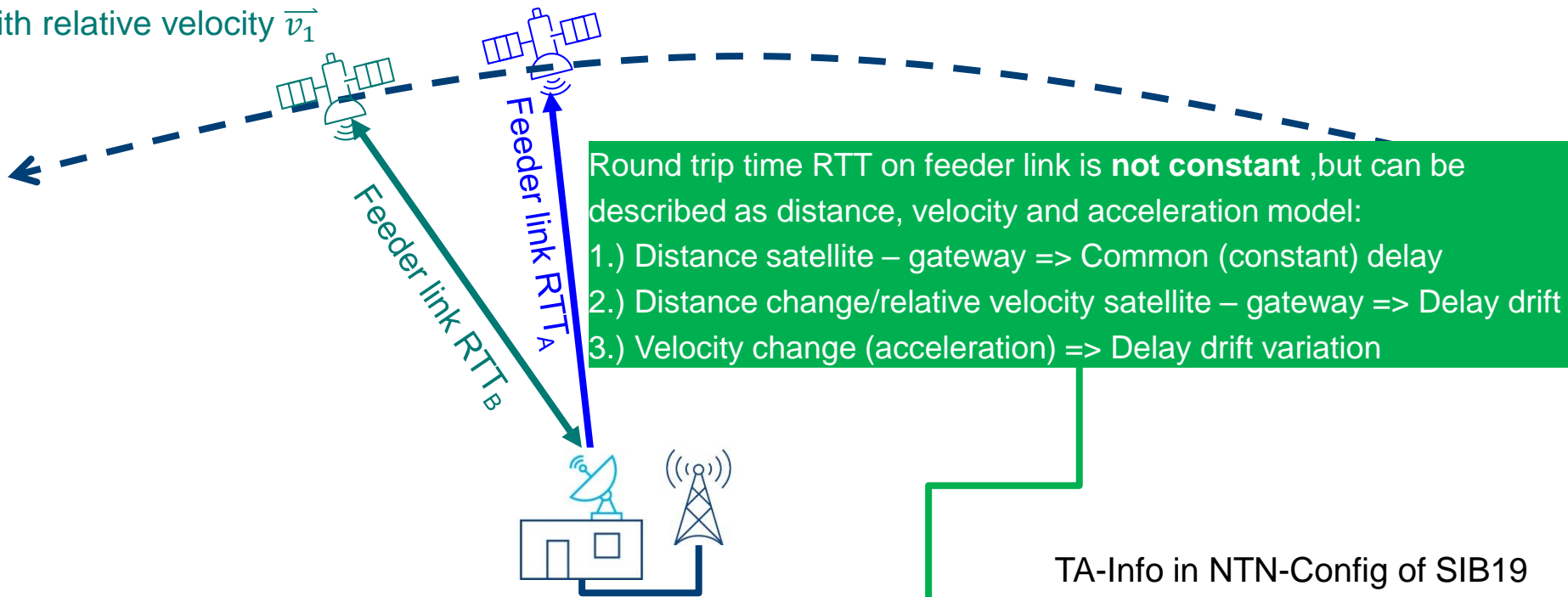
Large propagation times lead to delay variations as far as tens of microseconds per second. Legacy TA control mechanisms lead to impractical signaling overhead and TA control cycle is too slow wrt large delays in NTN. Risk of UL and DL mis-alignment at satellite. => Introduce kind of UE autonomy on TA adjustment.



NTN – TIMING ADVANCE FEEDER LINK

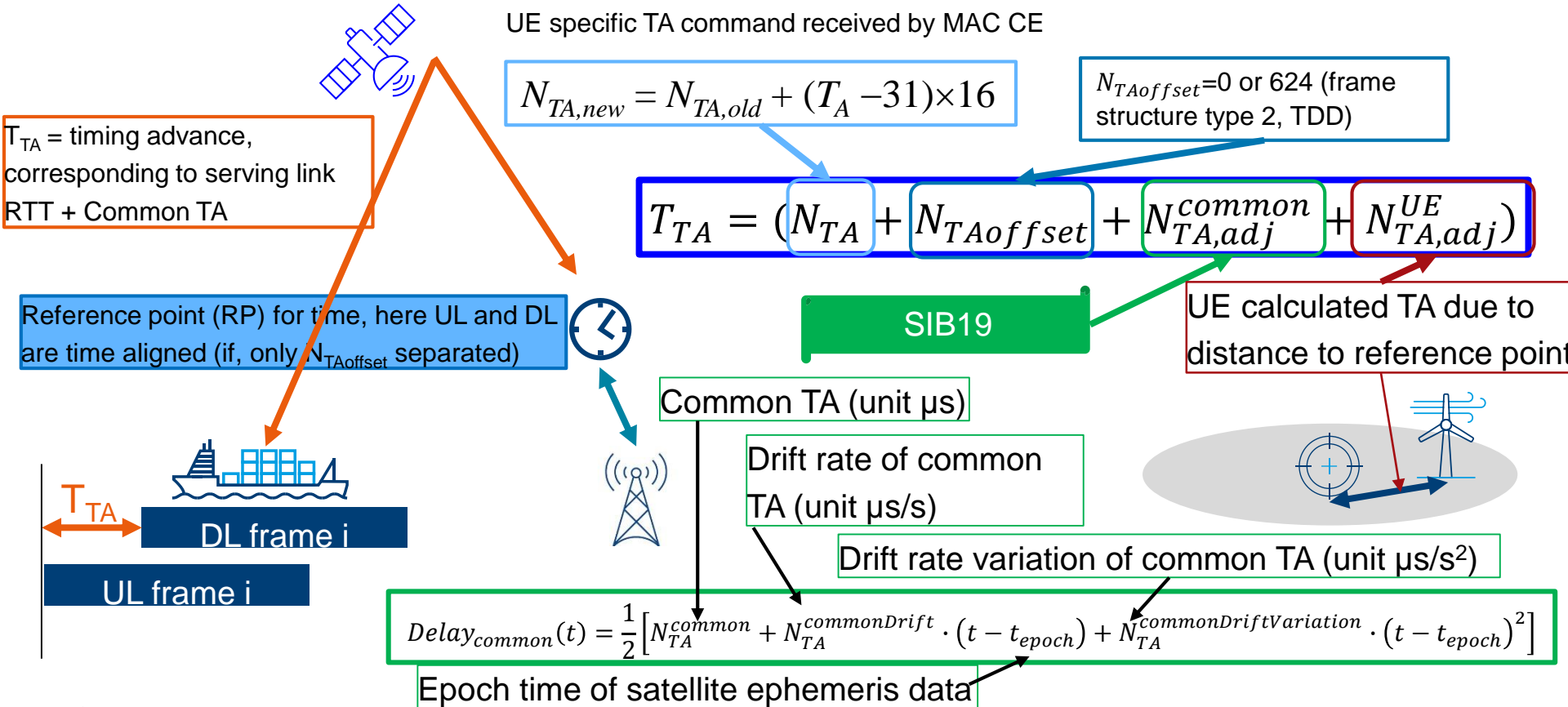
Satellite at time t_1 flying with relative velocity \vec{v}_1

