GISC 2024

Global ICT Standards Conference 2024

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ELTOWER GRACE Hall 6F

(세션3) 차세대통신: 인공지능과 함께 진화하는 미래 통신

우주 인터넷 시대를 열다: NTN 기술(표준) 현황과 미래 전망

노훈동 선임연구원, ETRI

ICT Standards and Intellectual Property : Inclusive Innovation

주최 과학기술정보통신부 특허청 주관 국립전파연구원 TTA IITP KEA kisto ETRI

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01. NTN Scenarios & Channel Models

3GPP Study Results on NTN

ICT Standards

3GPP RAN 에서 고려 중인 NTN 운영 시나리오들의 주요 특성들과 링크-레벨, 시스템-레벨 성능 평가를 위하여 정의된 NTN 채널모델을 소개한다.

01. NTN Scenarios & Channel Models

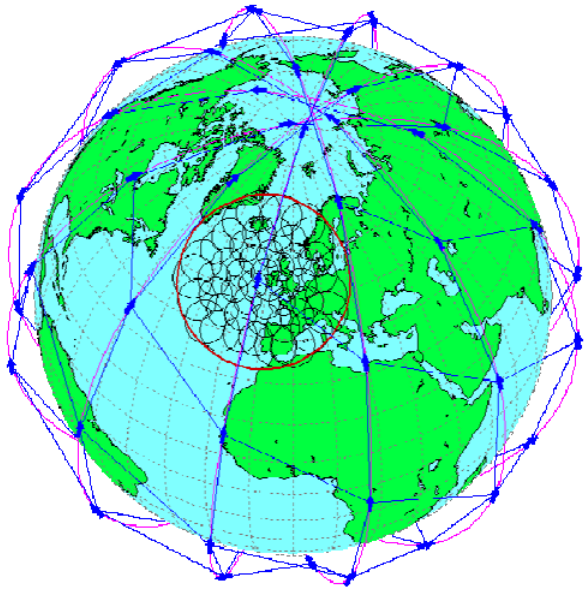
3GPP NTN commercialization plans: GSOA (global satellite operators association) presented 3GPP NTN based satellite network deployment plans in RAN#102 meeting (Dec. 2023, RP-232732)

	Narrowband connectivity to IoT devices (NTN-IoT in FR1)		Narrowband/Broadband connectivity to handheld devices (NTN-NR in FR1)	Broadband connectivity to non-handheld devices (VSAT) (NTN-NR in above 10 GHz Band)	
Space Segment	**Re-use of existing GSO**	**NGSO**	**NGSO**	**GSO**	**NGSO**
Operators	EchoStar Viasat-Inmarsat TerreStar Solutions	Sateliot EchoStar OmniSpace Viasat-Inmarsat	EchoStar OmniSpace Viasat-Inmarsat SES	Intelsat Eutelsat-Oneweb Viasat-Inmarsat SES	Intelsat Eutelsat-Oneweb Viasat-Inmarsat SES
Timeline Indication	2023-2025	2024-2029	2026-2029		

01. NTN Scenarios & Channel Models

3GPP NTN commercialization plans: Iridium half duplex SAN for NB-IoT

- In-orbit LEO constellation with 66 + α satellites (will be operated until 2035, at least)
- Regenerative payloads (software defined) with multiple feeder links
- Fully cross-linked in space
- New Rel-19 WID (Work Item Description) on IoT-NTN TDD mode (RP-242415)



Iridium 66-Satellite Constellation

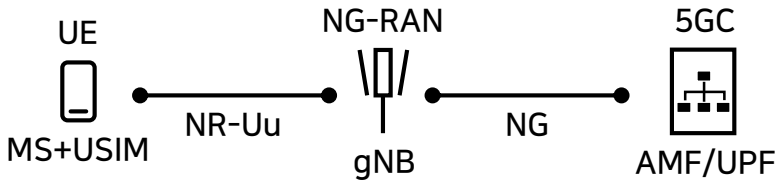
ICAO TECHNICAL MANUAL FOR IRIDIUM AERONAUTICAL MOBILE SATELLITE (ROUTE) SERVICE, available at https://www.icao.int/safety/acp/inactive%20working%20groups%20library/acp-wg-m-iridium-4/ird-swg04-wp04-iridium%20tech%20manual%20-%20051706.pdf

AMF: Access and Mobility Management Function
UPF: User Plane Function

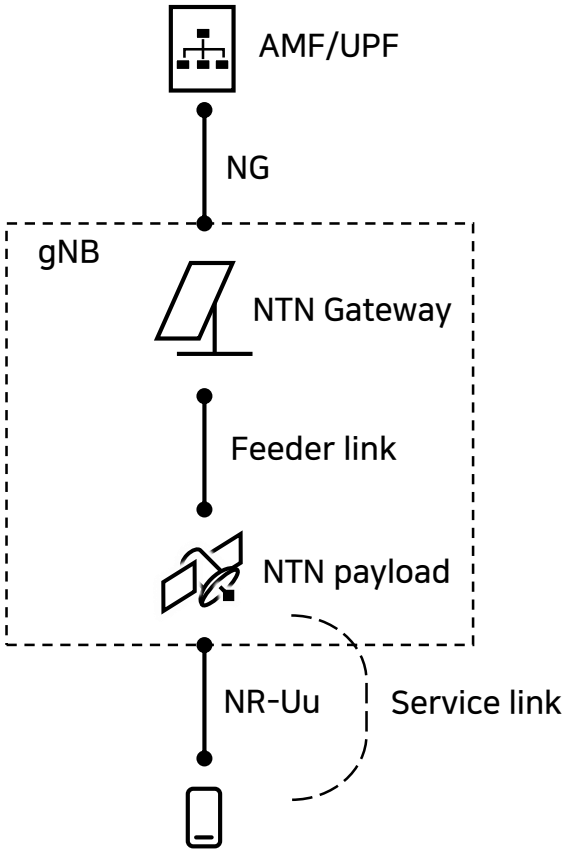
01. NTN Scenarios & Channel Models

A general description on NTN (Non-Terrestrial Network)

- **NTN**: an NG-RAN consisting of gNBs, which provide non-terrestrial NR access to UEs by means of an NTN payload embarked on an airborne or space-borne NTN vehicle and an NTN Gateway.
- **NTN gateway**: an earth station located at the surface of the earth, providing connectivity to the NTN payload using the feeder link. An NTN Gateway is a TNL node.
- **NTN payload**: a network node, embarked on board a satellite or high altitude platform station, providing connectivity functions, between the service link and the feeder link.



Overview of the 5GS in TN



Overall illustration of an NTN

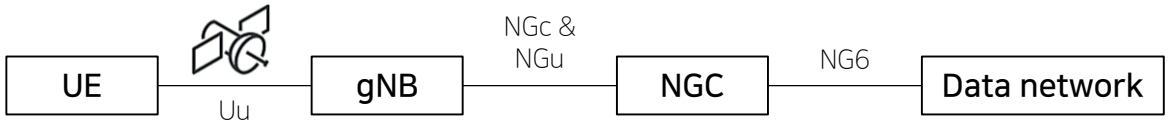
출처: 3GPP TS38.300

01. NTN Scenarios & Channel Models

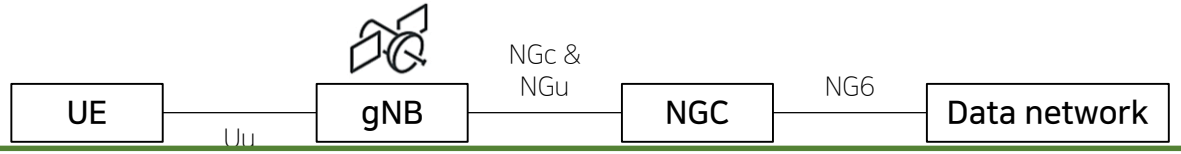
NTN architecture options

5G elements - NTN elements mapping			
NTN architecture options	**NTN Terminal**	**Space or HAPS**	**NTN Gateway**
A1	UE	Remote Radio Head	gNB
A2	UE	gNB or Relay Node functions	Router interfacing to Core network
A3	Relay Node	Remote Radio Head	gNB
A4	Relay Node	gNB or Relay Node functions	Router interfacing to Core network

- A1: access network serving UEs via bentpipe satellite/aerial



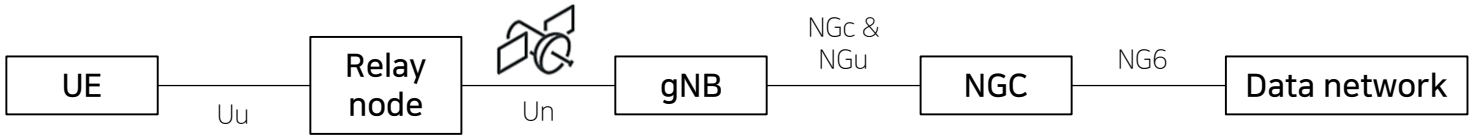
- A2: access network serving UEs with gNB on board satellite/aerial



