GISC 2025

Global ICT Standards Conference 2025

(세션1) ICT 표준화포럼 활동

# 위성-지상망 연동: 3GPP NTN 표준화 동향

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주최 과학기술정보통신부 지식재산처 주관 국립전파연구원 TTA IITP KEA kista ETRI

# Abstract

최초의 위성-지상망 연동 규격 제정을 진행한 3GPP NR NTN의 표준화 동향 소개

위성-지상 융합을 위한 3GPP 6GR NTN의 표준화 방향 및 ETRI View 소개

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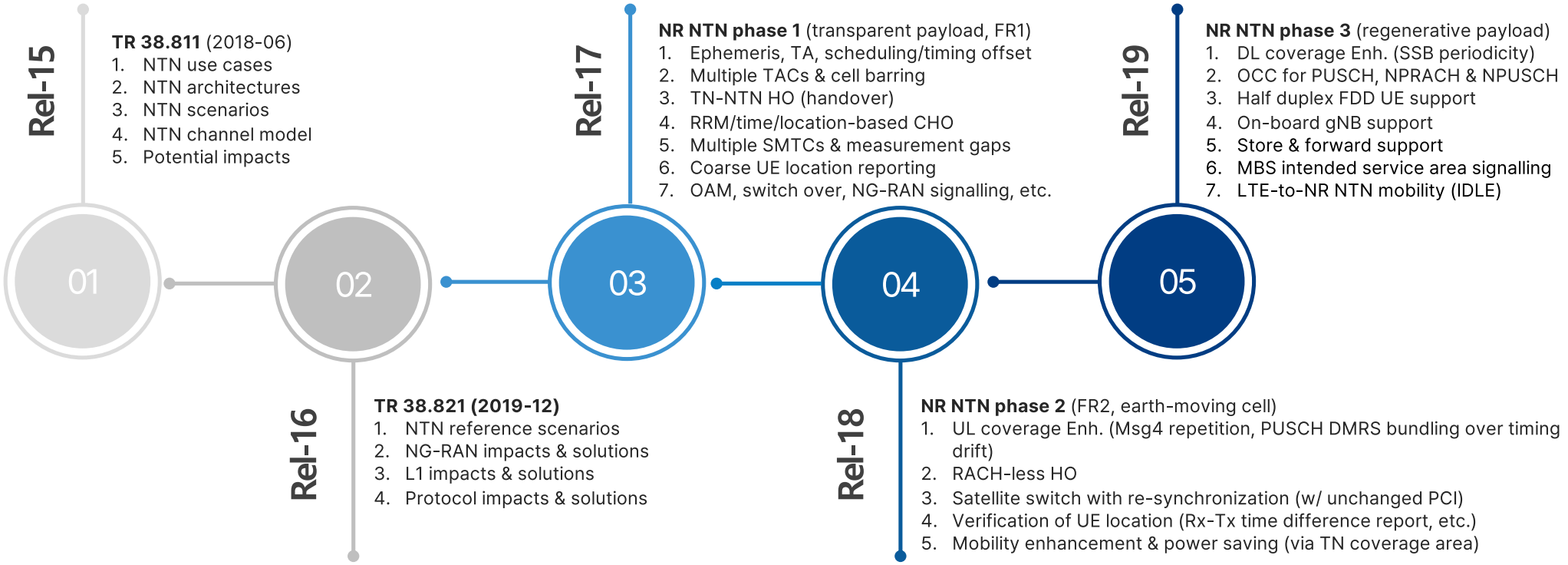
# Contents

# 3GPP NTN Specification Overview



# 3GPP NTN Key Features

## Rel-15 NTN SI: Study on NR to support NTN (TR 38.811)

- Channel model, potential impact on NR

## Rel-16 NTN SI: Solutions for NR to support NTN (TR 38.821)

- Architecture, potential solutions, reference scenario & parameters

## Rel-17 NTN WI (NR_NTN_solutions): Solutions

- Solutions (UL sync. Timing relation, HARQ, time/location-based CHO), multiple SMTC & measurement gaps

## Rel-18 NTN WI (NR_NTN_enh): Direct connectivity

- Direct connectivity (UL coverage enh.), NTN Bands (> 10GHz),
  RACH-less HO, network verified UE location, mobility enhancement, satellite switch with re-sync.

## Rel-19 NTN WI (NR_NTN_Ph3): Performance optimization

- Regenerative payload, Wide DL coverage, UL throughput enh (OCC),
  RedCap UE (Half-duplex FDD), store & forward, LTE-to-NR NTN mobility (idle mode)