Satellite at time t_0 flying with relative velocity \vec{v}_0



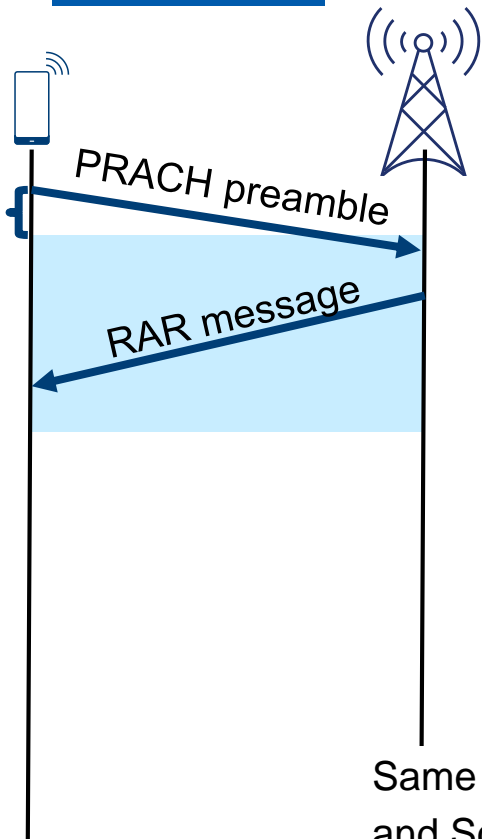
$$Delay_{common}(t) = \frac{1}{2} \left[N_{TA}^{common} + N_{TA}^{commonDrift} \cdot (t - t_{epoch}) + N_{TA}^{commonDriftVariation} \cdot (t - t_{epoch})^2 \right]$$

NTN – PHYSICAL LAYER ASPECTS, TIMING ADVANCE



NTN: RANDOM ACCESS PROCEDURE WHEN LARGE RTT

5G terrestrial



5G non-terrestrial

Problem: Failed PRACH attempt due to long delay

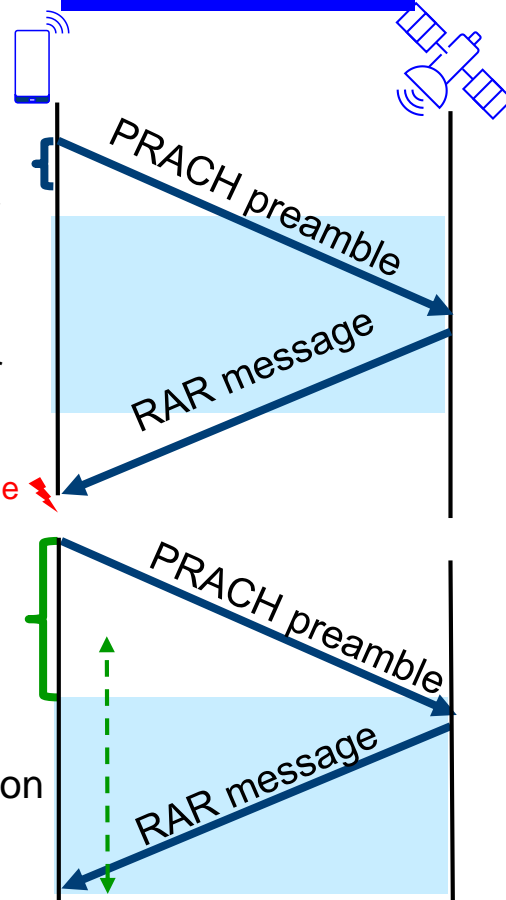
RAR window timer starts (X frames after PRACH TX)

RAR window timer ends (1-80 slots)

Out of time => retrans Preamble

Proposal:

- Offset to RAR window
- Extend RAR window (energy consumption)



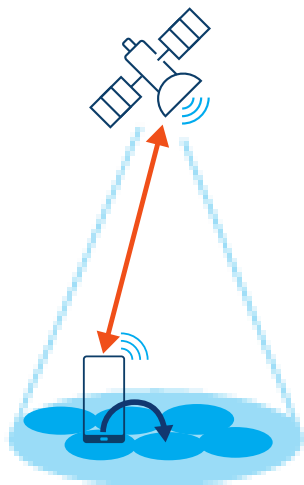
Same issue for Contention Resolution and Scheduling Request