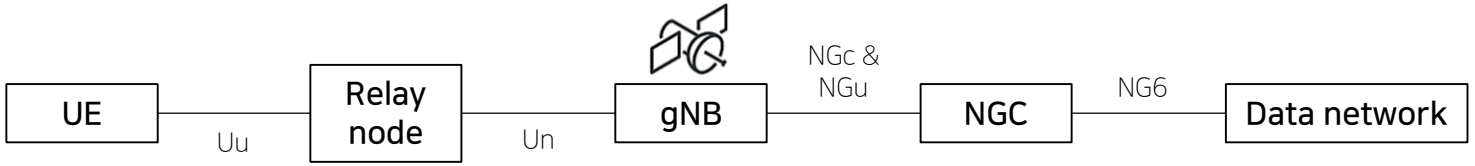
Rel-17/-18

Rel-19

- A3: access network serving Relay Nodes via bent pipe satellite/aerial



- A4: access network serving Relay Nodes with gNB on board satellite/aerial

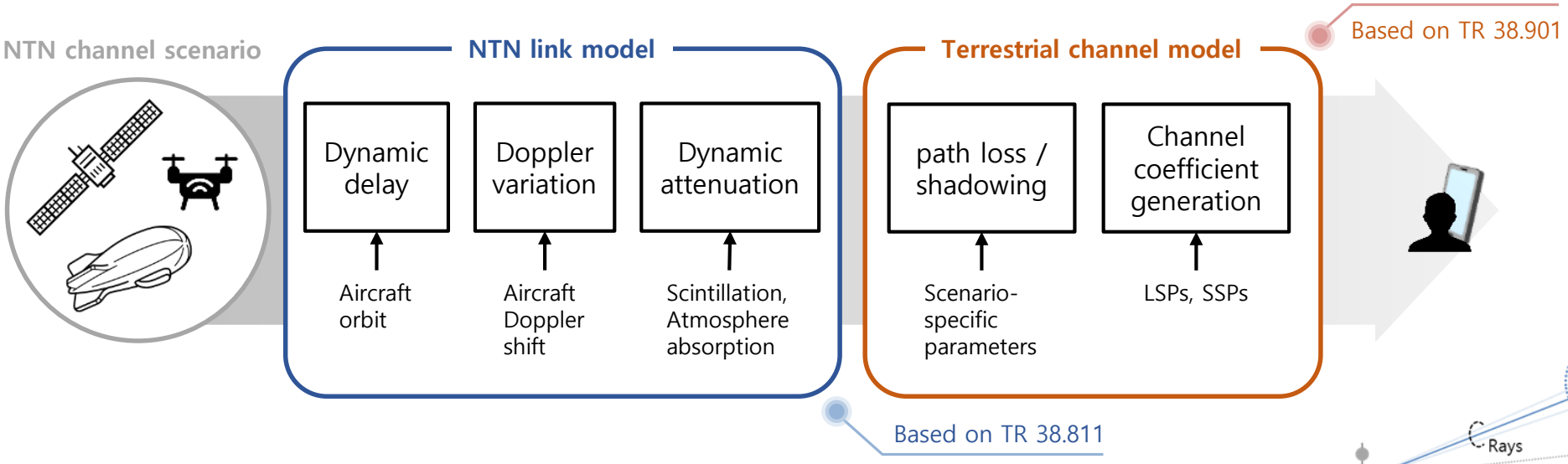


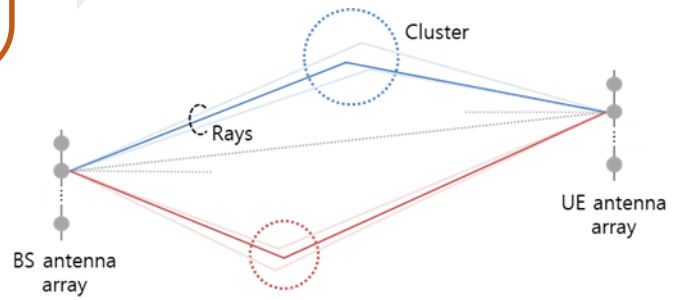
출처: 3GPP TR38.811

01. NTN Scenarios & Channel Models

3GPP NTN Channel Models (3GPP TR38.811)

- Support NTN-specific network layouts and channel coefficient generations based on the procedures in TR 38.901



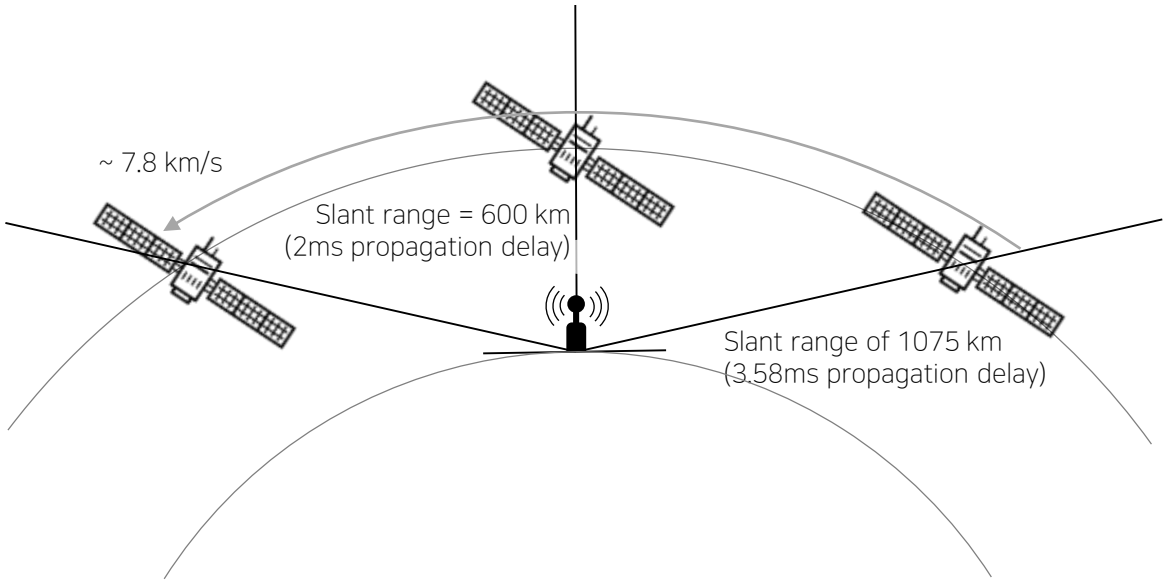


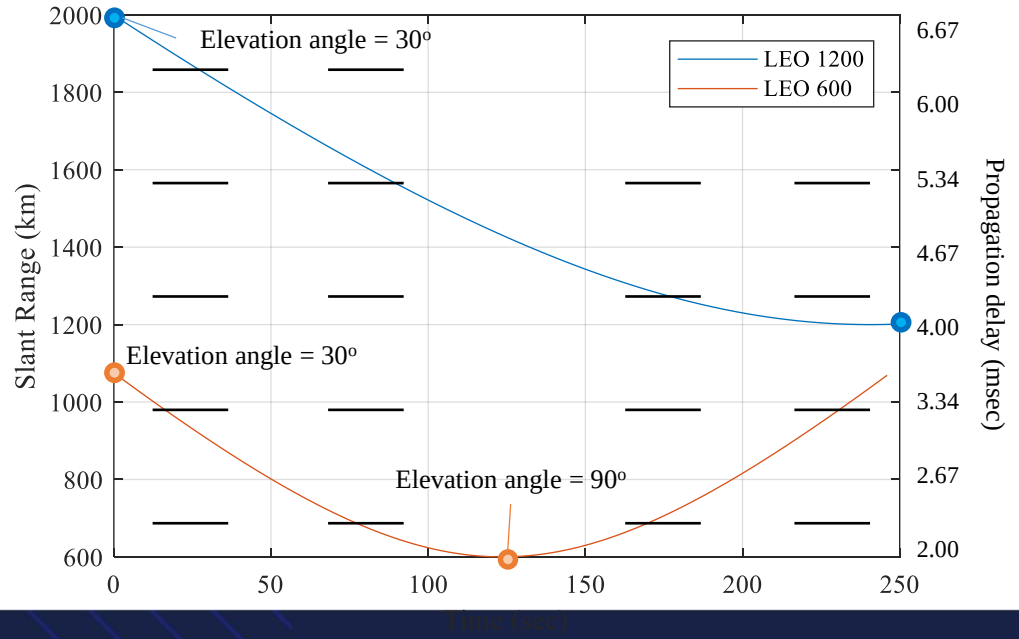
출처: 3GPP TR38.811, R1-2403030 (ETRI)

01. NTN Scenarios & Channel Models

NTN channel characteristics according to various satellite operation scenarios

Satellite & aerial Systems	Typical minimum Elevation Angle for terminals	Rationale/remarks
International GEO (Trunking)	5 degrees	Serving earth stations equipped with very large antennas
Regional GEO	10 degrees	Addressing regions in lower and medium latitude
International (GEO) Maritime	5 degrees	Addressing large ships
Aeronautical	20 degrees	Taking into account aero-dynamic constraints prevents operation at lower angles
Vehicles	15 degrees	Taking into account road conditions, terrain, and vehicle mechanics
Non GSO	10 to 30 degrees	Ensuring service continuity optimising the number of satellites
Aerial	In the range of 10 degrees	Maximising the service area





출처: 3GPP TS22.261

01. NTN Scenarios & Channel Models

NTN channel characteristics according to various satellite operation scenarios

- Specification supports on "uplink timing adjustment", "scheduling offset", "more margin for timers" are required to deal with large propagation delay.

