GCF 5G MENA Workshop

November 28, 2018

5G New Radio

Motivation, Design, Deployment Options & Challenges

MEDIATEK

New Radio to Drive Innovation

MOTIVATION

- Improved Performance, scalability and efficiency
- New & Diverse Services on the rise, driving the growth

RADIO CAPABILITY

- Diverse scalability for eMBB, IOT, Reliability and Latency
- Better usage of Spectrum
- Impact to Devices

4G 5G

» **8.9 bn** mobile subscription in **2023**
» **LTE** will continue to have **60%** of the share
» **5G** will account for **12%** of the share

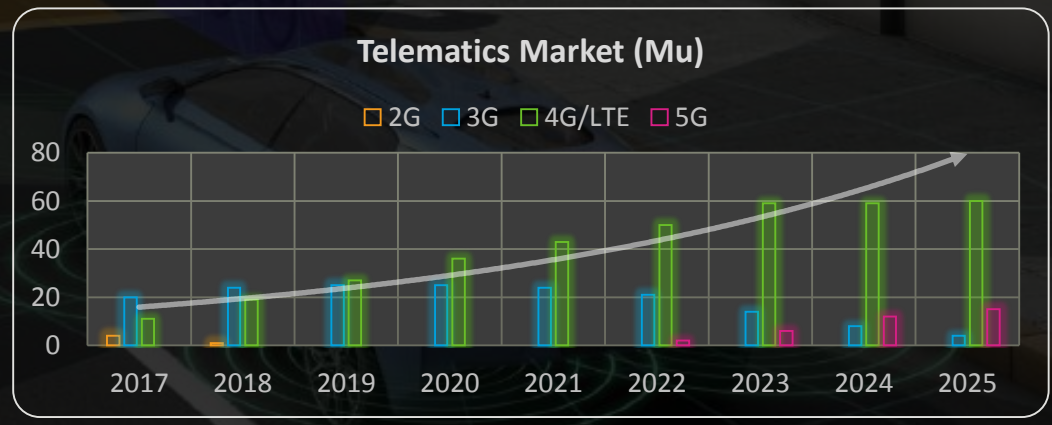
31% CAGR
Data Traffic*
3GB now → 17GB
2023

eMBB

30% CAGR
Wide-area IOT
0.8M now → 4.1B
2023

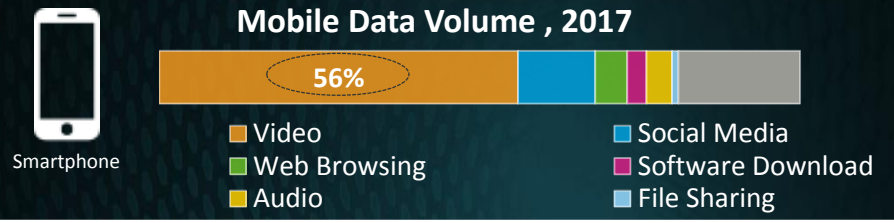
IOT

URLLC



From Ericsson Mobility Report, and MediaTek Research. *WW monthly/active smartphone

Data Experience



Augmented Reality (AR), Mixed Reality (MR) & Virtual Reality (VR)

5G NR Value Add:

- 200 Mbps to 1 Gbps streaming bandwidth
- Reliable sub-20 msec motion-to-photon latency VR

Mobile Media: 360°, 4K/8K Live Entertainment

~73% of mobile data traffic from **video/streaming** services in **2023**

5G NR Value Add:

- 8K: 100-500 Mbps streaming bandwidth, sub-10 msec latency
- 360°: 400-600 Mbps streaming BW, sub-10 msec latency

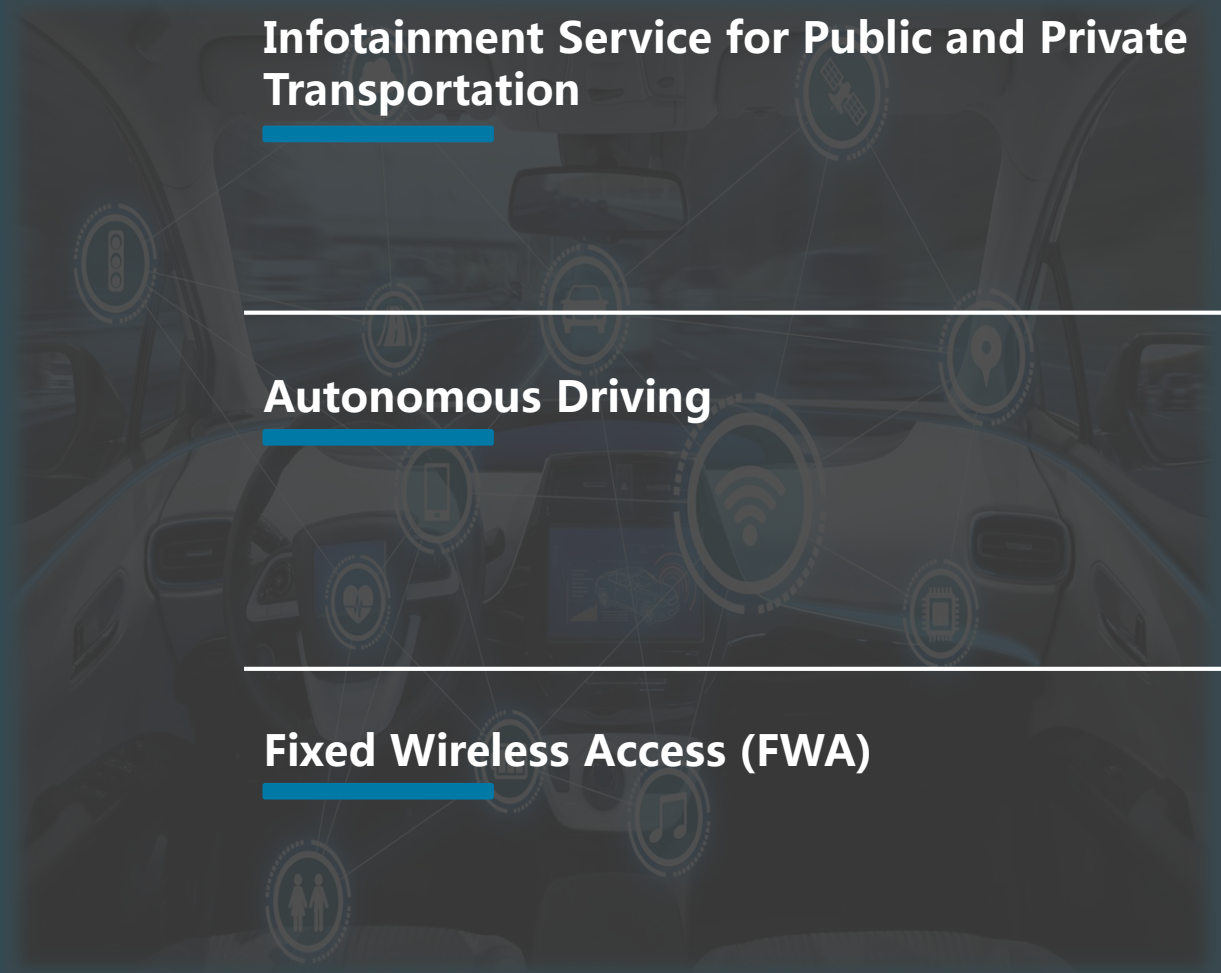
Game Streaming Services

5G NR Value Add:

- 200-500 Mbps streaming bandwidth
- Sub-10 msec latency for best user experience

Data Volume for Video is From Ericsson Mobility Report, 2018

Next level of Industry Revolution



Infotainment Service for Public and Private Transportation

5G NR Value Add:

- Extreme Capacity up to 40 Gbps DL
  - E.g. 500 people per train
- Low Latency for VR/AR

Autonomous Driving

5G NR Value Add:

- Ultra-low Latency with very high reliability
  - For safety and security
- 100 Mbps/vehicle, high capacity for fleet (10+ Gbps)

Fixed Wireless Access (FWA)

5G NR Value Add:

- Fiber+ like speed (10-40 Gbps) to multiple households
  - Within one site location

Next level of Personal Lifestyle

Tele-education, Tele-office Services

e.g. thin/zero client for mobile devices

5G NR Value Add:

- Minimum of 400-500 Mbps
- Up to 1 Gbps burst performance

Tele-health services

e.g. remote surgeries

5G NR Value Add:

- Ultra Reliable throughput
- Strict low e2e latencies (1-10 msec) with low jitter (1µs)

5G NR

Essential for next generation “everything” experience

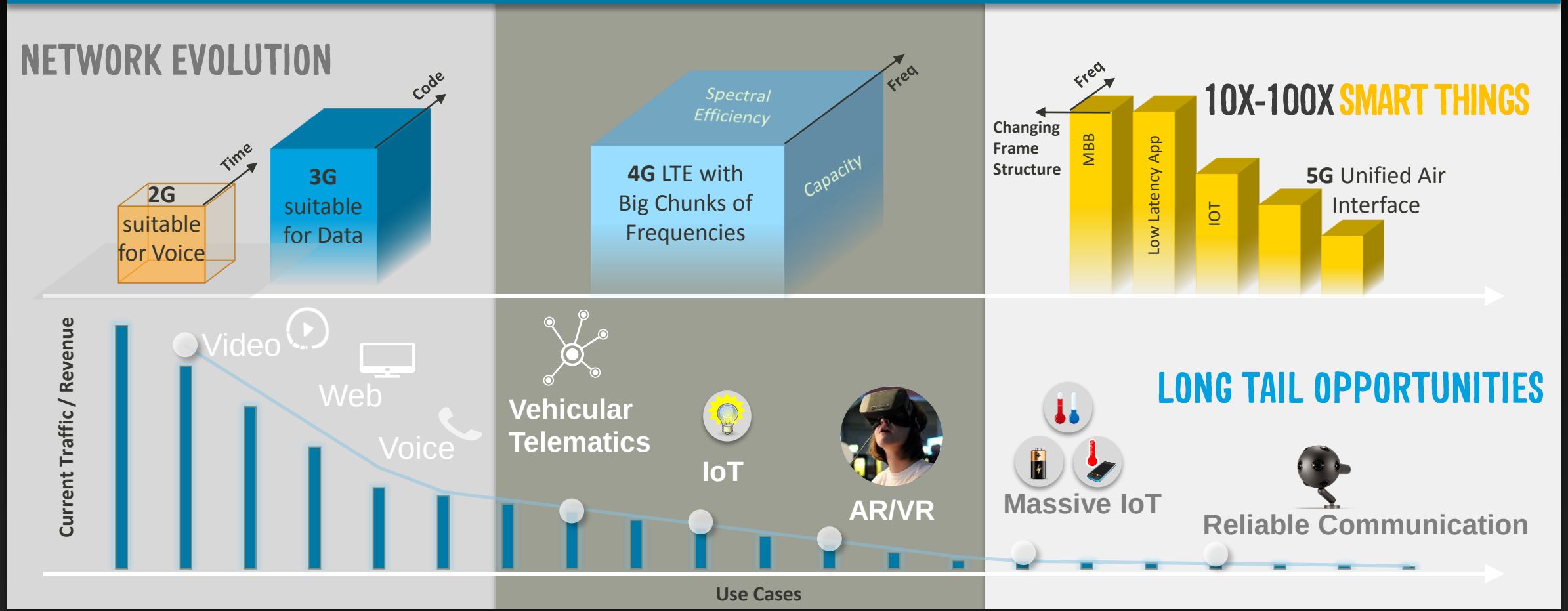
- **Extreme Data Speed**
- **Low Latency with High Reliability**
- **Massive Capacity for all Use Cases**
- **Diverse QoS & Consistent User Experience**

Technology Evolution is for Users & Services

Multiple Radios
Voice + Mobile Broadband (MBB)

