IET – 5G

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Contents

- Use cases
- What is 5G
- 3GPP Update
- Samsung 5G Development

Collaboration with UK Government and R&D

- Samsung UK is collaborating with UK government and agencies

Department for Culture Media & Sport

Standards

Ofcom

Frequency

Home Office

Emergency Service

- Over 200 R&D staff based in Samsung R&D Institute UK

UK 5GIC

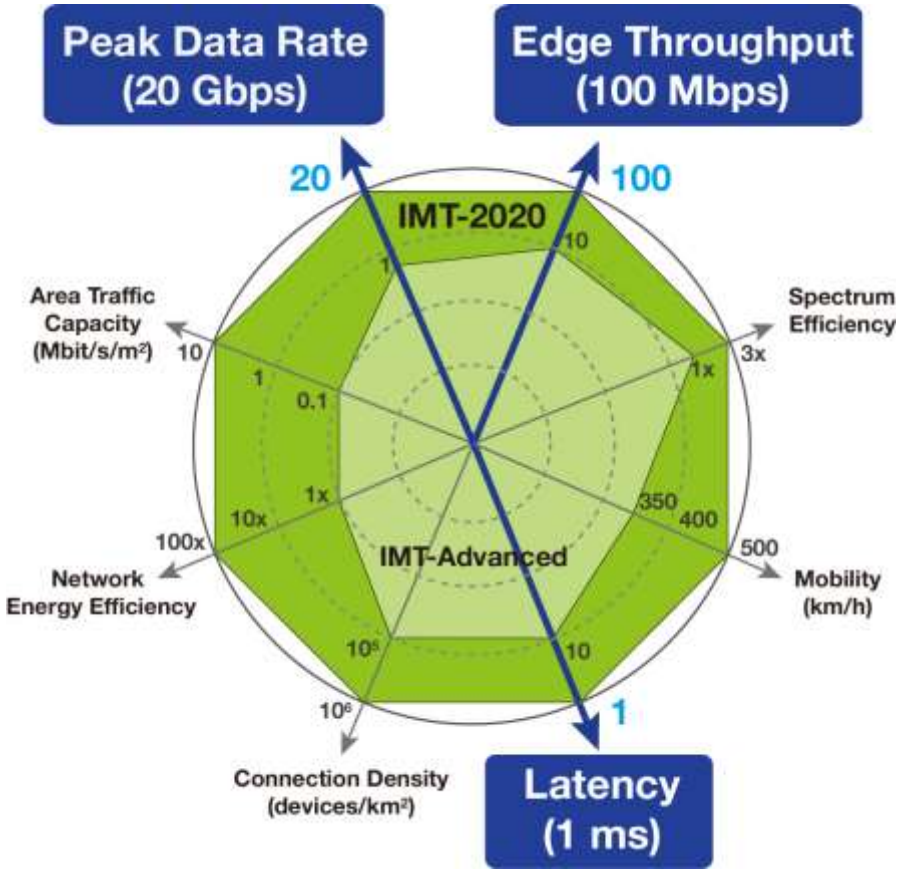
5G PPP
The 5G Infrastructure Public Private Partnership

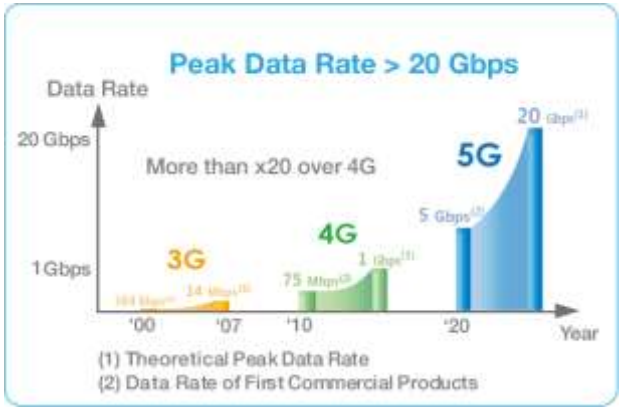
EU 5G PPP projects
in Horizon 2020

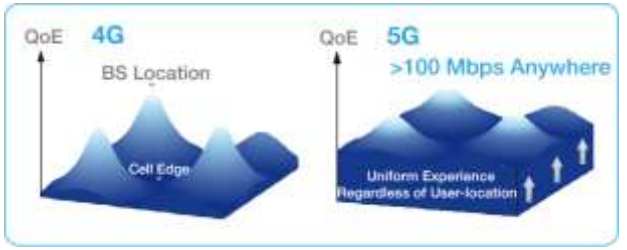
Use cases

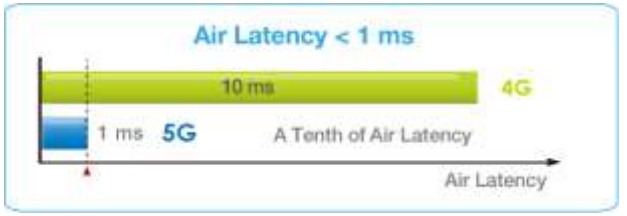
Key difference btw 5G and 4G

ITU 5G Requirements







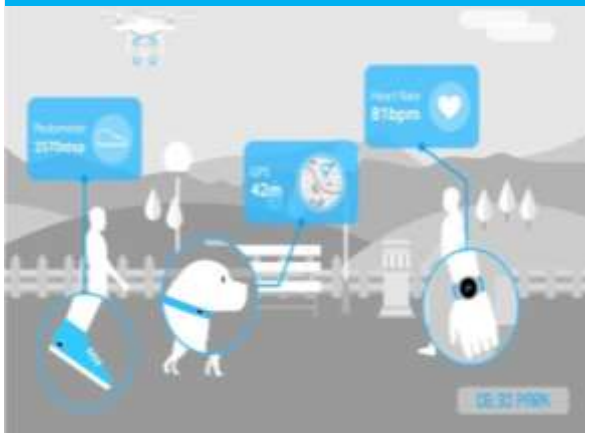


※ ITU-R document 5D/TEMP/625: ITU-R.M.[IMT.VISION] (June 2015)