	UE to serving satellite propagation delay [ms] [NOTE 1]		UE to ground max propagation delay [ms] [NOTE 2]
	Min	Max	
LEO	3	15	30
MEO	27	43	90
GEO	120	140	280
NOTE1: The serving satellite provides the satellite radio link to the UE NOTE2: delay between UE and ground station via satellite link; Inter satellite links are not considered			

01. NTN Scenarios & Channel Models

Various types of NTN UEs (e.g, VSAT, handheld UE, IoT device) had been studied

	Very Small Aperture Terminal (fixed or mounted on moving platforms)	Handheld or IoT devices (3GPP class 3)
Transmit Power	2 W (33 dBm)	200 mW (23 dBm)
Antenna type	60 cm equivalent aperture diameter (circular polarisation)	Omnidirectional antenna (linear polarisation)
Antenna gain	Tx: 43.2 dBi Rx: 39.7 dB	Tx and Rx: 0 dBi
Noise figure	1.2 dB	9 dB
EIRP	45.75 dBW	-7 dBW
G/T (NOTE 1)	18.5 dB/K	-33.6 dB/K
Polarisation (NOTE 2)	Circular	Linear

NOTE 1: For the computation of G/T or figure of merit, following formula applies in dB:

$$G/T = Ga - NF - 10*LOG\ (To+(Ta-To)/(10^{0.1*NF}))$$

Where:
- Antenna Gain : Ga in dBi
- Ambient Temperature : T0 (usually 290 K)
- Antenna temperature : Ta (typically 290 K with 0 dBi gain and 150 K with >30 dBi gain)
- Noise Figure: NF in dB

NOTE 2: For S band, we assume that the User Equipment has an omni-directional antenna of linear polarization, while the antenna on board space-borne or airborne platforms features typically employs circular polarization. Hence a polarization mismatch of 3 dB has to be taken into account for the radio link budget computation. This will impact the UE RF characteristics as below:
- Equivalent EIRP of 20 dBm (-10 dBW) under satellite coverage.
- Equivalent G/T of -36,6 dB/K under satellite coverage.

출처: 3GPP TR38.811

Note: Link level 분석의 경우 CNR margin 주로 사용

Carrier-to-noise-and-interference ratio (CNIR)

출처: 3GPP TR38.821

01. NTN Scenarios & Channel Models

It was concluded that NTN is feasible from link-level and system-level perspectives

- Examples on study cases

Case	Satellite orbit	Satellite parameter set	Central beam elevation	Terminal	Frequency Band	Frequency/ Polarization Reuse
1	GEO	Set 1	45 deg	VSAT	Ka-band	Option 1 (freq. reuse factor 1)
6	LEO-600	Set 1	90 deg	VSAT	Ka-band	Option 1
9	LEO-600	Set 1	90 deg	Handheld	S-band (2GHz)	Option 1
14	LEO-1200	Set 1	90 deg	Handheld	S-band (2GHz)	Option 1

- Link budget results

Case	Transmission mode	Frequency [GHz]	TX: EIRP [dBm]	RX: G/T [dB/T]	Bandwidth [MHz]	Free space path loss [dB]	Atmospheric loss [dB]	Shadow fading margin [dB]	Scintillation Loss [dB]	Polarization loss [dB]	Additional losses [dB]	CNR [dB]
SC1	DL	20.0	96.0	15.9	400.0	210.6	1.2	0.0	1.1	0.0	0.0	11.6
	UL	30.0	76.2	28.0	400.0	214.1	1.1	0.0	1.1	0.0	0.0	0.5
SC6	DL	20.0	60.0	15.9	400.0	179.1	0.5	0.0	0.3	0.0	0.0	8.5
	UL	30.0	76.2	13.0	400.0	182.6	0.5	0.0	0.3	0.0	0.0	18.4
SC9	DL	2.0	78.8	-31.6	30.0	159.1	0.1	3.0	2.2	0.0	0.0	6.6
	UL	2.0	23.0	1.1	0.4	159.1	0.1	3.0	2.2	0.0	0.0	2.8
SC14	DL	2.0	84.8	-31.6	30.0	164.5	0.1	3.0	2.2	0.0	0.0	7.2
	UL	2.0	23.0	1.1	0.4	164.5	0.1	3.0	2.2	0.0	0.0	-2.6

출처: 3GPP TR38.821

01. NTN Scenarios & Channel Models

It was concluded that NTN is feasible from link-level and system-level perspectives

- Examples on study cases

Case	Satellite orbit	Satellite parameter set	Central beam elevation	Terminal	Frequency Band	Frequency/ Polarization Reuse
1	GEO	Set 1	45 deg	VSAT	Ka-band	Option 1 (freq. reuse factor 1)
6	LEO-600	Set 1	90 deg	VSAT	Ka-band	Option 1
9	LEO-600	Set 1	90 deg	Handheld	S-band (2GHz)	Option 1
14	LEO-1200	Set 1	90 deg	Handheld	S-band (2GHz)	Option 1

- System-level calibration results

	DL Coupling Loss			DL Geometry SIR			DL Geometry SINR		
	@5%	@50%	@95%	@5%	@50%	@95%	@5%	@50%	@95%
SC1	109.3	113.6	117.9	-3.0	-1.0	1.2	-3.2	-1.2	1.0
SC6	96.2	97.5	98.9	-3.0	-1.1	1.1	-3.2	-1.2	0.8
SC9	123.7	125.3	127.0	-3.0	-1.1	1.1	-3.1	-1.1	1.0
SC14	129.8	131.3	133.0	-3.0	-1.1	1.1	-3.1	-1.1	1.0
NOTE: Geometry SINR = -10log10(I/C + N/C), where C, I and N equals the carrier, interferer and noise power levels measured over the configured signal bandwidth.									

	UL Coupling Loss			UL Geometry SIR			UL Geometry SINR		
	@5%	@50%	@95%	@5%	@50%	@95%	@5%	@50%	@95%
SC1	109.2	113.5	117.8	-6.9	-1.3	4.4	-7.0	-1.5	1.0
SC6	96.1	97.4	98.8	-3.9	-1.1	2.6	-3.9	-1.1	2.6
SC9	123.7	125.3	127.1	-4.0	-0.8	3.2	-4.1	-1.1	2.7
SC14	129.7	131.4	133.1	-4.0	-0.8	3.2	-4.5	-1.7	1.5
NOTE: Geometry SINR = -10log10(I/C + N/C), where C, I and N equals the carrier, interferer and noise power levels measured over the configured signal bandwidth.									

