

Device Technology Development Team
January 2023

The T-Mobile logo is displayed in white on a dark rectangular background. The background of the entire slide is a vibrant magenta with a complex network of glowing white and pink lines and dots, suggesting a global or digital network.

T-Mobile®

Network Technology Roadmap for Devices

Notice of Confidentiality

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T-Mobile Device Requirements

- This deck does not supersede the T-Mobile Master Terminal Requirements (MTR).
- The T-Mobile Master Terminal Requirements (MTR) is the authoritative source for Device Requirements for any devices to be validated by T-Mobile and used on T-Mobile's network.
- The latest Master Terminal Requirements package of documents can be found at <https://dice.t-mobile.com/tmo/projects/dice/wiki/51> .

Contents



- **T-Mobile Business and Network Update**
 - Device Technology Requirements and Roadmap
 - Spectrum and Frequency Bands
 - 5G Device Requirements and Roadmap
 - Fixed Wireless Access ***NEW SECTION***
 - Internet of Things
 - Regulatory and Location Technology
 - Device and IMS Services
 - Additional Material

MISSION

BEST IN THE WORLD AT CONNECTING CUSTOMERS TO THEIR WORLD

STRATEGIC PILLARS

PRODUCT LEADERSHIP

Build the World's
Best 5G Network

VALUE LEADERSHIP

Unlock the Value
Potential of
Synergies & Scale

EXPERIENCE LEADERSHIP

Deliver the Best
Experience from the
Best Team

VISION

#1 IN CUSTOMER CHOICE
IN CUSTOMERS' HEARTS

T Mobile

5G Network Delivers Differentiated Customer Experience and Drives Overall Network Leadership

T Mobile
5G Geographic Coverage



Sites
Combined LTE + 5G

79K
Macro Cell Sites

38K
Small cell/distributed
antenna systems sites

**Delivering more 5G geographic coverage than
Verizon and AT&T combined**

**EXTENDED
RANGE 5G**

97% of Americans

Mid-band and Millimeter Wave

**ULTRA
CAPACITY 5G**

250M POPs

The Most Awarded 5G Network

OOKLA

Fastest Overall Provider

OPENSIGNAL

Best 5G Availability

umlaut

Most Reliable 5G Network

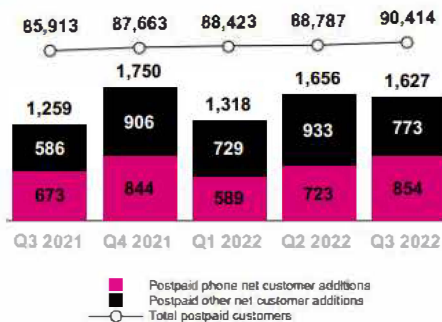
Q3'2022 Quarterly Results



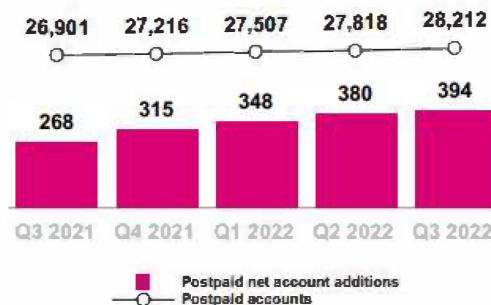
"We've always said our aspiration was to be the first and only provider to offer customers both the best network and the best value without having to sacrifice one for the other — and based on another set of standout customer and financial results for Q3, it's clear we're delivering on that promise. On the heels of our highest ever postpaid account net additions and industry-leading postpaid and broadband customer growth, we are raising guidance for the third time this year. Our Un-carrier playbook continues to win in this ever-changing competitive and macro-economic climate and our momentum is only getting stronger."

Mike Sievert, CEO

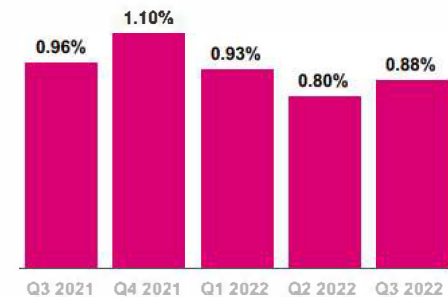
Postpaid Customers
(in thousands)



Postpaid Accounts
(in thousands)



Postpaid Phone Churn



T-Mobile Delivers Industry-Leading Customer and Cash Flow Growth in Q3 2022 and Raises 2022 Guidance for the Third Consecutive Quarter

POSTPAID
NET ACCOUNT ADDITIONS
394K

INDUSTRY LEADING
HIGHEST IN COMPANY HISTORY

POSTPAID
NET CUSTOMER ADDITIONS
1.6M

MORE THAN AT&T AND
VERIZON COMBINED

POSTPAID PHONE
NET CUSTOMER ADDITIONS
854K

INDUSTRY LEADING
HIGHEST SINCE MERGER

SERVICE REVENUES
\$15.4B

GREW 4% YoY
INCLUDING INDUSTRY LEADING POSTPAID
SERVICE REVENUE GROWTH OF 7%

NET INCOME
\$508M

Decreased YoY due to
MERGER-RELATED COSTS
AND LOSS ON ANTICIPATED SALE OF
WIRELINE BUSINESS

CORE ADJUSTED EBITDA
\$6.7B

GREW 11% YoY
INDUSTRY LEADING GROWTH

NET CASH
PROVIDED BY OPERATING ACTIVITIES

\$4.4B

GREW 26% YoY
INDUSTRY LEADING GROWTH

FREE CASH FLOW

\$2.1B

GREW 32% YoY
INDUSTRY LEADING GROWTH

HIGH SPEED INTERNET
NET CUSTOMER ADDITIONS

578K

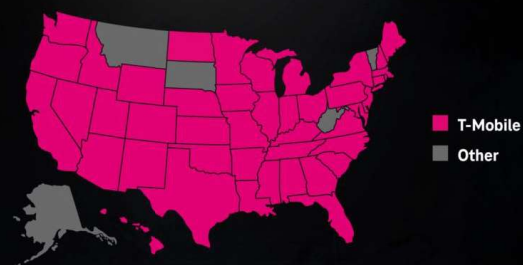
INDUSTRY LEADING
FOURTH CONSECUTIVE QUARTER

T-Mobile Kicks Off 2023 as the Nationwide Network Leader

January 17, 2023

Fastest Provider by State

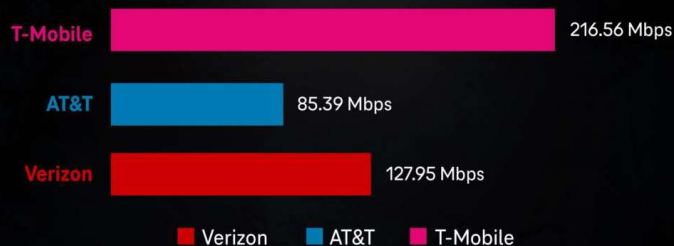
Ookla® Speedtest Intelligence® Q4 2022



Based on analysis by Ookla® of Speedtest Intelligence® data of median download speeds as reported for Q4 2022.
Ookla trademarks used under license and reprinted with permission.

5G Performance

Ookla® Speedtest Intelligence® Q4 2022

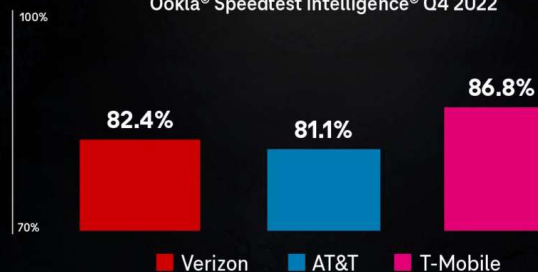


Based on analysis by Ookla® of Speedtest Intelligence® data of median download speeds as reported for Q4 2022.
Ookla trademarks used under license and reprinted with permission.

- T-Mobile's network proved fastest in 45 states and the District of Columbia as well as in 86 of the 100 most populous U.S. cities.
- T-Mobile's overall network performance swept the competition and placed first in all categories:
 - Fastest mobile operator in the U.S. with median download speeds more than 2x faster than Verizon and AT&T at 151.37 Mbps and median upload speeds recorded at 12.52 Mbps.
 - Lowest multi-server latency, meaning faster response times for gamers, improved IoT solutions for businesses and more.
 - Most consistent network, meaning customers have faster speeds more consistently than Verizon and AT&T users.
 - Best place to stream video with the highest video score ranking.

Consistency

Ookla® Speedtest Intelligence® Q4 2022



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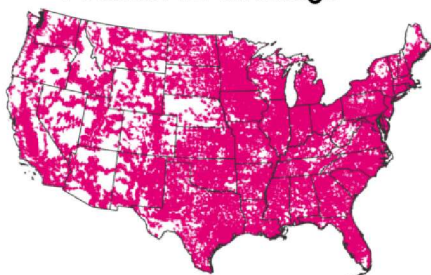
<https://www.t-mobile.com/news/network/t-mobile-kicks-off-2023-as-network-leader>

T-Mobile Expands Leading 5G Network with Additional Coverage and Capacity

December 12, 2022

COMPARING 5G COVERAGE

T-Mobile 5G Coverage



Verizon 5G Coverage



5G device required. Extended Range 5G includes dedicated low-band 5G signals & Ultra Capacity 5G includes dedicated mid- and/or high-band 5G signals. For details, see [T-Mobile.com/coverage](https://www.t-mobile.com/coverage)

- T-Mobile achieves year-end goal of covering **260 million** POPs with Ultra Capacity 5G
- T-Mobile Extended Range 5G has also expanded to cover **323 million** POPs
- 1900 MHz mid-band spectrum (n25) has been deployed nationwide

T-Mobile Lights Up Standalone Ultra Capacity 5G Nationwide

November 14, 2022

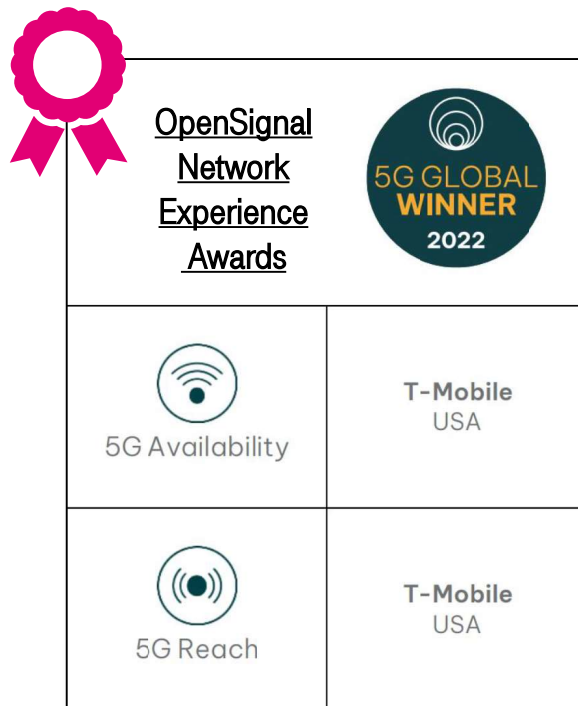


<https://www.t-mobile.com/news/network/t-mobile-lights-up-standalone-ultra-capacity-5g-nationwide>

- T-Mobile enables 5G Standalone (SA) on mid-band Ultra Capacity network nationwide, using the n41 band
- T-Mobile's Ultra Capacity network covers 250 million people nationwide
- Deploying 5G SA on n41 will allow for more 5G carrier aggregation combinations, increasing network speed and capacity

T-Mobile Rules the World for 5G Availability and 5G Reach

September 20, 2022



- OpenSignal's 5G Global Mobile Network Experience Awards names T-Mobile US best in the world for 5G Availability and 5G Reach
- T-Mobile is the only U.S. operator to earn top honors in this report
- This report further cements T-Mobile's status as the most-awarded 5G network in the nation

<https://www.t-mobile.com/news/network/t-mobile-rules-the-world-for-5g-availability-and-reach>

T-Mobile to Accelerate Winning 5G Strategy After Auction 108

September 16, 2022

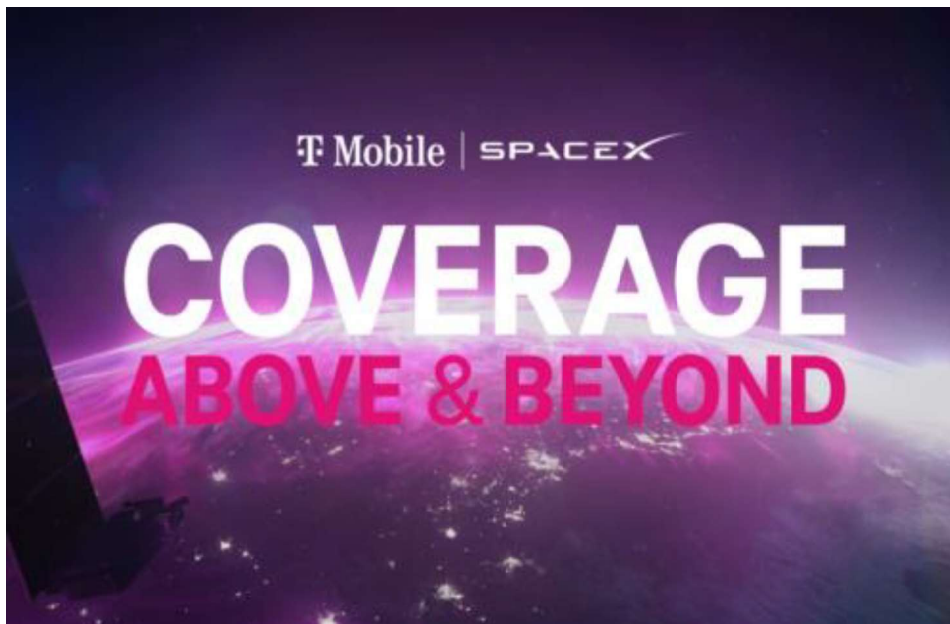


- T-Mobile won more than 7,000 2.5 GHz licenses in areas covering 81 million POPs
- Following Auction 108, T-Mobile can now expand Ultra Capacity 5G and deliver even greater performance and connectivity to those in underserved areas, for customers of both its mobile and broadband Internet services, bringing much needed choice and competition to millions more Americans.
- Following licensing, the Un-carrier will immediately begin deploying the new spectrum for 5G, boosting performance for customers across the country, especially in underserved markets.

<https://www.t-mobile.com/news/network/t-mobile-to-accelerate-winning-5g-strategy-after-auction-108>

T-Mobile Takes Coverage Above and Beyond With SpaceX

August 25, 2022



<https://www.t-mobile.com/news/un-carrier/t-mobile-takes-coverage-above-and-beyond-with-spacex>

- New service aims to connect vast majority of smartphones already on T-Mobile's network to Starlink satellites
- Pairing SpaceX's breakthrough satellite constellation with T-Mobile's industry-leading wireless network
- SpaceX and T-Mobile share a vision for universal coverage, where uncovered zones no longer exist

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TECHNOLOGIES

Spectrum & Bands



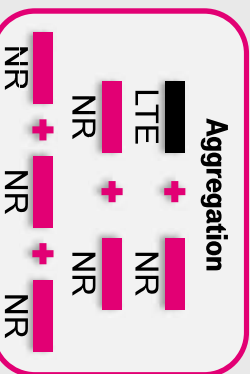
5G Enhancements

Battery
Saving
Features

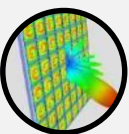
5G
Release 16
Features

Spectral
Efficiency
Features

Speed & Capacity



Massive MIMO



Voice & Services

EPS Fallback



VONR

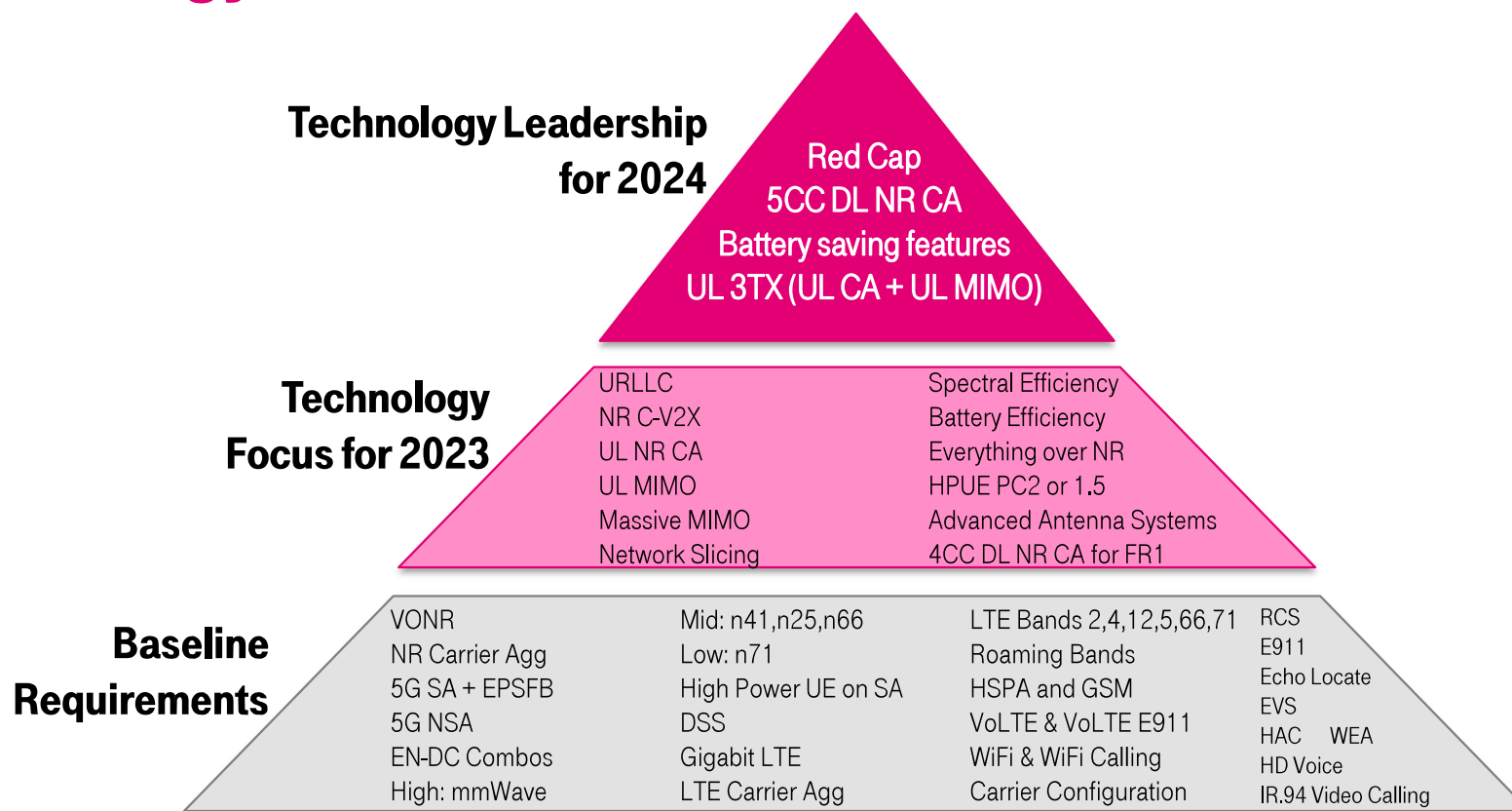


EONR

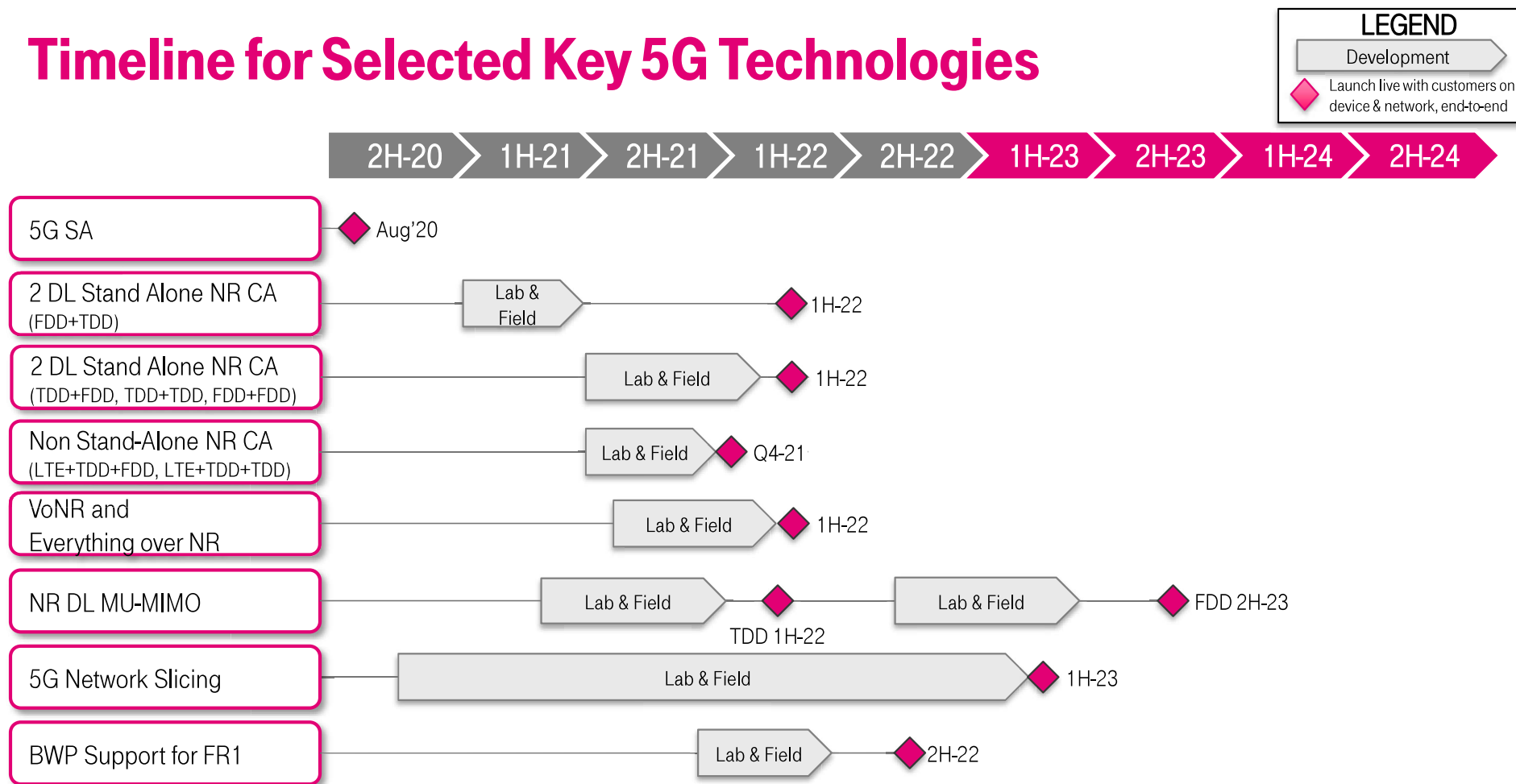
All Services
over NR
Regulatory
Features

Network
Slicing
Features

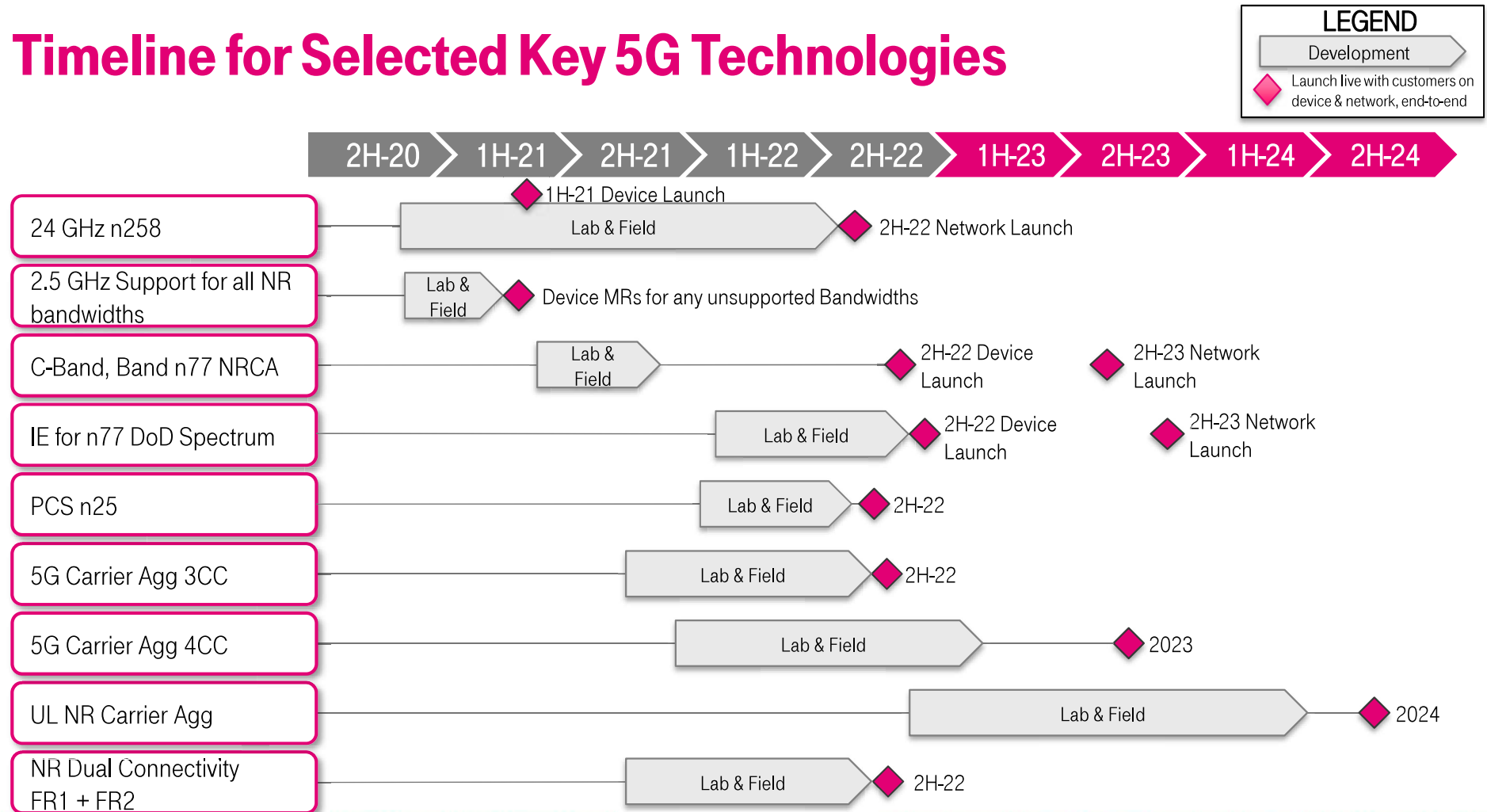
Technology Priorities



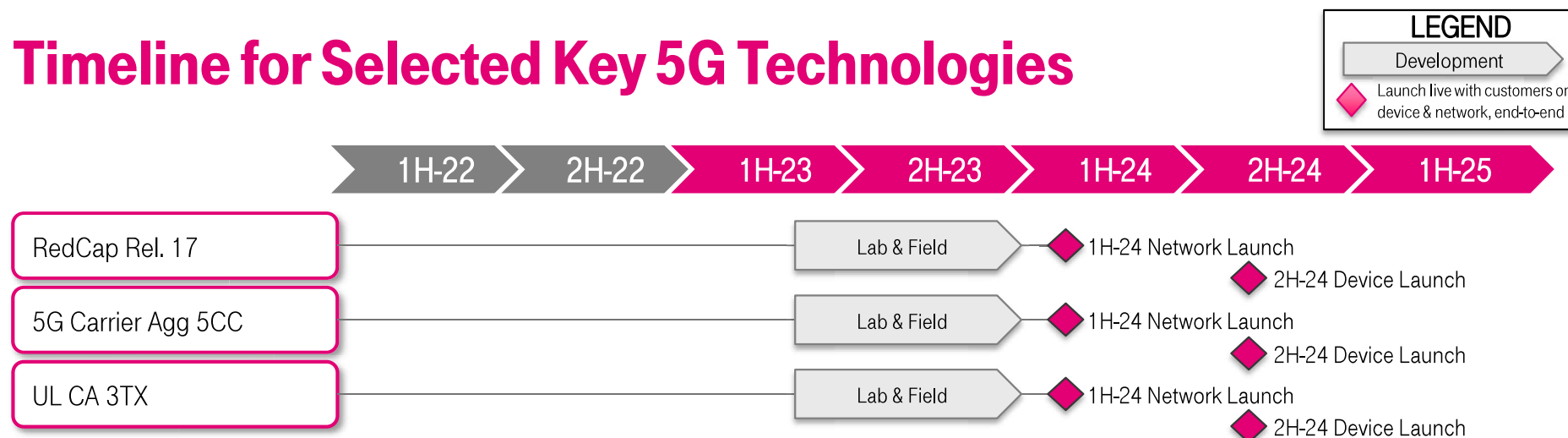
Timeline for Selected Key 5G Technologies



Timeline for Selected Key 5G Technologies



Timeline for Selected Key 5G Technologies



5G Device Requirements by Tiers

LEGEND

Required at
Launch

Required to add
via MR

Recommended

	1H-2022			2H-2022			1H-2023			2H-2023			1H-2024			2H-2024		
Feature	High	Mid	Low	High	Mid	Low	High	Mid	Low	High	Mid	Low	High	Mid	Low	High	Mid	Low
5G NR (n71 600 MHz)																		
5G NR (mmW n260, n261)																		
5G NR (mmW n258 24 GHz)																		
5G NR (n25, n66, n41)																		
5G NR (C-Band n77 SA with NR CA)																		
LTE+5G Aggregation (EN-DC)																		
Dynamic Spectrum Sharing on NSA																		
SA with EPS Fall back																		
SA with VoNR, Everything over NR																		
Dynamic Spectrum Sharing on SA																		
2 DL NR Carrier Agg on SA and NSA																		
HPUE for 2.5 GHz SA																		
Network Slicing																		
Advanced Antenna Systems																		
3 DL NR Carrier Agg for SA																		
4 DL NR Carrier Agg for SA																		
5 DL NR Carrier Agg for SA																		
Uplink NR CA																		

Key 5G Features Requirements Roadmap (Radio)

Bold = New for that time period
Blue = Required for certain tiers

2H-2022

1H-2023

2H-2023

1H-2024

Spectrum & Bands

- Sub 6 n71, n41, n25, n66, SA n48, SA n77
- mmW n260, n261, n258 (NSA)
- EN-DC with 5 LTE + 1 NR, 5 LTE + 2 NR
- 2 DL NR Carrier Aggregation for SA
- 3,4 DL NR Carrier Aggregation for SA
- UL NR Carrier Aggregation
- NR Dual Connectivity Sub6 + mmW
- NR Bandwidth Parts (FDD and TDD)
- BCS4 (Bandwidth Combination Set) Support

Architecture

- Non-Stand Alone, Option 3x
- Stand Alone with EPSFB, ES-FB
- HPUE for SA n41 (Power Class 2 and Power Class 1.5)
- 5G UL 256QAM FR1
- CP-OFDM/DFT-S Switching for FR1
- NR Closed Loop Power Control
- $\pi/2$ BPSK support with DFT-S-OFDM support in UE uplink
- Stand Alone with VoNR

Mobility

- LTE Mobility for EN-DC capable UE with NR Leg release
- NR Intra/Inter-Freq Intra gNB Handover
- ESFB using PS HO
- Cell Sub-Priority Selection SIB
- UL PUSCH and DMRS MIX
- ANR for SA iRAT LTE
- Periodic A4 based mobility

Spectrum & Bands

- Sub 6 n71, n41, n25, n66, SA n48, SA n77
- mmW n260, n261, n258 (NSA), **n262 (HW)**
- EN-DC with 5 LTE + 1 NR, 5 LTE + 2 NR
- 2 DL NR Carrier Aggregation for SA
- 3,4 DL NR Carrier Aggregation for SA
- UL NR Carrier Aggregation
- NR DC Sub6 + mmW
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Key 5G Features Requirements Roadmap (Radio, continued)

Bold = New for that time period
Blue = Required for certain tiers

2H-2022

VoNR

- Support for 5QI1 and 5QI2 GBR for voice
- RRC Reestablishment w Voice Bearers
- Minimum 4DRBs per session (ims: 5QI1,2,5 and 6)
- VoNR/ESPFB UE capability differentiation
- IRAT w PSHO with Voice Services
- Emergency RRC indication support (Emergency Cause)
- SIB broadcast emergency service support
- 5G QoS Aware Scheduler

Advanced Antenna Systems

- 4,8,16 and 32 port CSI-RS support for FDD and TDD
- 2Layer UL SU MIMO for n41 and n77
- Type1-Single Panel CSI feedback with PMI report
- SRS Antenna switching
- RRC configured PDSCH DMRS scrambling ID (MU MIMO)

Slicing

- Standard and non – standard NSSAIs
- 8 simultaneous network slices and QoS mapping
- Slice aware CN Instance selection – Traffic and route URSP descriptors
- Slice aware Inter frequency HO

1H-2023

VoNR

- Support for 5QI1 and 5QI2 GBR for voice
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- **VoNR RoHC (UDP/RTP)**

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2H-2022

Regulatory & Location

- E911: **LPP-based AGPS, LPPe**, ECID, CID
AGNSS "UE-B preferred mode" on 5G
- SUPL 2.0, IPv6, **HAC**
- **Real Time Text (RTT)**
- **WEA 3.0**
- **STIR & SHAKEN**
- **E911 Z-Axis**
- **Text to 911 with High Accuracy Location**
- **AGPS L5 for E911**
- Barometer
- Civic address

VoNR Services Layer

- EoNR to EoLTE mobility
- E2E 5QI-1/2/5/6
- VoWiFi and VoNR Handover
- BYE with Reason-text
- Disable VoNR via Carrier Config
- T-Mobile SIP Timer B1
- VoPS Call All TCP
- STIR/SHAKEN SIP Feature Tag
- RTToNR always-on

VoNR 911

- Emergency over NR
- Limited Service over NR
- Emergency Domain Selection
- PSAP Callback
- LRBT

1H-2023

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- PSAP Callback
- LRBT
- **Integrity Protection of User Plane Traffic**

Key LTE Features Requirements — 2024 and beyond

Applicable to T-Mobile Network.

Mandatory features for all devices

Spectrum & Bands

- LTE Cat 6
- 4x2 MIMO
- LTE Bands 2, 4, 5, 12, 25, 26, 41, 48, 66, 71
- GSM, GPRS and EDGE
- HSPA 21 DL, 5.76 UL Mbps
- HPUE Power Class 2 (26dBm for Band 41)
- 2 DL Carrier Aggregation (CA)
- TM 3 and 4 for FDD bands, TM8 for TDD Band 41

Regulatory

- E911 (AGPS) (on CS and VoLTE)
- SUPL 2.0, IPv6, WEA, HAC
- Real Time Text (RTT)
- Wi-Fi Crowdsourcing for E911, DBH
- Wireless Priority Services
- WEA 3.0
- STIR & SHAKEN
- Uncompensated Barometric Pressure (UBP)

Services

- VoLTE, SRVCC
- Enhanced Voice Services
- WFC 2.0, RCSUP2.x, IR.94
- VoLTE Roaming, VoLTE Prioritization
- 3-timer VoLTE E911 design
- Carrier Configuration
- Remote SIM Unlock
- WFC Cellular Preferred Design

Tier- and Cost-dependent features

Spectrum & Bands

- LTE FDD Roaming Bands 1, 3, 5, 7, 13, 20, 8, 28
- LTE Roaming TDD Bands 38, 40, 39
- LTE Band 66 (AWS3) with 2/3 DL CA
- LTE Band 71 600 MHz with 2 and 3 DL CA
- LTE Band 41 with DL 2 CA
- LTE Band 41 with UL 2 CA
- LTE 3.5 GHz- Band 48 with 2 and 3 DL CA
- LAA Band 46
- HPUE, Power Class 2 (26dBm for Band 41)

Speed & Capacity

- LTE Cat 6, 9, 11, 16, 18, 19, 20
- DL 2xCA, DL 3xCA, DL 4xCA, UL 2xCA
- Uplink Carrier Aggregation && UL 64 QAM
- Gigabit Class LTE (4x4, CA, 256 QAM)
- 1.6 Gbps Configuration :
 - 4CA with 4x4 MIMO (4/4) && 256 QAM
- 2.0 Gbps Configuration
 - 5CA with CBRS and 4x4 MIMO (5/5)

Non-Stock Key Features Requirements Roadmap – By Device Tier

Applicable to T-Mobile Network.

2023

LTE Spectrum and Features from 2H-2023

Spectrum & Bands

- LTE FDD Roaming Bands 1, 3, 5, 7, 13, 20, 8, 28
- LTE Roaming TDD Bands 38, 40, 39
- LTE Band 66 (AWS3) with 2/3 DL CA
- LTE Band 71 600 MHz with 2 and 3 DL CA
- LTE Band 41 with 2 and 3 DL CA
- LTE Band 41 with Uplink CA
- LTE 3.5 GHz- Band 48 with 2 and 3 DL CA
- LAA Band 46
- HPUE, Power Class 2 (26dBm for Band 41)
- 5G NR NSA

Speed & Capacity

- LTE Cat 6, 9, 11, 16, 18, 19, 20
- DL 2xCA, DL 3xCA, DL 4xCA, UL 2xCA
- Uplink Carrier Aggregation && UL 64 QAM
- Gigabit Class LTE (4x4, CA, 256 QAM)
- 1.6 Gbps Configuration :
 - 4CA with 4x4 MIMO (4/4) && 256 QAM
- 2.0 Gbps Configuration
 - 5CA with CBRS and 4x4 MIMO (5/5)

LTE-Advanced

- FD-MIMO 16 TX DMRS
- UE Based CRS-IC

5G NR

- Spectrum Bands: n71, n41, n25, n66, mmW
- Non-Stand Alone
- EN-DC Aggregation
- Dynamic Spectrum Sharing
- HPUE Power Class 2 (Hardware and SW)
- DL MIMO 16, 32-port CSI-RS
- Stand Alone with EPS-FB
- VoNR
- NR Carrier Agg
- 2Layer UL MIMO

2024

Spectrum & Bands

- LTE FDD Roaming Bands 1, 3, 5, 7, 13, 20, 8, 28
- LTE Roaming TDD Bands 38, 40, 39
- LTE Band 66 (AWS3) with 2/3 DL CA
- LTE Band 71 600 MHz with 2 and 3 DL CA
- LTE Band 41 with 2 and 3 DL CA
- LTE Band 41 with Uplink CA
- LTE 3.5 GHz- Band 48 with 2 and 3 DL CA
- LAA Band 46
- HPUE, Power Class 2 (26dBm for Band 41)
- 5G NR NSA

Speed & Capacity

- LTE Cat 6, 9, 11, 16, 18, 19, 20
- DL 2xCA, DL 3xCA, DL 4xCA, UL 2xCA
- Uplink Carrier Aggregation && UL 64 QAM
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 - 4CA with 4x4 MIMO (4/4) && 256 QAM
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 - 5CA with CBRS and 4x4 MIMO (5/5)

LTE-Advanced

- FD-MIMO 16 TX DMRS
- UE Based CRS-IC

5G NR

- Spectrum Bands: n71, n41, n25, n66, mmW, n77
- Non-Stand Alone
- EN-DC Aggregation
- Dynamic Spectrum Sharing
- HPUE Power Class 2 (Hardware and SW)
- DL MIMO 16, 32-port CSI-RS
- Stand Alone with EPS-FB
- VoNR
- NR Carrier Agg
- 2Layer UL MIMO
- SRS Antenna Switching for NSA and SA
- 5G UC Icon for TDD n41

Color Legend	
Mandatory Must Have	Optional Depends on needs of product/business Additional features that can provide better customer experience. Partners can propose support of these features. T-Mobile can provide recommendations. Additional Testing may be required.
Recommended Good to have, but can be waived	
Bold/Blue/Bold New Requirement	

These additional requirements apply to devices depending on Cost Tier

Non-Stock Key Features Requirements Roadmap – Mandatory for all LTE Devices

Applicable to T-Mobile Network.

2H-2023

2024

LTE Features

- LTE Cat 6
- 4x2 MIMO
- VoLTE & SRVCC, VoLTE E911
- LTE Bands 2, 4, 12, 5, 66, 71, 41
- HPUE, Power Class 2 (26 dBm for Band 41)
- TM3, TM8 for Band 41
- Transmission Mode 9 for FDD
- 2 DL Carrier Aggregation

- LTE Cat 6
- 4x2 MIMO
- VoLTE & SRVCC, VoLTE E911
- LTE Bands 2, 4, 12, 5, 66, 71, 41
- HPUE, Power Class 2 (26 dBm for Band 41)

- TM3, TM8 for Band 41
- Transmission Mode 9 for FDD
- 2 DL Carrier Aggregation

Services & VoLTE

- Enhanced Voice Services
- WFC 2.0, RCSUP2.x, IR.94
- VoLTE Roaming
- VoLTE Prioritization
- 3-timer VoLTE E911 design
- Carrier Configuration for RCS and 5G
- Remote SIM Unlock
- WFC Cellular Preferred Design

- Enhanced Voice Services
- WFC 2.0, RCSUP2.x, IR.94
- VoLTE Roaming
- VoLTE Prioritization
- 3-timer VoLTE E911 design
- Carrier Configuration for RCS and 5G
- Remote SIM Unlock
- WFC Cellular Preferred Design

3G/2G

- HSPA 21 DL, 5.76 UL Mbps Bands 2,4,5
- GSM, GPRS & EDGE

- HSPA 21 DL, 5.76 UL Mbps Bands 2,4,5
- GSM, GPRS & EDGE

Regulatory

- E911: AGPS, DBH
- SUPL 2.0, IPv6, WEA, HAC
- Real Time Text (RTT)
- Wireless Priority Services
- WEA 3.0
- STIR & SHAKEN
- UBP

- E911: AGPS, DBH
- SUPL 2.0, IPv6, WEA, HAC
- Real Time Text (RTT)
- Wireless Priority Services
- WEA 3.0
- STIR & SHAKEN
- UBP

LEGEND

Mandatory
Must Have

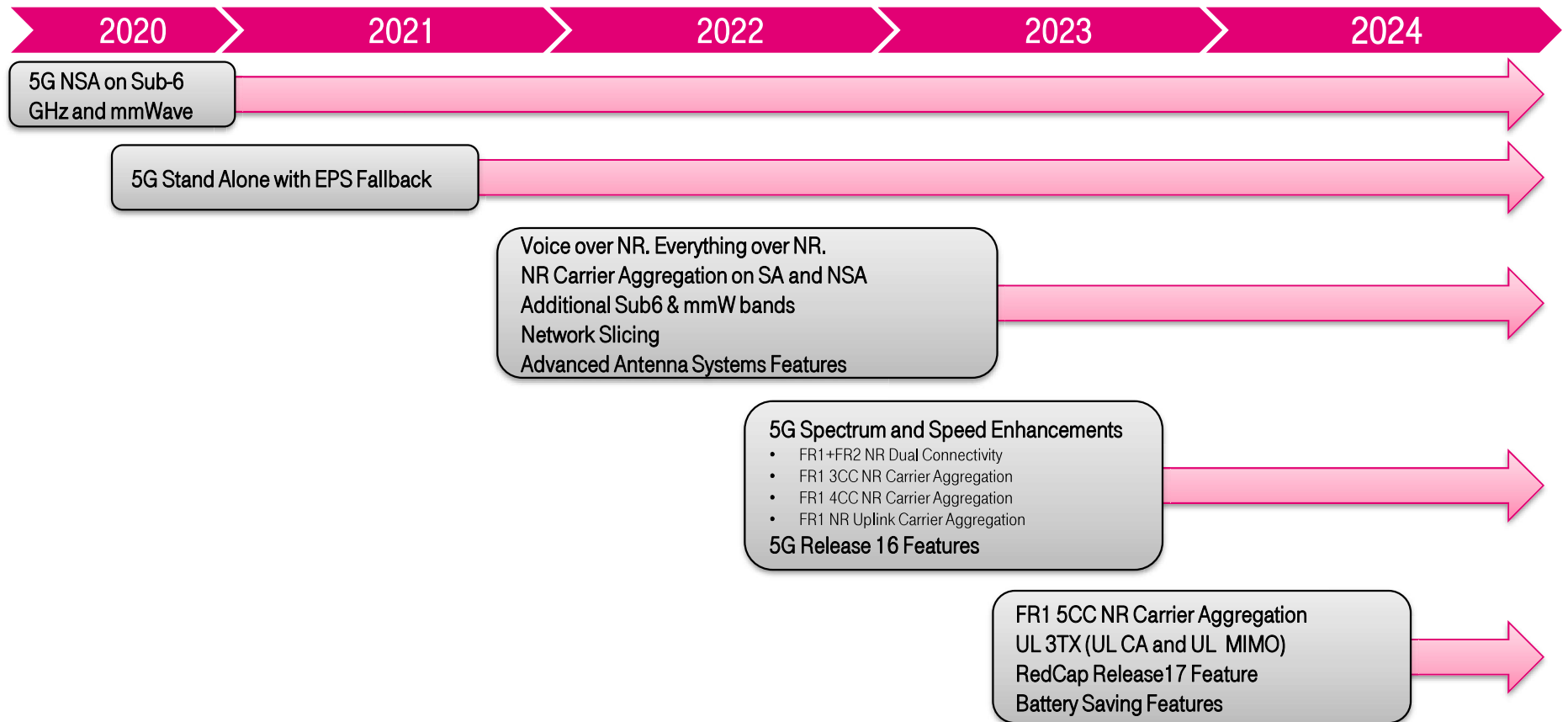
Recommended
Good to have, but can
be waived

Bold/Bold/Bold
New Requirement

Optional
Depends on needs of
product/business
Additional features that
can provide better
customer experience.
Partners can propose
support of these
features.
T-Mobile can provide
recommendations.
Additional Testing may
be required

Note: All regulatory
requirements can be
supported by T-Mobile,
however they are
contingent upon the
MVNO's agreement and
individual requirements.