## Rel-20 NTN WI (NR_NTN_Ph4): GNSS resilient operation

- GNSS resilient operation

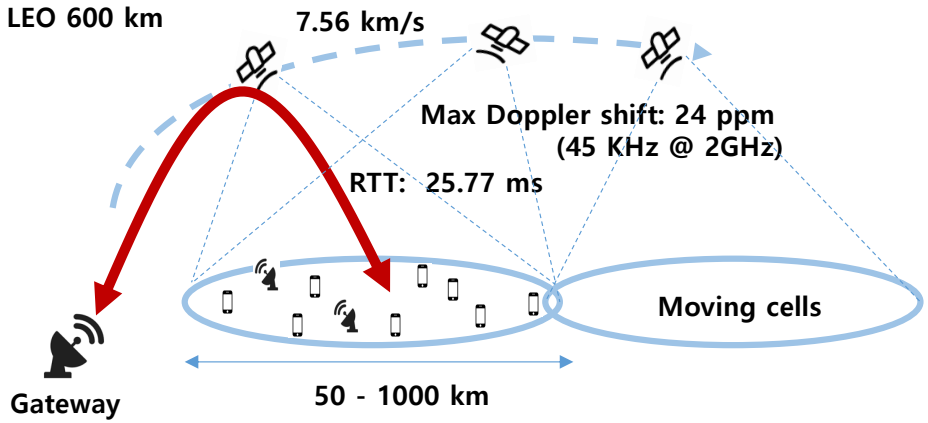
**Rel-17 WID & Results**

Rel-18 WID & Results

Rel-19 WID & Results

# WI for Rel-17 NR NTN solution

**Issues:** long propagation delays, large Doppler effects, moving cells



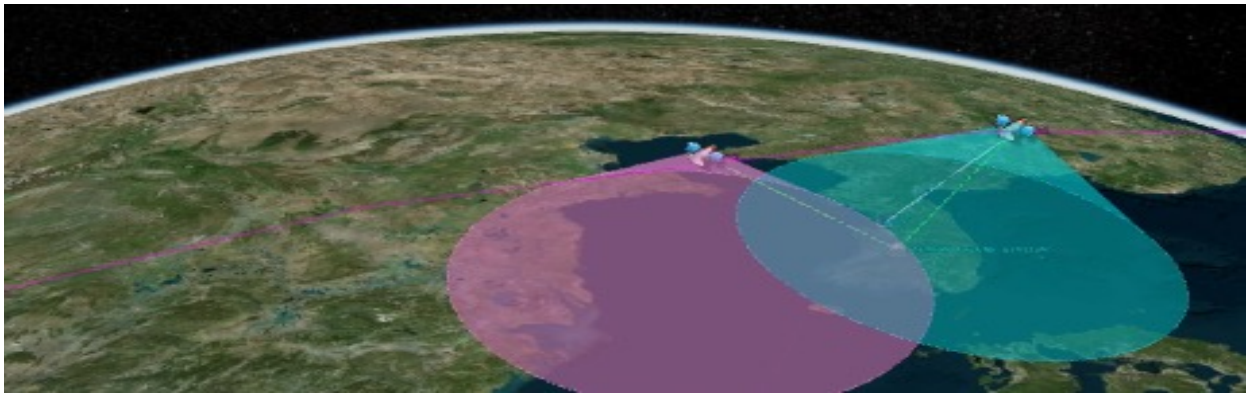

**Rel-17 NTN WI (NR_NTN_solutions): Solutions**
**To define solutions enabling NR and NG-RAN to support NTN**

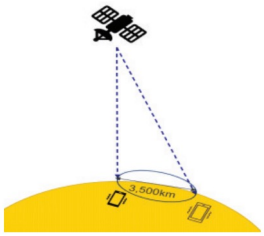
- Timing relationship enhancements (RAN1,2)
- Enhancements on UL time and frequency synchronization (RAN1,2)
- Enhancements on HARQ (RAN1,2)
- Signaling of polarization, beam management, feeder link switch, … (RAN1,2)
- Conditional handover

# Assumptions of Rel-17 NTN*

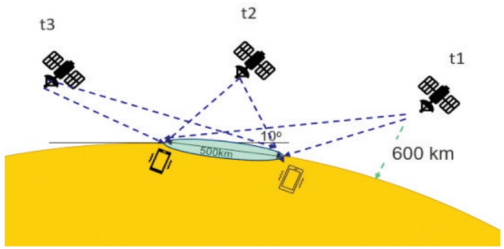
## Assumptions on WI

- FDD
- Earth fixed and moving cells
- UEs with GNSS capabilities
- Transparent payload

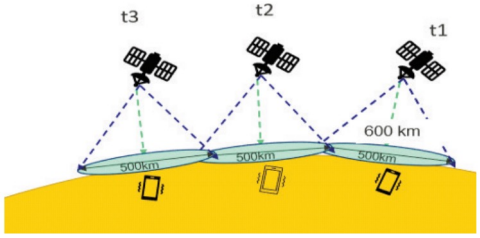





Earth-Fixed Cell




Quasi-Earth-Fixed Cell




Moving Cell

Source: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=10077212

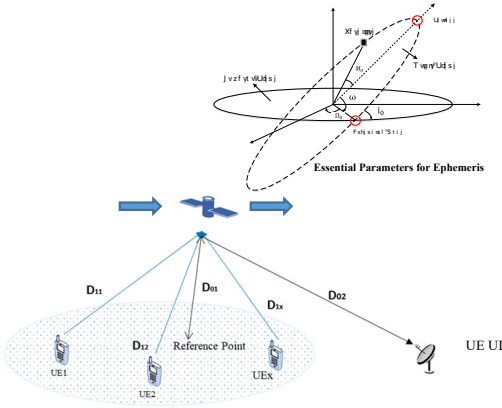
* RP-201256 " Solutions for NR to support NTN (Release 17)," e-meeting, June 29 - July 3, 2020. (← Rel-17 NR NTN WID)

# Objective of Rel-17 WI on NTN*

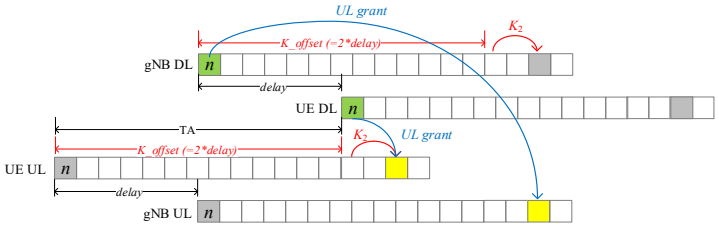
## Issues: long propagation delays, large Doppler effects, moving cells

## Solution

- Enhancements on UL time and frequency synchronization [RAN1,RAN2]
  - ✓ Pre-compensation by UE using GNSS & satellite orbit information




