5G Vision and Requirements Of 5G Forum, Korea

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5G Forum, Korea

Mobile Communication Trend

Smart Devices Explosion	Super-fast Hyper Connection	Cost Effective Systems	Giga Service Demand	Welfare Infra Demand
x10 ~ x1000 5Billion to 5Trillion	Connecting all devices derives new business models	Need New Solution to resolve ARPU reduction over CAPEX/OPEX	Driven by display tech. & Giga networks (AR, Hologram, UHD)	National wide knowledge based service for all people in need

Service Trend

- **Multimedia Services will Require More and More Bandwidth**

- **Mobile Cloud Services are Growing Rapidly**

- **Augmented Reality/Virtual Reality Services will Become Common**

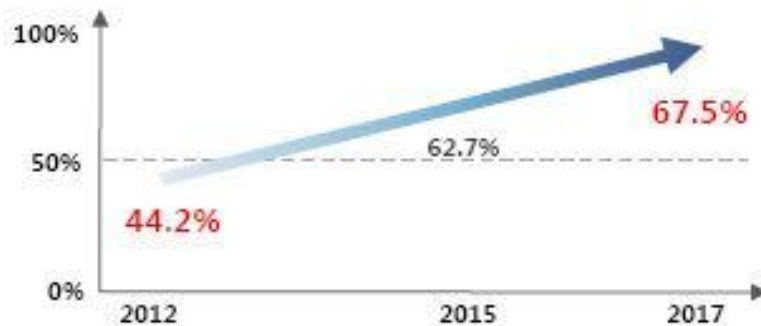- **Social Networking Services will be Expanded with Rich Contents**

- **M2M Devices Proliferate & High Data Rate Media-Based M2M Service will Grow**

- **Personalized Services will be Integrated into Daily Life (LBS, u-health)**

Device Trend

Penetration of Smartphone Terminals

- **The spread of smartphones will continue to rise worldwide**
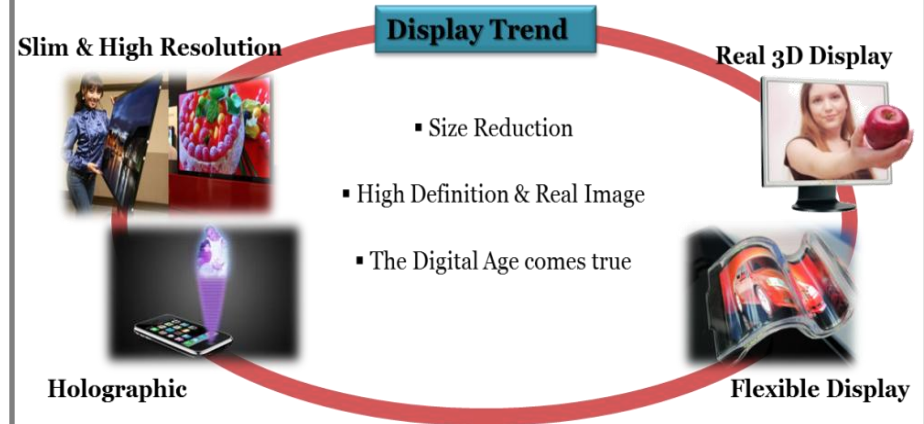 - Traffic share : 44.2%('12) → 67.5%('17)

- **Smartphones generate tremendous traffic (compared with feature phones)**
  - Smartphone : 24times ↑, Tablet : 122times ↑

