Mobile Test Summit Korea 2024

NTN : ARCHITECTURES AND TECHNOLOGIES

Jonghun Kim (Rohde & Schwarz Korea)

ROHDE&SCHWARZ

Make ideas real

MOBILE TEST SUMMIT KOREA 2024

NTN : Architectures and technologies

Agenda

- Timeline for NTN
- 5G NTN Frequency Aspects & Architecture
- 5G NTN Protocol Aspects & Procedure
- IoT-NTN Specific technology aspects
- Outlook

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

2024 | 2025 | 2026 | 2027 | 2028 | 2029

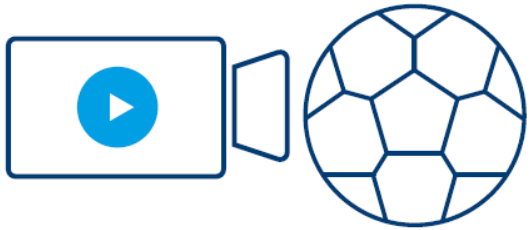
5G NR Narrowband

- SOS messaging
- Road safety
- Voice call (4kbps)

5G NR Wideband

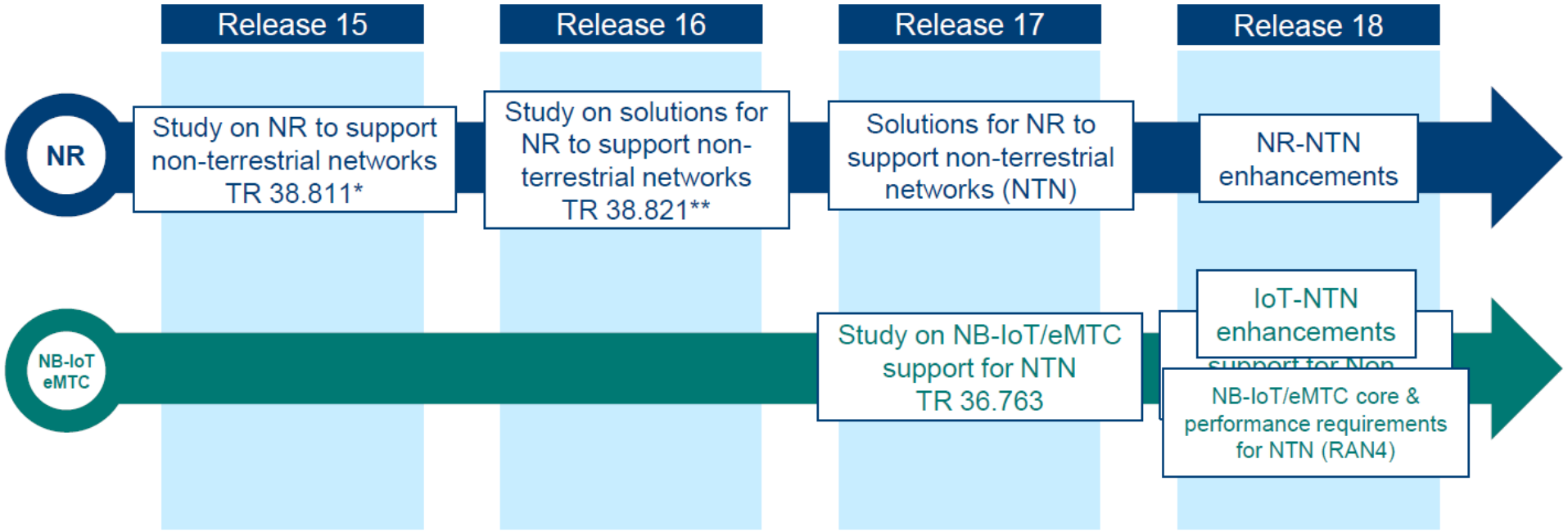
- Fleet monitoring
- Vehicle diagnostics
- Navigation support

5G NR Broadband



- Entertainment
- Video call / conference
- Gaming

3GPP TIMELINE FOR NTN



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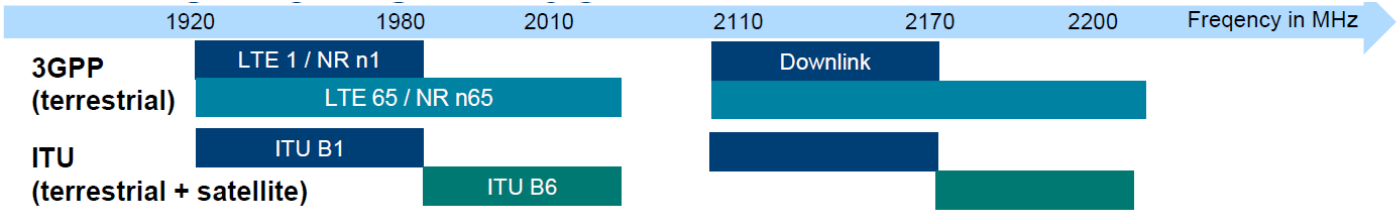
5G NTN FREQUENCY ASPECTS & ARCHITECTURE

NTN –SPECTRUMIN 5G FR1



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

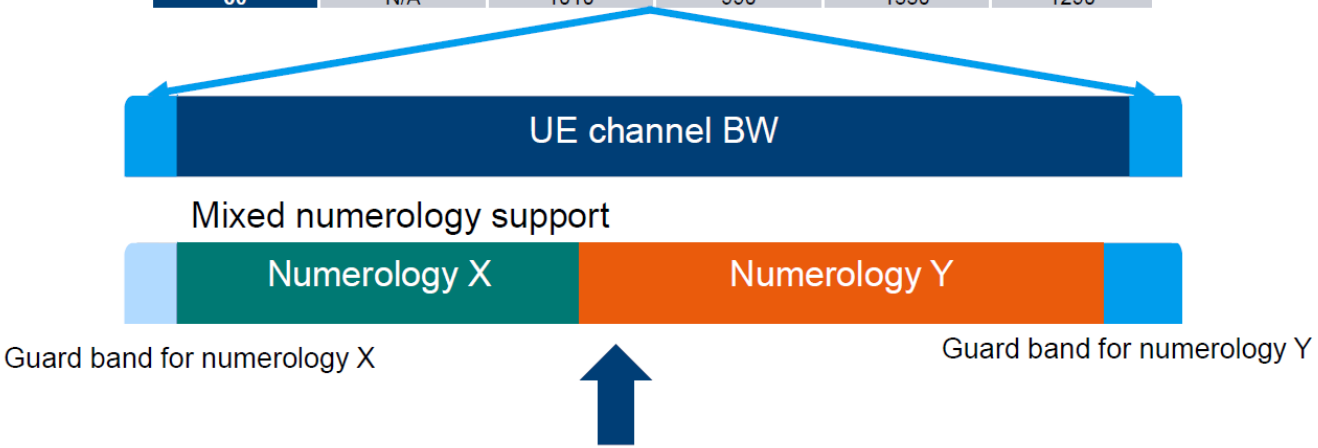
NTN band #	Uplink	Downlink	Duplex
n256	1980 – 2010 MHz	2170 – 2200 MHz	FDD
n255	1626.5 – 1660.5 MHz	1525 – 1559 MHz	FDD

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

NTN – SPECTRUMIN 5G FR1

Minimum guard band (kHz)

SCS (kHz)	5 MHz	10 MHz	15 MHz	20 MHz	30 MHz
15	242.5	312.5	382.5	452.5	592.5
30	505	665	645	805	945
60	N/A	1010	990	1330	1290



NTN satellite operating band	ΔF_{Raster} (kHz)	Uplink Range of N_{REF} (First – <Step size> – Last)	Downlink Range of N_{REF} (First – <Step size> – Last)	TX-RX frequency separation
n256	100	396000 – <20> – 402000	434000 – <20> – 440000	190 MHz
n255	100	325300 – <20> – 332100	305000 – <20> – 311800	-101.5 MHz

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

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

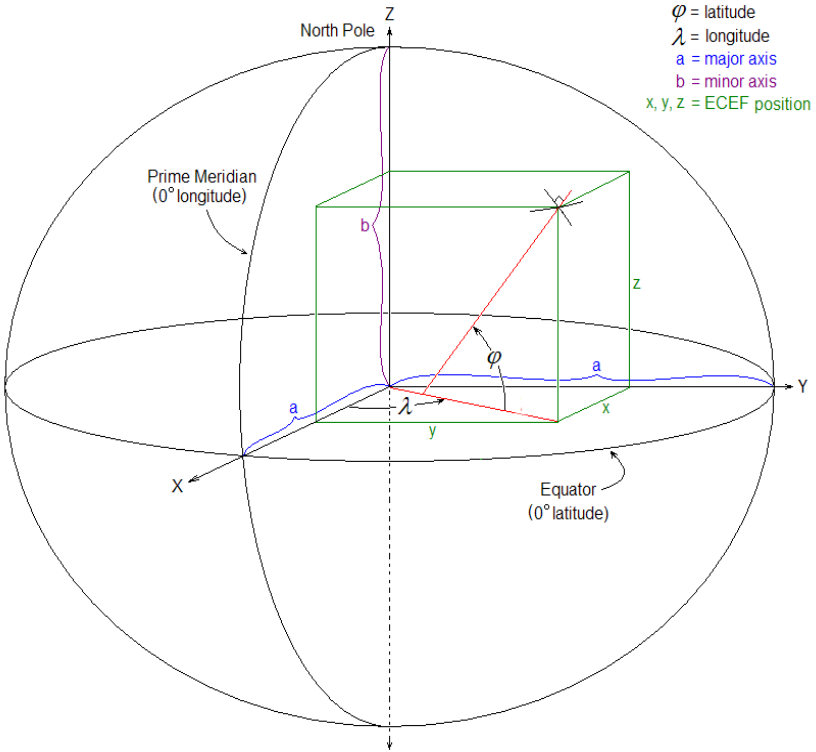
„FR3“ bands Ku: requested in R19

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

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

EPHEMERIS INFORMATION ON ORBIT



Satellite position is needed for:

- first synchronization
- Synchronization maintenance
- Mobility management procedures.

Satellite position is given:

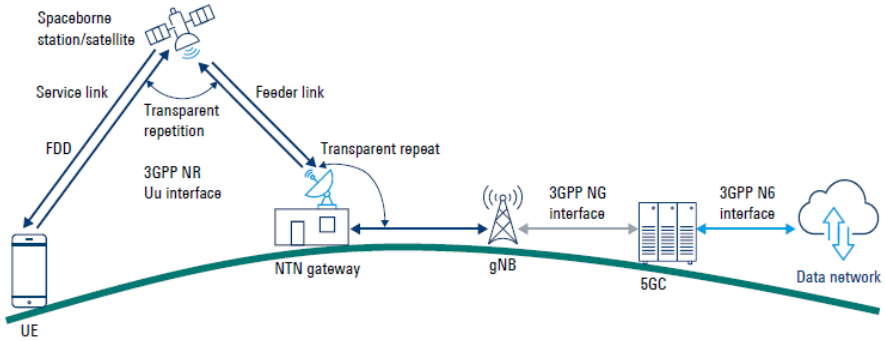
- Transmission over SIB19 (NR) or SIB31/32(LTE)
- Divided into serving cell's ephemeris and neighbor's ephemeris
- Possible pre-configuration in USIM

***EphemerisInfo* information element**

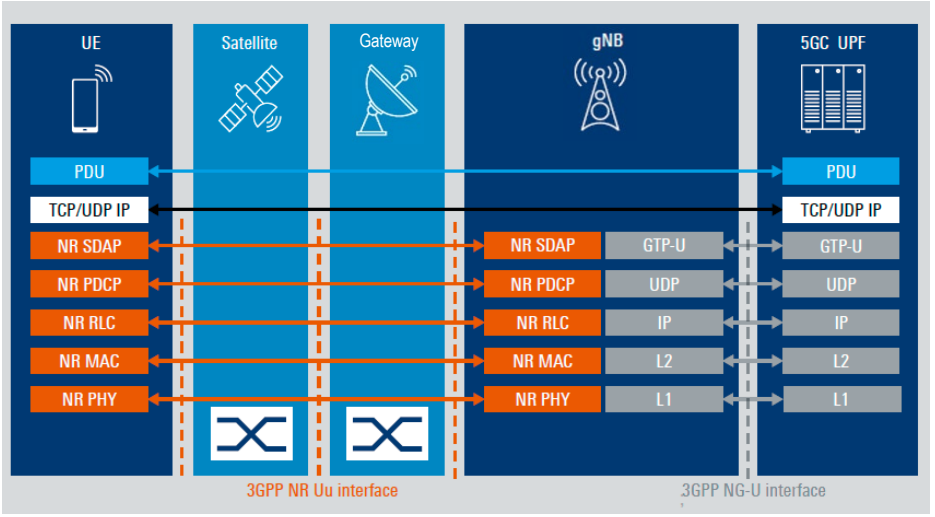
```
-- ASN1START
-- TAG-EPHEMERISINFO-START

EphemerisInfo-r17 ::=           CHOICE {
    positionVelocity-r17            PositionVelocity-r17,
    orbital-r17                     Orbital-r17
}

PositionVelocity-r17 ::=        SEQUENCE {
    positionX-r17                   PositionStateVector-r17,
    positionY-r17                   PositionStateVector-r17,
    positionZ-r17                   PositionStateVector-r17,
    velocityVX-r17                  VelocityStateVector-r17,
    velocityVY-r17                  VelocityStateVector-r17,
    velocityVZ-r17                  VelocityStateVector-r17
}
```

ARCHITECTURE OPTIONS

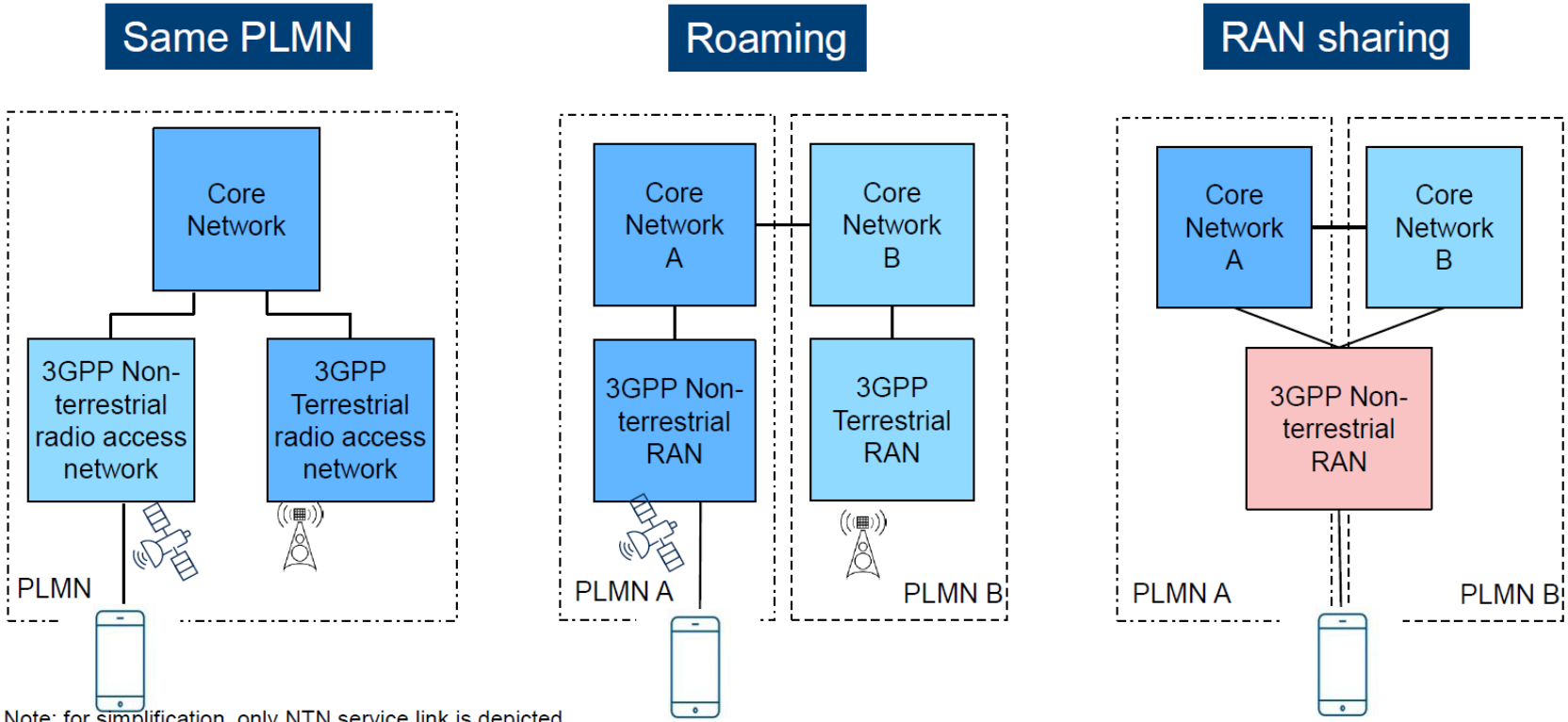
- TRANSPARENT NTN NG-RAN ARCHITECTURE



- gNB on Earth
- Satellite amplifies and forwards the Uu signals
- Longer L1 control plane latencies
- Uu interface = service link + feeder link
- 3GPP Rel. 17 to 18