5G NTN takes flight

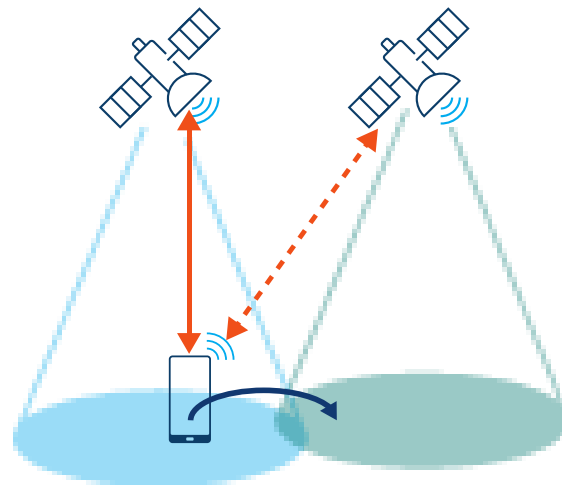
5G NTN MOBILITY SCENARIOS - EXAMPLES



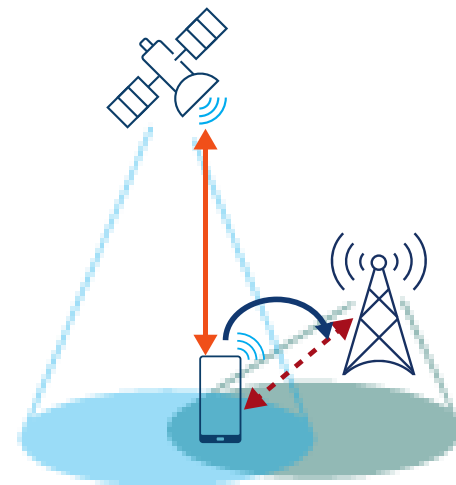
Cell selection/
cell reselection



Intra-satellite/
inter-beam handover



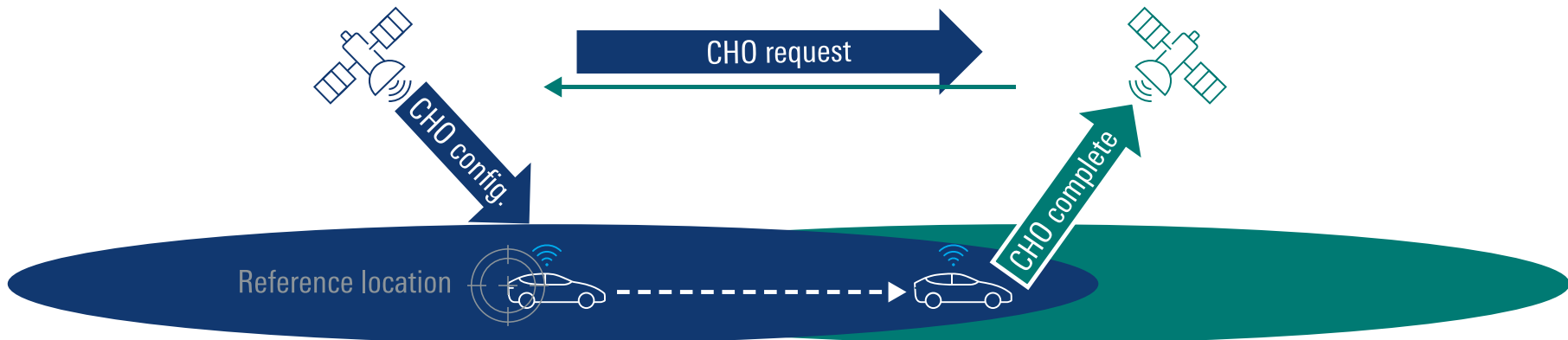
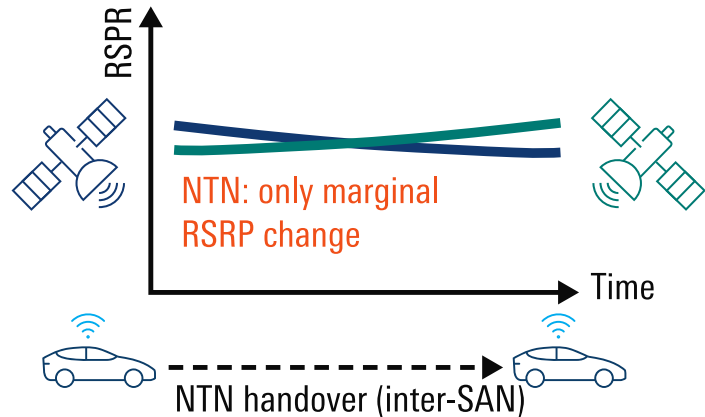
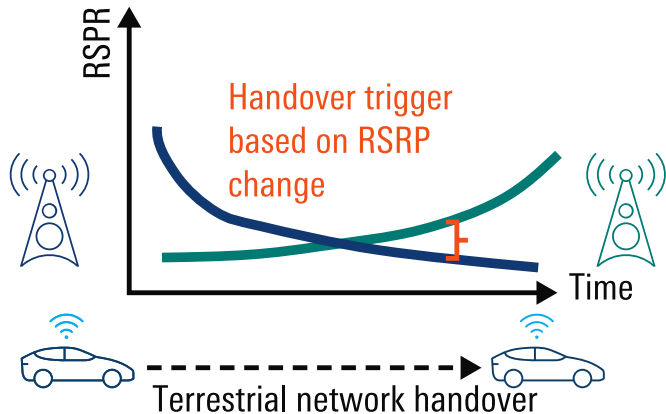
Inter-satellite handover/
inter-satellite dual connectivity (DC)



NTN – terrestrial
handover/DC

- ↔ NR-NTN connection
- ↔ Target or simultaneous dual connectivity NR-NTN connection
- ↔ Target or simultaneous dual connectivity terrestrial connection

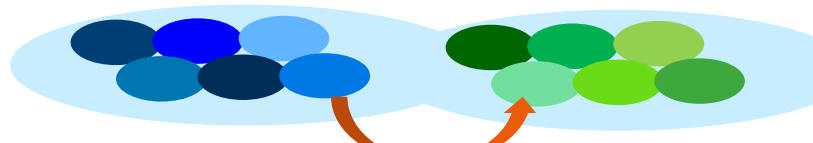
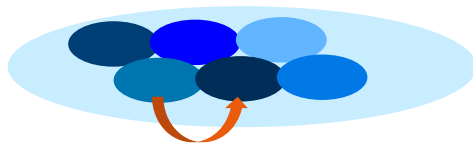
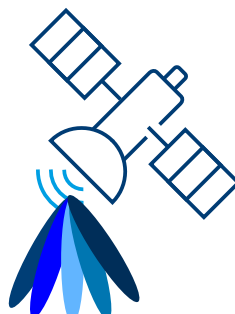
5G NTN HANDOVER EXAMPLE (CHO)



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

5G NTN MOBILITY SCENARIOS

Assumption: A satellite uses multiple beams in parallel. Each beam is identified via physical cell ID (PCI) and SSB index (SSB_ID)



Scenario 1:
Each beam is different SSB_ID
All beams have same PCI
=> Mobility of UE is via beam
change procedure

Scenario 2:
Each beam is different SSB_ID
Each beam is different PCI
=> Inter-cell change handover
=> Sat sends SIB19 neighbour info
with frequency & PCI