Device Environmental Trend

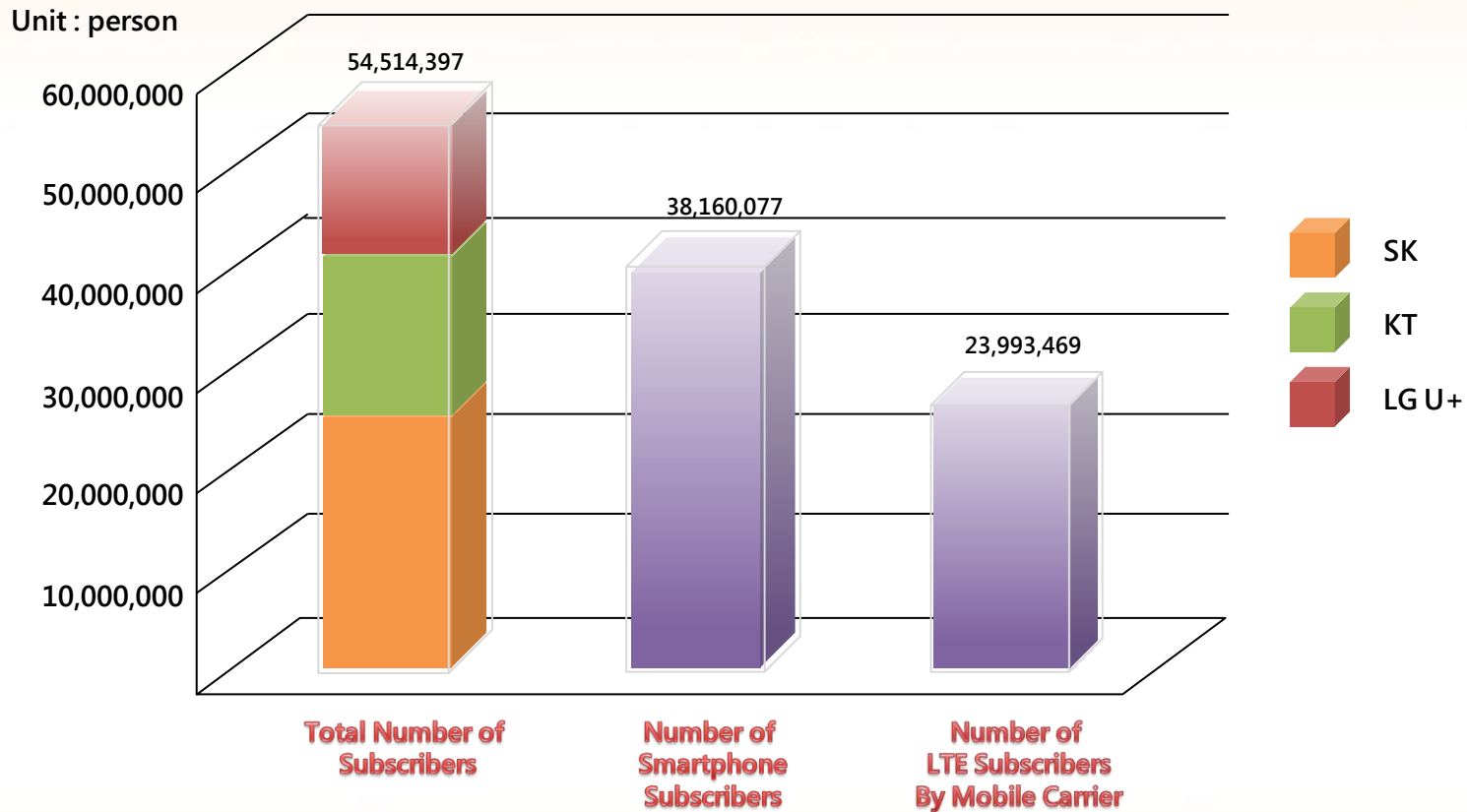- **Slim & High Resolution, Flexible Display will be introduced**

MPEG, HD

Early 2000s

Smart phone
Smart tablet

First Big Bang

UHD, Hologram M2M, Mobile Cloud

Folder tablet
Glasses phone

Big Bang accelerated

- Global Exponential Mobile Data Traffic Increase

  (Growth Rate : ≈2x per year, ≈1000x in 10 years)

- LTE 20MHz, 100Mbps/cell → require 20GHz, 100Gbps/cell

  ✓ Need 2GHz bandwidth even if the efficiency rises 10 times

  ✓ 100Gbps/cell → throughput 30Gbps/cell → 30 users/cell → 1Gbps/user/cell

■ Status of Mobile Subscribers(Korea)