Delay & doppler differences




UL time sync. & timing relation

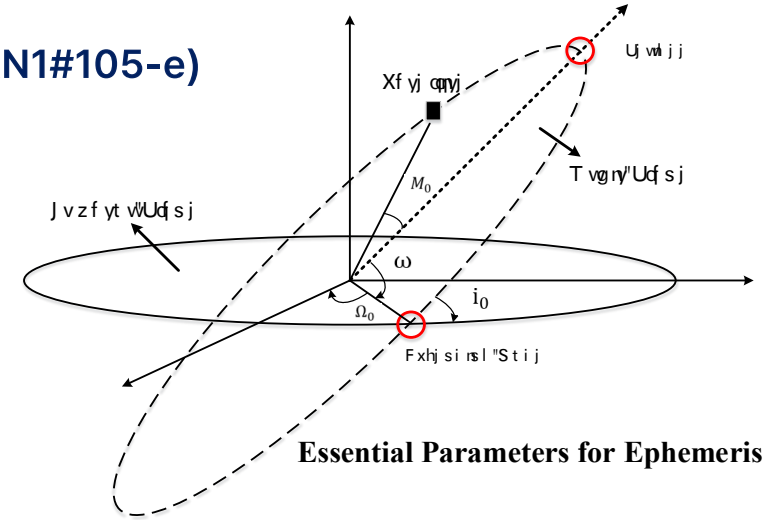
Source: [TR 38.821]

* RP-201256 " Solutions for NR to support NTN (Release 17),” e-meeting, June 29 - July 3, 2020. (← Rel-17 NR NTN WID)

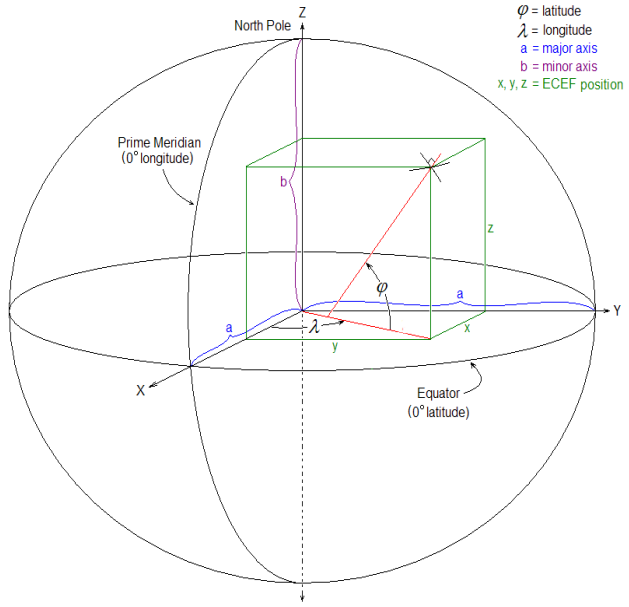
# UL Time/Frequency Synchronization

## Orbit information format (@RAN1#105-e)

- Ephemeris format
- ECEF format (x, y, z, dx, dy, dz)




**Essential Parameters for Ephemeris**




**Earth-Centered, Earth-Fixed (ECEF) coordinates in relation to latitude and longitude (source https://en.wikipedia.org/wiki/ECEF ) [TR 38.821]**

| | | |
|---|---|---|
| Orbital plane parameters | $\sqrt{a}$ | Square root of semi major axis（semi-major axis） |
| | e | Eccentricity（eccentricity） |
| | $i_0$ | Inclination angle at reference time（inclination） |
| | $\Omega_0$ | Longitude of ascending node of orbit plane（right ascension of the ascending node） |
| | $\omega$ | Argument of perigee（argument of periapsis） |
| Satellite level parameters | $M_0$ | Mean anomaly at reference time（true anomaly and a reference point in time） |
| | $t_{0e}$ | Ephemeris reference time（the epoch） |

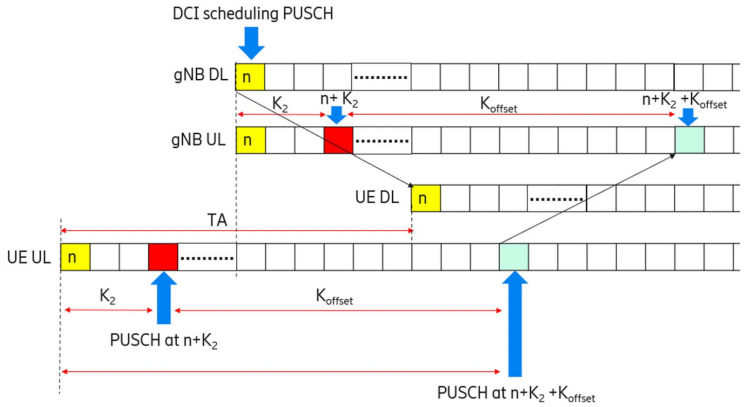
**Essential elements of ephemeris [TR 38.821]**

# Objective of Rel-17 WI on NTN*

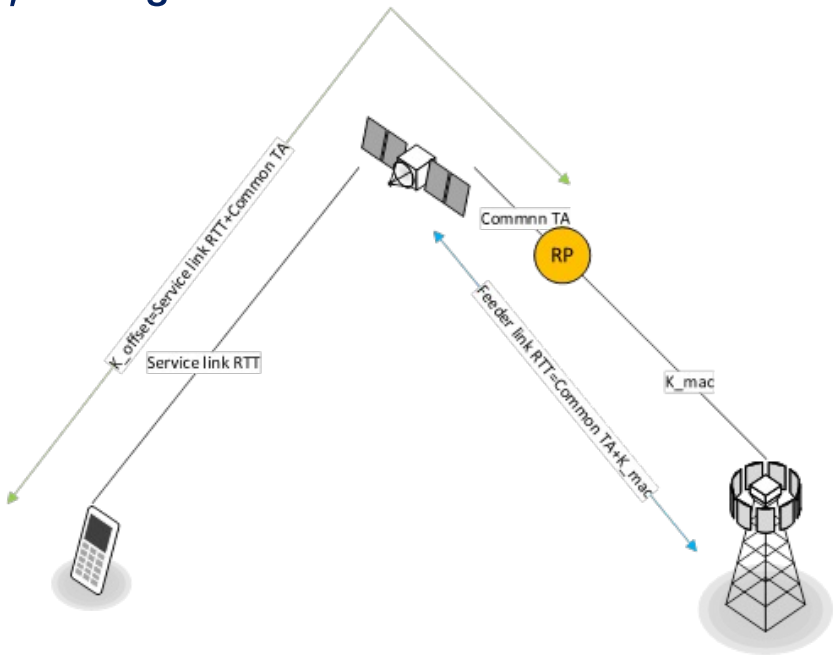
## Issues: long propagation delays, large Doppler effects, moving cells