02. NTN Specification Supports in 5G NR

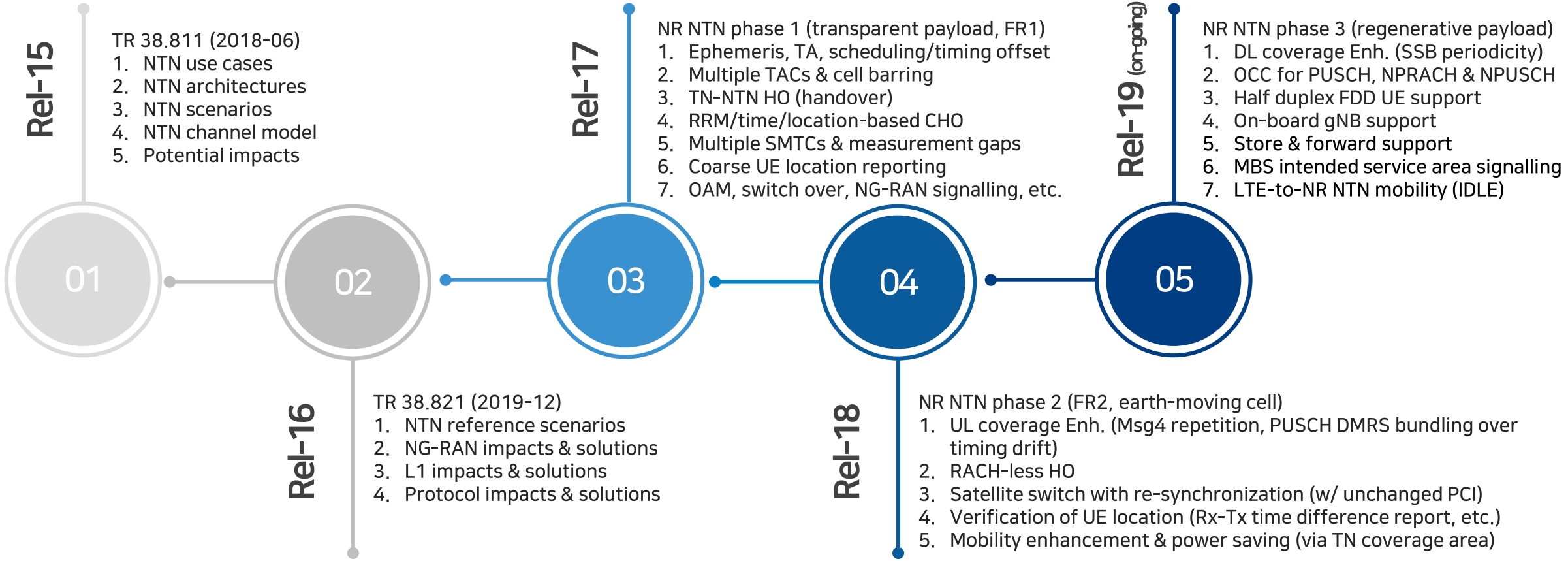
3GPP RAN Specifications for NTN phase 1/2/3

ICT Standards

3GPP Release 17 부터 Release 18 까지의 표준화 결과로 발간된 NTN 규격들을 소개하고, Release 19에서 진행 중인 NTN 표준화 논의 주제들을 살펴본다.

02. NTN Specification Supports in 5G NR

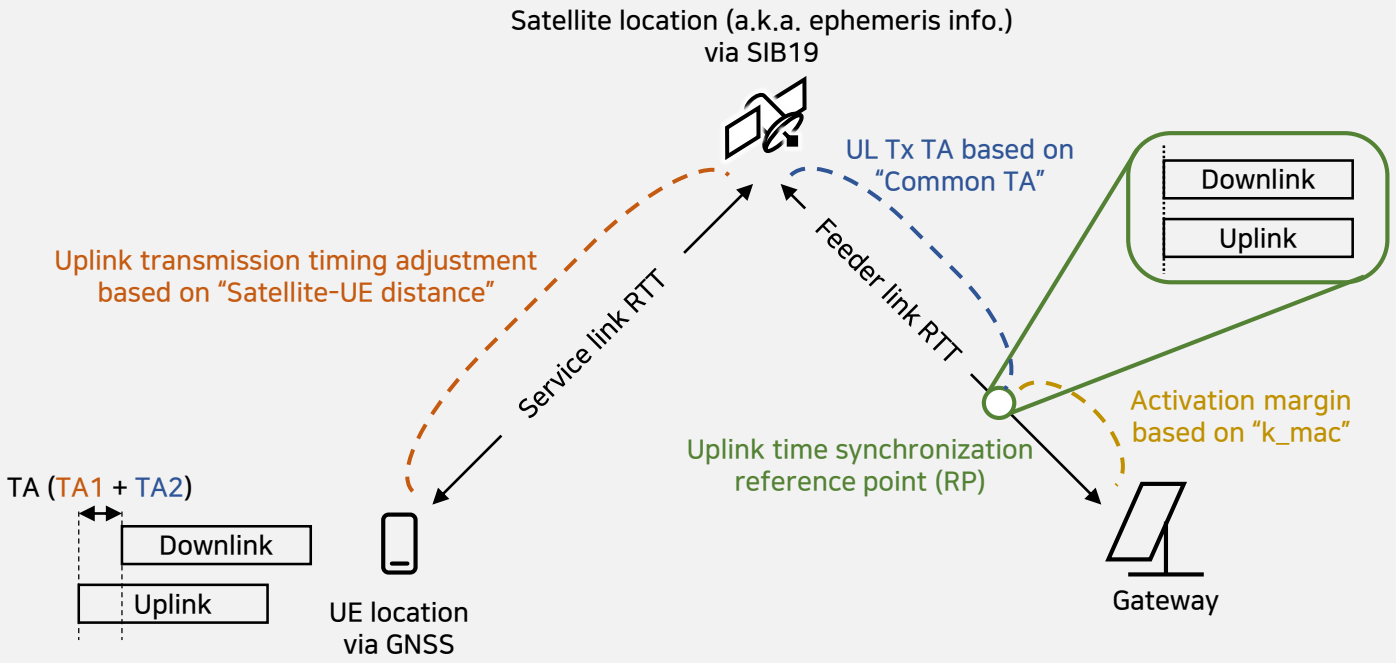
Overview on 3GPP NTN Specification Activities



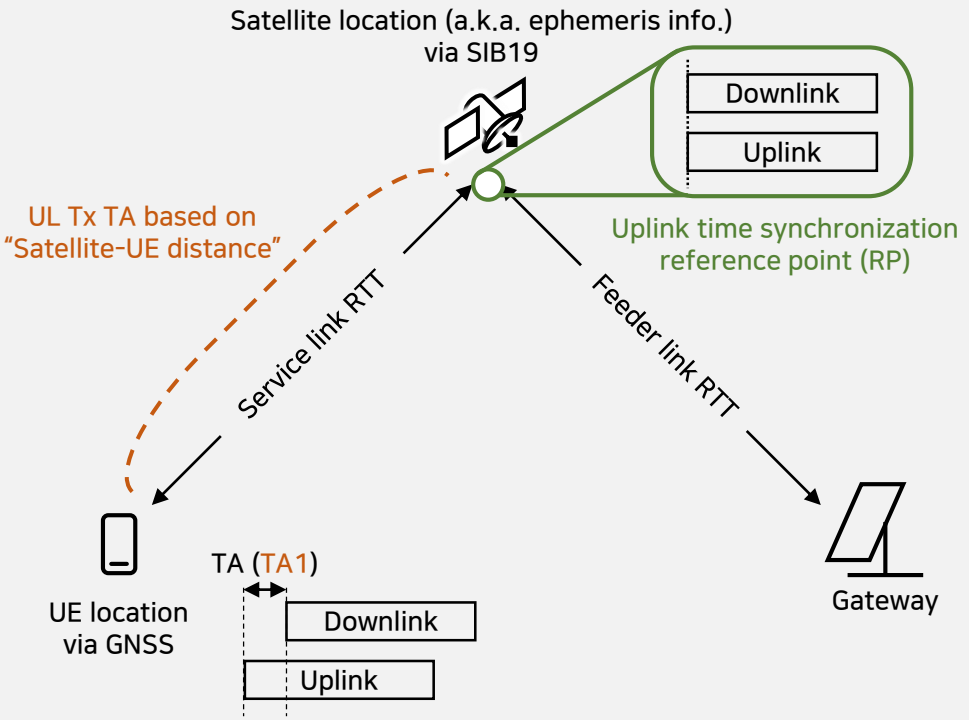
02. NTN Specification Supports in 5G NR

Rel-17: Uplink transmission timing adjustment (TA)

For transparent payloads



For regenerative payloads



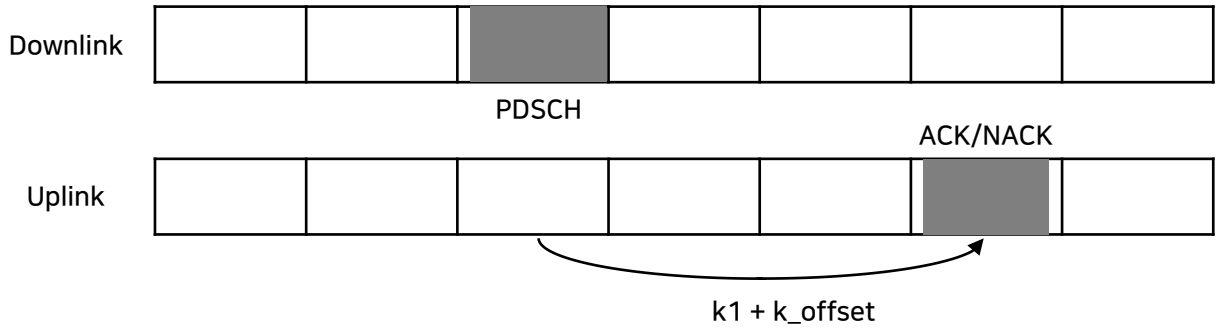
02. NTN Specification Supports in 5G NR

Rel-17: TA report

- UE calculates and applies TA values
- gNB can configure UE to report the applied TA values