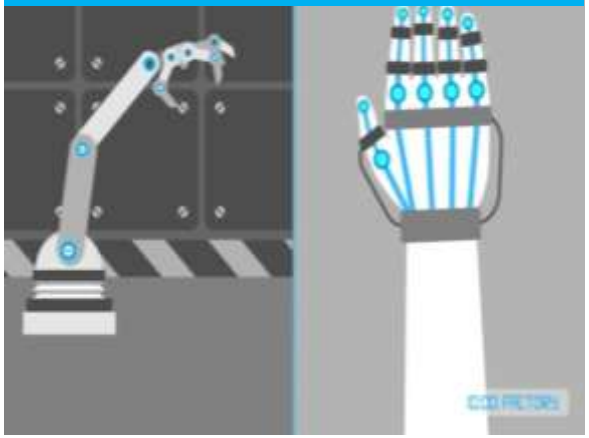
5G : Exploring New Use Cases beyond 4G

Mobile Cloud Service

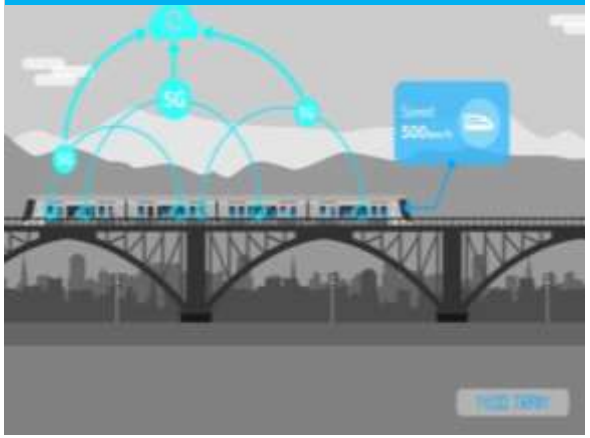
Internet of Things



VR Remote Machine Control



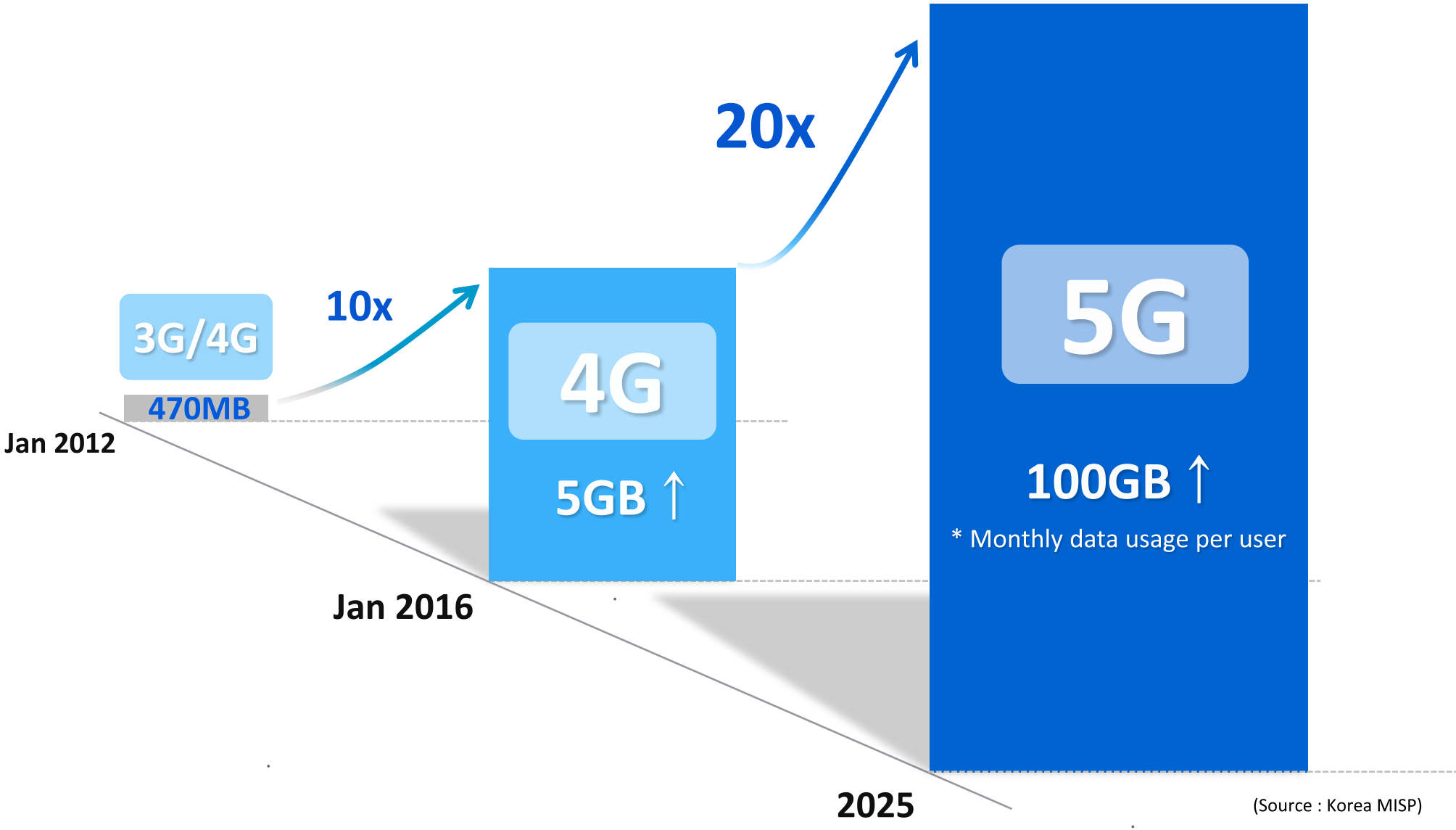
Mobile Giga Internet Service



Autonomous Driving and V2X

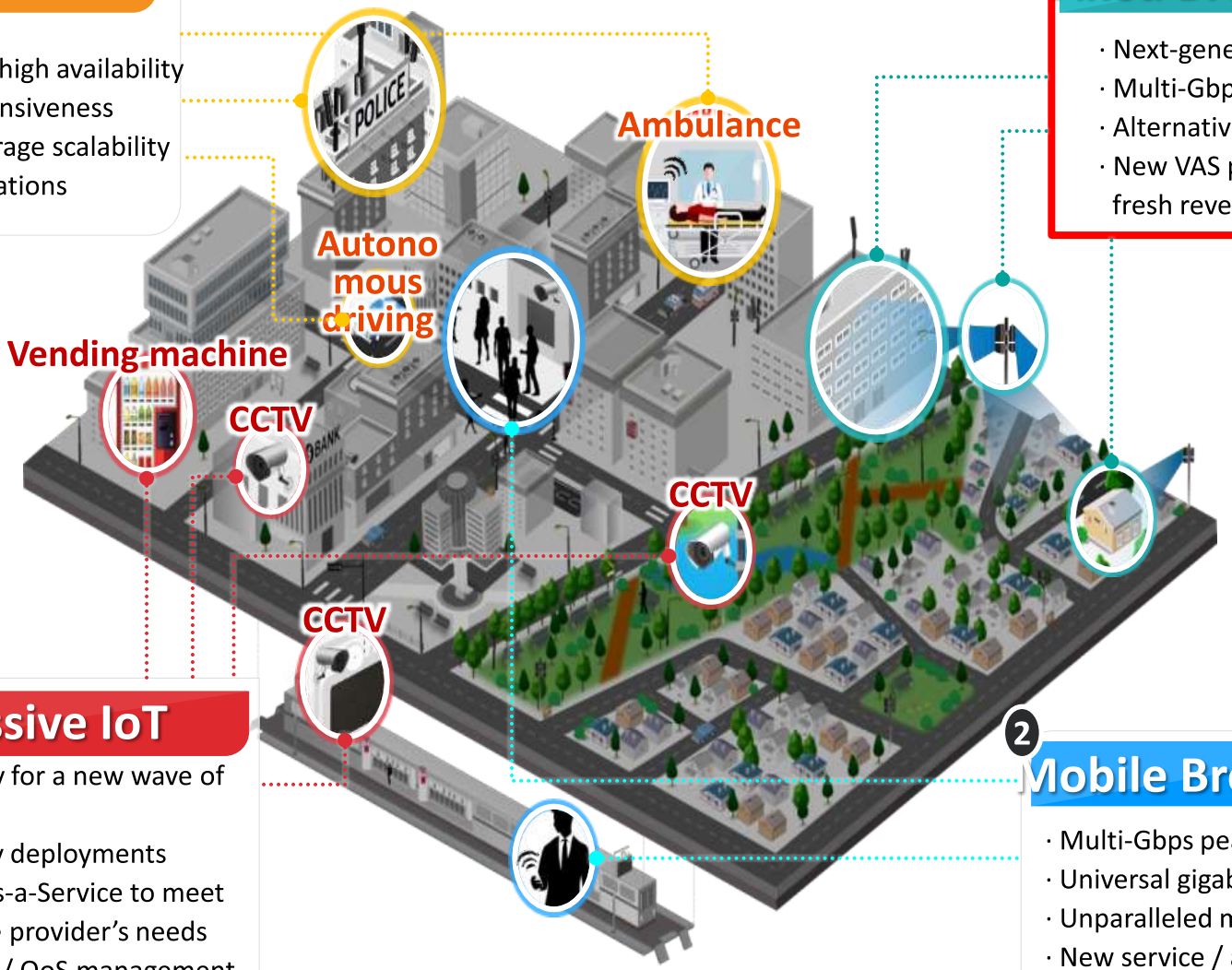
Wireless Backhaul Service

Mobile Traffic Explosion in 5G Era



(Source : Korea MISP)

5G Services Scenarios



3 Mission Critical Service

- full reliability & high availability
- Real-time responsiveness
- On-the-fly coverage scalability for disaster situations

1 Fixed Broadband

- Next-generation broadband
- Multi-Gbps peak throughputs
- Alternative to costly fibre
- New VAS possibilities for fresh revenue generation

4 Massive IoT

- Connectivity for a new wave of device types
- High density deployments
- Networks-as-a-Service to meet each service provider's needs
- Robust QoE / QoS management
- New revenue opportunities

2 Mobile Broadband

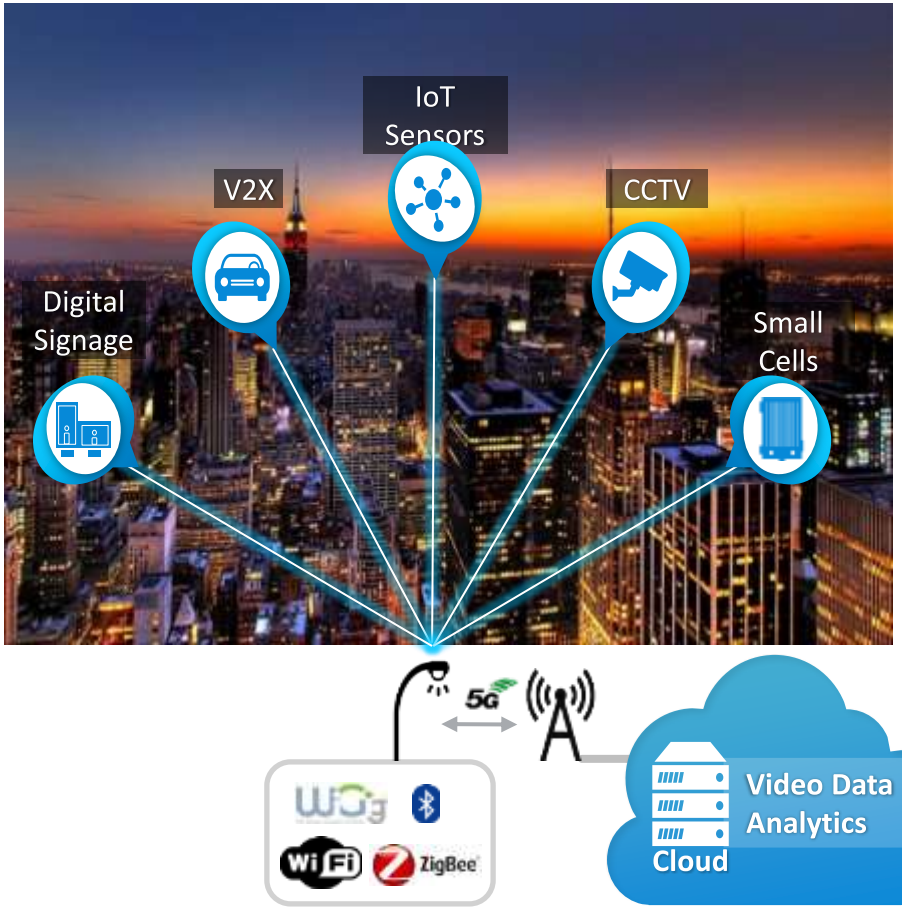
- Multi-Gbps peak throughputs
- Universal gigabit connectivity
- Unparalleled mobility support
- New service / application enablement
- Advanced big data analytics

mmWave 5G Fixed Wireless Access

* AU = Access Unit, CPE = Customer Premise Equipment

Smart City

5G Connectivity Node enables Collection, Delivery and Analysis of Live Data



One Connectivity Node covers

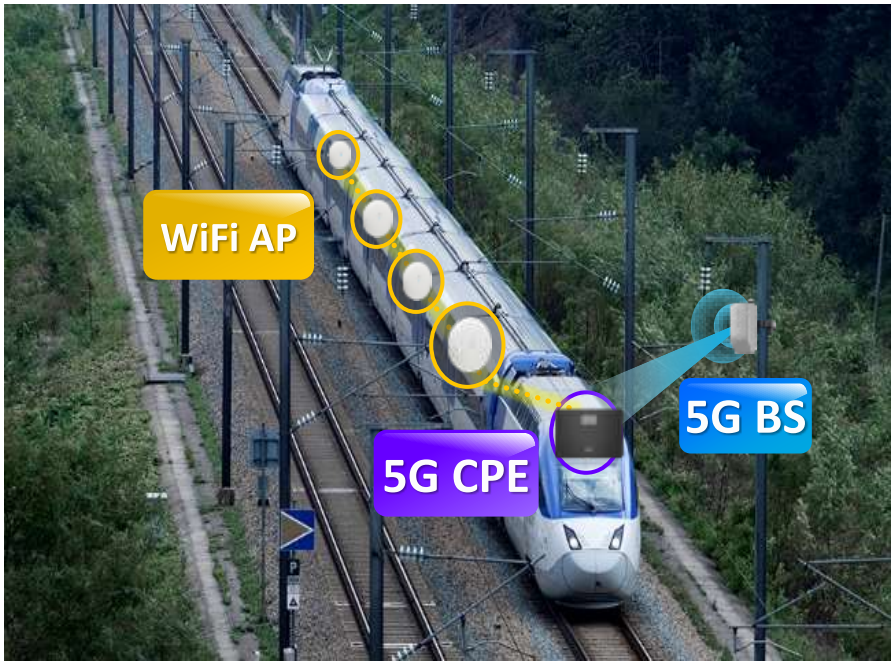
(500m Radius)

10 x CCTVs	10 x 24Mbps	=	240Mbps
1 x Digital Signage	1 x 24Mbps	=	24Mbps
5 x LTE Smallcells	5 x 240Mbps	=	1,200Mbps
250 x sensors	250 x 256kbps	=	62.5Mbps
5 x Public WiFi	5 x 300Mbps	=	1,500Mbps

Total 3Gbps

5G Train

Starting point for Mobile 5G



For Passenger

Internet on Board
(HD Video Streaming)

Passenger Assistance & Info.