## Solution

- Timing relationship enhancements [RAN1,RAN2]
  - ✓ Introducing K_offset ← reducing signaling overhead




Transmission timing of PUSCH (source: TR38.821)




NR timing enhancement [TS 38.300 ]

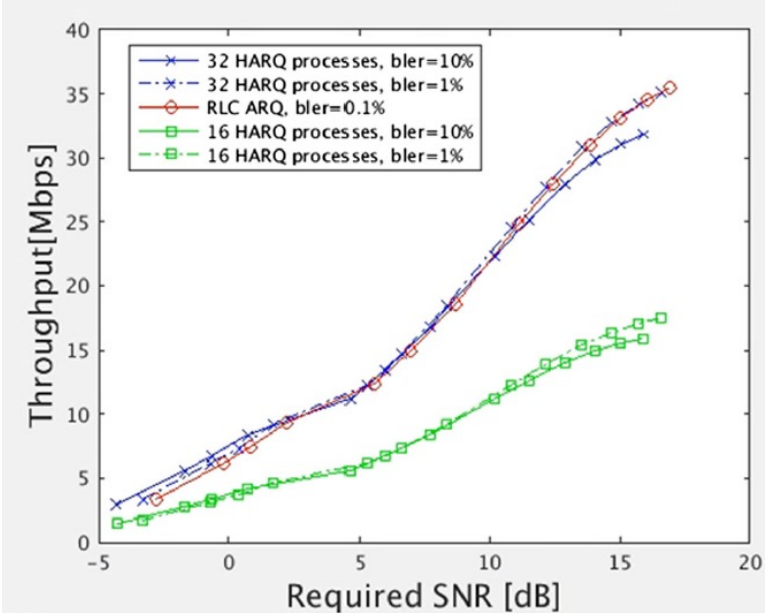
* RP-201256 " Solutions for NR to support NTN (Release 17)," e-meeting, June 29 - July 3, 2020. (← Rel-17 NR NTN WID)

# Objective of Rel-17 WI on NTN

## Issues: long propagation delays, large Doppler effects, moving cells

## Solution

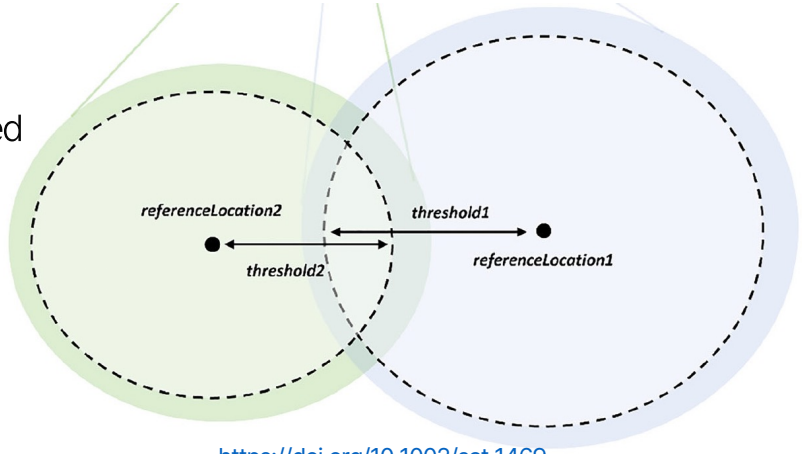
- HARQ enhancements (for throughput)
  - ✓ Number of HARQ process [RAN1] ➔ 16→ 32
  - ✓ Enabling/disabling of HARQ feedback (when using RLC ARQ, semi-statically )
  - ✓ Codebook enhancement & slot aggregation enhancement




https://doi.org/10.1002/sat.1461

## Solution

- Conditional handover
  - ✓ Location & timer based




https://doi.org/10.1002/sat.1469

# Objective of Rel-17 WI on NTN*

## Issues: long propagation delays, large Doppler effects, moving cells

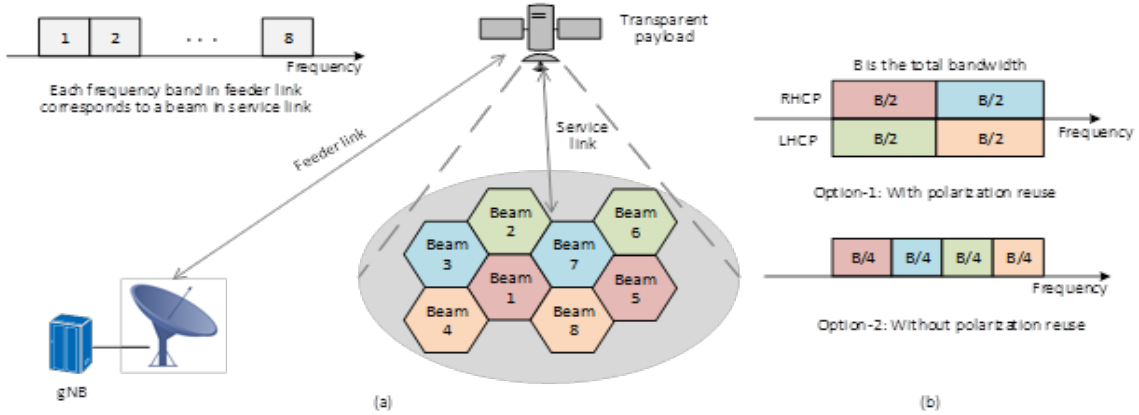
## Solution

- HARQ enhancements (for throughput)
  - ✓ Number of HARQ process [RAN1] ➔ 16→ 32
  - ✓ Enabling/disabling of HARQ feedback (when using RLC ARQ, semi-statically )
  - ✓ Codebook enhancement & slot aggregation enhancement