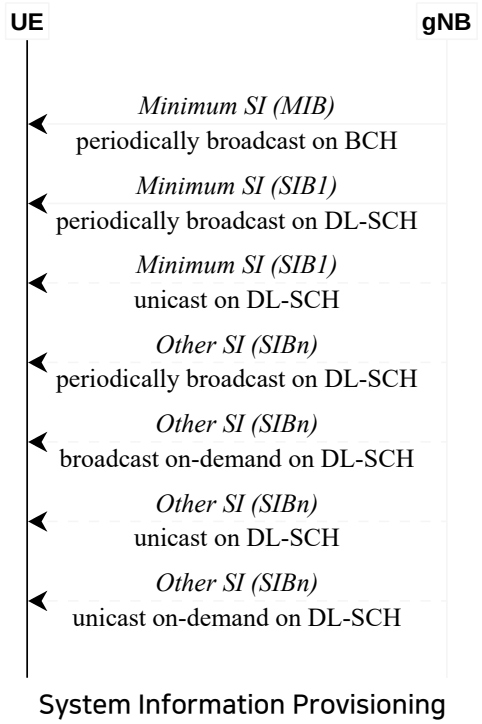
Rel-17: Various time offsets considering the long RTT in NTN

- Scheduling margin (k_offset)
- Activation margin (k_mac)
- Timer margin (ra-ResponseWindow, ra-ContentionResolutionTimer, sr-ProhibitTimer etc.)

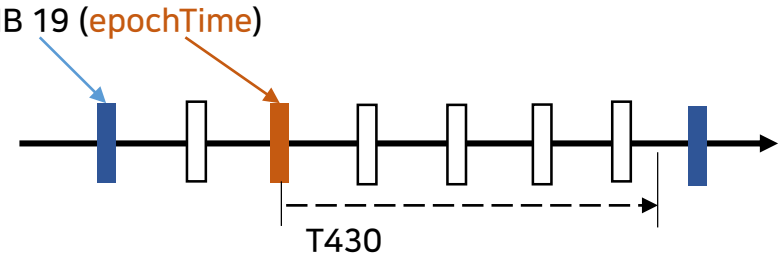


02. NTN Specification Supports in 5G NR

Rel-17: SIB19



System Information Provisioning



For non-terrestrial network, Other SI also includes:

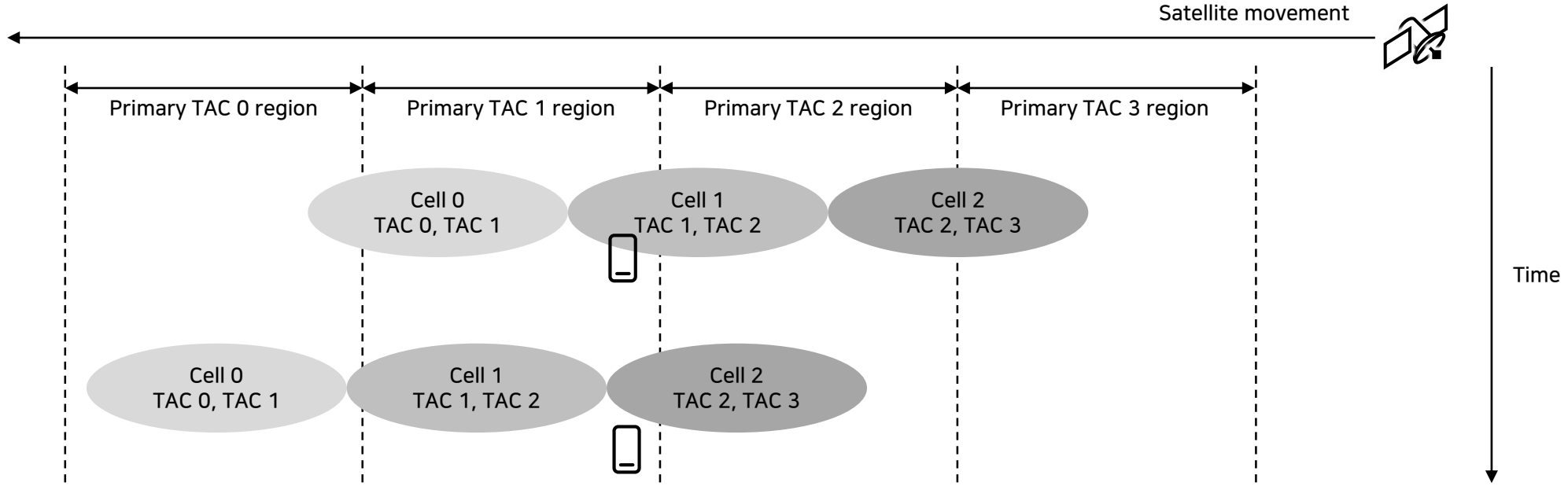
- *SIB19* contains NTN-specific parameters for serving cell and optionally NTN-specific parameters for neighbour cells as defined in TS 38.331.

SIB19 field descriptions
distanceThresh Distance from the serving cell reference location and is used in location-based measurement initiation in RRC_IDLE and RRC_INACTIVE. Each step represents 50m.
ntn-Config Provides parameters needed for the UE to access NR via NTN access such as Ephemeris data, common TA parameters, k_offset, validity duration for UL sync information and epoch.
ntn-NeighCellConfigList, ntn-NeighCellConfigListExt Provides a list of NTN neighbour cells including their *ntn-Config*, carrier frequency and *PhysCellId*. …
referenceLocation Reference location of the serving cell provided via NTN quasi-Earth fixed system and is used in location-based measurement initiation in RRC_IDLE and RRC_INACTIVE.
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. The reference point for *t-Service* is the uplink time synchronization reference point of the cell.

02. NTN Specification Supports in 5G NR

Rel-17: Multiple TACs

- In NTN, the network can broadcast more than one Tracking Area Codes (TACs) per PLMN in a cell

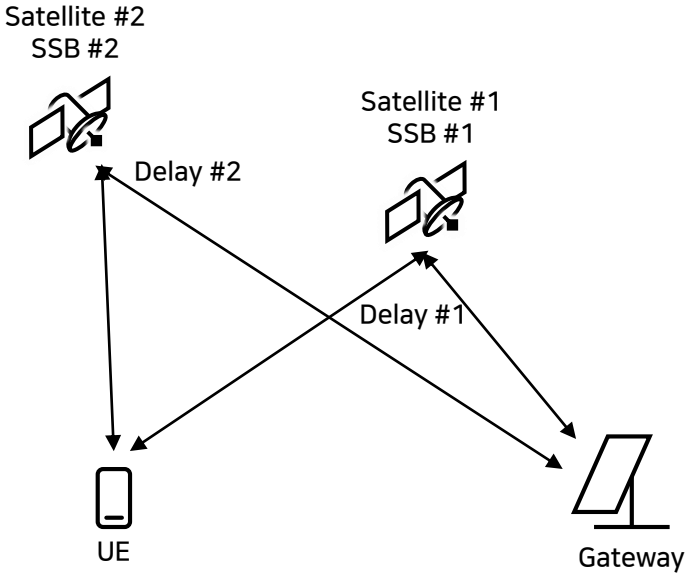


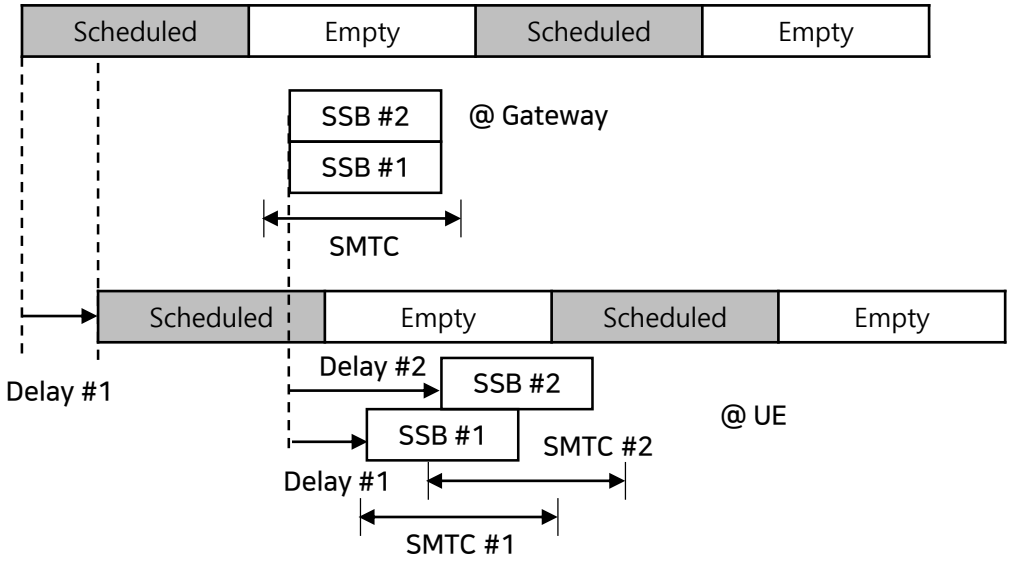
An example of multiple TACs broadcast with moving cells (a.k.a. soft switch)