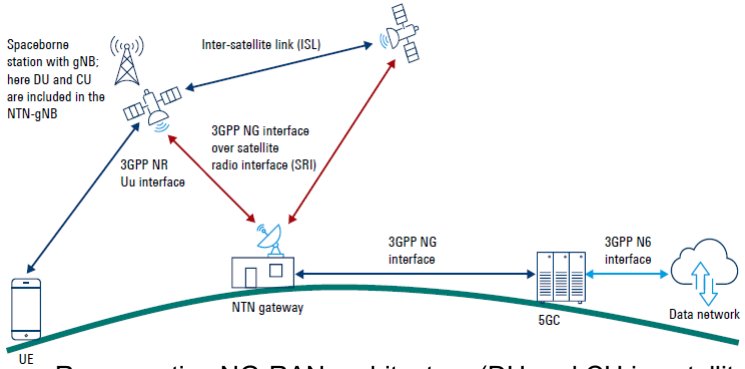
5G NTN INTEGRATION SCENARIOS WITH 5GC



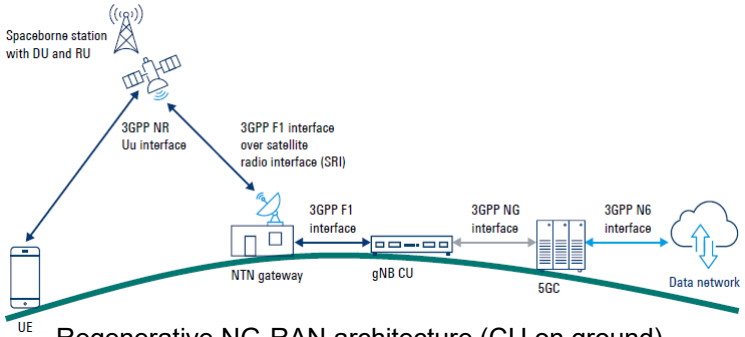
Note: for simplification, only NTN service link is depicted

ARCHITECTURE OPTIONS

- REGENERATIVE NTN NG-RAN ARCHITECTURE

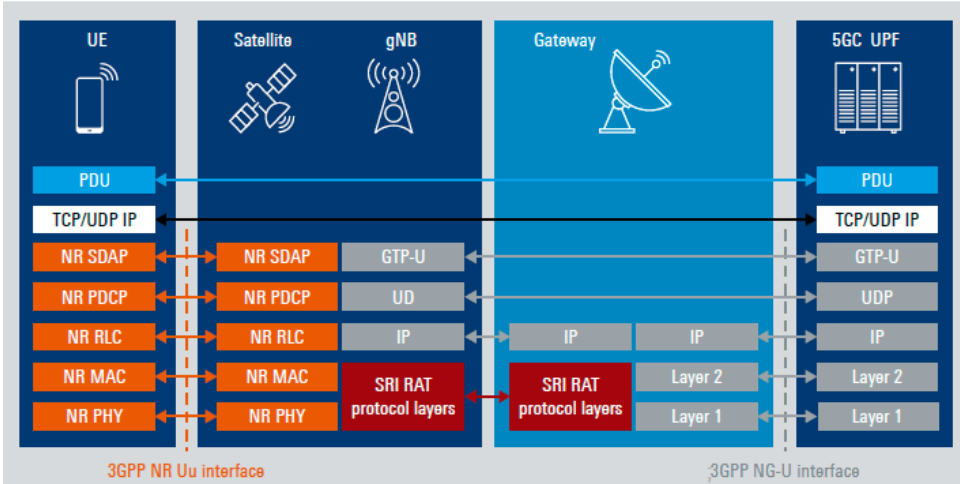


Regenerative NG-RAN architecture (DU and CU in satellite)

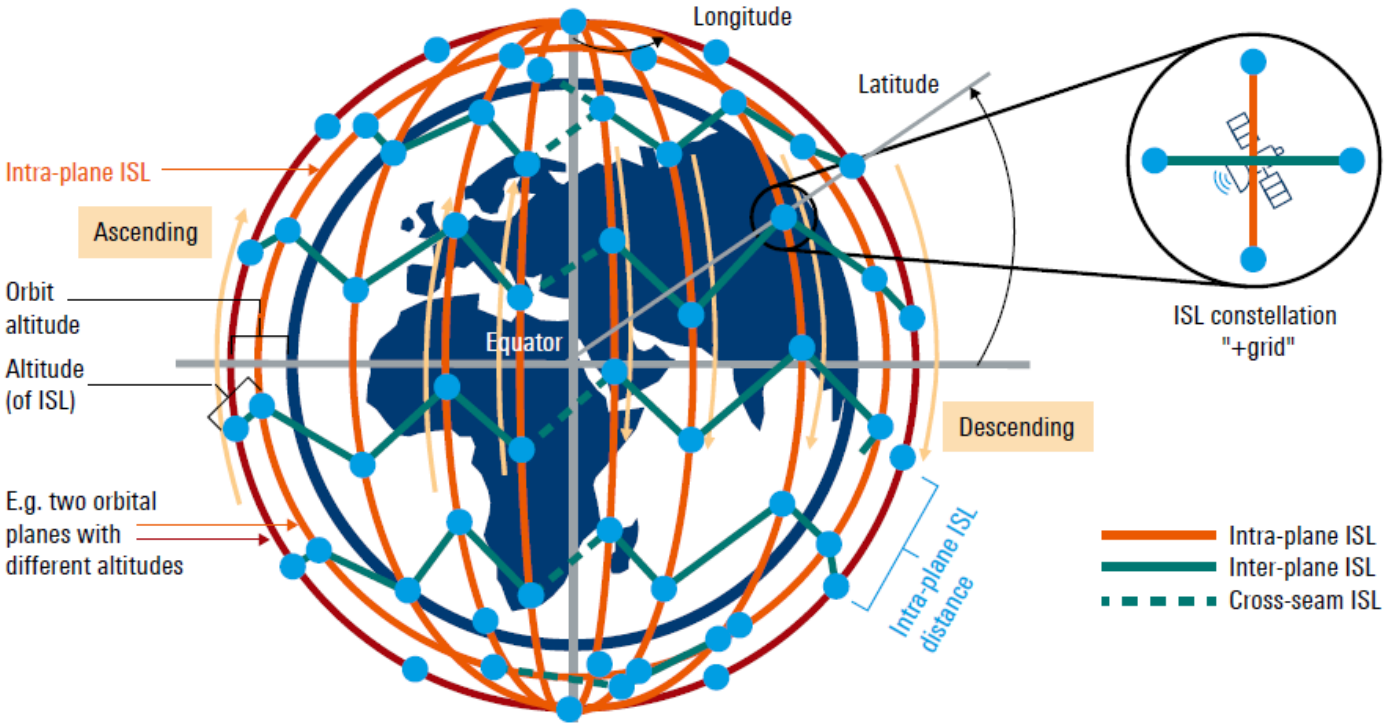


Regenerative NG-RAN architecture (CU on ground)

- gNB on satellite
- Shorter L1 control plane latencies
- Uu interface = service link
- NG or F1 interface = feeder link (SRI)
- 3GPP Rel. 19

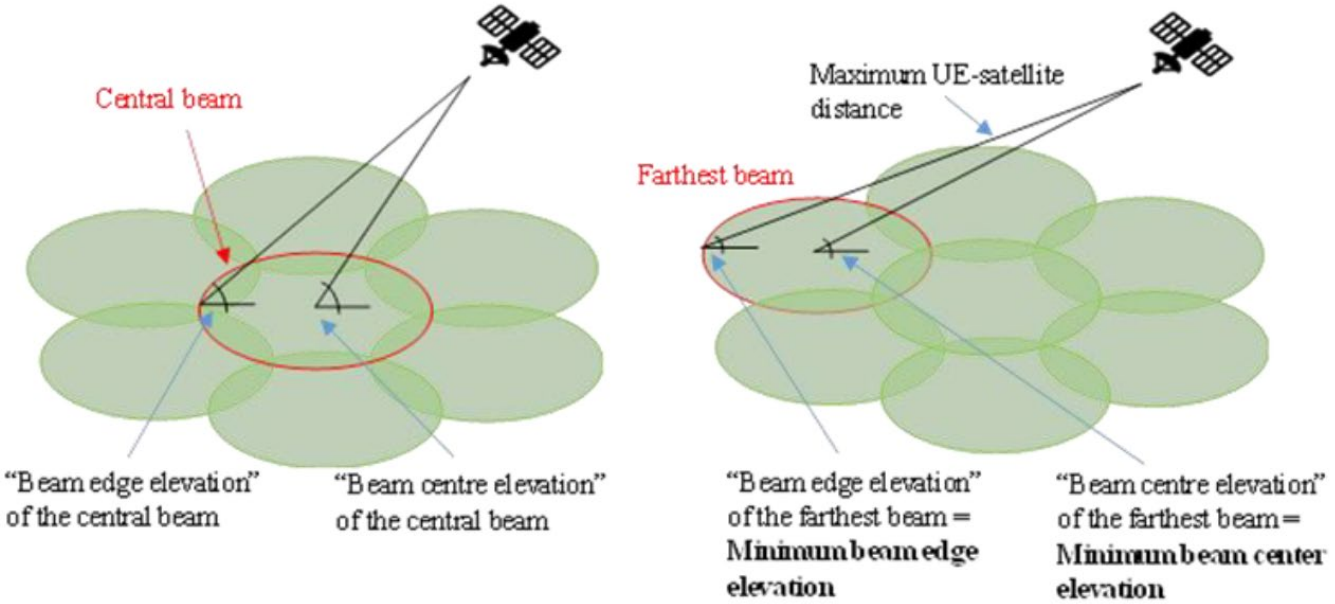


INTER SATELLITE LINKS (ISL)



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



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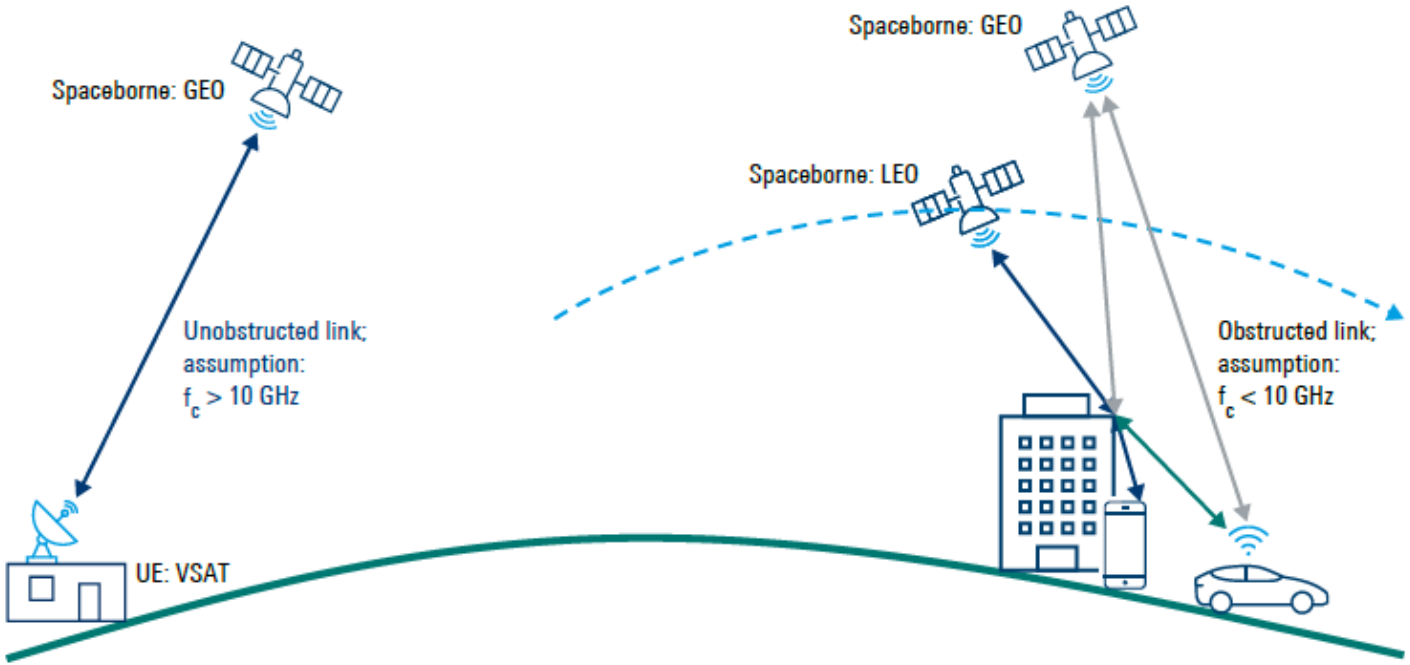
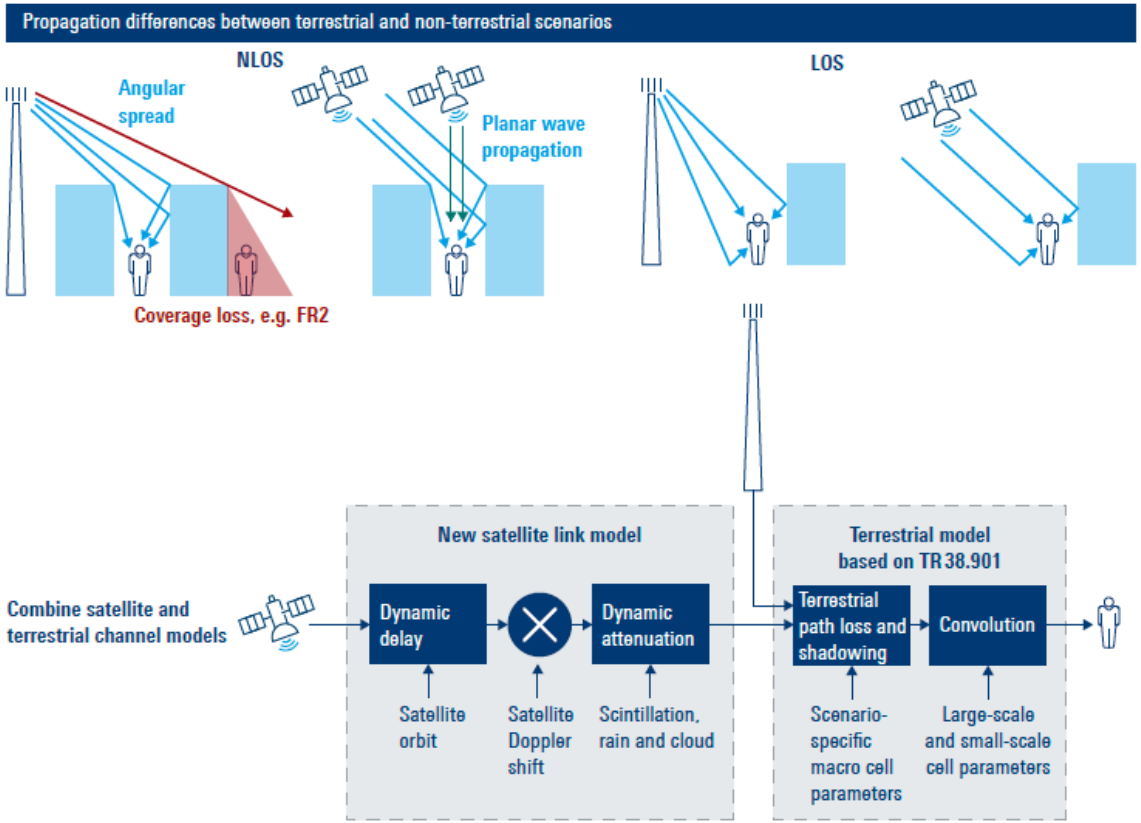
RF ASPECTS & CHALLENGES