# Objective of Rel-17 WI on NTN*

## Satellite beam operations based on NR

- Beam management and Bandwidth Parts (BWP) operation for NTN with frequency reuse [RAN1/2]
  - ✓ Define signalling of polarization mode: RHCP, LHCP, linear
  - ✓ Beam layout: reuse PCI and beam ID (for small beam indication) , BWP (for freq. reuse)




Beam layout & polarization

Source: R1-2007233 Feature lead summary#4 on other enhancements of NR NTN Moderator (MediaTek)

* RP-201256 " Solutions for NR to support NTN (Release 17)," e-meeting, June 29 - July 3, 2020. (← Rel-17 NR NTN WID)

Rel-17 WID & Results

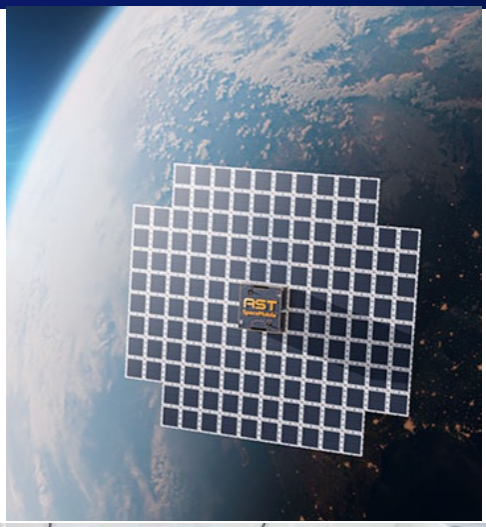
**Rel-18 WID & Results**

Rel-19 WID & Results

# WI for Rel-18 NR NTN Enh*

## Activities for Mobile Satellite Services (MSS)

- Sep. 8, 2023: first phone call b/w smartphone & LEO satellite (AT&T & AST SpaceMobile)**
- Jan. 3, 2024: SpaceX launched first T-Mobile Direct-to-Cell satellites (on 1900 MHz)
- Mar. 14, 2024: FCC approved SCS regulatory ***
- Commercial agreement & partnership
  - ✓AT&T & AST SpaceMobile (May 15, 2024)
  - ✓Verizon & AST SpaceMobile on 850 MHz (May 29, 2024)




Source: AST SpaceMobile

SCS: supplemental coverage from space

**WCA https://wca.org/the-initial-satellite-5g-phone-call-was-assisted-by-att/
*** https://spacenews.com/fcc-approves-direct-to-smartphone-regulatory-framework/

# WI for Rel-18 NR NTN Enh*

## Rel-18 NTN WI (NR_NTN_enh): Direct connectivity

- To introduce enhancements for NR NTN:
  - ✓Coverage enhancement (RAN1)
  - ✓NR-NTN deployment in above 10 GHz bands (RAN4)
  - ✓Network verified UE location (RAN1)
  - ✓NTN-TN and NTN-NTN mobility and service continuity enhancements (RAN2)

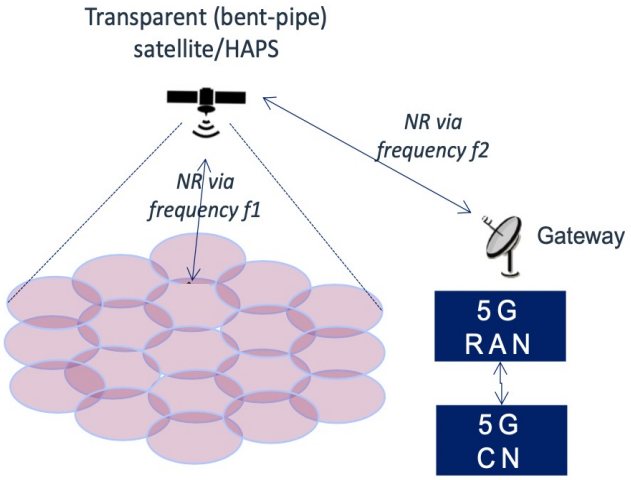
# WI for Rel-18 NR NTN Enh*

## Targeted services:

- VoIP using AMR* 4.75 kbps
- Low rate data service of 3 kbps

## Reference scenario & parameters (for UL CovEhn)

- Parameter set-1 for LEO-1200 satellite operating at LOS and commercial smartphones with -5.5 dBi antenna gain and 3 dB polarisation loss




Source: TR 38.821

## Detailed objectives (@RAN#97)

- PUCCH enhancements for Msg4 HARQ-ACK (e.g. repetition) [RAN1, RAN4]
- DMRS bundling for PUSCH for VoIP considering time-frequency pre-compensation [RAN1]

* RP-223534, "Revised WID: NR NTN enhancements, RAN#98e, Dec. 12 - 16, 2022.

AMR: adaptive multi-rate speech codec

Rel-17 WID & Results
Rel-18 WID & Results
**Rel-19 WID & Results**

# WI for Rel-19 NR NTN Ph3*

## Rel-19 NTN WI (NR_NTN_Ph3): Performance optimization

**To define further enhancements for NG-RAN based NTN:**

- NR-NTN downlink coverage enhancement (RAN1,2,4)
  - ➔ Introducing of new default 160ms SSB periodicity
  - ➔ Enhancing PDCCH CSS, PDSCH with Msg4, PDSCH with SIB1/SIB19
- NR-NTN uplink capacity/throughput enhancement (RAN1,2,4)
- Specify signaling of MBS broadcast via NTN (RAN2,3)
- Support of RedCap and eRedCap UEs with NR NTN operating in FR1-NTN bands (RAN4,1)
- Support of regenerative payload (RAN3,2,4)