5G Device Requirements Roadmap



Contents



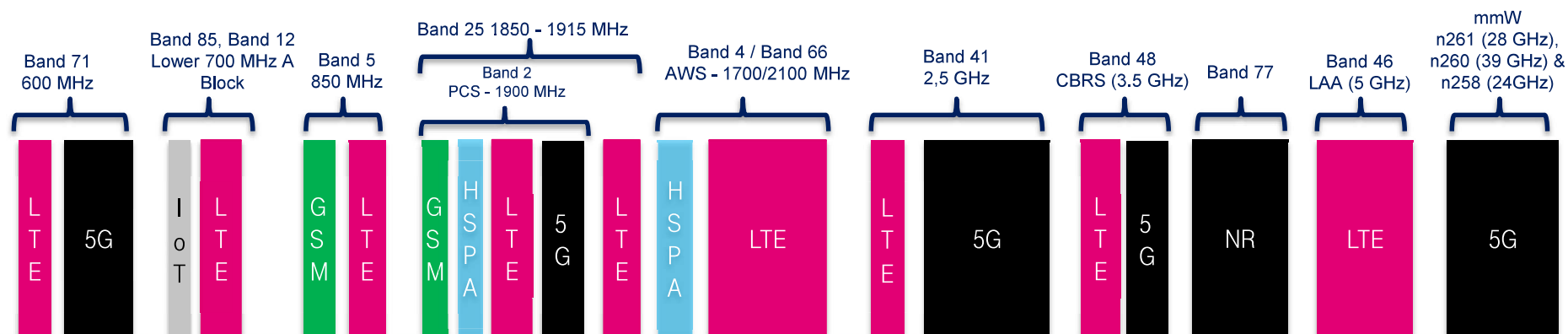
- T-Mobile Business and Network Update
- Device Technology Requirements and Roadmap
- **Spectrum and Frequency Bands**
- 5G Device Requirements and Roadmap
- Fixed Wireless Access ***NEW SECTION***
- Internet of Things
- Regulatory and Location Technology
- Device and IMS Services
- Additional Material

Frequency Band Requirements & Spectrum Assets

GSM	UMTS	T-Mobile LTE	LTE & 5G Roaming	T-Mobile 5G NR
Quad-band <ul style="list-style-type: none"> 1900 MHz (T-Mobile) 850 MHz (T-Mobile/Roaming) 900 MHz (Roaming) 1800 MHz (Roaming) 	<ul style="list-style-type: none"> Band II (1900 MHz) Roaming Band IV (1700/2100 MHz) Roaming Band V (850 MHz) Roaming Band I (2100 MHz) Roaming Band VIII (900 MHz) Roaming 	<ul style="list-style-type: none"> Band 4 (1700/2100 MHz) Band 12 (700 MHz) Band 2 (1900 MHz) Band 66 (2100 MHz) Band 5 (850 MHz) (select markets) Band 71 (600 MHz) Band 41 (2500 MHz) Band 46 (LAA, 5 GHz) Band 48 (CBRS, 3.5 GHz) Band 85 (700 MHz, NB-IoT) Band 25 (1900 MHz) 	LTE FDD Bands <ul style="list-style-type: none"> 25, 26 3, 7, 20, 1, 8, 13, 28 LTE TDD Bands <ul style="list-style-type: none"> 40, 39, 38 5G Bands <ul style="list-style-type: none"> n5, n78, n28, n1, n40, n7, n3, n38, n79, n258, n257, n77, n20 	<ul style="list-style-type: none"> Band n71 (600 MHz) Band n66 (AWS) Band n25 (PCS) Band n41 (2.5 GHz TDD) Band n261 (28 GHz TDD) Band n260 (39 GHz TDD) Band n258 (24 GHz TDD) Band n77 (C-Band & DoD) Band n48 (CBRS TDD)

- LTE Bands 12, 66, 85 require MFB1 support .
- LTE Roaming Bands must not impact the RF performance of T-Mobile Bands specified in the Radiated Performance TRD
- LTE Band 25 is required for T-Mobile network and Roaming (All Bandwidths must be supported per 3GPP including smaller bandwidths, 1.4, 3 and 5 MHz).**

Black = Mandatory,
Blue = Tier-based or optional
Black/Bold = Newly added

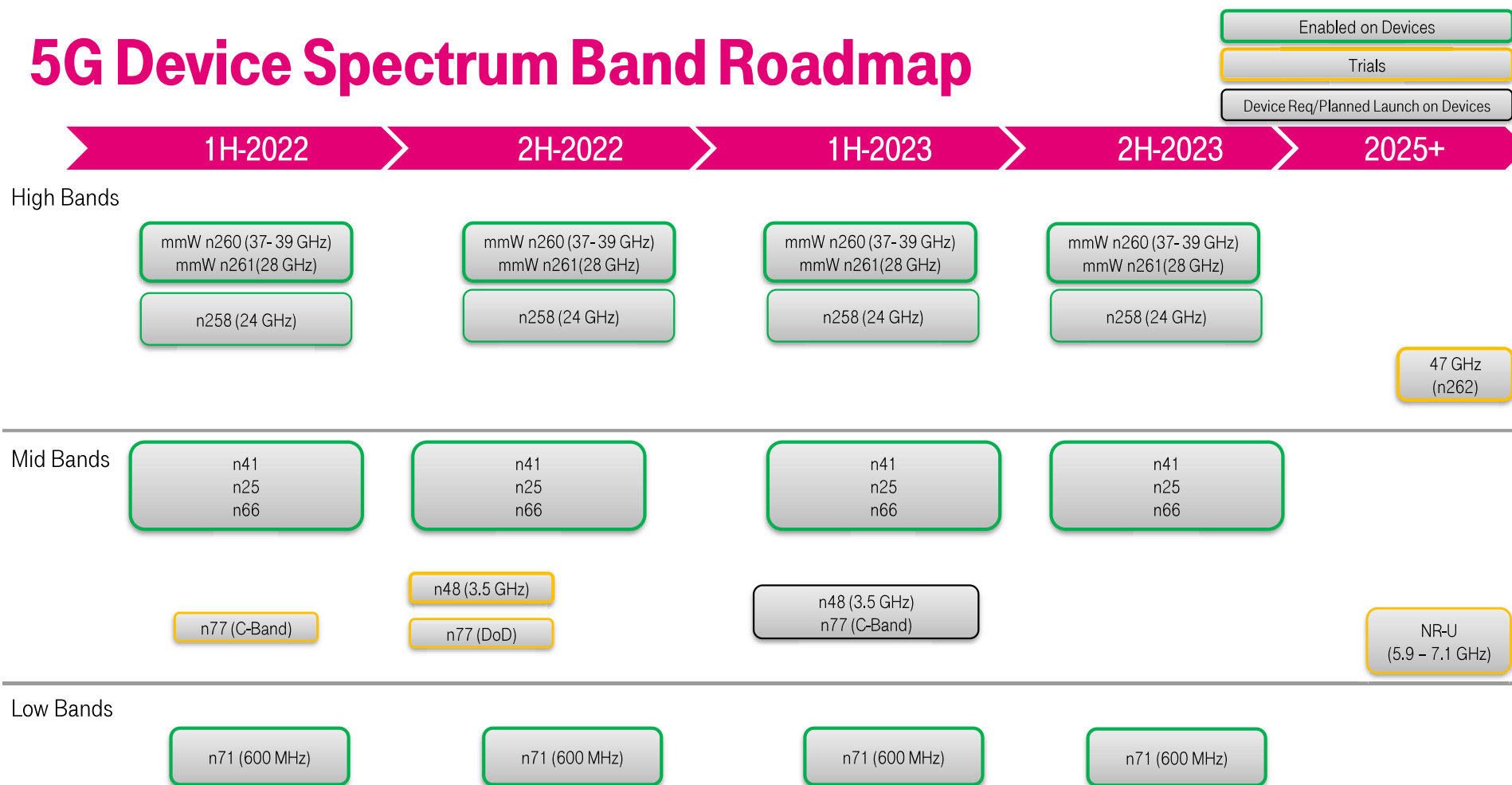


Spectrum Utilization Strategy

	2023	2024	2025	Near-Term Future
Band 2 (1900 MHz) as n25 for NR	4G	4G → 5G	5G	5G
	3G → 5G	5G	5G	5G
	2G	2G → 5G	5G	5G
	5G	5G	5G	5G
Band 4 & 66 (2100 MHz) as n66 for NR	4G	4G	4G → 5G	5G
	3G → 4G	4G → 5G	5G	5G
Band 12 (700 MHz)	4G	4G	4G	4G
Band 41 (2,5 GHz)	5G	5G	5G	5G
	4G → 5G			
Band 71 (600 MHz)	5G	5G	5G	5G
	4G	4G	4G	4G
Band 5 (850 MHz)	4G	4G	4G	4G
	2G	2G → 4G	4G	4G
Band 26 (800 MHz)	TBD	TBD	TBD	TBD
Band 48 CBRS (3,5 GHz)	4G	4G	4G	4G
	5G	5G	5G	5G
Band 46 (5 GHz Unlicensed)	4G		4G	4G
Band (5,9 to 7,1 GHz Unlicensed)			5G	5G
mmWave (24 GHz, 28 GHz & 39 GHz)	5G	5G	5G	5G
Band 77 (C-Band & DoD)		5G	5G	5G

This represents a general spectrum usage plan and not necessarily a specific re-farming schedule. Spectrum utilization can vary market-by-market and is not necessarily uniform nationwide.

5G Device Spectrum Band Roadmap



Spectrum Auctions



3.5 GHz

Auction 110 (100MHz)
3.45 to 3.55 GHz
Oct 5, 2021
Clock phase concluded on 11/16/2021
Assignment phase concluded on 1/4/22
~\$22.5 billion of gross proceeds

2.5 GHz

Auction 108
July 29, 2022 - August 29, 2022
The auction is for unlicensed spectrum that surrounds areas covered
by an incumbent licensee. ~\$428M gross proceeds.
T-Mobile acquired 91% of licenses

AWS3 & 600MHz

Cats & Dogs Auction

n77 Band (3.3 GHz to 4.2 GHz)

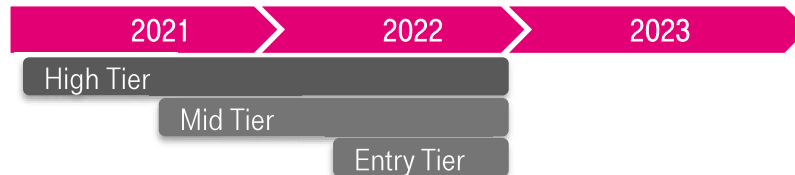
Business Benefits

- n77 spectrum has better propagation than high bands and higher bandwidth than regular FDD mid-bands
- FCC auctioned 280MHz of spectrum in the 3.7GHz band in Dec 2020 that are part of the C-Band (3.7 GHz to 4.2 GHz)
- FCC auctioned 100MHz of spectrum from 3.45 to 3.55GHz from DoD

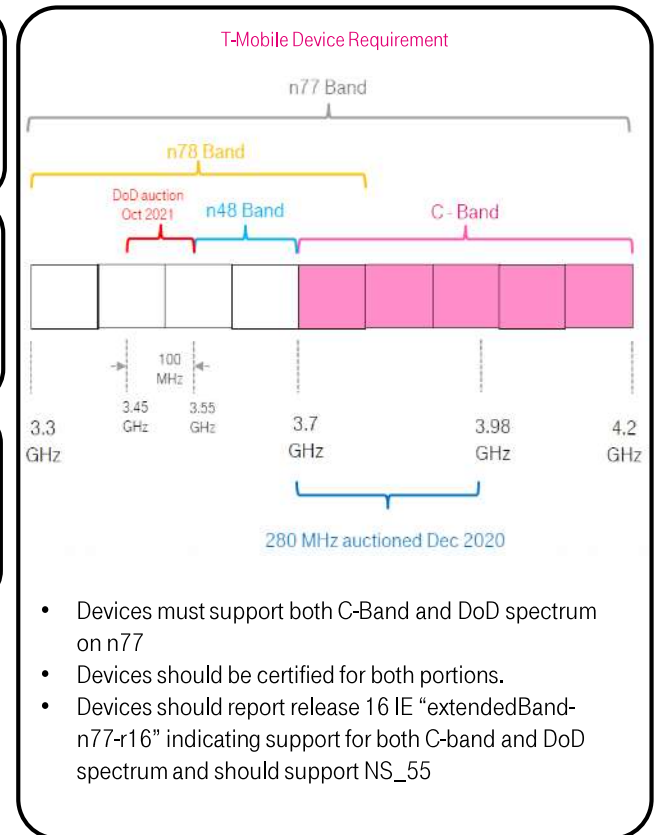
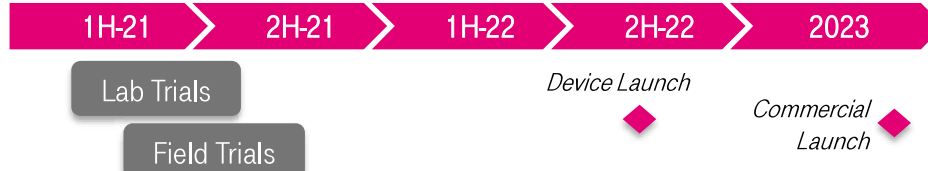
Functional Description

- Devices must support n77 band as defined in 3GPP from 3300 MHz to 4200MHz
- Chipset & devices are required to support 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 MHz carrier bandwidth with 30/60/120 KHz SCS as mandatory
- HPUE PC2 and PC 1.5 required
- SRS Antenna Switching Required

Device Requirements



Development Plan



5G Roaming Architecture

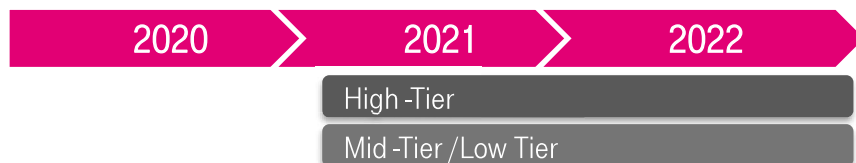
Business Benefits

- 5G features of low latency, higher capacity & increased bandwidth will help with a more secure, reliable experience for all roamers, as compared to LTE/4G

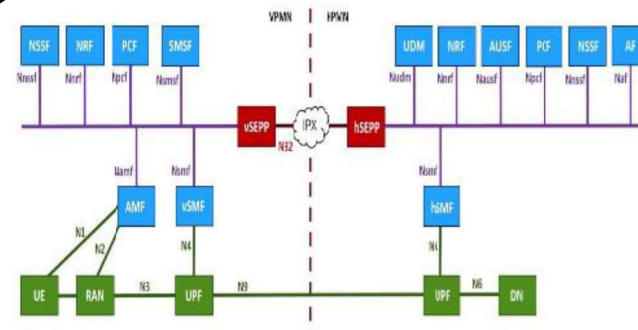
Functional Description

- More Network Functions due to functional split in 5GC architecture
- New Network element (SEPP) to support secure inter PLMN communication
- EPS-FB only devices or 5G SA Roaming partners with EPS-FB only support requires 4G network interworking

Device Requirements



Development Plan



- 5G Devices must support EN-DC combos of Domestic & International partners defined in the Roaming TRD for Outbound Roaming
- Test cases will be modified from time to time to take care of new roaming partners

ENDC combos - International Roaming Partners

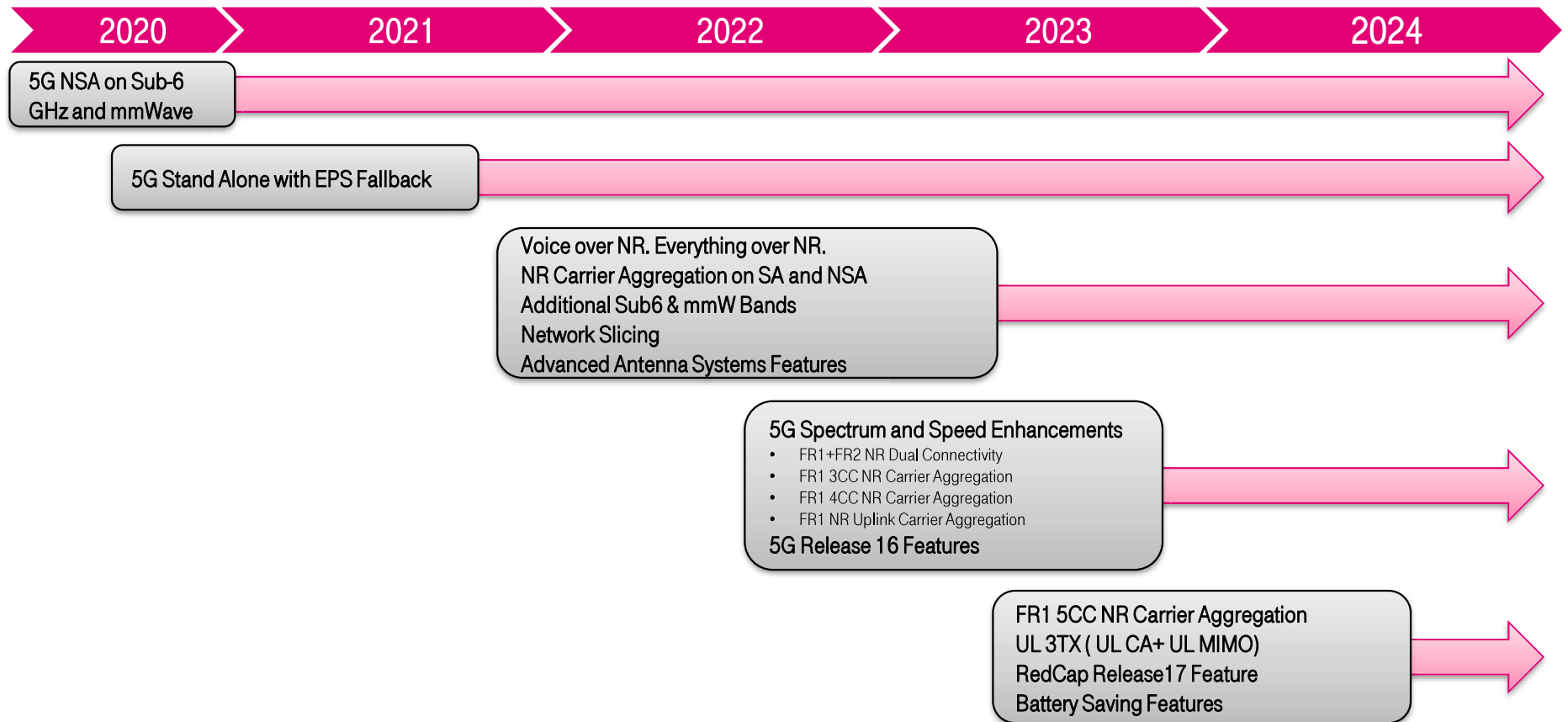
n78		n28	n78, n41	n1, n78	n1	n3, n28, n77, n257	n257, n258	n7
DC_1A_n78A	DC_7C_n78	DC_1A_n28A	DC_1A_n41A	DC_20A_n1A	DC_3A-7A-8A_n1A	DC_8A_n77A	DC_1A_257I	DC_66A_n7A
DC_3A_n78A	DC_7A-66A_n78	DC_3A_n28A	Dc_1A_n78A	DC_8A_n1A		DC_28A_n77A	DC_3A_n257I	DC_66A-66A_n7A
DC_8A_n78A	DC_7C-66A_n78		DC_3A_n41A	DC_3A_n1A		DC_8A_n3A	DC_8A_n257I	
DC_1A_5A_7A_n78AA	DC_7A-66A-66A_n78		DC_3A_n78A	DC_7A_n1A		DC_1A_n3A	DC_28A_n257I	
DC_1A_n78A	DC_7C-66A-66A_n78		DC_1A_3A_n78A	DC_20A_n78A		DC_1A_n257I		
DC_3A_n78A	DC_5A-7A_n78		DC_1A_3A_n41A	DC_3A_n78A		DC_3A_n257I		
DC_7A_n78A	DC_5A-7A-66A_n78			DC_1A_n78A		DC_8A_n257I		
DC_8A_n78A	DC_5A-66A_n78			DC_7A_n78A		DC_28A_n257I		
DC_20A_n78A	DC_5A-66A-66A_n78							
DC_66A__n78A	DC_5A-7C_n78							
DC-66A_66A_n78A	DC_5A-7C-66A_n78							
DC-7C_n78	DC_5A-7A-66A-66A_n78							
	DC_5A-7C-66A-66A_n78							

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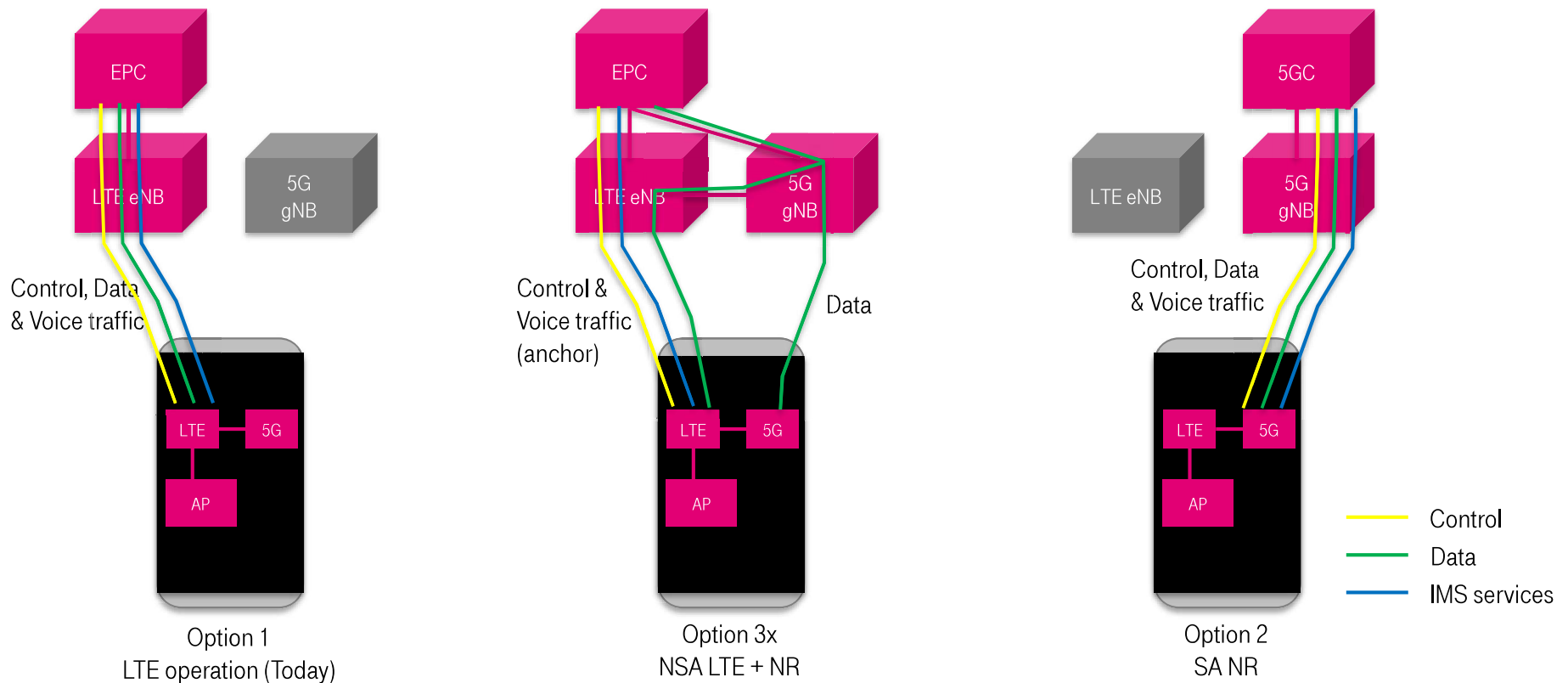


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5G Device Requirements Roadmap



How is traffic handled in architecture 1, 2, 3 ?



5G Device Requirements Overview 2022-2024

5G is Recommended for Low and Entry tier devices

Legend

Required at Launch

Recommended

Required to add via MR

Not required

5G Key Features			Device Launch Period									
Feature Area	Feature Group	Feature Details	1H'22		2H'22		1H'23		2H'23		1H'24	
			High	Mid	High	Mid	High	Mid	High	Mid	High	Mid
NR Bands	Sub6 Bands	n71, n25, n66, n41	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
		n77	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
		n48	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended
	mmW Bands	n260, n261	At Launch	Recommended	At Launch	Recommended	At Launch	Recommended	At Launch	Recommended	At Launch	Recommended
		n258 (24 GHz) Tri-Band	At Launch	Recommended	At Launch	Recommended	At Launch	Recommended	At Launch	Recommended	At Launch	Recommended
		n262 HW Ready	Not Required	Not Required	Not Required	Not Required	Not Required	Not Required	Not Required	Not Required	Not Required	Not Required
Architecture	Non-Stand Alone (NSA)		At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	SA with EPS-FB	SA on all Sub6 NR Bands	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	SA with VoNR and EoNR	SA on all Sub6 NR Bands	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
DSS	DSS on NSA and SA		At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
HPUE	HPUE PC2 for n41 SA	26 dBm HPUE	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	HPUE PC 1.5 for n41 SA	29 dBm HPUE	Recommended	Recommended	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	HPUE PC2 for n77 SA	26 dBm HPUE	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	HPUE PC1.5 for n77 SA	29 dBm HPUE	Recommended	Recommended	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
Network Slicing	Standard and non-standard NSSAI	e.g., eMBB / URLLC	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	Slice aware CN Instance	e.g., use of DNN /App ID descriptor	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	Slice aware inter frequency HO	e.g., HO from n41 to n71/n66	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch

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5G Device Requirements Overview 2022-2024

Legend	
Required at Launch	Recommended
Required to add via MR	Not required

5G is Recommended for Low and Entry tier devices

5G Key Features			Device Launch Period									
			1H'22		2H'22		1H'23		2H'23		1H'24	
Feature Area	Feature Group	Feature Details	High	Mid	High	Mid	High	Mid	High	Mid	High	Mid
AAS features	DL MIMO 16 and 32 port CSI-RS	FDD and TDD support for sub6 bands	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	SRS Antenna Switching NSA and SA, n41 and n77	Support for devices supporting MIMO	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	UL MIMO for n41 SA	Codebook based 2L UL MIMO	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	UL MIMO for n77 SA	Codebook based 2L UL MIMO	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	UL 256QAM	Support for SA, NSA on TDD and FDD	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
Spectrum Features	n41 Bandwidths	20,30,40,50,60,70,80,90,100	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	n25 and n66 Bandwidths	More than 20 MHz required	Recommended	Recommended	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	200 MHz Bandwidth for FR2		Recommended	Recommended	At Launch	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended
	Bandwidth Parts for FDD and TDD		At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	1000 MHz IBW for n258		At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	1400 MHz IBW for n260		Recommended	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended	Recommended
NR CA Features	TDD as Primary Cell in NR CA	Supporting TDD as Primary during NR CA	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch

5G Device EN-DC & NR CA Requirements Overview 2022-2024

Legend

Required at Launch

Recommended

Required to add via MR

Not required

5G is Recommended for Low and Entry tier devices

LTE MB LTE LB NR LB NR MB NR FDD FR1 NR TDD FR1 NR TDD FR2
B2/B66 B12/B71 n71 n25/n66/n41 n25/n66/n71 n41 n260/n261/n258

5G Key Features			Device Launch Period									
Feature Area	Feature Group	Feature Details Examples (More combos in NR CA List)	1H'22		2H'22		1H'23		2H'23		1H'24	
			High	Mid	High	Mid	High	Mid	High	Mid	High	Mid
Non-Stand Alone ENDC Combos LTE + 1NR	LTE MB + NR LB	e.g., B2+B66+B46+n71	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	LTE MB + NR MB	e.g., B2+B46+n41	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	LTE MB + NR MB	e.g., B2+n66, B66+n25	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	LTE LB + NR MB	e.g., B12+n25, B12+n66	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	LTE MB + NR mmW	e.g., B2+B66+B46+n261	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	LTE + LAA + mmW	e.g., B46+n261	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend
Non-Stand Alone ENDC Combos LTE + 2 NR	LTE MB + NR FDD + NR TDD FR1	e.g., B2+B66+LAA+n71+n41	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	LTE MB + NR FDD + FDD	e.g., B2+B66+n71+n71	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	LTE MB + NR TDD FR1 + NR TDD FR1	e.g., B2+n41+n41	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
Stand Alone NR CA 2 CC	NR FDD + TDD FR1	e.g., n71+n41, n25+n41	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	NR FDD + FDD	e.g., n71+n71, n25+n71	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	NR TDD FR1 + NR TDD FR1	e.g., n41+n41	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
Stand Alone NR CA Combos 3 and 4 CC	3 DL CC: 3FDD, 3TDD, 2FDD+TDD, 2TDD+FDD	e.g., n71+n41+n41, n25+n41+n71	At Launch	Recommend	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch	At Launch
	4 DL CC: 4FDD, 3FDD+TDD	e.g., n41+n25+n66+n71	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend
	4 DL CC: 2 TDD + 2 FDD	e.g., n41+n41+n66+n71	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend
Stand Alone Uplink NR CA	Sub-6 2 UL CC: FDD+FDD, TDD+TDD, FDD+TDD	e.g., n66+n71, n41+n41, n41+n71	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend
	mmW 4 UL CC	e.g., n260l	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend
FR1+FR2 DC	NR FDD + TDD FR2	e.g., n71+n260	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend
	NR TDD FR1 + TDD FR2	e.g., n41+n261	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend	At Launch	Recommend
FR1 +FR2 CA	NR FDD + TDD FR2	e.g., n71+n260	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend
	NR TDD FR1 + TDD FR2	e.g., n41+n261	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend	Recommend

ENDC Roadmap

LTE	B2, B66, B71, B12, B46, B48
NR FR2	n260, n261, n258
NR FR1	n66, n25, n71, n41, n2

Combinations Launched on Devices

Combinations targeted for launch on devices

2019

1H 20

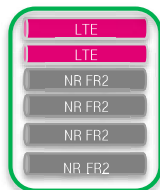
2H 20

1H 21

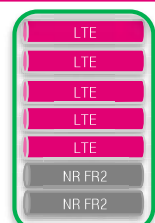
2H 21

2022

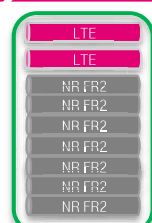
Non-Standalone Mode ENDC: mmW



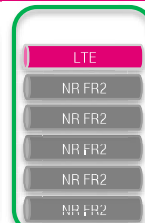
Bands-n260, n261
2LTE +4NR



n261 5 LTE +2NR



n260, 2LTE+8NR

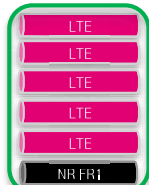


n258, 1LTE+5NR

Non-Standalone Mode, ENDC – Sub 6 GHz



Bands-n71
3LTE + 1NR



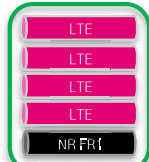
Bands-n71, n41
5LTE + 1NR



Bands-n2
1LTE + 1NR

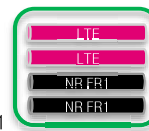


Bands-n66
2LTE + 1NR

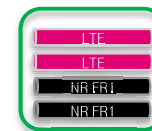


Bands-n66, n25
4LTE + 1NR

Non-Standalone Mode, ENDC NR CA – Sub 6 GHz



n71, n41
2 LTE CC+2NR CC (1FDD+1TTD)



n41, n41
2 LTE CC+2NR CC (1TDD+1TDD), 200MHz, Min carrier aggregated BW required on NR side.

NR CA & NR DC Roadmap

FDD n71,n66,n25
TDD n41,n77
FR2 n260,n261,n258

Combinations Launched on Device

Combinations targeted for launch on devices

2021

1H '22

2H '22

2023

2024

SA, NR CA - Sub 6 GHz



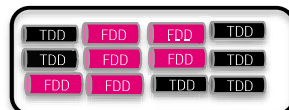
2CC NR CA (n71+n41, n66+n41)



2CC NR CA - 2T



2CC NR CA



3CC NR CA



4CC NR CA



5CC NR CA

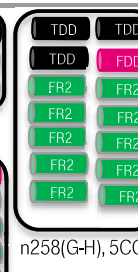
SA, NR DC - Sub 6 GHz + mmW



n260 8CC
FR1+FR2



n261 2CC
Non-Contiguous



n258(G-H), 5CC

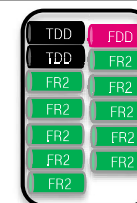
2FR1+FR2



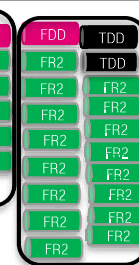
n260, 8CC
Contiguous & Non-Contiguous

SA, NR CA - Sub 6 GHz + mmW

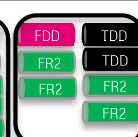
n258(G-H), 5CC



n258, 5CC
Non-Contiguous



n260, 8CC
Contiguous & Non-Contiguous



n261, 2CC
Non-Contiguous

EN-DC Aggregation

Business Benefits

- Provides 5G Connectivity in Non-standalone mode with LTE as an anchor
- Increased Data rates by aggregation of LTE and 5G Carriers for all combinations of spectrum bands

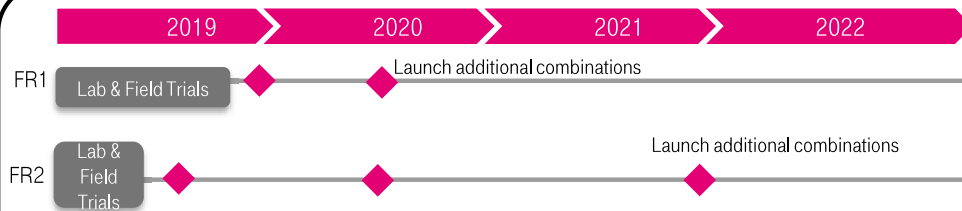
Functional Description

- Dual connectivity between LTE and 5G with LTE as anchor.
- Initial registration with LTE and then LTE would add one or more 5G secondary cells.
- EN-DC combinations include aggregation of spectrum across multiple LTE carriers and multiple 5G carriers.

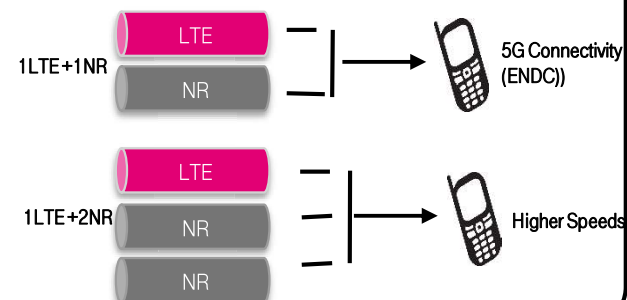
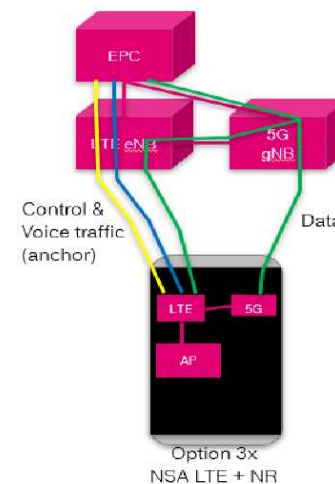
Device Requirements

- FR2(mmW) only devices: Support all EN-DC FR2 combinations listed in TRD
- FR1(Sub 6) only devices: Support all EN -DC FR1 combinations listed in TRD
- FR1 & FR2 Support devices: Support EN-DC FR1 & FR2 Combinations listed in TRD

Development Plan



EN-DC Aggregation



NR Bands – FR1 & FR2

Devices must support all bandwidths defined for all frequency bands listed below

Frequency Range Designation	NR Operating Band	Uplink (UL) Operating Band BS receive / UE transmit	Downlink (DL) Operating Band BS transmit / UE receive	Carrier Component BW	Duplex Mode
FR1	n25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	5, 10, 15, 20, 25 30, 35, 40, 45* MHz	FDD
FR1	n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 MHz	TDD
FR1	n48*	3550 MHz – 3700 MHz	3550 MHz – 3700 MHz	10, 15, 20, 40, 50, 60, 80, 90, 100 MHz	TDD
FR1	n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	5, 10, 15, 20, 25 30, 35, 40, 45* MHz	FDD
FR1	n71	663 MHz – 698 MHz	617 MHz – 652 MHz	5, 10, 15, 20 MHz	FDD
FR1	n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	10, 20, 30, 40, 50, 60, 70, 80, 90, 100MHz	TDD
FR2	n258	24250 MHz – 27500 MHz	24250 MHz – 27500MHz	100, 200 MHz	TDD
FR2	n260	37000 MHz - 40000 MHz	37000 MHz - 40000MHz	100, 200 MHz	TDD
FR2	n261	27500 MHz – 28350 MHz	27500 MHz – 28350 MHz	100, 200 MHz	TDD

* Recommended
n48 is plan to support private network solutions

ENDC & NR CA Nomenclature

Dual connectivity \swarrow \searrow
DC_2A-66A_n260A
LTE carriers (no leading "n") 5G NR carriers with a leading "n"

Dual connectivity \swarrow \searrow
DC_2A-66A_n260(4A)
LTE carriers (no leading "n") Four Non-Contiguous 5G NR carriers

Dual connectivity \swarrow \searrow
DC_2A-66A_n260M
LTE carriers (no leading "n") Eight Contiguous 5G NR carriers

The parentheses around the (n) indicates there is contiguous spectrum across both LTE and 5G NR

DC_(n)71AA
 \swarrow \searrow
Left letter is the CA Bandwidth class for LTE carrier
Right Letter is the CA Bandwidth class for 5G carrier

Carrier Aggregation \leftarrow **CA_n41(2A)n71A** \rightarrow Two Non-Contiguous n41 NR carriers

Carrier Aggregation \leftarrow **CA_n41Cn71A** \rightarrow Two contiguous n41 NR carriers



FR1 (Sub6) CA Bandwidth Classes



NR CA bandwidth class	Aggregated channel bandwidth	Number of contiguous CC	Fallback group
A	$BW_{\text{Channel}} \leq BW_{\text{Channel,max}}$	1	0, 1, 2
B	$20 \text{ MHz} \leq BW_{\text{Channel,CA}} \leq 100 \text{ MHz}$	2	0
C	$100 \text{ MHz} < BW_{\text{Channel,CA}} \leq 2 \times BW_{\text{Channel,max}}$	2	1
D	$200 \text{ MHz} < BW_{\text{Channel,CA}} \leq 3 \times BW_{\text{Channel,max}}$	3	
E	$300 \text{ MHz} < BW_{\text{Channel,CA}} \leq 4 \times BW_{\text{Channel,max}}$	4	
F	$50 \text{ MHz} < BW_{\text{Channel,CA}} \leq 100 \text{ MHz}$	2	2
G	$100 \text{ MHz} < BW_{\text{Channel,CA}} \leq 150 \text{ MHz}$	3	
H	$150 \text{ MHz} < BW_{\text{Channel,CA}} \leq 200 \text{ MHz}$	4	
I	$200 \text{ MHz} < BW_{\text{Channel,CA}} \leq 250 \text{ MHz}$	5	
J	$250 \text{ MHz} < BW_{\text{Channel,CA}} \leq 300 \text{ MHz}$	6	
K	$300 \text{ MHz} < BW_{\text{Channel,CA}} \leq 350 \text{ MHz}$	7	
L	$350 \text{ MHz} < BW_{\text{Channel,CA}} \leq 400 \text{ MHz}$	8	

FR2 (mmW) CA Bandwidth Classes

NR CA bandwidth class	Aggregated channel bandwidth	Number of contiguous CC	Fallback group
A	$BW_{\text{Channel}} \leq 400 \text{ MHz}$	1	1,2,3,4
B	$400 \text{ MHz} < BW_{\text{Channel,CA}} \leq 800 \text{ MHz}$	2	1
C	$800 \text{ MHz} < BW_{\text{Channel,CA}} \leq 1200 \text{ MHz}$	3	
D	$200 \text{ MHz} < BW_{\text{Channel,CA}} \leq 400 \text{ MHz}$	2	2
E	$400 \text{ MHz} < BW_{\text{Channel,CA}} \leq 600 \text{ MHz}$	3	
F	$600 \text{ MHz} < BW_{\text{Channel,CA}} \leq 800 \text{ MHz}$	4	
G	$100 \text{ MHz} < BW_{\text{Channel,CA}} \leq 200 \text{ MHz}$	2	3
H	$200 \text{ MHz} < BW_{\text{Channel,CA}} \leq 300 \text{ MHz}$	3	
I	$300 \text{ MHz} < BW_{\text{Channel,CA}} \leq 400 \text{ MHz}$	4	
J	$400 \text{ MHz} < BW_{\text{Channel,CA}} \leq 500 \text{ MHz}$	5	
K	$500 \text{ MHz} < BW_{\text{Channel,CA}} \leq 600 \text{ MHz}$	6	
L	$600 \text{ MHz} < BW_{\text{Channel,CA}} \leq 700 \text{ MHz}$	7	
M	$700 \text{ MHz} < BW_{\text{Channel,CA}} \leq 800 \text{ MHz}$	8	
O	$100 \text{ MHz} \leq BW_{\text{Channel,CA}} \leq 200 \text{ MHz}$	2	4
P	$150 \text{ MHz} \leq BW_{\text{Channel,CA}} \leq 300 \text{ MHz}$	3	
Q	$200 \text{ MHz} \leq BW_{\text{Channel,CA}} \leq 400 \text{ MHz}$	4	

FR1 EN-DC Combinations High Level Requirements: 2021-2024 Devices

FR1 with 1 NR CC		B2	B2	B2	B2	B2	B2	B12	B12	B2	B2	B46	B2	B2	B48	B48	B2	B2					
		B66	B2	B46	B2	B46	B12		B66	B66	B46	B66	B66	B48	B66	B66	B48	B66					
		B66	B66	B66	B66	B66							B71										
		n71	n71	n71	n41	n41	n66	n2	n25	n25	n66	n25	n71	n66	n25	n48	n48	n66					
		For 2022 Devices: Priority-Mandatory												For 2022 Devices : Priority-Mandatory									
For 2023 Devices: Priority-Mandatory																		For 2023 Devices: Priority-Mandatory					

FR1 with 2 NR CC		B2	B2	B46	B2	B2	B66	B2	B2	B46	B2	B2	B48
		B46	B46	B66	B66	B46		B66	B46	B66		B48	B66
		B66				B66							
		n41	n41	n25	n41	n41	n25	n71	n66	n25	n66	n48	n25
		n71	n66	n41	n41	n41	n71	n71	n71	n71	n71	n66	n48
For 2022 Devices: Priority-Mandatory													
For 2023 Devices: Priority-Mandatory													



All subset combinations within the above supersets are required to be supported.