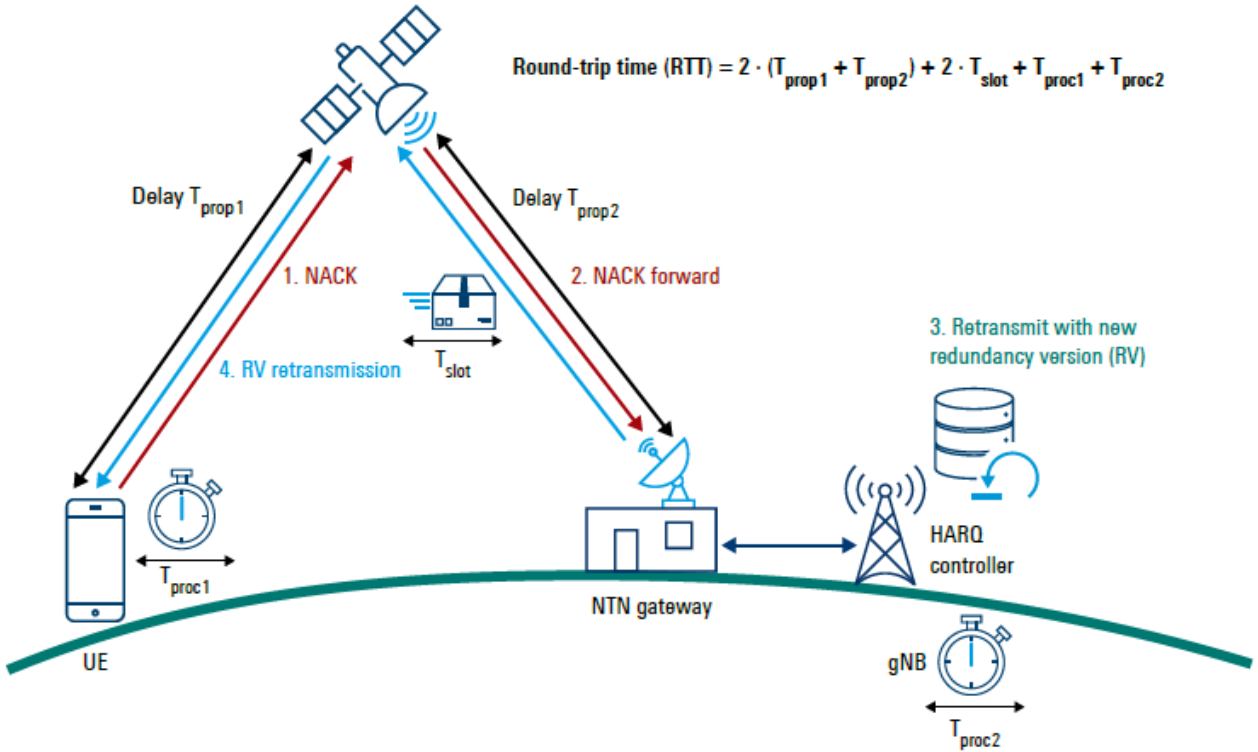
NTN PROPAGATION ASPECTS



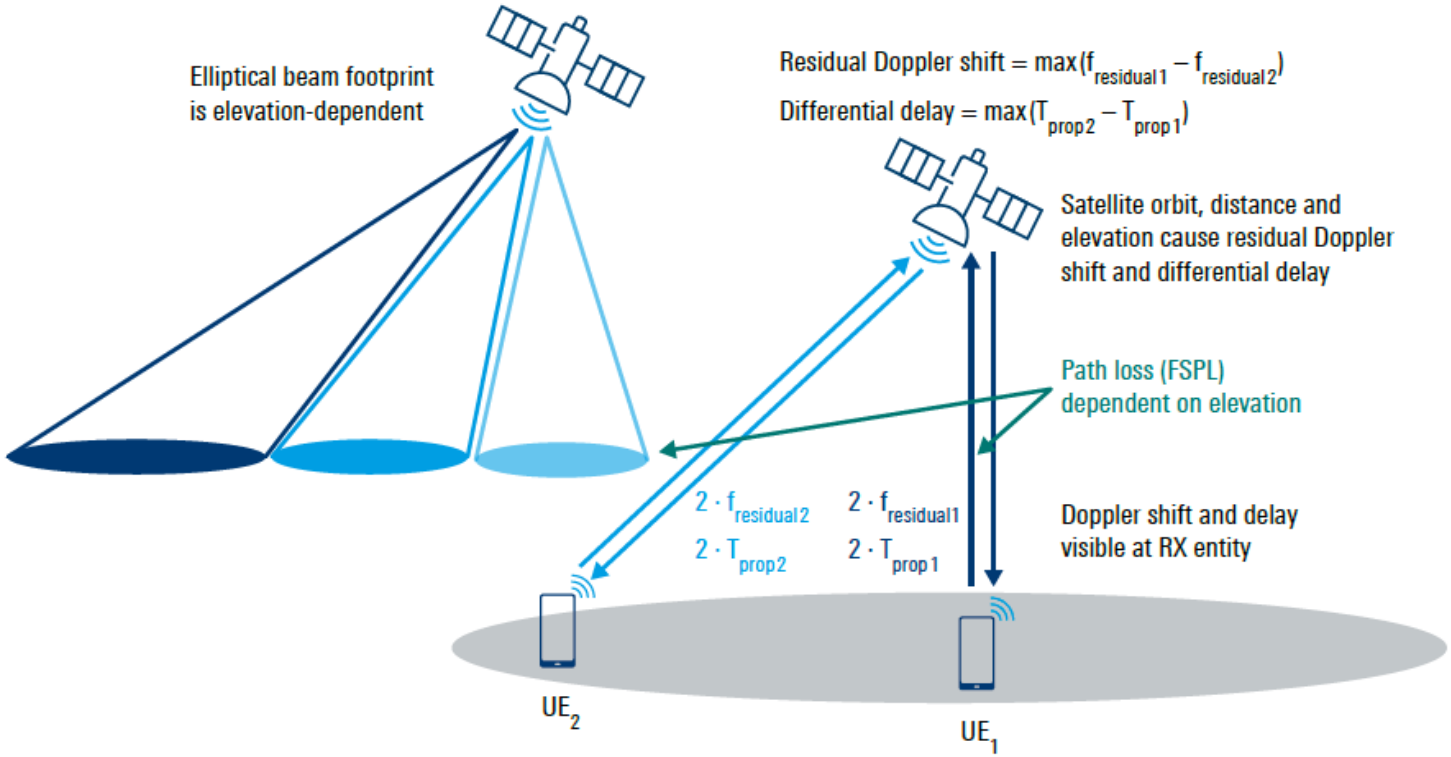
NTN FADING ASPECTS



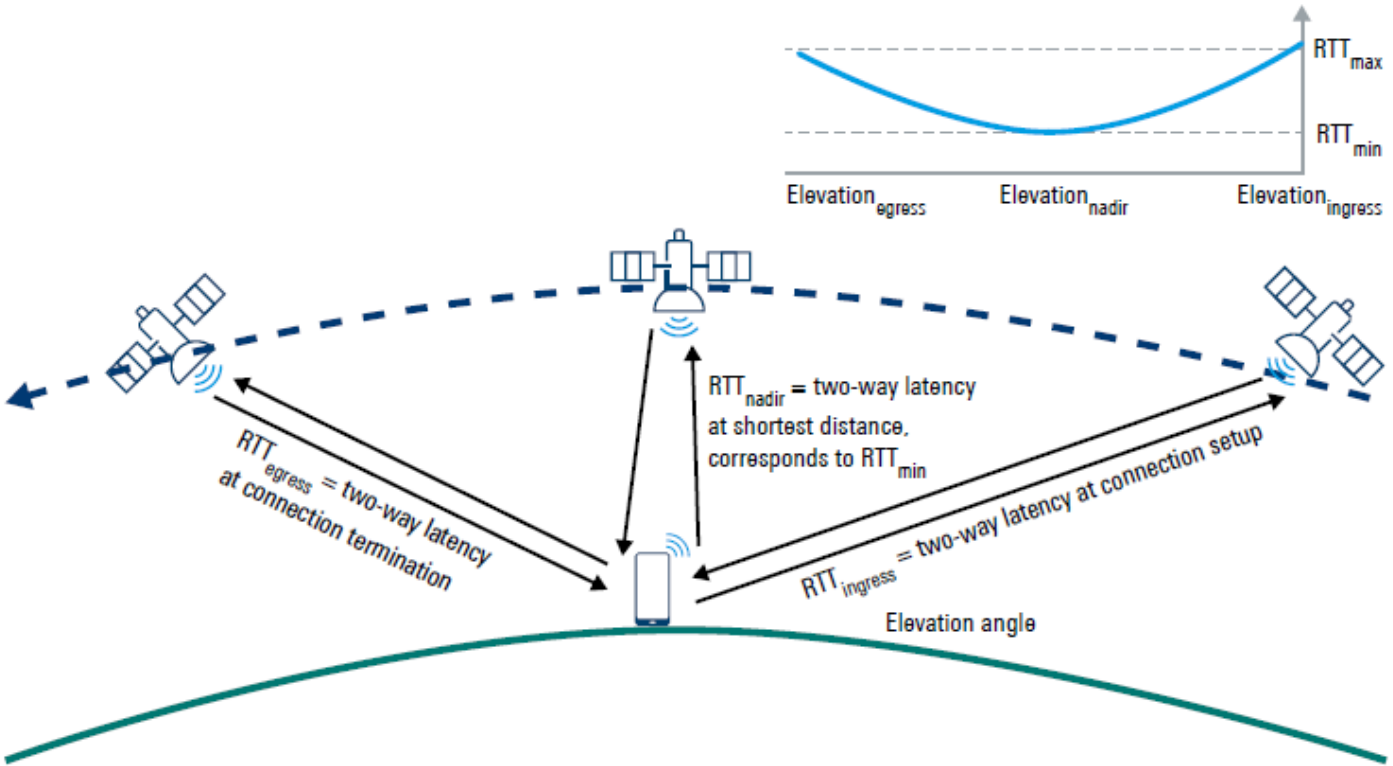
CHALLENGES OF RTT AND DIFFERENTIAL TIME DELAY
- ROUND-TRIP TIME



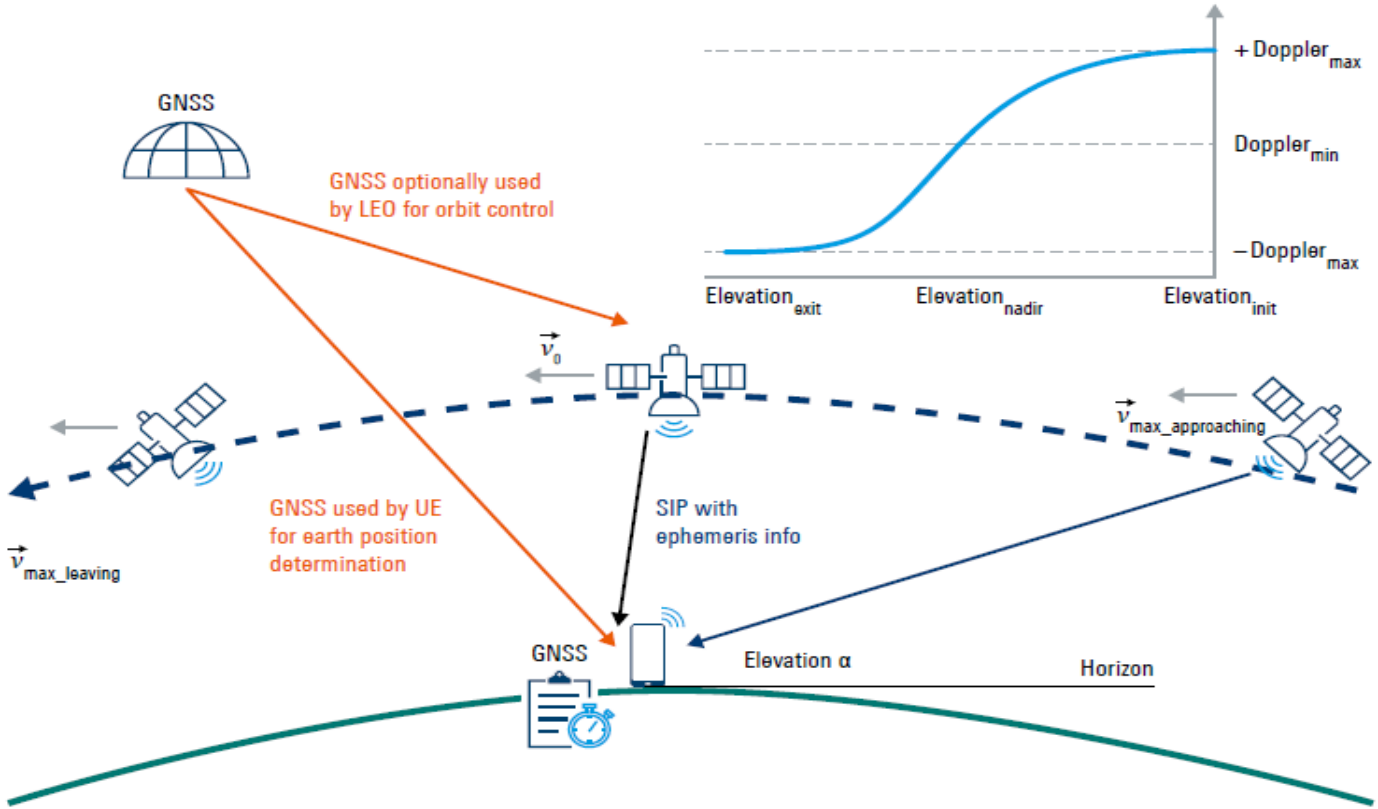
CHALLENGES OF RTT AND DIFFERENTIAL TIME DELAY
- PERSPECTIVE NTN SATELLITE



CHALLENGES OF RTT AND DIFFERENTIAL TIME DELAY
- PERSPECTIVE UE



CHALLENGES OF DOPPLER SHIFT WITH TIME



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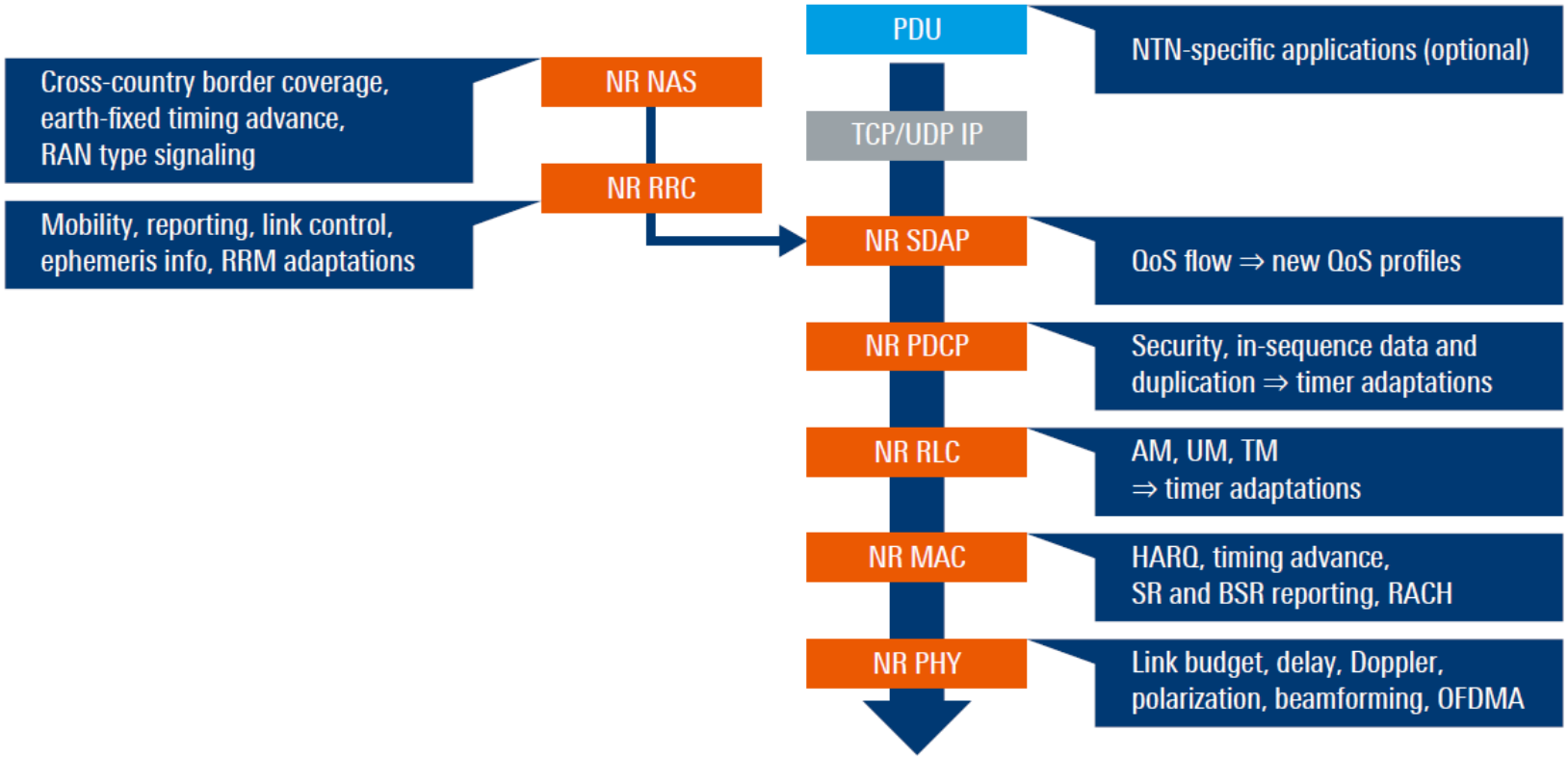
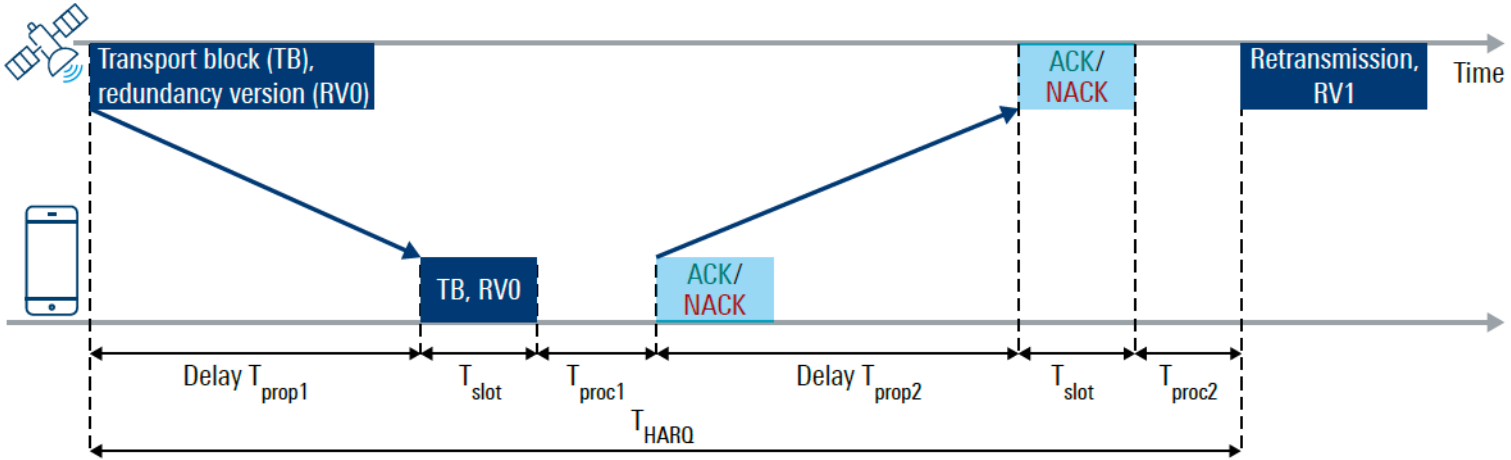
5G NTN PROTOCOL ASPECTS AND PROCEDURES

PROTOCOL STACK FOR 5G NTN



SOLUTION TO LONGER AND VARYING DELAY

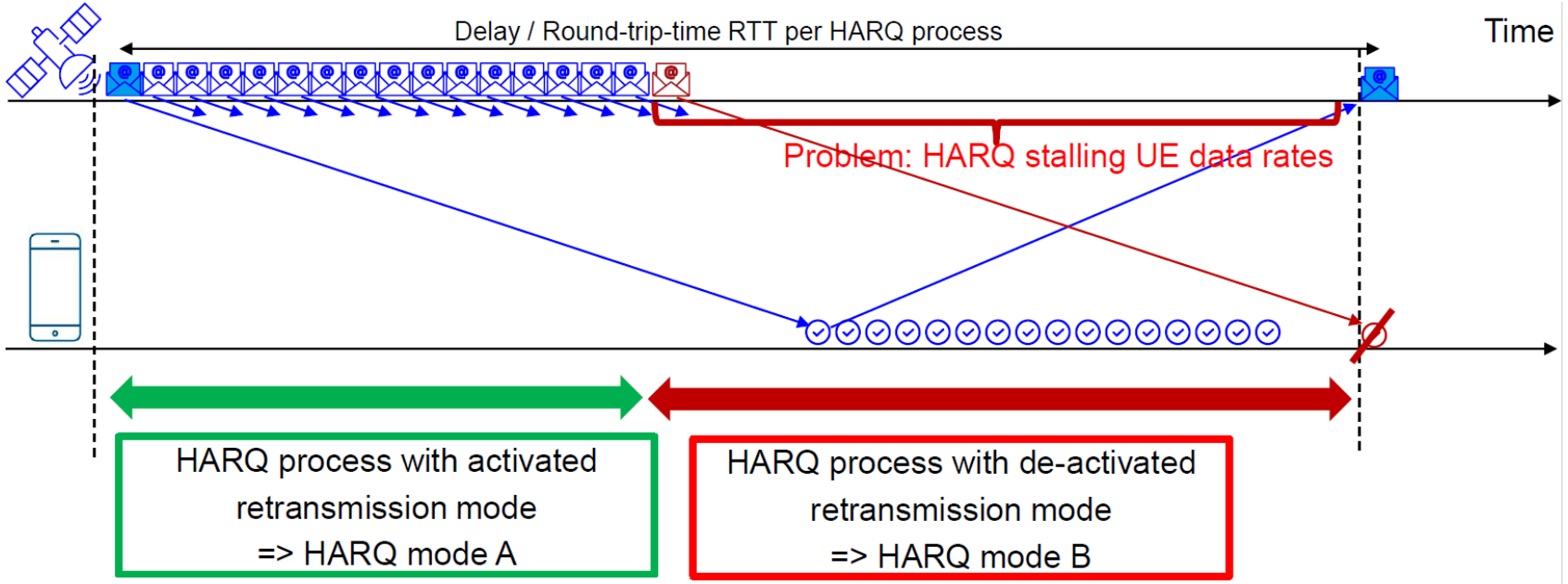
- HARQ OPERATION ASPECTS WITH NTN



Constellation	T_{HARQ} max.	No. of HARQ processes	UE side feasibility