One Efficient Network
IP Voice Services + MBB + Some Things

Clustered Network
eMBB + More Things + Moving Nodes + Slicing + Verticals



3GPP Standard for 5G NR Evolution

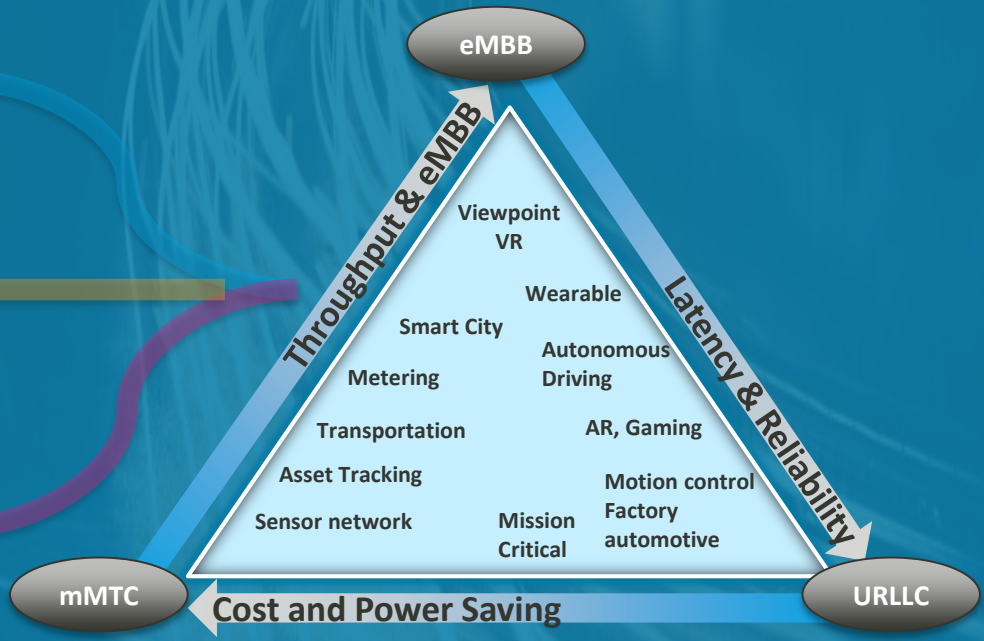
	Rel-15 Phase-1	Rel-16 Phase-2
eMBB	• Stand-alone/Non-Standalone • 4G -5G interworking • Band Combinations with LTE • MIMO/Beamforming	• Unlicensed standalone 5G • MIMO enhancements • High UE Speed 5G Support • Wireless/self backhaul

mMTC	• Continue Rel-13/14 NB-IOT & eMTC
	• Improved features for NB-IOT & eMTC
	  • WUS, SPS, EDT, RLC UM …
		• 5G mMTC "NR+LTE+NB-IoT/eMTC"
		  • In-band 5G NR, Grant-free …

URLLC	• Short TTI with few msec latency • Improved Latency for Cellular V2V • partial URLLC use case	• 5G URLCC with 0.5 msec Latency • Autonomous driving

June 2018	December 2019
Test Spec [RAN-5]	SA Op. 2/5 (PH-2)
NSA Op. 3 (PH-1.5)	NSA Op. 3 (PH-3)/7

Scalable and Unified 5G Air Interface



- Based on Test Spec (Rel-15 #81..#84), The overall industry will be mature for certification process based on 3GPP testing by Q3'2019
- Rel-17 is expected in June 2021
- Only summary of features is shown in this roadmap

Spectrum and Radio

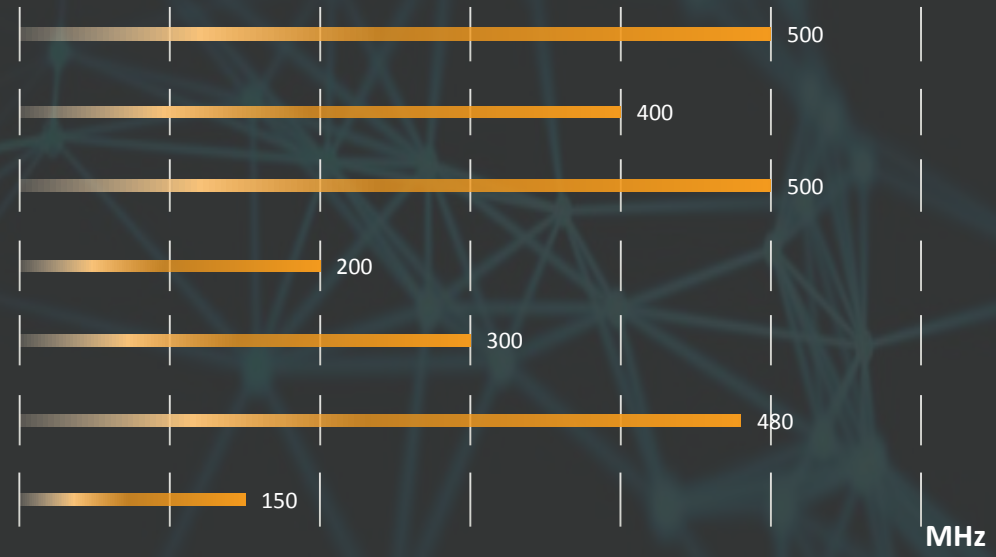
5G NR TECHNICAL EVOLUTIONS

Global Race Towards 5G

Market	Launch Timeline
China	CT, CM, CU
Germany	DT
Japan	KDDI, NTT, S.Bank
Singapore	Sing
S. Korea	KT, SKT, LG+
UK	EE
USA	VZW, AT&T, Sprint, TMO

2018 /// 2021

Amount of mid-band [1GHz-6GHz] confirmed for 5G assignment by 2022



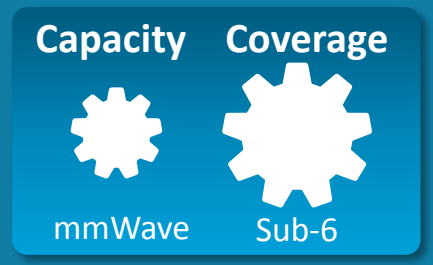
Analysis Mason, 2018

5G Deployment Influenced by Available Spectrum

- High-bands above 24 GHz (mmWave) → FR2
- Mid-bands 1 GHz to 6 GHz (sub-6) → FR1
- Low-bands below 1 GHz (sub-6) → FR1

Spectrum Status, NR

	Sub-6GHz			Above-6GHz		
	<1 GHz	1-3 GHz	3-5 GHz	6-24 GHz	24-30 GHz	30-40 GHz
China	Band 8	Band 1, 3, 41	**3.3-3.6GHz** **4.8-5.0GHz**		**26GHz**	37-42.5GHz
Japan			**3.6-4.2GHz** **4.4-4.9GHz**		**27.5-29.5GHz**	
S. Korea		Band 1, 3			**27.5-28.5GHz** **26.5-29.5GHz**	
USA	Band 71	Band 66, 41			**27.5-28.35GHz**	37-37.6GHz 37.6-40GHz
Europe	Band 20, 28		**3.4-3.8GHz**	5.925-8.5GHz	**24.25-27.5GHz**	31.8-33.4GHz
Others (MEA/AUS)		1.427-1.518GHz	**3.3-3.8GHz**		**24.25-29.5GHz**	

