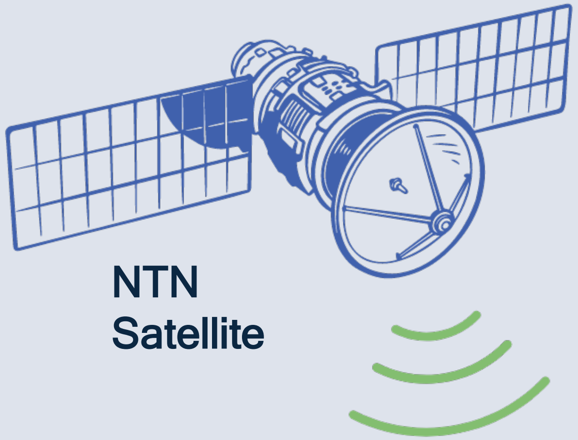
Qualcomm

Direct to Device Satellite communications

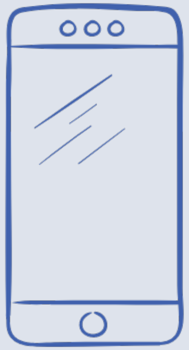
Jitendra Singh
Head, Govt. Affairs (Qualcomm India)

Overview of D2D technology



NTN Satellite

End user terminal



D2D enables the delivery of satellite services directly to user terminals bypassing the need for intermediary terrestrial infrastructure

It is poised to play a crucial role in achieving ubiquitous connectivity

Rapidly evolving market landscape due to significant interest from satellite operators

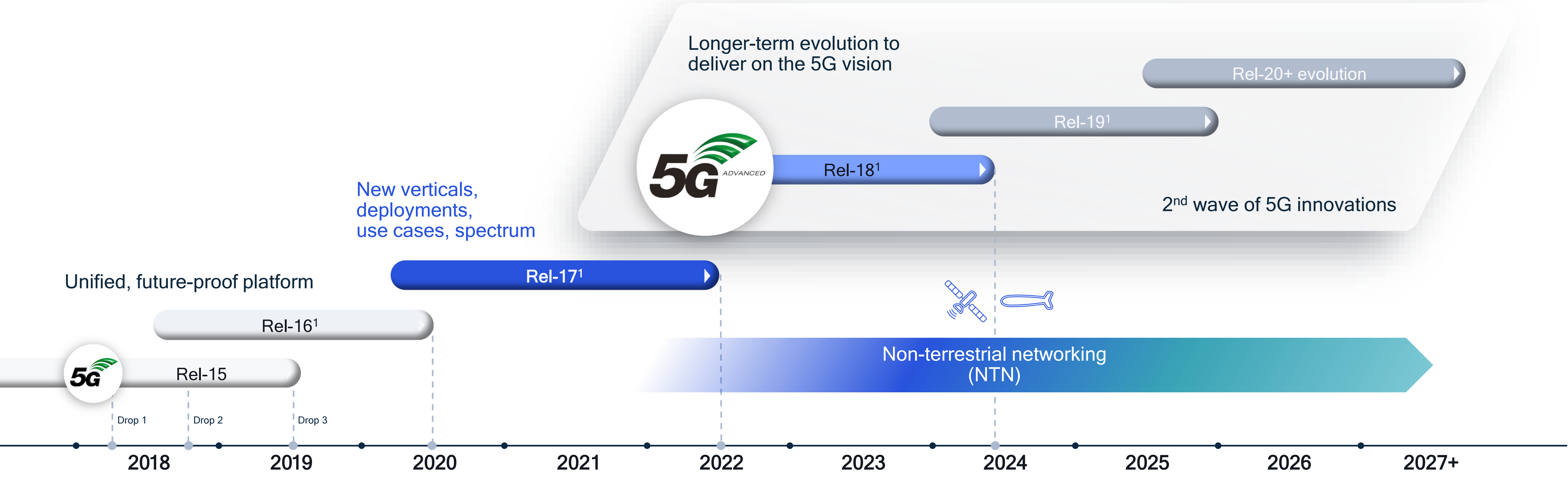
Regulatory bodies are considering the implications of D2D and working on regulatory efforts to foster a competitive and sustainable market

Note : D2D is also called as DC MSS IMT- Direct to Cellular MSS IMT

Satellite Direct-to-Device (D2D)

- Three Trends in Satellite Direct-to-Device
  - **Traditional Mobile Satellite Service (MSS):**
    - MSS involves dedicated spectrum and proprietary technology.
    - Example: Frequency range 1900 MHz is used in China. In other places, leveraging Globalstar's satellite network, etc.
  - **3GPP NTN technology:**
    - Upgrading existing satellite and network infrastructure.
    - Example: Omnispace 2GHz NTN
  - **Reuse of Terrestrial IMT Frequency and MNO Network (Satellite Direct-to-Cell):**
    - Modifications to the current ITU-R regulatory framework are necessary. Resolve potential interference and coordination procedures.
    - Examples: Space-X and T-Mobile using 1900 MHz spectrum.