In all the ENDC combinations, must support 4 layers on LTE mid band carriers

 Combinations highlighted are Obsolete, Changes will be reflected in MTR 2022 4Q

Total Combinations = 90

FR2 EN-DC Combinations High Level Requirements: 2021-2024 Devices

FR2		<div>B2</div> <div>B66</div>	<div>B2</div> <div>B46</div> <div>B66</div>	<div>B2</div> <div>B66</div>	<div>B2</div> <div>B46</div> <div>B66</div>	<div>B2</div>	<div>B66</div>	<div>B48</div>	<div>B48</div>	<div>B2 or B66</div> <div>B46</div>
		<div>n260</div> <div>Up to 4CC non-Contiguous Up to 8CC Contiguous</div>	<div>n260</div> <div>Up to 4CC non-Contiguous</div>	<div>n261</div> <div>Up to 4CC non-Contiguous</div>	<div>n261</div> <div>Up to 2CC non-Contiguous</div>	<div>n258</div> <div>Up to 5CC non-Contiguous</div>	<div>n258</div> <div>Up to 5CC non-Contiguous</div>	<div>n260</div> <div>Up to 4CC non-Contiguous</div>	<div>n261</div> <div>Up to 2CC non-Contiguous</div>	<div>n260</div> <div>Up to 4CC Contiguous</div>
For 2022 Devices: Priority-Mandatory										
For 2023 Devices: Priority-Mandatory										

FR1 & FR2		<div>B66</div>	<div>B2</div> <div>B66</div>	<div>B66</div>	<div>B2</div> <div>B66</div>	<div>B2</div> <div>B66</div>
		<div>n71</div> <div>n260</div>	<div>n41</div> <div>n260</div>	<div>n71</div> <div>n261</div>	<div>n41</div> <div>n261</div>	<div>n71</div> <div>n261</div>

In all the ENDC combinations, must support 4 layers on LTE mid band carriers

All subset combinations within the above supersets are required to be supported.

Total Combinations = 97 + 0



Combinations highlighted are Obsolete, Changes will be reflected in MTR 2022 4Q

Launched on Devices - 60
Not Launched Yet - 25
In Development - 5
Obsolete - 15 + 20

[illegible]

ENDC Combinations for FR2 (mmW)

Launched on devices
Not Launched Yet
In Development
Obsolete - 38

B2, B66, n260	B2, B66, n261	B2, B46, B66, n260	B2, B46, B66, n261	B48, n260	B48, n261	B2, B46, B66, n258
DC_2A_n260A	DC_2A_n261A	DC_46A-66A_n260A	DC_2A-46A_n261A	DC_48A_n260A	DC_48A_n261A	DC_2A_n258(2A)
DC_2A_n260(2A)	DC_2A_n261G	DC_46A-66A_n260(2A)	DC_2A-46C_n261A	DC_48A_n260(2A)	DC_48A_n261(2A)	DC_2A_n258(3A)
DC_2A_n260(3A)	DC_2A_n261(2A)	DC_46C-66A_n260A	DC_2A-46D_n261A	DC_48A_n260(3A)	DC_48C_n261A	DC_2A_n258(4A)
DC_2A_n260(4A)	DC_2A_n261H	DC_46C-66A_n260(2A)	DC_2A-46A_n261(2A)	DC_48A_n260(4A)	DC_48C_n261(2A)	DC_2A_n258(5A)
DC_66A_n260A	DC_2A_n261(3A)	DC_46D-66A_n260A	DC_2A-46C_n261(2A)	DC_48C_n260A	DC_48D_n261A	DC_66A_n258(2A)
DC_66A_n260(2A)	DC_2A_n261I	DC_46D-66A_n260(2A)	DC_2A-46D_n261(2A)	DC_48C_n260(2A)	DC_48D_n261(2A)	DC_66A_n258(3A)
DC_66A_n260(3A)	DC_2A_n261(4A)	DC_46D-66A_n260I	DC_2A-46A_n261A	DC_48C_n260(3A)		DC_66A_n258(4A)
DC_66A_n260(4A)	DC_2A_n261J	DC_46C-66A_n260I	DC_46A-66A_n261A	DC_48C_n260(4A)		DC_66A_n258(5A)
DC_2A-66A_n260A	DC_2A_n261K	DC_46A-66A_n260I	DC_46C-66A_n261A	DC_48C_n260(2A)		DC_66A_n258
DC_2A-66A_n260(2A)	DC_2A_n261L	DC_46D-66A_n260H	DC_46D-66A_n261A	DC_48D_n260A		DC_2A_n258
DC_2A-66A_n260(3A)	DC_2A_n261M	DC_46C-66A_n260H	DC_46A-66A_n261(2A)	DC_48D_n260(2A)		
DC_2A-66A_n260(4A)	DC_2A_n261I	DC_46A-66A_n260H	DC_46C-66A_n261(2A)	DC_48D_n260(3A)		
DC_2A-66A_n260M	DC_66A_n261A	DC_46D-66A_n260G	DC_46D-66A_n261(2A)	DC_48D_n260(4A)		
DC_2A-66A_n260L	DC_66A_n261G	DC_46C-66A_n260G	DC_2A-46A-66A_n261A			
DC_2A-66A_n260K	DC_66A_n261(2A)	DC_46A-66A_n260G	DC_2A-46C-66A_n261A			
DC_2A-66A_n260J	DC_66A_n261H	DC_2A-46D_n260I	DC_2A-46D-66A_n261A			
DC_2A-66A_n260I	DC_66A_n261(3A)	DC_2A-46C_n260I	DC_2A-46C-66A_n261A			
DC_2A-66A_n260H	DC_66A_n261I	DC_2A-46A_n260I	DC_2A-46D-66A_n261A			
DC_2A-66A_n260G	DC_66A_n261(4A)	DC_2A-46D_n260H	DC_2A-46A-66A_n261(2A)			
DC_2A_n260M	DC_66A_n261J	DC_2A-46C_n260H	DC_2A-46C-66A_n261(2A)			
DC_2A_n260L	DC_66A_n261K	DC_2A-46A_n260H	DC_2A-46D-66A_n261(2A)			
DC_2A_n260K	DC_66A_n261L	DC_2A-46D_n260G	DC_2A-46D-66A_n261(2A)			
DC_2A_n260J	DC_66A_n261M	DC_2A-46C_n260G				
DC_2A_n260H	DC_66A_n260I	DC_2A-46A_n260G				
DC_2A_n260G	DC_2A-66A_n261A					
DC_2A-66A_n260(6A)	DC_2A-66A_n261(2A)					
DC_2A-66A_n260(5A)						

FR2 total combinations - 97

ENDC Combinations — FR1 & FR2

Launched on devices
Not Launched Yet
In Development
Obsolete - 26

B66, n71, n261

DC_66A_n71A-n261A
DC_66A_n71A-n261(2A)

B66, n71, n260

DC_66A_n71A-n260A
DC_66A_n71A-n260(2A)

B2, B66, n41, n261

DC_2A_n41A-n261A
DC_2A_n41A-n261A(2A)
DC_66A_n41A-n261A
DC_66A_n41A-n261(2A)
DC_2A-66A_n41A-n261A
DC_2A-66A_n41A-n261(2A)

B66, n41, n260

DC_2A_n41A-n260A
DC_2A_n41A-n260(2A)
DC_2A_n41A-n260(3A)
DC_2A_n41A-n260(4A)
DC_66A_n41A-n260A
DC_66A_n41A-n260(2A)
DC_66A_n41A-n260(3A)
DC_66A_n41A-n260(4A)
DC_2A-66A_n41A-n260A
DC_2A-66A_n41A-n260(2A)
DC_2A-66A_n41A-n260(3A)
DC_2A-66A_n41A-n260(4A)

B2, n71, n261

DC_2A_n71A-n261(2A)
DC_2A_n71A-n261A
DC_2A-66A_n71A-n261(2A)
DC_2A-66A_n71A-n261A

FR1 & FR2 Combinations - 26

n25 Standalone with NR Carrier Aggregation

Business Benefits

- Increased 5G Speeds and Capacity by aggregation of multiple 5G Carriers for all combinations of spectrum bands
- Extends 5G Ultra capacity coverage on 2.5 GHz through NR Carrier Aggregation

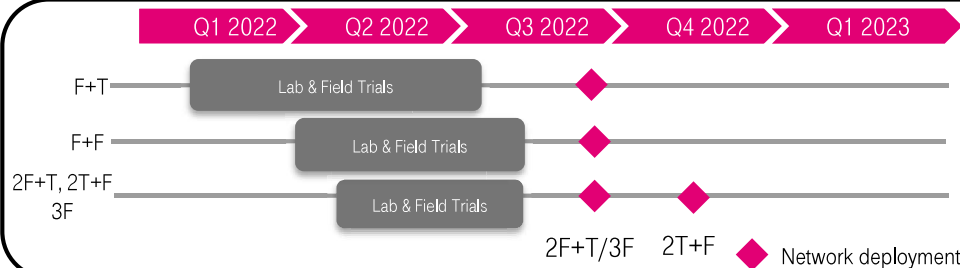
Functional Description

- n25 provides 5G operation on the PCS 1900 band
- NR CA**
 - Aggregation of Multiple NR carriers in standalone and non-standalone modes.
 - Single Uplink
 - Theoretical DL speeds of up to 2.2Gbps DL speeds possible with 3CCA

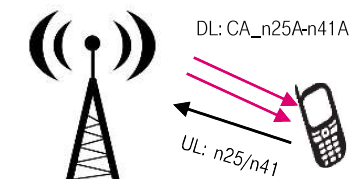
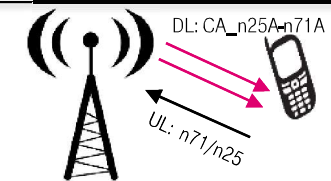
Device Requirements

- Devices must support the following 2 and 3 CA combinations in DL
- FDD+TDD: n25+n41
 - FDD+FDD: n25+n71, n25+n66
 - 2FDD+TDD: n25/n66/n71+n41
 - 2TDD+FDD: n41+n41+n25
 - 3FDD: n25+n66+n71

Development Plan



NR – Carrier Aggregation



n25 & n66 Channel Bandwidths greater than 20MHz

Business Benefits

- Better Spectrum Utilization for NR
 - Better UL/DL throughput
 - Improved spectral efficiency
- Reduced UE complexity
- Simple ENDC NRCA combinations

Functional Description

- A bigger channel bandwidth allows for higher throughput and capacity
- No different in functionality than any of the current supported channel bandwidth

Device Requirements

- Devices should be HW ready to support higher Channel Bandwidths for FDD bands
- CBWs of 25, 30, 35, 40 MHz are mandatory
- 45MHz CBW is recommended

Development Plan



Covered POPs in areas T-Mobile owns > 20MHz contiguous spectrum

Licensed POPs by Carrier Bandwidth (based on 2019 POPs)	Contiguous carrier		Total holdings	
	n 66	n 25	n 66	n 25
25 MHz	75M	53M	116M	25M
30 MHz	5M	25M	9M	98M
35 MHz	2M	7M	2M	147M
40MHz	-	-	-	53M
45 MHz	-	-	-	1M
50MHz	-	0.2M	-	0.2M

T-Mobile is the largest owner of PCS spectrum in US with an average of 35MHz (DL).

Markets with PCS contiguous > 20 MHz – NY, Miami, Atlanta, Seattle, Detroit

Markets with AWS contiguous > 20MHz – NY, Detroit, Boston, Atlanta, Seattle, Tampa, Phoenix

Uplink NR Carrier Aggregation

Business Benefits

- Providing more spectrum utilization in the uplink direction to improve uplink speed and capacity, improving user experience
- FDD+TDD Uplink NR carrier aggregation provides extension in UL coverage

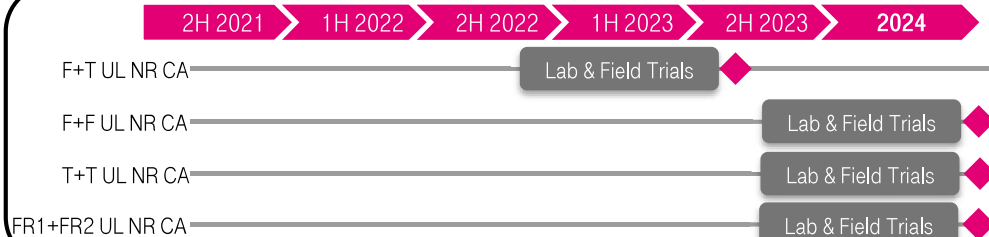
Functional Description

- Aggregating of spectrum across multiple bands, up to 2 carriers, leading to increased capacity, coverage and speed in uplink direction
- Utilizes the same bands as the relative downlink NR carrier aggregation combination

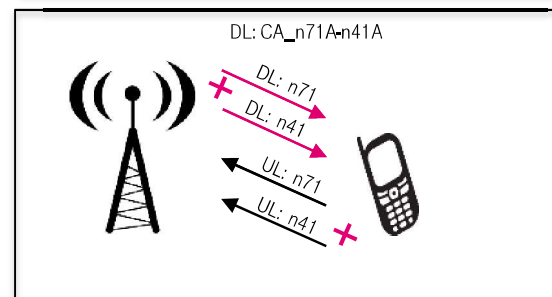
Device Requirements

- Devices must support all UL FR1 combinations in the TRD requirements including:
 - FDD+TDD (EX: n71+n41)
 - FDD+FDD (EX: n25+n71)
 - TDD+TDD (EX: n41C)
 - FR1+FR2 (EX: TBD)
- Devices must also support Downlink NR Carrier Aggregation

Development Plan





NR – Uplink Carrier Aggregation



DL Configuration	Uplink Configuration
CA_n25A-n41A	CA_n25A-n41A
CA_n25A-n41C	CA_n25A-n41A
CA_n25A-n41(2A)	CA_n25A-n41A
CA_n25A-n71A	CA_n25A-n71A
CA_n41A-n66A	CA_n41A-n66A
CA_n41A-n71A	CA_n41A-n71A
CA_n66A-n71A	CA_n66A-n71A
CA_n25A-n66A	CA_n25A-n66A
CA_n25(2A)-n66A	CA_n25A-n66A
CA_n41C	CA_n41C
CA_n25A-n77A	CA_n25A-n77A
CA_n41A-n77A	CA_n41A-n77A
CA_n71A-n77A	CA_n71A-n77A
CA_n48B	CA_n48B




FR1 NR 2CA Combinations High Level Requirements: 2021-2024 Devices

FR1 2CC																					
FR1 2NR CC		n71	n41	n41	n41	n41	n25	n66	n25	n66	n41	n77	n66	n71	n25	n25	n48	n48	n48	n48	
		n71	n41	n71	n66	n25	n71	n71	n66	n66	n77	n77	n77	n77	n77	n48	n66	n48	n71	n77	
For 2022 Devices : Priority-Mandatory																For 2022 Device: Priority-Recommended					
For 2023 Devices: Priority-Mandatory																For 2023 Devices: Priority-Mandatory					

26 Combinations




FR1 NR 3CA Combinations High Level Requirements: 2021-2024 Devices

FR1 3CC

FR1 3 NRCC		n41	n25	n25	n25	n41	n41	n25	n25	n41	n25	n66	n25	n25	n41	n66	n25	n25	n41
		n66	n66	n25	n41	n41	n41	n41	n41	n71	n71	n71	n25	n25	n41	n66	n25	n66	n66
		n71	n71	n66	n71	n71	n66	n66	n41	n71	n71	n71	n41	n25	n41	n71	n71	n66	n66

For 2022 Devices: Priority-Mandatory

For 2023 Devices: Priority-Mandatory

FR1 3 NRCC		n71	n25	n25	n66	n71	n41	n25	n66	n41	n41	n25	n66	n48	n48	n48	n48	n48	n48
		n71	n25	n77	n77	n77	n77	n66	n66	n41	n48	n48	n48	n48	n48	n71	n66	n66	n66
		n77	n77	n77	n77	n77	n77	n77	n77	n48	n48	n48	n48	n71	n77	n71	n77	n71	n66

For 2022 Devices: Priority-Mandatory








For 2022 Devices: Priority-Recommended

For 2023 Devices: Priority-Mandatory

For 2023 Devices: Priority-Mandatory

60 Combinations

FR1 NR 4CA Combinations High Level Requirements: 2021-2024 Devices

FR1 4CC																														
FR1 4 NR CC		n41	n66	n25	n25	n25	n25	n25	n25	n25	n25	n41	n41	n41	n41	n41	n41	n25	n25	n25	n25	n25	n25	n41	n25	n25	n41			
		n41	n66	n41	n41	n66	n25	n41	n25	n25	n41	n41	n66	n66	n41	n41	n25	n41	n25	n25	n41	n41	n66	n66	n48	n41				
		n41	n71	n71	n66	n71	n41	n41	n41	n71	n66	n41	n71	n66	n66	n71	n41	n66	n66	n66	n66	n41	n66	n66	n48	n48				
		n71	n71	n71	n66	n71	n66	n41	n41	n71	n66	n66	n71	n71	n71	n71	n71	n71	n71	n71	n77	n66	n41	n71	n71	n66	n48			
	For 2022 Devices : Priority-Recommended																													
For 2023 Devices : Priority-Mandatory																														
FR1 4NR CC		n25	n25	n25	n25	n41	n25	n41	n41	n41	n66	n66	n25	n25	n41	n25	n71	n25	n66	n66	n41	n48	n48	n48	n48	n48	n48	n48		
		n41	n66	n41	n25	n41	n71	n66	n66	n71	n71	n66	n41	n25	n71	n71	n66	n71	n66	n71	n71	n66	n48	n48	n48	n48	n48	n48		
		n71	n71	n41	n71	n41	n71	n77	n66	n71	n71	n71	n77	n77	n77	n77	n77	n77	n77	n77	n77	n66	n66	n66	n66	n71	n77	n66	n66	
		n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n71	n71	n77	n66	n71	n77	n77	n71
	For 2022 Devices : Priority-Recommended																													
For 2023 Devices : Priority-Mandatory																														

89 Combinations

FR1 NR 5 CA Combinations High Level Requirements: 2021-2024 Devices

FR1 5 CC

FR1 5NR CC	5G	n25	n41	n25	n25	n25	n25	n25	n25	n25	n41	n41	n25	n41	n25	n25	n25	n25	n41	n41	n66	n41	n41	n41
	5G	n41	n41	n41	n41	n25	n25	n41	n66	n66	n66	n41	n41	n41	n41	n41	n41	n41	n41	n66	n66	n41	n71	n41
	5G	n41	n66	n41	n41	n66	n66	n66	n66	n66	n71	n41	n66	n41	n41	n66	n41	n66	n66	n71	n71	n71	n71	n71
	5G	n66	n71	n66	n71	n66	n77	n77	n77	n71	n77	n66	n71	n66	n71	n77	n77	n77	n77	n77	n77	n77	n77	n71
	5G	n71	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n77	n71	n77	n77	n77	n77	n77	n77	n77	n77	n77

FR1 5NR CC	5G	n25	n41	n25	n25	n25	n25	n25	n25	n25	n25	n25	n25	n41	n41	n41	n41	n41	n25	n25	n25	n25	n25	n25	n41
	5G	n25	n41	n41	n41	n41	n41	n41	n25	n25	n25	n25	n25	n41	n41	n41	n41	n41	n41	n41	n66	n25	n25	n41	n41
	5G	n41	n41	n41	n41	n41	n41	n41	n41	n41	n41	n41	n71	n66	n66	n41	n41	n41	n66	n71	n71	n41	n41	n66	n41
	5G	n41	n66	n66	n41	n41	n41	n66	n77	n41	n41	n41	n77	n66	n66	n66	n66	n66	n71	n66	n77	n77	n66	n71	n71
	5G	n41	n66	n66	n66	n71	n77	n66	n77	n66	n71	n77	n77	n71	n77	n71	n77	n77	n77	n77	n77	n77	n77	n77	n71

For 2022 Devices : Priority-Recommended

For 2023 Devices : Priority-Recommended

FR1 NR 5 & 6 CA Combinations High Level Requirements: 2021-2024 Devices

FR1 5NR CC	5G	n41	n25	n66	n25	n25	n41
	5G	n66	n71	n71	n41	n41	n41
	5G	n71	n71	n71	n71	n41	n66
	5G	n71	n77	n77	n71	n71	n71
	5G	n77	n77	n77	n77	n71	n71
FR1 6NR CC	5G	n41	n25				
	5G	n66	n25				
	5G	n66	n66				
	5G	n71	n66				
	5G	n77	n77				
	5G	n77	n77				



For 2022 Devices: Priority-Recommended

For 2023 Devices: Priority-Recommended

6CC Combinations - 3

FR1 & FR2 NR DC High Level Requirements: 2021-2024 Devices



FR1 & FR2 NR DC 150 Combinations

FR1		n25	n41	n41	n66	n41	n25	n41	n66	n25	n41	n41	n66	n25
				n41		n41						n41		n41
FR2		n260	n260	n260	n260	n261	n261	n261	n261	n258	n258	n258	n258	n260
		Up to 8CC Contiguous & Non-Contiguous				Up to 2CC Non-Contiguous				Up to 5CC Non-Contiguous and n258(G-H)			Up to 4CC Contiguous & 2CC Non Contiguous	
		For 2022 Devices: Priority-Mandatory												
		For 2023 Devices: : Priority-Mandatory												

FR1	n25	n41	n66	n66	n77
	n41	n66	n77	n77	
FR2	n258	n260	n260	n261	n260
	Up to 2CC Contiguous & Non-Contiguous	Up to 4CC Contiguous & 2CC Non Contiguous	Up to 8CC Contiguous	Up to 2CC Non -Contiguous	Up to 8CC Contiguous
For 2022 Devices: Priority-Mandatory					
For 2023 Devices: : Priority-Mandatory					



FR1 & FR2 NR CA High Level Requirements: 2021-2024 Devices

FR1 & FR2 NR CA 172 Combinations

FR1		n71	n25	n41	n66	n77	n41	n71	n25	n77	n66	n25	n41	n66	n77
FR2		n260	n260	n260	n260	n260	n261	n261	n261	n261	n261	n258	n258	n258	n258
Up to 8CC Contiguous & Non-Contiguous						Up to 2CC Non-Contiguous				Up to 2CC Non-Contiguous Up to 8CC					

For 2022 Devices: Priority-Recommended

For 2023 Devices: Priority-Recommended

FR1		n25	n25	n41	n66	n66
FR2		n258	n260	n260	n260	n261
Up to 3CC Non Contiguous.		Up to 4CC Contiguous & 2CC non-Contiguous		Up to 4CC Contiguous & 2CC non Contiguous	Up to 8CC Contiguous	Up to 2CC Non-Contiguous

FR2	n258
FR2	n260
N258 – Upto 5CC(G+H) N260 – Upto 4CC contiguous	

For 2022 Devices: Priority-Recommended

For 2023 Devices: Priority-Recommended

Launched on Devices
Not Launched Yet
In Development

FR1 NR CA Combinations — 2CC,3CC,4CC

NR CA 2CC	NR CA 3CC				NR CA 4CC			
F+T	2F+T	2T+F	3F	3T	2T+2F	3F+1T	3T+1F	4F
CA_n41A-n71A CA_n25A-n41A CA_n41A-n66A CA_n48A-n66A CA_n25A-n48A CA_n25A-n77A CA_n66A-n77A CA_n71A-n77A CA_n48A-n66A CA_n48A-n77A	CA_n25A-n41A-n71A CA_n41A-n66A-n71A CA_n41A-n71B CA_n25A-n41A-n66A CA_n25(2A)-n41A CA_n25A-n48A-n66A CA_n41A-n71(2A) CA_n25A-n66A-n77A CA_n25A-n71A-n77A CA_n66A-n71A-n77A	CA_n41(2A)-n71A CA_n25A-n41(2A) CA_n25A-n41C CA_n41C-n71A CA_n41(2A)-n66A CA_n41C-n66A CA_n48(2A)-n66A CA_n48C-n66A CA_n25A-n48C CA_n25A-n48(2A) CA_n25A-n41A-n77A CA_n41A-n66A-n77A CA_n41A-n71A-n77A CA_n66A-n77(2A) CA_n71A-n77(2A) CA_n25A-n77(2A) CA_n48C-n66A CA_n48B-n71A CA_n48B-n66A CA_n48(2A)-n71A CA_n48A-n66A-n77A	CA_n25A-n66A-n71A CA_n25(2A)-n66A CA_n25A-n71(2A) CA_n66A-n71(2A) CA_n25A-n66(2A) CA_n66(2A)-n71A CA_n25A-n71B CA_n66A-n71B CA_n25(3A) CA_n25(2A)-n71A	CA_n41(2A)-n77A CA_n41C-n77A CA_n41A-n77(2A) CA_n41(3A) CA_n41(A-C) CA_n41C-n48A CA_n41(2A)-n48A CA_n41A-n48C CA_n41A-n48B CA_n41A-n48(2A) CA_n48B-n77A CA_n48(2A)-n77A	CA_n25A-n41(2A)-n71A CA_n25A-n41C-n71A CA_n41(2A)-n66A-n71A CA_n41(2A)-n71B CA_n41C-n66A-n71A CA_n41C-n71B CA_n25A-n41(2A)-n66A CA_n25A-n41C-n66A CA_n25A-n48C-n66A CA_n25A-n48(2A)-n66A CA_n41A-n66A-n71A-n77A CA_n25A-n41A-n66A-n77A CA_n25A-n41A-n71A-n77A CA_n41(2A)-n71(2A) CA_n41C-n71(2A) CA_n25(2A)-n41A-n77A CA_n25(2A)-n41A-n77A CA_n41A-n66A-n71(2A) CA_n41A-n66A-n71B CA_n41A-n66(2A)-n71A CA_n66A-n71(2A)-n77A CA_n66(2A)-n71A-n77A CA_n25(2A)-n66A-n77A CA_n25A-n66(2A)-n77A CA_n25A-n66(2A)-n71A CA_n25A-n66A-n77(2A) CA_n25(2A)-n77(2A) CA_n71B-n77(2A) CA_n71(2A)-n77(2A) CA_n25A-n71A-n77(2A) CA_n66(2A)-n77(2A) CA_n25A-n71A-n77(2A) CA_n25(2A)-n41C-n66A	CA_n25A-n41A-n66A-n71A CA_n25A-n66A-n71A-n77A CA_n25(2A)-n41A-n66A CA_n25A-n41A-n71B CA_n25A-n41A-n66(2A) CA_n25A-n41A-n71(2A) CA_n25A-n71B-n77A CA_n25A-n71(2A)-n77A CA_n25(2A)-n41A-n71A CA_n25(2A)-n71A-n77A CA_n41A-n66A-n71(2A) CA_n41A-n66A-n71B CA_n41A-n66(2A)-n71A CA_n66A-n71B-n77A CA_n66A-n71(2A)-n77A CA_n66(2A)-n71A-n77A CA_n25(2A)-n66A-n77A CA_n25A-n66(2A)-n77A CA_n25A-n66(2A)-n71A CA_n25A-n66A-n77(2A) CA_n25(2A)-n77(2A) CA_n71B-n77(2A) CA_n71(2A)-n77(2A) CA_n25A-n71A-n77(2A) CA_n66(2A)-n77(2A) CA_n25A-n71A-n77(2A) CA_n25(2A)-n41C-n66A	CA_n25A-n41(2A)-n77A CA_n25A-n41C-n77A CA_n41(2A)-n66A-n77A CA_n41(2A)-n66A-n77A CA_n41C-n66A-n77A CA_n41(2A)-n71A-n77A CA_n41C-n71A-n77A CA_n25A-n41(A-C) CA_n25A-n41(3A) CA_n41(A-C)-n66A CA_n41(3A)-n71A CA_n41(A-C)-n71A CA_n41A-n66A-n77(2A) CA_n25A-n41A-n77(2A) CA_n41A-n71A-n77(2A) CA_n48B-n66A-n77A CA_n48(2A)-n66A-n77A CA_n41(4A) CA_n41(2A)-C CA_n41(2A)-n77(2A) CA_n41C-n77(2A) CA_n48(2A)-n77(2A)	CA_n25(2A)-n66(2A) CA_n25(2A)-n71(2A) CA_n25(2A)-n71B CA_n66(2A)-n71B CA_n66(2A)-n71(2A) CA_n25A-n66A-n71(2A) CA_n25A-n66A-n71B CA_n25A-n66(2A)-n71A 4T CA_n41(3A)-n77A CA_n41(A-C)-n77A CA_n41(2A)-n48C CA_n41C-n48C CA_n41(2A)-n48B CA_n41C-n48B CA_n41(2A)-n48(2A) CA_n41(4A) CA_n41(2A)-C CA_n41(2A)-n77(2A) CA_n41C-n77(2A) CA_n48(2A)-n77(2A)
T+T	CA_n41A-n66(2A) CA_n25(2A)-n77A CA_n71B-n77A CA_n71(2A)-n77A CA_n25A-n66A-n77A CA_n66A-n71A-n77A	CA_n25A-n41A-n77A CA_n41A-n66A-n77A CA_n41A-n71A-n77A CA_n66A-n77(2A) CA_n71A-n77(2A) CA_n25A-n77(2A) CA_n48C-n66A CA_n48B-n71A CA_n48B-n66A CA_n48(2A)-n71A CA_n48A-n66A-n77A	CA_n25A-n41A-n77A CA_n41A-n66A-n77A CA_n41A-n71A-n77A CA_n66A-n77(2A) CA_n71A-n77(2A) CA_n25A-n77(2A) CA_n48C-n66A CA_n48B-n71A CA_n48B-n66A CA_n48(2A)-n71A CA_n48A-n66A-n77A	CA_n41(2A)-n77A CA_n41C-n77A CA_n41A-n77(2A) CA_n41(3A) CA_n41(A-C) CA_n41C-n48A CA_n41(2A)-n48A CA_n41A-n48C CA_n41A-n48B CA_n41A-n48(2A) CA_n48B-n77A CA_n48(2A)-n77A	CA_n25A-n41(2A)-n71A CA_n25A-n41C-n71A CA_n41(2A)-n66A-n71A CA_n41(2A)-n71B CA_n41C-n66A-n71A CA_n41C-n71B CA_n25A-n41(2A)-n66A CA_n25A-n41C-n66A CA_n25A-n48C-n66A CA_n25A-n48(2A)-n66A CA_n41A-n66A-n71A-n77A CA_n25A-n41A-n66A-n77A CA_n25A-n41A-n71A-n77A CA_n41(2A)-n71(2A) CA_n41C-n71(2A) CA_n25(2A)-n41A-n77A CA_n25(2A)-n41A-n77A CA_n41A-n66A-n71(2A) CA_n41A-n66A-n71B CA_n41A-n66(2A)-n71A CA_n66A-n71B-n77A CA_n66A-n71(2A)-n77A CA_n66(2A)-n71A-n77A CA_n25(2A)-n66A-n77A CA_n25A-n66(2A)-n77A CA_n25A-n66(2A)-n71A CA_n25A-n66A-n77(2A) CA_n25(2A)-n77(2A) CA_n71B-n77(2A) CA_n71(2A)-n77(2A) CA_n25A-n71A-n77(2A) CA_n66(2A)-n77(2A) CA_n25A-n71A-n77(2A) CA_n25(2A)-n41C-n66A	CA_n25A-n41A-n66A-n71A CA_n25A-n66A-n71A-n77A CA_n25(2A)-n41A-n66A CA_n25A-n41A-n71B CA_n25A-n41A-n66(2A) CA_n25A-n41A-n71(2A) CA_n25A-n71B-n77A CA_n25A-n71(2A)-n77A CA_n25(2A)-n41A-n71A CA_n25(2A)-n71A-n77A CA_n41A-n66A-n71(2A) CA_n41A-n66A-n71B CA_n41A-n66(2A)-n71A CA_n66A-n71B-n77A CA_n66A-n71(2A)-n77A CA_n66(2A)-n71A-n77A CA_n25(2A)-n66A-n77A CA_n25A-n66(2A)-n77A CA_n25A-n66(2A)-n71A CA_n25A-n66A-n77(2A) CA_n25(2A)-n77(2A) CA_n71B-n77(2A) CA_n71(2A)-n77(2A) CA_n25A-n71A-n77(2A) CA_n66(2A)-n77(2A) CA_n25A-n71A-n77(2A) CA_n25(2A)-n41C-n66A	CA_n25A-n41(2A)-n77A CA_n25A-n41C-n77A CA_n41(2A)-n66A-n77A CA_n41(2A)-n66A-n77A CA_n41C-n66A-n77A CA_n41(2A)-n71A-n77A CA_n41C-n71A-n77A CA_n25A-n41(A-C) CA_n25A-n41(3A) CA_n41(A-C)-n66A CA_n41(3A)-n71A CA_n41(A-C)-n71A CA_n41A-n66A-n77(2A) CA_n25A-n41A-n77(2A) CA_n41A-n71A-n77(2A) CA_n48B-n66A-n77A CA_n48(2A)-n66A-n77A CA_n41(4A) CA_n41(2A)-C CA_n41(2A)-n77(2A) CA_n41C-n77(2A) CA_n48(2A)-n77(2A)	CA_n25(2A)-n66(2A) CA_n25(2A)-n71(2A) CA_n25(2A)-n71B CA_n66(2A)-n71B CA_n66(2A)-n71(2A) CA_n25A-n66A-n71(2A) CA_n25A-n66A-n71B CA_n25A-n66(2A)-n71A 4T CA_n41(3A)-n77A CA_n41(A-C)-n77A CA_n41(2A)-n48C CA_n41C-n48C CA_n41(2A)-n48B CA_n41C-n48B CA_n41(2A)-n48(2A) CA_n41(4A) CA_n41(2A)-C CA_n41(2A)-n77(2A) CA_n41C-n77(2A) CA_n48(2A)-n77(2A)
F+F	CA_n25A-n71A CA_n71B CA_n66A-n71A CA_n25(2A) CA_n25A-n66A CA_n71(2A) CA_n66(2A)	CA_n25A-n71A CA_n71B CA_n66A-n71A CA_n25(2A) CA_n25A-n66A CA_n71(2A) CA_n66(2A)	CA_n25A-n71A CA_n71B CA_n66A-n71A CA_n25(2A) CA_n25A-n66A CA_n71(2A) CA_n66(2A)	CA_n25A-n71A CA_n71B CA_n66A-n71A CA_n25(2A) CA_n25A-n66A CA_n71(2A) CA_n66(2A)	CA_n25A-n71A CA_n71B CA_n66A-n71A CA_n25(2A) CA_n25A-n66A CA_n71(2A) CA_n66(2A)	CA_n25A-n71A CA_n71B CA_n66A-n71A CA_n25(2A) CA_n25A-n66A CA_n71(2A) CA_n66(2A)	CA_n25A-n71A CA_n71B CA_n66A-n71A CA_n25(2A) CA_n25A-n66A CA_n71(2A) CA_n66(2A)	CA_n25A-n71A CA_n71B CA_n66A-n71A CA_n25(2A) CA_n25A-n66A CA_n71(2A) CA_n66(2A)

Total NR CA FR1 Combinations = 273

Launched on Devices
Not Launched Yet
In Development

FR1 NR CA Combinations — 5CC & 6CC

NR CA 5CC

2T+3F

CA_n25A-n41(2A)-n66A-n71A	CA_n41A-n66A-n71(2A)-n77A
CA_n25A-n41C-n66A-n71A	CA_n41A-n66A-n71B-n77A
CA_n25(2A)-n66A-n77(2A)	CA_n25A-n71(2A)-n77(2A)
CA_n25A-n66(2A)-n77(2A)	CA_n25A-n71B-n77(2A)
CA_n41A-n66(2A)-n71A-n77A	CA_n66A-n71B-n77(2A)
CA_n25A-n66(2A)-n77(2A)	CA_n66A-n71(2A)-n77(2A)
CA_n41A-n66(2A)-n71A-n77A	CA_n25A-n41A-n71(2A)-n77A
CA_n25A-n41C-n66(2A)	CA_n25A-n41(2A)-n71(2A)
CA_n25A-n41(2A)-n66(2A)	CA_n25A-n41(2A)-n71B
CA_n25(2A)-n41C-n71A	CA_n25A-n41C-n71B
CA_n25(2A)-n41(2A)-n66A	CA_n25A-n41C-n71(2A)
CA_n25(2A)-n41(2A)-n71A	CA_n41(2A)-n66A-n71(2A)
CA_n25(2A)-n41(2A)-n77A	CA_n41(2A)-n66A-n71B
CA_n25(2A)-n71A-n77(2A)	CA_n41C-n66A-n71(2A)
CA_n41C-n66(2A)-n71A	CA_n41C-n66A-n71B
CA_n41(2A)-n66(2A)-n71A	
CA_n25A-n41A-n66(2A)-n77A	
CA_n25A-n66A-n71A-n77(2A)	
CA_n25(2A)-n41A-n66A-n77A	
CA_n25(2A)-n41A-n71A-n77A	
CA_n25A-n41A-n66A-n71A-n77A	

2F+3T

CA_n41(2A)-n66A-n71A-n77A	CA_n41(3A)-n71B
CA_n41C-n66A-n71A-n77A	CA_n41(3A)-n71(2A)
CA_n25A-n41(2A)-n66A-n77A	CA_n41(A-C)-n71B
CA_n25A-n41(2A)-n71A-n77A	CA_n41(A-C)-n71(2A)
CA_n25A-n41C-n66A-n77A	CA_n41A-n71B-n77(2A)
CA_n25A-n41C-n71A-n77A	CA_n41A-n71(2A)-n77(2A)
CA_n25A-n41A-n66A-n77(2A)	CA_n41C-n71B-n77A
CA_n41A-n66A-n71A-n77(2A)	CA_n41C-n71(2A)-n77A
CA_n25A-n41A-n66A-n77(2A)	CA_n41(2A)-n71B-n77A
CA_n41A-n66A-n71A-n77(2A)	CA_n41(2A)-n71(2A)-n77A
CA_n25(2A)-n41(3A)	
CA_n25(2A)-n41(A-C)	
CA_n25A-n41(A-C)-n66A	
CA_n41(3A)-n66(2A)	
CA_n41(A-C)-n66(2A)	
CA_n25A-n41(3A)-n66A	
CA_n25A-n41(3A)-n71A	
CA_n25(2A)-n41A-n77(2A)	
CA_n25(2A)-n41C-n77A	
CA_n41C-n66(2A)-n77A	
CA_n41(2A)-n66(2A)-n77A	
CA_n41(3A)-n66A-n71A	
CA_n41(A-C)-n66A-n71A	
CA_n25A-n41A-n71A-n77(2A)	

4T+F

CA_n25A-n41(2A)-n77(2A)
CA_n25A-n41C-n77(2A)
CA_n41C-n66A-n77(2A)
CA_n41(2A)-n66A-n77(2A)
CA_n41(2A)-n71A-n77(2A)
CA_n25A-n41(3A)-n77A
CA_n25A-n41(A-C)-n77A
CA_n41(3A)-n66A-n77A
CA_n41(3A)-n71A-n77A
CA_n41(A-C)-n66A-n77A
CA_n41(A-C)-n71A-n77A

4F+T

CA_n25(2A)-n66(2A)-n77A
CA_n25(2A)-n66A-n77(2A)

NR CA 6CC

3T+3F

CA_n41A-n66(2A)-n71A-n77(2A)
CA_n41A-n66(2A)-n71A-n77(2A)

4F+2T

CA_n25(2A)-n66(2A)-n77(2A)

Launched on Devices
Not Launched Yet
In Development

Total NR CA FR1+FR2 Combinations = 200

NR DC Combinations — FR1 + FR2

Launched on Devices
Not Launched Yet
In Development
Obsolete

n25, n260	n41, n260		n41, n261	n66, n260	n25, n258	n41, n258		n66, n258
DC_n25A-n260A	DC_n41A-n260A	DC_n41C-n260A	DC_n41A-n261A	DC_n66A-n260A	DC_n25A-n258A	DC_n41A-n258A	DC_n41(2A)-n258(G+H)	DC_n66A-n258A
DC_n25A-n260G	DC_n41A-n260G	DC_n41C-n260G	DC_n41A-n261(2A)	DC_n66A-n260G	DC_n25A-n258(2A)	DC_n41A-n258(2A)	DC_n41(2A)-n258(2G)	DC_n66A-n258(2A)
DC_n25A-n260H	DC_n41A-n260H	DC_n41C-n260H	DC_n41C-n261A	DC_n66A-n260H	DC_n25A-n258(3A)	DC_n41A-n258(3A)	DC_n41(2A)-n258(A-G)	DC_n66A-n258(3A)
DC_n25A-n260I	DC_n41A-n260I	DC_n41C-n260I	DC_n41C-n261(2A)	DC_n66A-n260I	DC_n25A-n258(4A)	DC_n41A-n258(4A)	DC_n41(2A)-n258(A+H)	DC_n66A-n258(4A)
DC_n25A-n260J	DC_n41A-n260J	DC_n41C-n260J	DC_n41C-n261A	DC_n66A-n260J	DC_n25A-n258(5A)	DC_n41A-n258(5A)	DC_n41(2A)-n258G	DC_n66A-n258(5A)
DC_n25A-n260K	DC_n41A-n260K	DC_n41C-n260K	DC_n41(2A)-n261A	DC_n66A-n260K	DC_n25A-n258(5A)	DC_n41C-n258A	DC_n41(2A)-n258H	DC_n66A-n258(5A)
DC_n25A-n260L	DC_n41A-n260L	DC_n41C-n260L	DC_n41(2A)-n261(2A)	DC_n66A-n260L	DC_n25A-n258(G+H)	DC_n41C-n258(2A)	DC_n41A-n258(G+H)	DC_n66A-n258(G+H)
DC_n25A-n260M	DC_n41A-n260M	DC_n41C-n260M		DC_n66A-n260M	DC_n25A-n258(2G)	DC_n41C-n258(3A)	DC_n41A-n258(2G)	DC_n66A-n258(2G)
DC_n25A-n260(2A)	DC_n41A-n260(2A)	DC_n41C-n260(2A)	n77, n260	DC_n66A-n260M	DC_n25A-n258(A-G)	DC_n41C-n258(4A)	DC_n41A-n258(A-G)	DC_n66A-n258(A-G)
DC_n25A-n260(3A)	DC_n41A-n260(3A)	DC_n41C-n260(3A)	DC_n77A-n260M	DC_n66A-n260(2A)	DC_n25A-n258(A+H)	DC_n41C-n258(5A)	DC_n41A-n258(A+H)	DC_n66A-n258(A+H)
DC_n25A-n260(4A)	DC_n41A-n260(4A)	DC_n41C-n260(4A)	DC_n77A-n260L	DC_n66A-n260(3A)	DC_n25A-n258G	DC_n41C-n258H	DC_n41A-n258G	DC_n66A-n258G
DC_n25A-n260(5A)	DC_n41A-n260(5A)	DC_n41C-n260(5A)	DC_n77A-n260K	DC_n66A-n260(4A)	DC_n25A-n258H	DC_n41(2A)-n258A	DC_n41C-n258(G+H)	DC_n66A-n258H
DC_n25A-n260(6A)	DC_n41A-n260(6A)	DC_n41C-n260(6A)	DC_n77A-n260J	DC_n66A-n260(5A)	n41, n66, n260	DC_n41(2A)-n258(2A)	DC_n41C-n258(2G)	DC_n66A-n258(2G)
DC_n25A-n260(7A)	DC_n41A-n260(7A)	DC_n41C-n260(7A)	DC_n77A-n260I	DC_n66A-n260(6A)	DC_n41A-n66A-n260I	DC_n41(2A)-n258(3A)	DC_n41C-n258(A-G)	DC_n66A-n258(A-G)
DC_n25A-n260(8A)	DC_n41A-n260(8A)	DC_n41C-n260(8A)	DC_n77A-n260H	DC_n66A-n260(7A)	DC_n41A-n66A-n260H	DC_n41(2A)-n258(4A)	DC_n41C-n258(A+H)	DC_n66A-n258G
	n41, n25, n260	DC_n41(2A)-n260A	DC_n77A-n260G	DC_n66A-n260(8A)	DC_n41A-n66A-n260G	DC_n41(2A)-n258(5A)	DC_n41C-n258G	DC_n66A-n258H
	DC_n25A-n41A-n260(2A)	DC_n41(2A)-n260G	DC_n77A-n260A		DC_n41A-n66A-n260(2A)	DC_n41C-n258H		
	DC_n25A-n41A-n260A	DC_n41(2A)-n260H	n66, n77, n260	n66, n261	DC_n41A-n66A-n260A	n66, n261	n66, n77, n261	n41, n25, n258
	DC_n25A-n41A-n260I	DC_n41(2A)-n260I	DC_n66A-n77A-n260A	DC_n66A-n261A		DC_n66A-n261M	DC_n66A-n77A-n261A	DC_n25A-n41A-n258(2A)
	DC_n25A-n41A-n260J	DC_n41(2A)-n260J	DC_n66A-n77A-n260M	DC_n66A-n261L		DC_n66A-n261L	DC_n77A-n261(2A)	DC_n25A-n41A-n258A
	DC_n25A-n41A-n260K	DC_n41(2A)-n260K	DC_n66A-n77A-n260L	DC_n66A-n261K		DC_n66A-n261K	DC_n77A-n261A	DC_n25A-n41A-n258G
	DC_n25A-n41A-n260L	DC_n41(2A)-n260L	DC_n66A-n77A-n260K	DC_n66A-n261J		DC_n66A-n261J		
	DC_n25A-n41A-n260M	DC_n41(2A)-n260M	DC_n66A-n77A-n260J	DC_n66A-n261I		DC_n66A-n261I		
	DC_n25A-n41A-n260H	DC_n41(2A)-n260H	DC_n66A-n77A-n260I	DC_n66A-n261H		DC_n66A-n261H		
	DC_n25A-n41A-n260G	DC_n41(2A)-n260G	DC_n66A-n77A-n260H	DC_n66A-n261G		DC_n66A-n261G		
		DC_n41(2A)-n260(2A)	DC_n66A-n77A-n260G					
		DC_n41(2A)-n260(3A)	DC_n66A-n77A-n260M					
		DC_n41(2A)-n260(4A)	DC_n66A-n77A-n260L					
		DC_n41(2A)-n260(5A)	DC_n66A-n77A-n260K					
		DC_n41(2A)-n260(6A)	DC_n66A-n77A-n260J					
		DC_n41(2A)-n260(7A)	DC_n66A-n77A-n260I					
		DC_n41(2A)-n260(8A)	DC_n66A-n77A-n260H					
			DC_n66A-n77A-n260G					

Total NR DC - FR1+FR2 Combinations = 161

Service Based C-DRX — Connected Mode DRX

Business Benefits

- Improve device battery life, which is really important for a 5G device that consumes more power when attach to both LTE and NR

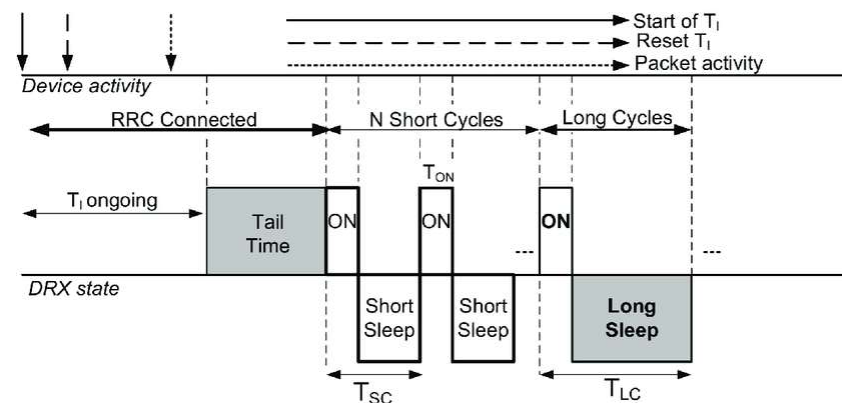
Functional Description

- By means of discontinuous reception when UE is inactive the UE only decodes PDCCH when is awake and if no data for the UE then it goes back to sleep for a period of time.
- With this procedure the UE reduces its battery consumption.