Entertainment
(Movie & TV)

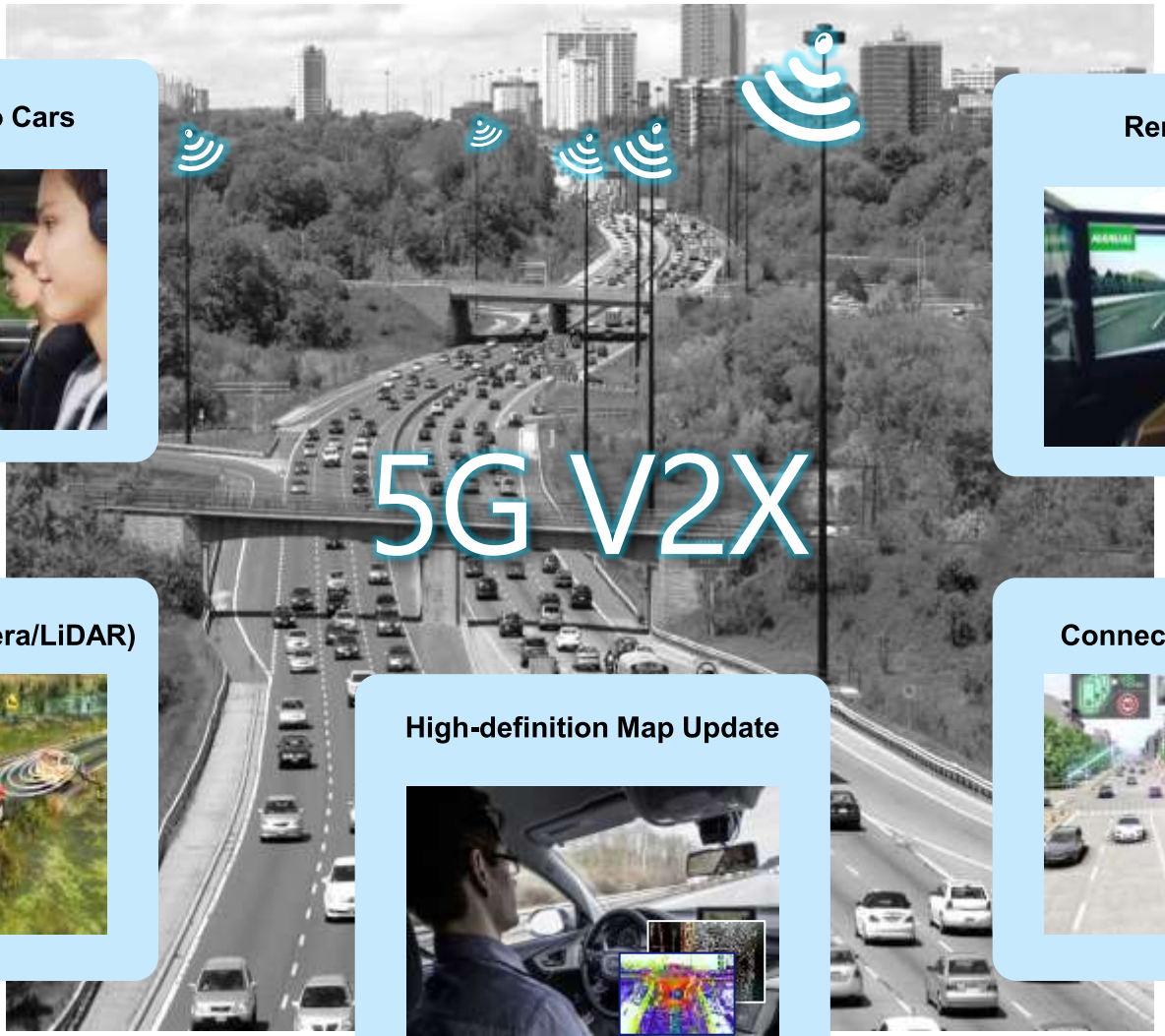
For Train Operator

Security

Train Control
(Real-time Monitoring)

Crew Assistance
(Video Call, Ticket sales)

Connected Car : Evolve to V2X Services



UHD Streaming to Cars

Remote Driving

Vision Sharing (Camera/LiDAR)

High-definition Map Update

Connected Traffic Lights

V2X : Vehicular to Everything LiDAR : Light Detection and Ranging

Spectrum

5G Spectrum Status

ITU/3GPP have initiated 5G frequency and standardization discussions

- **ITU** Completed selection of candidate 5G frequency bands at WRC-15 (Nov. '15)

  ※ Above 6GHz : 24.25~27.5GHz, 31.8~33.4GHz, 37~43.5GHz, 45.5~50.2GHz, 50.4 ~52.6GHz, 66 ~76 GHz, 81~86 GHz

Frequency allocation status in US, Korea, and Japan

- US: FCC approves spectrum for 5G frequency
- Korea: Allocated 28GHz frequency band for 5G services during the 2018 Winter Olympics in PyeongChang.
- Japan: Evaluating 28GHz frequency band after low bands (3.6GHz~ 4.2GHz and 4.4GHz ~4.9GHz) were rejected at WRC-15

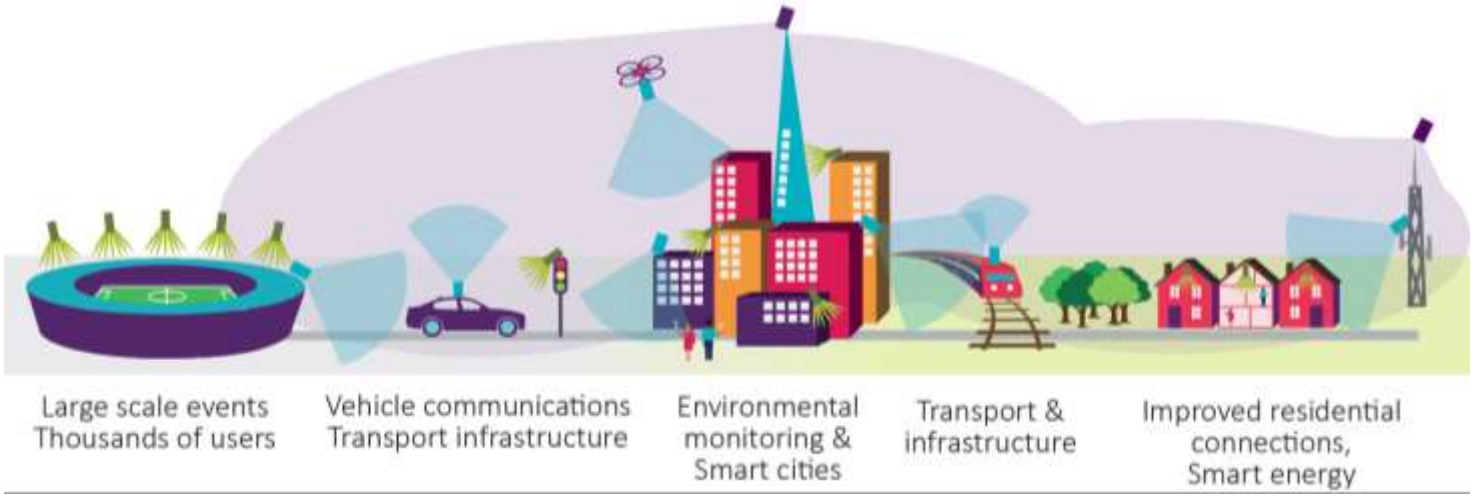
(Zdnet.com, July 14, 2016)
http://www.zdnet.com/article/fcc-adopts-rules-to-open-up-high-band-spectrum-for-5g-wireless/

Seeking to establish the US as a leader in 5G technologies, the Federal Communications Commission (FCC) on Thursday approved new rules that open up high frequency for next-generation wireless services.

Spectrum is the key for 5G

- UK released an updated plan for 5G spectrum (8 Feb 2017)

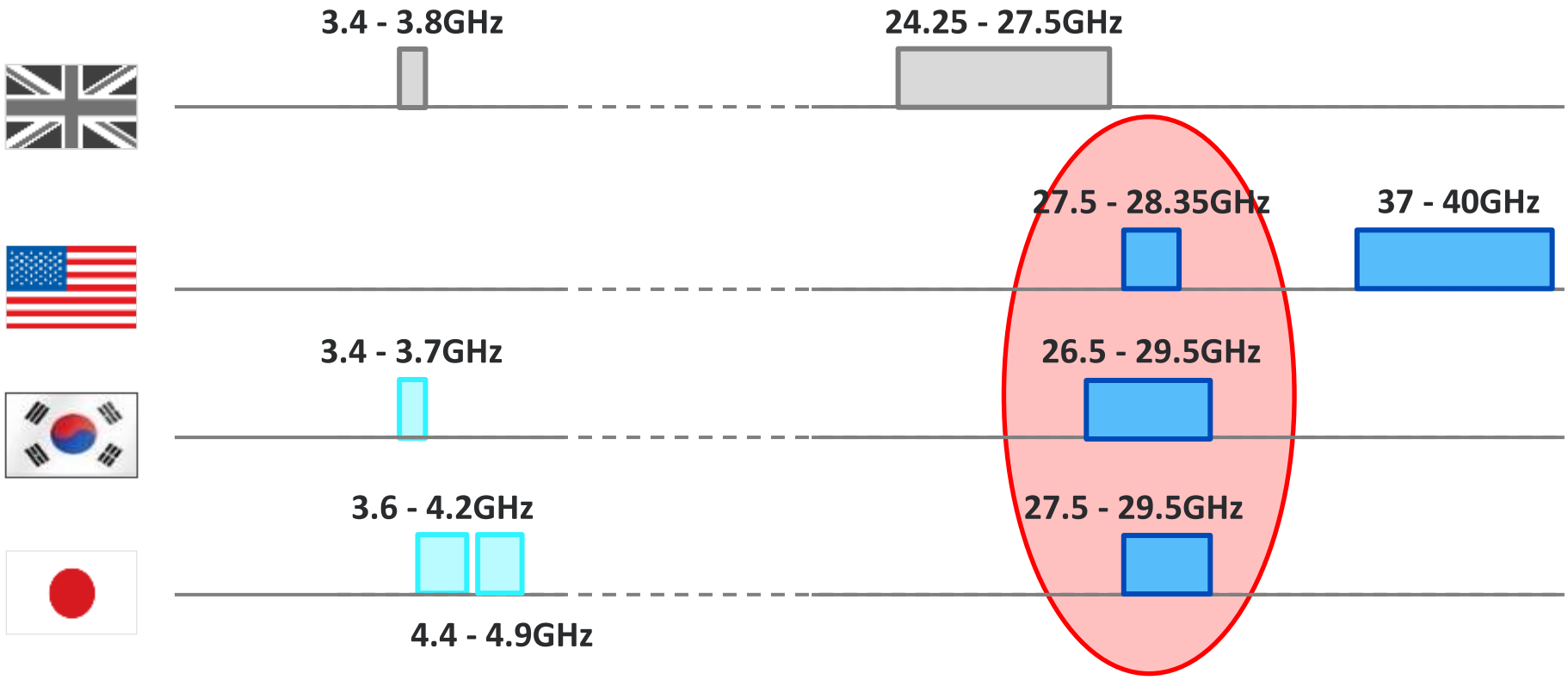
For wide coverage | 5G primary band | For ultra high capacity