02. NTN Specification Supports in 5G NR

Rel-17: Multiple SMTCs

- A proper timing of the SMTC (SS/PBCH block measurement timing configuration) can be different across different links

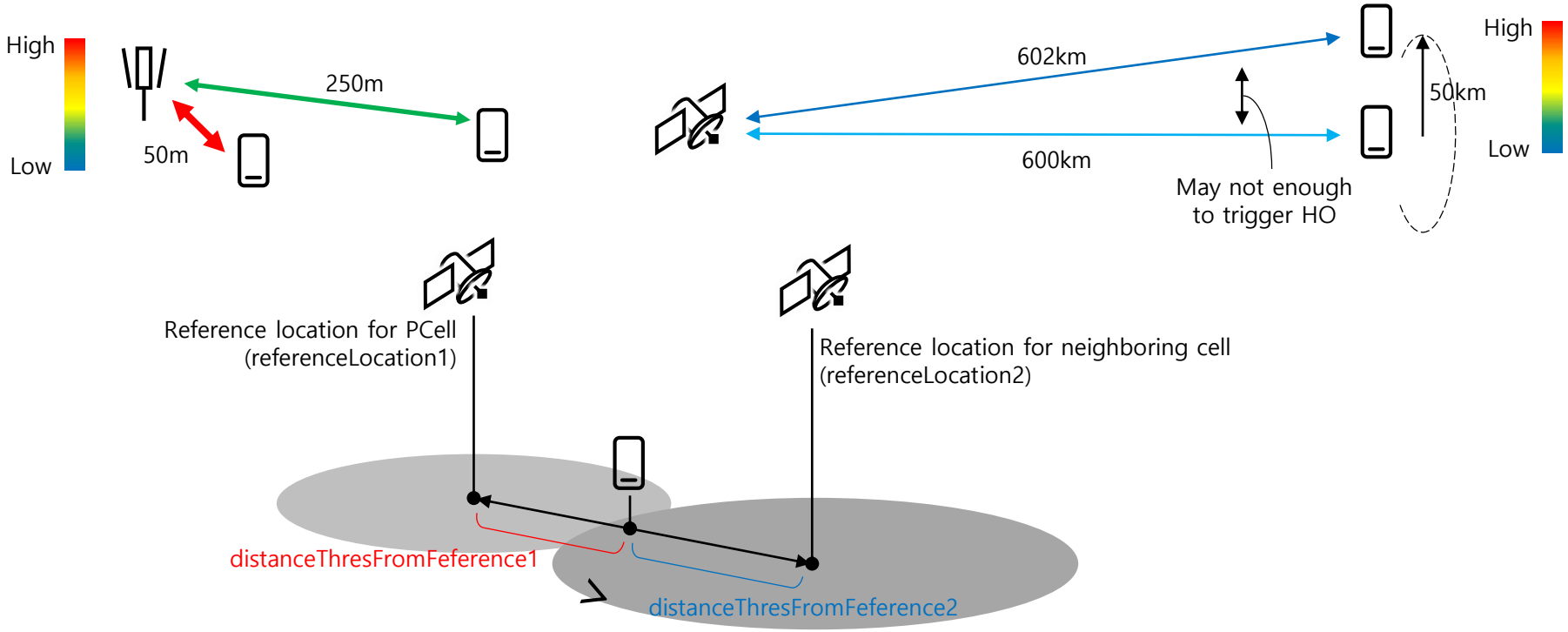




02. NTN Specification Supports in 5G NR

Rel-17: Handover (HO) and conditional HO (CHO)

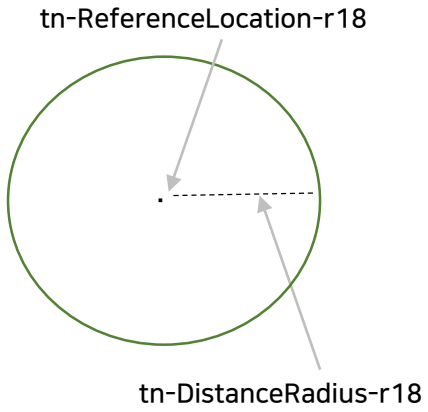
- NTN to TN HO (hand-in) and from TN to NTN HO (hand-out)
- Location-based CHO, Time-based CHO, and Measurement-based CHO

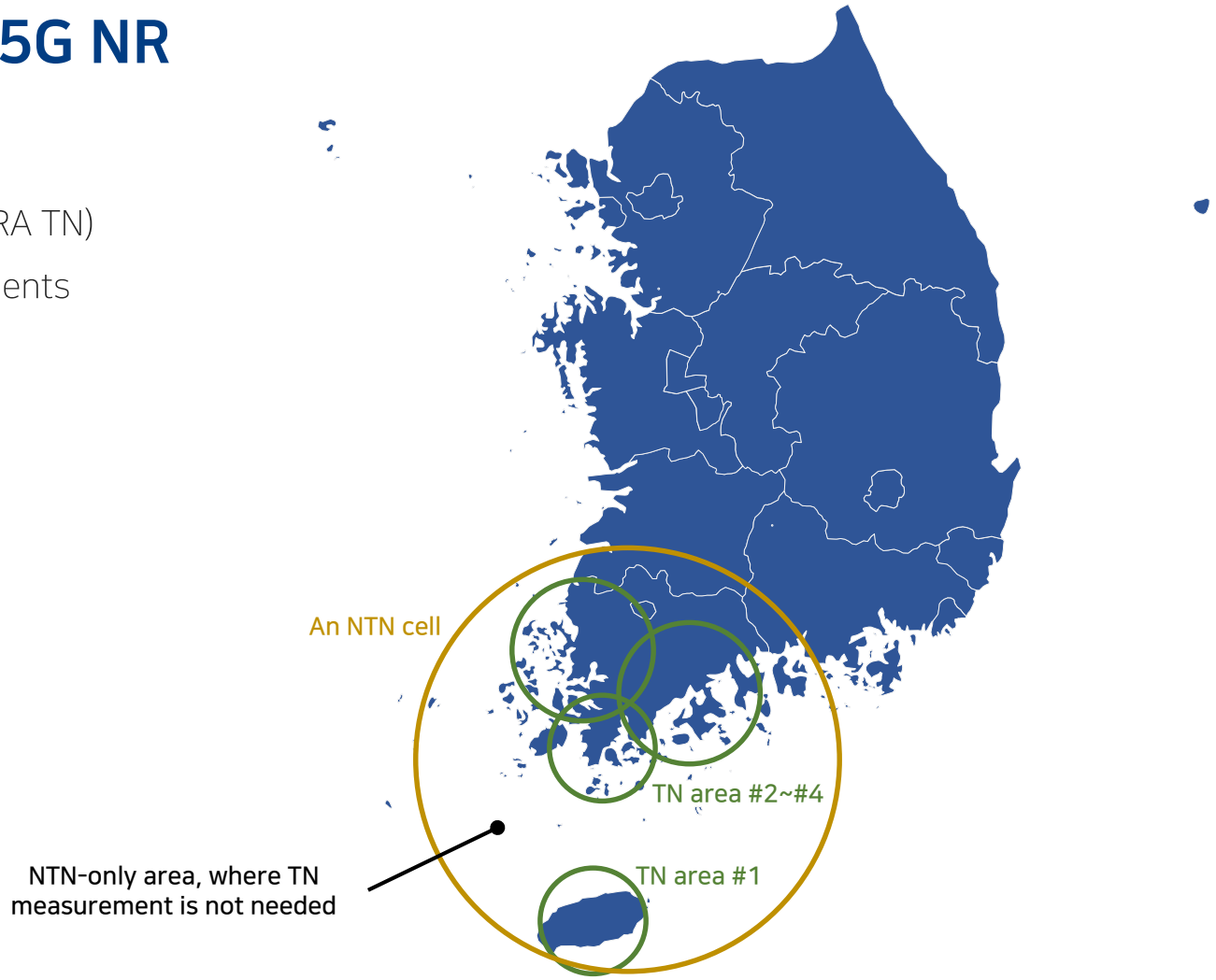


02. NTN Specification Supports in 5G NR

Rel-18: Power Saving in NTN-TN Coverage Area

- The network broadcasts TN areas (:= NR TN + E-UTRA TN)
- @Outside of TN area, the UE can skip TN measurements