3GPP Release 17 and 5G Advanced expand 5G for non-terrestrial networking



Rel-15 eMBB focus

- 5G NR foundation
- Sub-7 and mmWave
- Scalable & forward compatible
- Basic URLLC support
- mMTC via eMTC & NB-IoT

Rel-16 industry expansion

- Unlicensed spectrum (NR-U)
- Enhanced URLLC
- New functionalities: Sidelink (NR V2X), Positioning
- 5G broadcast
- eMTC/NB-IoT with 5G core
- Topology: IAB
- eMBB enh: MIMO, device power, CA/DC, mobility

Rel-17 continued expansion

- mmWave extended to 71GHz
- Lower complexity "NR-Light" (RedCap)
- Non-terrestrial communication: NR NTN and IoT NTN with satellites and HAPS[2]
- Improved IIoT, positioning, V2X
- Enhanced IAB, RF repeaters

Rel-18+ 5G-Advanced

- Next set of 5G releases (i.e., 18, 19, 20, …)
- Rel-18 scope decided in Dec '21
- Rel-18 study/work to start in Q2-2022
- **Enhancements for IoT-NTN and NR-NTN**

1. 3GPP start date indicates approval of study package (study item->work item->specifications), previous release continues beyond start of next release with functional freezes and ASN.1
2. HAPS: High altitude platform systems

5G NTN

IMT-2020-Sat candidate technologies

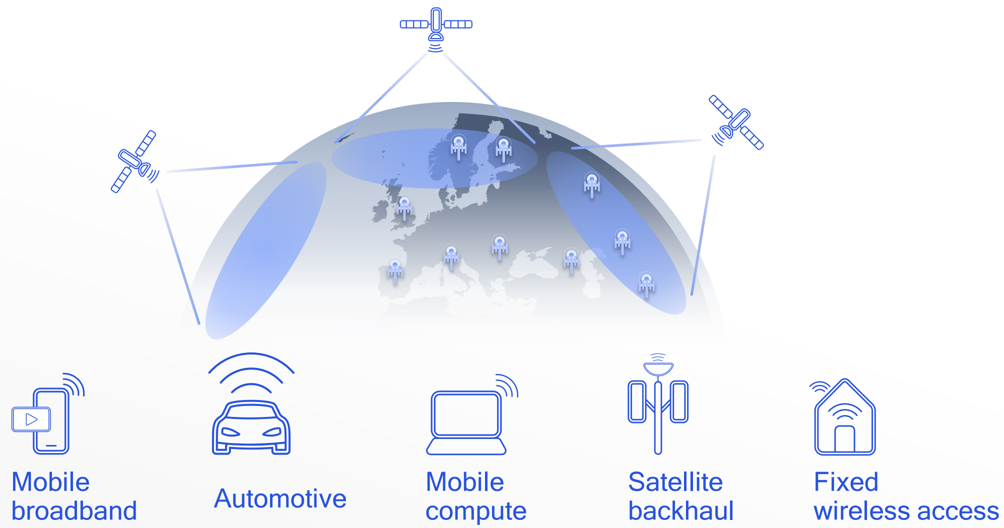
Support a broad range of use cases with 5G non-terrestrial networking