Terrestrial	16 ms	16	Rel. 15
LEO	50 ms	50 theoretically, 3GPP agrees to 32	HARQ extension
GEO	600 ms	600 theoretically	For future study

Assumption: 15 kHz SCS and 1 ms slot duration [TR 38.811]

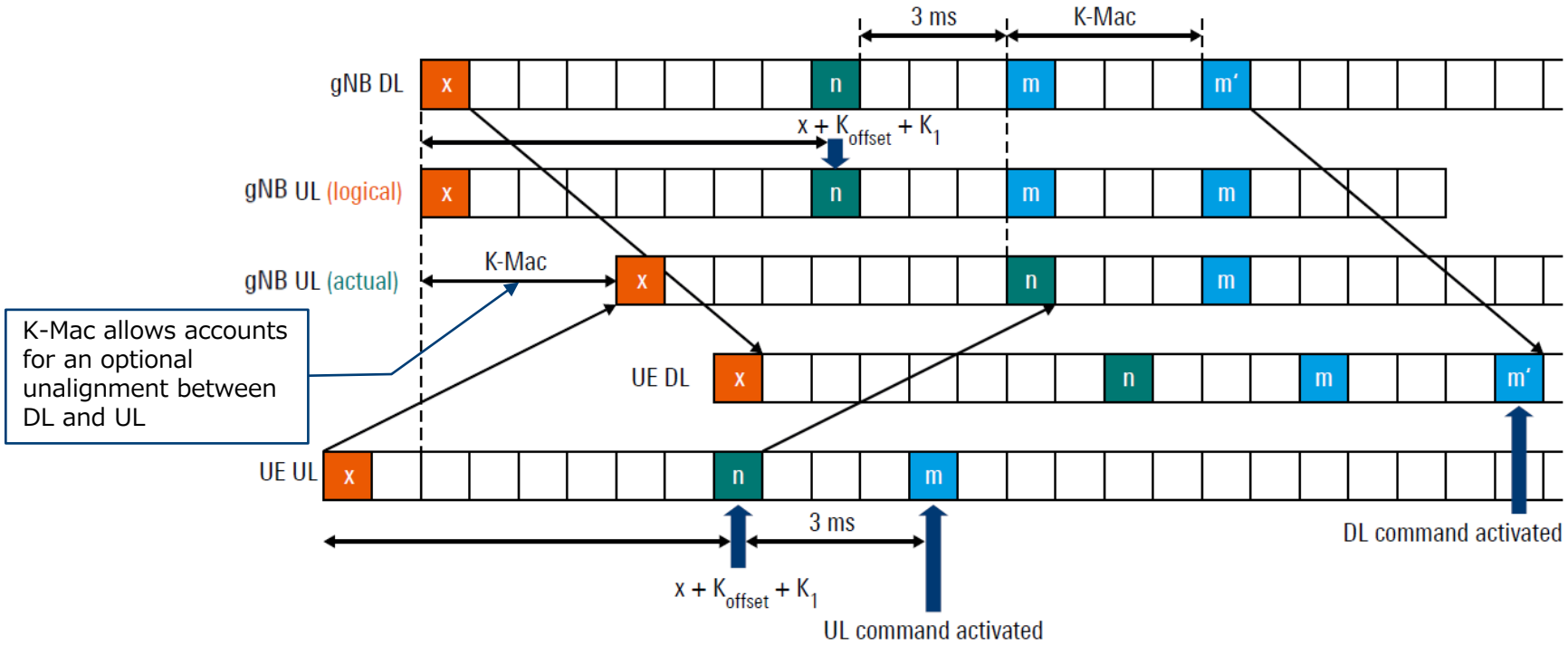
SOLUTION TO LONGER AND VARYING DELAY
- HARQ OPERATION ASPECTS WITH NTN



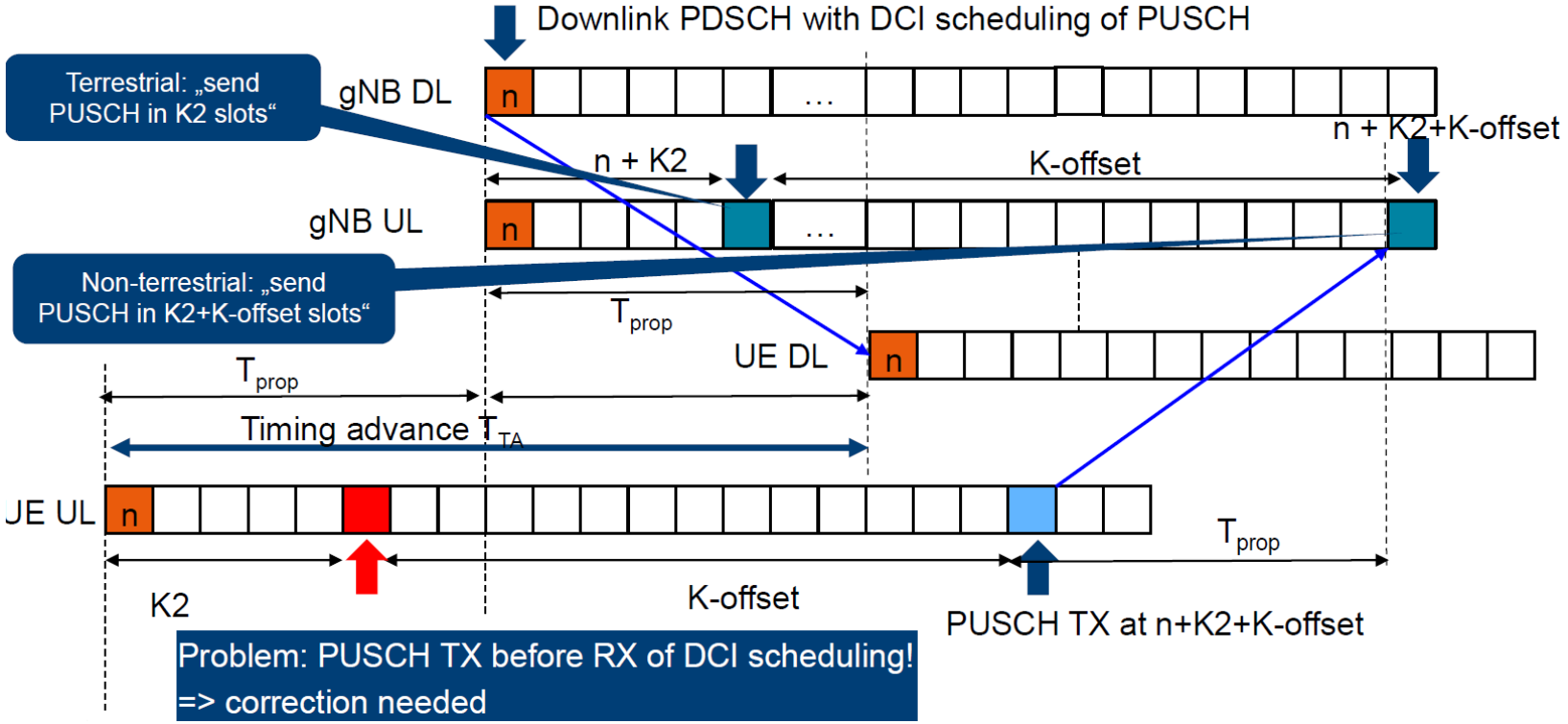
Long RTT will hinder UE data rates (HARQ stalling). Countermeasure:

- Extend the number of HARQ processes up to 32
- Disable HARQ per process and send data with de-activated retransmission mode

SOLUTION TO LONGER AND VARYING DELAY
- K-MAC

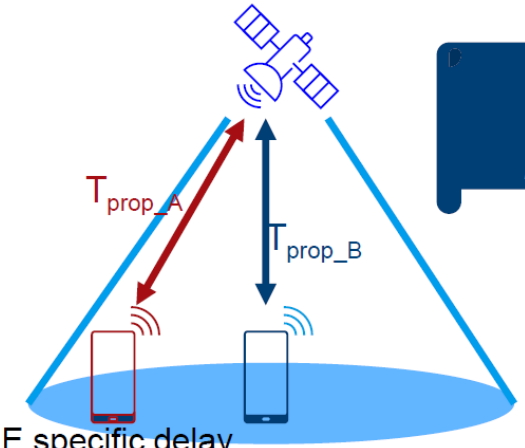


SOLUTION TO LONGER AND VARYING DELAY
- K-OFFSET



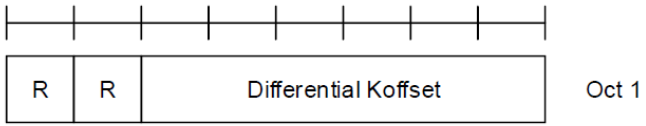
SOLUTION TO LONGER AND VARYING DELAY
- K-OFFSET

3GPP: Hybrid approach of cell-specific and UE-specific offset parameters for efficient timing