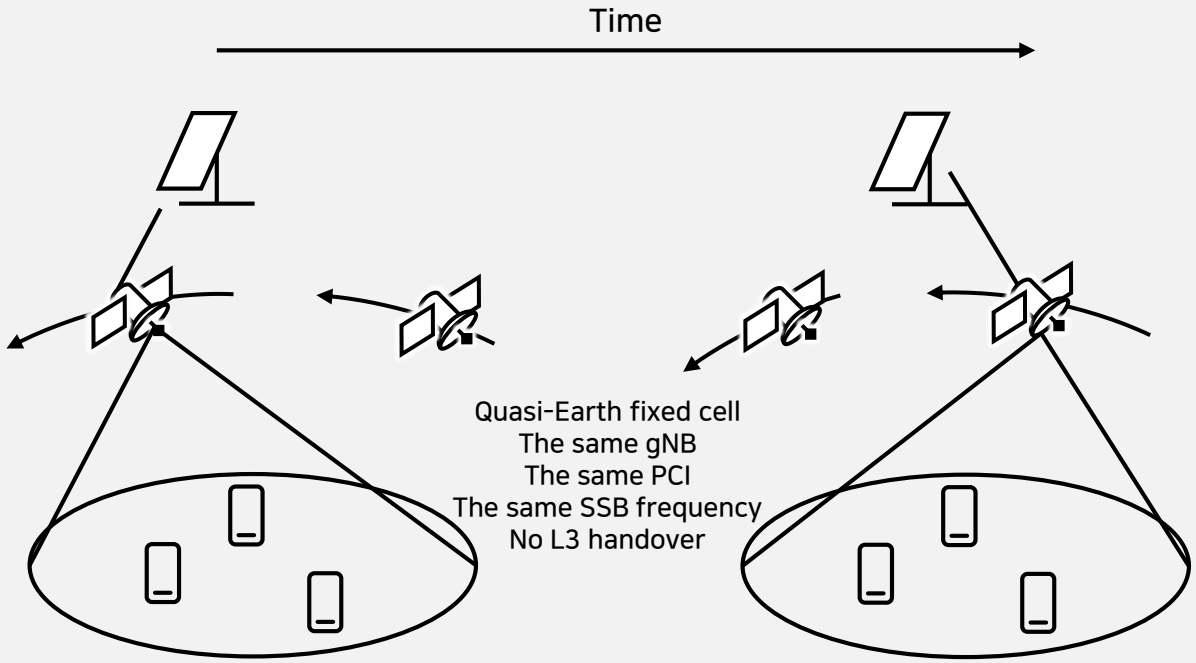
02. NTN Specification Supports in 5G NR

Rel-18: RACH-less HO

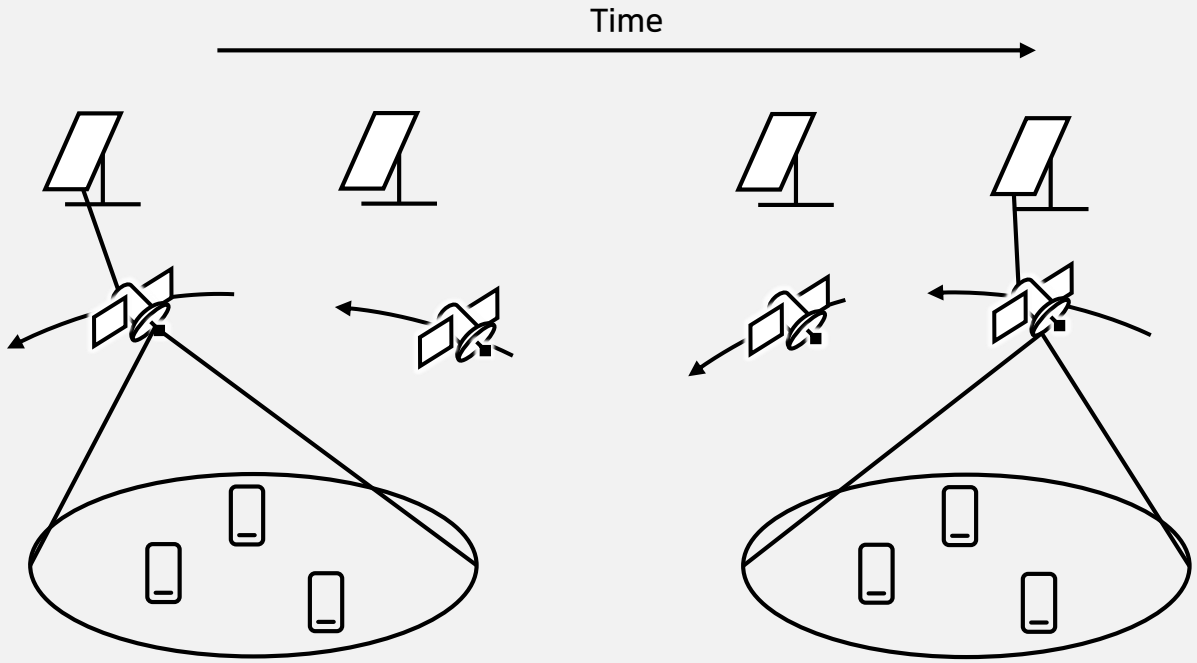
- Need to resolve RACH congestion due to high satellite mobility (e.g., LEO with 7.x Km/s)
- 2 types of HO with RACH are supported (dynamic grant (DG)-RACH-less HO, and configured grant (CG)-RACH-less HO)
- PUSCH beam and transmission power determination after HO without RACH

02. NTN Specification Supports in 5G NR

Rel-18: Satellite switch with re-sync.



Satellite switch with re-synchronization



Handover

02. NTN Specification Supports in 5G NR

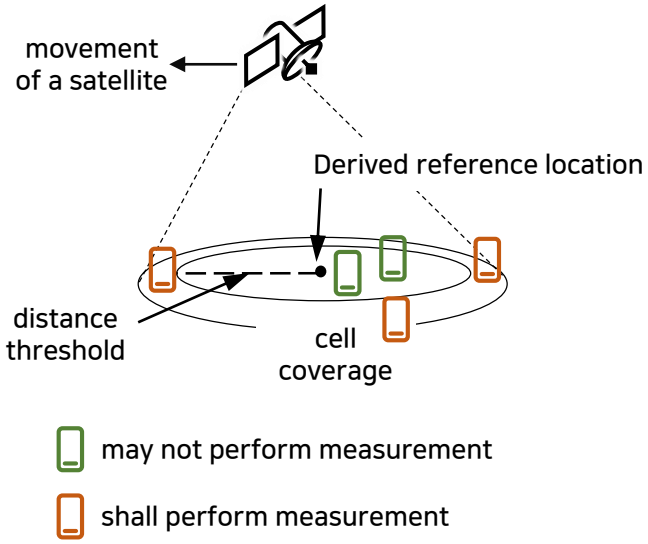
Rel-18: Earth-Moving Cell (EMC)

- SIB19 includes a new parameter (movingReferenceLocation)
- Enhancements on Location-based CHO, Time-based CHO, and Measurement-based CHO considering EMC

not present in SIB19 if the serving cell is an EMC

```
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            OCTET STRING                  OPTIONAL,
    ...,
    [[
    ntn-NeighCellConfigListExt-v1720    NTN-NeighCellConfigList-r17   OPTIONAL        -- Need R
    ]],
    [[
    movingReferenceLocation-r18         ReferenceLocation-r17         OPTIONAL,       -- Need R
    ntnCovEnh-r18                       NTN-CovEnh-r18                OPTIONAL,       -- Need R
    satSwitchWithReSync-r18             SatSwitchWithReSync-r18       OPTIONAL        -- Need R
    ]]
}
```

Present only in an EMC.
Thus, the presence of this parameter indicates to UEs that the serving cell is an EMC



02. NTN Specification Supports in 5G NR

Rel-18: FR2 support

Red texts: Updates for Rel-18 NTN

4.1 Cell search

Cell search is the procedure for a UE to acquire time and frequency synchronization with a cell and to detect the physical layer Cell ID of the cell.

A UE receives the following synchronization signals (SS) in order to perform cell search: the primary synchronization signal (PSS) and secondary synchronization signal (SSS) as defined in [4, TS 38.211].