5G Advanced will further enhance the non-terrestrial networks (NTN) foundation

5G NR-NTN

Complementing terrestrial networks in underserved areas

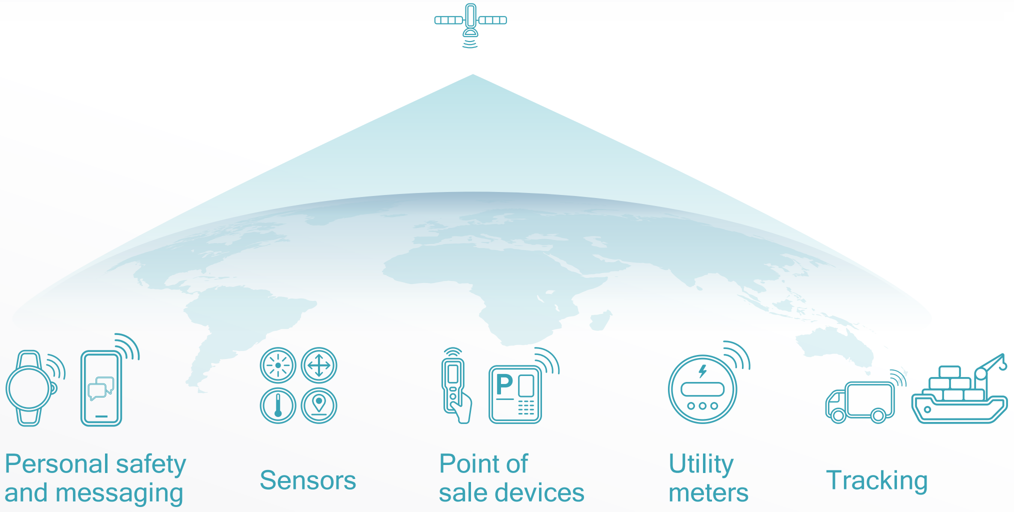
Rel-17+ NR-NTN
GEO / MEO / LEO



5G IoT-NTN

Expanding addressable market for the 5G massive IoT

Rel-17+ NB-IoT
GEO / MEO / LEO



Leveraging cellular for non-terrestrial communication

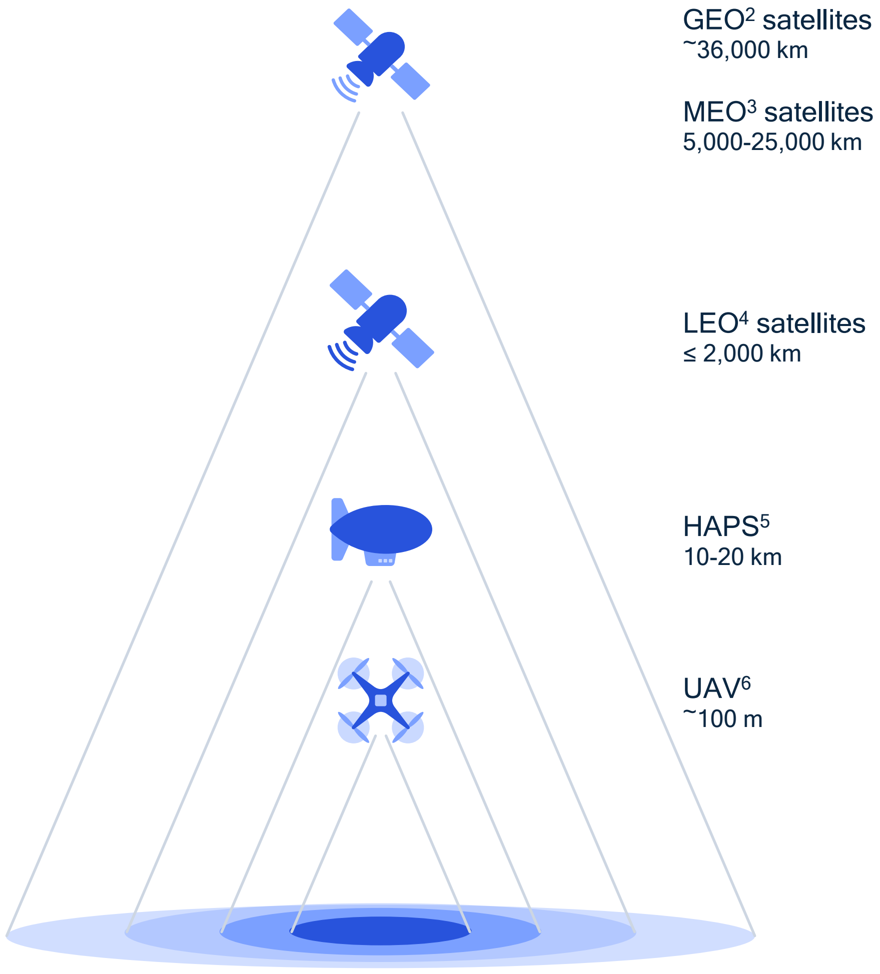
5G Rel-15
Study focused on deployment scenarios and channel models