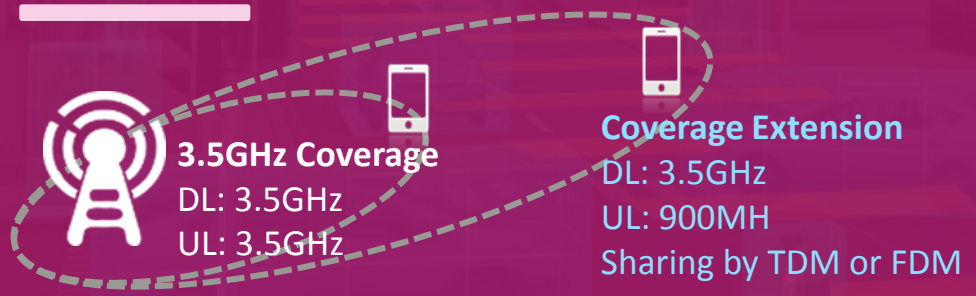


5G Early Deployment is Possible due to Available Spectrum

- **Table is based on Telecom Operators Band Interest Proposals for NR in 3GPP – RAN4**
- **How to introduce legacy LTE spectrum to NR bands is more about network migration paths**

5G NR Flexible Spectrum Access

UL SHARING (SUL) FOR COVERAGE PURPOSE

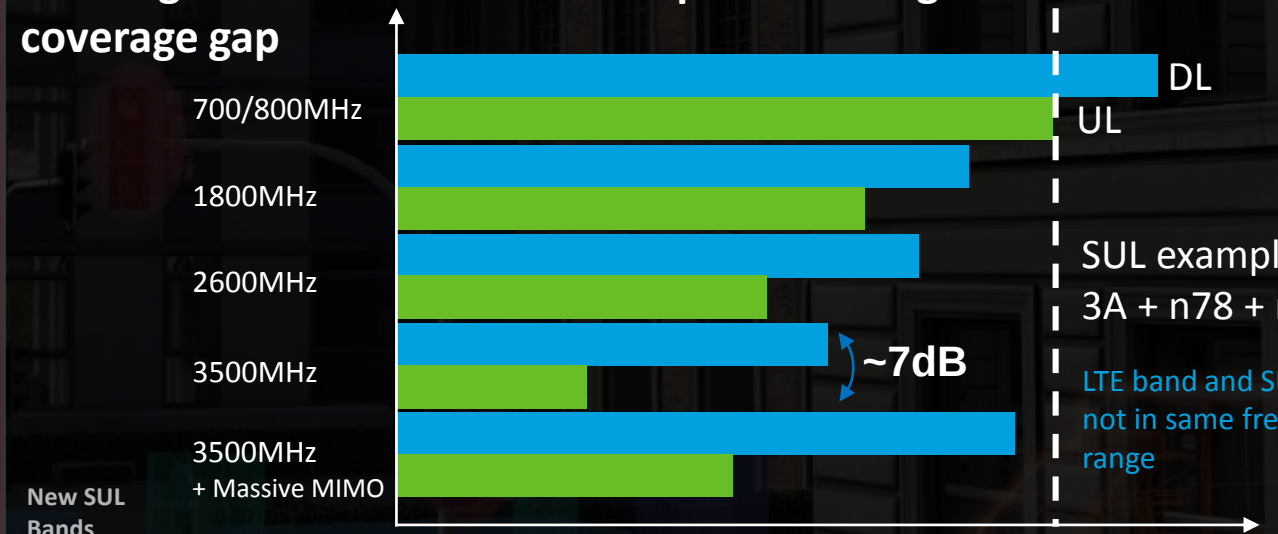


DL SHARING FOR NR SPECTRUM EXTENSION

- Basic idea is NR signals are transmitted over un-used LTE resource
- Useful for operators who consider LTE spectrum migration ex., USA

Read Whitepaper https://cdn-www.mediatek.com/page/MediaTek-5G-NR-White-Paper-PDF5GNRWP.pdf

Cell-edge UE can use low-band uplink to mitigate the coverage gap

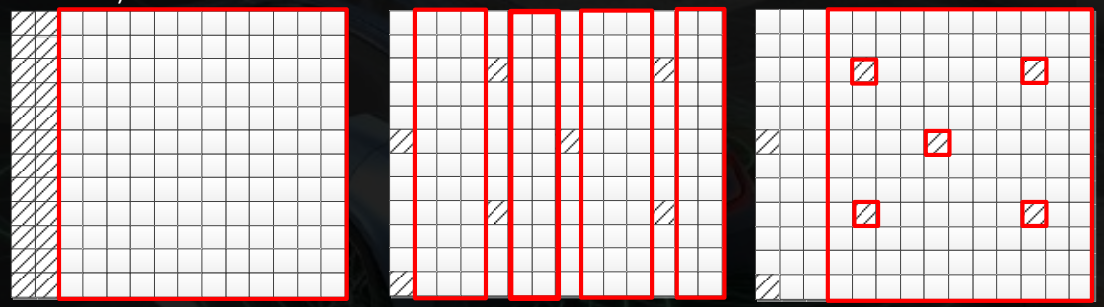


New SUL Bands	
n80	1710 – 1785 MHz
n81	880 – 915 MHz
n82	832 – 862 MHz
n83	703 – 748 MHz
n84	1920 – 1980 MHz
n85	2496 – 2690 MHz

The DL coverage of 700MHz and 3.5GHz with massive MIMO are similar, but not UL

LTE Uplink **LTE Downlink**

Strategy used in LTE today (e.g., ICIC, RS overhead reduction for TM9)