## Assumptions

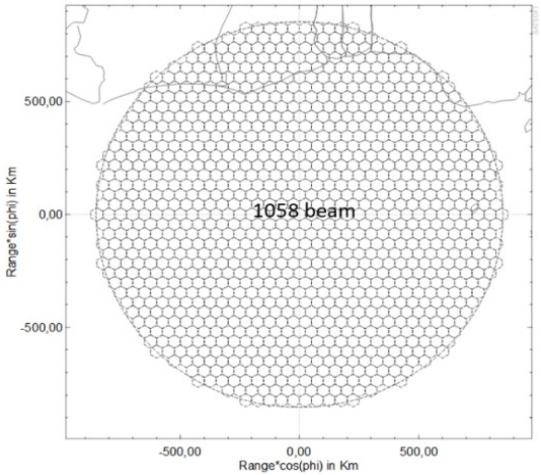
- Transparent payload & regenerative payload
- Earth fixed & Earth moving cells
- FDD
- UEs with GNSS
- Band: only VSAT for FR2

* RP-244078, New WID: NTN for NR Phase 3, RAN#102, Dec. 11-15, 2023.

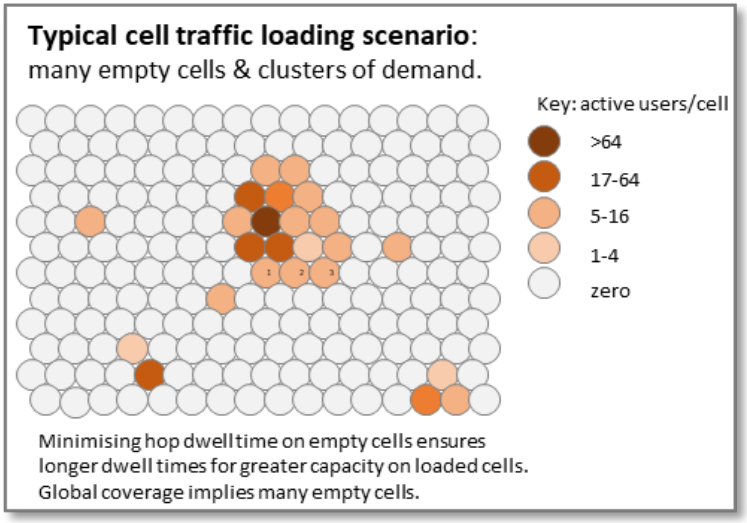
# Motivation for DL CE*

## Motivations: cost reduction

- Wide satellite coverage (> 1500 km)
- Cell traffic adaptation




Source: Thales




DL CE system-level aspect [R1-2400897, Eutelsat]
- **Different cell traffic load**

## Justification: To offer optimized performance

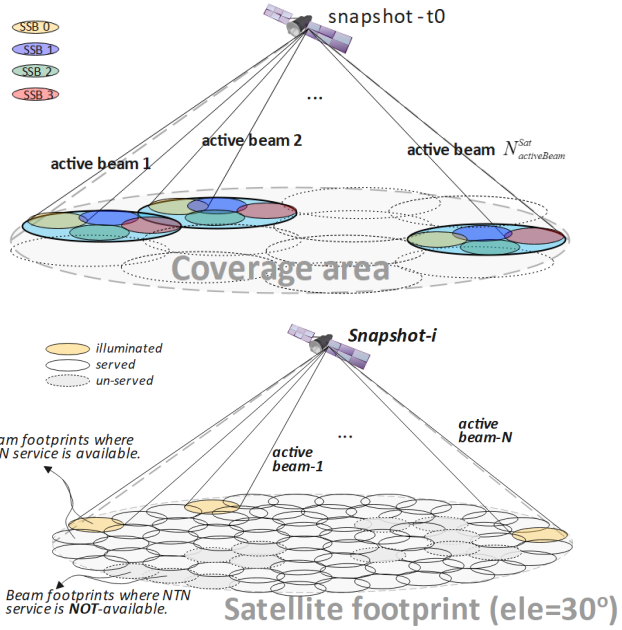
- Objective
  - ✓ Maximizing the number of beams & overall throughput ➔ by beam hopping (TDM manner)
  - ✓ All cells are kept alive
- Constraints
  - ✓ Limited power & feeder link BW

* RP-244078, New WID: NTN for NR Phase 3, RAN#102, Dec. 11-15, 2023.

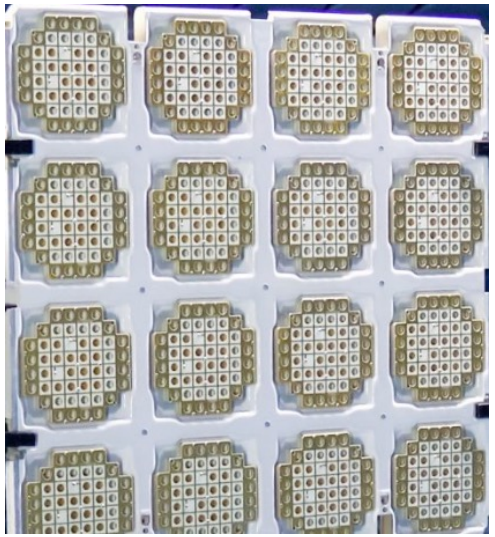
# Considering Scenarios

## Beam operation scenario: beam hopping

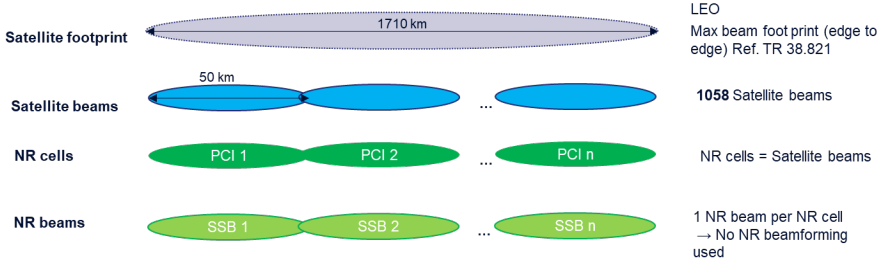
- Power sharing
- Dynamic beam size




Source: HW



Phased antenna array [AST SpaceMobile]