5G Rel-16
Study focused on adapting 5G NR to support NTN

5G Rel-17
Projects focused on satellites for eMBB & IoT[1] and HAPS/UAV

5G Rel-18+
Further enhancements for UAV, HAPS, and satellites

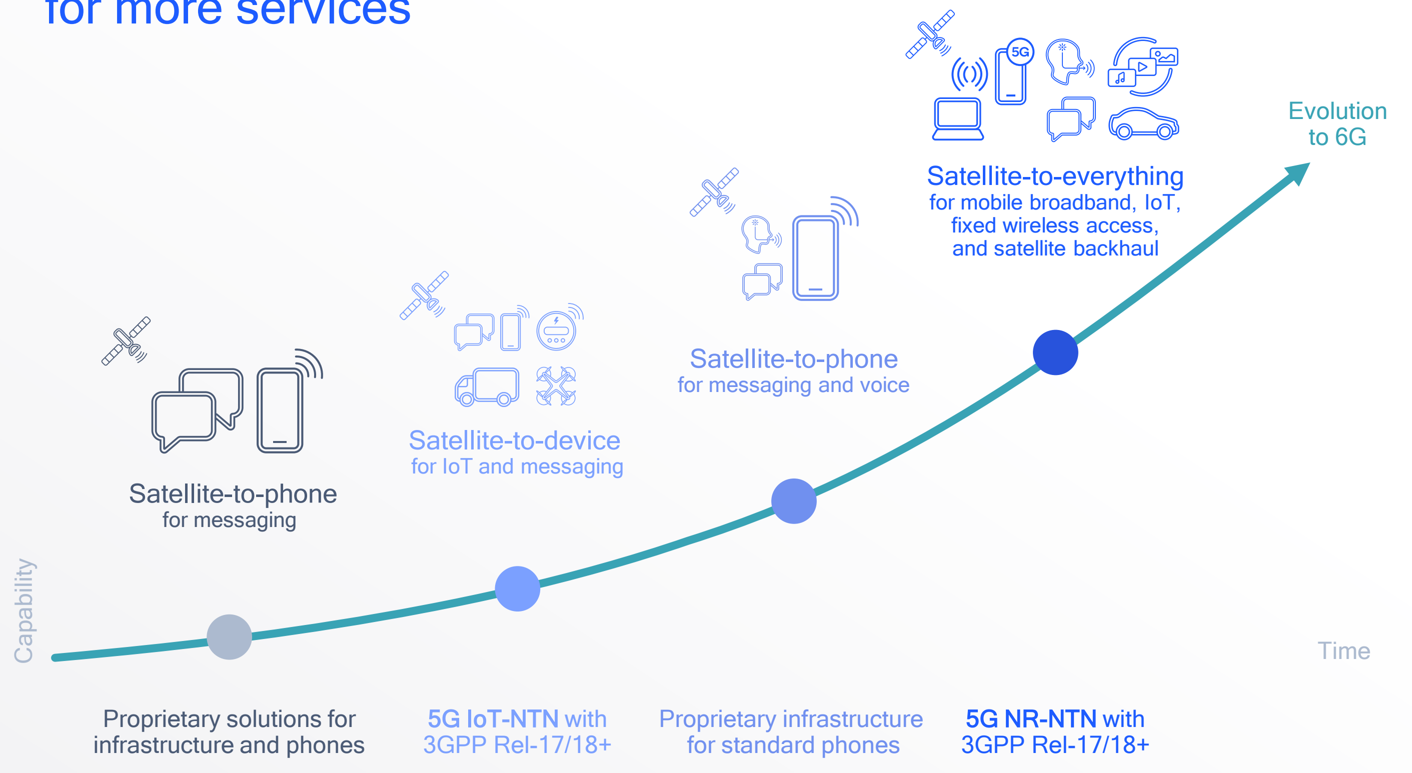
6G
Continued evolution of 5G NTN & NTN IOT into the 6G era, depending on ecosystem status at that time