Device Requirements

- Follow 3GPP TS 38.331 6.3.2
 - Service Specific cDRX cycle for Voice and Data connected mode sessions.
 - Long , Short DRX cycle
 - On Duration
 - mmW 600 MHz, 2.5G NR deployed

Development Plan VoNR cDRX



- UE decodes PDCCH during the ON Duration period
- Reduced power consumption during the sleep time or no PDSCH activity

5G Standalone (SA)

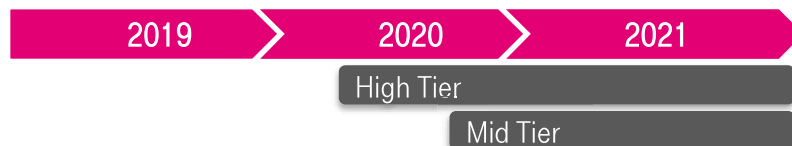
Business Benefits

- 5G Standalone (SA) enables devices to use the 5G network without needing to be connected to the 4G LTE network. Device experience and performance are superior on 5G SA, and it uses network resources more efficiently.

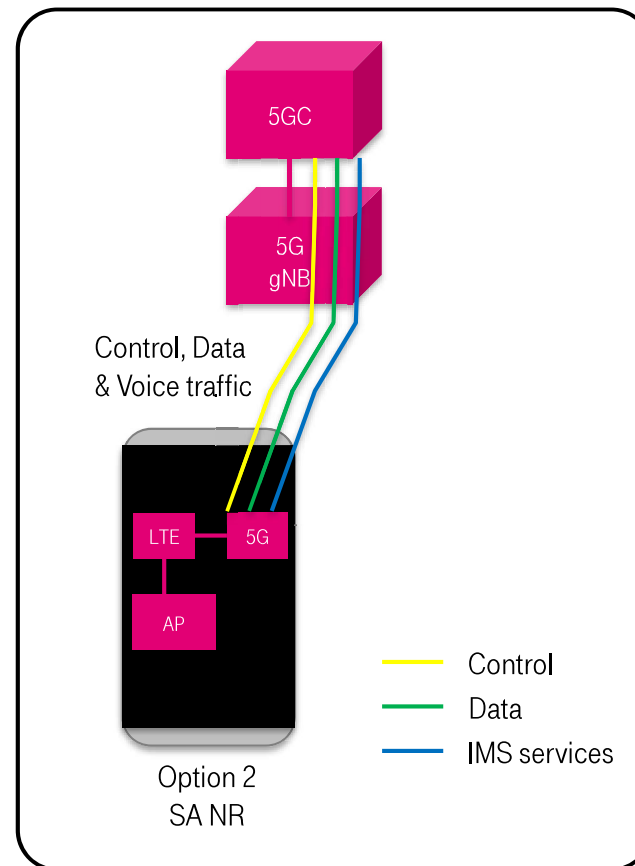
Functional Description

- Device shall support the 5G NR L3 SA data call establishment
- Device shall support the 5G NR N1-based Non-Access-Stratum (NAS)
- Required on all Sub6 Bands
 - Devices with NR CA: SA on n71, n25, n66, n41
 - Devices with SA and no NR CA: SA on n71, n41, NSA on n25 and n66
- 1H20 SA with EPS-FB for real time services (Voice, Video calling, E911 call)
 - RCS and WEA shall be supported at NR layer

Device Requirements



Development Plan



HPUE Power Class 1.5 for 2.5 GHz n41 SA

Business Benefits

- Increase cell radius for PC1.5 Compatible devices on network side and improve cell-edge performance in both UL and DL directions for end-user

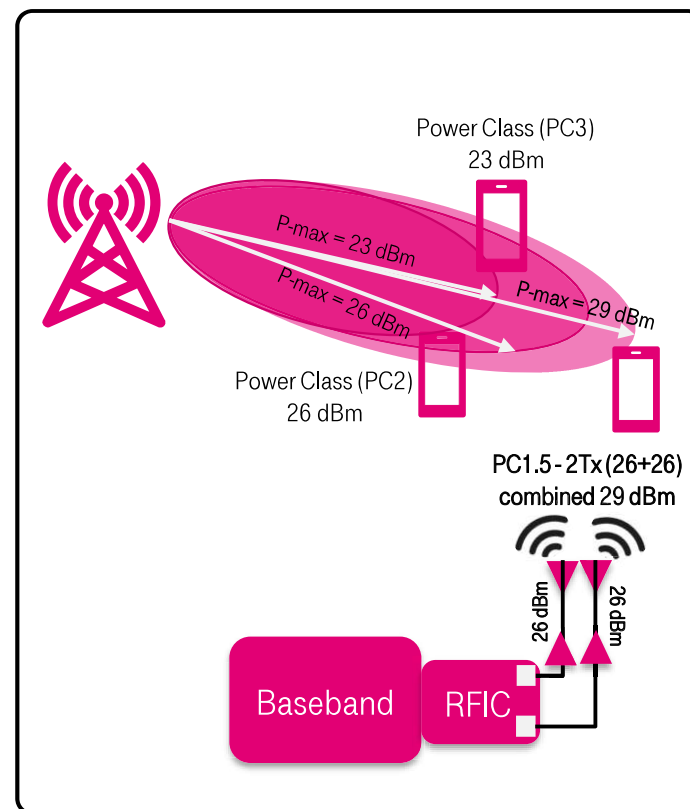
Functional Description

- Increase UE transmit power to 26 dBm on each path for 2Tx device to reach 29 dBm combined transmit power ($29 \text{ dBm} + 2/-3 \text{ dB}$)
- Provides better results with DFT-s-OFDM waveform

Device Requirements

- Follow 3GPP TS 38.101-1 6.2 Rel 16
- Mandatory for n41 SA devices to support HPUE PC1.5 fully (both hardware and software)
- Support R16 ULFP Modes 0,1,2 and Transmit Diversity

Development Plan



SRS Antenna Switching n41, n77 SA & NSA

Business Benefits

- Improve TDD performance by increasing user peak throughput for UEs capable of 1T2R/1T4R/2T4R/4T4R

Functional Description

- Due to the TDD structure, the channel state information acquisition is based on Uplink RS for Downlink channel estimation. This is 64x4 estimation matrix which is different than 4x4 PMI based channel state estimation

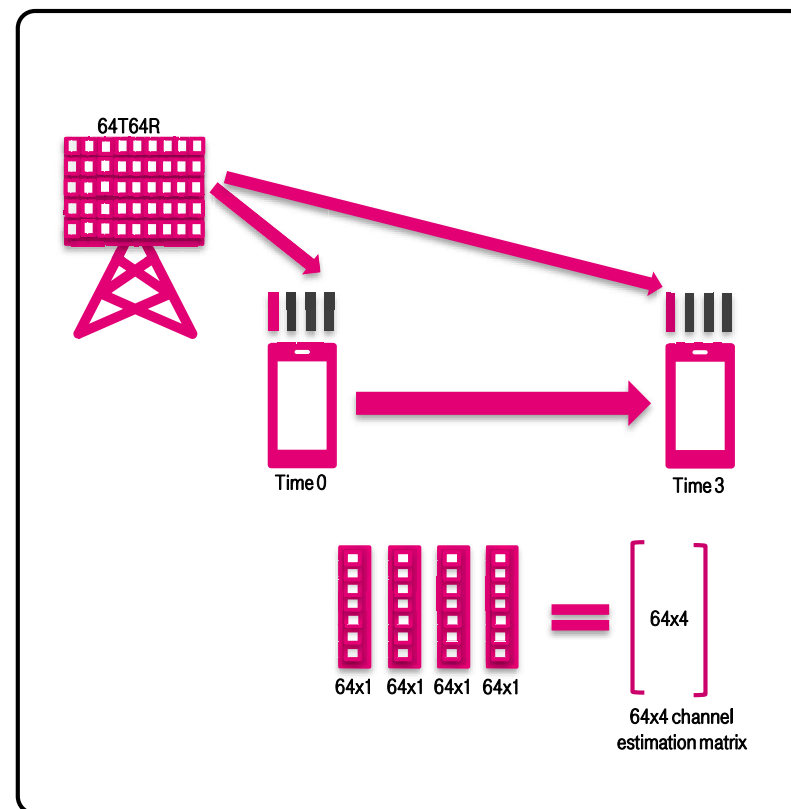
Device Requirements

- Follow 3GPP TS 38.214 6.2.1.2 and perform antenna switching based on network configuration (1T2R or 1T4R or 2T4R)
- Mandatory for n41 SA devices in 2021 and beyond
- Support required for NSA and SA

Development Plan

2022 Q2 > 2022 Q3 > 2022 Q4 > 2023 Q1 > 2023 Q2

◆ Launched



UE assistance handling: Overheating and No. of CC

Business Benefits

- Graceful device overheating handling in coordination with network

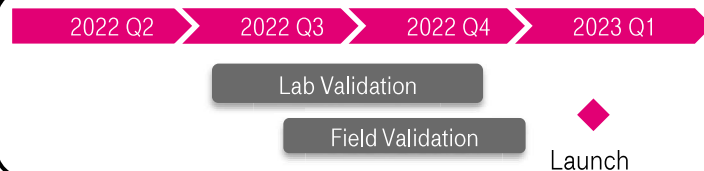
Functional Description

- UE transmits the UE Assistance Info to gNodeB when overheated
- Reduction of Scells by gNodeB due to overheating
- Scells are added back when overheating ends
- Feature applies to both TDD & FDD

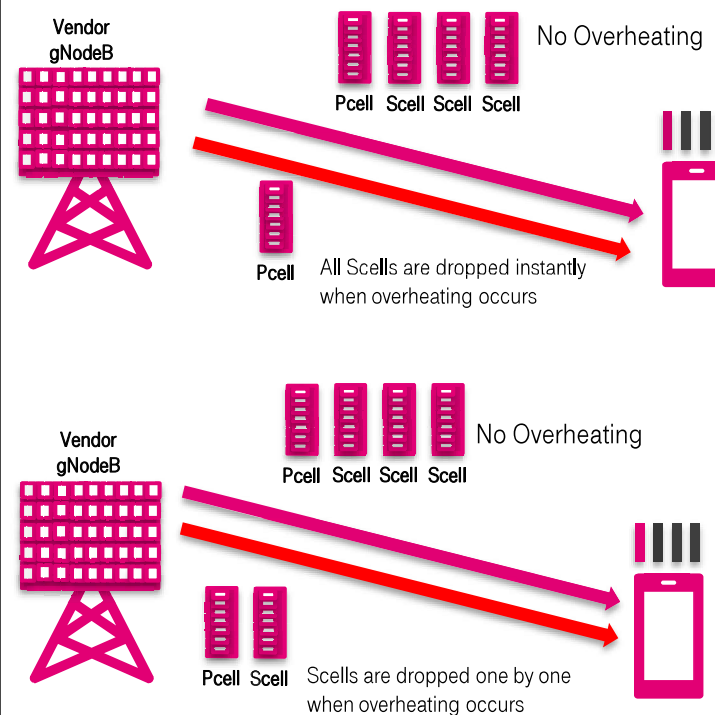
Device Requirements

- UE transmits the UE Assistance Info to gNodeB when overheated
- Support required for SA

Development Plan



4CC scenario



LTE to NR Packet Switched Handover

Business Benefits

- LTE to NR PSHO allows UEs in connected mode to gracefully transition from LTE (voice and data) to NR without packet loss or user interruption.

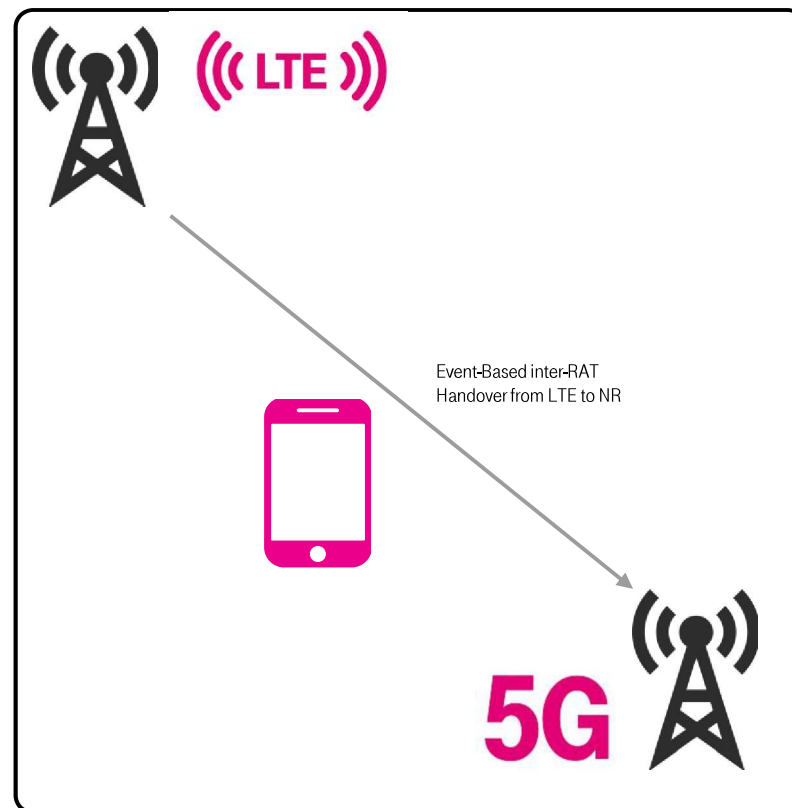
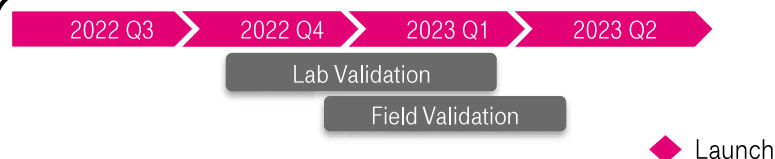
Functional Description

- UEs camped on LTE will be configured with handover events via RRC to which the UE can send measurement reports. If the UE's NR measurements meet the event thresholds, the UE will be transitioned from LTE to NR.

Device Requirements

- UEs will need to support the inclusion of the associated EUTRA IEs which advertise capability for EUTRA to NR handover capability.
- This feature is mandatory for SA capable UEs.

Development Plan



NR DL Single-User MIMO

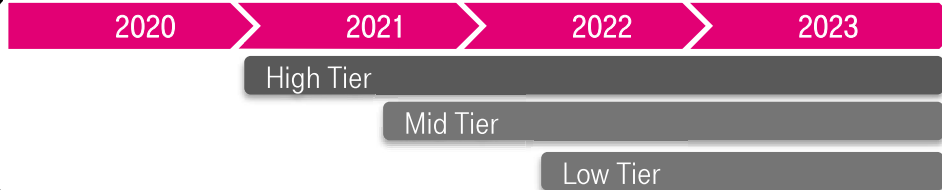
Business Benefits

- Increase in single user peak throughput
- Robust coverage due to spatially selective , user specific beamforming

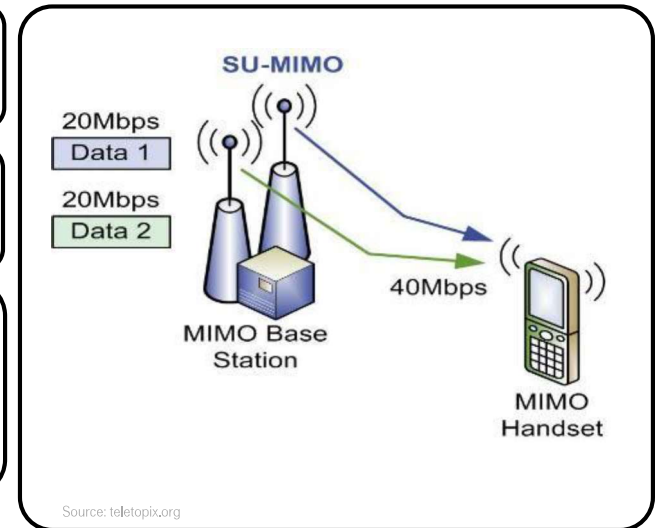
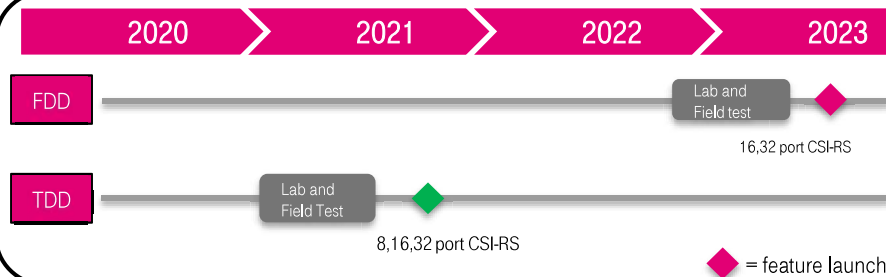
Functional Description

- In SU-MIMO, all the streams of antenna arrays are focused on a single user.
- The available SINR is split between multiple data layers towards the single target UE simultaneously, where each layer is separately beamformed.

Device Requirements



Development Plans



UE DEPENDENCY:

- Support of 4,8,16 and 32 CSI-RS ports with all codebook combinations of "Type1-SinglePanel" CSI feedback with PMI report
- Support Support of "maxlayerMIMO-Indication" IE
- Support of SRS Antenna switching

NR DL Multi-User MIMO

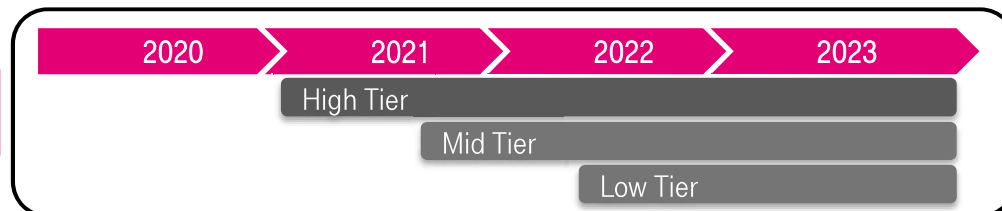
Business Benefits

- Increase in cell capacity
- Improved user experience even in loaded cells
- Improved cell coverage

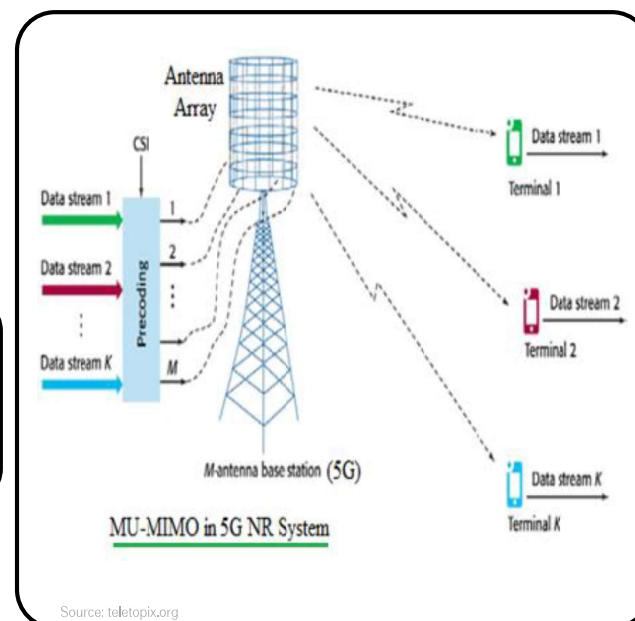
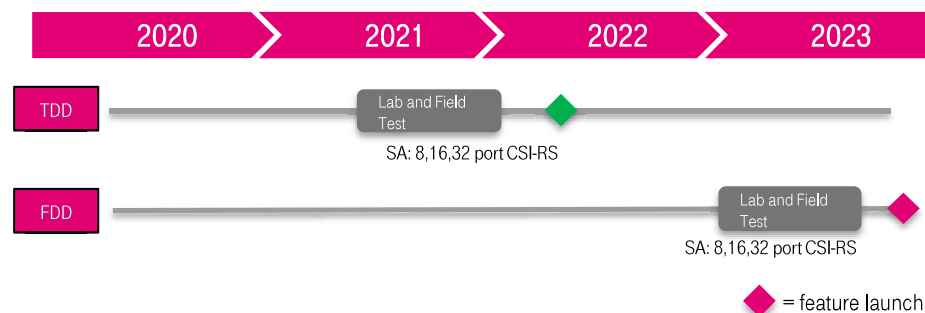
Functional Description

- In MU-MIMO, Multiple UEs are spatially multiplexed on different beams with the same resource blocks. Co-scheduled users must have orthogonal precoders.
- Available SINR is shared between multiple data layers towards multiple UEs simultaneously where each layer is separately beamformed.

Device Requirements



Development Plans



UE DEPENDENCY:

- Support of 32 and 16 CSI-RS port with all codebook combinations
- Support of "Type1-SinglePanel" CSI feedback with PMI report
- Support of RRC configured PDSCH DMRS scrambling ID
- Support of "maxlayerMIMO-Indication" IE
- Support of SRS Antenna switching

NR FDD and TDD UL MIMO

Business Benefits

- Higher SA uplink throughput, single UE with up to 2 layers transmission on the same physical resources
- UE average and peak throughput increase
- Uplink spectrum efficiency is increased, and hence the uplink cell throughput is increased

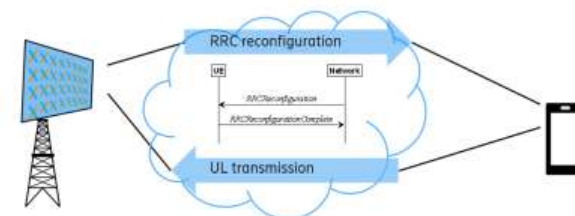
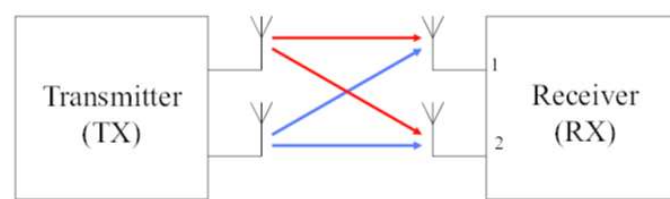
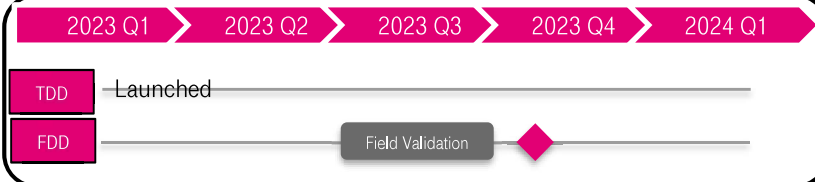
Functional Description

- The feature enables uplink transmission for one or two layers for FDD and TDD
- Basic principle of codebook-based transmission is that the network decides on an uplink transmission rank (number of layers) and corresponding precoder matrix to use for transmission
- The network informs the device about selected transmission rank and precoder matrix as part of the UL scheduling grant
- To select suitable rank and corresponding precoder matrix, the network need estimates of the channels between the device and antenna ports and the corresponding network receive antennas

Device Requirements

- Device shall follow technical requirements to enable/disable MIMO UE capabilities for the required NR bands including n41, n48, n77, n25, n66 and n71 (CPE only)
- Device requires 2 Tx hardware antennas

Development Plan



TPMI index	W	
	rank 1	rank 2
0	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 0 & 0 \end{bmatrix}$	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$
1	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 \\ \sqrt{2} & 1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 1 & 1 \\ 2 & 1 & -1 \end{bmatrix}$

Uplink Grant Skipping

Business Benefits

- Reduces UE power consumption and uplink interference while providing latency improvement in URLLC scenarios.

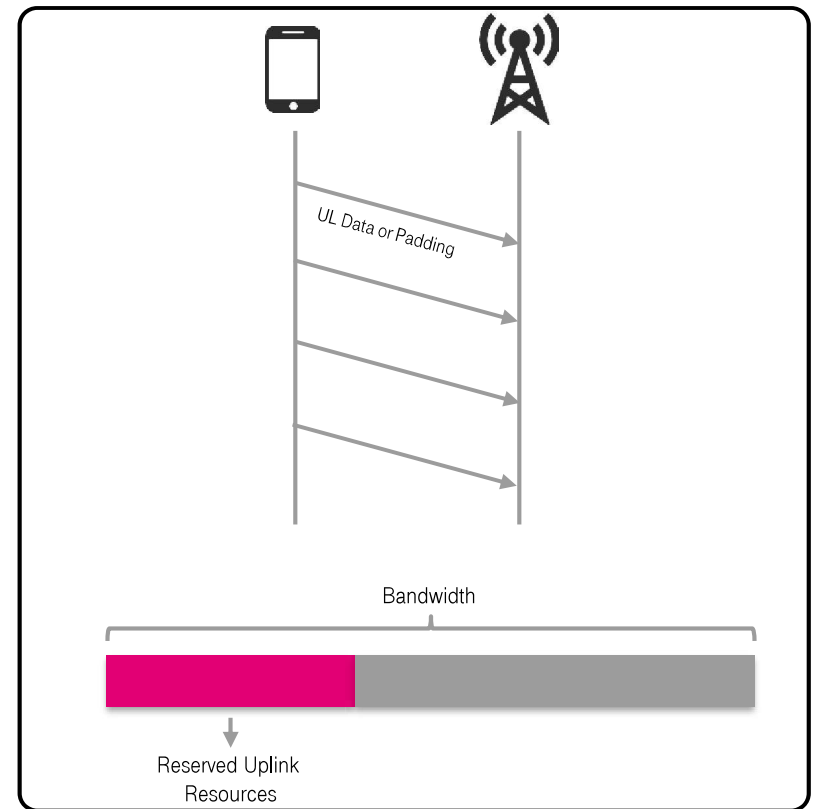
Functional Description

- Uplink Grant Skipping allows the UE to initiate uplink transmissions without sending scheduling request and waiting for grants which reduces needs for PDCCH resources. The feature also allows the UE to skip uplink grants when there is no data to transmit.

Device Requirements

- UEs with this feature shall advertise support for grant type 2 (for configured grant configurations) and appropriate enhancedSkipUplinkTx information elements corresponding to configured and dynamic skip uplink transmission.

Development Plan



NR Uplink 256QAM

Business Benefits

- Improve uplink throughput and spectral efficiency on both TDD and FDD bands

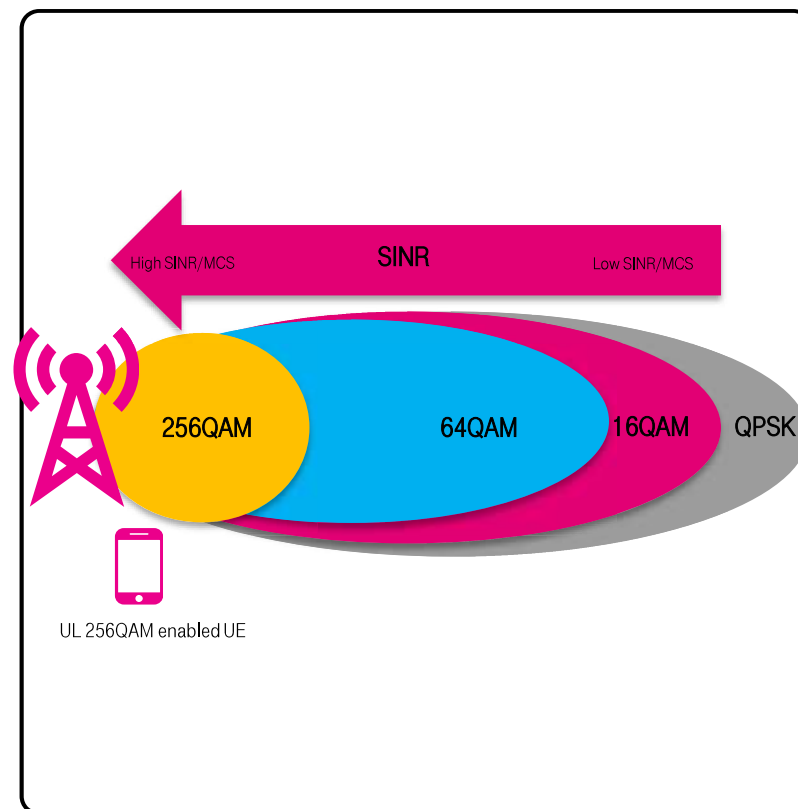
Functional Description

- In favorable channel conditions, MCS index values allocated for 256QAM are signaled via the gNB's link adaption algorithm on PDCCH DCI format 0_0 or 0_1 allowing for higher data transmission rates that are achieved by decreasing the distance between points of the constellation.

Device Requirements

- Mandatory support for SA and NSA devices in 2022 and beyond.
- Mandatory support for both FDD and TDD bands
- Mandatory for CP-OFDM and DFT-S-OFDM

Development Plan



NR DL 256QAM (FR2)

Business Benefits

- Improved DL speeds and spectral efficiency in good RF conditions

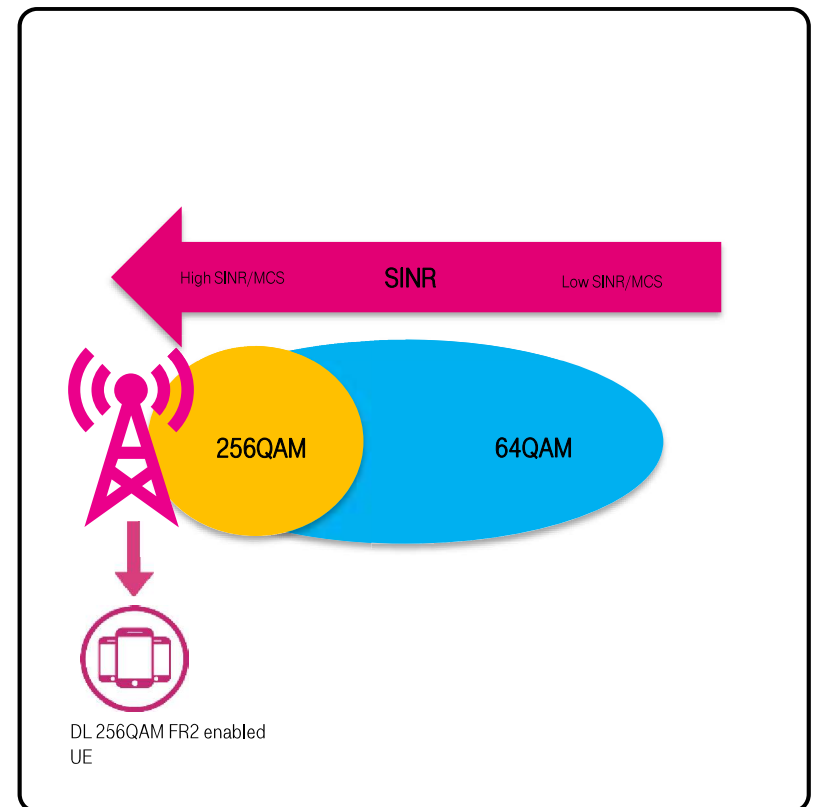
Functional Description

- This feature allows 256 QAM DL for mm-wave (FR2) sites. This will allow 8 bits per symbols as opposed to the 64 QAM DL which is 6 bits per symbol

Device Requirements

- Mandatory support for SA and NSA devices in 2022 and beyond.
- Mandatory support for all mmW bands (n260, n261 and n258)

Development Plan



Balanced TDD Pattern for FR2

Business Benefits

- Faster DL speeds in the special sub-frame and a more balanced UL for mm-wave (FR2)
- Uplink capacity increase for use cases like events at stadiums, IoT or time-critical services in local deployment scenarios

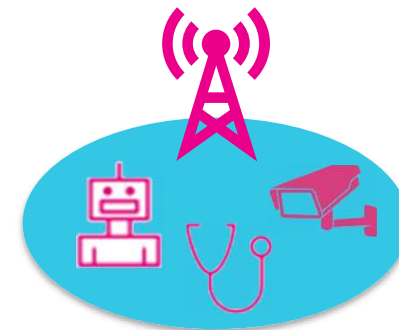
Functional Description

- This features sets up the TDD pattern DDSUU with the special sub-frame having 12:2:0 (DL:Guard Period: UL/SRS)

Device Requirements

- Mandatory support for SA and NSA devices in 2022 and beyond.
- Mandatory support for mmW bands

Development Plan



- Real-time media
- Remote control
- Industrial control
- Special Events and Venues (Stadiums)



NR Device Stand Alone Band Management

Business Benefits

- Enable layer management strategies to help steer devices to the target NR bands.
- Utilize network spectrum efficiently and maintain user experience

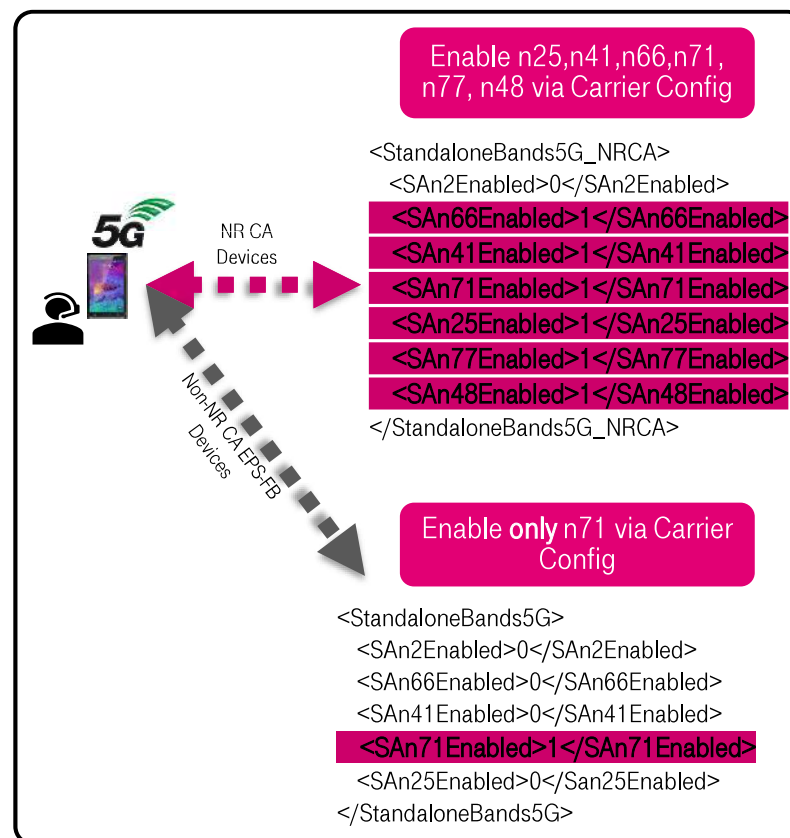
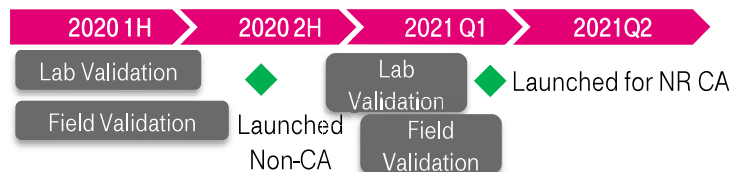
Functional Description

- To enable network layer management and load balancing as well as provide the best device user experience, devices must support SA band enablement through carrier config.
- NR Carrier Aggregation capable devices will be steered to n71, n66 and n25 to configure CA with n41 and must support Stand Alone on all Sub-6 bands.
- Non-NR Carrier Aggregation & EPS-FB capable devices will keep n71 band as standalone mode and must keep n41, n25 and n66 Stand Alone disabled by default.
- Both NR CA and Non-NR CA Devices must continue to support NSA

Device Requirements

- Device shall follow carrier configuration to enable/disable NR bands for all NR stand alone capable devices

Development Plan



VoNR — Voice over NR

Business Benefits

- Allows users to perform voice calls over NR without the need for a remaining LTE anchor
- VoNR enablement is an important step towards T-Mobile's goal of **EoNR (Everything over NR)**
- The ability to do everything over NR allows T-Mobile to transition more spectrum to 5G from other technologies over time, providing a better user experience on 5G

Functional Description

- VoNR, or voice over NR, is the full cooperation between device, RAN, and core to establish voice bearers over NR without the need to fallback to an LTE carrier, as required for EPSFB
- VoNR covers typical voice calls as well as emergency calls being established on NR
- This allows more flexibility as it requires only a single technology, also allows for lower latency when placing voice calls.

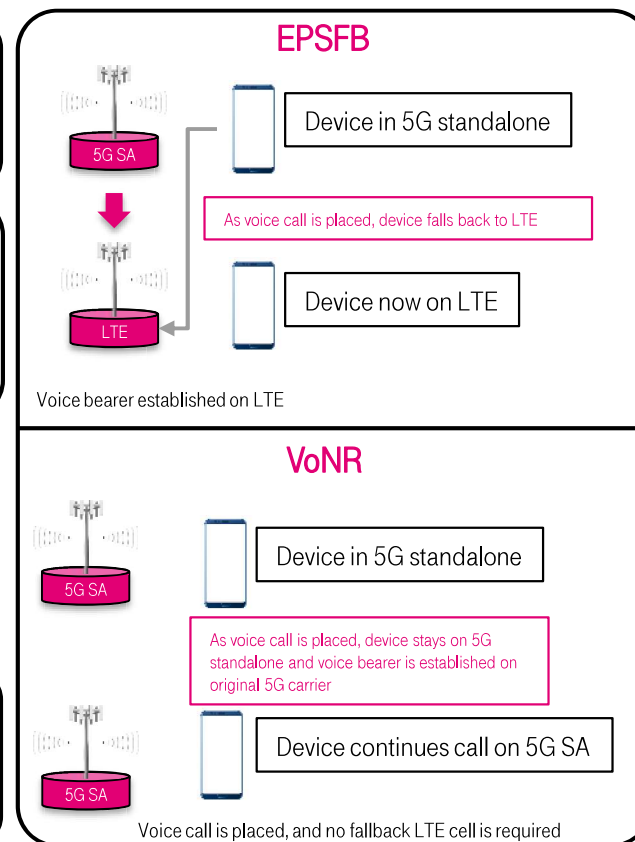
Device Requirements

- All 5G devices launching in 2021 must support VoNR, either at launch or by MR
- Device, chipset, RAN, and core must all support
- 5QI – 1 (GBR for voice), 2 (GBR for video call), 5 (for IMS), 6 (for data, RCS)
- Minimum 4 DRBS per session – Required to support all 5QI above at same time
- Mobility with voice bearers and GBR
- SOS DNN for Emergency calls

Development Plan



Transition and difference from EPSFB to VoNR



Network Selection UI Redesign

Business Benefits

- Improved and simplified user experience for the Network Selection menu option
 - User has visibility on 5G NR and 5G VoNR toggle options
 - Carrier Config allows TMO to disable 5G toggle if needed or remove it from UI display

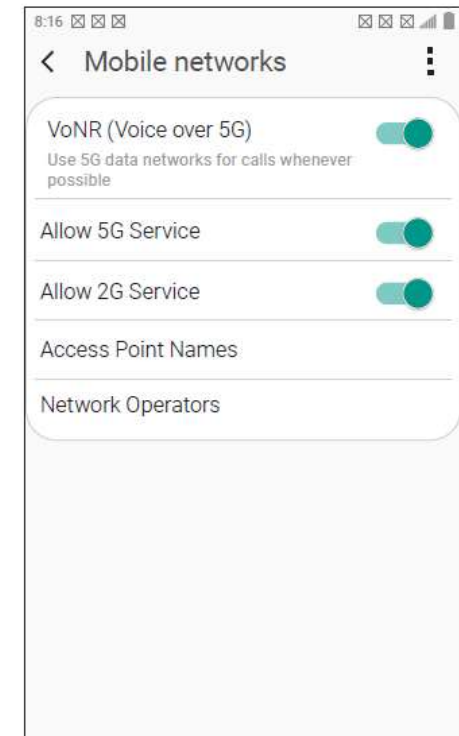
Functional Description

- The UI for the Network Selection menu has changed.
 - Instead of a drop-down list, the new UI will implement a 2G toggle and 5G toggle.
 - Users will be able to toggle 2G on/off and 5G on/off manually.
 - LTE and 3G will be enabled in the background by default.
 - Non-5G devices will not have the 5G and VoNR toggle switches.