NTN-Config contains:
cellSpecificKoffset
[0..1023 slots @15kHz]

To cater for UE specific delay,
$K_{UE,offset}$ as UE-specific value [0..63ms]

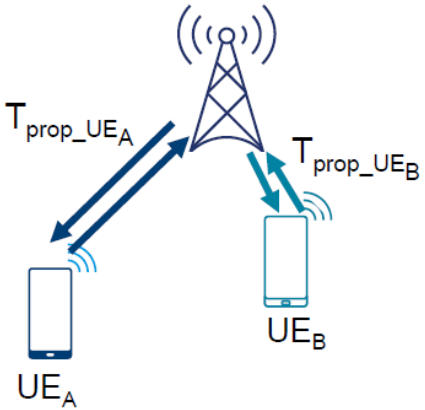


$$K_{offset} = K_{cell,offset} - K_{UE,offset}$$

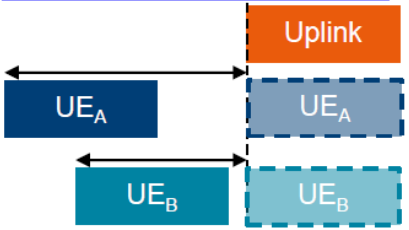
Koffset has an impact on timing of:

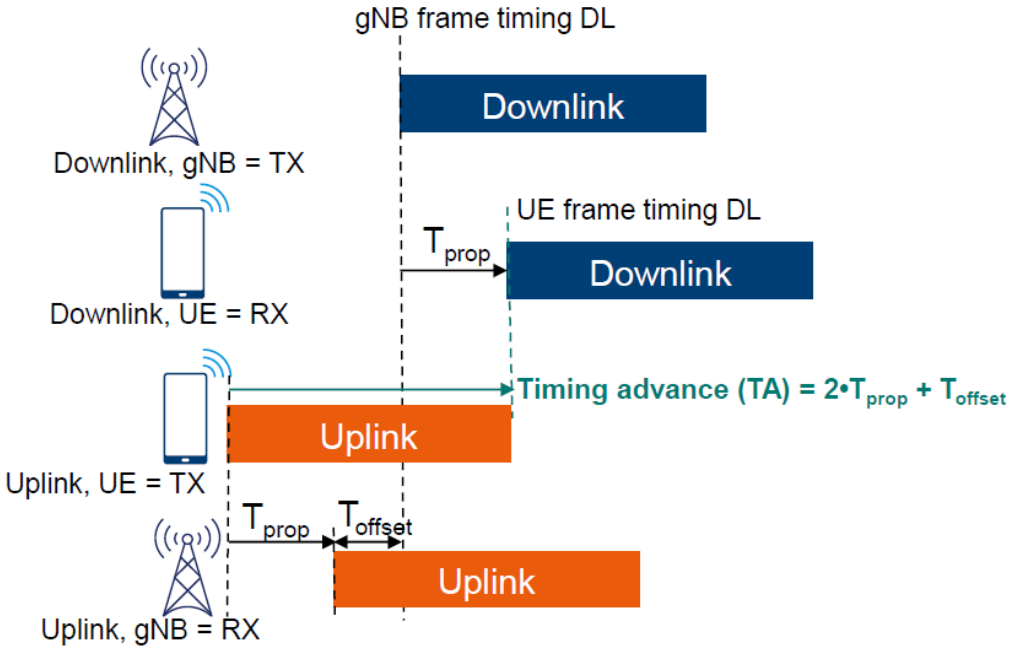
- DCI scheduling of PUSCH
- PUSCH TX as RAR response
- HARQ-ACK timing
- PDCCH orderer PRACH transmissions
- Timing advance
- Transmission of SRS
- CSI-RS reference timing

SOLUTION TO LONGER AND VARYING DELAY
- 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

SOLUTION TO LONGER AND VARYING DELAY
- TIMING ADVANCE ASPECTS: SIMPLIFIED VIEW

$N_{TA,adj}^{UE}$

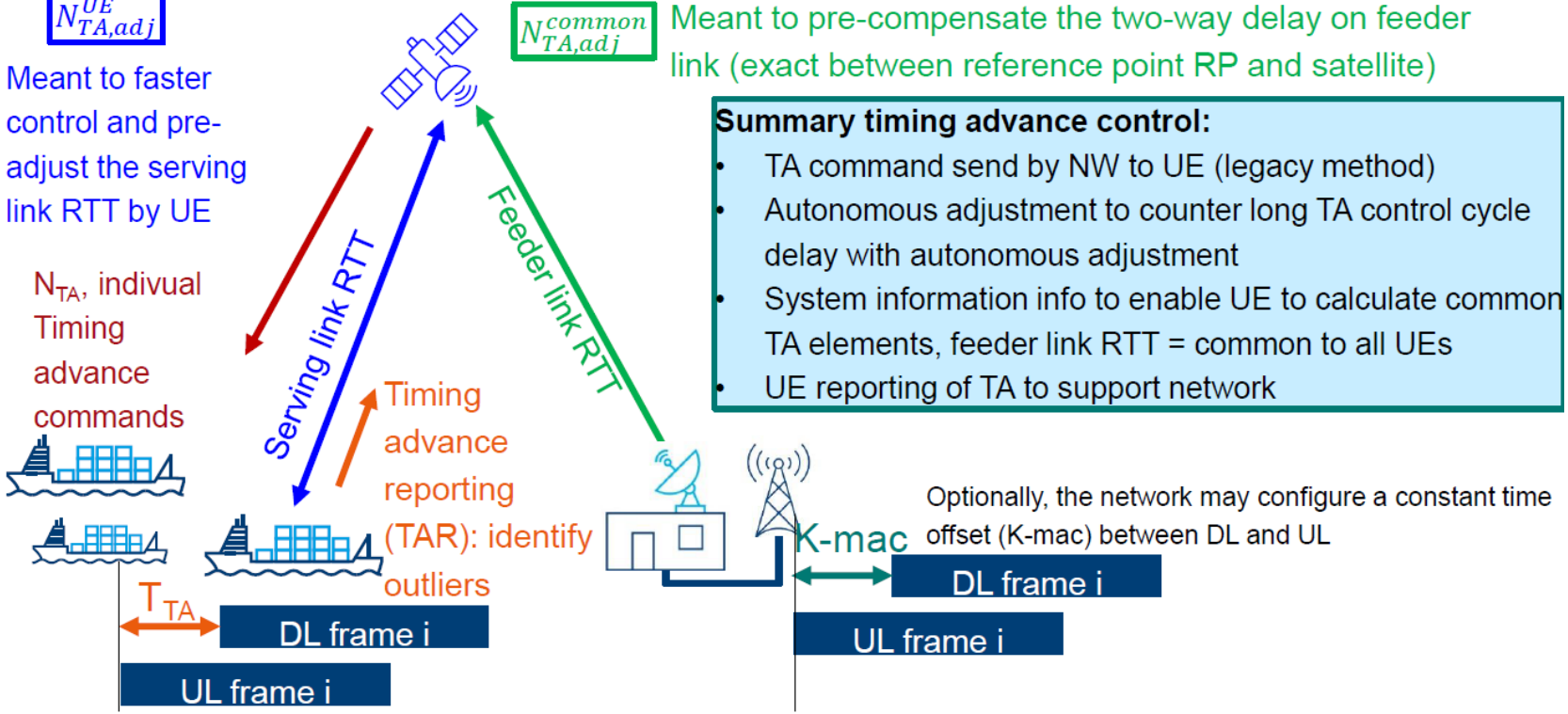
Meant to faster control and pre-adjust the serving link RTT by UE

$N_{TA,adj}^{common}$

Meant to pre-compensate the two-way delay on feeder link (exact between reference point RP and satellite)

Summary timing advance control:

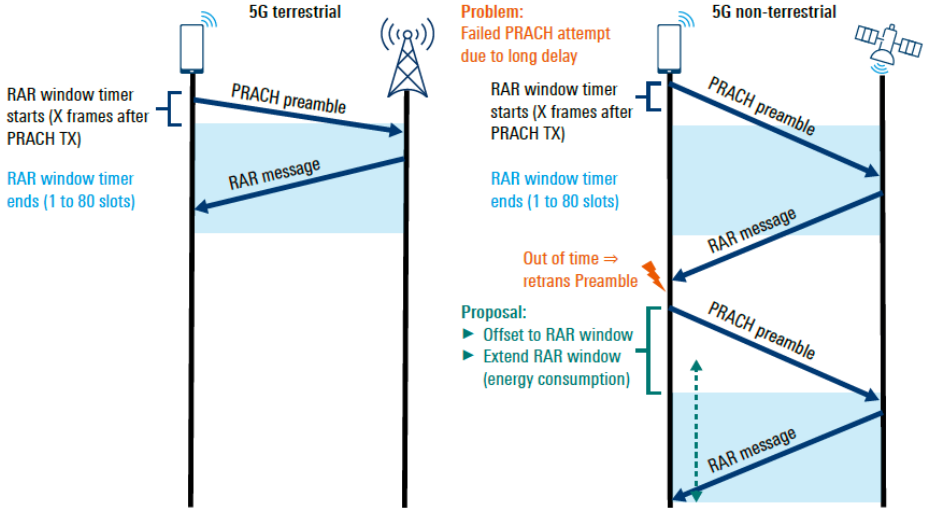
- TA command send by NW to UE (legacy method)
- Autonomous adjustment to counter long TA control cycle delay with autonomous adjustment
- System information info to enable UE to calculate common TA elements, feeder link RTT = common to all UEs
- UE reporting of TA to support network



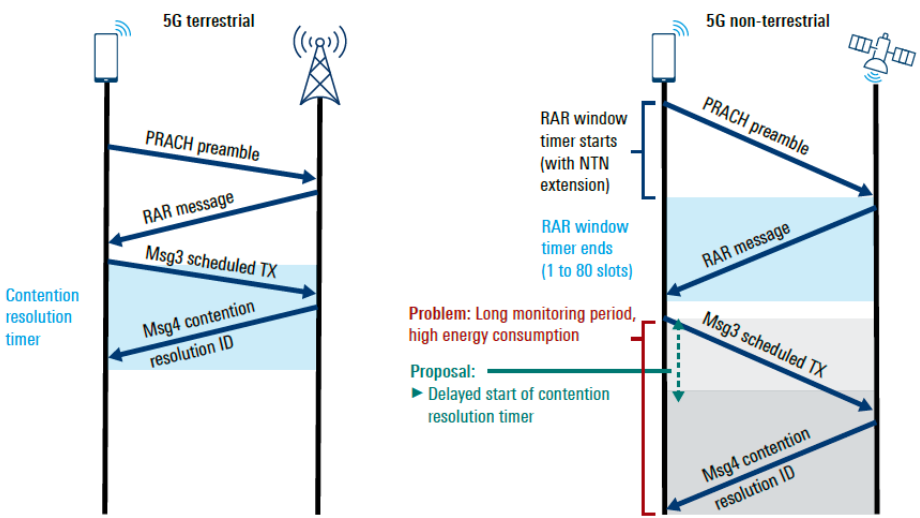
Optionally, the network may configure a constant time offset (K-mac) between DL and UL