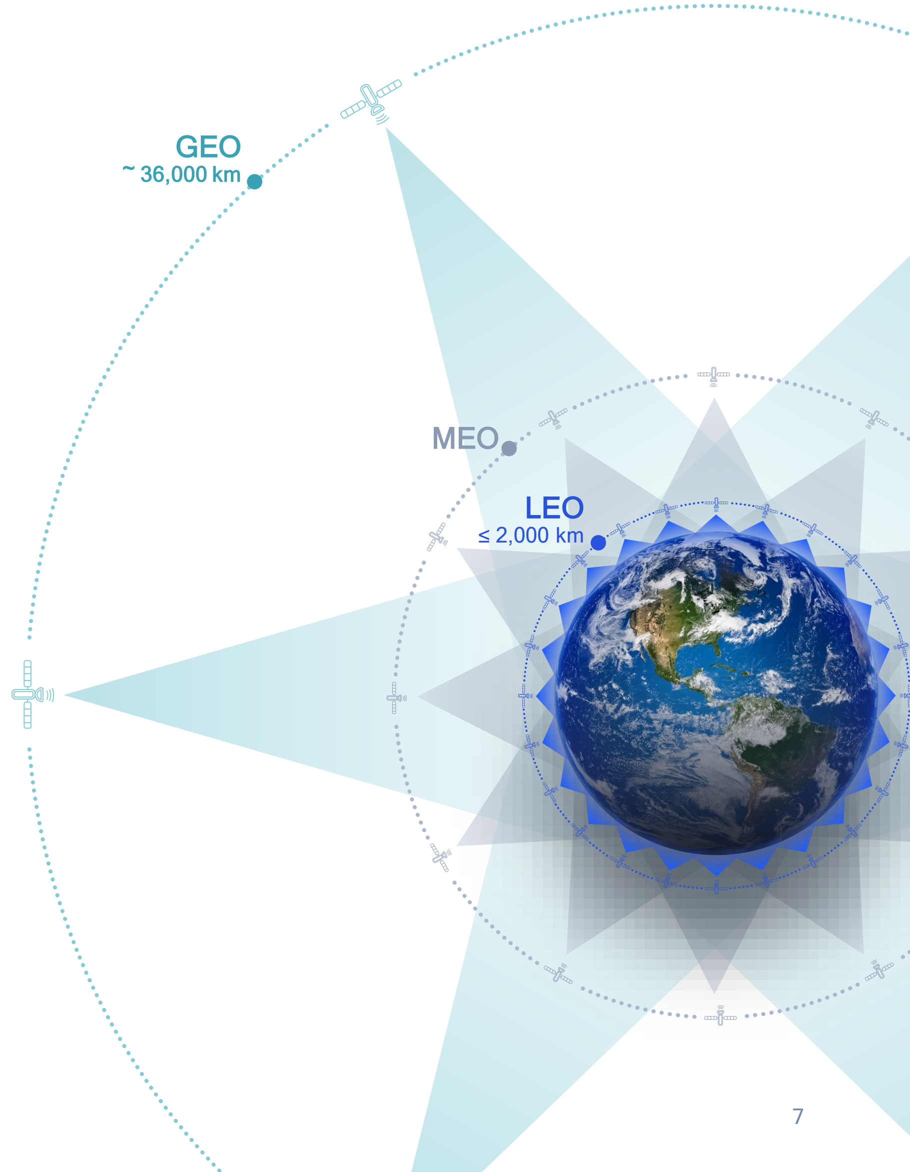


1 eMTC and NB-IoT; 2 Geostationary; 3 Medium Earth Orbit; 4 Low Earth Orbit;
5 Unmanned Aerial Vehicles; 6 High Altitude Platform Station;