Device Requirements

- The display for 5G toggle shall be controlled by Carrier Config.
- New devices must comply to the new requirements in the Q3 2023 or later releases of Carrier Config TRD and Network Connectivity TRD.

Development Plan



VoNR & 5G Toggle Interaction

Business Benefits

- On VoNR capable device, allow the user to turn off/on 5G and VoNR via UI toggles in the same UI menu page, with the built-in dependency between VoNR & 5G toggles.
- Allow the interaction between Carrier Config and the user control on VoNR and 5G toggles.

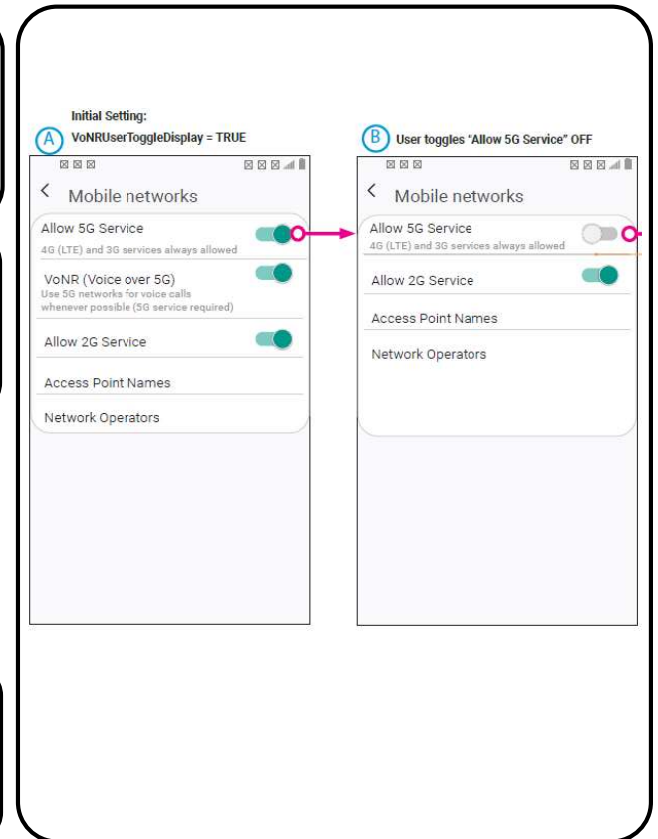
Functional Description

- Developed a complete set of logic for:
 - The dependency between VoNR & 5G toggles, and
 - The interaction between Carrier Config and the user control on VoNR and 5G toggles.

Device Requirements

- GID-MTRREQ-524076 (5G Voice TRD), with UI Wireframes attached with enhanced 5G&VoNR UI toggle interaction with Carrier Config, merged in the content of GID-MTRREQ-524524.
- **OEMs please treat this as a CR, and get it implemented on VoNR device ASAP.**

Development Plan



Bandwidth Part (BWP) – Device Requirements

Business Benefits

- Improves Battery efficiency.
- Flexibility in how resources are assigned in each carrier.
- Allows for legacy devices not supporting full carrier bandwidth to utilize portion of the bandwidth.

Functional Description

- A bandwidth part is a subset of contiguous common physical resource blocks (PRBs). A UE can be configured with up to four BWPs in the uplink or four BWPs in the downlink.
- Each carrier bandwidth has its own numerology and, thus, can have their signal characteristics, like reduce energy requirements or design for different services.
- Only one BWP can be active at a time.

Device Requirements

- FR1 TDD for 2021/1H 2022, FDD and FR2 mmW to follow.
- Intra/inter-band CA with BWP
- Support wireless Emergency Alerts (WEA) information (SIB8 info) when BWPs are configured by gNB
- Up to 4 BWP support as per TS 38.213/38.212 and 38.331
- BWP for both PCell and SCell
- BWP Switching DCI Based.
 - Cross Slot Scheduling of A-CSI-RS (rel 16)
 - Cross BWPs Scheduling DCI based (rel 16)

Development Plan

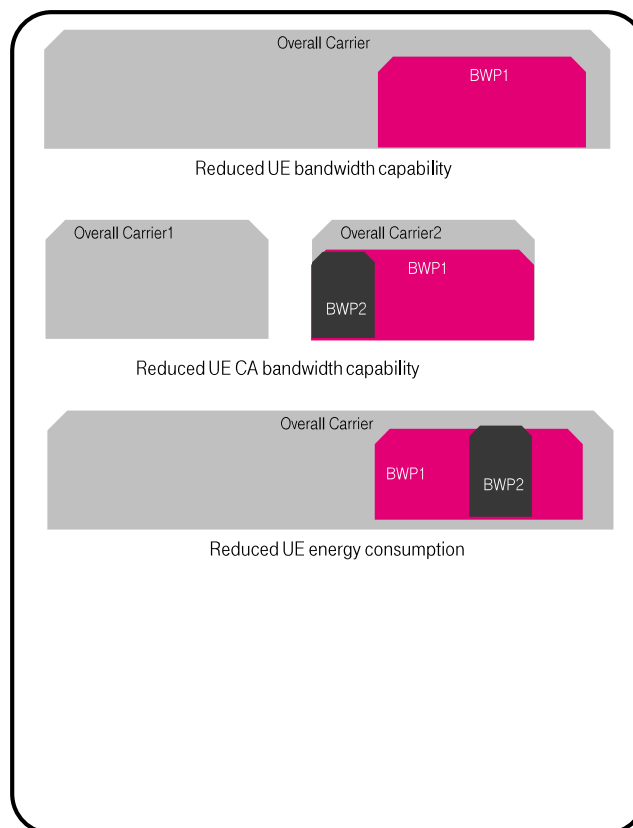


Diagram Source: Keysight

SIB24 New Scheduling Info (3GPP CR#4444)

Business Benefits

- Allow 5G SA devices to move from LTE to NR SA and utilize NR spectrum effectively

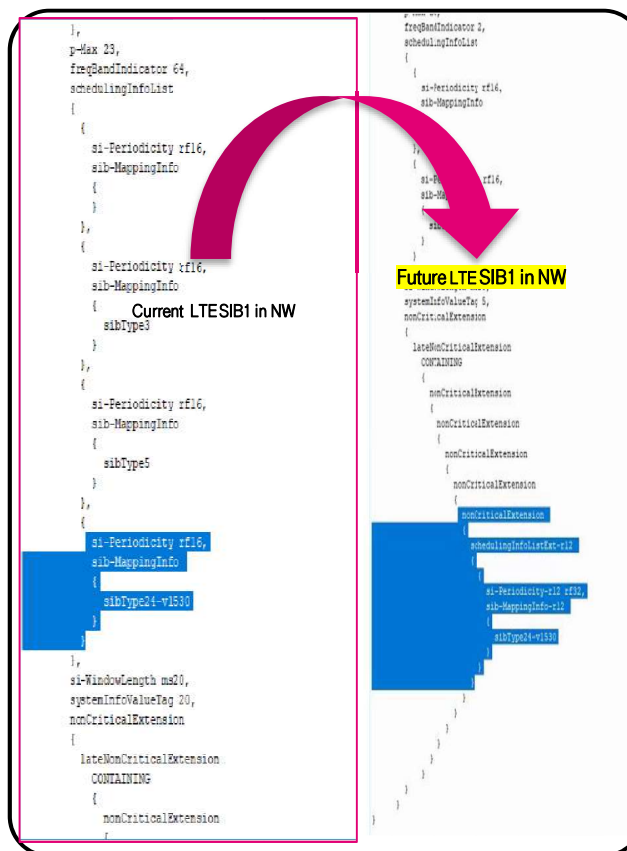
Functional Description

- SIB24 is used to move devices from LTE to NR SA in idle mode
- Because some legacy devices are impacted once SIB24 scheduling info is broadcast by the network, 3GPP released a CR to fix the issue.
- The new scheduling info of the SIB24 is ignored by the legacy devices therefore issue is solved for legacy devices.
- 5G SA devices should have this CR to understand the scheduling information and decode SIB24 properly for reselection to NR

Device Requirements

- All 5G SA devices shall integrate the new CR#4444 into their device software
- 3GPP CR covers all Rel15 SIBs 19 to 29
- Depending on T-Mobile strategy these can be scheduled differently and nonCriticalExtension should be covered for SchedulingInfoList-v12j0 or SchedulingInfoListExt.

Development Plan



CP-OFDM/DFT-s-OFDM Waveform Switching

Business Benefits

- Increase the 5G SA uplink coverage by switching waveform from CP-OFDM to DFT-s-OFDM which allows less maximum power reduction (MPR)

Functional Description

- Waveform switching mechanism enables devices to switch between CP-OFDM and DFT-s-OFDM waveforms. By using DFT-s-OFDM waveform at the cell edge the PUSCH coverage is improved 1-3 dB which is coming from newly introduced Pi/2 BPSK modulation
- Based on Uplink SINR, switch between CP-OFDM (high SINR, near cell, mid-cell) to DFT-s-OFDM (low SINR, cell edge)

Device Requirements

- Support CP-OFDM, DFT-s-OFDM
- Support switching RRC based
- Include necessary IE in UE Capability to support Pi/2 BPSK modulation (i.e *pusch-HalfPi-BPSK*)

Development Plan

2022 Q4

2022 Q1

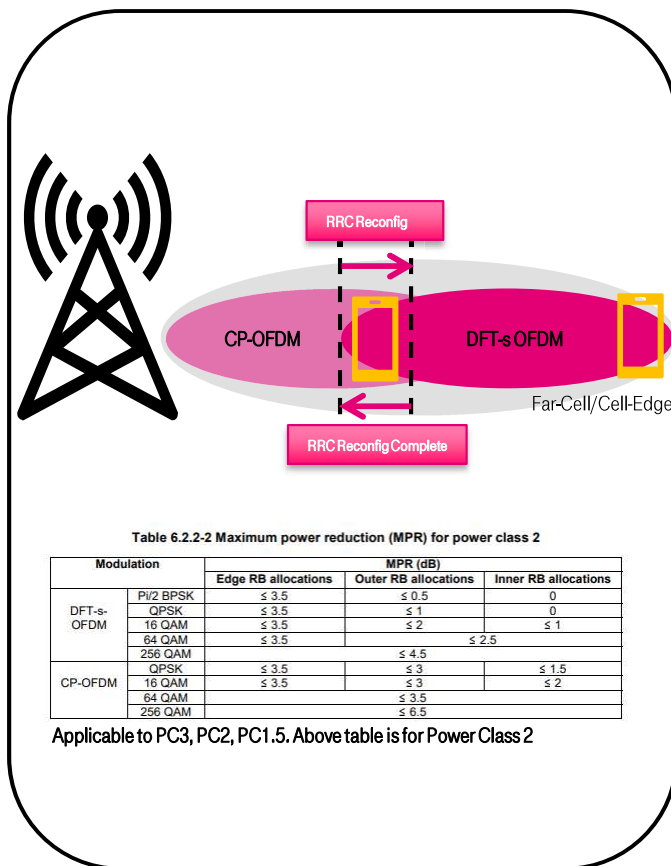
2022 Q2

2022 Q3

2023 Q4

Lab & Field Validation

◆ Launch



Closed Loop Power Control

Business Benefits

- Closed loop power control feature gives capability to manage better power control of the devices and manage better interference in the network

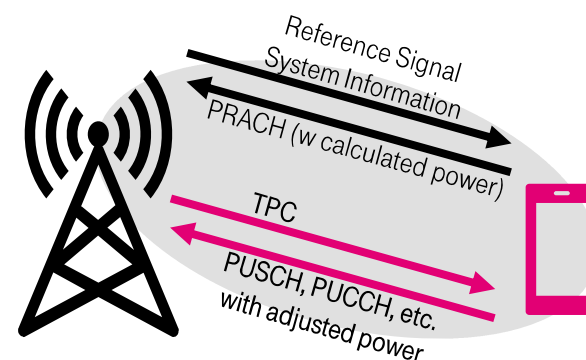
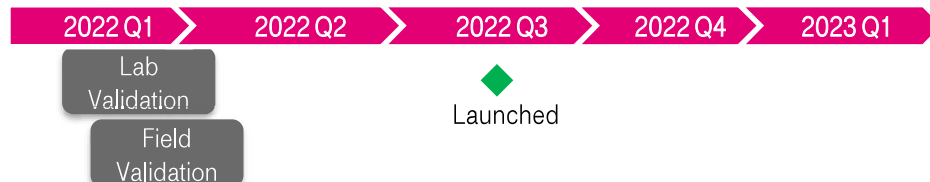
Functional Description

- With the help of closed loop power control gNB can send TPC (Transmit Power Control) command to the UE to increase the power and meet the required SNR or decrease to minimize interference in the network

Device Requirements

- Comply with
 - 38.213 NR Physical Layer
 - 38.321 NR Medium Access Control (MAC)
 - 38.331 NR Radio Resource Control (RRC)

Development Plan



NR SA Robust Header Compression (RoHC)

Business Benefits

- RoHC feature is bringing header compression for IP protocol-based services as each service competes for resources to bring Quality of Service to the customer

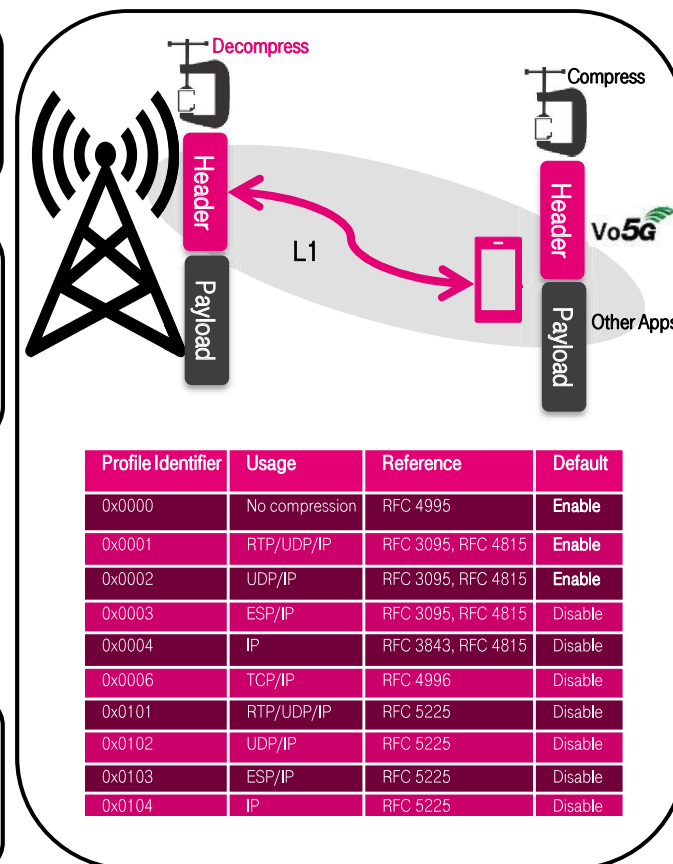
Functional Description

- In services like voice, messaging, gaming, etc. payload of the IP packets is almost same size or much smaller compared to the header therefore the header can be compressed at UE and can be decompressed at gNB. By doing this, IP header compression may provide better bandwidth usage, less packet loss or even better latency in networks where many users are connected

Device Requirements

- Device should provide supported RoHC profiles in NR UE Capability Information and
- Comply with
 - 38.223 Packet Data Convergence Protocol (PDCP)
 - 38.331 NR Radio Resource Control (RRC)

Development Plan



NR Cell Reselection Sub Priority

Business Benefits

- Layer Management and steering devices in Idle mode between LTE and NR for optimized network experience
- To steer devices in idle mode between LTE and NR current cell reselection priority is not sufficient to cover all T-Mobile LTE and NR layers.
- The feature NR cell reselection sub priority overcomes this limit by providing a sub-priority

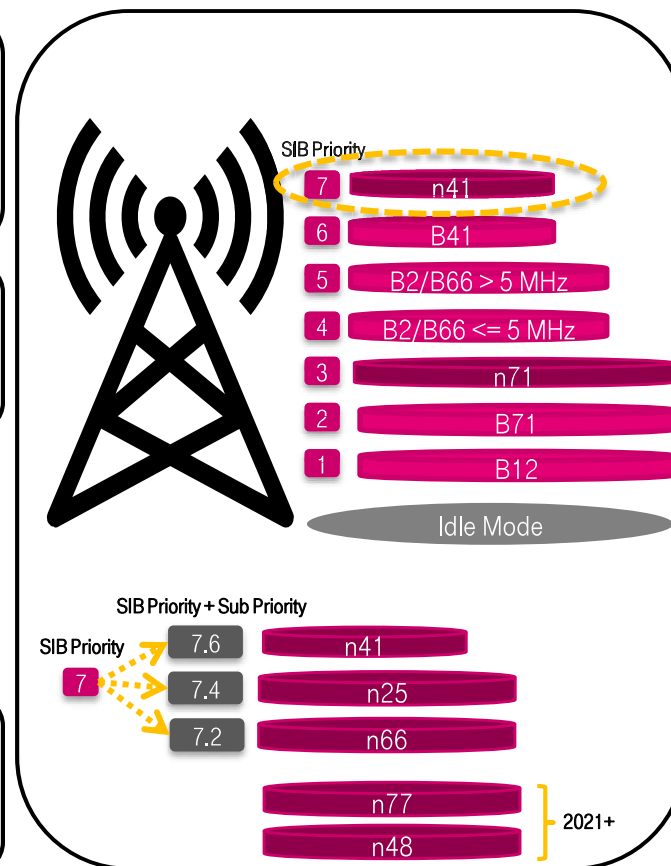
Functional Description

- NR cell reselection sub priority specifies the fractional priority value added to cell reselection priority for NR and LTE
- It will be used for NR to NR , NR to LTE and LTE to NR cell reselection

Device Requirements

- Required for all 5G devices for operation on T-Mobile 5G network
- Follow 3GPP TS 38.331
- Decode Cell Reselection Sub Priority from SystemInformation messages and perform NR to NR , NR to LTE and LTE to NR cell reselection in idle mode as broadcasted by network

Development Plan



RRC Inactive Mode

Business Benefits

- Bring back devices to connected mode as quickly as possible and reduce signaling during transition

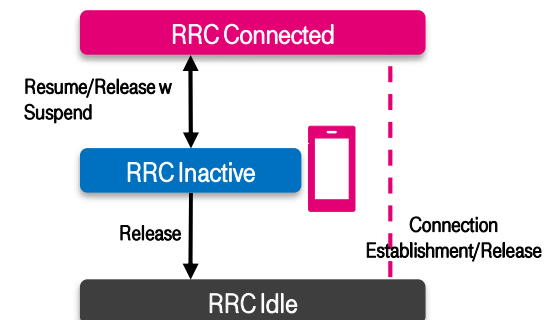
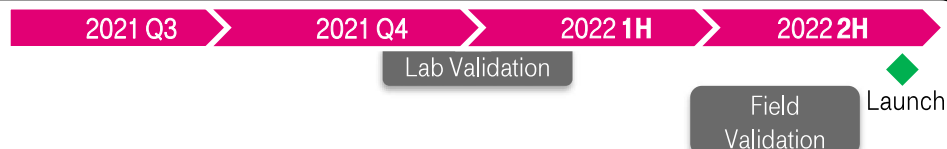
Functional Description

- Frequent transmission of small packets is very common considering latest smartphone applications and the result is frequent transition between idle and connected mode. These transitions come with a huge signaling cost and network load which can result in latency. Reducing the signaling and load will also reduce the latency and because of this new 3rd state "RRC Inactive state" is defined in NR 5G

Device Requirements

- Comply with
 - TS 38.331 Radio Resource Control (RRC); Protocol specification
 - TS 38.304 User Equipment (UE) procedures in idle mode and in RRC Inactive state
- Support RRC Inactive State and all necessary IEs

Development Plan



CV2X – Cellular Vehicle-To-Everything

Business Benefits

- Introduction of cutting-edge services such as but not limited to:
 - Connected cars Applications.
 - Self Driving Cars.
 - Autonomous Taxi Apps
 - Multi traffic autonomous communication

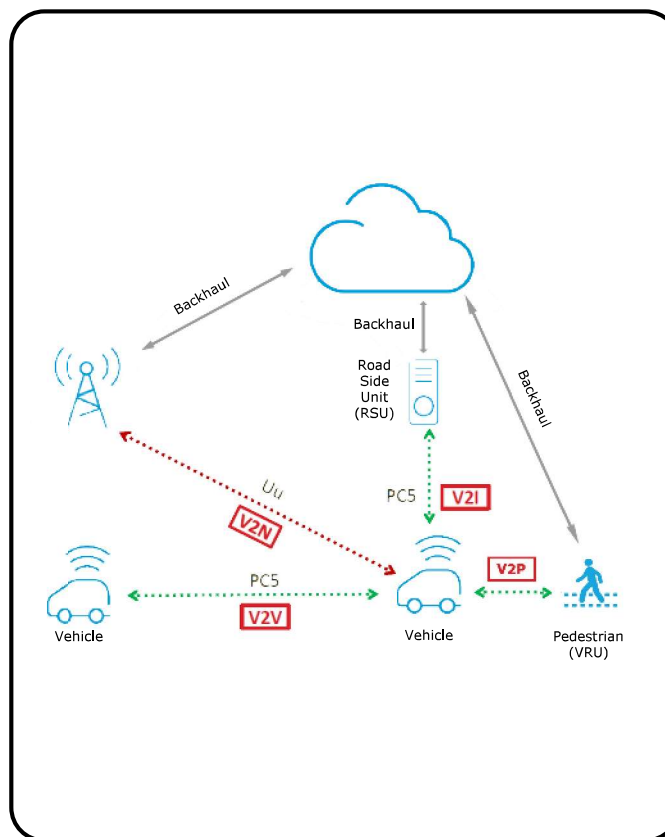
Functional Description

- Sidelink GroupCast and Unicast
- Periodic/Aperiodic Traffic type
- PSFCH
- NR/LTE Uu sidelink control.
- AM/UM RLC state machine
- PC5 radio link management based.

Device Requirements

- Sidelink groupcast support
- PSFCH support
- AM/UM RLC state support

Development Plan



5G Ultra Capacity Icon

Business Benefits

- 5G UC Icon is a customer facing endorsement of Ultra Capacity 5G
- T-Mobile wants to inform users when they are served by the Ultra Capacity network by displaying a "5G UC" icon on the phone
- 5G UC icon display matches our recently published 5G map
- Network already serving 225 Million POPs with n41 (2.5 GHz)

Functional Description

- 5G UC Icon to be shown when camping or connected to NR on 2.5 GHz or mmW
- For NR FDD only cases a minimum Bandwidth check must be met
- 5G UC Icon must have support for control via Carrier Config
 - 5G Band definition as 5G UC or 5G
 - Bandwidth Check parameters

Device Requirements

- Devices should comply to the use cases on the table on the right
- Requirements are included in 5G NR TRD (Q2 2022)
- FDD BW Check included in 5G NR TRD (Q1-2023)
- Mandatory for all customer brands (T-Mobile, Sprint, Metro and Assurance)

Development Plan



Some implementations will include BW check for both TDD and FDD

5G UC

5G UC Use Cases

Scenario	5G Band	Regular 5G Icon	5G UC Icon New
Connected	n71, n25, n66 NSA/SA < Min BW	5G	5G
	n71, n25, n66 NSA/SA >= Min BW	5G	5G UC
	n41 or mmW NSA	5G	5G UC
	n41 SA	5G	5G UC
	NRCA - UC Band is Primary or Sec. cell (ex.n66+n41)	5G	5G UC
	NRCA FDD aggregated BW > Min BW	5G	5G UC
Idle	n71, n25, n66 NSA/SA < Min BW	5G	5G
	n71, n25, n66 NSA >= Min BW	5G	5G UC w memory*
	n41 NSA or mmW NSA	5G	5G UC w memory*
	n41 SA	5G	5G UC
	n71, n25, n66 SA >= Min BW	5G	5G UC
	NR CA with UC band as Primary or FDD Pcell w BW >= Min BW	5G	5G UC
EPSFB	NR CA with non-UC Band Primary UC band Secondary	5G	5G UC w memory*
NSA VoLTE	UE has 5G UC icon and voice call	5G	5G UC w memory*

Additional Requirements

Design must include future flexibility to designate future bands as Ultra Capacity and to check minimum aggregated NR BW as per parameter (40MHz) for FDD (Single band or NRCA)

- Follow a 30 second (Configurable) refresh timer for transitions between 5G and "5G UC"
- "Memory/Retain "5G UC" in Idle Mode and EPSFB until
 - RAT Change to LTE
 - NR added for non-Ultra Capacity band
 - mobility to a new cell for both NSA and SA

Ultra Capacity Band must be determined through Carrier Config
Initial Launch of UC: n41 and mmW

Bandwidth Combination Set 4 Support (BCS4)

Business Benefits

- Flexibility in adding new bandwidth combinations without creating new BCS per combination

Functional Description

- When UE report support of BCS4 for the NRCA NRDC combination the network can allow adding any individual BW for each band in the combination if it does not exceed the max channel bandwidth for the band

Device Requirements

- Request to support BCS4 for all combinations
- BCS4 was approved in 3GPP RAN4 in September 2021

Development Plan BCS4

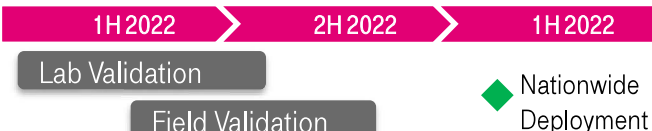


Table 5.3.5-1 Channel bandwidths for each NR band

NR Band	SCS (kHz)	UE Channel bandwidth (MHz)														
		5	10	15	20	25	30	35	40	45	50	60	70	80	90	100
n41	60															
	15															
	30															
	60															
n66	15	5	10	15	20	25	30	35 ^a	40	45 ^a						
	30															
	60															
	60															

- Table 5.3.5-1 shows that n41 supports 70MHz and n66 45MHz
- BCS0 and BCS1 from table 5.5A.3.1-1 for CA_n41A-n66A do not specify combinations with n41 70MHz or n66 45MHz
- If network is configured with n41 70MHz or/and n66 45MHz and UE advertises support for BCS4 than the network should assigned CA_n41A-n66A even if these BWs are not part of any BCS
- Without BCS 4 support, this NR Carrier Aggregation cannot be assigned

Table 5.5A.3.1-1: NR CA configurations and bandwidth combinations sets defined for inter-band CA (two bands)

NR CA configuration	Uplink CA configuration or single uplink carrier ¹⁸	NR Band	Channel bandwidth (MHz) (NOTE 3)													Bandwidth combination set
			5	10	15	20	25	30	40	50	60	70	80	90	100	
CA_n41A-n66A	n41 ¹⁹ CA_n41A-n66A ⁸	n41														0
		n66	5	10	15	20			40	50	60					1
		n41														
		n66	5	10	15	20			40	50	60					1
		See n41 channel bandwidths in Table 5.3.5-1 See n66 channel bandwidths in Table 5.3.5-1													4 and 5	
		n41														

Example based on 38,101-1 V17.4.0 (2021-12)

BCS and Bandwidth combination requirements for TDD+TDD Aggregation

Business Benefits

- Ensure devices with different T+T aggregated BW support enable all BCS and bandwidth combinations to work on T-Mobile network

Max 100MHz T+T

N41C (Contiguous Aggregation)

- Not required as BW is not greater than 100MHz

N41(2A) (Non-Contiguous)

- Support BCS 0,1,2,3,4
- 90 MHz + 10 MHz
- 80 MHz + 20 MHz
- 70 MHz + 30 MHz
- 60 MHz + 40 MHz
- 50 MHz + 50 MHz

Max 120MHz T+T

N41C (Contiguous Aggregation)

- Support BCS 0,1
- 100 MHz + 20 MHz

N41(2A) (Non-Contiguous)

- Support BCS 0,1,2,3,4
- 100 MHz + 20 MHz
- 90 MHz + 30 MHz
- 80 MHz + 40 MHz
- 70 MHz + 50 MHz
- 60 MHz + 60 MHz

Max 140MHz T+T

N41C (Contiguous Aggregation)

- Support BCS 0,1, 2, 4
- 100 MHz + 40 MHz

N41(2A) (Non-Contiguous)

- Support BCS 0,1,2,3,4
- 100 MHz + 40 MHz
- 90 MHz + 50 MHz
- 80 MHz + 60 MHz
- 70 MHz + 70 MHz

Max 200MHz T+T

N41C (Contiguous Aggregation)

- Support BCS 0,1, 2, 4
- 100 MHz + 100 MHz

N41(2A) (Non-Contiguous)

- Support BCS 0,1,2,3,4
- 100 MHz + 100 MHz

Low Latency 5QI

Business Benefits

Allows T-Mobile to allocate particular 5QIs for use cases requiring lower latency function such as AR/VR

Functional Description

Low latency 5QIs have lower allowed latency when compared to standard 5QIs and allow new use cases which require low latency.

For example, 5QI 80 has an allowed latency of 10ms, compared to 5QI 1 or 5QI 6 which are 100-300ms.

Device Requirements

Device must support 5QI 80, 82-85

Most of the critical lower latency functionality is done at RAN and core level, but device must be able to support network assigning low latency 5QIs

Development Plan



5QI Value	Resource Type	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Maximum Data Burst Volume	Default Averaging Window	Example Services
80	Non-GBR	68	10 ms	10^{-6}	N/A	N/A	Low Latency eMBB applications Augmented Reality
82	Delay Critical GBR	19	10 ms	10^{-4}	255 bytes	2000 ms	Discrete Automation (TS 22.261[2])
83	Delay Critical GBR	22	10 ms	10^{-4}	1354 bytes	2000 ms	Discrete Automation; V2X messages
84	Delay Critical GBR	24	30 ms	10^{-5}	1354 bytes	2000 ms	Intelligent transport systems (TS 22.261[2])
85	Delay Critical GBR	21	5 ms	10^{-5}	255 bytes	2000 ms	Electricity Distribution high voltage, V2X messages

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- Spectrum and Frequency Bands
- 5G Device Requirements and Roadmap
- **Fixed Wireless Access** **NEW SECTION**
- Internet of Things
- Regulatory and Location Technology
- Device and IMS Services
- Additional Material

Technology Guidelines for Fixed Wireless Access Products

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T-Mobile®

Key 5G Radio Requirements for Fixed Wireless Access

1H'23

2H'23

2024 & Beyond

5G EN-DC Operation

3GPP Rel-15

3GPP Rel-16

- EN-DC n71 & n41
- EN-DC 2CC DL NR CA
- UL 256QAM
- EN-DC SRS Ant. Sw. (1T4R)
- HPUE PC 2
- 4x4 MIMO on Low & Mid

5G SA Operation

Spectrum

- Bands: n25,n41,n66,n71,n77, n48
- n25 and n66 Bandwidth > 20 MHz
- Bandwidth Combination Set 4 (BCS 4)

Speeds, Coverage and Efficiency

- UL 256QAM
- 2CC DL NR Carrier Aggregation
- SRS Antenna Switching (2T4R)
- HPUE PC 2 (ULFP Mode 0,1,2)
- HPUE PC 1.5 (ULFP Mode 1, Transmit Diversity)
- 2 Layer UL-MIMO FDD and TDD
- 8 DL Receive Diversity on TDD
- 4x4 MIMO on Low & Mid Bands

5G EN-DC Operation

3GPP Rel-15

3GPP Rel-16

- EN-DC n71 & n41
- EN-DC 2CC DL NR CA
- UL 256QAM
- EN-DC SRS Ant. Sw.
- HPUE PC 2
- 4x4 MIMO on Low & Mid

5G SA Operation

Spectrum

- Bands: n25,n41,n66,n71,n77, n48
- n25 and n66 > 20 MHz bandwidth
- Bandwidth Combination Set 4 (BCS 4)

Speeds, Coverage and Efficiency

- UL 256QAM
- 2CC DL NR Carrier Aggregation
- SRS Ant. Switching (2T4R)
- HPUE PC 2 (ULFP Mode 0,1,2)
- HPUE PC 1.5 (ULFP Mode 1, Tx/D)
- 2 Layer UL-MIMO FDD and TDD
- 8 DL Receive Diversity on TDD
- 4x4 MIMO on Low & Mid Bands
- **Uplink NR CA FDD+TDD**
- **3Tx (UL MIMO + SISO)**

Under Research for potential future implementation

3GPP Rel-17/18

All Requirements for 2023

Additional 5G SA Operation

- 1024 QAM DL FR1 – Rel-17
- DL 256 QAM 8 Layer
- DL 8Rx Diversity – Rel-17
- UL 8Tx Diversity – Rel-17
- UL 4x4 MIMO 4Tx – Rel-18
- UL 4x4 MIMO 8Tx – Rel-18 (2Tx per MIMO Branch)
- UL NR CA 2CC T+T, T+F – Rel-17
- UL NR CA 3CC 2T+F, T+2F – Rel-18
- HPUE PC 2 for n25,n66 – Rel-17/18 (Power Class Release Independent)
- HPUE PC 2 with UL NR CA – Rel-17
- HPUE PC 1 for TDD and FDD – Rel-18

Key 5G Radio Requirements for Fixed Wireless Access (2023)

Device Technologies	Priority	Benefit
Radio Access		
5G NSA (Non-Stand Alone)	Mandatory	Primary 5G high-speed network through 2030
5G Stand Alone	Mandatory	Long-term independence from LTE with 5G RAN and Core, Enables advanced 5G Features. Lower Latency.
LTE	Mandatory	Fallback in case of 5G no coverage or failures
Bands & Spectrum		
NR Basic: NR 71, 41, 25, 66	Mandatory	NR Basic: Primary 5G Bands for coverage and speed
NR High Speed: mmW	Optional	NR High Speed: Highest 5G speeds, limited coverage
NR High Speed: n48	Mandatory	NR High Speed: Additional Capacity on TDD
NR C-Band n77 incl DoD	Mandatory	Additional 5G mid-band capacity leveraged with NR CA
LTE Basic: B2, 12, 66, 71, 41	Mandatory	Primary LTE Bands for coverage and speed LTE Band 41 adds speed but not coverage
LTE High Speed: B46, B48	Optional	High LTE speeds, limited coverage
Carrier Agg		
Carrier Agg: 2 DL CA FDD+TDD	Mandatory	Improved coverage of TDD and improved speeds
Carrier Agg: 2DL CA TDD+TDD	Mandatory	Increase DL speeds and utilization of 2.5 GHz spectrum
Carrier Agg: 2DL CA FDD+FDD	Mandatory	Improved coverage and speeds cell middle-cell edge and Rural 5G
Carrier Agg: 3 and 4 DL CA	Preferred	Increase DL speeds and utilization of all spectrum bands, 3 FDD NR CA required for Rural 5G.
Carrier Agg: NR Dual Conn (FR1+FR2)	Optional	Highest speeds in standalone mode by aggregating mmW bands and Sub 6 GHz bands.

Device Technologies	Priority	Benefit
5G Data Features		
HPUE		
HPUE: PC2 for n41 and n77 SA	Mandatory	Improve coverage on 2.5 GHz and 3.5 GHz
HPUE: PC 1.5 for n41 and n77 SA	Mandatory	Improve coverage on 2.5 GHz and 3.5 GHz
AAS and Spectral Efficiency Features		
16 and 32 Ports CSI-RS DL MIMO	Mandatory	Improved DL speeds at cell edge without additional spectrum
2-Layer UL SU-MIMO (2 Tx)	Mandatory	Doubles UL speeds and performance
4x4 DL MIMO on NR low and mid (n71, n41, n25 and n66)	Mandatory	Improved DL speeds and performance
SRS Antenna Switching for NSA and SA	Mandatory	Improved DL speeds and performance
8 Rx DL Receive Diversity	Mandatory	Improved Speed, coverage and capacity
UL 256 QAM	Mandatory	Improved UL speeds and performance
Spectral Compatibility		
Bandwidth Parts	Mandatory	Allows devices to operate on a limited block of 5G spectrum
Bandwidth Combination Set	Mandatory	Allows devices to aggregate channels of varying bandwidths
n41 Bandwidth Support	Mandatory	Support 20,30,40,50,60,70,80,90,100 MHz Aggregated BW of two carriers up to 200 MHz
n77 Bandwidth Support	Mandatory	Support for 10, 20,30,40,50,60,70,80,90 and 100 MHz
> 20 MHz N25 and n66 bandwidth support	Mandatory	Support for 25,30, 35 and 40 MHz spectrum bandwidths

FR1 3Tx (SISO + MIMO) Uplink

Business Benefits

- Increased Uplink Throughput and improved user experience
 - Performance improvement through Uplink NR CA
 - Coverage improvement during Uplink NR CA (F+T, T+F)

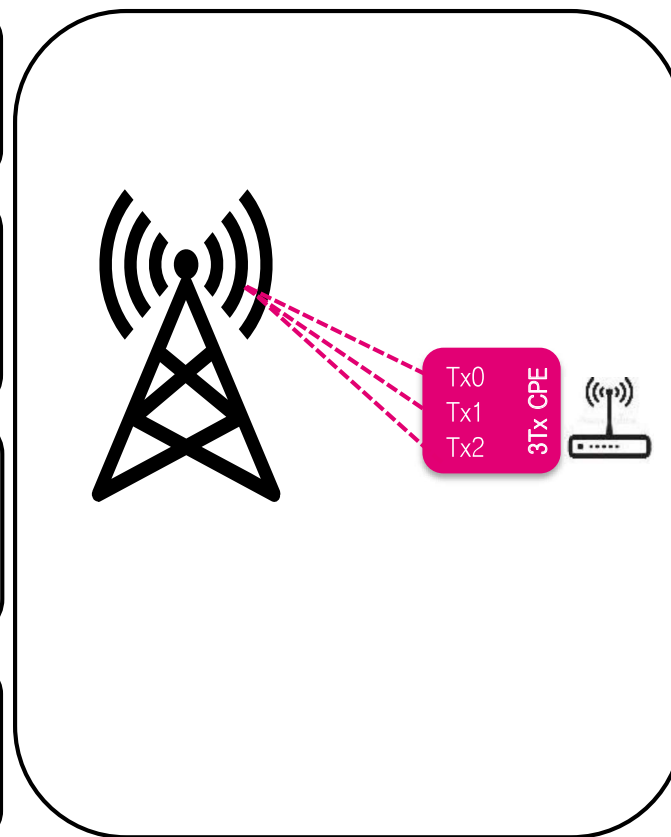
Functional Description

- 3Tx UL SISO + MIMO bring benefits without network infrastructure upgrades
 - Increased UL throughput by using 3Tx antennas where TDD is 2Tx and FDD is 1Tx during UL NR CA
 - Improved or matched Uplink Coverage/Performance w PC 1.5 on TDD
 - And overall improved customer experience

Device Requirements

- 3Tx Uplink operation capable chipset
- 3 Transmit Antennas and suitable RF IC
- Required to support *higherPowerLimit-r17*

Development Plan



8Rx DL Receive Diversity

Business Benefits

Increased Capacity, Coverage and improved user experience

- Coverage improvement through Rx Sensitivity improvement
- Capacity improvement through more CPEs for the same cell coverage

Functional Description

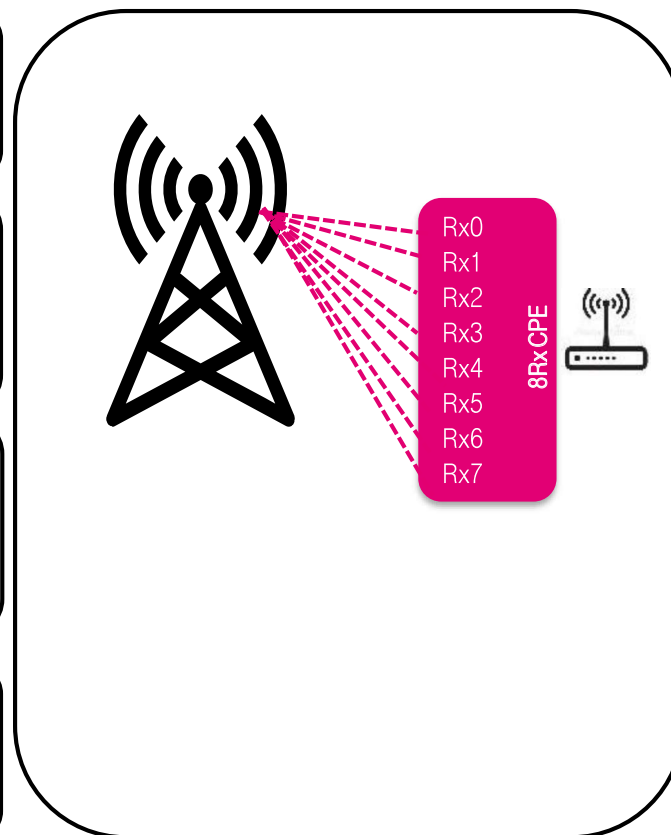
8Rx DL Receive Diversity brings several benefits without network infrastructure upgrades

- Increased spectral efficiency therefore more higher order modulation usage
- Improved high number of DL layers therefore improved MIMO performance
- 3 dB improvement in Rx Sensitivity
- And overall improved customer experience

Device Requirements

- 8Rx DL Receive Diversity capable chipset
- 8 Receive Antennas and suitable RF IC
- Required with DL NR Carrier Aggregation and up to 200 MHz aggregated BW
- Required for NR TDD Bands

Development Plan

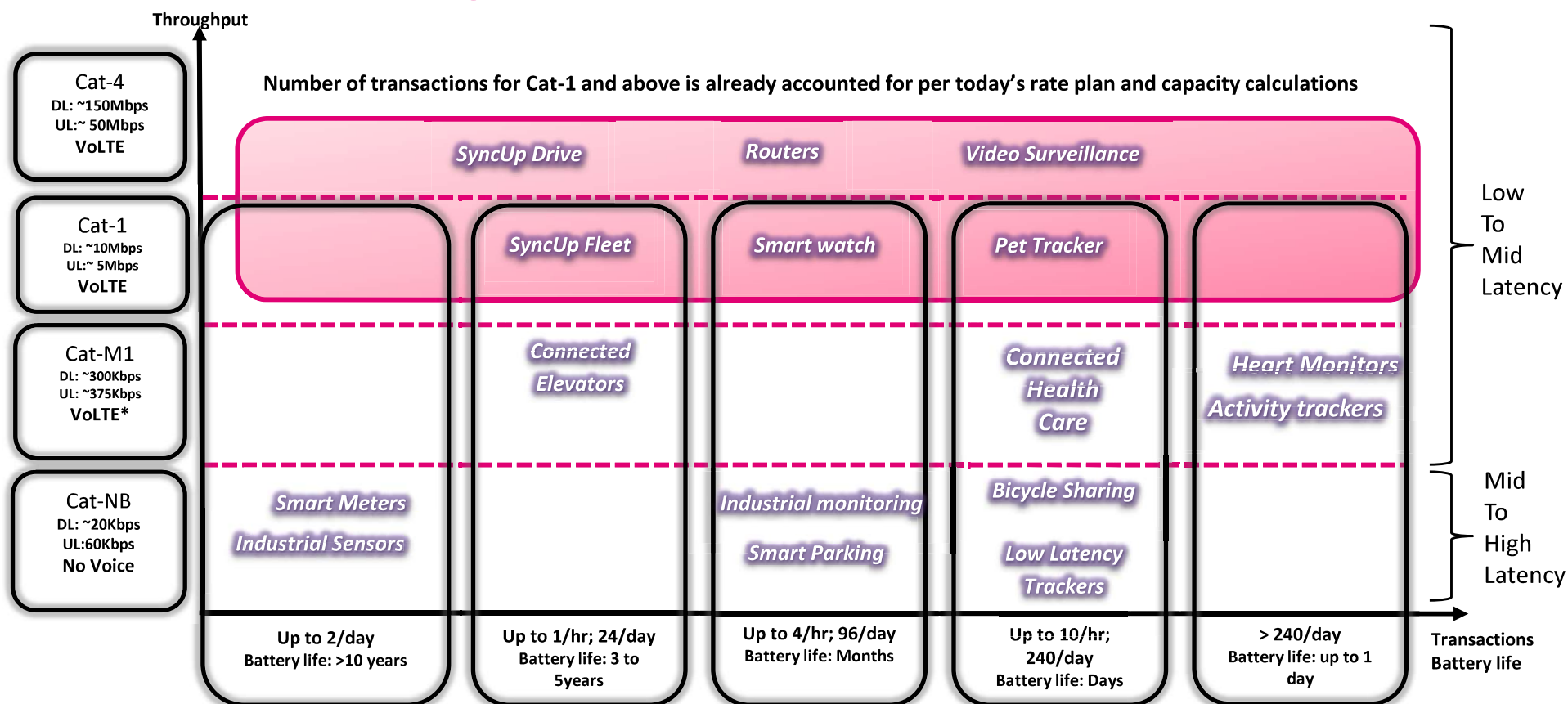


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IoT Device Categorization with Sample Use Cases

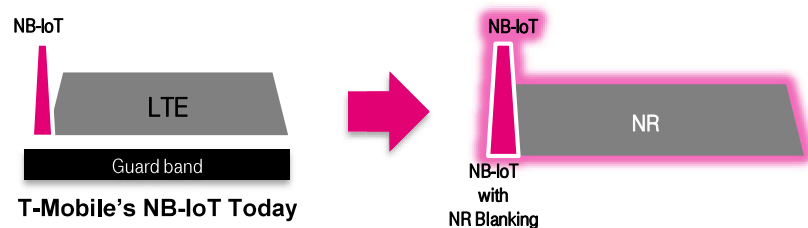


Long battery life based on PSM/eDRX features

* Technology supports VoLTE but not plan for deployment due to Quality and capacity constraints

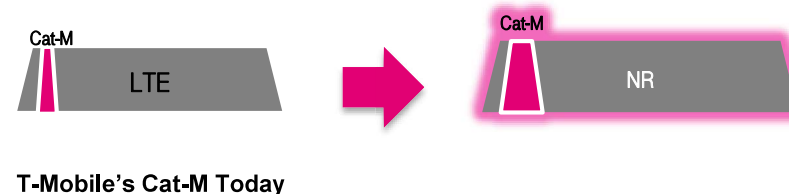
Rel 16 Coexistence of NB-IoT and Cat-M with NR

Enables NB-IoT and CAT-M service to exist seamlessly as we transition from LTE to 5G and remove the LTE network while satisfying the mMTC requirements for 5G IoT with minimum impact to 5G resources while maintaining support for existing devices



For NB-IoT in-band, guard band and standalone operation to coexist with NR

- 15KHz numerology for NR FR1
- Channel raster, PRB and subcarrier grid alignment between NB-IoT and NR
- Synchronization issue between NR and NB-IoT, including timing advance
- Support Resource Allocation Type 1 Feature



Coexist with multiple SCS configurations

- For 15 kHz SCS, subcarrier blanking maybe required for resource alignment due to the presence of a DC carrier on LTE-MTC

For collision avoidance











- LTE-MTC can avoid NR signals via MBSFN
- NR can avoid LTE-MTC signals via resource reservation feature
- Support for resource allocation type 1

Should work on 1.4MHz of LTE spectrum

Network support expected by end of 2023

Category 1 for IoT Use Cases

- Cat 1 technology can be used to support use cases with higher speeds and voice support.
- Cat 1 devices can also support the power and coverage enhancements of Cat M like PSM and e-DRX for battery improvements

Metrics	LTE Category 1		LTE Category M1
Max. Bandwidth & Spectral Efficiency		Cat 1: Spectrally Efficient	
Rx-Diversity (Device)		Cat 1: + 3dB Coverage	
Speeds		Cat 1: More use cases with higher throughput	
Battery		Battery comparable by enabling PSM and e-DRX on Cat 1	
Coverage		CE Mode A on Cat M matches Cat1 coverage	
Voice	Full Duplex	Cat 1 offers full duplex well established VoLTE	Half Duplex

Cat-M & NB-IoT Spectrum Utilization Strategy

	2022	2023	2024	Future
Band 2 (1900 MHz)	NB-IoT	NB-IoT	NB-IoT	NB-IoT
	Cat-M	Cat-M	Cat-M	Cat-M
Band 4 & 66 (2100 MHz)	NB-IoT	NB-IoT	NB-IoT	NB-IoT
Band 12 (700 MHz)	NB-IoT	NB-IoT	NB-IoT	NB-IoT
	Cat-M	Cat-M	Cat-M	Cat-M
Band 71 (600 MHz)		NB-IoT	NB-IoT	NB-IoT
		Cat-M	Cat-M	Cat-M
Band 85 (700 MHz)		NB-IoT	NB-IoT	NB-IoT

- This represents a general spectrum usage plan and not necessarily a specific re-farming schedule. Spectrum utilization can vary market-by-market and is not necessarily uniform nationwide
- Cat-M and NB-IoT- band deployment strategy based on supported bands and bandwidth on the site, Cat 1 IoT is available as part of regular 4G LTE. LwM2M for Cat 1 devices is optional.