Option-1 MBSFN based | Option-2 Mini slot | Option-3 Rate-Matching

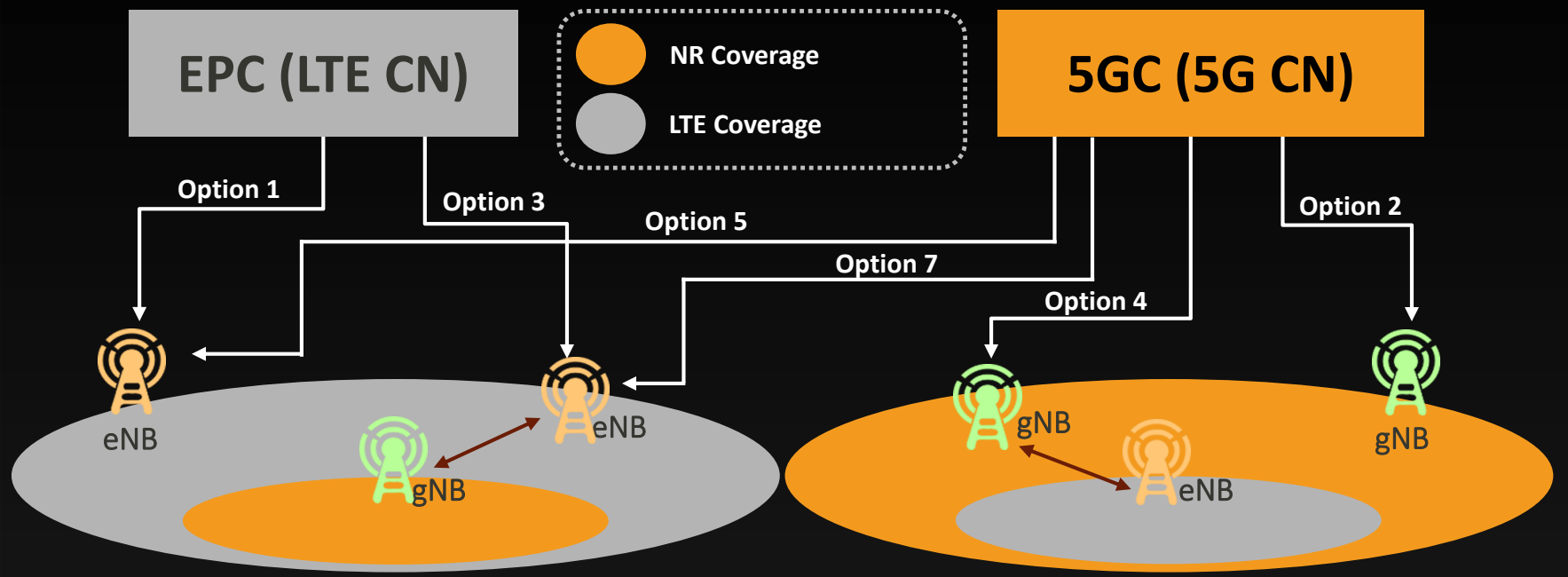
NR Options

NON-STANDALONE

- Partial NR functions from SA
- DuCo requires 2 modems activated

STANDALONE

- Full NR functions For C/U Planes
- Additional complexity in Idle mode

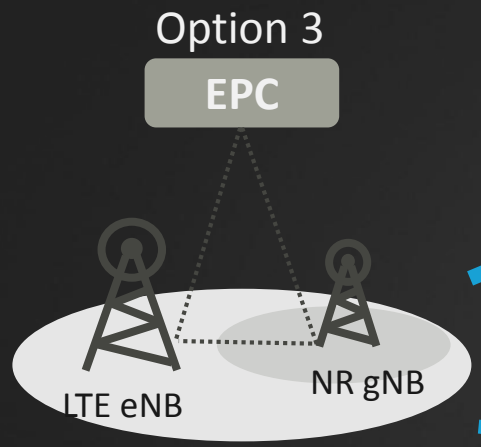


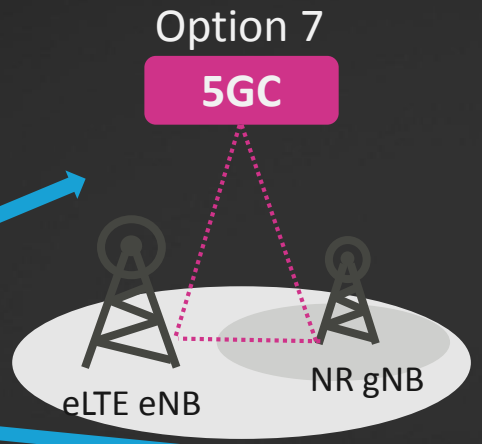
Option	Type	Description	3GPP Completion	Comments
2	SA	SA to NGC	Sep 2018	Standalone – China market interest
3/3a/3x	NSA	EPC + LTE Assisted	Mar 2018	3x is current main stream
4/4a	NSA	5GC + NR Assisted	Mar 2019	Late-drop ASN.1 freeze in 1Q19
5	SA	LTE + 5GC	Sep 2018*	Could be in late-drop if can't be completed in Sep 2018
7/7a/7x	NSA	5GC+ LTE Assisted	Mar 2019	Late-drop ASN.1 freeze in 1Q19

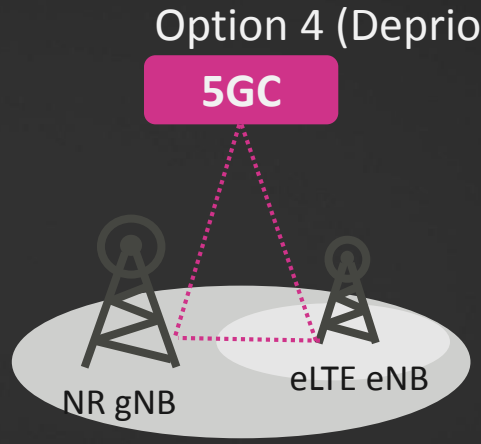
**In case Option 5 is not completed by September ASN.1 drop, it will be part of the late drop*

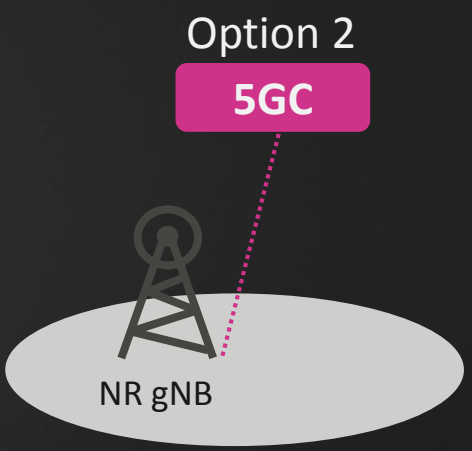
Deployment Options Applicability – MediaTek view

Initial deployment | **Intermediate migration options (>2022)** | **Ultimate goal (>2025)**