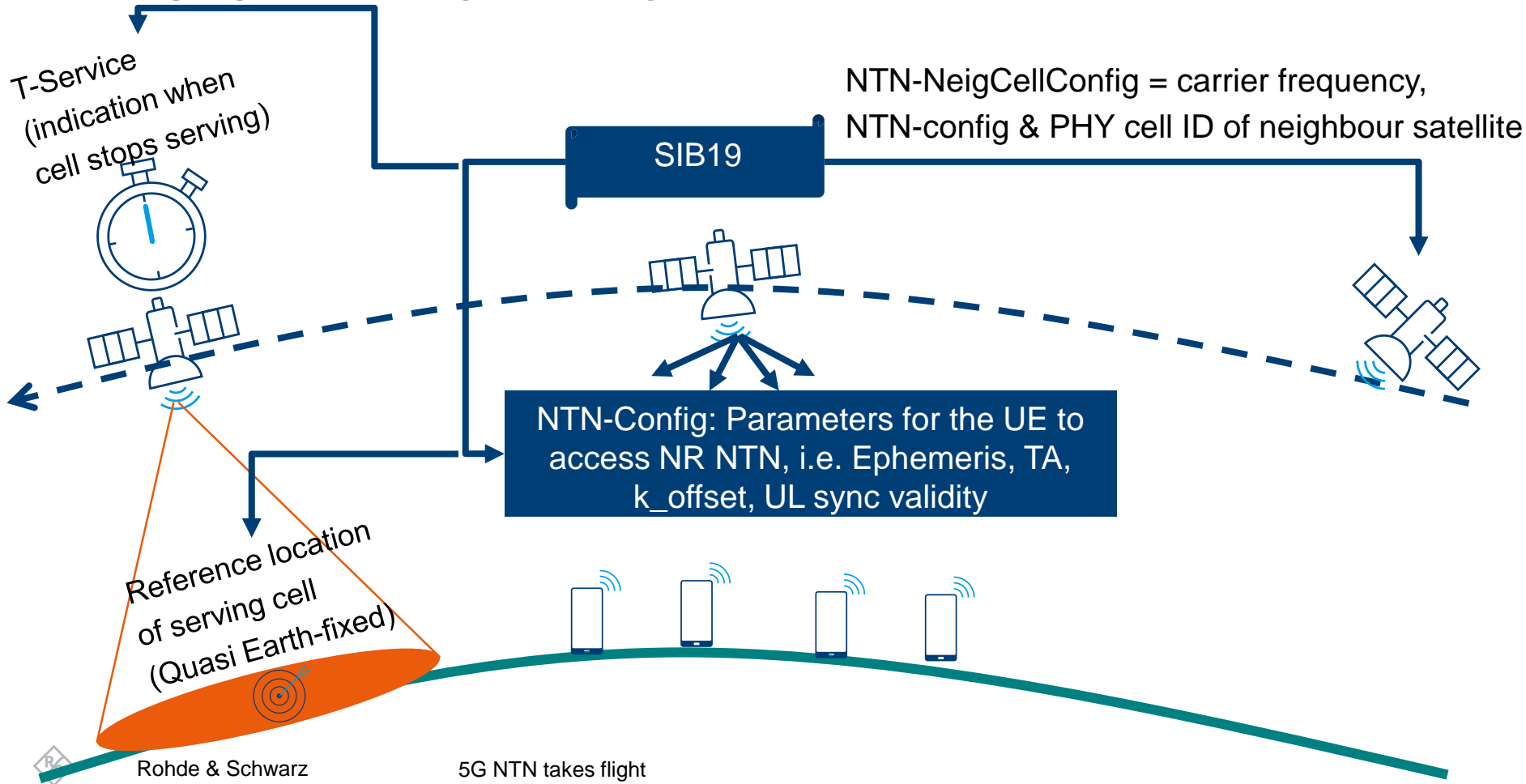
Scenario 3:
Handover to another satellite
=> Inter-cell change handover
=> Sat sends SIB19 neighbour info with
frequency & PCI & satellite
ephemeris info (NTN_config)



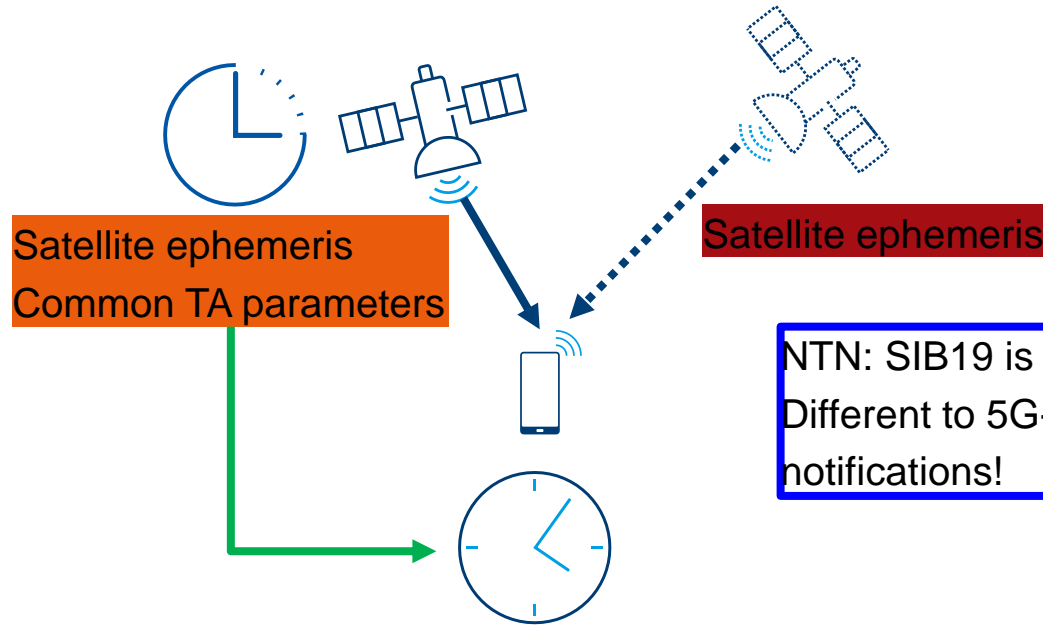
Non-terrestrial networks (NTN)