Cat-M Spectrum Utilization Strategy

2022 B12 and B2

Urban Core 1	PCS (B2) 700 MHz (B12) AWS (B66/B4)	Cat-M on B12
Urban Core 2	PCS (B2) AWS (B66/B4)	Cat-M on B2
Rural/Hwy	PCS (B2) 700MHz (B12)	Cat-M on B12
Rural (700 MHz only)	700 MHz (B12)	Cat-M on B12

2023 – 2024 Introduction of B71

Urban Core 1	PCS (B2) 700 MHz (B12) AWS (B66/B4)	Cat-M on B12
Urban Core 2	PCS (B2) AWS (B66/B4) 600MHz (B71)	Cat-M on B2 Cat-M on B71
Rural/Hwy	PCS (B2) 700MHz (B12)	Cat-M on B12
Rural 1 (700 MHz only)	700 MHz (B12)	Cat-M on B12
Rural 2 (600 MHz only)	600MHz (B71)	Cat-M on B71

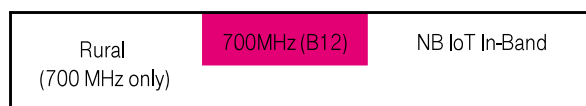
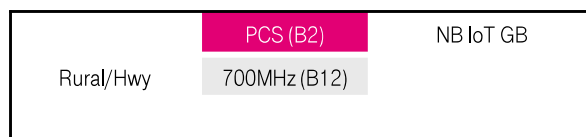
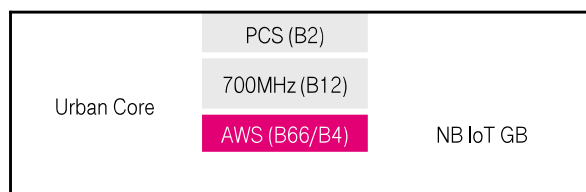
Future Low Band only B12 & B71

Urban Core 1	PCS (B2) 700 MHz (B12) AWS (B66/B4)	Cat-M on B12
Urban Core 2	PCS (B2) AWS (B66/B4) 600MHz (B71)	Cat-M on B71
Rural/Hwy	PCS (B2) 700MHz (B12)	Cat-M on B12
Rural 1 (700 MHz only)	700 MHz (B12)	Cat-M on B12
Rural 2 (600 MHz only)	600MHz (B71)	Cat-M on B71

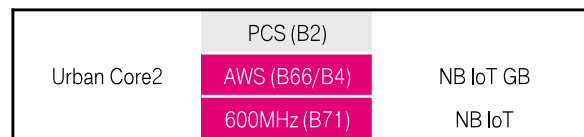
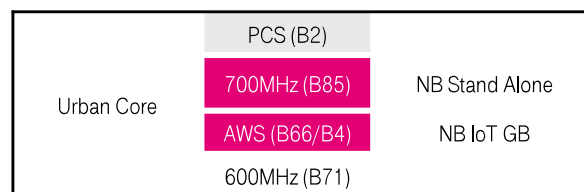
B12 will be the main band
B71 only where no B12

NB Spectrum Utilization Strategy

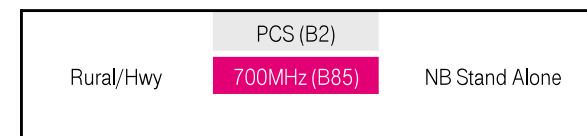
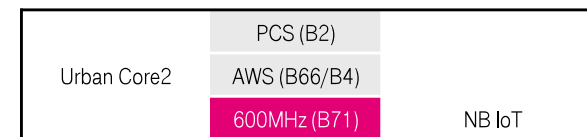
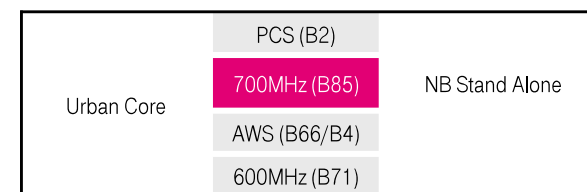
2022
B4, B2 and B12



2023 – 2024
Introduction of B71 & B85



Future
Low Band only B71 & B85



GB: Guard Band

B85 – deployment in selected areas

B85 will be the main band
B71 only where no B85

NB-IoT Technology Features Roadmap

Feature available for Technology Development
New for the time period
 Features Deployed

Deployed Today	2022	2023
Functional <ul style="list-style-type: none"> NB-IoT, Cat NB-1 Paging e-DRX (Extended DRX) Intra-Frequency Idle Mode Mobility Inter-Frequency Idle Mode Mobility 	<ul style="list-style-type: none"> NB-IoT, Cat NB-1 Paging e-DRX (Extended DRX) Intra-Frequency Idle Mode Mobility Inter-Frequency Idle Mode Mobility NB-IoT on 5GC 	<ul style="list-style-type: none"> NB-IoT, Cat NB-1 Paging e-DRX (Extended DRX) Intra-Frequency Idle Mode Mobility Inter-Frequency Idle Mode Mobility NB-IoT on 5GC
Coverage <ul style="list-style-type: none"> Guard Band (2,66) In-Band (12) 3 Coverage Extension Levels 	<ul style="list-style-type: none"> Guard Band (2,66) In-Band (12) 3 Coverage Extension Levels LTE Band 85 Stand Alone LTE Band 71 Guard Band 	<ul style="list-style-type: none"> Guard Band (2,66) In-Band (12) 3 Coverage Extension Levels LTE Band 85 Stand Alone LTE Band 71 Guard Band
Performance <ul style="list-style-type: none"> NB-IoT, Cat NB-1 UL Multi-Tone 	<ul style="list-style-type: none"> NB-IoT, Cat NB-1 UL Multi-Tone CAT-NB2 Support – Larger TBS CAT-NB2 with 2 HARQs 	<ul style="list-style-type: none"> NB-IoT, Cat NB-1 UL Multi-Tone CAT-NB2 Support – Larger TBS CAT-NB2 with 2 HARQs
Congestion Control & Capacity <ul style="list-style-type: none"> Idle Mode Load Balancing 	<ul style="list-style-type: none"> Idle Mode Load Balancing Multicarrier – 1 Anchor + 1 Non Anchor Multicarrier – 1 Anchor + multiple Non Anchor Enhanced Access Barring 	<ul style="list-style-type: none"> Idle Mode Load Balancing Multicarrier – 1 Anchor + 1 Non Anchor Multicarrier – 1 Anchor + multiple Non Anchor Enhanced Access Barring

Device Technology Requirements for IoT Devices 1H'22 & beyond

Technology Requirements		Considerations	(Applicable to T-Mobile and Non-T-Mobile branded devices)
5G	Requirements, based on Use Case <ul style="list-style-type: none">5G Non Stand-Alone OperationStand Alone Operation on all bandsSub 6 Bands n71,n41Dynamic Spectrum Sharing*5G Dual Connectivity (EN-DC)	<u>Recommended</u> <ul style="list-style-type: none">mmW Bands: n260, n258, n261Sub 6 bands n25, n66, n77	<div>Color Legend</div> <div>Mandatory Must Have</div> <div><u>Recommended</u> Good to have Based on the use case</div> <div><u>Special Considerations</u> Depends on needs of product/business</div>
	Mandatory <ul style="list-style-type: none">LTE Cat 4 or higherVoLTE on voice capable & VoLTE E9114x2 MIMOLTE Band 4, 2, 12, 71,66, 25	<u>Recommended</u> <ul style="list-style-type: none">LTE Cat 6 with 4x4 MIMO/CA4x4 MIMOCarrier AggregationLTE Band 5& LTE Band 41	
LTE High <ul style="list-style-type: none">Consumer HomeConnected CarVideo Surveillance	<ul style="list-style-type: none">LTE Cat 1VoLTE on voice capable & VoLTE E9112 Rx AntennasLTE Band 4, 2, 12, 71, 66, 25	<ul style="list-style-type: none">Power Save ModeExtended DRX <u>Recommended</u> <ul style="list-style-type: none">Low Priority IndicatorLTE Band 5 & LTE Band 41	Coverage is impacted with only one Rx antenna Cat 1 supports VoLTE depending on the chipset <i>B25 for consumer devices with messaging capability</i>
	<ul style="list-style-type: none">LTE Cat MLTE Bands 2, 12, 71 at minimumCoverage Enhancements Mode ALocation Technologies over IP	<ul style="list-style-type: none">Power Save ModeExtended DRX <u>Recommended</u> <ul style="list-style-type: none">Recommended Band 4/66,5Low Priority Indicator, MFBI 4/66	
LTE Lite <ul style="list-style-type: none">WearablesPersonal Technology	<ul style="list-style-type: none">LTE Cat NB-IoTLTE Bands 4,66,2, 12, 71, 85 at minimumIn Band, Guard Band & Stand AloneCoverage Enhancements Level 0/1/2Data over NAS (IP and Non-IP)*Single Tone and Multi-ToneMFBI for Bands 4/66 Interop	<ul style="list-style-type: none">Location Technologies over IP and Non-IPPower Save Mode and eDRX <u>Recommended</u> <ul style="list-style-type: none">Recommended Band 5Multimode LTE/ GSM 1900Low Priority Indicator	Limited VoLTE Support Connected Mode Mobility Half Duplex
	<ul style="list-style-type: none">SMS over SGIPv6AGPS + GLONASSDevice Management Protocols	<u>Recommended</u> <ul style="list-style-type: none">Fallback for voice GSM/3GSMS over IP (needs IMS stack)	
Mass IoT <ul style="list-style-type: none">Smart CityParkingIndustrial	NB-IoT does not support Connected Mobility NB-IoT does not support VoLTE *Switch to IP for data intensive payloads		PSM and eDRX should be disabled by default and only be activated by solutions that required them
	Support for roaming		
All IoT (Basic Requirements)	2G-Only and 3G-Only Devices Prohibited. All devices must support LTE.		Technology Requirements for IoT Devices may vary significantly based on the product's features and use case scenarios.

Device Technology Requirements for IoT Devices 1H'22 & beyond

All IoT Devices Support

All IoT

- Bands 4/66, 2, 71, 12, 5
(In Order of Priority)
- Combined Attach Required for SMS
- SMS over NAS
- SMS
- Intra & Inter-frequency Cell Re-selection
- IPv6 for both platform and application*
- Device Management (LwM2M or OMA DM)
- APN Settings

**If product supports hotspot use case, XLAT translation for IPv4 applications will be required. If there is no hotspot use case, XLAT is not required.*

Select LTE Category based on Use Case

Cat 4



- 2 Rx Antennas
- All Standard LTE requirements
- All Standard VoLTE requirements

Cat 1



- 2 Rx Antennas
- All standard LTE requirements
- Standard VoLTE & Voice Req.

Cat M



- In Band
- 1 Rx Antenna
- Half Duplex Type B
- Multimode LTE/GSM 1900

Cat NB-IoT

- In Band, Guard Band, Stand Alone
- Data Over NAS (IP and Non-IP)
- MFB for B4-B66 Interop
- Single Tone and Multi-Tone
- Half Duplex Type B
- Multimode LTE/GSM 1900

Add Features based on Use Case and UE Category support

Coverage

- Coverage Enhancements Modes
- NB-IoT: level 0, 1 and 2
 - Cat-M: Mode A

Congestion Control

- Low Access Priority Indicator
- Delay Tolerant Indicator
- Extended Access Barring

Location

- AGPS+GLONASS
- SUPL 2.0
- OTDOA
- NB-IoT: Min. AGNSS, Cell Based Technology, Require Non-IP and IP

Power Save

- Power Save Mode
- Power Preference Indicator
- Connected Mode DRX
- Idle Mode Extended DRX

Voice

- VoLTE on voice devices
- VoLTE E911

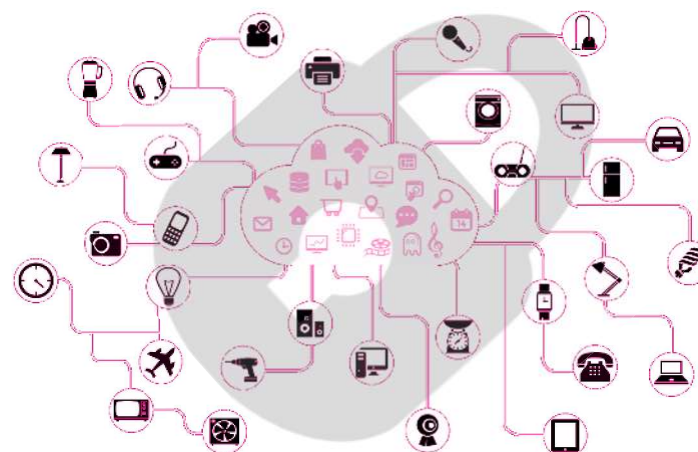
*NB-IoT technology does not support Voice
T-Mobile does not currently support VoLTE on Cat-M. This is mainly for quality experience and to prioritize LTE traffic*

IoT Security Requirements

Please see IoT Platform Security TRD for additional details

Applicable Products

- Connected Home
- Trackers (Cars, Cargo, Personal, Wearables)
- Web Cameras
- Routers
- SyncUp Drive/Fleet
- Smart Devices
- Smart Cities Devices (i.e. Array of Things)
- Connected Cars



Functional Description

Requirements

- Communications

- Flexible requirements allow for utilization of either standardized encryption schemes or proprietary
- Direct access to devices via Web disallowed, ports should be suppressed
 - Expectation is that web access allows for remote management via cloud, cloud communicates with device(s)

- Client and/or Web

- Requirements genericized for applicability to both web and phone client management solutions

- Administration/User Credentials

- User/Admin accounts should have a clear separation of privileges
- Pay special attention to login failures and communication/delays

Key Technologies Requirements for NB-IoT/Cat-M Operation

Operation of Dual Mode, Technology Devices

NB-IoT/Cat-M + GSM

- 1 NB-Preferred
- 2 GSM Fallback

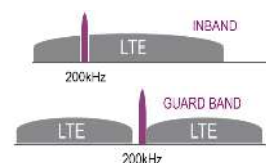
Operation mode of a device is based on the user subscription and application design.

Use LwM2M to manage device settings for RAT selection

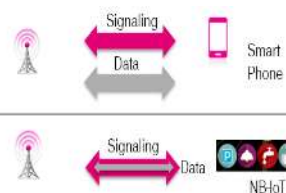
Cat-M has similar requirements but is only deployable in In-band mode and the supported Coverage Enhancement is Mode A with two levels

NB-Technology

In-Band & Guard Band for all bands



Data Over NAS

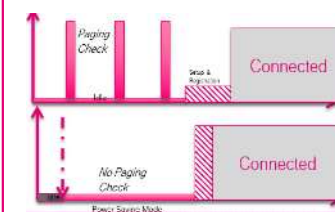


Coverage and Power

Coverage Enhancements



Power Save Mode*
Extended DRX*



* PSM and eDRX features are available but need to be tested between partner and network for proper timer alignment

IoT Device Management

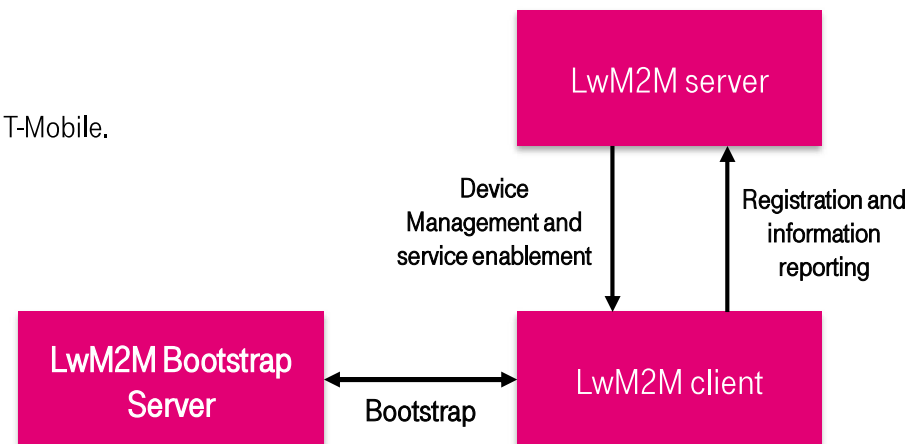
T-Mobile uses Lightweight M2M (LwM2M) v1.1, standardized by OMA, to support device management functionality for all IoT (Cat NB, Cat-1, and Cat-M) devices.

IoT Device Management highlights

- ❑ Avoids fragmented and proprietary solutions
- ❑ Ensured network safety by full control of devices
- ❑ Ability to control the device using a secure LwM2M platform hosted by T-Mobile.
- ❑ Flexible security bootstrapping
- ❑ Firmware updates
- ❑ Lock and wipe the device for security purposes
- ❑ Information reporting

OEM on-boarding

- ❑ OEM integrates LwM2M in chipset/module/product
- ❑ OEM can build their own LwM2M client or develop a client with E/// SDK
- ❑ Client is certified by T-Mobile as per the established validation process



IoT NIDD (Non-IP Data Delivery)

■ Why use non-IP data?

- For NB-IoT use case, the amount of data transferred would be in the order of few bytes
- Using traditional IP based mechanism can increase signalling overhead to transfer few bytes of data
- Leverage LTE NAS encryption, no need to setup IP layer security (DTLS, TLS)
- Better battery performance by removing TCP header and handshake

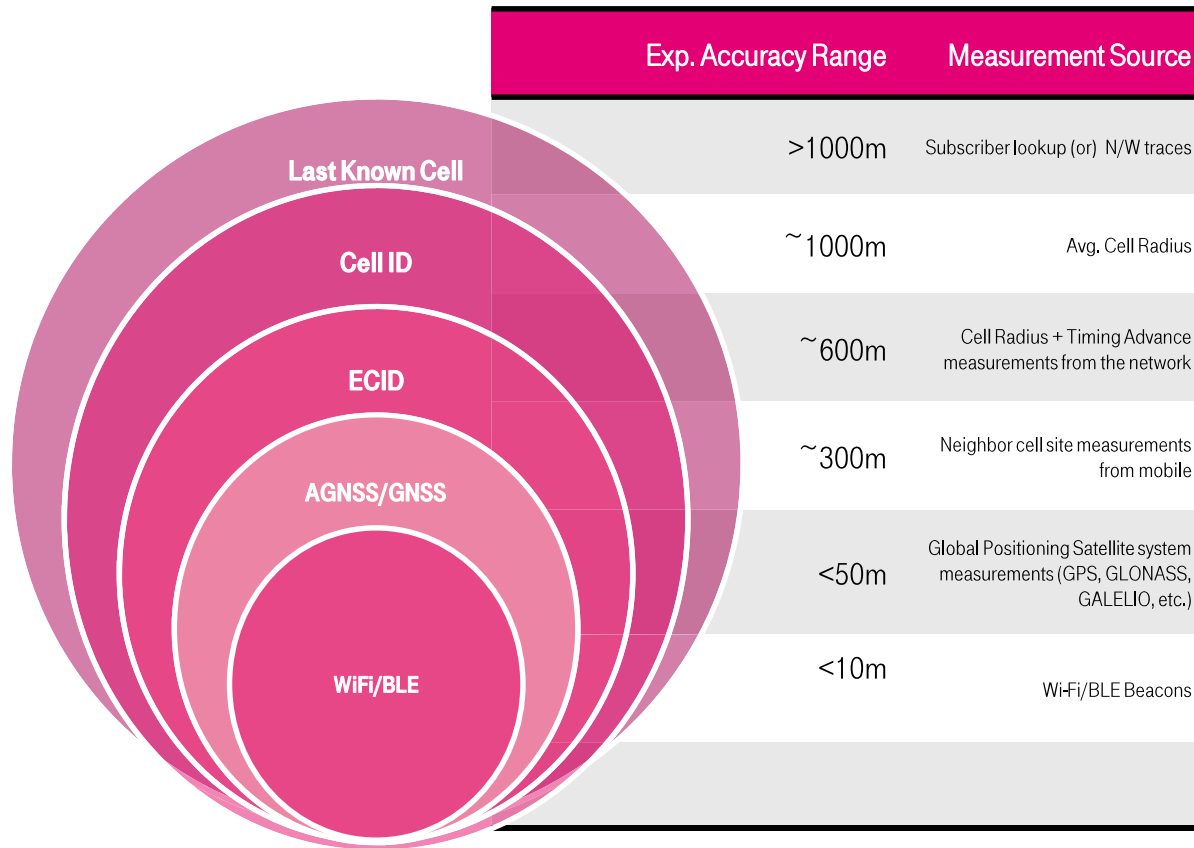
■ Current landscape for device management with NIDD

- OMA LwM2M v1.1 released with specifications for Non-IP data delivery
- Non-IP data delivery can be challenging for data intensive payloads due to reduced bitrates
- Switch to IP for data intensive payloads such as firmware updates, expected to be a less frequent event
- Device will use NIDD most of the time as payload size for non-firmware update events would be in the order of few bytes

Device Category Applicability for Network Services Enablement Platform (NSEP – configuration portal)

Channel	LTE Category	Device Management via NSEP (OMA DM or LwM2M)		FOTA via NSEP	Data collection via NSEP (IP or NIDD)	
TMO Stock (Branded and SyncUp)	Cat-NB	Mandatory	LwM2M	Mandatory	Mandatory	CoAP or MQTT
	Cat-M	Mandatory	LwM2M	Mandatory	Mandatory	CoAP or MQTT
	> Cat-1	Mandatory	LwM2M or DM	Mandatory	Recommended	MQTT
Non-stock (Partner, wholesale)	Cat-NB	Mandatory	LwM2M	Mandatory	Recommended	CoAP or MQTT
	Cat-M	Mandatory	LwM2M	Mandatory	Recommended	CoAP or MQTT
	> Cat-1	Recommended	LwM2M or DM	Recommended	Recommended	MQTT

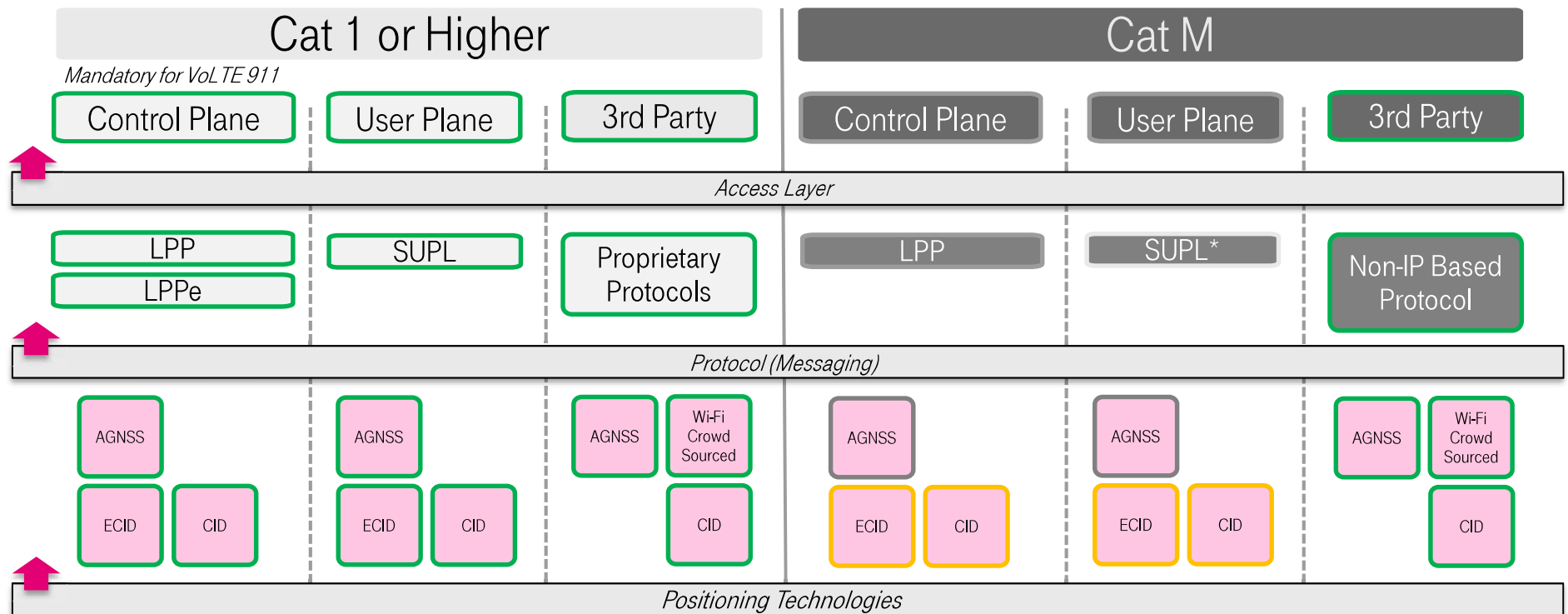
Location Technology – Accuracy Ranges



IoT positioning technologies required vary by use case and dependent on accuracy, power and cost impacts.

Location Technologies for IoT Devices

IoT Device with AGPS & SUPL Client



*CAT NB in eSMC will only support CID or ECID (if LPP or LPPa is available)

LTE Band 85 for NB-IoT

Business Benefits

Additional Low-Band spectrum enables deployment of NB stand alone in already owned spectrum adjacent to Band 12 without impacting capacity.

Functional Description

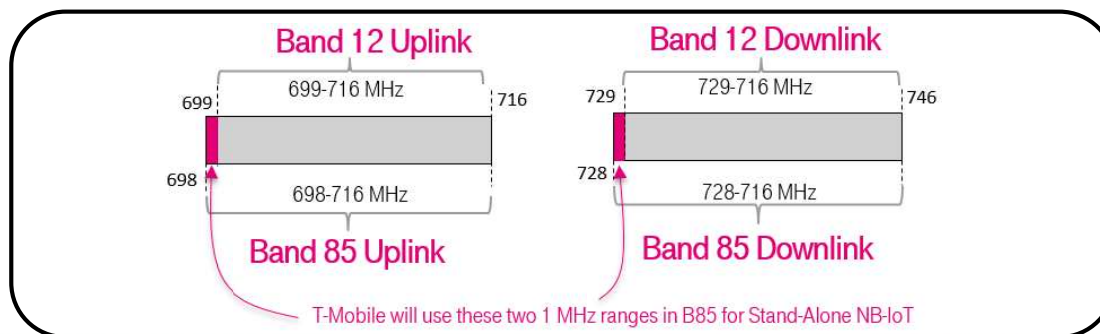
- Band 85 is a superset of Band 12 and extends current Band 12 DL/UL bandwidth one MHz more.

Device Requirements

- NB devices must support Band 85

Network Availability

- Network support by 2H 2023



LTE for IoT (Category 1, Category M and NB IoT)

Business Benefits

- Enables LTE in the Wearable, IoT and M2M Segment
- Support M2M and IoT business using LTE spectrum and technologies.

Functional Description

3GPP Release 13 defines LTE Categories M1 and NB-1 for lower speed, complexity and lower cost IoT devices
Release 14 adds Cat-M2 and NB-2 capabilities

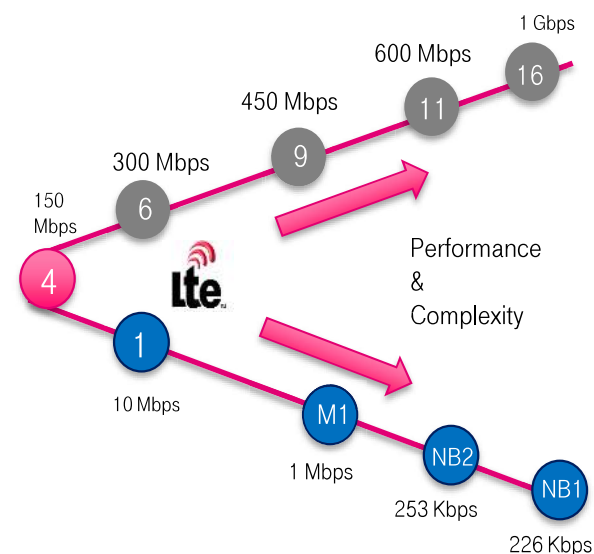
Device Requirements

- NB- IoT addresses specific IoT use cases that have **LOW** requirements for:
 - Cost, Connection frequency, Data Consumption, Throughput, Mobility. No Voice.
- Cat NB-IoT devices are recommended to have dual mode GSM and LTE Cat NB-IoT for early commercialization (*GSM in non NB-IoT markets, NB-IoT in supported markets*)

Deployment Status

- Nationwide NB-IoT Network Launched July 2018
- Cat M Deployment Launched Q4-20

LTE Device Categories for IoT



Reduced Capability (RedCap) Rel. 17 feature

Business Benefits

- RedCap technology is part of the 3GPP Release 17 specification for low cost, low complexity & small form factor 5G devices.
- Migrating LTE Cat-4 or lower throughput devices to generic 5G standalone radio access, i.e., expanding 5G SA use cases to wearables, health care, IoT, etc.

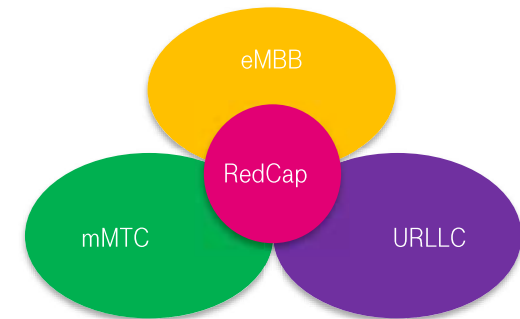
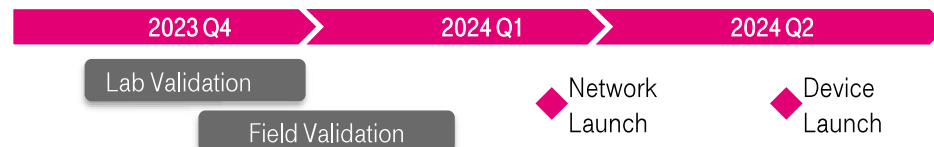
Functional Description

- Reduce complexity and cost by
 - Targeting much lower throughput than generic 5G smartphone
 - Reduced carrier BW Support (up to 20MHz for FDD SA only; No TDD use)
 - 64 QAM DL/UL
 - 1 TX antenna for uplink and 2 RX antennas for downlink
 - Battery saving & heat dissipation features

Device Requirements

- UE to support Release 17 RedCap features
- Coverage Enhancement
- Power Saving Solutions
- RedCap technology shall **NOT** be enabled for data heavy products, e.g., smartphones, CPE or MiFi hotspots products.

Development Plan



RedCap devices

- Wearables (Smart Watch)
- Wearables (Augmented Reality glasses)
- Industrial IoT

Non-IP Data Transfer for Cat NB

Business Benefits

- Allow UE to transfer data in a very energy efficient manner by eliminating the IP header overhead and signaling
- Enable TMO to deploy massive IoT in the near future

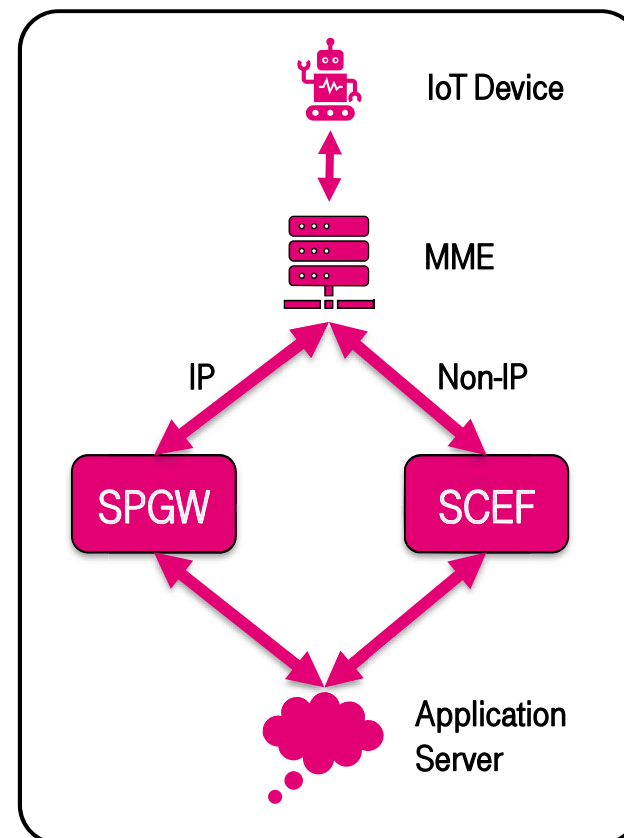
Functional Description

- Provide a standardized method to switch between Non-IP and IP transport
- Enhanced registration sequence mechanisms

Device Requirements



Development Plan



Contents



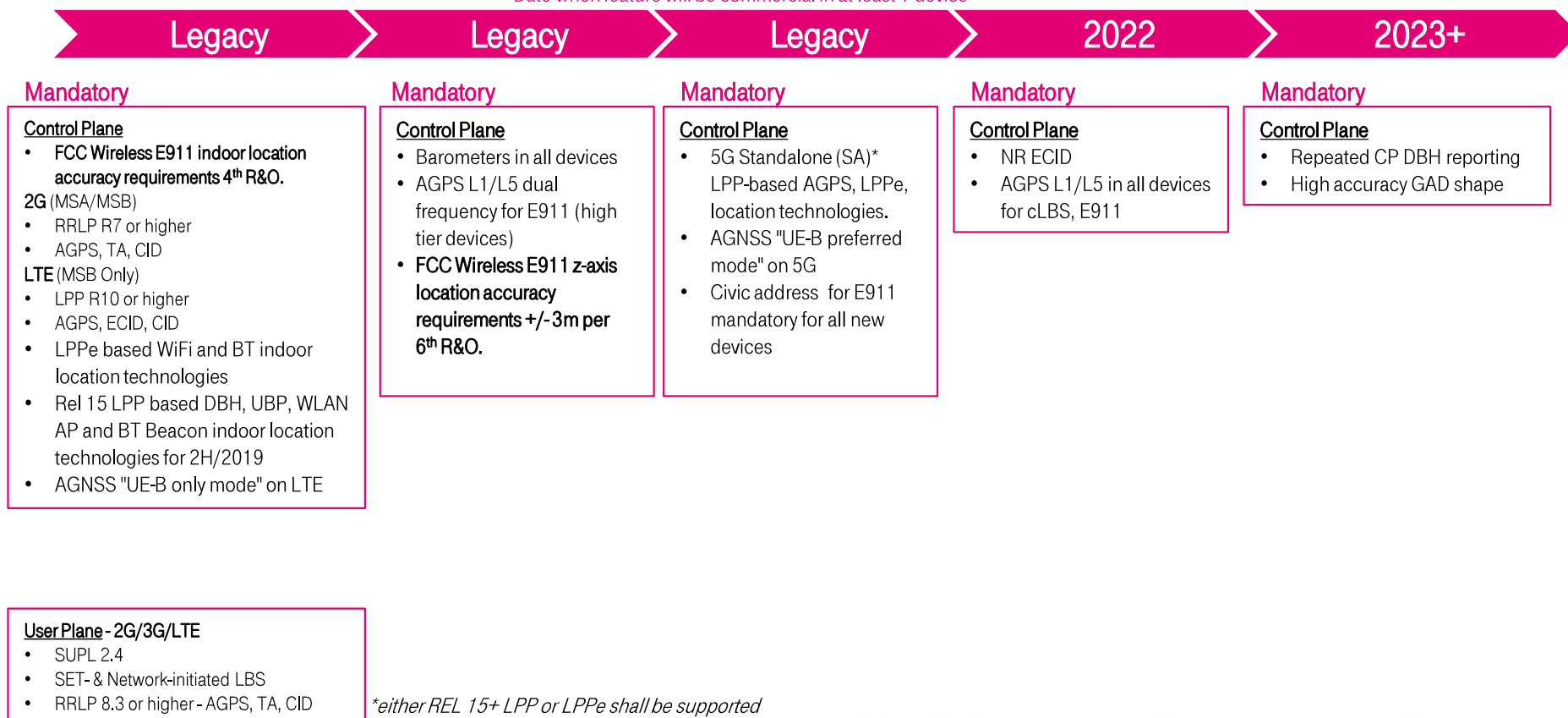
- T-Mobile Business and Network Update
- Device Technology Requirements and Roadmap
- Spectrum and Frequency Bands
- 5G Device Requirements and Roadmap
- Fixed Wireless Access ***NEW SECTION***
- Internet of Things
- **Regulatory and Location Technology**
- Device and IMS Services
- Additional Material

Regulatory & Location Device Requirements — Summary

	2H 2021	2022	2023+
Location Technologies for E911	<ul style="list-style-type: none"> • AGNSS, ECID, LPP, LPPe, DBH • Barometers Mandatory in all devices • +/- 3m z-axis accuracy mandate takes effect • Civic address mandate on all devices 	<ul style="list-style-type: none"> • NR ECID 	<ul style="list-style-type: none"> • Repeated CP DBH reporting on all devices • High accuracy GAD shape
L5 AGPS	<ul style="list-style-type: none"> • Required support in high end devices for cLBS, E911. 	<ul style="list-style-type: none"> • Required Support in all devices (cLBS, E911) 	
Non-Framework Location	<ul style="list-style-type: none"> • Mandatory customer disclosure during OOBE 		
Wireless Emergency Alerts	<ul style="list-style-type: none"> • WEA 3.0 Mandatory (Chipset utilized must support WEA 3.0 capabilities to comply) • WEA Mandatory on Handsets, Watches, Tablets, and all products that support messaging 		
Hearing Aid Compatibility	<ul style="list-style-type: none"> • ANSI C63.19-2011 HAC Certification Required now • FCC Rules will require certification per the ANSI C63.19-2019 standard after June 5, 2023 for new devices. • Pre-2019 certification will continue to be recognized as HAC Compliant. 		