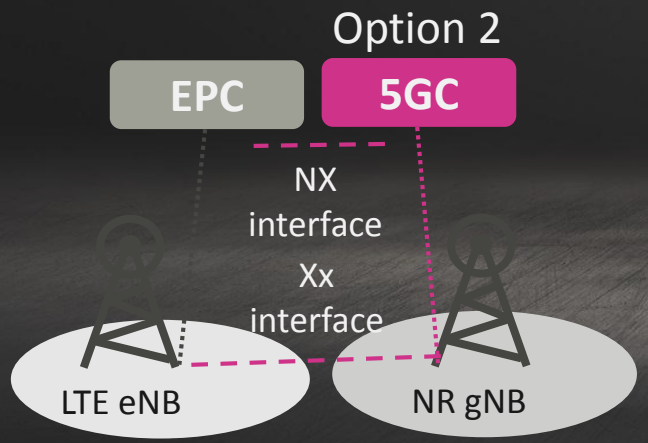


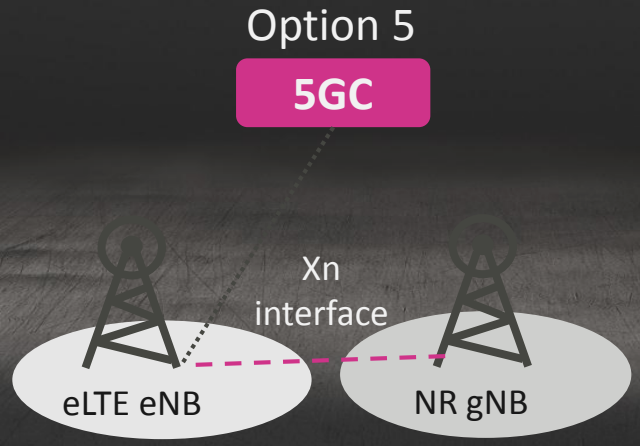






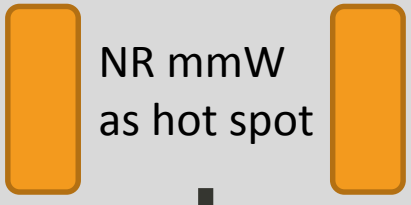
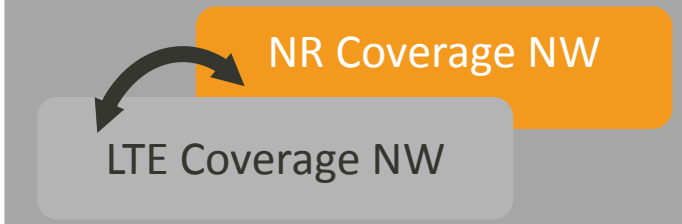
Only consider Op3&2 for initial 5G





- **At least 2-3 years after initial launch (our guess)**
- **From EPC to 5GC**
  - Op.3 seems to be kept for long while, then directly move to Op.2?
  - UE preference of option 3 family:
    - 3a (simpler UE with no split bearer) > 3x (avoid LTE PDCP bottleneck) > 3

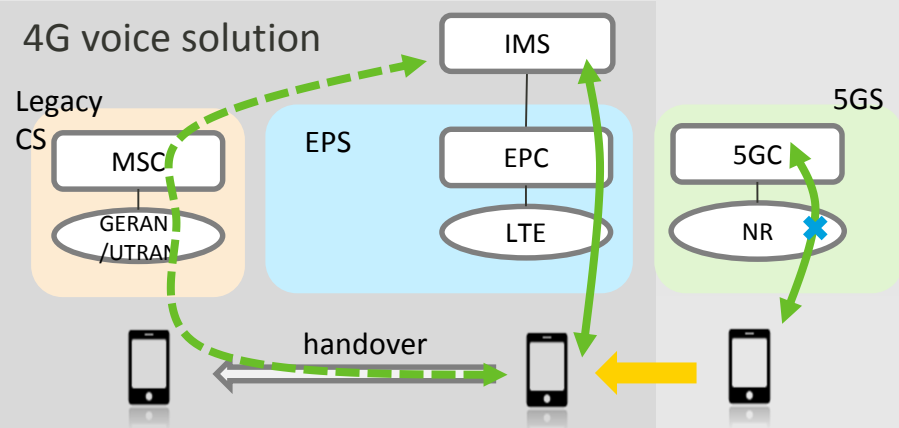
Possible Three of Major Deployment Scenarios

	Case1 : LTE coverage + NR hot spot Non-standalone	Case2: LTE coverage + NR sub-6 carriers Non-standalone	Case3: LTE + NR Standalone (Inter-RAT, no aggregation)
DEPLOYMENT			
ADVANTAGES	Very wide BW, can achieve >5 Gbps peak T-put	Better coverage Mature ecosystem	Better coverage Mature ecosystem Simpler migration path to NGC
CHALLENGES	**Need mmW** Very limited coverage Unreliable signal quality	Limited available spectrum Peak T-put ~4Gbps **Fragment spectrum leads to multiple CA combos**	Need wide enough contiguous spectrum for sub-6 NR Best case in HW cost & complexity
	US JP KR	US JP KR EU	US CN

5G Voice Solutions

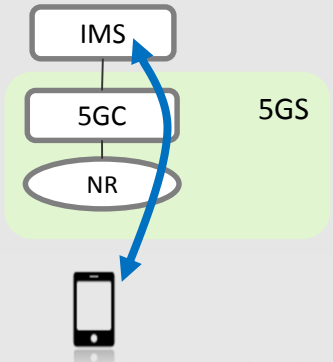
EPS Fallback

- Single Radio operation
- Handover to EPS when making call
- Requires 5GC/EPC interworking
- Voice performance = legacy VoLTE
- Preferred approach for UE vendors



5G VoNR

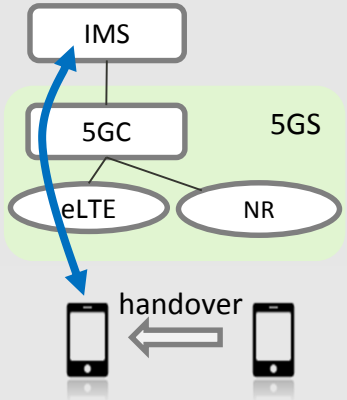
- IMS Voice call possible in NR cell
- Intra 5GS Inter RAT handover possible (5G VoLTE)
- SRVCC to 4G VoLTE possible
- SRVCC to GSM/UMTS not supported in Rel-15
- SRVCC to UMTS CS under study in Rel-16



EPS = EPC + E-UTRAN (E-UTRA (LTE) & NR) + UE
5GS = 5GC + NG-RAN (E-UTRA (eLTE) & NR) + UE

5GS Fallback to E-UTRA [5G VoLTE]

- Intra-5GS handover to E-UTRA when making call
  - Only available with E-UTRA connected to 5GC (Options 5, 7)
- SRVCC to 4G VoLTE possible
- SRVCC to GSM/UMTS not supported in Rel-15
- SRVCC to 3G CS under study in Rel-16