700 MHz band : 694-790MHz 3.4-3.8 GHz band : 3.4-3.8 GHz 26 GHz band : 24.25-27.5 GHz

Comparison of 5G Spectrum

- US, Korea and Japan are leading 5G deployment on 28GHz Spectrum



28GHz Spectrum Allocation in UK

▶ 28GHz band is already allocated for Broadband FWA

Arqiva | Telefónica UK | Vodafone | UK Broadband

Spectrum bands

Region

	27.8285 - 28.0525 GHz 28.8365 - 29.0605 GHz	28.05025 - 28.1645 GHz 29.0605 - 29.1725 GHz		28.1925 - 28.3045 GHz 29.2005 - 29.3125 GHz		28.3325 - 28.4445 GHz 29.3405 - 29.4525 GHz
	(2 x 224 MHz)	(2 x 112 MHz)		(2 x 112 MHz)		(2 x 112 MHz)
A	Arqiva	Telefónica		Urban Wimax		UKB (3UK)
B		Vodafone		Telefónica		
C		Telefónica		Vodafone		
D		Vodafone		UKB (3UK)		
E						
F						
G						
H						
I		Telefónica		Vodafone		
J		Vodafone				
K				UKB (3UK)		
L				Telefónica		
M				UKB (3UK)		
N		Telefónica				

※ FWA : Fixed Wireless Access

What is 5G

5G Key Standards Features (PHY)

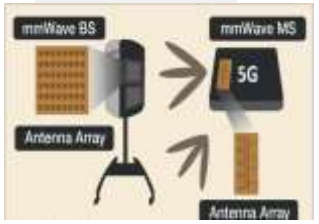
- **Massive MIMO & Hybrid-BF for Coverage and Spectral Efficiency Enhancements**
- **Flexible Multi-numerology Support for Various Vertical Services and Scenarios**
- **Advanced Channel Coding for Multi-Gbps (LDPC) and Small Control Data (Polar)**

Massive MIMO & Hybrid-BF

- mmWave Hybrid-BF based Transceiver
  - ✓ Beamformed data/control TRx
  - ✓ Beam management & Tracking
- Sub-6GHz massive MIMO
  - ✓ Coverage extension w/ multi-beam Tx
  - ✓ Flexible CSI process & FB enhancement

Massive MIMO

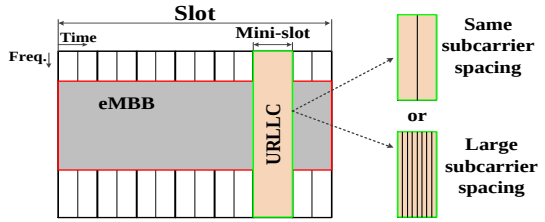
mmWave H-BF



Flexible Multi-numerology Support

- Mini-slot with fewer symbols (TTI shortening)
- Slot/mini-slots with multiple numerologies
  - ✓ Flexible utilization of resources for different service requirements
- Dynamic eMBB and URLLC Multiplexing
  - ✓ URLLC mini-slot preemption of eMBB data resources

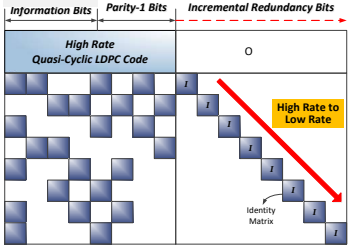
eMBB/URLLC Multiplexing



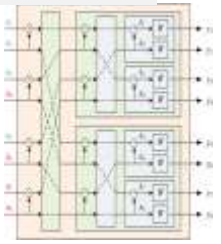
Advanced Channel Coding

- LDPC for data channels
  - ✓ Low complexity and High energy efficiency for Gbps data reception
- Polar code for broadcast/control channels
  - ✓ Performance gain for small information bit sizes

LDPC



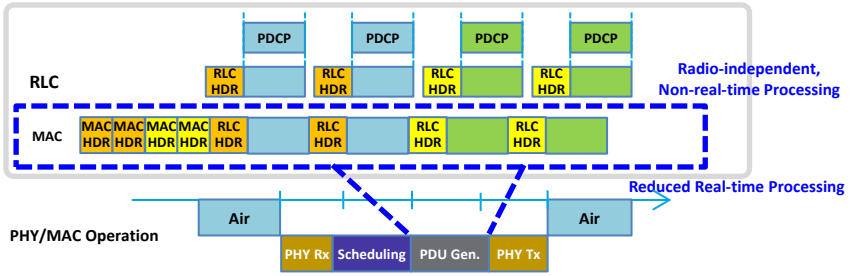
Polar Code



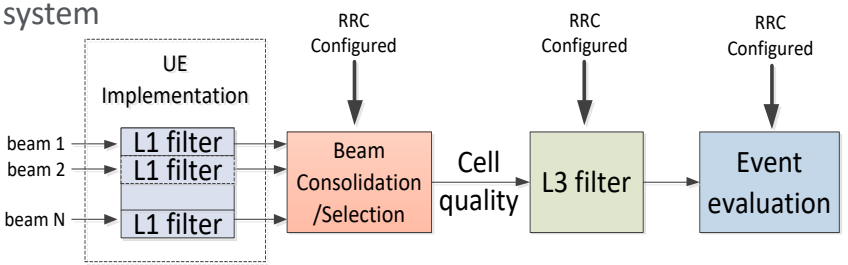
5G Key Standards Features (MAC)

- **Simple Data Processing for Multi-Gbps Data Rate & New Sublayer for Packet Level QoS**
- **Multi-beam Mobility in mmWave & New MAC State ("Inactive") for Energy Efficiency**

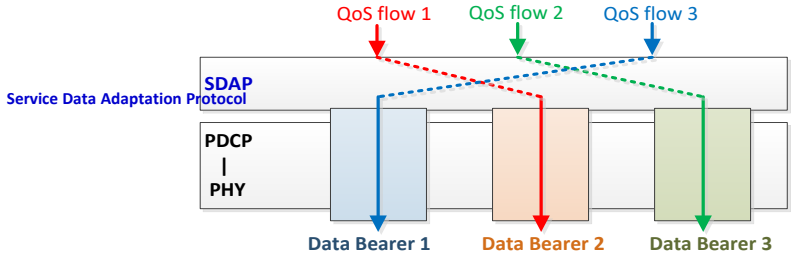
Simple Data Processing for Gbps data rate support



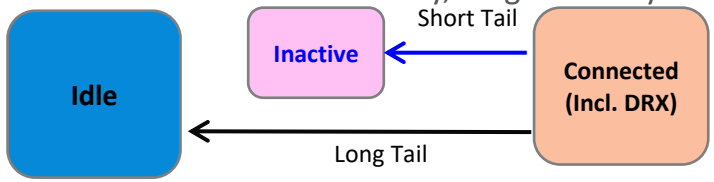
Measurement Model for mobility in beamforming system



New Layer 2 Sublayer for realizing packet level QoS



Inactive MAC State for low latency, longer battery life

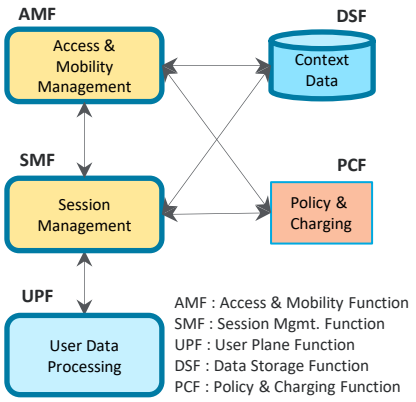


5G Key Standards Features (NW)

- Cloud-native Architecture to Fit Network Functions into Virtualization Environments
- Simple and Flexible User Plane to Enable Low-Latency Services
- Network Slicing to Enable New Services with Separate Network Resources
- Common MM/SM/Authentication for Fixed & Mobile Convergence

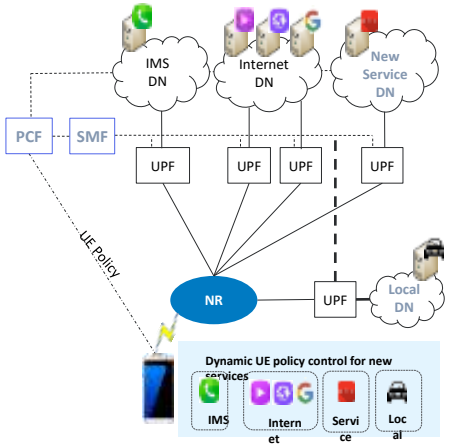
NFs Fit for Virtualization

- Stateless call control
- Stateless user plane function



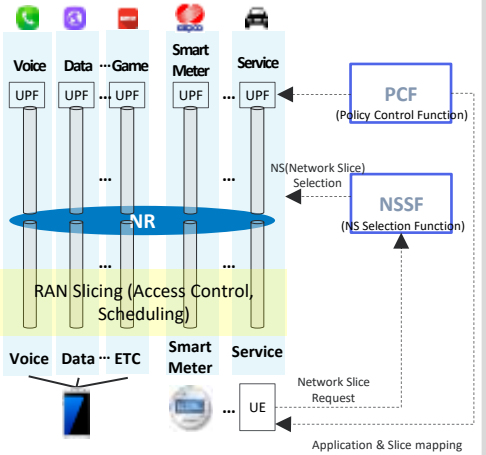
Low-latency Services

- Service network can be dynamically created by controlling SMF/UPF and UE together



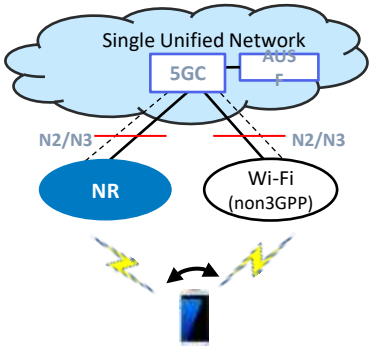
Network Resource Separation

- Services do not affect each other
- Optimized per-Service Networks



Common MM/SM/Auth.