Unit : person

	SK
	KT
	LG U+

Total Number of Subscribers: 54,514,397

Number of Smartphone Subscribers: 38,160,077

Number of LTE Subscribers By Mobile Carrier: 23,993,469

[Source: Ministry of Science, ICT & Future Planning, Nov. 2013]

Korea Mobile Trend

1G
Carrier operating

- Only voice call
- 1984' service start

[first cellphone]

[Car phone]

2G
Government leading

- Voice call, SMS, e-mail (data transmission)
- 1996' service start
- IS-95 (USA, Synchronous) GSM(Europe)

[2G phone]

[SMS]

3G
Carrier leading

- Voice data, non voice data transmission
- 2003' service start
- Composite IMT-2000

  ※ WCDMA, CDMA2000, TD-SCDMA

[WCDMA]

[SNS]

4G
Manufacturer leading

- Fast data rate, High quality HD visual phone

  ※ Full All-IP -> M-VoIP, VoLTE service

- 2011' service start
- LTE, LTE-A(2013')

Quadruple X1000

Thousands
of times
Mobile Device

Thousands
of times
Mobile Traffic

Thousands
of times
Latency

Thousands
of times
Energy savings

Service Considerations

User Friendly

Realistic applied service

Highly reliable

Personalized

Very fast, High traffic data

High secured

Cloud system based Service

Lower battery consumption

Millisecond latency

5G Service Vision

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                        ┌─────────────────────┐
                        │         5G          │
                        └─────────────────────┘
```