Location Technology Requirements – Key Features Timeline

Date when feature will be commercial in at least 1 device



Non-Framework Location Requirements

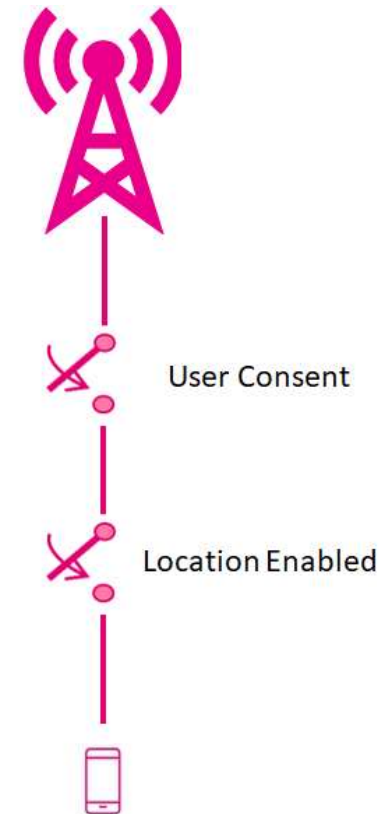
Background and Impact

- Google's Location policies in Android Q have changed and now need user consent and have location enabled for carriers to use their location.
- New Requirements will be in the Q4 2020 MTR All device will need to comply
- Requirements will be in the LBS TRD
- TRDs Impacted:
 - Device Control Plane Location
 - LBS
 - Terminal and UICC Interface
 - Network Connectivity and Operations
 - Wifi calling

Non-Framework Location Requirements

New Requirements

- Android devices shall comply with the latest Google Non-Framework location Privacy guidelines
- Android Devices shall provide setup wizard option for the user to turn on/off non-framework location access during OBB initialization. If the user does not take action during OOB a reminder shall pop up after device restart or power cycle to remind user and a shortcut to the Carrier Location Permissions embedded within the Location Settings area for the user to take action. The reminder shall repeat after each restart or power cycle until the user takes action.
- Android devices shall also support non-framework apps permission per Google's guidelines and include a shortcut to the Carrier location Permissions embedded with the Location Settings area



Z-Axis Positioning (UE-Based Solution + Barometer For E911)

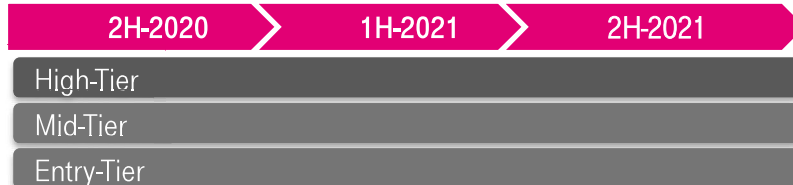
Business Benefits

- Meeting the new FCC 6th R&O Wireless E911 Z-Axis accuracy mandate of +/- 3m accuracy on 80% of wireless E911 calls in top 25 CMA by April 2021, in Top 50 CMAs by April 2023 and nationwide by April 2025
- Improved user experience, life-saving at times!

Functional Description

- Barometric pressure sensor equipped UE measures atmospheric pressure when users dial 911
- Google FLP or iPhone HELO-Z calculated Z location with the help of barometric measurement and other location technologies
- UE sends altitude data to eSMC through (1) LPPe or (2) 3GPP REL15 LPP protocol. The eSMC forwards the data to GMLC/PSAP

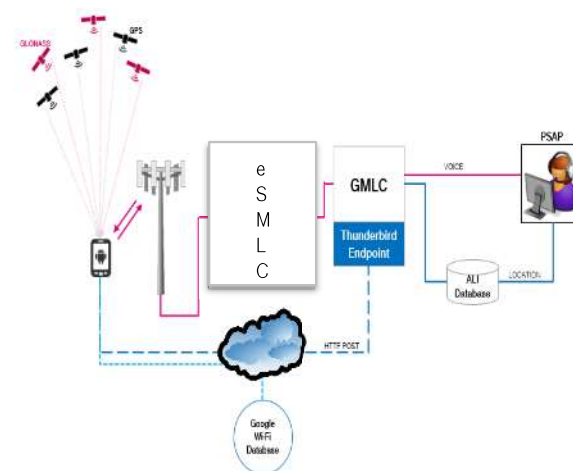
Device Requirements



Deployment Status

- Devices – mandated for all devices at TA, 2H'20
- Network – support for LTE & 5G

Uncompensated Barometric Pressure for E911 Z-Axis Architecture



High Accuracy Scalable Uncertainty GAD Shape for Control Plane Locations Delivery

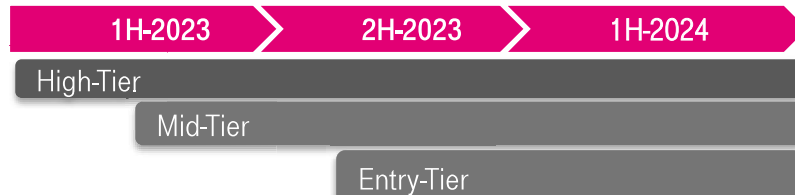
Business Benefits

- Deliver precise Z location to meet the FCC 6th R&O & Consent Decree **Wireless E911 Z-Axis accuracy** mandates nationwide starting April 2022
- Improved user experience, life-saving at times

Functional Description

- UE generates high quality UE-B AGPS X-Y & Z location that needs to be encoded before delivering to network
- A new high accuracy scalable GAD shape formula was defined in 3GPP R16 to allow encoding/decoding altitude and X-Y and Z uncertainty with much higher fidelity than can be achieved through existing formula
- The high accuracy AGPS location is preserved during transit from UE to network and can better help T-Mobile meeting FCC mandates

Device Requirements



Deployment Status

- Devices – mandated for all new devices at TA, starting 1H'23
- Network – support for LTE & 5G by Q4'22

3GPP TS 23.032 Universal GAD Shape ver. g10

3GPP TS 37.355 LPP protocol ver. g80

1. High Accuracy Extended Uncertainty formula

$r = C((1+X)^K - 1)$ with $C = 0.3$ and $x = 0.02594$, K is between 0 and 255.

The useful range is between 0 and 200m.
For $K = 0$ to 254

2. High Accuracy Altitude formula

$$a = N \times 2^{-7}$$

High accuracy altitude is encoded as a number N between -64000 and 1280000 using 2's complement binary on 22 bits.

Civic Address for Wireless E911

Business Benefits

- Meeting the new FCC 6th R&O requiring tier-1 wireless services providers to start delivery **civic address to PSAP starting January 2022 when it's technically feasible to do so.**
- Improved user experience, save life

Functional Description

- UE calculate a X-Y location when user dial 911
- Google reverse geocode convert the X-Y to civic address including street address and floor number. iPhone HELO-Z follow similar process for Z-axis.
- Android devices forward the civic address through LPPe to eSMC/LMF or through IMS PIDF-LO to GMLC directly. eSMC/LMF forward the civic address to GMLC/PSAP. iPhone forward through IMS PIDF-LO.

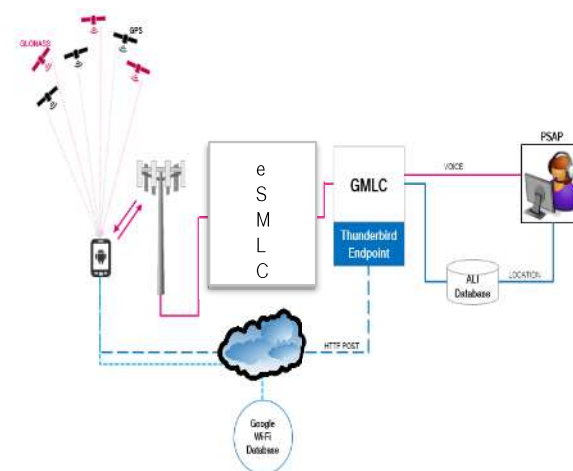
Device Requirements



Deployment Status

- Devices – mandated for all devices at Initial launch in 2H'21
- Network – supported for LTE & 5G

Civic address with floor number for E911 Architecture



5G VoNR E911 Location Requirements

Business Benefits

- Enable T-Mobile to meet FCC E911 location accuracy mandates in 5G network
- Providing precise location of a 5G VoNR E911 call to first responders.
- Providing the best user experience, save life

Functional Description

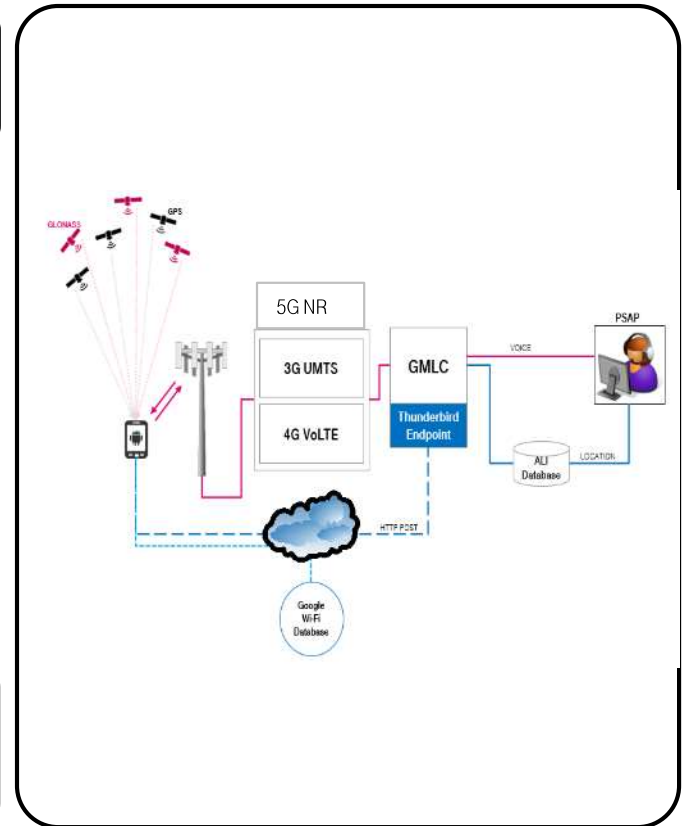
Make AGNSS and other advanced location technology available to 1st responders when a 5G VoNR E911 call is made

Device Requirements

The 5G SA devices must support the following location technology through LPP protocol.

- AGPS
- LPPe (DBH, UBP, Altitude) or REL15 LPP (DBH, UBP, Altitude)
- 5G NR CID

Development Plan



AGPS L1 & L5 Dual Frequency For E911 Requirements

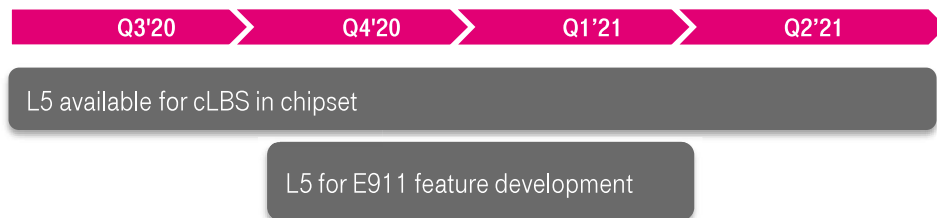
Business Benefits

- Improving E911 AGPS location yield and accuracy in multipath environment. Help T-Mobile meeting FCC E911 indoor location accuracy mandates
- Providing more precise E911 location to first responders
- Mandatory for high-tier devices. Optional for mid-/Low-tier devices

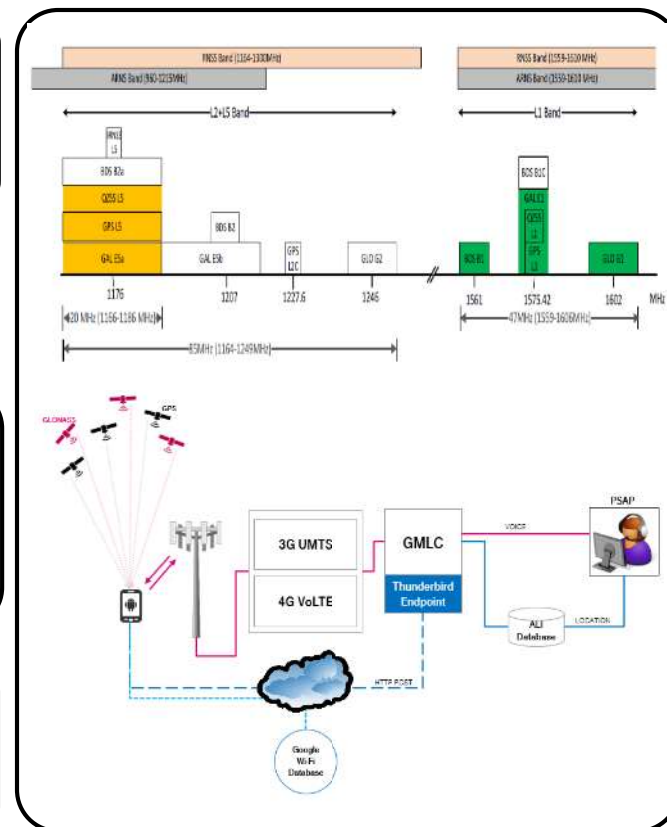
Functional Description

- Including AGPS L5 signal in addition to L1 signal for E911 location calculation and make highly accurate E911 location available to 1st responders when E911 call is made

Chipset Development



Device Development



“UE-Based AGNSS” Configuration for LTE/5G Devices

Business Benefits

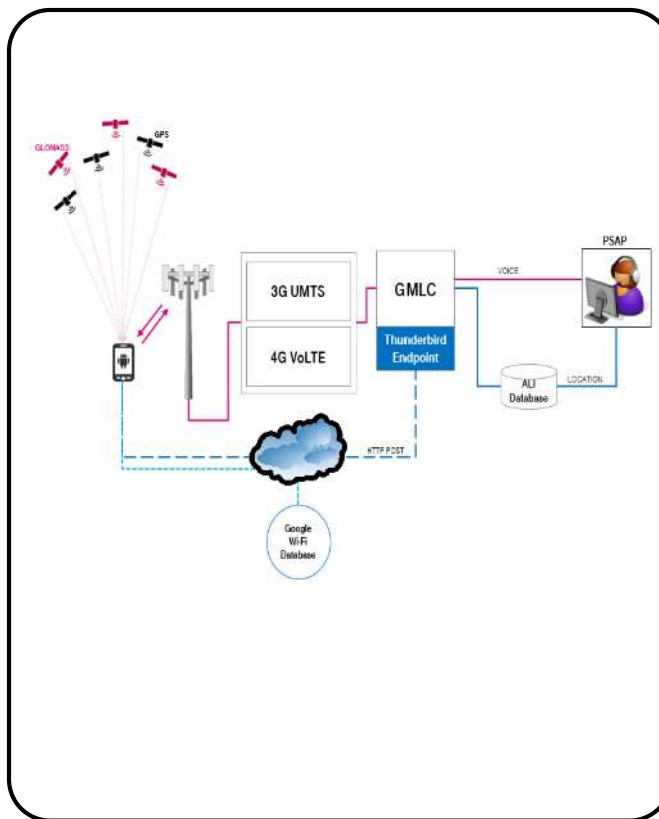
- Improving overall E911 AGPS location yield and accuracy in challenging environment to help T-Mobile meeting FCC E911 indoor location accuracy mandates
- Help improve ELS and LPPE location accuracy by allowing AGNSS be part of the Device-based Hybrid location calculation
- Providing more precise E911 location to first responders
- Enhancing the best user experience to our customers through shortened 1st responder response time to emergency call

Functional Description

- UE configured to use MS-Based/UE-Based mode will calculate location estimate in UE instead of in network
 - Only LTE are configured to “MSB AGNSS Only”/“UEB AGNSS Only” mode.
- **GSM** still needs to be configured to “MSA **preferred**” mode.
- **5G** is configured to UEB-**Preferred** mode

Status

- Required for all devices
- Tested as part of Spirent Fit4Launch program



Wireless Priority Services

Business Benefits

- Wireless Priority Service is a subscription based wireless service
- T-Mobile was the first to implement WPS program on 2G wireless network in 2004
- DHS Office of Emergency Communications (OEC) intend to extend WPS voice priority services into TMUS LTE IMS network

Functional Description

- WPS subscribers receive priority for voice, text and SMS
- WPS subscribers have special access class provisioning on their SIM (11-15)
- WPS subscribers receive dial *272 prefix before number to invoke call priority
- RRC Signaling indicates to the network a high priority call is requested.

Device Requirements

- Devices must support access class barring for voice and data on LTE
- Devices must support SIM OTA to update Access class from 0-9 to 11-15
- Devices must comply to access class barring based on SIM access class
- Devices must support (*272) over IMS

Deployment Status

- Launched on T-Mobile Network
- Devices must continue to comply with requirements

1. SIM OTA for WPS Device

WPS



SIM OTA updates
Access Class to 11-15

All Devices



Access Class
0-9

2. WPS gets Priority Service



Load based AC Barring

WPS



Voice & Data

✗ All Devices



Limited

Real-Time Text (RTT)

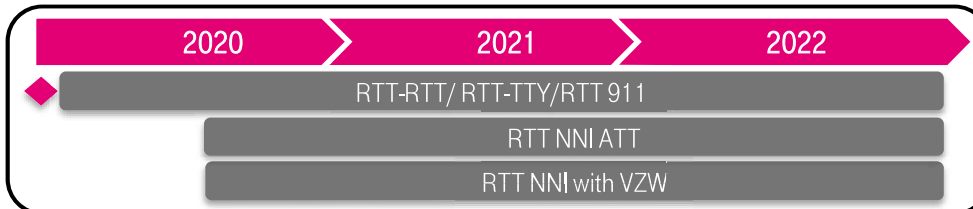
Business Benefits

- IP-based successor to TTY technology over IMS (VoLTE and WFC)
- FCC mandated service: all devices manufactured and sold in 2020 must support RTT

Functional Description

- RTT Calls are part of voice calls NOT SMS, Each text character appears same time it is typed, no need to press “send”
- 911 Support mandatory
- Interoperability between OEM devices a must

Development Plan



FCC Deadline: Dec 31, 2017

OEMs must implement RTT in newly manufactured equipment if readily achievable



FCC Deadline: Dec 31, 2019

Each Tier1 CMRS provider (including resellers) shall support RTT for all Voice capable devices over LTE & NR



FCC Deadline: June 30, 2021

Each non-Tier1 CMRS provider (including resellers) shall support RTT for all new authorized user devices

Additions

- **RTT 5G:**
 - Compliance with EPS-FB and VoNR, Full handover, and more in 5G Voice TRD
- **UI Enhancement:**
 - Text Predictions
 - Transcripts, Emojis
 - RTT Preference
 - RTT Help Menu
- **RTT on standalone watches**

PIDF-LO support for Text to 911

Business Benefits

- PIDF-LO addition improves location accuracy for SIP SMS to 911
- Reduce the number of “bounce back texts” due to lack of initial location information

Functional Description

- For Text to 911, Location information is Critical for successful routing
- If UE does not provide any location or provide incorrect location; Network won't be able to connect you to PSAP Operator i.e., User will receive a bounce back text saying "Please make a voice call to 911. There is no text service at this time"
- Along with MT-LR support, going forward we will require device to support PIDF-LO for Text to 911

Device Requirements

- The device shall include PIDF-LO (see RFC 4119, as modified by RFC 5491 and RFC 5139) in the body of the SIP MESSAGE and include a Geolocation Header with a Location URI using the Content-ID format pointing to it as specified for location by value in RFC-6442.
- 8 new requirements added to SMS-MMS Q3'23 TRD

Development Plan

- Launched on T-Mobile Network
- T-Mobile already have live devices on Network which shows improvement post PIDF-LO addition

IMS Log Snippet

```
<dm:device
  id="Wifi">
  <gp:geopriv>
    <gp:location-info>
      <gs:Circle
        srsName="urn:ogc:def:crs:EPSG::4326">
        <gml:pos>
          37.223108 -121.862495
        </gml:pos>
        <gs:radius
          uom="urn:ogc:def:uom:EPSG::9001">
          130.000000
        </gs:radius>
      </gs:Circle>
      <con:confidence
        pdf="normal">
          95
        </con:confidence>
      </gp:location-info>
    <gp:method>
      A-GPS
    </gp:method>
    <gp:usage-rules/>
  </gp:geopriv>
  <dm:timestamp>
    2020-05-14T21:32:59Z
  </dm:timestamp>
</dm:device>
</presence>
```

Hearing Aid Compatibility

Business Benefits

- Provides customers who use hearing aids better audio quality and satisfaction
- Required for products used by governmental agencies and accessibility conscientious organizations; Device sales and contracts increase
- Hearing Aid Compatibility for mobile phones is mandated by the FCC and codified as law in the Code of Federal Regulation 47CFR 20.19.

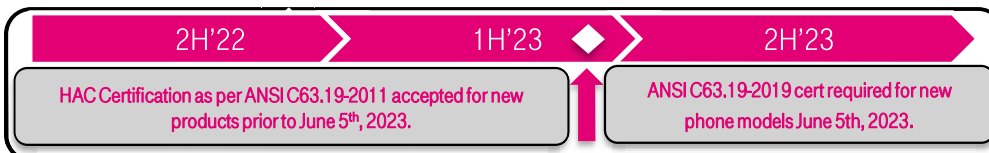
Functional Description

- HAC Compliance Certification is based upon testing in accordance with the Industry Test Standard ANSI C63-19.
 - At this time 66% of device models offered by Tier 1 wireless carriers must be certified for HAC Compliance
 - The number of models will increase to 85% on April 4th, 2022.
 - The FCC will decide by 2024 whether to require that 100% of handsets must be hearing aid compatible.
 - This is not an issue for T-Mobile as both legacy Sprint and T-Mobile have had a 100 % HAC certified phone penetration rate for years

Device Requirements

- Device certification in accordance with the new HAC Test Standard ANSI C63.19-2019 will only be required for new devices on or after June 5, 2023
- ANSI C63.19-2019 certification is the responsibility of the Device OEM (not the wireless carrier) as part of the FCC's Grant of Equipment Authorization process

Implementation Plan



- Hearing Aid Compatibility Ratings for Mobile Phones in accordance with the - 2019 standard will change from M-1 through M-4 (acoustic) and T-1 through T-4 (telecoil or magnetic interface) to "HAC Compliant"

Sustainability – UL Compliance Certification

Business Benefits

- T-Mobile is a responsible corporate citizen taking action to make our industry and devices more sustainable in the pursuit of cleaner water, air, and more efficient use of our natural resources.
- Goodwill with governmental agencies and ecologically conscientious organizations.; Device sales and contracts increase.

Functional Description

- UL 110, UL 2710, and IEEE 1680.1 standards establish a set of sustainability performance criteria with metric ratings targeted at specific device types:
 - Safe Materials – Energy efficient practices and devices – End-of-Life management & the extension of useful product life – Recycled / recyclable packaging – Sustainable corporate practices – Credit awarded device manufacturer for sustainable innovations.
- Prerequisite requirements of compliance with internationally recognized regulations and directives such as REACH and RoHS (European Union requirements.).

Device Requirements

- Required for all T-Mobile, Metro by T-Mobile, and Assurance branded / Stock / White label devices launched after Q1 2021, and ALL Stock / White label Devices launched after Q3 2022. ECOLOGO / Certificate of Compliance must be uploaded into DICE as an IEC deliverable no later than the IEC Review Process Period.

Sustainability Plan



**Underwriters
Laboratories**

- **Mobile Phones:**
 - UL 110 Standard Compliance Certification
- **Other Portable Electronic Products - including Wearables, Hotspots, Dongles, etc.:**
 - UL 2710 Standard Compliance Certification
- **Tablets, Computers, & Displays:**
 - IEEE 1680.1-2018 Standard and IEEE 1680.1a Addendum Compliance Certification

Contents



- T-Mobile Business and Network Update
- Device Technology Requirements and Roadmap
- Spectrum and Frequency Bands
- 5G Device Requirements and Roadmap
- Fixed Wireless Access ***NEW SECTION***
- Internet of Things
- Regulatory and Location Technology
- **Device and IMS Services**
- Additional Material

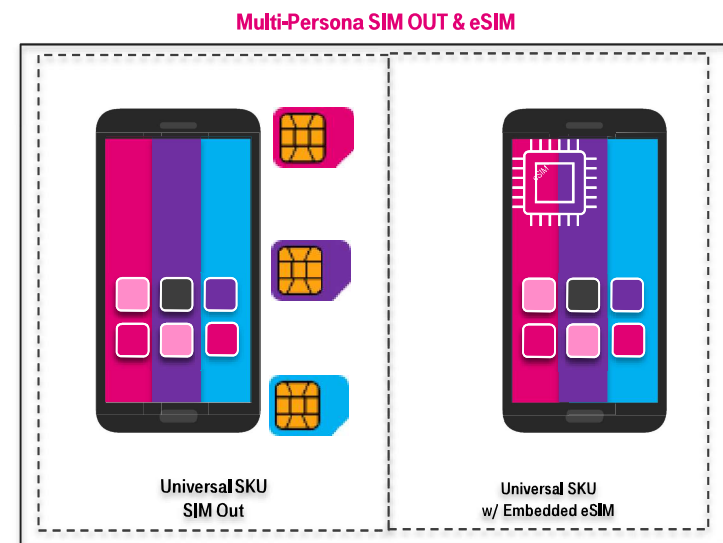
Universal SKU (USKU) Summary

Business Goal:

A Universal SKU device aims to provide **common packaging**, single hardware and software, and **adaptive carrier branded experience** while maintaining subsidy and fraud protections and **brand separation** on network.

Main Features:

- Support T-Mobile, Metro, and Assurance Brands with one Firmware for all tiers
- Devices SIM locked to all T-Mobile, Metro, and Assurance SIM cards
- Support unique experience for each brand with OEM and T-Mobile Branding Tools
- Physical SIM not included for all devices (SIM Out)



XP w/Magenta SIM still supported

Universal SKU (USKU) Feature Overview

Core Requirements

- **Sprint persona removed from Scope.**
- **Cross Provisioning for Sprint still supported with T-Mobile Persona.**
- Single hardware and single software for all TMO brands
- SIM Out. SIM no longer included in box by OEM
- Common Packaging and kit for all brands
- Common revenue identifiers for all brands
- Common core services across T-Mobile, Assurance, and Metro
- Common radio requirements for all brands by tier
- Supports T-Mobile, Assurance, and Metro.
- Dynamic Branding Enablers preloaded from Factory
- eSIM to support USKU organically but requires eSIM ecosystem support

Oobe Requirements

- Devices are multi-brand locked at factory
- Default branding prior to SIM activation is OEM for physical SIM and eSIM
- Default network config is T-Mobile and utilizes APN based on SIM
- Delays branding until branding and SIM Lock Policy Updated

Subsidy Lock Requirements

- Allows all 3 profiles out of box
- Single Lock Policy for Postpaid, Assurance, or Metro post Activation

Branding

- OEM can set brand after Subsidy Lock whitelist update based on MNC-MCC+GID.
- OEM Applies OEM Based Branding (Settings, APNs, UI)
- OEM Triggers Carrier Preloaded Enablers to Complete Branding Experience

Preloads

- Preloaded applications expected to be the same or updated version of the current Sprint and T-Mobile offerings today: Adapt, MCM, CDM, SMF, and Installer



Unified Device
Sprint in Scope



Universal SKU Device
Sprint NOT in Scope

		Sprint	T-Mobile (+ Sprint XP)	Metro	Assurance
OEM Managed	Device Feature	Sprint	T-Mobile (+ Sprint XP)	Metro	Assurance
	Radio Technologies	5G NSA, 4G LTE, 3G, 2G, CDMA	T-MO Specs (5G SA/NSA, 4G LTE, 3G, 2G)		
	Radio bands	Sprint Specs	TMO Spec		
	Core Services	Sprint Specs (VoLTE, RCS, IR.94, WFC)	TMO Specs (VoLTE, RCS, IR.94, WFC)		
	Regulatory	Sprint Specs (WEA, RTT, e911, AGPS)	TMO Specs (WEA, RTT, e911, AGPS)		
	Subsidy lock at Factory	Locked to all 3 TMO brands			
TMO Managed	Subsidy lock post activation	MCC/MNC Network Lock	MCC/MNC + GID Lock	MCC/MNC + GID Lock	MCC/MNC + GID Lock
	Carrier ID	T-Mobile			
	Unlock Tool	RSU/OEM Tool			
	Branding	Sprint	Magenta	Metro	Assurance
	VAS	Sprint	Magenta	Metro	Assurance

5G Network Slicing

Business Benefits

- Network Slicing is a mandatory 5G feature in 3GPP, deeply integrated in NW node. Provide the necessary flexibility and scalability for future NW implementation
- A service driven approach, increase the capability to meet the vertical industry differentiation and customization requirements

Functional Description

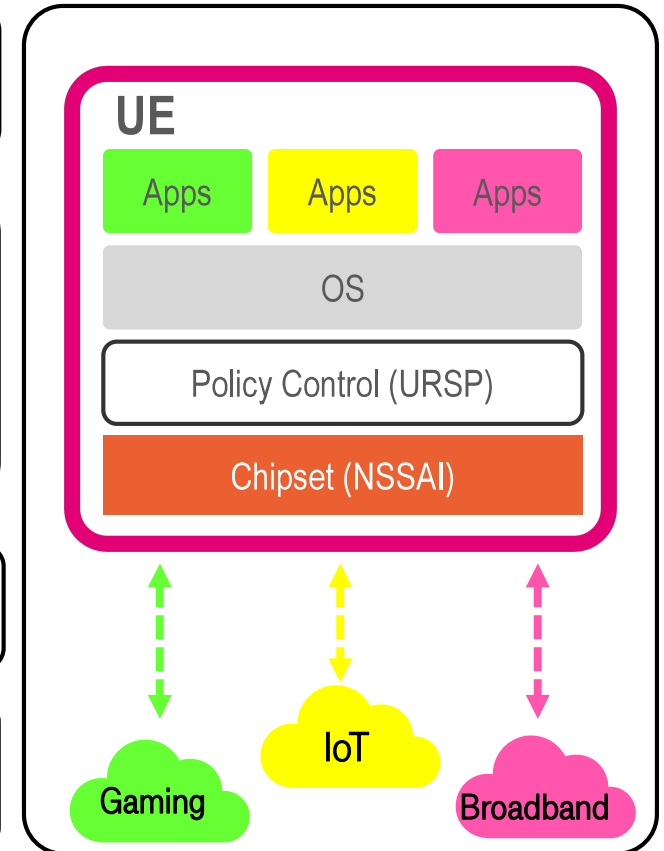
Network Slicing is a mandatory feature for 5G defined in 3GPP

- **NSSAI (Network Slicing Selection Assistance Information)**
 - Exchanged in the 5G attach/reg procedure
 - Provide specific Network Slicing information and expected behavior
 - UE can connect to 8 NS at 1 time
- **URSP (UE Routing Selection Policy)**
 - Policy use to direct traffic on different RAT, QoS
 - Trigger the establishment of a new PDU Session
 - Integration and framework development required on OS and application layer

Device Requirements



Device Development Plan



Rich Communication Services (RCS)

- Mandatory to support RCS Universal Profile (2.x) across all smartphone device tiers



Google Messages on the Hotseat

Functional Description

- **Single Registration** to TMO RCS NW
- OMA CPM session-based Chat
- RCC, 71v1.0 based implementation - Universal Profile 1.0
- Open Group Chat and File Transfer over HTTP

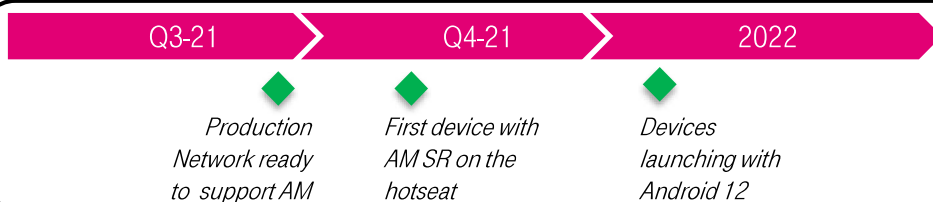
Device Requirements

- Android 12 is baseline
- Device/Chipset manufacturers need to support 5 new APIs by Google
- Only on the device launched with Android 12 or later – No MR update on the devices launched without SR AM client

Additional information

- Interchangeability between the 2 RCS clients
 - Database

Development Plan



Messages by Google

Verified Business Calling – EC for Business

Business Benefits

- Providing confidence to customers to pick up the call from verified business entities including – picture, reason for calling, and importance of call.

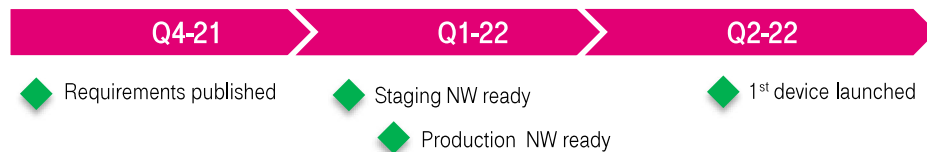
Functional Description

- **Pre-call:** Users and businesses can add a subject, picture, importance, and location prior to placing a voice or video call.
- **In-call:** Share image, video, share screen, share sketch – **not in current scope**
- **Post call:** Note and voice message – **not in current scope**

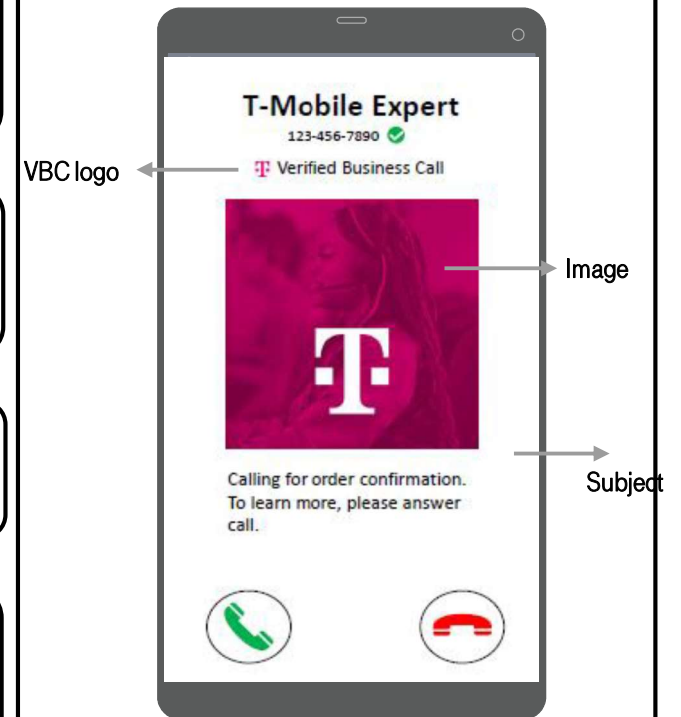
Device Requirements

- Need to be supported by all smartphone tiers
- T-Mobile is launching with the pre-call feature only
- Business to Consumer only, which requires "Organization" header in the INVITE

Development Plan



Incoming Call Screen with EC



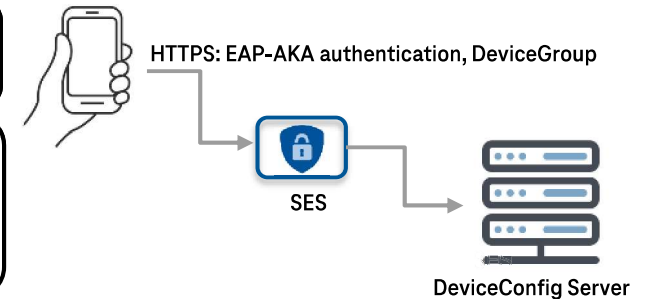
Carrier Configuration

Business Benefits

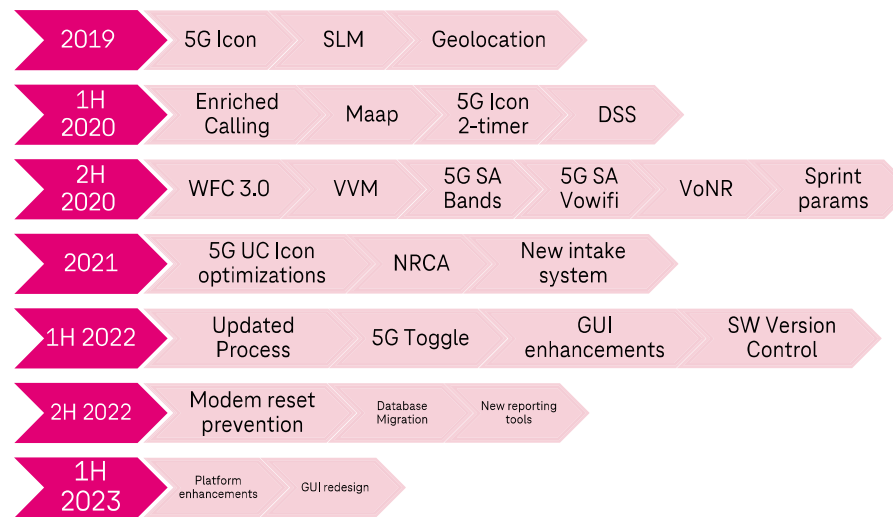
- Carrier Configuration enables devices to retrieve specific configuration and parameters without a need for MR or hardcoding

Functional Description

- Authentication with entitlement server and download the config XML file (Https transaction)
- Parsing the content of the XML config file and apply those settings on device.
- Device Group name Format: OEM-NSDS-DeviceModel-Channel-SoftwareVersion
- Used for controlling RCS, VVM, 5G Icon, 5G SA Bands, 5G UC Icon, VoNR, NRCA, Wifi Calling



Development Plan



Carrier Configuration – Call Drop Prevention

Opportunity

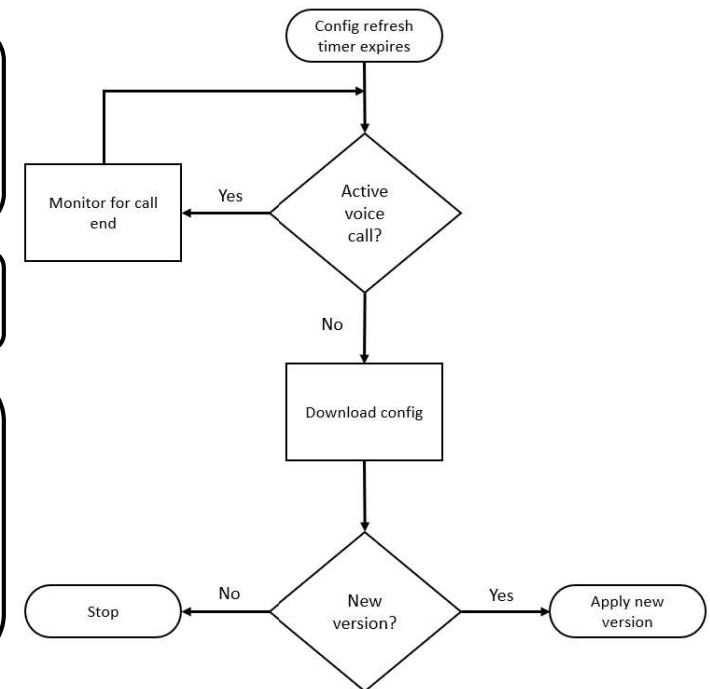
- Modem-related Carrier Config updates require a modem reset to apply changes
- Applying Carrier Config updates during a voice call could result in call drops and poor customer experience

Solution

- Create a new requirement prohibiting downloading the Carrier Config file during a voice call

Requirement

- GID-MTRREQ-526839
- Device shall not download a configuration while in a cellular or VoWiFi voice call. If the refresh timer expires during an active voice call, device shall monitor the call state and download the configuration at the end of the call.



Native Visual Voicemail

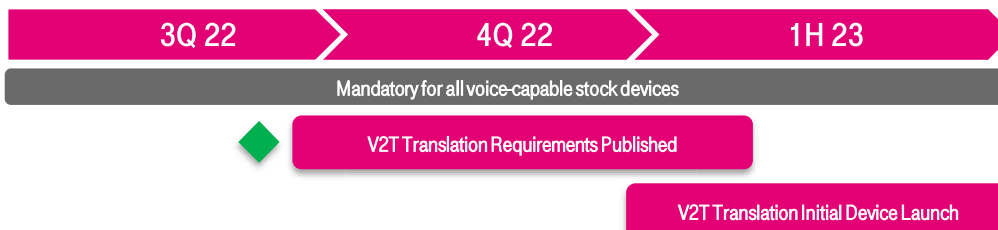
Business Benefits

- Visual Voicemail adds a graphical user interface to view and listen to voicemails in any order.
- Accessible from the native dialer app.
- Content can be downloaded on local memory and stay on device.
- Visual Voicemail adds transcription for voice messages as a paid service.

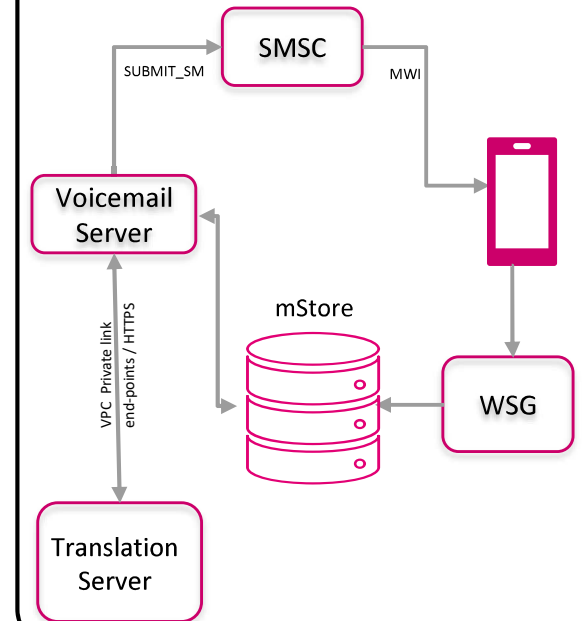
Functional Description

- GBA Authentication for all transactions.
- UE receives an MWI notification for new voicemail and triggers a Search towards WSG, and a GET request for the new VM
- All transactions use mStore OMA REST API through WSG. Transactions include: Get VM, mStore Sync, Delete VMs, Record/Update Greetings, Update VMs.
- V2T Translation provided via Translation Server, supports ~80 languages for two use cases, Translation language update & Ad-Hoc Translation.