5G NTN PROTOCOL LAYER SIGNALING DETAILS

NTN: SYSTEM INFORMATION



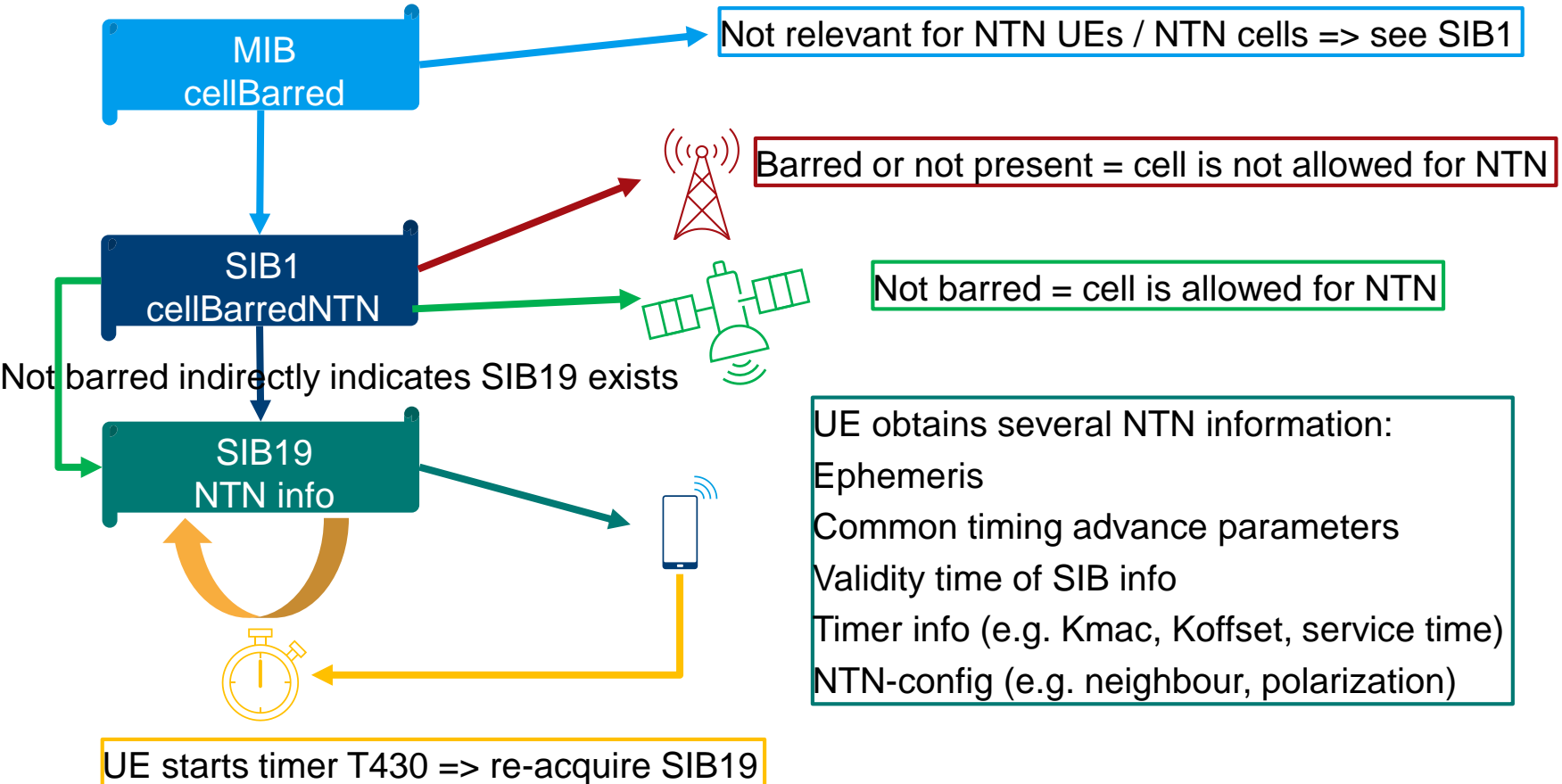
NTN: NETWORK ASSISTANCE INFORMATION AND VALIDITY



NTN: SIB19 is updated frequently and autonomously. Different to 5G-NR, this will not result in SIB change notifications!

Ntn-ULSyncValidityDuration indicates the maximum time during which the UE can apply assistance information without having acquired new assistance information

NTN: CELL ACQUISITION



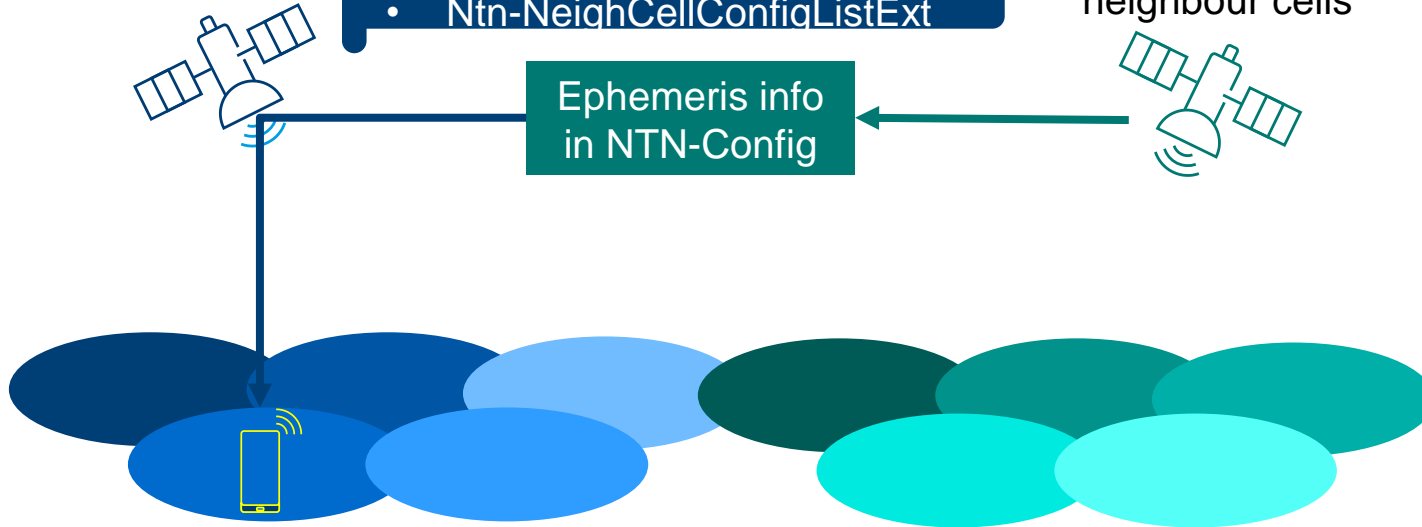
NTN: NEIGHBOUR CELL INFORMATION IN SIB19

SIB19:

- Ntn-NeighCellConfigList
- Ntn-NeighCellConfigListExt

Neighbour list and neighbour list extension to allow up to 8 NTN neighbour cells

Ephemeris info
in NTN-Config



Neighbour cells are possible on the same satellite => absence of NTN-Config in neighbour list

5G NTN – SERVICE TIME INDICATION VIA SIB19

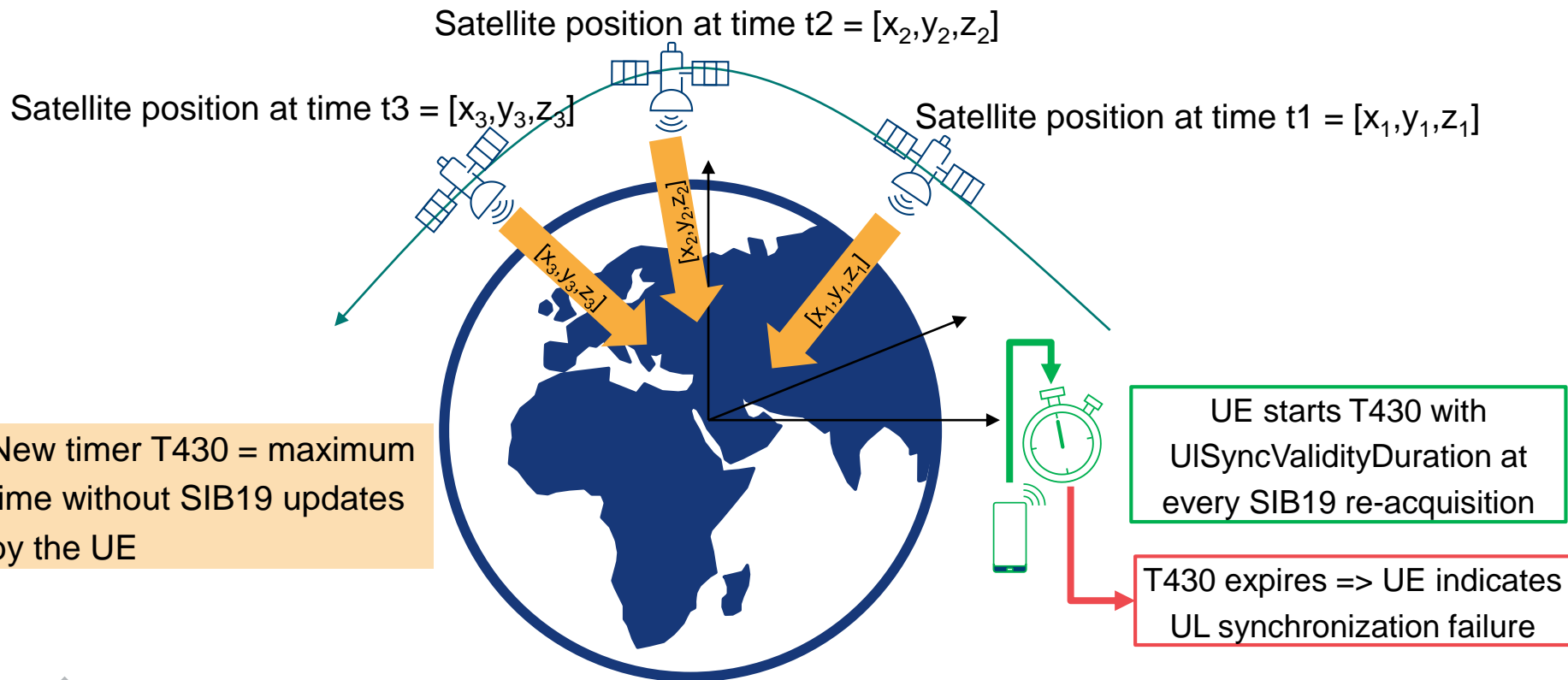


t-Service
Indicates the time information on when a cell provided via NTN quasi-Earth fixed system is going to stop serving the area it is currently covering. The field indicates a time in multiples of 10 ms after 00:00:00 on Gregorian calendar date 1 January, 1900 (midnight between Sunday, December 31,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



5G NTN – SYSTEM INFORMATION UPDATES

NTN: Satellite automatically updates SIB19 information, e.g. Ephemeris & position info.
=> no SIB change notification resulting



NTN: SYSTEM INFORMATION BLOCK 19 (SIB19)

```
SIB19-r17 ::= SEQUENCE {
    ntn-Config-r17                NTN-Config-r17,                OPTIONAL, -- Need R
    t-Service-r17                INTEGER (0..549755813887),        OPTIONAL, -- Need R
    referenceLocation-r17        ReferenceLocation-r17,          OPTIONAL, -- Need R
    distanceThresh-r17           INTEGER(0..65525),              OPTIONAL, -- Need R
    ntn-NeighCellConfigList-r17  NTN-NeighCellConfigList-r17,  OPTIONAL, -- Need R
    lateNonCriticalExtension
    ...,
    [[
    ntn-NeighCellConfigListExt-v1720  NTN-NeighCellConfigList-r17,  OPTIONAL, -- Need R
    ]]
}
```

```
NTN-NeighCellConfigList-r17 ::= SEQUENCE (SIZE(1..maxCellNTN-r17)) OF NTN-NeighCellConfig-r17
```

```
NTN-NeighCellConfig-r17 ::= SEQUENCE {
    ntn-Config-r17                NTN-Config-r17                OPTIONAL, -- Need R
    carrierFreq-r17               ARFCN-ValueNR                 OPTIONAL, -- Need R
    physCellId-r17                PhysCellId                    OPTIONAL, -- Need R
}
```