- Unified MM/SM/Authentication
- Common interface(N2/N3) with access



Common Authentication, Unified Mobility/Session Mgmt.

NR Profile for Commercial : PHY

CATEGORY	FEATURE	mmWave NR	Sub-6GHz NR
Spectrum	Frequency Bands	28GHz (26.5~29.5GHz) 39GHz (37~40GHz)	3.5GHz (3.3~4.2GHz) 4.5GHz (4.4~4.99GHz) 2.6GHz (Band 41)
Numerology	Bandwidth	[50]/100/150/200MHz	5~100MHz
	Subcarrier Spacing	• 60kHz for data/control (FFS: 120kHz) • 240kHz for SS block (FFS: 120kHz @50MHz CBW)	Multi-Numerology (15/30/60kHz)
	TTI	0.25msec	Multi-Numerology (e.g., 1.0/0.5/0.25msec)
Channel Coding	Data Channel	LDPC	
	Control Channel	Polar Code	
Waveform	Waveform	· DL CP-OFDM · UL CP-OFDM	· DL CP-OFDM · UL CP-OFDM
	Spectral Confinement	95~98% spectrum utilization	95~98% spectrum utilization
MIMO	Massive-MIMO / BF	· Hybrid BF w/ massive antennas · 4T4R for gNB / 2T2R or 1T2R for UE	· 32T32R or 64T64R · 8- or 16(TBD)-UE MU-MIMO
	MIMO Feedback	· Flexible CSI process	· CSI FB enhancement (FDD) · Flexible CSI process
	Spatial Multiplexing	2x2 MIMO	DL High-order MIMO/QAM (e.g., 4x4 MIMO+256-QAM)
Duplexing	TDD/FDD	(Dynamic) TDD	(Dynamic) TDD / FDD
Dynamic Multiplexing	eMBB/URLLC Multiplexing	N/A	Multi-numerology multiplexing (eMBB/URLLC muxing & pre-emption)
	LTE-NR Multiplexing	N/A	LTE-NR coexistence

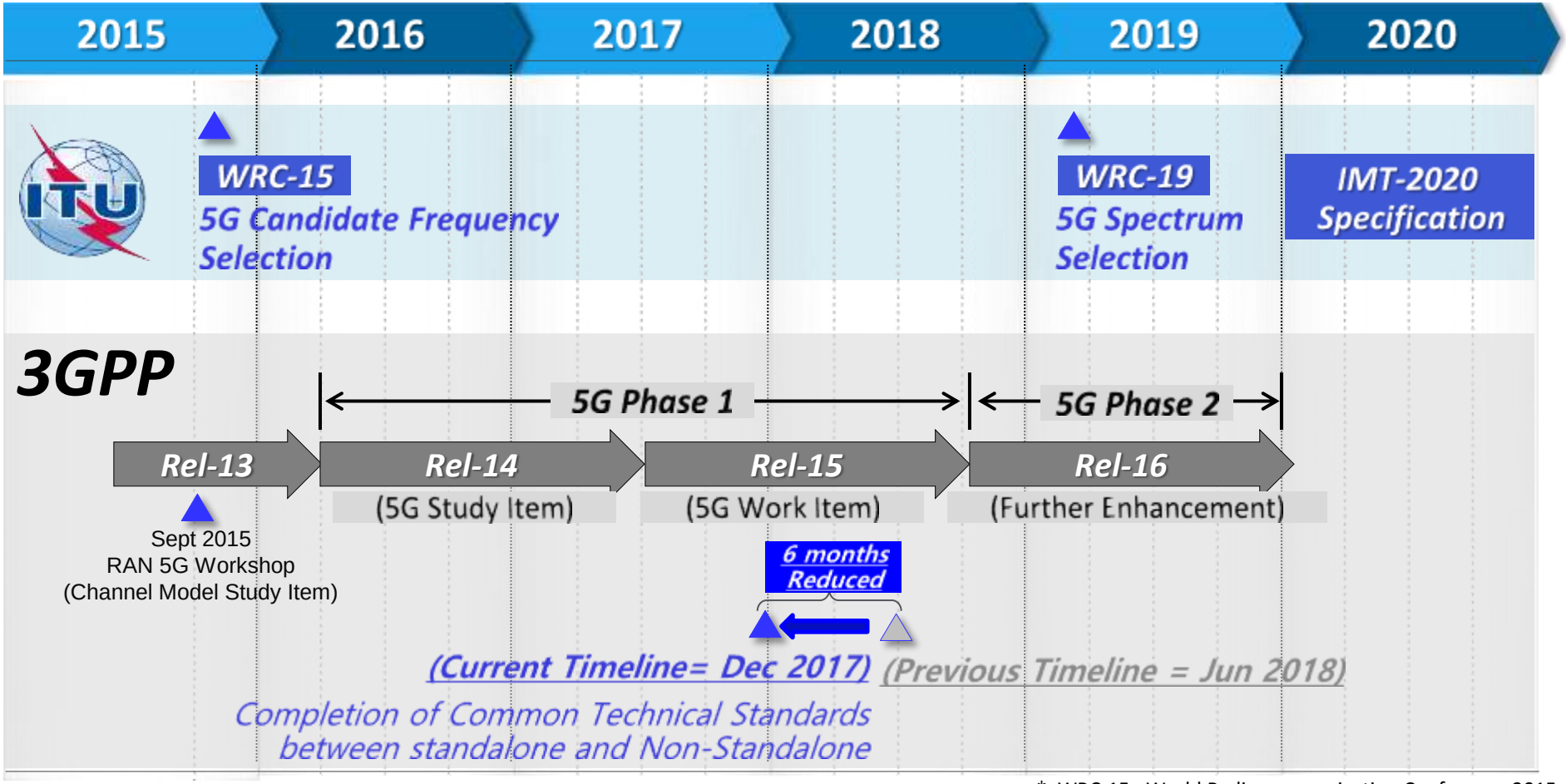
NR Profile for Commercial : MAC

CATEGORY	FEATURE	mmWave NR	Sub-6GHz NR
Control Plane	Supported Signaling Bearers	MCG SRB (w/o split and duplication), SCG SRB	
	MAC State	3 states (Idle / Connected / Inactive)	
	System Information	MCG based on-demand SI request SI index: value tag (FFS: area ID) SI update: value tag and Update notification in paging	
User Plane	Supported Bearer Types	MCG Bearer / SCG Bearer / Split Bearer (Anchored at MCG)	
	Bearer Type Change	MCG ↔ SCG, Split (@SCG) ↔ SCG	
	Split Bearer Control	Pre-configured hard split between MCG leg and SCG leg	
	QoS	Reflective QoS for uplink, No QoS flow mobility	
Mobility	Mobility without RRC Involvement	MAC CE for beam switch command L2 ACK for beam switch command Beam recovery parallel to RLF procedure	NA
	Mobility with RRC Involvement	NW-controlled hard handover NW-controlled UE-based handover FFS: DC-based handover	NW-controlled hard handover FFS: MBB handover, RACH-less handover, UE-based handover
	RRM Measurement	SYNC and CSI-RS based RRM Report event: A1 ~ A6 Cell quality derivation from maximum N good beams Relative threshold for good beam determination Neighbor cell/beam info in measurement report (FFS: beam info for cells not triggered measurement repot)	SYNC and CSI-RS based RRM Report event: A1 ~ A6 Neighbor cell info in measurement report
Idle / Inactive	Access Control	Unified access control for AS and NAS	
	Cell Selection / Reselection	LTE baseline, NW slice-aware cell selection and reselection	
	Ranking	Cell quality derivation from maximum N good beams	LTE baseline

Progress in 3GPP

5G Standardization Timelines

- **Last year reduced timeline by 6 months**
  Complete the standardization of common standards(L1/L2)
  between Standalone and Non Standalone (Jun 2018 → Dec 2017)