5G NR Key Components

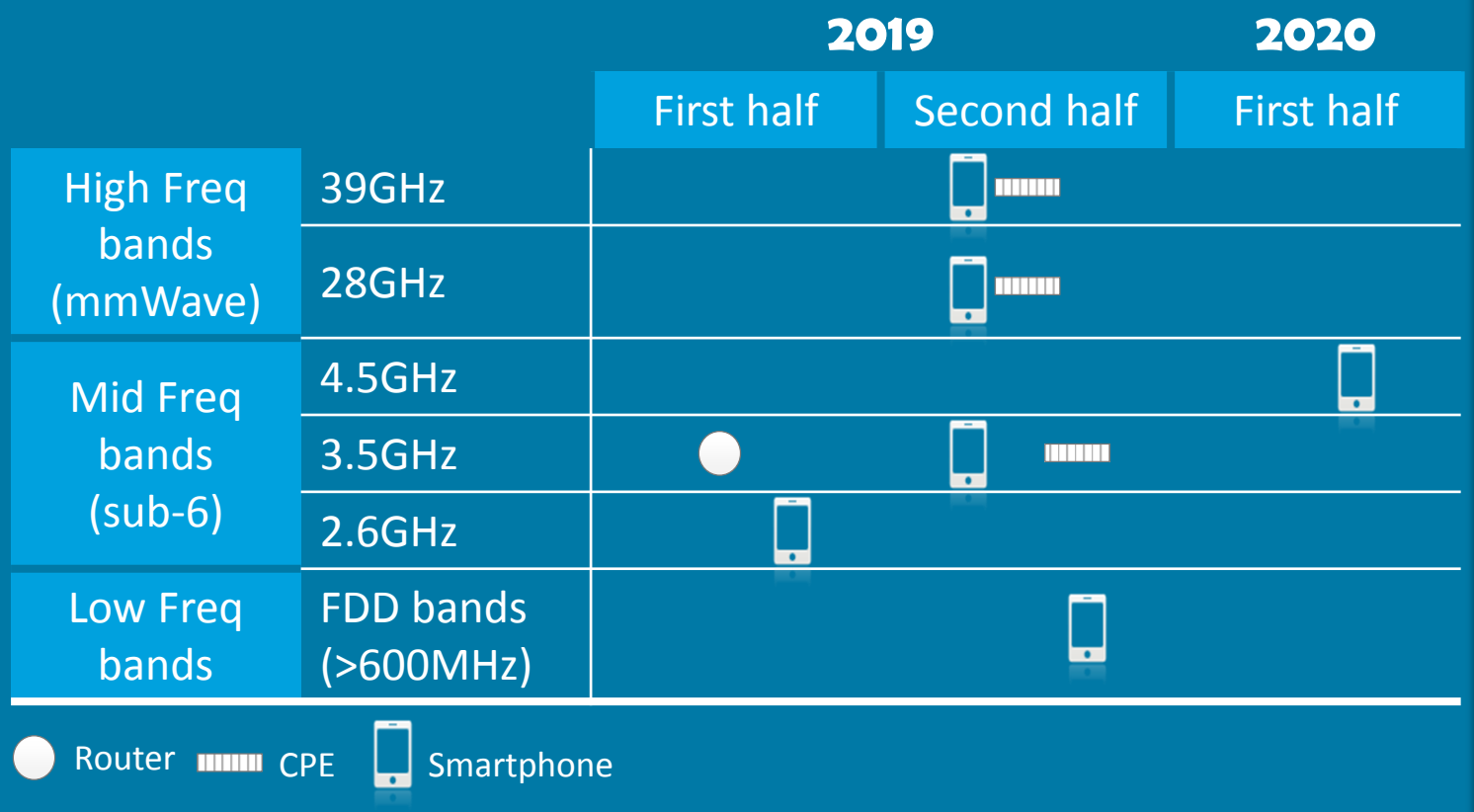
		LTE	Rel-15 NR
Waveform	Target: compatibility with MIMO, Spectral efficiency, Low Peak to Average Power ratio (PAPR), high time localization to support TDD systems and URLLC use cases, Acceptable complexity and low out of band emissions	• DL: CP-OFDM • UL: DFT-S-OFDM • < 6 GHz Freq Range	• DL: CP-OFDM • UL: CP-OFDM, DFT-S-OFDM • Up to 52.6 GHz Freq Range
Channel BW	Target: compared to LTE, 5GNR is designed to have higher Bandwidth efficiency, reaching 99% → compared to 90% in LTE, where 100 RB cover only 18 MHz in a 20 MHz Bandwidth carrier	• 20 MHz • CA: Up to 32 carriers; DuCo: Up to 64 carriers • HARQ RTT: ≥ 10 ms	• Sub6: 100MHz • Above6: 400MHz • CA: Up to 16 carriers; DuCo: up to 32 carriers • HARQ RTT: 0.25-16 ms
Numerologies	Target: scalable and flexible physical layer design. Divide a wide OFDM channel into orthogonal narrow subcarriers. E.g. the lower the Sub carrier spacing the larger the cell size is (suitable for the lower frequency). Larger sub carrier spacing for better latency since the symbol duration is shorter	• SCS: 15 KHz • CP: Normal CP; Extended CP • Max # SC: 1200 • Slot size: 2/7/14 symbols	• SCS: 15/30/60/120/240 KHz • CP: Normal CP for all SCS, Extended CP for 60KHzs SCS • Max # SC: 3300 • Slot size: 1-14 symbols
Modulation & MIMO	Target: improve throughput/capacity in different radio conditions	• Up to 256-QAM • Beamforming, open/closed loop	• Up to 256-QAM (1024-QAM) • Beamforming, open/closed loop
Channel Coding	Target: enhance data and control channel performance with reasonable complexity	• Turbo Code & RM Block Code	• Polar Code (control) & LDPC (data)

"MediaTek was among the first to perform interoperability testing on Polar Code with Huawei, for network capacity boost & low design complexity."

Chipset and Devices

5G DEVICE EVOLUTIONS & MEDIATEK READINESS

5G Devices Outlook



From Ericsson Mobility Report, 2018. The figure shows device availability for Non-Standalone 5G NR, with the exception of the 3.5GHz band, where Standalone is also shown

"MediaTek has been heavily investing in the development of 5G and is committed to accelerating its adoption, by bringing the technology to all tiers, including the mid-tier market from early launch."