NTN: NTN-CONFIG AS MAJOR INFO ABOUT NTN CELL

```
NTN-Config-r17 ::=
    epochTime-r17
    ntn-ULSyncValidityDuration-r17
OPTIONAL, -- Cond SIB19
    cellSpecificKoffset-r17
    kmac-r17
    ta-Info-r17
    ntn-PolarizationDL-r17
    ntn-PolarizationUL-r17
    ephemerisInfo-r17
    ta-Report-r17
    ...}
SEQUENCE {
    EpochTime-r17, OPTIONAL, -- Need R
    ENUMERATED { s5, s10, s15, s20, s25, s30, s35,
                s40, s45, s50, s55, s60, s120, s180, s240, s900}
    INTEGER(1..1023) OPTIONAL, -- Need R
    INTEGER(1..512) OPTIONAL, -- Need R
    TA-Info-r17 OPTIONAL, -- Need R
    ENUMERATED {rhcp,lhcp,linear}, OPTIONAL, Need R
    ENUMERATED {rhcp,lhcp,linear} OPTIONAL, Need R
    EphemerisInfo-r17 OPTIONAL, -- Need R
    ENUMERATED {enabled} OPTIONAL, -- Need R
}
```

```
EpochTime-r17 ::=
    sfn-r17
    subFrameNR-r17
SEQUENCE {
    INTEGER(0..1023),
    INTEGER(0..9) }
```

```
TA-Info-r17 ::=
    ta-Common-r17
    ta-CommonDrift-r17
    ta-CommonDriftVariant-r17
SEQUENCE {
    INTEGER(0..66485757),
    INTEGER(-257303..257303) OPTIONAL, -- Need R
    INTEGER(0..28949) OPTIONAL -- Need R }
```



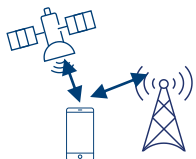


Non-terrestrial networks (NTN)

OUTLOOK

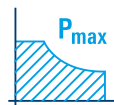
NTN REL. 18 TOPICS OVERVIEW

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



Mobility & service continuity

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



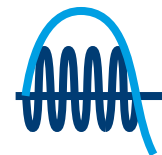
Coverage extension & power aspects

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



NW estimated UE location

- <10km accuracy position estimate
- UL TX-RX time difference



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

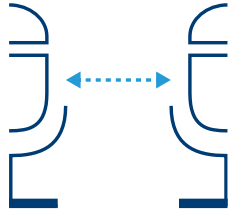
- Conditional handover for eMTC
- Time-based triggering of neighbour cell measurements
- RRM measurements location based



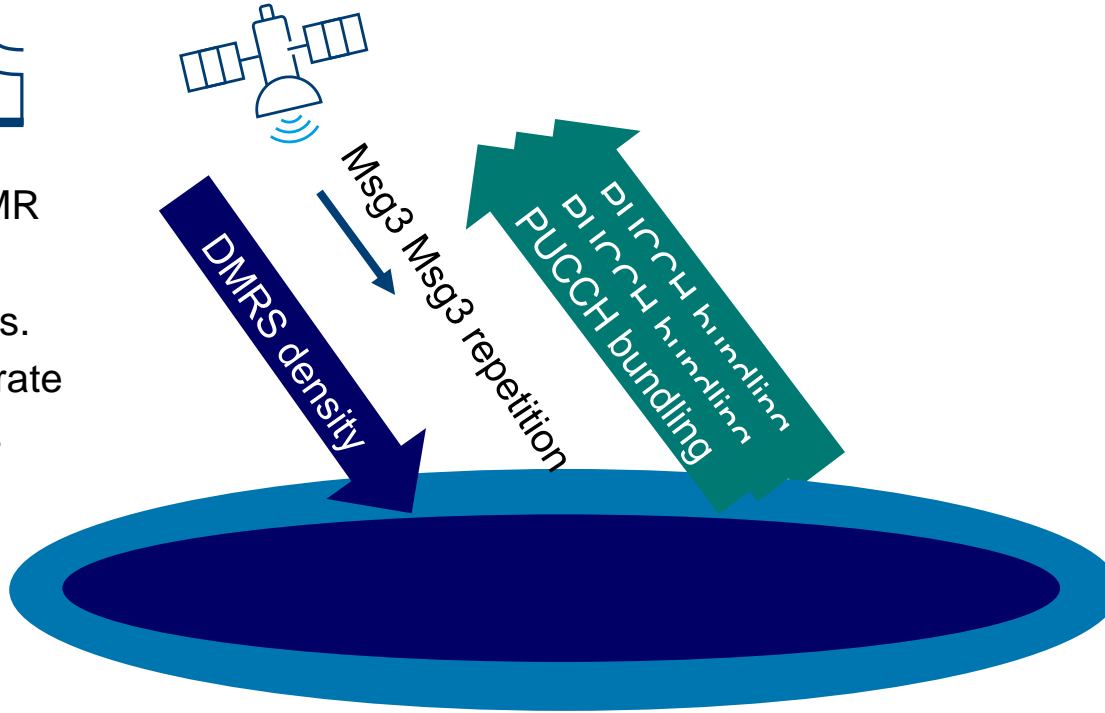
Discontinuous coverage

- Mobility management
- Power saving enhancements

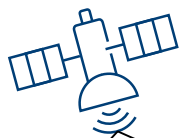
5G NTN RELEASE 18 COVERAGE ENHANCEMENTS



VoNR with AMR
4.75kbps
TBS = 184 bits.
20ms packet rate
+ two packets
combined



NTN REL. 18 UE CATEGORY DISCUSSION (>10 GHZ)

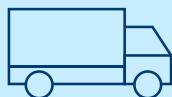


Proposed naming in RAN4		CEPT	FCC	ACMA	Mobility	Satellite tracking feature
NTN VSAT		VSAT	Earth station	VSAT	No, fixed	No
NTN ESIM		ESOMP	ESIM	ESIM	Yes	Yes
	NTN ESIM-L	Land ESOMP	ESIM / VMES	ESIM-L		
	NTN ESIM-M	Martime ESOMP	ESIM / ESAA	ESIM-M		
	NTN ESIM-A	Aeronautical ESOMP	ESIM / ESV	ESIM-A		

Aeronautical



Maritime



Land (mobile)



Land (stationary)

RRM discussions:

Case-1: Stationary UE for GSO

Case-2: Stationary UE for LEO

Case-3: Mobile UE for GSO

UE architectures:

Fully electronically-steered beam UEs (Type 1)

Fully mechanically-steered beam UEs (Type 2)