A UE assumes that reception occasions of a physical broadcast channel (PBCH), PSS, and SSS are in consecutive symbols, as defined in [4, TS 38.211], and form a SS/PBCH block. The UE assumes that SSS, PBCH DM-RS, and PBCH data have same EPRE. The UE may assume that the ratio of PSS EPRE to SSS EPRE in a SS/PBCH block is either 0 dB or 3 dB. If the UE has not been provided dedicated higher layer parameters, the UE may assume that the ratio of PDCCH DMRS EPRE to SSS EPRE is within -8 dB and 8 dB when the UE monitors PDCCHs for a DCI format 1_0 with CRC scrambled by SI-RNTI, P-RNTI, or RA-RNTI, or for a DCI format 2_7, or for a DCI format 4_0.

For a half frame with SS/PBCH blocks, the first symbol indexes for candidate SS/PBCH blocks are determined according to the SCS of SS/PBCH blocks as follows, where index 0 corresponds to the first symbol of the first slot in a half-frame.

- Case A - 15 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes of $\{2,8\} + 14 \cdot n$.
- …
- Case D - 120 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes *4,8,16,20+28·n*. For carrier frequencies within FR2 and FR2-NTN, *n=0, 1, 2, 3, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 17, 18*.
- Case E - 240 kHz SCS: the first symbols of the candidate SS/PBCH blocks have indexes *8,12,16,20,32,36,40,44+56·n*. For carrier frequencies within FR2-1 and FR2-NTN, *n=0, 1, 2, 3, 5, 6, 7, 8*.
- …

02. NTN Specification Supports in 5G NR

On-going discussions in Rel-19 (specifications will be available in 2025)

- DL coverage enhancement (SSB periodicity extension)
- OCC for NR-NTN uplink (PUSCH)
- OCC for IoT-NTN uplink (NPRACH & NPUSCH)
- Half duplex FDD UE support
- On-board gNB support (regenerative payload)
- Store & forward support
- MBS intended service area signalling
- LTE-to-NR NTN mobility (IDLE mode cell (re)selection)
- IoT-NTN TDD mode (Iridium)

03. NTN in Beyond 5G and 6G

Potential topics for B5G/6G NTN specifications

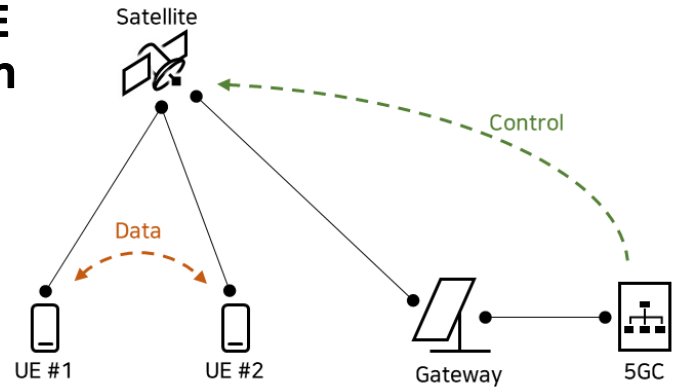
ICT Standards

Release 20 이후 5G NR 및 6G 에서 예상되는 NTN 표준화 진행 방향들을 논의한다

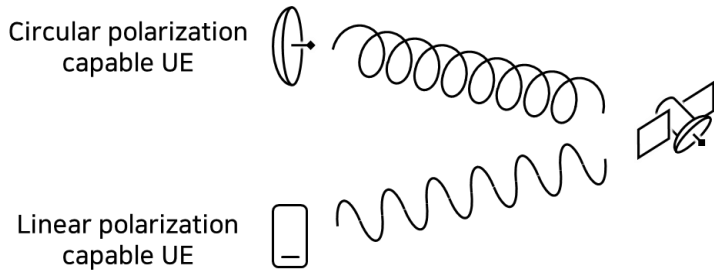
03. NTN in Beyond 5G and 6G

Possible topics for NR NTN Release 20 and beyond

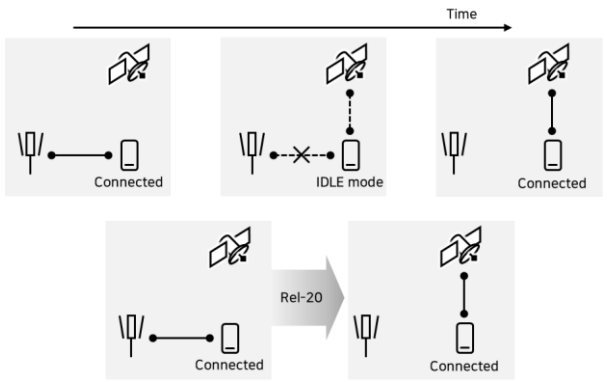
UE-satellite-UE communication



UE-satellite antenna polarization alignment



LTE TN-to-NR NTN connected mode mobility



- DL coverage enhancement (Asynchronous DL-UL beam width)
- More energy saving for networks and Ues (half duplex FDD UE enhancements, TDD mode enhancements)
- Etc.

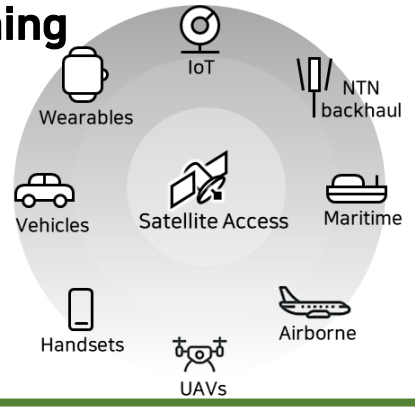
Rel-19 leftovers

AMF: Access and Mobility Management Function
UPF: User Plane Function

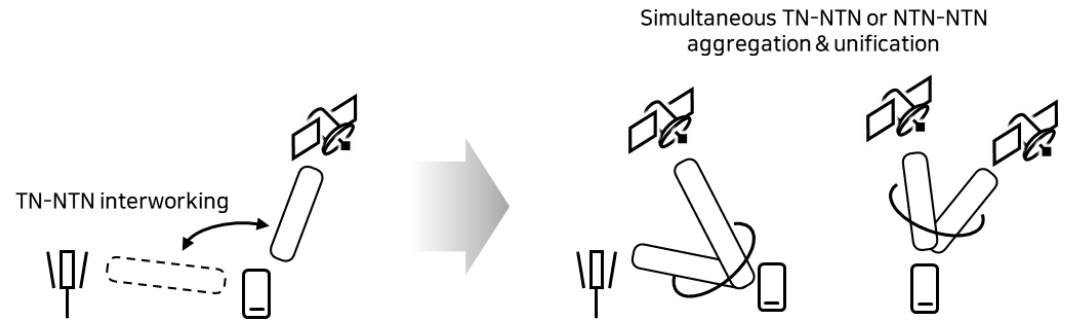
03. NTN in Beyond 5G and 6G

Potential topics for 6G NTN

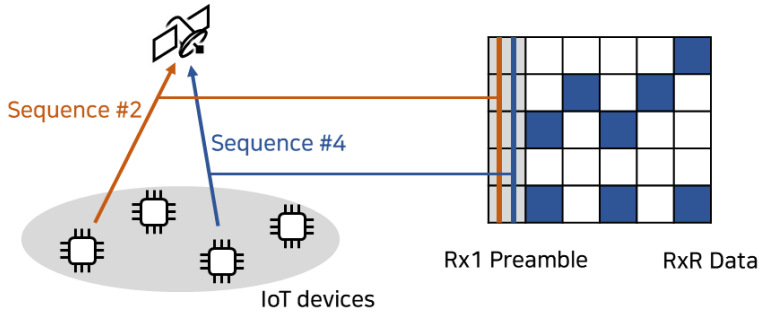
NTN for everything



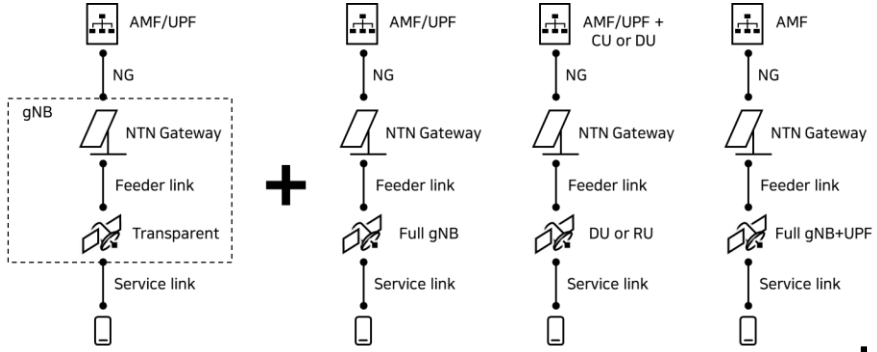
TN-NTN and NTN-NTN aggregation & unification



Multiple access (NOMA, RSMA) for NTN



NTN architectures



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