Option 1: Single NR cell per satellite beam and single NR beam cell [Thales]

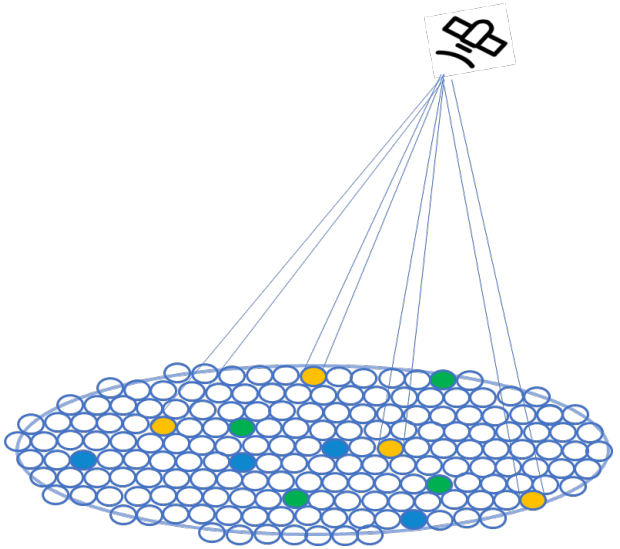
# Reference Parameters for Evaluations

## Updated reference parameters (@ RAN1#116 , Mar. 2024)

- Additional reference satellite parameters scenarios:
  LEO600km Set1-1 FR1, Set1-2 FR1, and Set1-3 FR1 (S-band)

| LEO600km Set1-1 FR1 (i.e., S-band) | |
|---|---|
| Maximum Bandwidth per beam | 5 MHz |
| SCS | 15 kHz |
| Beam size(Note 1) | 50km |
| Satellite EIRP density /beam (dBW/MHz) | 34 |
| Payload Total DL power level (dBW) | 31.24 |
| Aggregated EIRP (Total) (dBW) | 61.24* |
| Satellite Tx max Gain | 30 dBi |
| Maximum EIRP per Satellite beam (dBW) | 41 |
| Total number of beam footprints*** | 1058 |
| Total number of simultaneously active beams ** | 106 |
| % simultaneously active beams** | 10.02 % |

*Note: EIRP limit is 61.24 dBm for the reference configuration.
**Assuming 100 % Resource Block utilization within the same beam at max power. Absolute number of simultaneously active beams is up to 212 (due to limitation of RF)
*** For a constellation design at 600km with low elevation angle with 30° and selected (i.e Set 1 parameters) beam size
Note 1: At least this beam size is considered in this scenario, ~~different~~ larger beam sizes maybe evaluated and reported by companies



# Reference Parameters for Evaluations

## Updated reference parameters (@ RAN1#116 , Mar. 2024)

- Additional reference satellite parameters scenarios:
  LEO600km Set1-1 FR1, Set1-2 FR1, and Set1-3 FR1 (S-band)

| LEO600km Set1-2 FR1 (i.e., S-band) | |
|---|---|
| Maximum Bandwidth per beam | 5 MHz |
| SCS | 15 kHz |
| Beam size (note 1) | 50km |
| Satellite EIRP density /beam (dBW/MHz) | 34 |
| Payload Total DL power level (dBW) | 23 |
| Aggregated EIRP (Total) (dBW) | 53* |
| Satellite Tx max Gain | 30 dBi |
| Maximum EIRP per Satellite beam (dBW) | 41 |
| Total number of beam footprints | 1058 |
| Total number of simultaneously active beams** | 16 |
| % simultaneously active beams** | 1.5 % |
| *Note: EIRP limit is 53 dBm for the reference configuration.<br>**Absolute number of simultaneously active beams is up to 16 (due to limitation of RF)<br>Note 1: At least this beam size is considered in this scenario, larger ~~different~~ beam sizes maybe evaluated and reported by companies | |

| LEO600km Set 1-3 FR1 (i.e., S-band) | |
|---|---|
| Maximum Bandwidth per beam | 5 MHz |
| SCS | 15 kHz |
| Beam size (note 1) | 50km |
| Satellite EIRP density /beam (dBW/MHz) | 26 |
| Payload Total DL power level (dBW) | 23.24 |
| Aggregated EIRP (Total) (dBW) | 53.24* |
| Satellite Tx max Gain | 30 dBi |
| Maximum EIRP per Satellite beam (dBW) | 33 |
| Total number of beam footprints | 1058 |
| Total number of simultaneously active beams** | 106 |
| % simultaneously active beams** | 10.02 % |
| *Note: EIRP limit is 53.24 dBm for the reference configuration.<br>**Absolute number of simultaneously active beams is up to 212 (due to limitation of RF)<br>Note 1: At least this beam size is considered in this scenario, larger ~~different~~ beam sizes maybe evaluated and reported by companies | |

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# Contents

# Rel-20 new SID (NR_NTN_Ph4): Study on GNSS resilient NR-NTN operation

## Objectives

- The study will be carried assuming that
  - ✓ The GNSS information in UE with GNSS capability may be 1/ temporarily unavailable or 2/ available but with GNSS position accuracy degradation or 3/ available but with increased GNSS measurement period for power saving purpose
  - ✓ This study will initially focus on 1/ (where GNSS information is temporarily unavailable)
  - ✓ Note: This study does not include any enhancement on positioning for the above scenario

- Study GNSS resilient NR-NTN operation [RAN1, RAN4]
  - ✓ Assess impact on initial access and connected mode procedures for NR-NTN, including potential implications if any on RAN4 RRM specifications
    - Aim to minimize physical layer procedures impact
    - Avoid physical layer channel/signal changes
    - Backward compatible issues with legacy NTN capable UEs will be assessed and should be prevented
    - Applicable to NGSO and GSO constellations, NTN operating in below and in above 10 GHz frequency bands, transparent and regenerative satellites
  - ✓ Check in RAN#112 (June, 2026) to decide whether to proceed with normative work, extend the study item, or postpone normative work to Release 21

* RP-251863, New SID: Study on GNSS resilient NR-NTN operation, RAN#108, June 9-13, 2025.