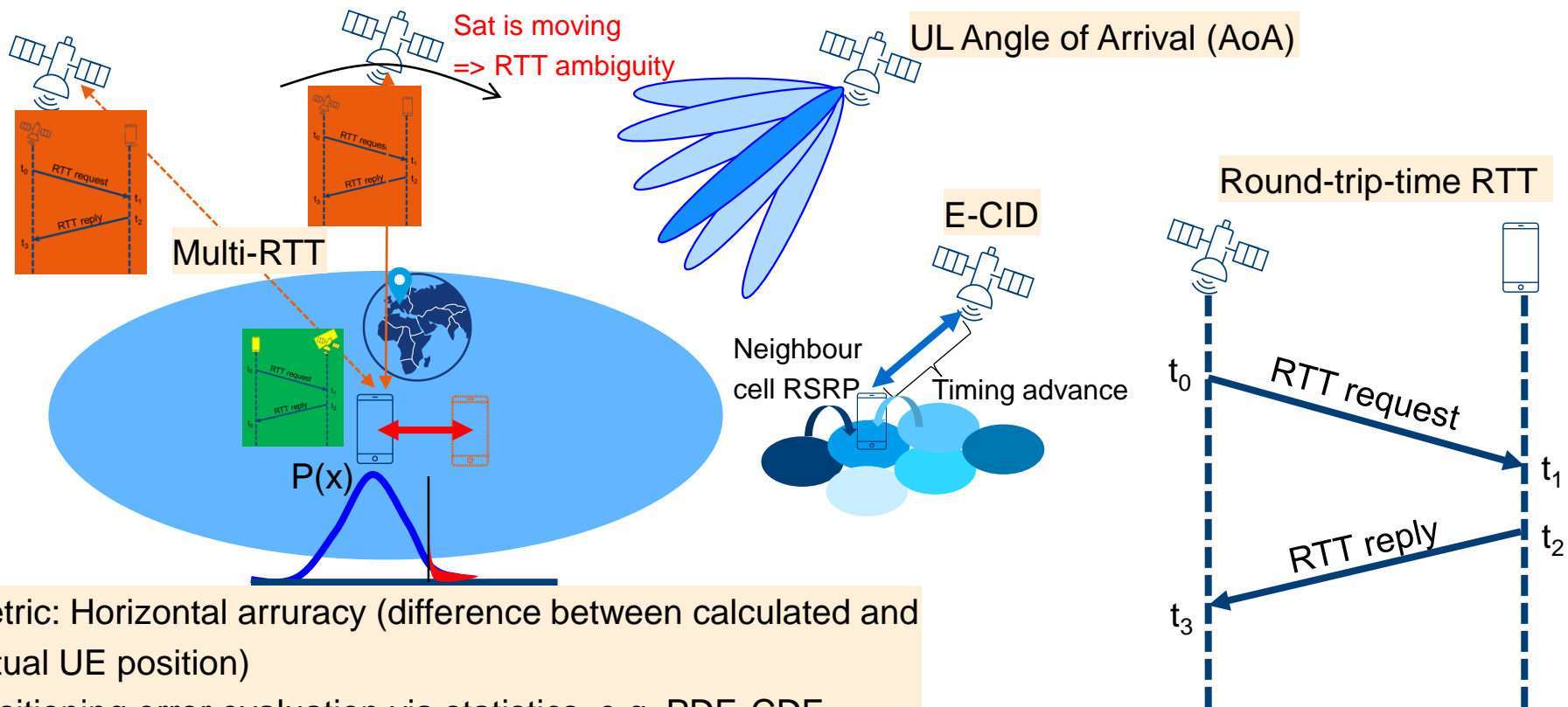
VSAT = Very small aperture terminal

ESIM = Earth station in motion

ESOMP = Earth station on mobile platform



5G NTN REL. 18 – NETWORK VERIFIED UE LOCATION



Metric: Horizontal accuracy (difference between calculated and actual UE position)

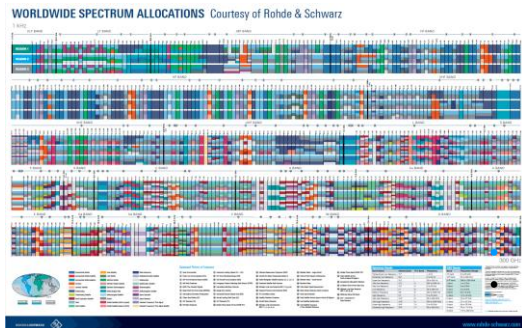
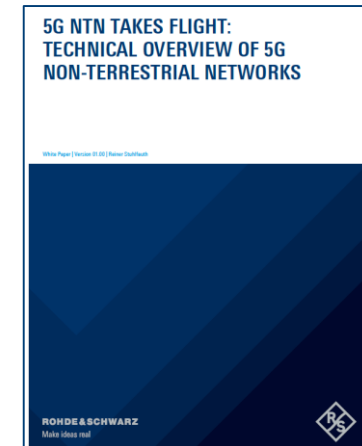
Positioning error evaluation via statistics, e.g. PDF, CDF

$$\text{Round-trip-time: } \delta = (t_3 - t_0) - (t_2 - t_1)$$



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 \(rohde-schwarz.com\)](#)

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



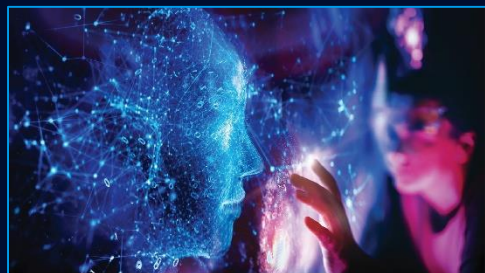
NR-NTN on CMX500

- ▶ Press released **Feb'24**
- ▶ Constellations (planned):
 - **GEO**, GSO, **LEO**, MEO
- ▶ Constellation config: sample list, rinex import, parameters for GEO: elevation angle for LEO: orbit height
- ▶ All CMsquares interfaces planned
- ▶ Automation (SCPI, XLAPI)
- ▶ NTN Fading (3GPP: pathloss, TDL, CDL (if required))
- ▶ 3GPP RF Measurements
- ▶ SIB1 → SIB19 (TA, K_Mac, K_Offset, etc.)
- ▶ FDD only (N255, N256), doppler +/-50KHz@2GHz
- ▶ Optional GNSS support via SMBV100B



技術談窓口を開設しています！

- ▶ 弊社のアプリケーションエンジニアが、お客様の計測に関する、困りごとを解決します。是非、この機会に技術相談窓口にお立ち寄りください！



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