Release-15

Ready in 2019

SA/NSA capable

5 Gbps Speed

Diverse bands

5G NR Features

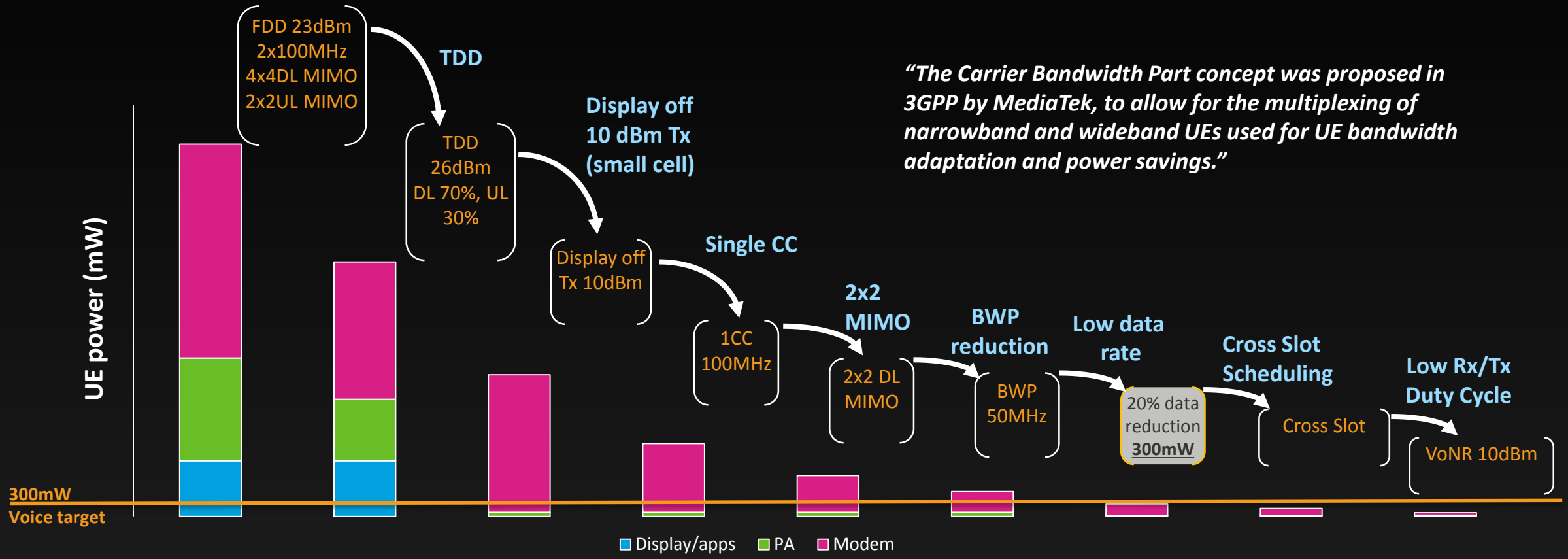
Read more https://www.mediatek.com/blog

eMBB Device Segments – MediaTek view by 2020

		Device Type	Technologies	DL Peak Data Rate
mmWave Centric	High Cost, Small Volume	CPE, tablet Smartphone (?)	LTE + [NR sub-6] + NR mmW (incl. SA and NSA)	6-8 Gbps
Sub-6GHz Centric	Medium Cost, Large Volume	CPE, tablet, Smartphone, VR/AR helmat, ...	LTE + NR sub-6 (incl. SA and NSA)	2.5-5 Gbps
Baseline LTE	Cost Optimized, Power Optimized LTE Generation	Tablet, Smartphone	LTE	~1 Gbps

Volume

Enabling UE Power Scaling & Reaching Competitive VoNR Power



"The Carrier Bandwidth Part concept was proposed in 3GPP by MediaTek, to allow for the multiplexing of narrowband and wideband UEs used for UE bandwidth adaptation and power savings."

Standalone VoNR power requires carefully designed UE configurations

Single Carrier	BW Part – UE bandwidth reduction	2x2 MIMO for Rx	Cross-slot scheduling	Aggressive Rx/Tx duty cycle reduction

- Small cells – Power dominated by Rx in baseband and transceiver
- Macro cells – Higher Tx power adds around 1.5 Watt for 21 dBm average

MediaTek Active Contributions in 5G Commercialization

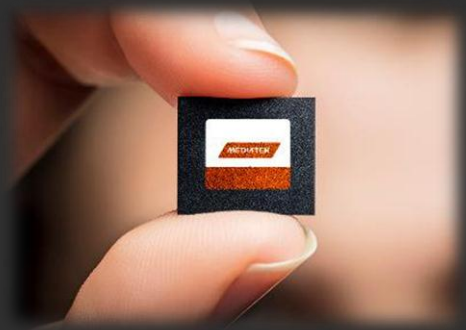
Standard Bodies

3GPP
- 3GPP RAN2 Vice Chair
- 3GPP 5G NR Spec. Rapporteur
- ~20 delegates, ~100+ Tdocs for each WG meeting
- Major contributors of key 5G features (e.g. Polar code, BWP, …)

GTI
- 5G Sub-6GHz Project Lead
- Lead GTI publish key 5G white papers:
- Received “Honorary Award of GTI Awards 2018”

Other
- TAICS: Chair of Technical Committee
- CCSA, IMT2020 PG, 5GMF, GSMA

Chipset Announcement



Helio M70

- MediaTek Modem for 5G, ready in 2019
- 3GPP Rel-15 capable
- 5 Gbps data rate
- NSA/SA support
- Support major carrier features

Partnerships

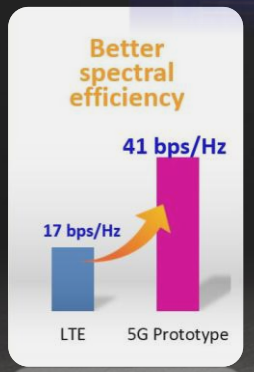
R&D
- MediaTek and China Mobile launch a joint R&D project to develop 5G Terminals for pre-commercial launch in 2019

Value
- 5G terminal form factors, technical solutions, testing and verification, and product research and development

Timing
- Accelerate the maturity of 5G chips and end devices for 2018, preliminary rollout in 2019, and the commercial rollout target for 2020

MediaTek Prototypes Development

Sub-6GHz Prototype



MediaTek and Huawei achieved an impressive peak performance of 8.5Gbps with 5Gbps sustained, using just 200MHz of bandwidth and 8x8 MIMO in the 3.5GHz range during recently-completed 5G NR Interoperability Development Testing (IODT)

- World's 1st IODT of UE with 8 phone-integrated antenna
- World's 1st IODT of Polar code Compliance with 3GPP NR standard

mmWave Beam-Tracking

Beam tracking is key for mmWave systems to align gNB beam and UE beam

- Benefit at system side
  - In general, number of gNB beams is huge (several tens or hundreds of beams)
  - Hierarchy concept can save beam tracking time and hence improve system capacity
- Benefit at UE side
  - No need to waste too much time on beam alignment
  - Reduce power consumption

Next-Gen Multiple Access

System

- **DOCOMO Non-Orthogonal Multiple Access and MediaTek Multi-User Interference Cancellation were used on the same compact test chipset, an experiment that verified the spectral efficiency improvement has potential for 5G standardization**

R&D

- **~2.3X spectral efficiency improvement in field tests**
- **joint field trial confirms 10%~40% cell capacity gain at 50% of test locations with up to 137.5% gain in some particular location**

MEDIATEK