# 6GR RAN1 Study Agenda

## 11 Rel-20 Study of 6GR

- Please refer to RP-251881 for the scope of the SI. The maximum number of contributions per company/organization/university is limited to 1 per agenda item unless stated otherwise.
- 11.1 Overview of 6GR air interface
  - ✓ High level design proposals/principles/target and overall design of 6G air interface to illustrate/address the pain points observed from different angles, … as well as concepts and aspects of harmonization of TN and NTN, etc
- 11.2 Evaluation assumptions for 6GR air interface
- 11.3 Waveform and frame structure for 6GR air interface
  - ✓ 11.3.1 Waveform
  - ✓ 11.3.2 Frame structure
- 11.4 Channel coding and modulation for 6GR interface
  - ✓ 11.4.1 Channel coding
  - ✓ 11.4.2 Modulation, joint channel coding and modulation
- 11.5 Energy efficiency
- 11.6 AI/ML in 6GR interface

  ….

  ….
- 11.12 NTN
  - ✓ No contributions before RAN1#124

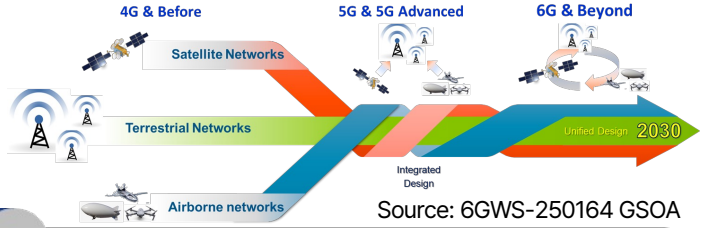
# ETRI's View on 6GR Unified TN-NTN

**Unified TN-NTN**

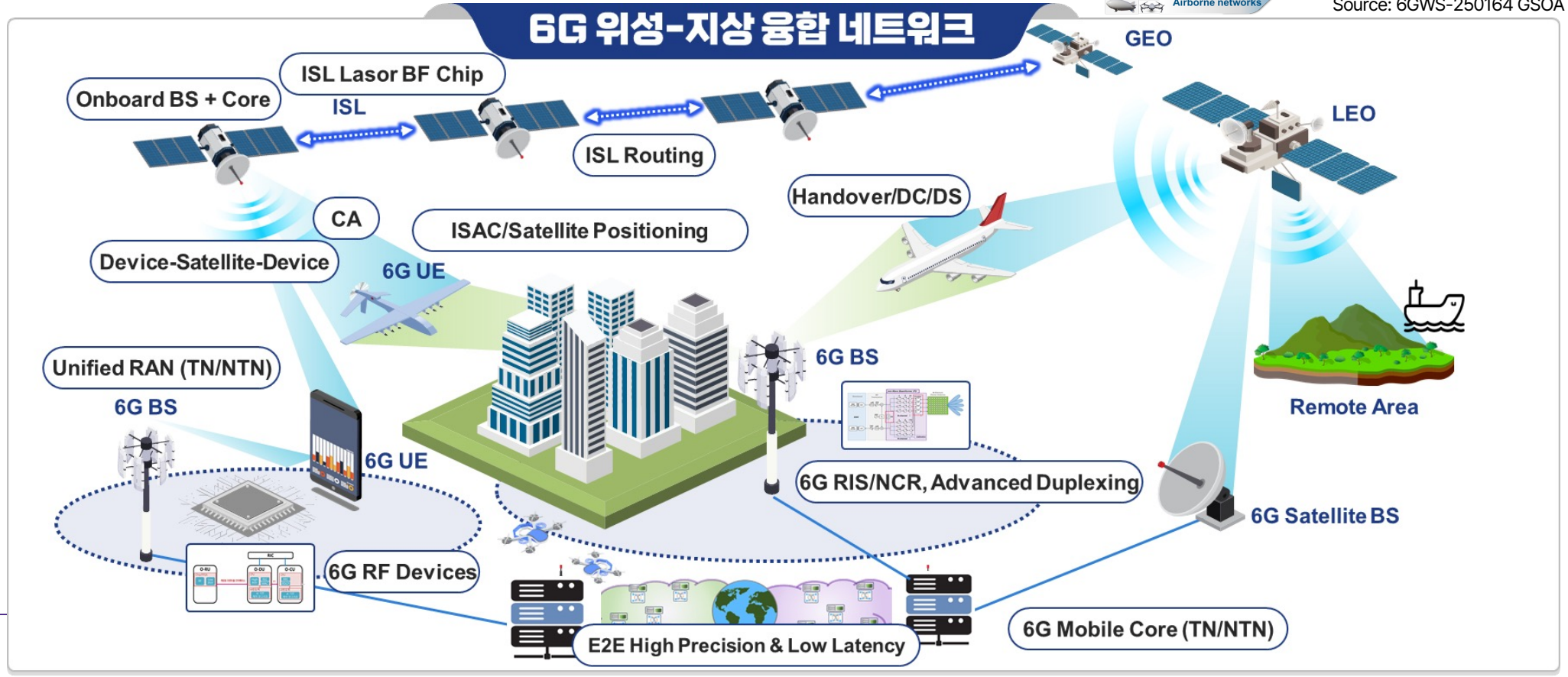
- 위성 내재와 및 성능 최적화

**Seamless Ubiquitous**

- 3차원 전 지구영역에서 이동간에도 비단절




Source: 6GWS-250164 GSOA



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## - 감사합니다 -

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**ICT Standards and Intellectual Property:**
**AI for All**

주최 과학기술정보통신부 지식재산처 주관 국립전파연구원 TTA IITP KEA kista ETRI