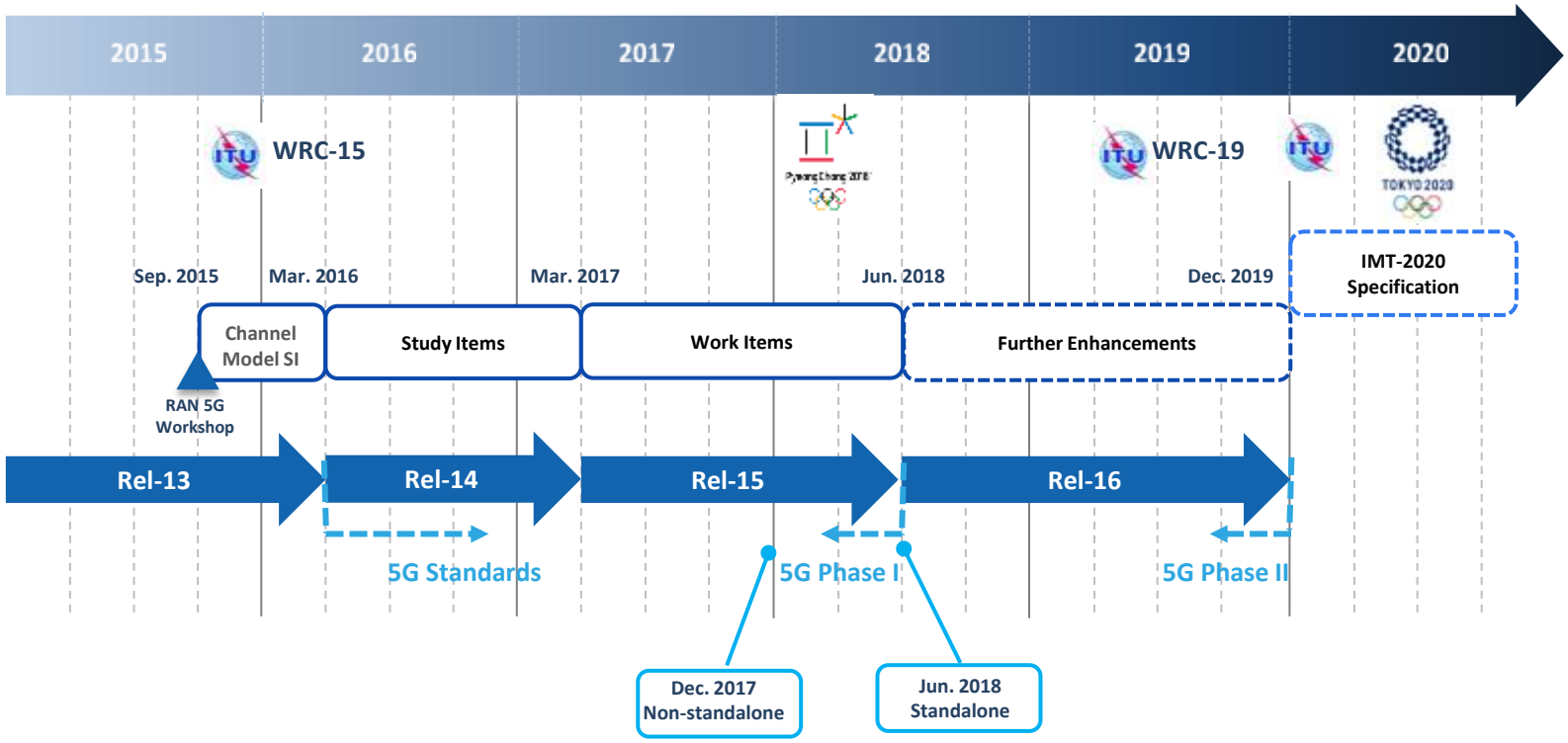
* WRC-15: World Radiocommunication Conference 2015
* WRC-19: World Radiocommunication Conference 2019

5G Standards : Timeline

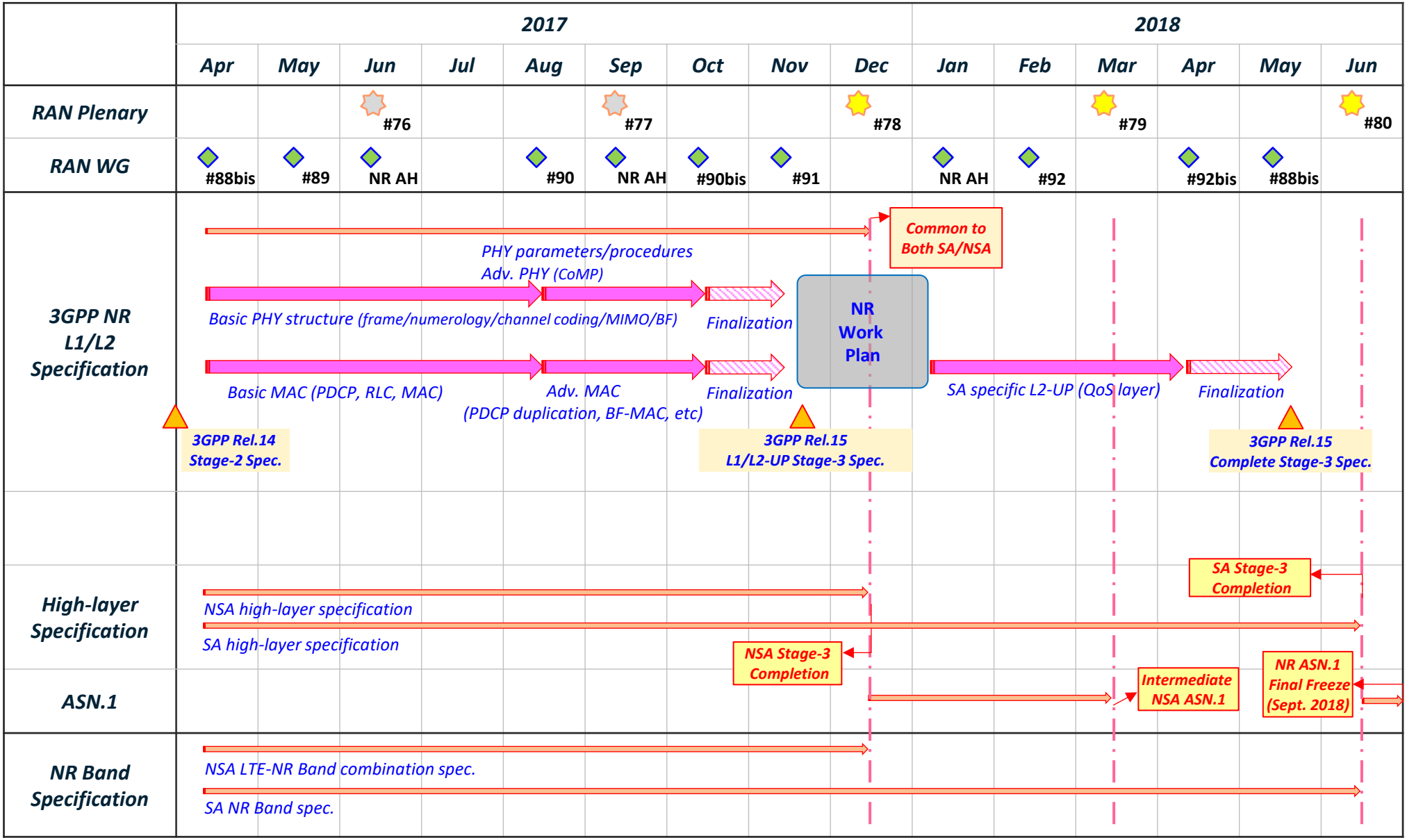
Two-Track Strategies for 5G Standardization

- Both 5G Standalone (SA) and Non-Standalone (NSA) in above-6GHz and below-6GHz spectrum bands

3GPP NR Standards Timeline



3GPP NR Work Plan



The new 38 Series – All available from www.3gpp.org

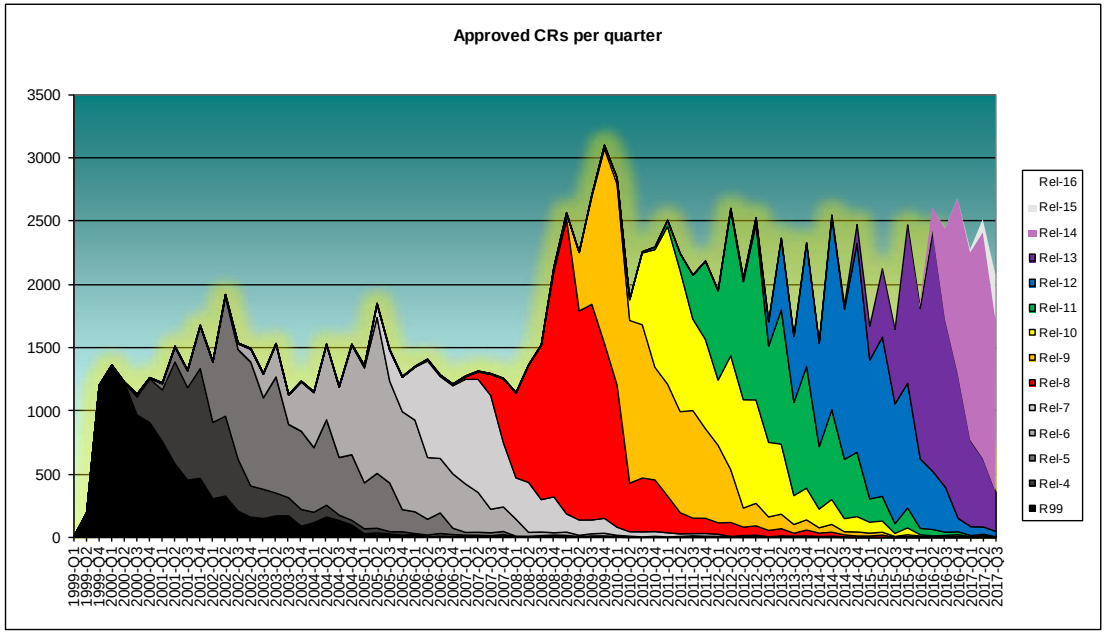
spec number	title
TS 38.101	NR; User Equipment (UE) radio transmission and reception
TS 38.101-1	NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone
TS 38.101-2	NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone
TS 38.101-3	NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios
TS 38.101-4	NR; User Equipment (UE) radio transmission and reception; Part 4: Performance requirements
TS 38.104	NR; Base Station (BS) radio transmission and reception
TS 38.113	NR; Base Station (BS) and repeater ElectroMagnetic Compatibility (EMC)
TS 38.124	NR; Electromagnetic compatibility (EMC) requirements for mobile terminals and ancillary equipment
TS 38.133	NR; Requirements for support of radio resource management
TS 38.141	NR; Base Station (BS) conformance testing
TS 38.141-1	NR; Base Station (BS) conformance testing Part 1: Conducted conformance testing
TS 38.141-2	NR; Base Station (BS) conformance testing Part 2: Radiated conformance testing
TS 38.201	NR; Physical layer; General description
TS 38.202	NR; Services provided by the physical layer
TS 38.211	NR; Physical channels and modulation
TS 38.212	NR; Multiplexing and channel coding
TS 38.213	NR; Physical layer procedures for control
TS 38.214	NR; Physical layer procedures for data
TS 38.215	NR; Physical layer measurements
TS 38.300	NR; Overall description; Stage-2
TS 38.304	NR; User Equipment (UE) procedures in idle mode
TS 38.305	NG Radio Access Network (NG-RAN); Stage 2 functional specification of User Equipment (UE) positioning in NG-RAN
TS 38.306	NR; User Equipment (UE) radio access capabilities
TS 38.307	NR; Requirements on User Equipments (UEs) supporting a release-independent frequency band
TS 38.321	NR; Medium Access Control (MAC) protocol specification
TS 38.322	NR; Radio Link Control (RLC) protocol specification
TS 38.323	NR; Packet Data Convergence Protocol (PDCP) specification
TS 38.331	NR; Radio Resource Control (RRC); Protocol specification
TS 38.401	NG-RAN; Architecture description
TS 38.410	NG-RAN; NG general aspects and principles
TS 38.411	NG-RAN; NG layer 1
TS 38.412	NG-RAN; NG signalling transport
TS 38.413	NG-RAN; NG Application Protocol (NGAP)
TS 38.414	NG-RAN; NG data transport
TS 38.420	NG-RAN; Xn general aspects and principles
TS 38.421	NG-RAN; Xn layer 1
TS 38.422	NG-RAN; Xn signalling transport
TS 38.423	NG-RAN; Xn Application Protocol (XnAP)
TS 38.424	NG-RAN; Xn data transport
TS 38.425	NG-RAN; NR user plane protocol
TS 38.455	NG-RAN; NR Positioning Protocol A
TS 38.470	NG-RAN; F1 general aspects and principles
TS 38.471	NG-RAN; F1 layer 1
TS 38.472	NG-RAN; F1 signalling transport
TS 38.473	NG-RAN; F1 Application Protocol (F1AP)
TS 38.474	NG-RAN; F1 data transport
TS 38.475	NG-RAN; F1 interface user plane protocol
TS 38.508-1	5GS; User Equipment (UE) conformance specification; Part 1: Common test environment
TS 38.508-2	5GS; User Equipment (UE) conformance specification; Part 2: Common Implementation Conformance Statement (ICS) proforma
TS 38.509	5GS; Special conformance testing functions for User Equipment (UE)
TS 38.521-1	NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: Range 1 Standalone
TS 38.521-2	NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 2: Range 2 Standalone
TS 38.521-3	NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 3: NR interworking between NR range1 and NR range2; and between NR and LTE
TS 38.521-4	NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 4: Performance
TS 38.522	NR; User Equipment (UE) conformance specification; Applicability of RF and RRM test cases
TS 38.523-1	5GS; UE conformance specification; Part 1: Protocol conformance specification
TS 38.523-2	5GS; UE conformance specification; Part 2: Implementation Conformance Statement (ICS) proforma specification
TS 38.523-3	5GS; UE conformance specification; Part 3: Test Suites
TS 38.533	NR; User Equipment (UE) conformance specification; Radio Resource Management (RRM)
TR 38.801	Study on new radio access technology: Radio access architecture and interfaces
TR 38.802	Study on new radio access technology Physical layer aspects
TR 38.803	Study on new radio access technology: Radio Frequency (RF) and co-existence aspects
TR 38.804	Study on new radio access technology Radio interface protocol aspects
TR 38.805	Study on new radio access technology; 60 GHz unlicensed spectrum
TR 38.806	Study of separation of NR Control Plane (CP) and User Plane (UP) for split option 2
TR 38.810	Study on test methods for New Radio
TR 38.811	Study on NR to support non-terrestrial networks
TR 38.812	Study on Non-Orthogonal Multiple Access (NOMA) for NR
TR 38.813	New frequency range for NR (3.3-4.2 GHz)
TR 38.814	New frequency range for NR (4.4-4.99 GHz)
TR 38.815	New frequency range for NR (24.25-29.5 GHz)
TR 38.816	Study on CU-DU lower layer split for NR
TR 38.817-01	General aspects for UE RF for NR
TR 38.817-02	General aspects for BS RF for NR
TR 38.818	General aspects for RRM and demodulation for NR
TR 38.874	NR; Study on integrated access and backhaul
TR 38.889	Study on NR-based access to unlicensed spectrum
TR 38.900	Study on channel model for frequency spectrum above 6 GHz
TR 38.901	Study on channel model for frequencies from 0.5 to 100 GHz
TR 38.903	NR; Derivation of test tolerances for RRM and User Equipment (UE) radio reception conformance tests
TR 38.905	NR; Derivation of test points for radio transmission and reception conformance test cases
TR 38.912	Study on new radio access technology
TR 38.913	Study on scenarios and requirements for next generation access technologies