SOLUTION TO LONGER AND VARYING DELAY
- RANDOM ACCESS

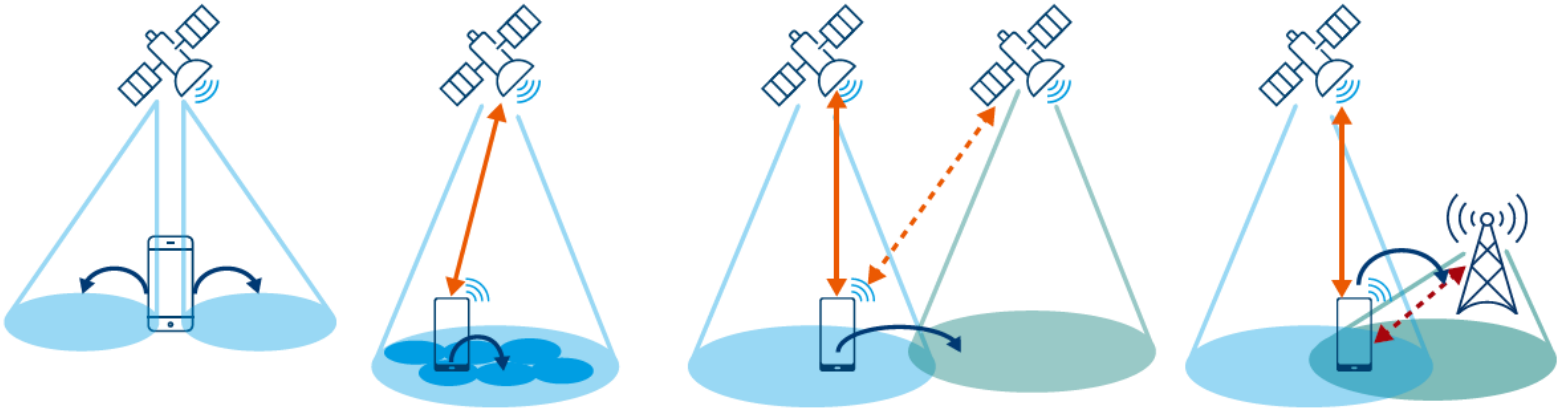
- RACH extension and response timing



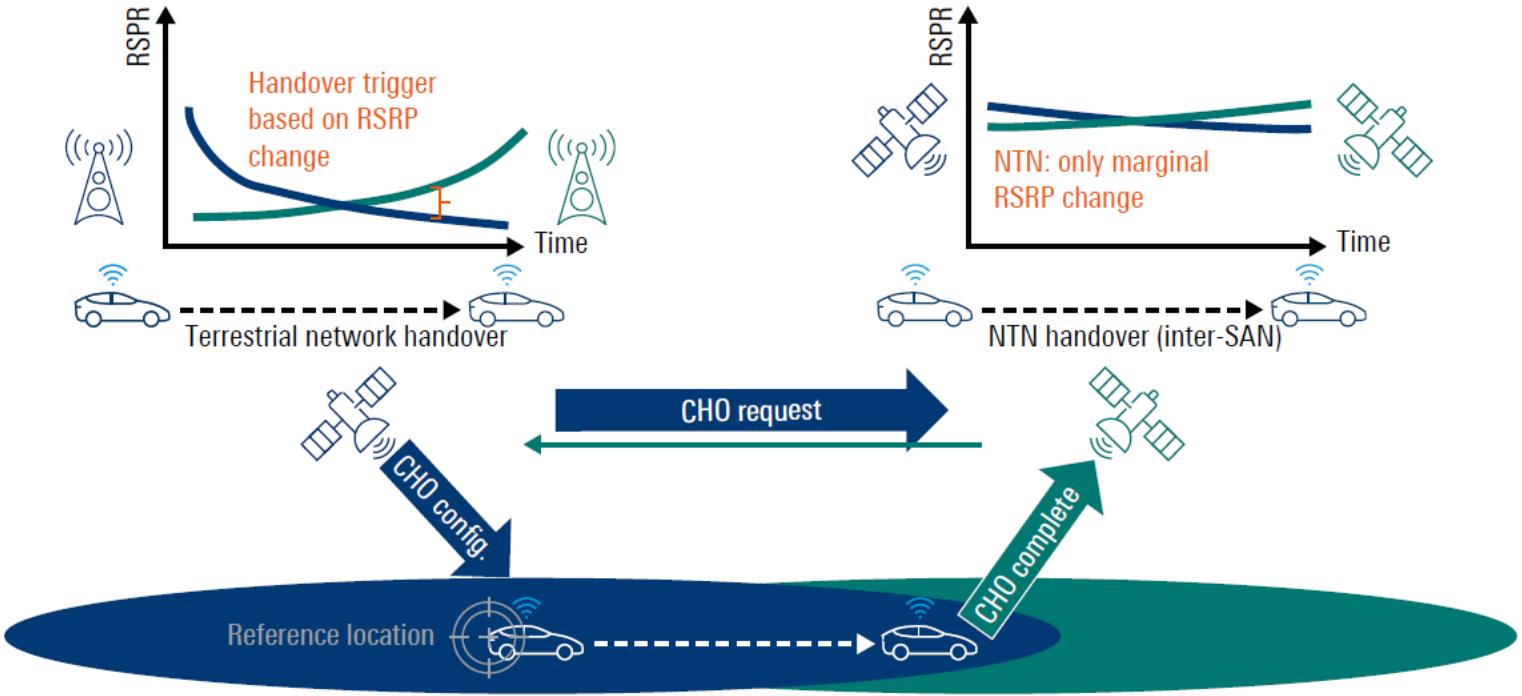
- RACH contention resolution



NTN MOBILITY SCENARIOS

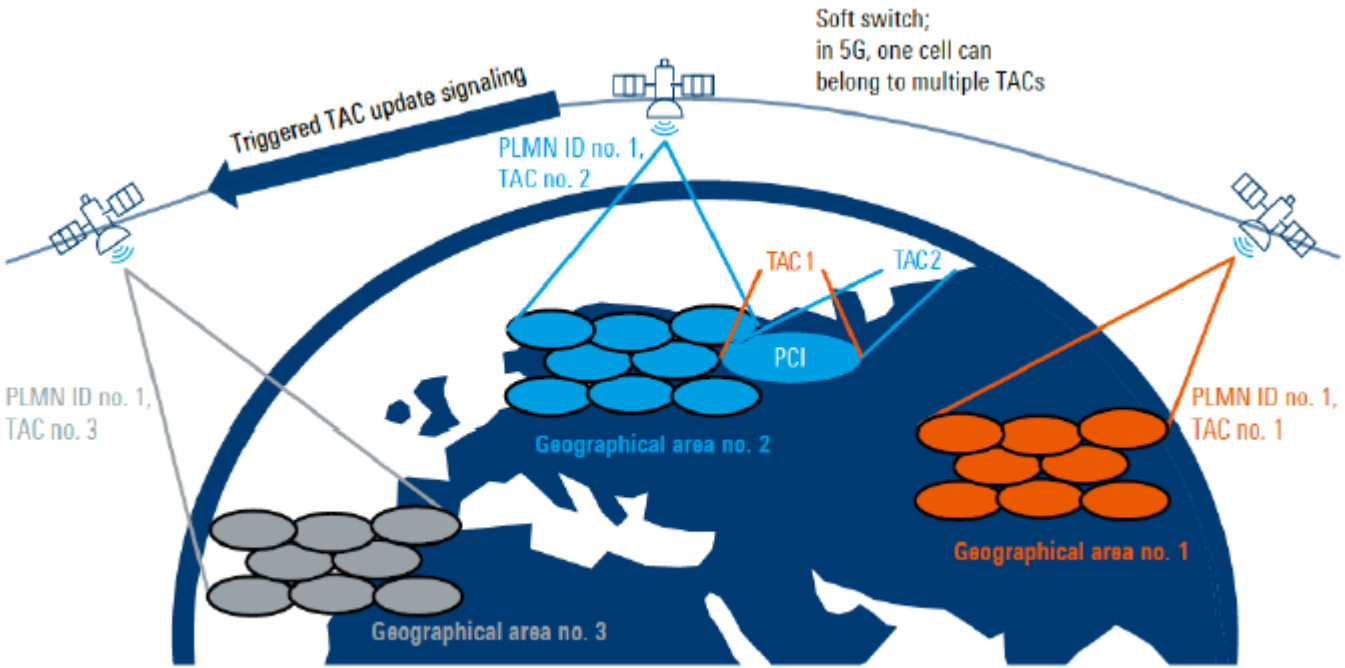


NTN MOBILITY SCENARIOS
- CONDITIONAL HANDOVER PROCEDURE



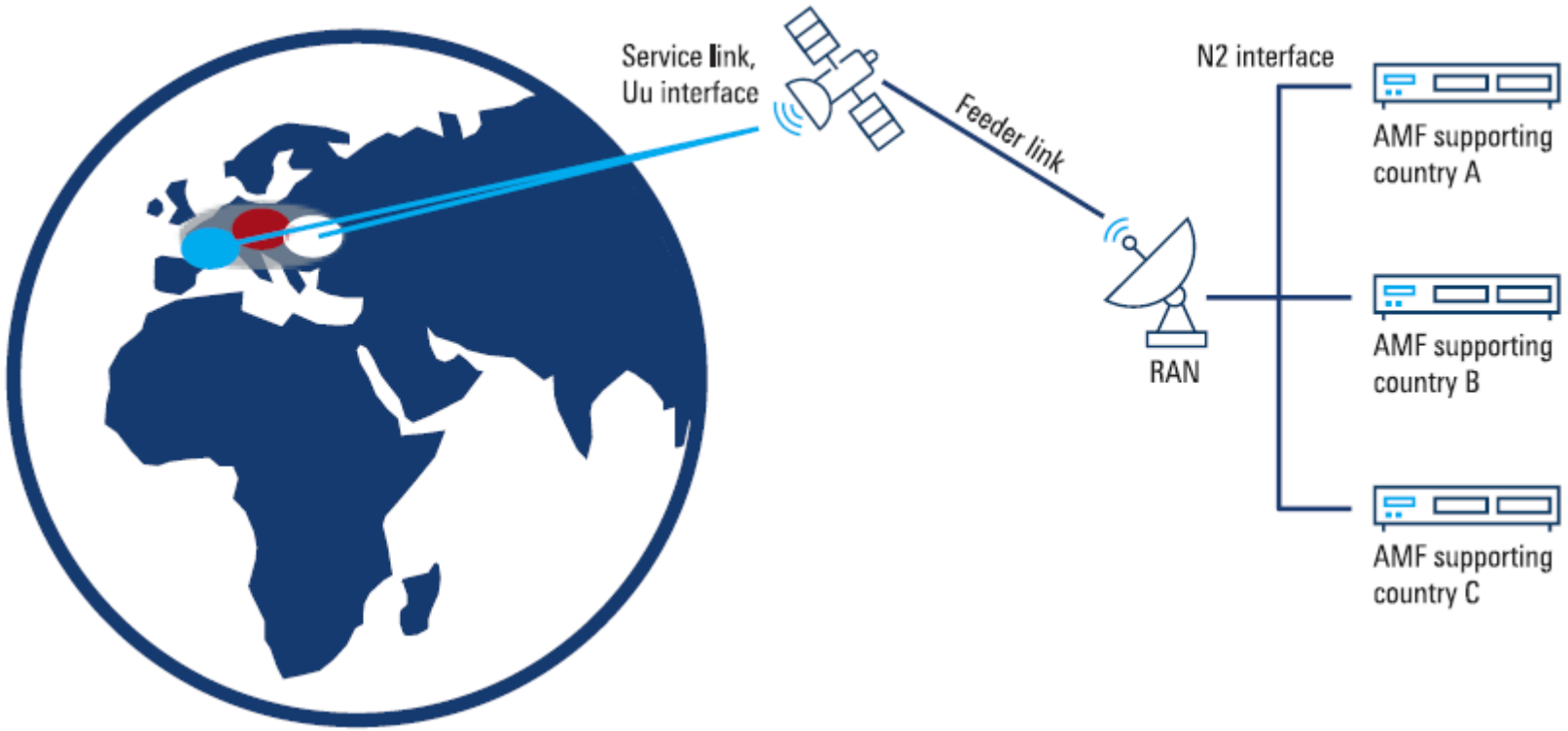
Conditional handover (CHO): network configures UE with triggering condition; e.g. distance between UE and reference location

NTN TRACKING AREA ASPECTS



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

NTN TRACKING AREA ASPECTS



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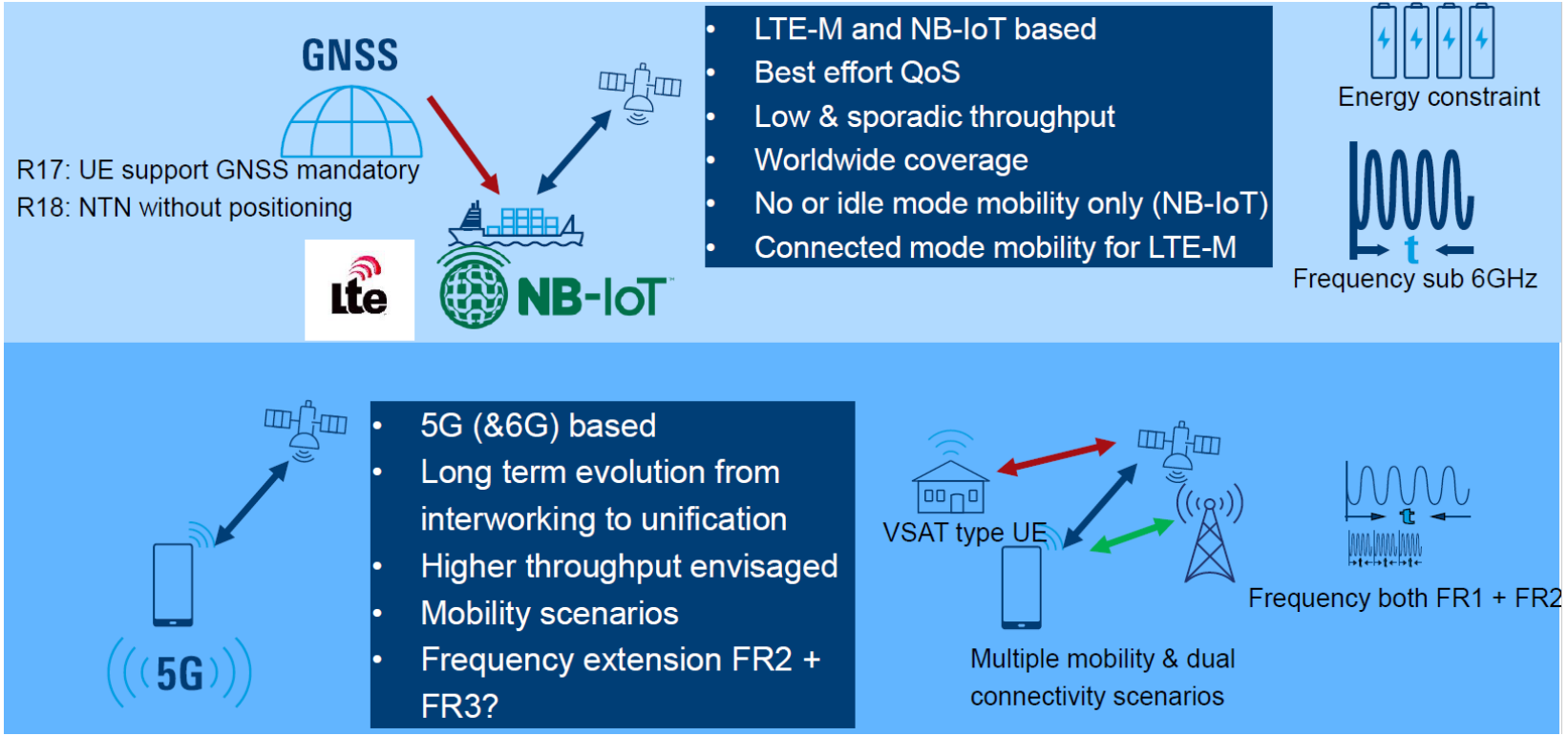
IOT-NTN SPECIFIC TECHNOLOGY ASPECTS

IoT-NTN vs NR-NTN
CONCISE OVERVIEW



NB-IoT/eMTC SUPPORT FOR NTN
MOTIVATION

Motivation: Making the Internet of Things ubiquitous and global

Justification

- Industries where IoT operation is critical in remote areas:
  - Transportation, logistics, solar & oil industries, gas harvesting, farming; environmental monitoring, mining, etc.

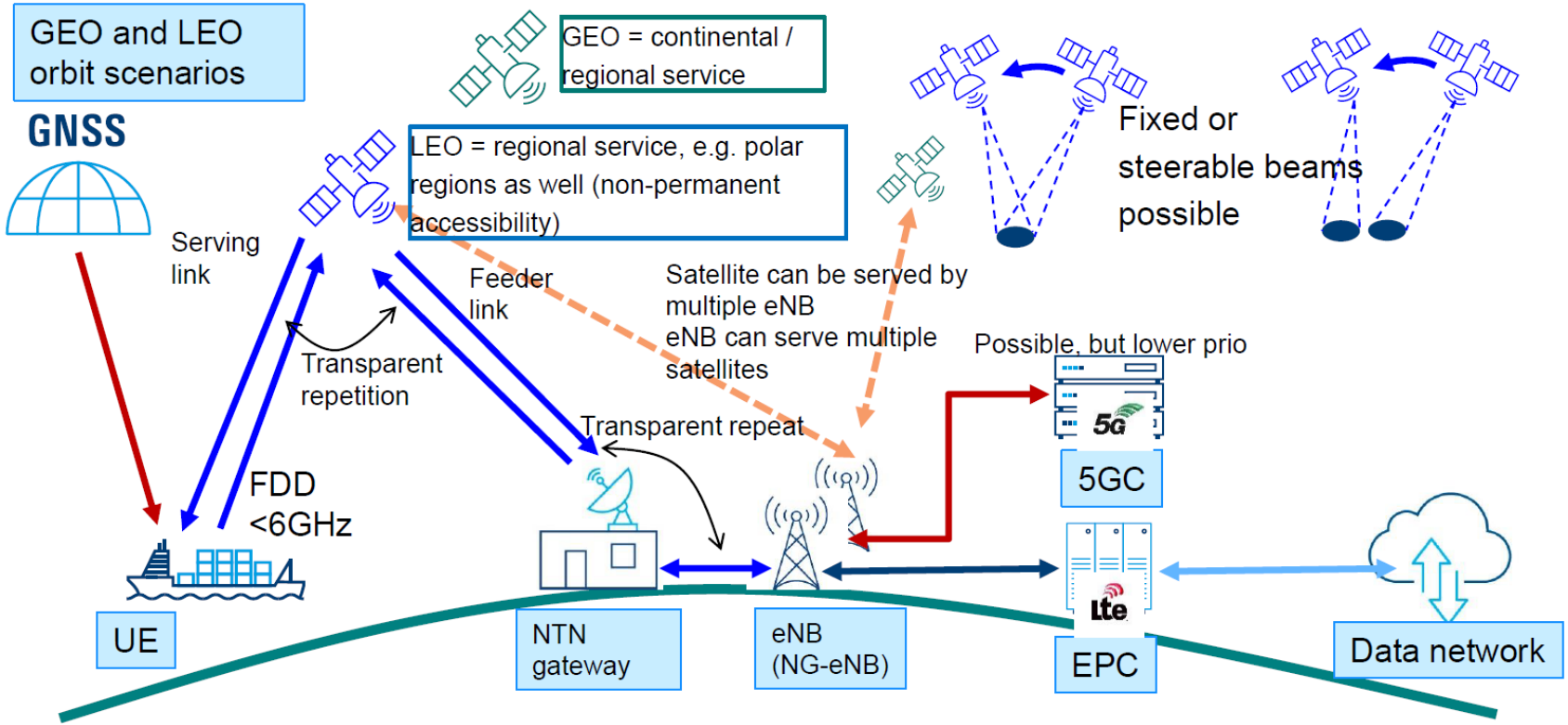
- Best effort QoS
- Delay tolerant
- Low throughput

UE types for IoT-NTN:
- Bandwidth limited, low complexity (BL UE) = LTE-M
- UE in coverage enhanced mode
- NB-IoT UEs

- NB-IoT and eMTC fit these use cases but suffer from low/no cellular connectivity.
  - Satellite connectivity it's required to provide global coverage beyond terrestrial deployments.