Development Plan



New Voicemail Download



Remote SIM Unlock (RSU)

Business Benefits

- ☐ Subsidy Protection of Stock USKU Android Smartphones, Tablets and Feature Phones
- ☐ Automatic removal of subsidy lock when customer eligibility is met

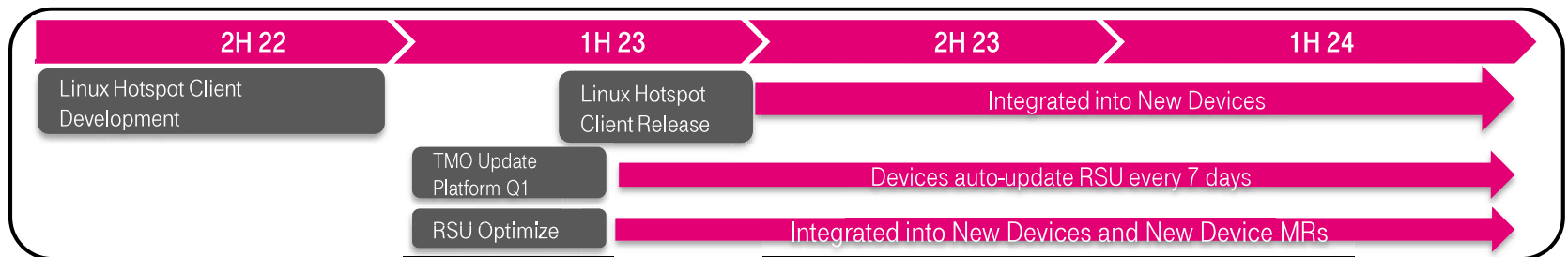
Functional Description

- ☐ Android application integrated with chipset vendors to control the lock state of the device
- ☐ On device UI allows for Temporary Unlocks based on Brand
- ☐ RSU Support on Android touch enabled and non-touch screen devices

Upcoming Development

- ☐ Including a Customer Friendly issue report button to troubleshoot complaints – In Test
- ☐ Developing New LinuxOS Client for use in TMO Mobile Hotspots
- ☐ Partnering with Mobile Solutions Team to implement OTA Update System – Targeted Q1'2023
- ☐ Updating the RSU Android Client to improve the overall UI / Customer Experience – Targeted Q1'2023

Development Plan



CS-Sunset

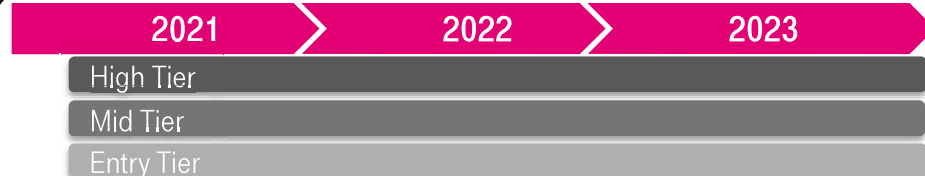
Business Benefits

- ❑ Reduce 3G capacity and coverage gradually, a pathway for future spectrum re-farming.
- ❑ 2G shutdown is completed in 2022

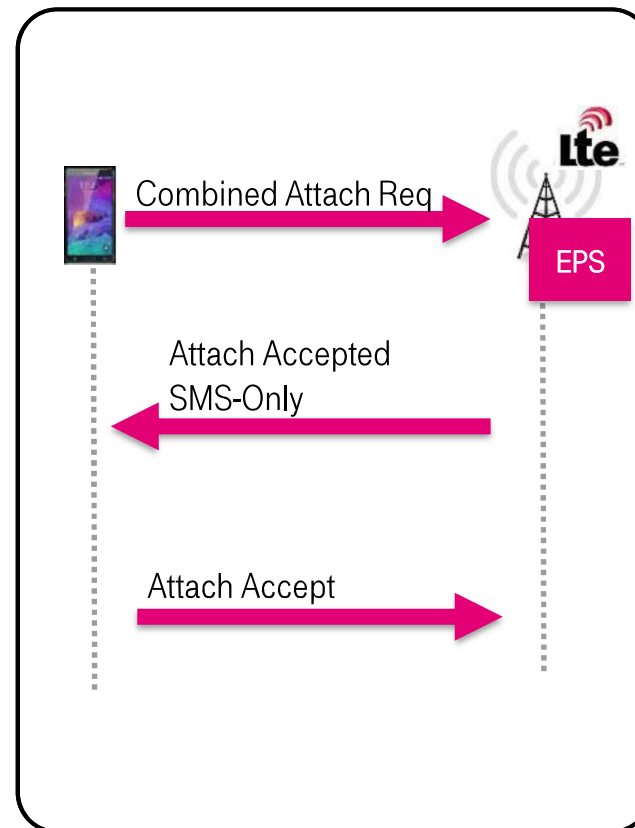
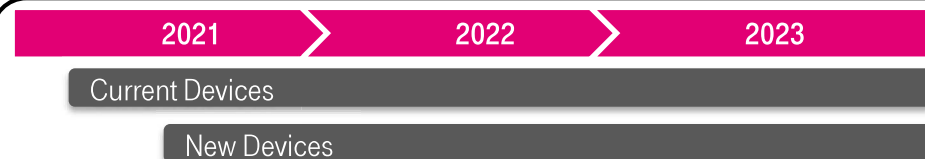
Functional Description

- ❑ NW controls attachment type (EPS-IMSI or Combined with SMS-Only) via the response message to UE's LTE-CS combined attachment request.
- ❑ Once UE is LTE-Only connected, NW will not provide a CS fallback option.

Device Compliance



Development Plan



Push to Talk (PTT)

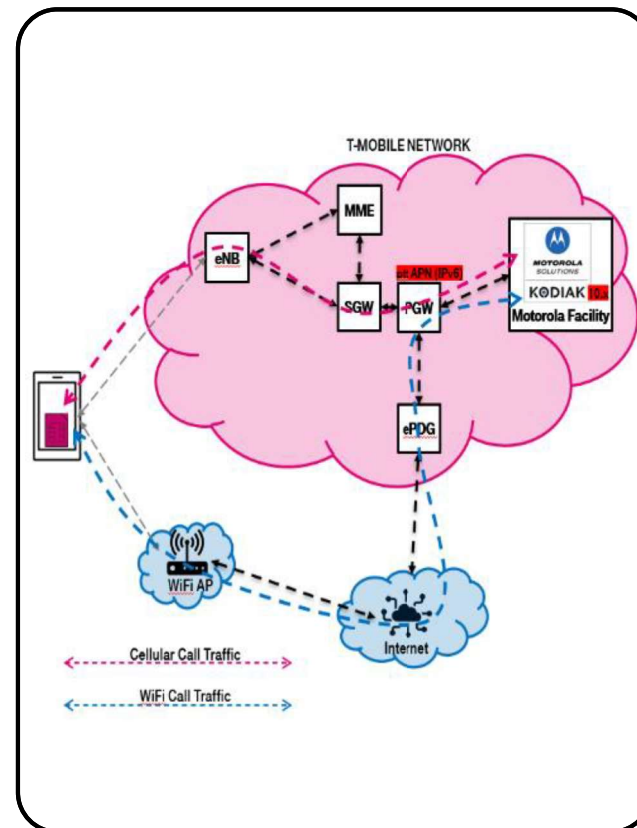
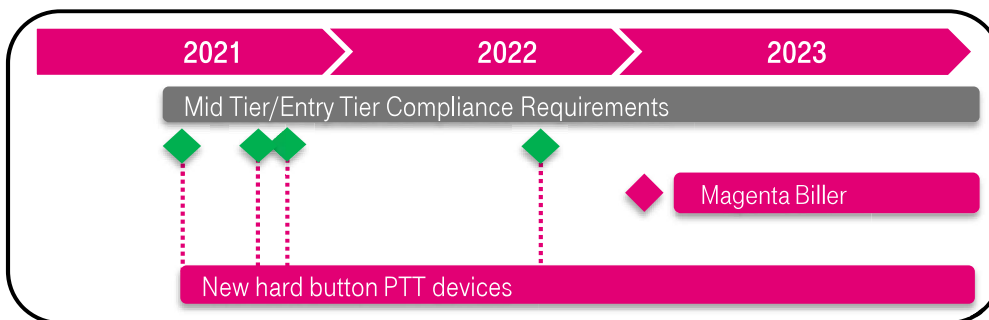
Business Benefits

- Launch new hard button PTT devices in Magenta network & Biller.
- Migrate Legacy PTT hard button devices to Magenta network.

Functional Description

- New Magenta SIM PTT hard button devices: Samsung Galaxy X Cover Pro 6
- PTT APN (IPv6)
 - Kodiak 10.x based PTT services (voice, messaging, video, presence, etc.)
 - Oct '22 Yellow -> Magenta Biller Migration
 - Applicable to stock voice capable devices designed for PTT service

Development Plan



Quick Settings – Android

Business Benefits

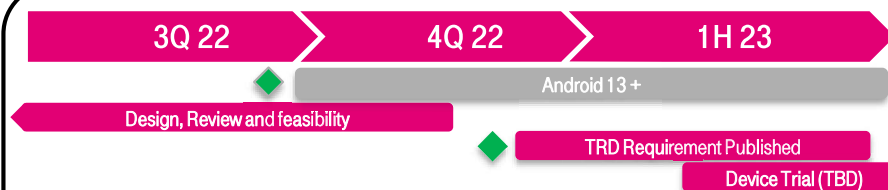
- Minimize user accidentally hitting quick access icons and may have to live in inadvertent state unknowingly.
- Provides standard Quick Settings Experience for all T-Mobile Android device portfolio

Functional Description

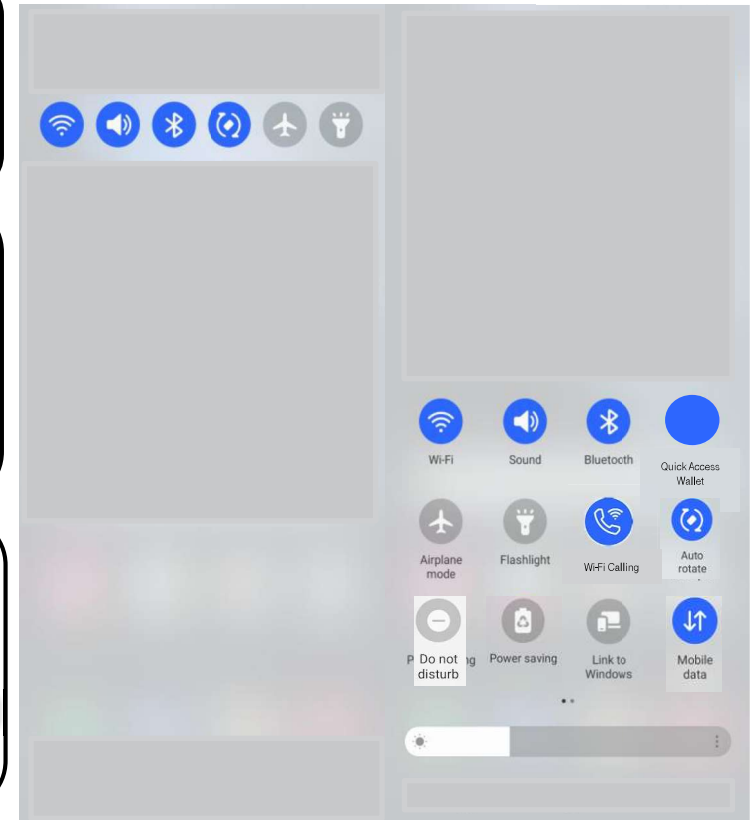
Mandate default Quick Settings for all Android devices as OOB E.

- Order of quick access icons in first and second page
- Applicable to Android 13 +
- Does not remove user ability to edit/manage element/icon order nor remove ability to have additional number of pages

Development Plan



Default Layout- Android



IR.94 user privacy with virtual background

Business Benefits

- A number of customers don't want to show the clear background image during the video call for the privacy concern. Zoom or Webex currently provides the related service for that reason.

Functional Description

Video call user can hide the background image as below.

- Video call user can show virtual background like tropical island scene or whichever user chooses.
- Video call user can blur background image hiding the sensitive image in background.

Device Requirements

2022 2H

2023 1H

2023 2H

2024 1H

All Video Call Capable UE

Device Development Plan

2H 22

1H 23

2H 23

1H 24

◆ Trial

◆ 1st Launch



Wi-Fi Calling — Android Websheet based E911 Address Update

Business Benefits

- ❑ Improve Android user experience on E911 address update for WiFi Calling, user doesn't need to log in T-MO account in web portal.
- ❑ Unify E911 address update user experience between Android and iOS.
- ❑ Allow non-account-owner(e.g. family member) to be able to set their E911 address independently.

Functional Description

- ❑ UE interacts with T-MO DES (Device Entitlement Server) and web server for E911 address update based on GSMA TS.43.
- ❑ UE integrates Mobile Solutions SDK, and invokes Mobile Solutions API for the communication with DES and web server.

Device Compliance

2022 Q3 > 2022 Q4 > 2023 Q1 > 2023 Q2

High Tier
Mid Tier
Entry Tier

Development Plan

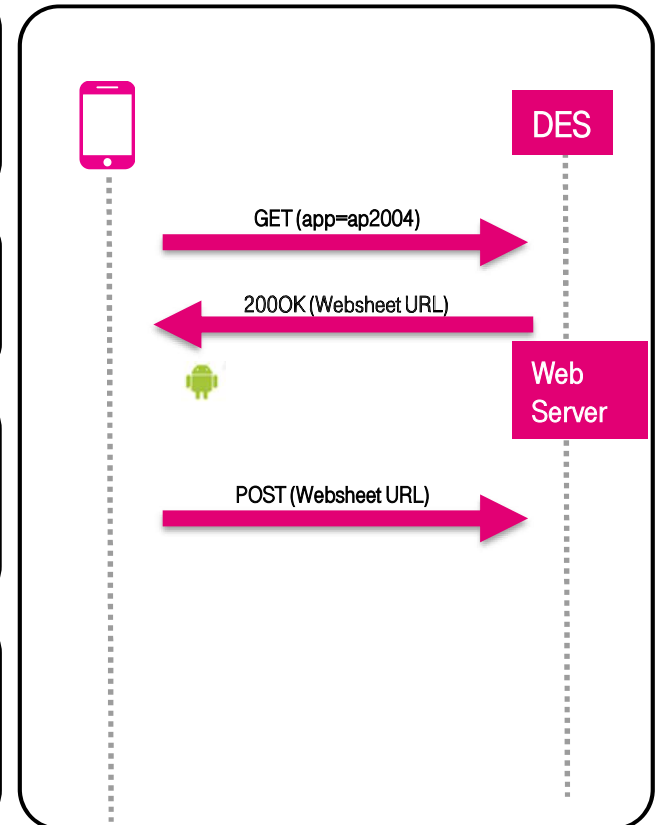
2022 Q2 > 2022 Q3 > 2022 Q4 > 2023

DES & Web server ready

Mobile Solutions SDK ready

1st device Launch

Launch on more devices



Mobile Solutions — Mobile Services

Business Benefits

- Mobile Services provides the ability to interact with our customers on devices
- Application consolidation of Carrier Hub, CDM, and Customer Engagement from Adapt.

Functional Description

- Policy Enforcement
- Wi-Fi Calling e911 Address Updates
- OneClick Fixes – Care Tools
- Customer Messaging

Device Requirements

2022 Q4 > 2023 Q1 > 2023 Q2 > 2023 Q3

Android Devices with OS12 or above

Development Plan

2022 Q4

2023 Q1

2023 Q2



9/1/22 Device launch with MS



1/19/23 Device launch with MS

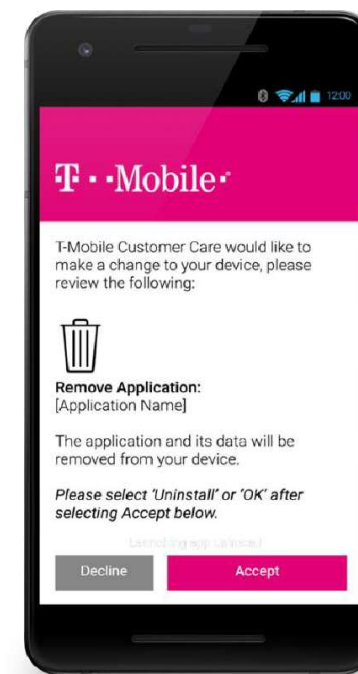


1/19/23 Device launch with MS



1 Click Fix Launch

Care 1-Click Fixes



Mobile Solutions — Content Manager

Business Benefits

- Content Manager provides Branding and Application Management
- Application consolidation of Mobile Installer/Mobile Content Manager

Functional Description

- On-Device Branding
- Application Management
- 3rd Party Revenue Attribution

Device Requirements

2022 Q4 > 2023 Q1 > 2023 Q2 > 2023 Q3

Android Devices with OS12 or above

Development Plan

2022 Q4 > 2023 Q1 > 2023 Q2



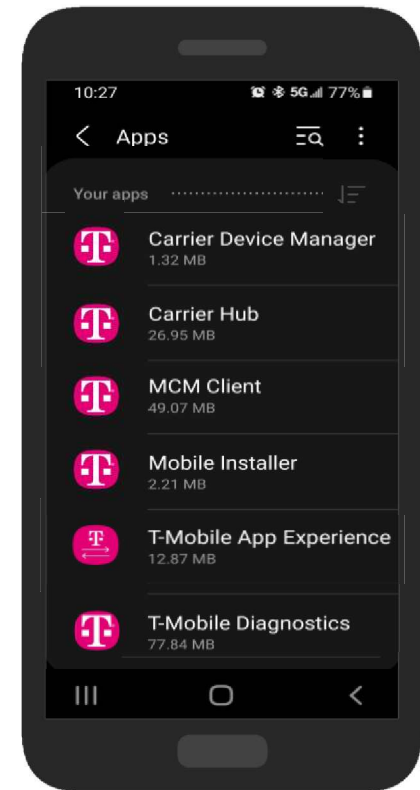
9/1/22 Device launch with Content Manager



1/19/23 Device launch with Content Manager



1/19/23 Device launch with Content Manager



Echo Locate — Diagnostics

Business Benefits

- To assess network issues and device performance on time in accordance with latest technology development, data collection and reduction drive testing vertically expanded

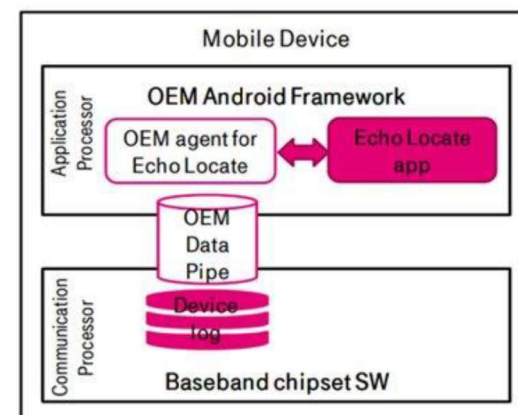
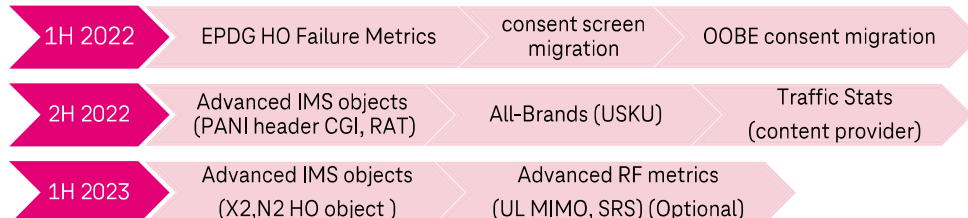
Functional Description

- To be preloaded with privilege permission being granted in Device Reporting APK TRD
- To be activated via user consent during the OOB for all-brands
- To collect voice and data metrics for LTE and 5G devices within same metrics classes
- To report/upload once in a day with reasonable environment detection logic

Device Requirements

- Echo Locate features are reflection and a part of telemetry services of T-Mobile
- To support recent 5G and spectrum features on time via 2022 Q4 and 2023 Q2 TRD
 - VoNR enabled device support voice metrics via IR and MR
 - NRCA enabled device support data metrics via IR and MR
 - LTE only, Tablet, eSIM, and DSDS devices to support metrics per roadmap 2023

Development Plan



Echo Locate — Recommendation

Opportunity

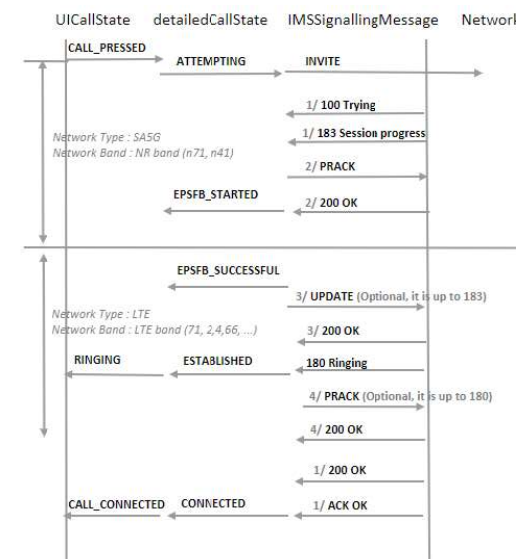
- IMS Call Flow is the criteria prior to application framework event
- EPSFB and PSHO needs call flow logic if no modem events
- CA combination setting to be reflected with latest tag and values

Solution

- Refer to latest voice supporting documents' IMS and flow
- Refer to metrics example source files
- Utilize public Android API and other TRDs

Results

- Design review earlier and wrapper implementation earlier
- History of release notes minimize misinterpretation
- EPSFB successful event without modem IPC API



<Example - Supporting Document>

Old Devices

```

<StandaloneBands5G>
  <SAn2Enabled>false</SAn2Enabled>
  <SAn66Enabled>false</SAn66Enabled>
  <SAn41Enabled>true</SAn41Enabled>
  <SAn71Enabled>true</SAn71Enabled>
  <SAn25Enabled>false</SAn25Enabled>
</StandaloneBands5G>
    
```

```

{"SAn2Enabled": false,
 "SAn66Enabled":
 false,"SAn41 Enabled":
 true,"SAn71Enabled":
 true,"SAn25Enabled":false}
    
```

New Devices

```

<StandaloneBands5G_NRCA>
  <SAn2Enabled_NRCA>false</SAn2Enabled_NRCA>
  <SAn66Enabled_NRCA>true</SAn66Enabled_NRCA>
  <SAn41Enabled_NRCA>true</SAn41Enabled_NRCA>
  <SAn71Enabled_NRCA>true</SAn71Enabled_NRCA>
  <SAn25Enabled_NRCA>true</SAn25Enabled_NRCA>
</StandaloneBands5G_NRCA>
    
```

```

{"SAn2Enabled_NRCA": false,
 "SAn66Enabled_NRCA":
 true,"SAn41Enabled_NRCA":
 true,"SAn71Enabled_NRCA":
 true,"SAn25Enabled_NRCA": true}
    
```

<Example – section 2.5.3.4 >

Contents



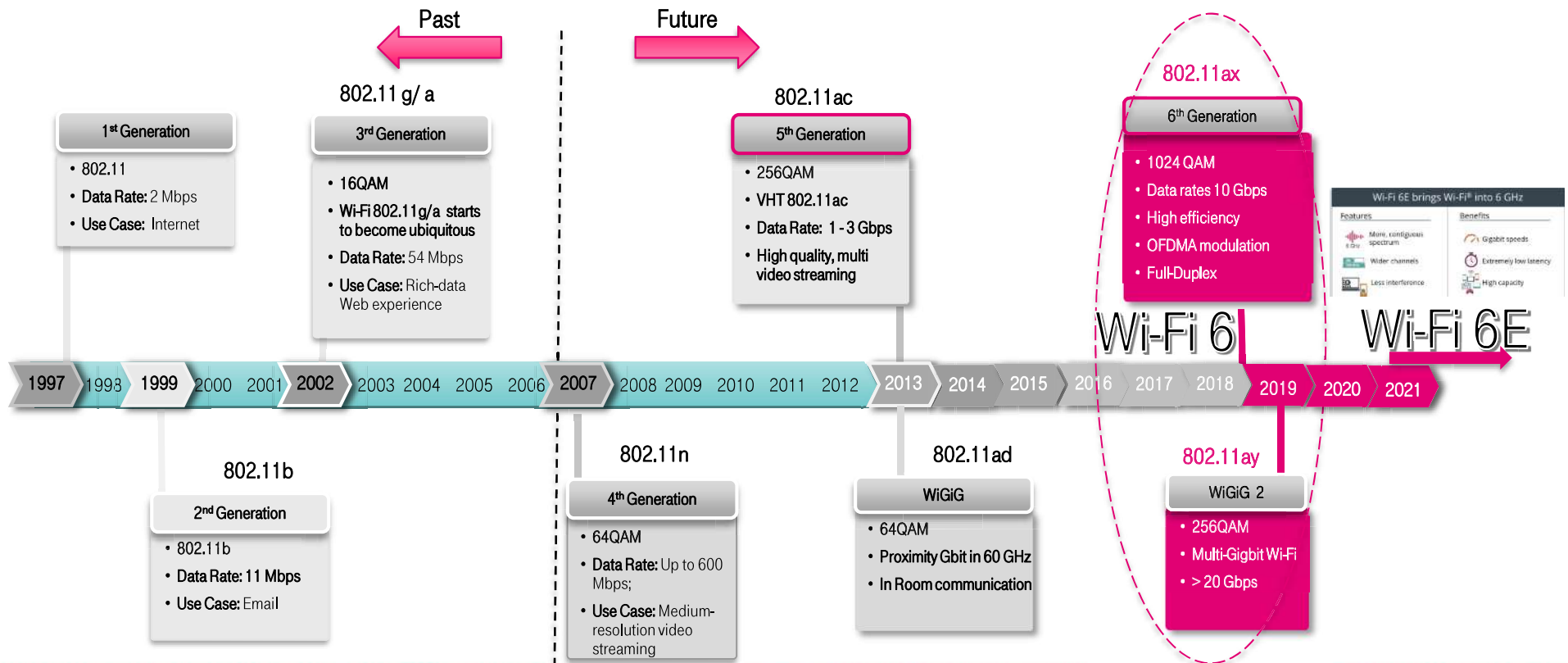
- T-Mobile Business and Network Update
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- Internet of Things
- Regulatory and Location Technology
- Device and IMS Services
- **Additional Material**

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➤ Additional Material

- Wi-Fi Technologies
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- IPv6 and APNs
- LTE UE Categories
- LTE Bands Around the World
- Technologies Under Evaluation
- Document Change Log

Wi-Fi Standards Evolution



eSIM Remote Provisioning

Business Benefits

- Facilitate OEM single SKU device with GSMA RSP standard compliant implementation
- eSIM will save space (no SIM slot needed) on small form factor devices (e.g. wearable devices)
- Dual SIM Dual Standby (DSDS) to solve roaming and multiple line one device use cases.

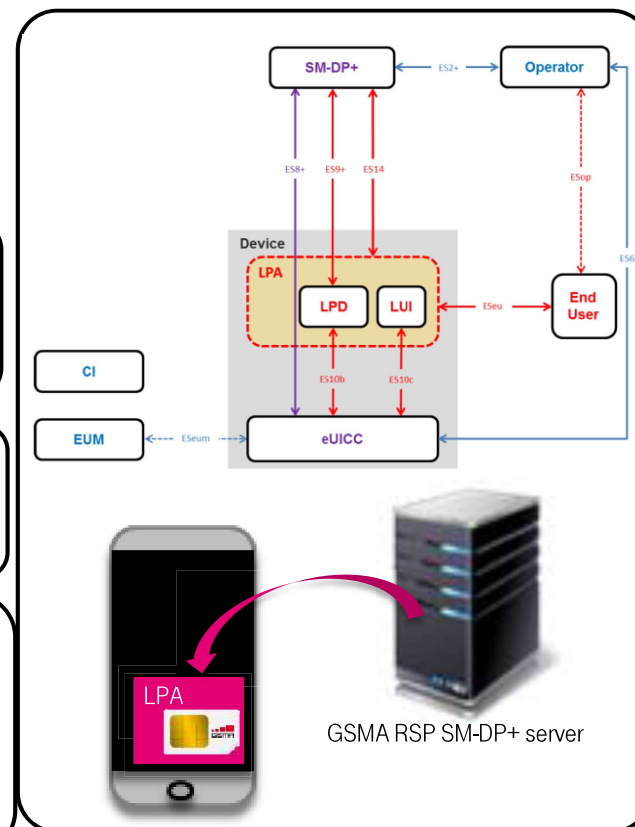
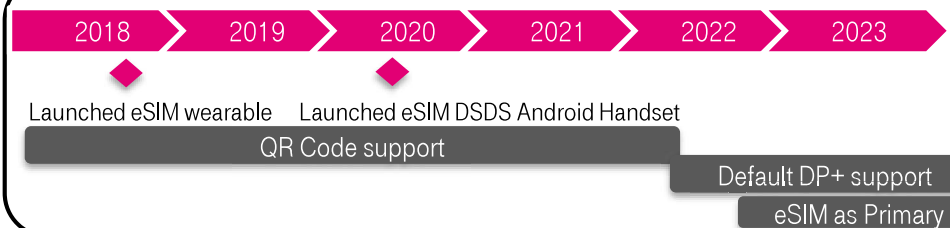
Functional Description

- OEM-specific Local Profile Assistant (LPA) handle interaction with servers
 - Seamless Profile discovery, download and activation
- Multiple profile management

Device Support



Development Plan





Chipset Certification Program

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Chipset Certification Program Phases



Technology and Roadmap Alignment

- Regular alignment on chipset roadmap
- Monthly TMUS technology roadmap update
- TMO Chipset Ecosystem Forecast and HLFS on Key Chipsets



Certification Planning

- Determine chipset capability, certification scope, test coverage, and schedule
- On-board Chipset on DICE
- Define Scope for Chipset Certification



Primary Chipset Certification

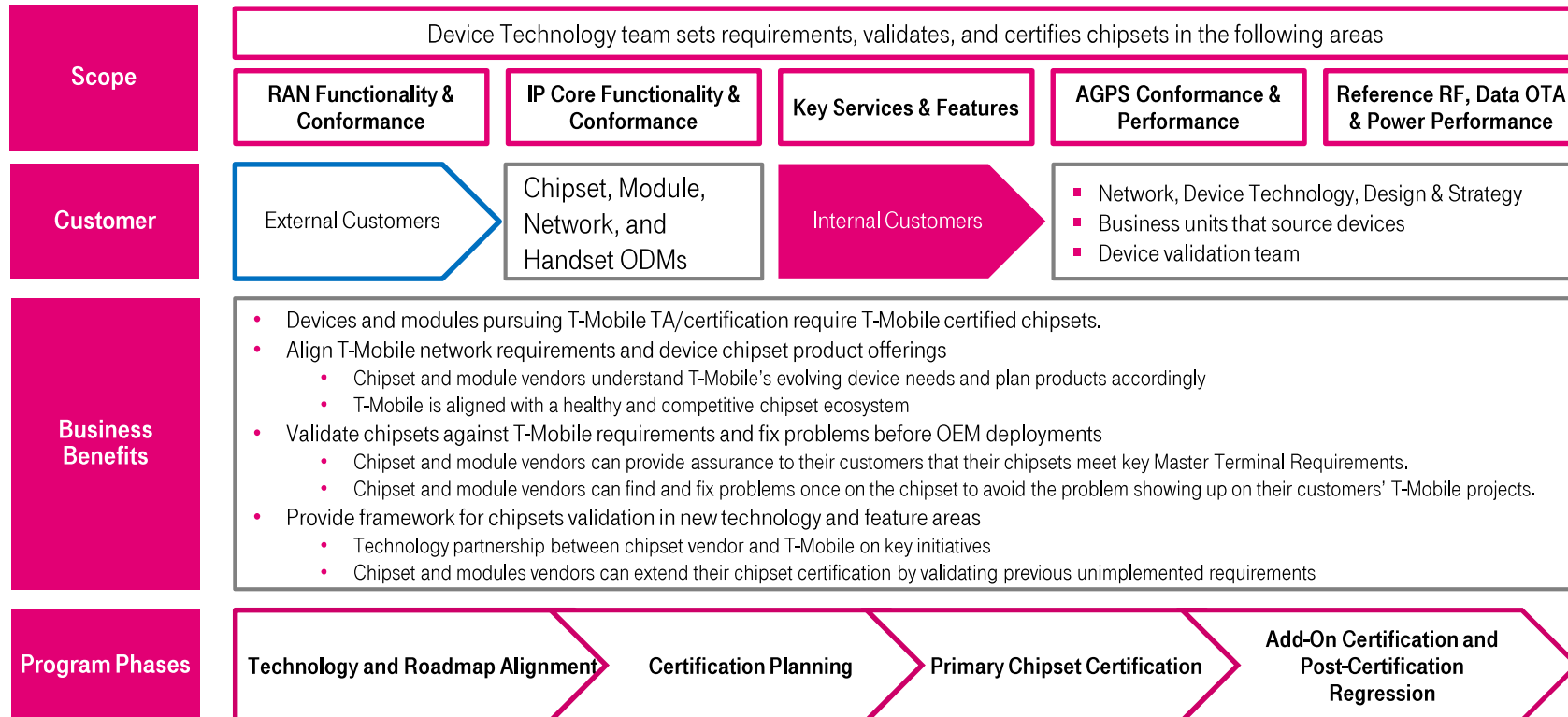
- Chipset validation and resolution of chipset defects
- A Test Manager from PQE (Product Quality Evaluation) will oversee the end-to-end process



Add-On & Post-Cert Regression

- Determine chipset changes and new features and validate the chipset changes accordingly

Chipset Certification Program Detailed Overview



High-level Scope of Chipset Certification

	NVIOT	T-Mobile Conformance Protocol	T-Mobile Conformance RF Parametric	T-Mobile Conformance Data and Battery Performance	T-Mobile Field	T-Mobile Lab IOT
Goal	Baseline interoperability on TMUS networks.	In-depth protocol and functional conformance testing.	RF OTA conformance for chipset + reference RFFE	Data OTA conformance for chipset + reference RFFE	Functional and performance in real-life TMUS production NW.	Key production scenarios that are difficult to validate in the field.
Test Plan	Ericsson T-Mobile NVIOT Nokia T-Mobile NVIOT	<ul style="list-style-type: none"> T-Mobile Device Test Plan AKA the quarterly "QC Test Plan", which contains protocol, RF Parametric and Data Performance test plans. T-Mobile Battery Drain TRD Part of the MTR release contains battery drain requirements and test plan. 		Test scripts for the test plan are available from the following vendors. <ul style="list-style-type: none"> Keysight Anritsu Rhode & Schwartz Spirent (Data Performance) 	T-Mobile Device Test Plan AKA the quarterly "QC Test Plan", which contains protocol, IOT test plans to be executed in T-Mobile lab, and the field test plan/field test guide.	
Test Sites	Infra NVIOT labs	<ul style="list-style-type: none"> Vendor performing testing at their own R&D facility using approved simulators and T-Mobile scripts packages. Approved third-party labs 			Field Test Guide (FTG) specifies the required field test routes	T-Mobile device lab
High-level Summary	NSN, E///: 2G, 3G, 4G LTE, 5G NSA and SA, IMS/VoLTE, Location Technologies	Protocol conformance	RF Parametric conformance	Data and battery performance	Real-life network scenarios and performance.	Pre-production and other sanity testing in controlled lab environment.

Sample Timeline of a Chipset Certification

- The recommended timeline below assumes a never-certified* multi-mode chipset supporting 2G, 3G, 4G LTE, IMS/VoLTE, 5G (NSA & SA) and AGPS
- Timelines can be compressed further with efficient planning and proactive work by vendor

	Month #1	Month #2	Month #3	Month #4	Month #5	Month #6	Month #7
MTR/CFS/TEST SCOPE							
NVIOT							
RF SIMULATION (Test Equipment Vendor RF Protocol & Parametric Scripts)							
FIELD Testing							
TMO LAB							
TA REPORT/REVIEW/ APPROVAL							

**No previous test results to leverage*

IPv6 and APNs

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APN and IP Address Configuration on Devices

For Handsets and Tablets

APN Purpose	APN	IP Address Type
For Internet	fast.t-mobile.com fast.metropcs.com	IPv6
For Tethering	pcweb.tmobile.com pcweb.metropcs.com	IPv6**
For IMS*	ims ims	IPv6

For WiFi Hotspots and Data Sticks

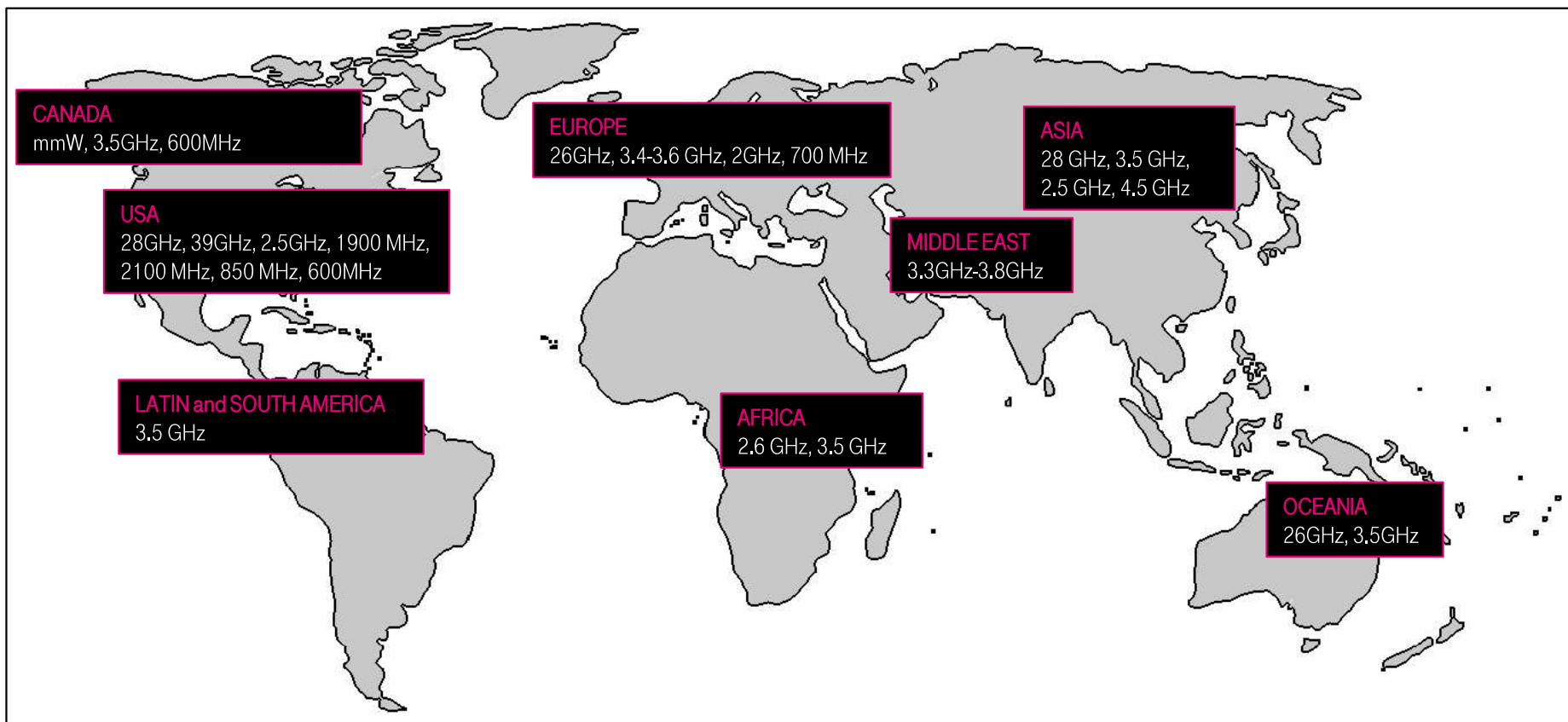
APN Purpose	APN	IP Address Type
For Internet/Tethering	fast.t-mobile.com fast.metropcs.com	IPv4/IPv6**

Notes: (1) When roaming, use IPv4 for all APN except sos APN which must use IPv4v6. (2) All TMO APNs are not user editable.

* IMS APN is only needed if device supports IMS Services like VoL TE, WFC, RCS, Video Calling

** Support of IPv4/IPv6 for MBB devices or for tethering purposes should reference RFC7278.

5G Spectrum Around The World





Technologies Under Evaluation

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Technologies Under Evaluation

- **Being considered for future deployment, but no specific launch date currently planned**
 - LTE Carrier Aggregation
 - 5 DL CA on Licensed Spectrum
 - LTE UL 256QAM
 - eMBMS
 - LTE Latency Reduction- User Plane Latency Reduction
 - Sustainability Self-Certification in accordance with the European Eco Rating Consortium methodology
- **Must not be enabled on devices until future confirmation from T-Mobile**
 - GLONASS
 - RRC Establishment Cause
 - VoLTE SPS
 - LTE Carrier Aggregation Combos that are not specified in T-Mobile Requirements.
 - Intelligent NW Selection & ANDSF



Document Change Log

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Changes since previous version (December 2022)

Section	Dec'22	Jan'23
Business and Network Update	Updated	Updated
Technology Requirements & Roadmap	No Changes	Updated
Spectrum and Frequency Bands		
Spectrum and Band Requirements	No Changes	Updated
Spectrum Utilization Strategy	No Changes	Updated
mmWave Spectrum	No Changes	No Changes
C-Band and n77	No Changes	No Changes
Upcoming Spectrum Auctions	No Changes	Updated
5G Roaming Architecture	No Changes	No Changes
5G Requirements and Roadmap		
5G Device Requirements & Roadmap	No Changes	No Changes
EN-DC and NR CA Combos	Updated	No Changes
n25 Standalone with NR CA	No Changes	No Changes
n25 & n66 CBW > 20MHz	No Changes	No Changes
Service Based C-DRX	No Changes	No Changes
HPUE for Stand Alone	No Changes	No Changes
SRS Antenna Switching	No Changes	Updated
UE assistance handling: Overheating and No. of CC	No Changes	No Changes
LTE to NR Packet Switched Handover	No Changes	Updated
SU-MIMO, MU-MIMO and UL MIMO	No Changes	Updated
Uplink Grant Skipping	No Changes	Updated
DL 256QAM (FR2)	No Changes	No Changes
Balanced TDD Pattern FR2	No Changes	No Changes
Voice over NR (VoNR)	No Changes	No Changes
VoNR & 5G Toggle Interaction		New
Bandwidth Part (BWP)	No Changes	No Changes
CP-OFDM/DFT-s-OFDM Waveform Switching	No Changes	No Changes
Closed Loop Power Control	No Changes	No Changes
Robust Header Compression (RoHC)	No Changes	No Changes
Cell Reselection Sub Priority	No Changes	No Changes

Section	Dec'22	Jan'23
5G Requirements and Roadmap Contd.		
RRC Inactive Mode	No Changes	No Changes
Cellular Vehicle-To-Everything (CV2X)	No Changes	No Changes
Ultra Capacity Icon	No Changes	No Changes
Network Selection UI Redesign	No Changes	Updated
BCS4	No Changes	No Changes
Low Latency 5QI		New
Fixed Wireless Access		New
Internet of Things	No Changes	No Changes
Regulatory & Location Technology	Updated	Updated
Device and IMS Services	No Changes	No Changes
Universal SKU	No Changes	No Changes
IMS Services (5G and LTE)	No Changes	Archived
Network Slicing	No Changes	No Changes
Rich Communication Services (RCS)	No Changes	No Changes
Google Messages on the Hotseat	No Changes	No Changes
Enriched Calling	No Changes	No Changes
Carrier Configuration	No Changes	No Changes
Visual Voicemail	No Changes	No Changes
Remote SIM Unlock (RSU)	No Changes	No Changes
CS Sunset	Updated	No Changes
Push to Talk	No Changes	No Changes
Quick Setting – Android	No Changes	Updated
IR,94 user privacy with virtual background	No Changes	No Changes
Wi-Fi Calling – Android E911 Address	No Changes	Updated
Device Mobile Solutions – Mobile Services	No Changes	No Changes
Device Mobile Solutions – Content Manager	No Changes	No Changes
Echo Locate	No Changes	No Changes
Additional Material	No Changes	No Changes

Summary of Changes for January 2023

Section	Updates
Business and Network Update	<ul style="list-style-type: none"> Added "T-Mobile Kicks Off 2023 as the Nationwide Network Leader" - Results from Ookla Q4 2022 Market Analysis Report
Device Technology Requirements & Roadmap	<ul style="list-style-type: none"> Updated Technology Priorities for 2023 and 2024 Updated Timeline for Selected Key 5G Technologies Updated Device Requirements and Roadmaps Added Mobility and iRAT features
Spectrum & Frequency Bands	<ul style="list-style-type: none"> Frequency Band Requirements & Spectrum Assets – UMTS bands required for roaming Spectrum Utilization Strategy – updates to include 2024 and 2025 view Spectrum Auctions – editorial updates 5G Device Spectrum Band Roadmap – update timeline view with 2023
5G Device Requirements & Roadmap	<ul style="list-style-type: none"> Updated development plan for "UL Grant Skipping" Added "VoNR & 5G Toggle Interaction" Added "Low Latency 5QI" Updated "Network Selection UI Redesign" to include Q3 2023 TRD Updated development plan for "LTE to NR PSHO" Updated development plans for MIMO features (SU MIMO, MU MIMO, UL MIMO) Added explicit band requirements for UL MIMO Archived slide for HPUE PC2 for 2.5 GHz n41 SA feature
Fixed Wireless Access <small>*NEW SECTION*</small>	<ul style="list-style-type: none"> New 5G Radio Requirements and Technology Guidelines for Fixed Wireless Access Products New detail slide for UL CA 3TX feature New detail slide for 8Rx DL Receive Diversity feature
Device & IMS Services	<ul style="list-style-type: none"> Updated detail slide for Android Quick Settings Updated development plan for Android Websheet based E911 Address Update for WiFi Calling

List of Changes in January — EN-DC and NR CA Combos

ENDC FR1

No Changes in combinations.

ENDC FR2

No Changes in combinations.

NR CA FR1

No Changes in combinations.

NR CA FR1+FR2

No Changes in combinations.

NR DC FR1+FR2

No Changes in combinations.

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