Some interesting numbers

- 100,000 input contributions in 2017
- 75,000 delegate days of meetings

* To date, excluding current TSG meetings

Release	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017*	Total
R99	1408	4398	2266	1004	581	512	111	42	23	5	5	1	0							**10356**
Rel-4		376	2828	1900	690	257	122	63	48	22	20	13	11	8	7	2				**6367**
Rel-5		27	644	3274	2842	2162	1357	509	94	25	22	7	7	5	3	2				**10980**
Rel-6				172	1088	2458	3721	2074	1078	212	74	19	17	10	4	4				**10931**
Rel-7					1	20	663	2529	3132	1262	492	176	91	43	25	15				**8449**
Rel-8								49	777	4609	7073	2347	706	347	184	91	46	22	7	**16258**
Rel-9										49	2918	4991	3252	1366	376	165	70	26	19	**13232**
Rel-10											47	1722	3800	3103	1636	584	267	50	17	**11226**
Rel-11												32	1152	4178	3525	2186	622	163	29	**11887**
Rel-12													6	102	2254	5181	4287	1530	169	**13529**
Rel-13															8	200	2648	5571	1522	**9949**
Rel-14																	24	2315	4641	**6980**
Rel-15																		6	471	**477**
Rel-16																		0	11	**11**
Total	**1408**	**4801**	**5738**	**6350**	**5202**	**5409**	**5974**	**5266**	**5152**	**6184**	**10651**	**9308**	**9042**	**9162**	**8022**	**8430**	**7964**	**9683**	**6886**	**130632**



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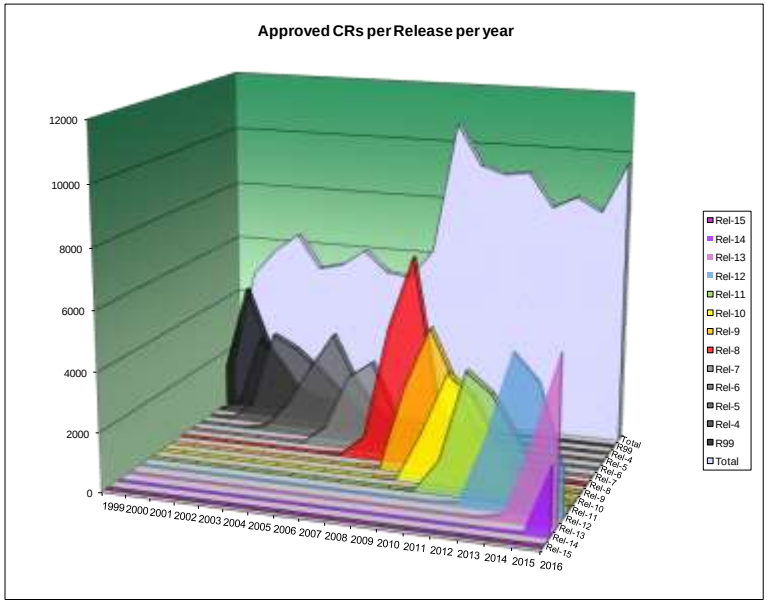


Samsung 5G developments

5G Technical Achievements

2012

- **Started mmWave R&D**

2013

- **World's first 5G mmWave mobile technology**
  - Developed the world's 1st adaptive array transceiver technology operating in the millimeter-wave Ka bands for cellular communications

2014

- **Post-OFDM** (QAM-FBMC) **development**
- **SWSC technology research**
- **World's 1st 5G data transmission at highway speeds**
  - Record-breaking 7.5Gbps in stationary conditions using 28GHz spectrum

2015

- **Demonstrated trio of 28Ghz technology dev. at MWC 15'**
- **Low latency network technology development**
  - FD-MIMO PoC testing and development

2016

- **60GHz technology showcase with Tier 1**
  - Mobile device hand-off btw base stations and from 5G to LTE network
- **Tier 1 HQ 5G indoor & mobility tests**
  - 3.7Gbps peak real world mobility test

World's 1st 5G mmWave 1Gbps transmission at 2km distance

7.5 Gbps stationary transmission

1.2Gbps un-interrupted transmission at >100km/hr

~1 ms latency delivered

Full dimension MIMO proof of concept

1st 5G intra-network mobile handoff & inter-network 5G to LTE

Real-world 1.2Gbps in-door penetration trial at Tier 1's HQ

mmWave Wireless Backhaul

FD-MIMO

'Samsung Delivers on Gigabit Wireless Promise of 5G'

Samsung 5G Achievements

World's 1st mmWave High Speed Mobility Test

World best 7.5Gbps data speed & World first 110 km/h mobility (2014)

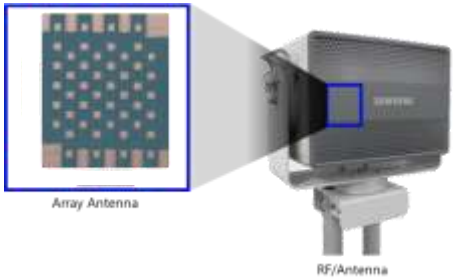
5G Mobility Test
1.2Gbps @110km/h

Peak Data Rate
7.5Gbps

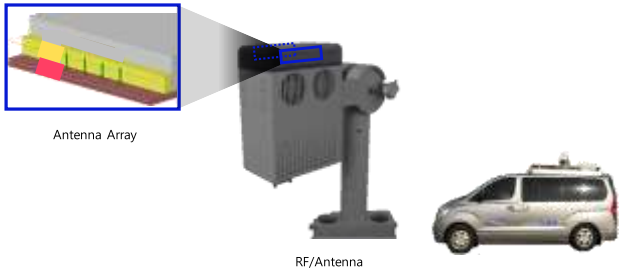
Samsung 5G Achievements

World's 1st mmWave Multi-Cell Handover with 3 Test Base Stations

Handover Tests in 3-Cell Network (Average ISD : 178m)
Handover Latency of 21 ms
Average Throughput of 1.67 Gbps at Driving Speed of 25 km/h



Base Station RFU



Mobile Station RFU

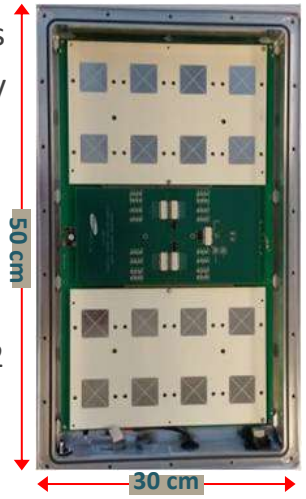
FD-MIMO

FD-MIMO

- 2D array based adaptive beamforming at the base station
- Higher-order MU-MIMO with 3D beamforming
- High order (≥8 UEs) MU-MIMO demonstration by FD-MIMO System at 3.5 GHz