Challenges:
- Link budget (UE = PC3 (23dBm)
- FR1 spectrum + Omnidirectional antenna (~1RX)
- Satellite accessibility vs. Battery consumption
- Doppler shift and timing advance

IoT-NTN
TRANSPARENT PAYLOAD ARCHITECTURE



NB-IoT OVER NTN
PHYSICAL LAYER ASPECTS

The uplink and downlink total transmission bandwidth is 180 kHz (200kHz channel BW)

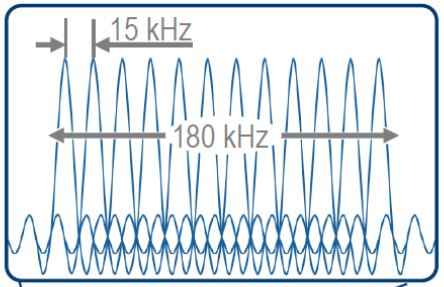
Downlink: OFDM with 15 kHz subcarrier spacing (1PRB)

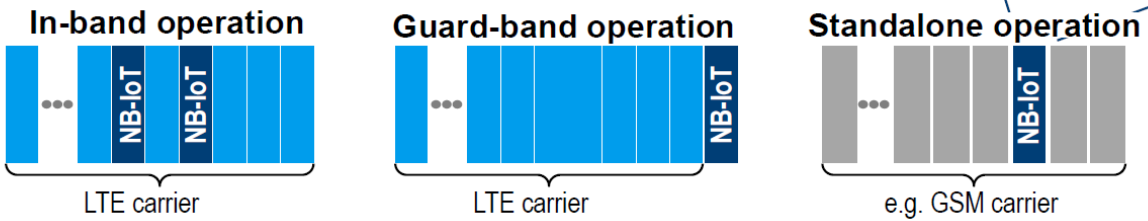
Uplink: SC-FDMA with 3.75 kHz and 15 kHz for single-tone transmissions and optional multi-tone transmissions with 15 kHz subcarrier spacing

Only FDD in **half-duplex mode** (analog to UE Cat. 0 half-duplex Type B)

Reduced downlink **transmission schemes (MIMO)**:
TM1: single antenna port, TM2: two antenna ports, using transmit diversity

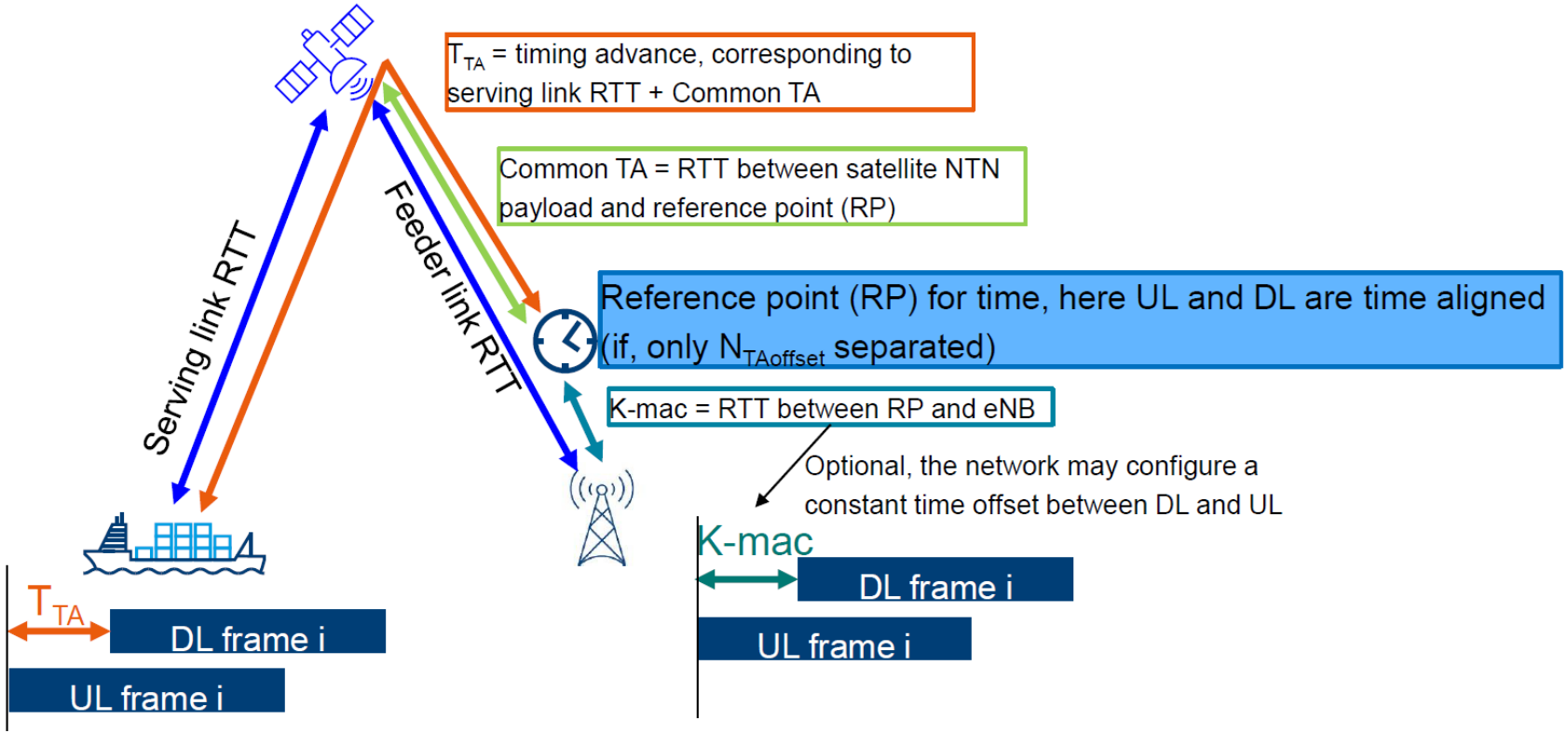
Only **mobility** in IDLE mode is supported



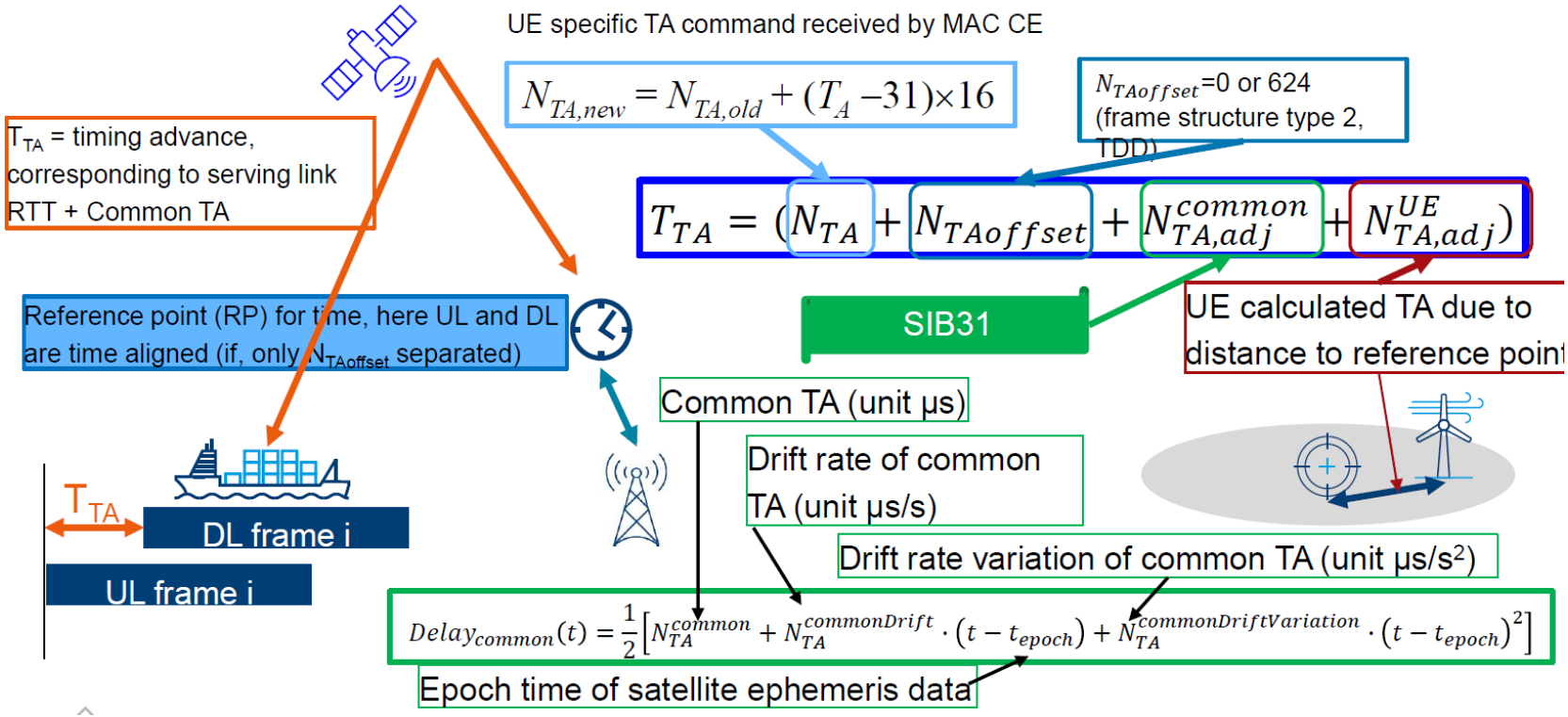


IoT-NTN potentially focus on standalone operation or guard-band operation (e.g. using NewSpace proprietary channels guard bands or in combination with NR-NTN)

NB-IoT NTN
PHYSICAL LAYER ASPECTS - TIMING

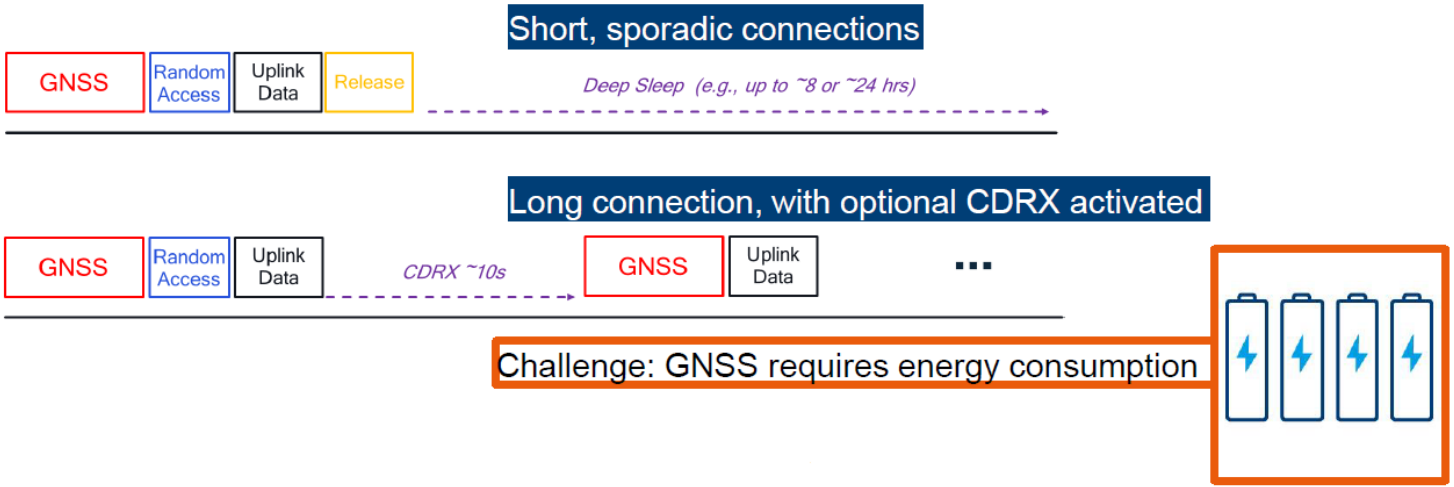


NB-IoT NTN
PHYSICAL LAYER ASPECTS - TIMING ADVANCE



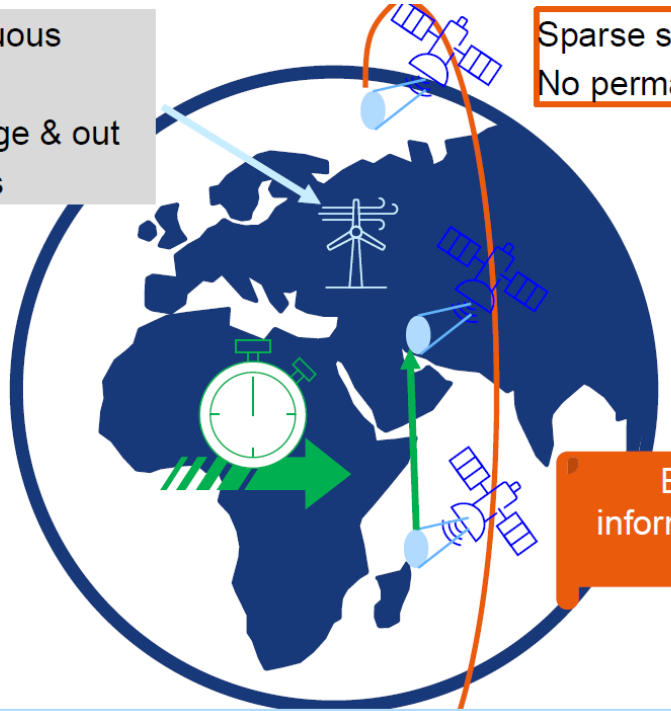
NB-IOT NTN CONNECTION SCENARIOS

IoT-NTN UE is equipped with GNSS positioning, but no simultaneous NTN and GNSS operation



IoT-NTN DISCONTINUOUS COVERAGE

UE faces discontinuous coverage.
UE predicts coverage & out of coverage periods



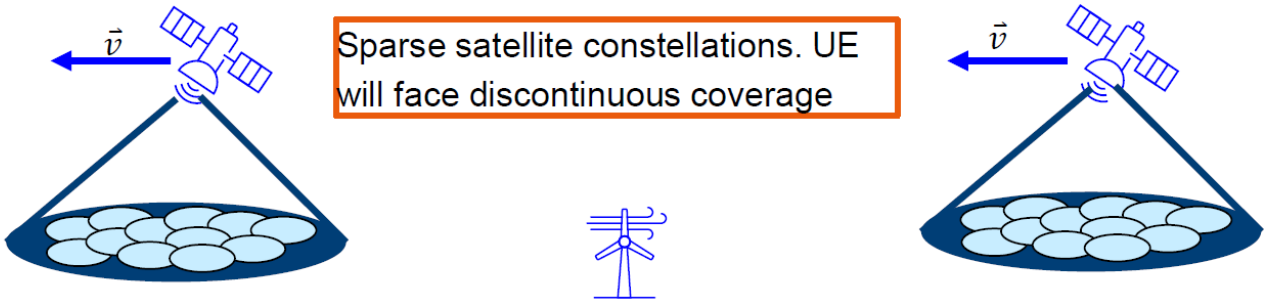
Sparse satellite constellations.
No permanent coverage

UE may stop cell retrieval steps when in „discontinuous coverage“ situations, to save battery

Ephemersis information in SIB32

To enable UE DRX and power saving periods, the network supports with start-time of upcoming coverage info