5G NTN brings new efficiencies for a broad range of use cases

Provide ubiquitous connectivity for more services





5G NTN brings new efficiencies for a broad range of use cases

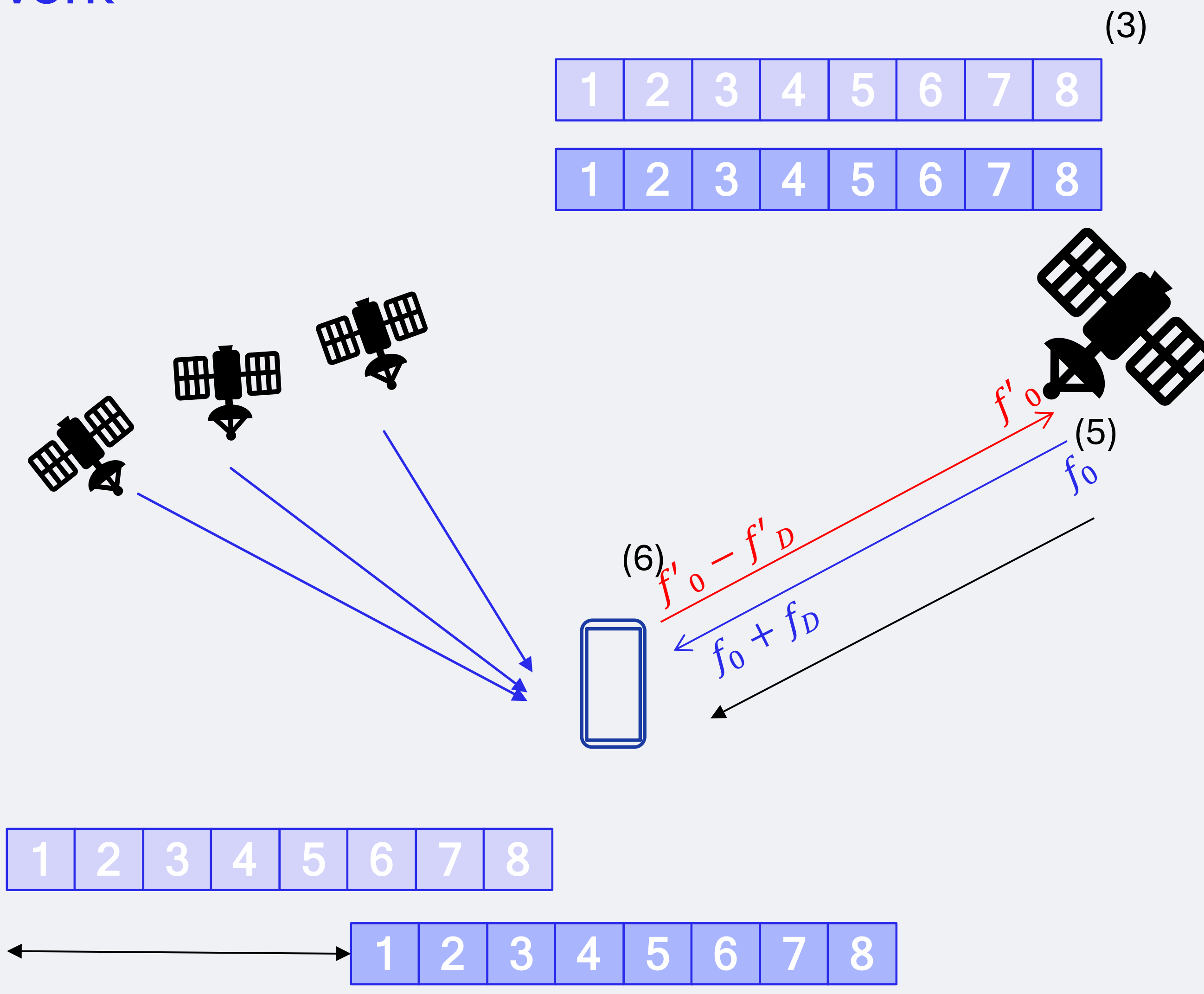
- Initial proprietary solutions for small data/messaging with mobile phones and satellite
- 3GPP standardized solution for IoT/NTN
- Legacy mobile phones connecting to Satellite for Voice and Data
  - Mobile phones tricked to believe that it is connected to terrestrial Base Station
  - To achieve this, additional compensation is applied to the frame structure and network signals
  - This is done to manage Doppler effect and timing errors
  - This leads to reduced capacity
  - Typical footprint is 50 Kms and the correction is applied to the centre of beam
- 5G NR-NTN mobile phone is aware of its connection to the satellite and is therefore able to manage connection

NR NTN: General introduction

- The first version of NR NTN was introduced in Rel-17, aiming at supporting satellite communication leveraging the NR standard.
  - One of the targets of NR NTN was to enable hardware reuse in handsets, i.e., the introduced features can be implemented with minimal incremental firmware / software development.
    - No new channels / waveforms / coding / etc.
  - The introduced features aim at addressing specific issues of a satellite system not present in terrestrial:
    - Large cells
    - Large RTT
    - Timing drift / Doppler
    - Deployment / cell planning (transparent vs regenerative, earth moving vs earth fixed cell)
- Although NR NTN has been initially defined targeting MSS bands, it can be deployed in any FDD spectrum.
  - Current band definition for NR NTN covers only MSS bands, any other bands can be added at any time (if desired).

NR NTN: General time-frequency framework

- 1) The UE knows its rough own location.
- 2) The UE knows that it is connecting to a satellite and knows the satellite ephemeris.
- 3) Timing and framing are aligned at the "uplink synchronization reference point"
  - For a regenerative architecture, this point will be at the satellite
- 4) UE pre-compensates delay / drift
- 5) There is no downlink drift / Doppler pre-compensation (transmission at nominal frequency f_0)
- 6) UE pre-compensates Doppler for its uplink transmissions.



Benefits of frequency pre-compensation in uplink

- Since there is no frequency control in NR TN, different UEs will be received with different Doppler at the satellite, causing loss of orthogonality.

- The impact of the loss of orthogonality depends on:
  - Maximum relative frequency error.
  - Operating SNR
  - Relative power imbalance between multiple users.
  - Allocation separation
  - Type of physical channel.