Key Features

- LTE pre-release small-cell FD-MIMO
  - 20MHz BW TDD @3.5GHz, 32-TRX ports
  - Compact eNB with fully integrated array antenna, RF, and baseband
  - Novel antenna calibration network and compact array architecture
- Support of adaptive 3D-Beamforming and high-order MU-MIMO
  - Support of multi-user MIMO up to 8~12 UEs simultaneously



Inside
(RF/Antenna Board)

FD-MIMO MU-MIMO Test Results

- High-order multi-user MIMO with FD-MIMO PoC
  - 12-UE MU-MIMO indoor test: 422Mbps DL aggregated throughput
  - Realtime demo at NIWeek2015 (Aug. 2015, Austin TX)

Samsung 5G Technology Leadership (Below 6GHz)

Below 6GHz 5G Demo : 1 Gbps Throughput at 3.5GHz Spectrum (June, 2017)

- 3GPP 5G NR key features including 60kHz subcarrier spacing, LDPC and self-contained subframe

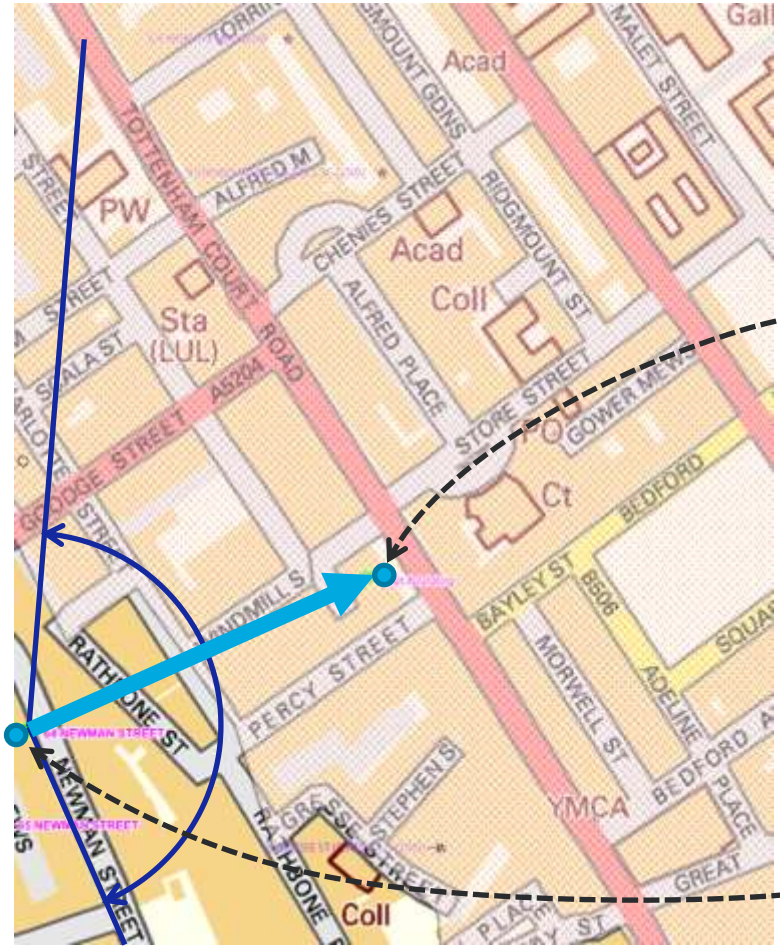
Parameters	Value
TTI	0.25ms
Subcarrier Spacing	60 kHz
Bandwidth	80 MHz x 2

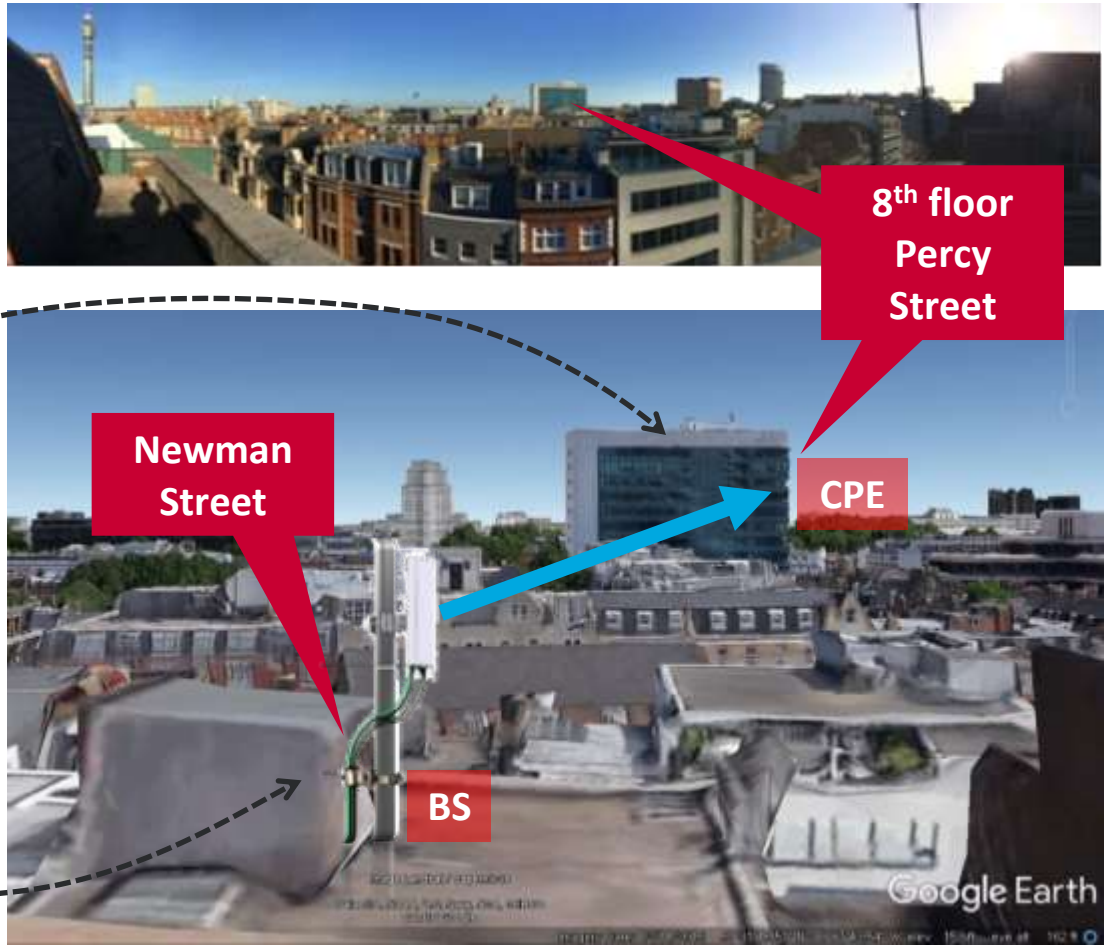
MAU (Massive MIMO Active Antenna Unit)

NDU (Next-generation Digital Unit)

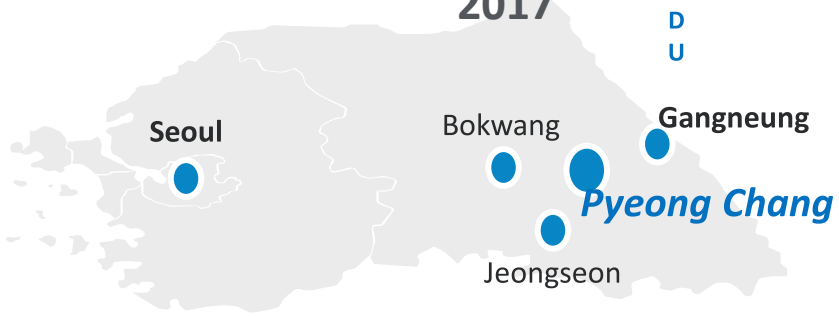
5G Field Trials in UK

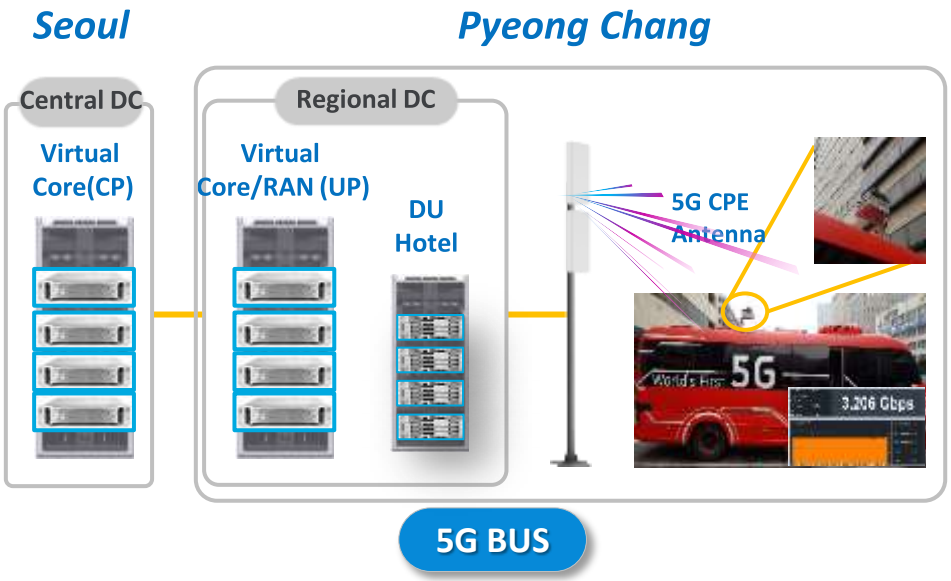
- First 5G FWA Field Trial/Showcase in Europe (@London, ‘17.2H)





5G Trial at PyeongChang 2018 Winter Olympics





PyeongChang 5G Trial Scenarios (Source : KT)

Challenges to Achieve Economics

- **SoC modem and RFIC are key drivers to achieve economics**
  - Current prototypes of 5G system are built with FPGA-based modem and discrete RF components
  - Commercial products are expected to come at mid 2018

- **Chip & Equipment vendors are hesitating to invest heavily on non-standardized products.**
  - First official 5G standards will be frozen by 2019 (Rel.15), and need strong commitment by operators to commercialize in early