IoT-NTN DISCONTINUOUS COVERAGE



Sparse satellite constellations. UE will face discontinuous coverage

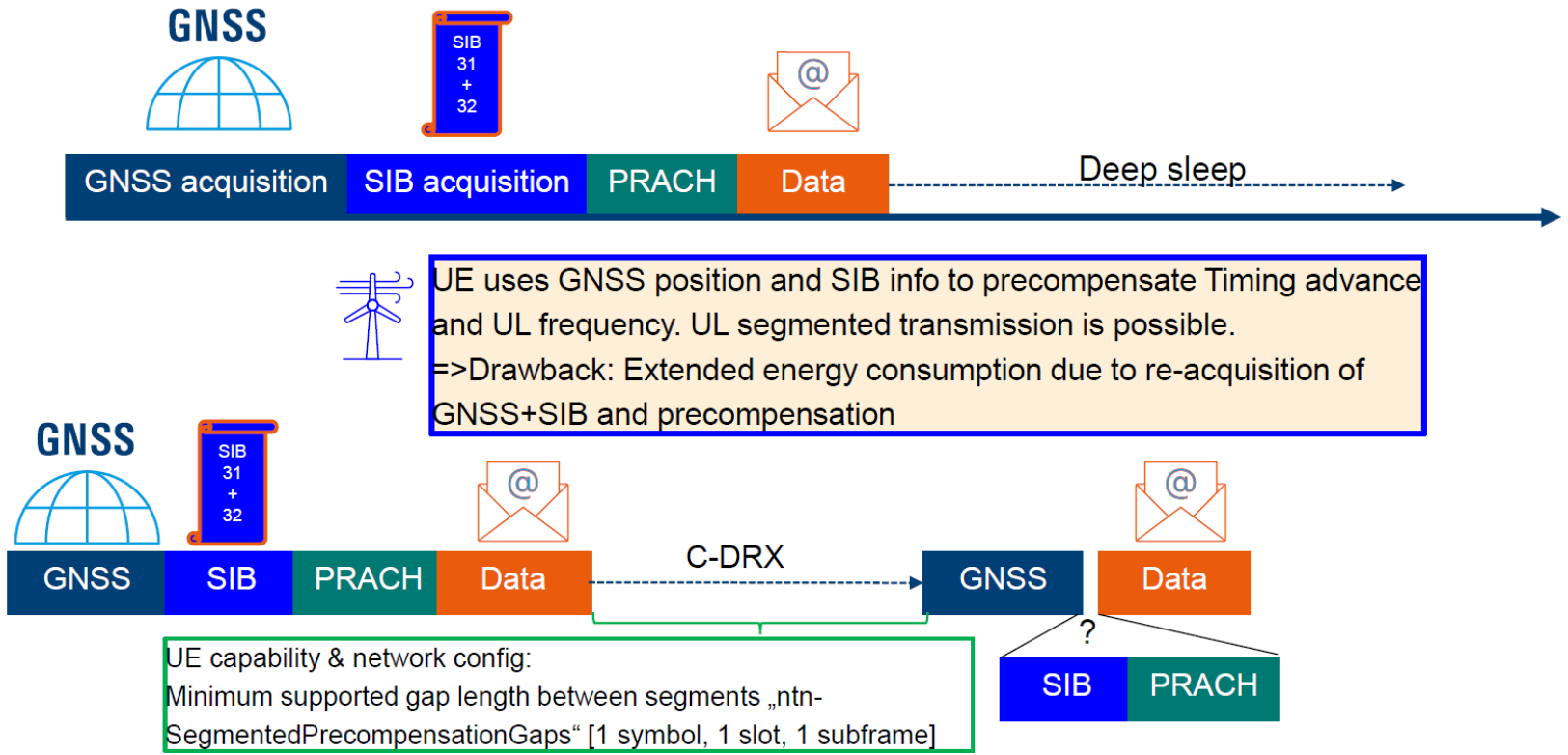
Connected mode:

- Not considered as cumbersome sore point as best effort QoS and delay tolerant + sporadic transmissions
- Handover for LTE-M based on Rel.16 legacy or CHO methods.
- IoT-NTN may need several retransmissions => if cell disappeared, retransmission on new cell tbd

Idle mode:

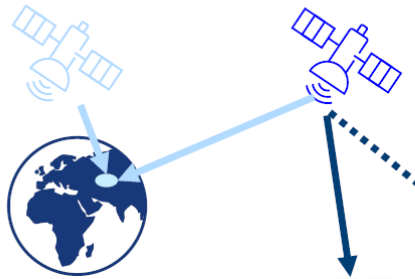
- Network may support with new cell info like e.g. time to service start (SIB32)
- Critical aspect is the configuration of DRX/PSM cycles. What if active period coincides with discontinuous coverage?
- Predicting of coverage and out-of-coverage is up to the UE implementation

IoT-NTN SHORT AND LONG CONNECTIONS, SEGMENTATION



IoT-NTN NON-ACCESS STRATUM(NAS), TAC SIGNALING

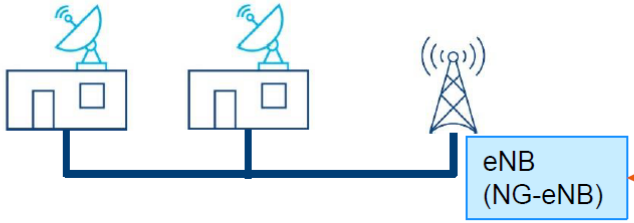
Network supports with Earth-fixed tracking areas + multi-TAC signaling in SIB



E-UTRAN cell global ID (CGI) [28 bits]
(5G NR CGI [36 bits])

Switchover
= feeder link change to other gateway
(transport network procedure)
Note: eNB change is possible with feeder link switch

Wrt to Earth footprint, the cell ID is a „mapped cell ID“. E.g. a geographical area can be mapped by multiple cell IDs



eNB
(NG-eNB)

EPS

RAN configures mapping between mapped cell ID and geographical area. E.g. when UE reports location info, RAN coordinates

Coordination on eNB broadcasted TAC between RAN & MME

IoT-NTN UE INFORMATIONREQUEST& REPORTING

Network may retrieve information from the UE

Security activation

UE information request

UE information response

May include:

- RACH info: #preambles and contention resolution result
- Coverage enhancement level or initial NRSRP level
- Radio link failure (RLF) report
- Logged measurement results
- Coarse location info (accuracy ±2km)

REL-17 NR-NTN vs IoT-NTN

Scenarios and general			
	NR	NB-IoT	eMTC
Support for GEO, MEO, LEO, HAPS	✓	✓	✓
Payload type	Transparent	Transparent	Transparent
Cell-ID / CGI corresponds to fixed geographical areas	✓	✓	✓
Specific support for sporadic short-data transmission	✗	✓ (main use case)	✓ (main use case)
Support for soft and hard feeder link switchover	✓	✓	✓
GNSS support for TA estimation and frequency pre-compensation	✓	✓	✓
Support for indication of DL/UL polarization information	✓	✗	✗
TDD/FDD	FDD only	FDD only	FDD only
Support of Discontinuous Coverage	✗	✓ (SIB32-NB)	✓ (SIB32)
Broadcast of satellite assistance information for the serving cell. (state vectors or orbital parameters formats)	✓ SIB19	✓ SIB31-NB	✓ SIB31
Positioning based on GNSS	✓	✓	✓

✓ Supported ✗ Not Supported / Not introduced ⊘ Not Applicable ⚠ Topic not fully discussed by 3GPP

REL-17 NR-NTN vs IoT-NTN

Mobility			
	NR	NB-IoT	eMTC
Connected mode NTN mobility	Enhancements to CHO • Time-based triggered • Location-based triggered	Legacy RLF and connection re-establishment procedures*	Rel-16 CHO
Broadcast information on when a cell is going to stop serving the area for cell (re)selection and cell measurements in quasi-earth fixed cell scenarios	✔ *t-Service* in SIB19	✔ *t-Service* in SIB3-NB	✔ *t-Service* in SIB3
TN-NTN mobility	✔	⚠ Not disallowed –May work**	⚠ Not disallowed – May work**

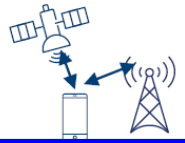
✔ Supported ✖ Not Supported / Not introduced ⊘ Not Applicable ⚠ Topic not fully discussed by 3GPP

Mobile Test Summit Korea 2024

OUTLOOK

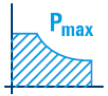
NTN REL-18 TOPICS OVERVIEW

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

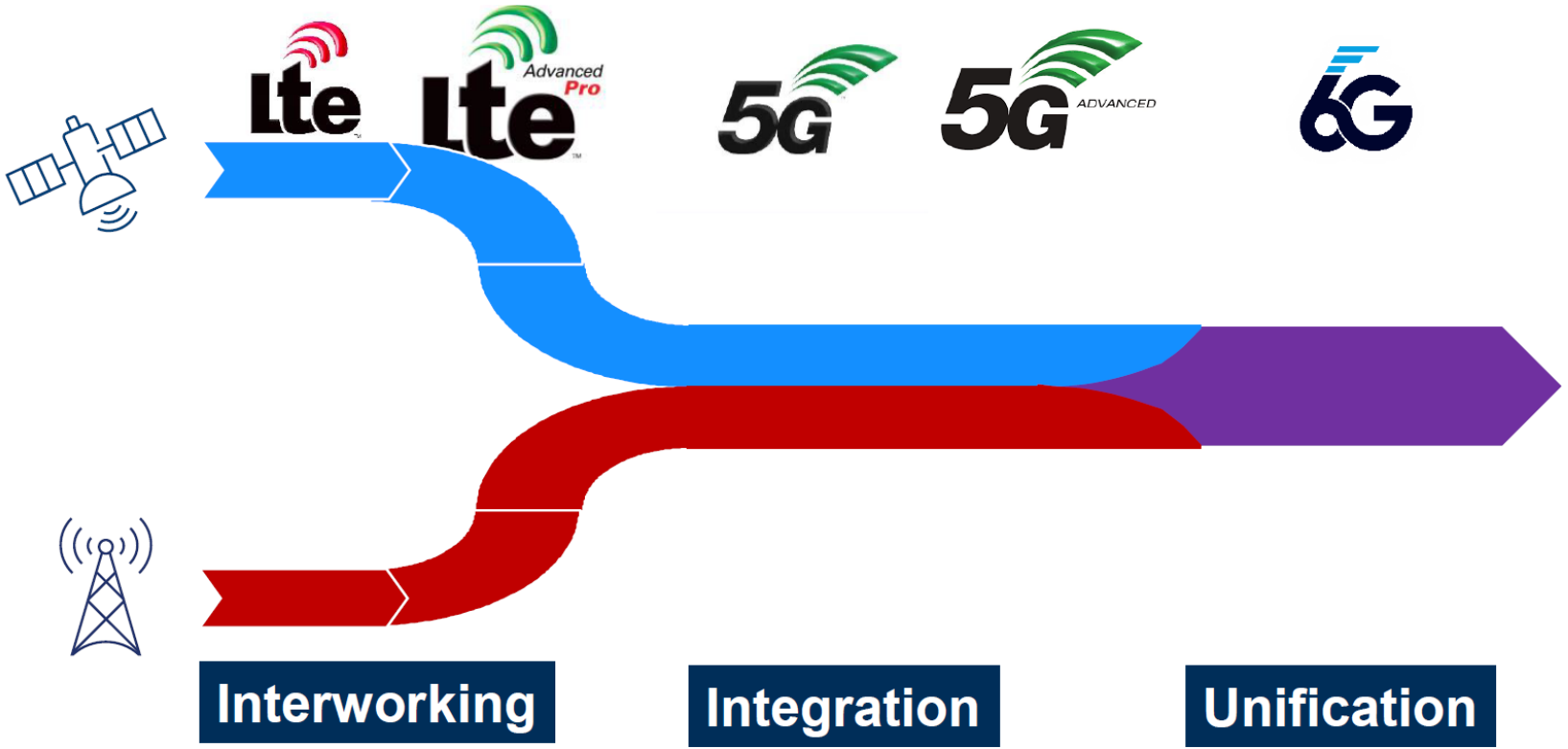
Mobility

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

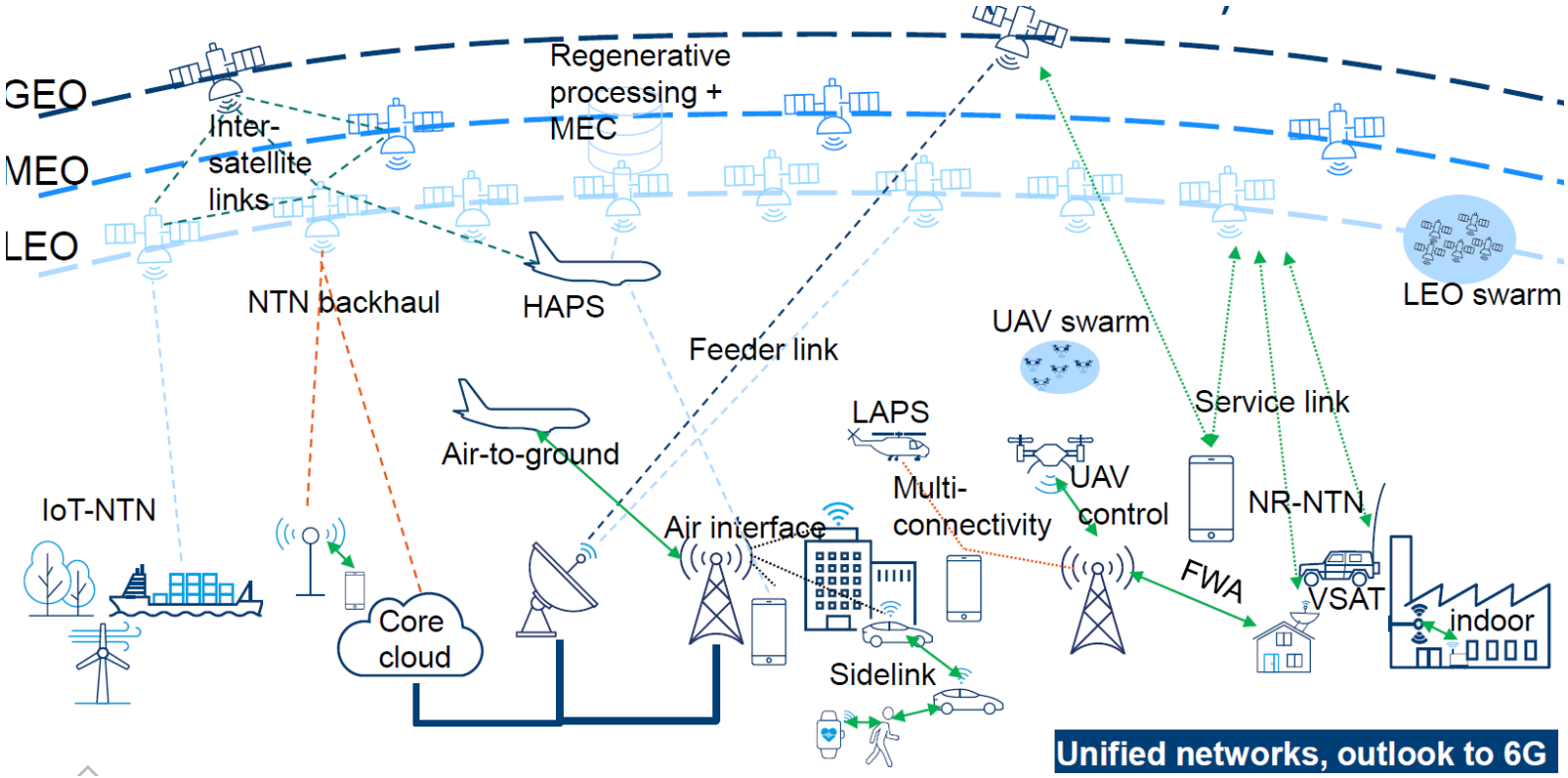
Discontinuous coverage

- Mobility management
- Power saving enhancements

INTERACTION BETWEEN TERRESTRIAL AND NON-TERRESTRIAL

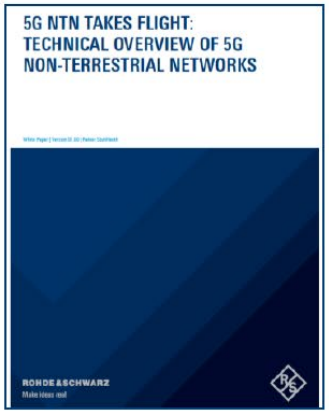


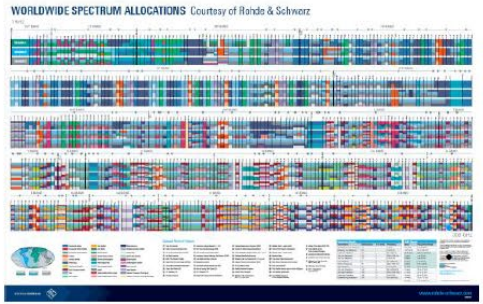
MULTI-LAYER MULTI-DIMENSION MULTI-BAND (ML-MD-MB) TOPOLOGY



ADDITIONAL RESOURCES

5G technology book oline 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

END