- With a maximum CFO error of +/-6.25kHz (maximum differential of 12.5kHz) performance is drastically reduced

Network signaling to inform UEs about its connection with Satellite

- The requirement for the network is to implement the following signaling:
  - Signal the cell as an NTN cell in System Information Block (SIB1)
  - Broadcast System Information Block (SIB19)

Overhead of satellite information (mandatory)

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

```
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
}

Orbital-r17 ::=             SEQUENCE {
    semiMajorAxis-r17           INTEGER (0..8589934591),
    eccentricity-r17            INTEGER (0..1048575),
    periapsis-r17               INTEGER (0..268435455),
    longitude-r17               INTEGER (0..268435455),
    inclination-r17             INTEGER (-67108864..67108863),
    meanAnomaly-r17             INTEGER (0..268435455)
}

PositionStateVector-r17 ::= INTEGER (-33554432..33554431)

VelocityStateVector-r17 ::= INTEGER (-131072..131071)

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

Overhead calculation

Field	Size
EpochTime-r17 ::= SEQUENCE { sfn-r17 INTEGER(0..1023), subFrameNR-r17 INTEGER(0..9) }	14 bits
ntn-UlSyncValidityDuration-r17 ENUMERATED{ s5, s10, s15, s20, s25, s30, s35, s40, s45, s50, s55, s60, s120, s180, s240, s900}	4 bits
cellSpecificKoffset-r17 INTEGER(1..1023) OPTIONAL	10 bits
Ephemeris with PVT	54 (velocity) + 78 bits (position) = 132 bits
Ephemeris with Keplerian	164 bits
Total (with Keplerian)	**192 bits**
Total (with PVT)	**160 bits**

Assuming a periodicity of 320ms the required data rate for this overhead is **500-600 bits/s** (+ some additional ASN.1 overhead)

(as a reference, PBCH requires an overhead of 400 bits/s, 32 bit payload every 80ms)

WRC-27 Mobile Satellite Service Agenda Items

- Triggered by the ubiquitous connectivity goal of UN sustainable development, there is growing demand for mobile satellite service.

WP 4C leads
WP 5D,4B and others contribute

WRC-27 AI1.12
MSS allocation for Low-data-rate NGSO mobile satellite system

Frequency bands:
1 427-1 432 MHz (s-to-E),
1 645.5-1 646.5 MHz (s-to-E) (E-to-s),
1 880-1 920 MHz (s-to-E) (E-to-s),
2 010-2 025 MHz (s-to-E) (E-to-s)

Potential Technology:
3GPP IoT NTN
Proprietary satellite access tech

WP 4C leads
WP 5D,4B and others contribute

WRC-27 AI1.13
MSS allocation in IMT bands for direct connectivity to complement the terrestrial IMT network coverage

Frequency bands:
the frequency bands between 694/698 MHz to 2700 MHz range with terrestrial IMT deployment in M.1036

Potential Technology:
3GPP LTE, 5G NR
3GPP LTE NTN, NR NTN

WP 4C leads
WP 5D,4B and others contribute

WRC-27 AI1.14
Additional allocation to mobile satellite system

Frequency bands:
2 010-2 025 MHz (E-to-s) in R1&R3
2 160-2 170 MHz (s-to-E) in R1&R3
2 120-2 160 MHz (s-to-E)

Potential Technology:
3GPP NR NTN
Proprietary satellite access tech

WRC-27 Agenda Item 1.13

Topic	Responsible group	Action to be taken by the group	Contributing group
1.13 to consider studies on possible new allocations to the mobile-satellite service for direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage, in accordance with Resolution **253 (WRC-23)**;			
Resolution **253 (WRC-23)** Studies on possible new allocations to the mobile-satellite service for direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage	**WP 4C***	*resolves to invite the ITU Radiocommunication Sector to complete in time for the 2027 world radiocommunication conference* 1 studies on possible allocations to the MSS in the frequency range between 694/698 MHz and 2.7 GHz, taking into account the IMT frequency arrangements addressed in the most recent version of Recommendation ITU-R M.1036; 2 studies on spectrum requirements and on technical, operational and regulatory matters related to the implementation of the mobile-satellite service for direct connectivity to the IMT user equipment to complement the terrestrial IMT network coverage, *further resolves* 1 to conduct studies on sharing and compatibility between incumbent services, including in adjacent frequency bands, ensuring the protection of incumbent services in accordance with the Radio Regulations; 2 to study possible technical and operational measures to ensure that the stations in the MSS do not cause harmful interference to, or claim protection from, stations operating in the mobile service, ... *invites the 2027 world radiocommunication conference* to consider, based on the results of studies, the appropriate regulatory actions, including possible new allocations to the MSS for direct connectivity between space stations and IMT user equipment to complement terrestrial IMT network coverage.	**WP 3L** **WP 3M** **WP 4A** **WP 4B** **WP 5A** **WP 5B** **WP 5C** **WP 5D*** **WP 6A** **WP 7B** **WP 7C** **WP 7D**

* **WP 4C will carry out the studies** on possible allocations to the MSS in the frequency bands between 694/698 MHz and 2.7 GHz provided by input contributions, **including those from WP 5D** based on the IMT frequency arrangements contained in the most recent version of Recommendation ITU-R M.1036.

WP 4C, in close collaboration with WP 5D, will conduct studies referred to in the resolves to invite the ITU Radiocommunication Sector to complete in time for the 2027 world radiocommunication conference 2.

WP 4C will carry out the studies requested in the further resolves 1 and 2. **WP 5D is expected to provide studies which include regulatory considerations** on the protection of terrestrial component of IMT.

WP 4C should take the lead in developing the draft CPM text by including the WP 5D's results on the regulatory considerations on the protection of terrestrial component of IMT. To facilitate the work, the Chairs of both WPs should coordinate the schedule of WPs meetings, as appropriate, and provide a note to both WPs in this regard.

WRC-27 Agenda Item 1.13

WRC-27 AI 1.13 to consider studies on possible new allocations to the mobile-satellite service for **DC-MSS-IMT** (direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment) to complement terrestrial IMT network coverage, in accordance with **Resolution 253 (WRC-23)**

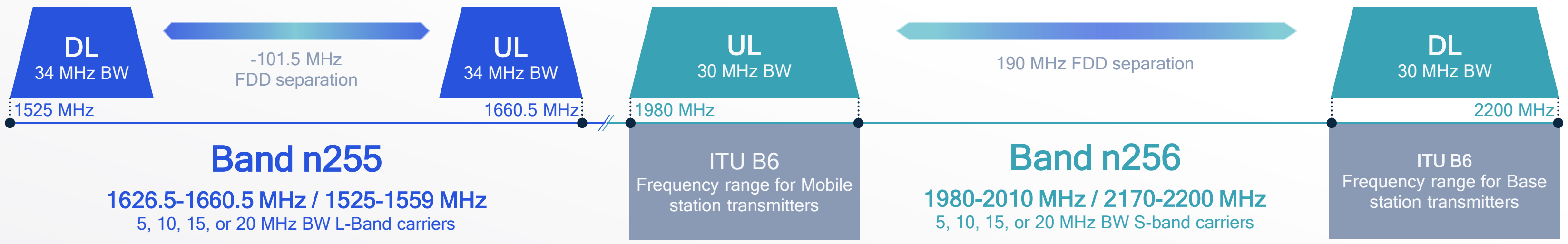
List of the IMT candidate frequency arrangements and associated frequency bands

Direction	
Uplink (MHz)	Downlink (MHz)
[814/824-849]	[859/869-894]
880-915	925-960
832-862	791-821
698-716 776-798	716-746 746-768
698-748	753-803
1 427-1 470	1 475-1 518
1 920-1 980	2 110-2 170
1 710-1 785	1 805-1 880
1 850-1 920	1 930-2 000
1 710-1 780	2 110-2 180
2 000-2 020	2 180-2 200
2 010-2 025	1 880-1 920
2 305-2 320	2 345-2 360
2 500-2 570	2 620-2 690

Leverage a global NTN ecosystem

with 3GPP standardized frequency bands

FR1 FDD frequency bands for 5G NTN in 3GPP Release 17



FDD frequency band candidates > 10 GHz for 5G NTN in 3GPP Release 18*

* Reference: R4-2220239 WF for above 10GHz band definition and system parameters_v8

Thank you

Nothing in these materials is an offer to sell any of the components or devices referenced herein.

© Qualcomm Technologies, Inc. and/or its affiliated companies. All Rights Reserved.

Qualcomm and Snapdragon are trademarks or registered trademarks of Qualcomm Incorporated.
Other products and brand names may be trademarks or registered trademarks of their respective owners.

References in this presentation to “Qualcomm” may mean Qualcomm Incorporated, Qualcomm Technologies, Inc., and/or other subsidiaries or business units within the Qualcomm corporate structure, as applicable. Qualcomm Incorporated includes our licensing business, QTL, and the vast majority of our patent portfolio. Qualcomm Technologies, Inc., a subsidiary of Qualcomm Incorporated, operates, along with its subsidiaries, substantially all of our engineering, research and development functions, and substantially all of our products and services businesses, including our QCT semiconductor business.

Snapdragon and Qualcomm branded products are products of Qualcomm Technologies, Inc. and/or its subsidiaries.
Qualcomm patented technologies are licensed by Qualcomm Incorporated.

Follow us on:

For more information, visit us at qualcomm.com & qualcomm.com/blog