Hyper-reactivity	Hyper-connectivity	Hyper-realistic	Hyper-low cost	Hyper-energy saving	Hyper-reliability
Fast, low latency, real-time response.	Connection for everything on wireless/wired.	Augmented reality service, hologram service.	Cost effective infrastructure for device & network.	Energy efficiency and power-saving system & service.	Error-free service for medical service, public safety, etc.

5G Configuration of Core Service

Hyper–
connectivity

Hyper–
reactivity

Hyper–
low cost

Hyper–
energy saving

Hyper–
realistic

Hyper–
reliability

Driver Services

Emergency

Traffic efficiency & Safety

Smart Grid Network

Smart Display

Smart Home

Stadium & Shopping mall

Sensor Network

Remote medical

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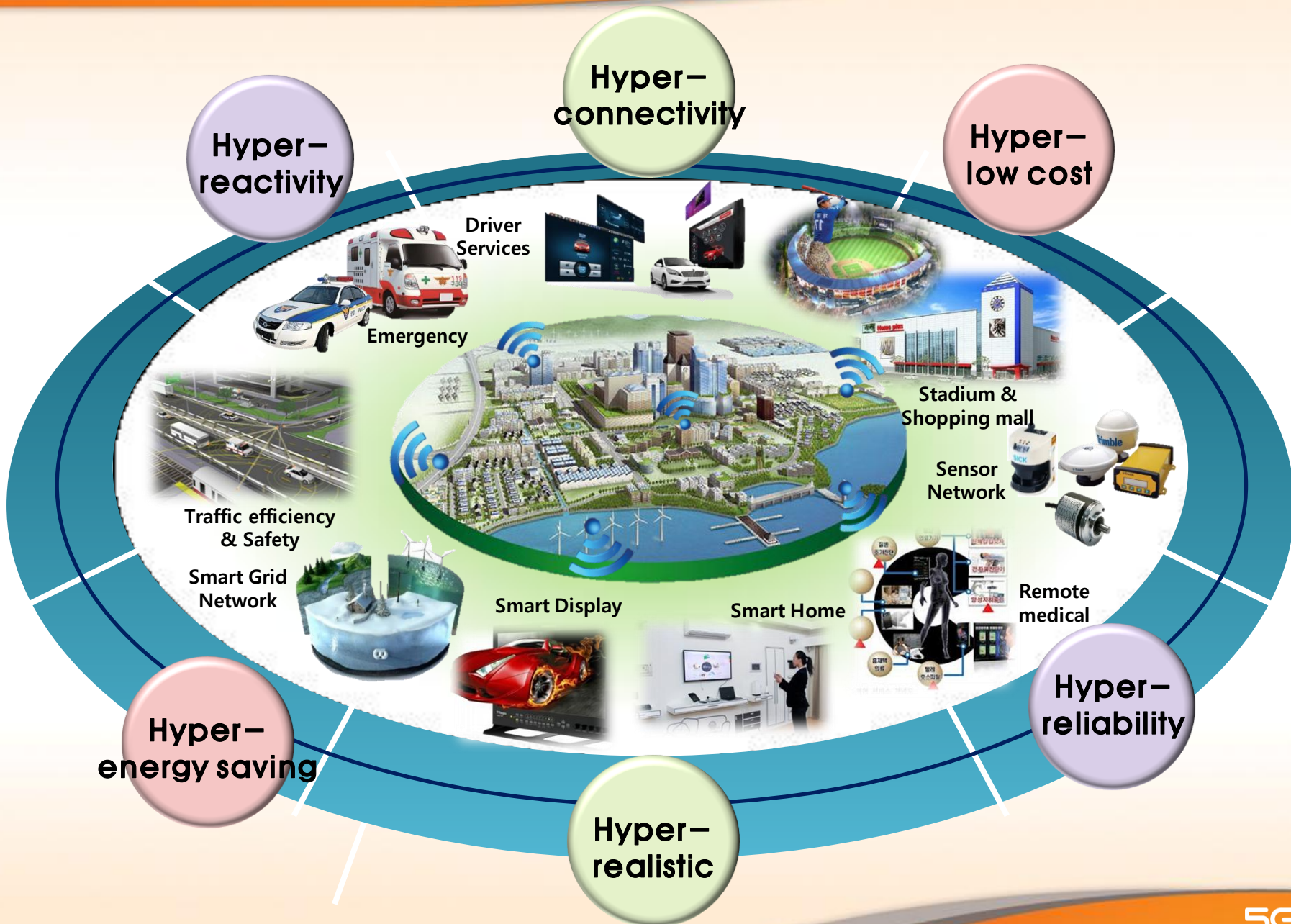
5G Core Service - Smart Car

LIDAR

GPS
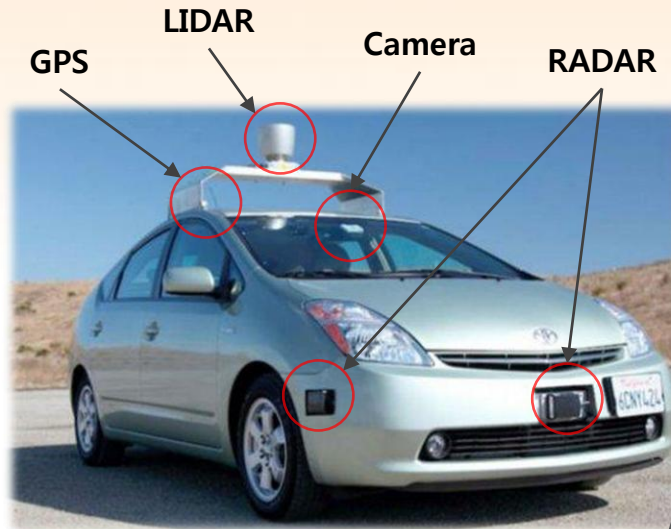
Camera

RADAR

Giga Communication

- V2N(Vehicle to Nomadic devices)
- V2V(Vehicle to Vehicle)
- V2I(Vehicle to Infrastructure)

5G, 100GB/s

CLOUD

Measuring /Position Sensor

- Sensor Requirement GPS

  Camera

  RADAR

  LIDAR

Sensor Data

- Distance data
- Color data
- Position data
- Velocity data
- Direction data

Control Data

- Steering control values
- Break control values
- Acceleration control values
- Geer control values

Data Manufacturing

- Map build
- Path determine
- Path planning
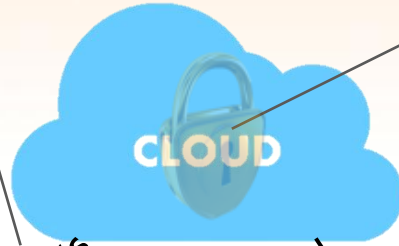- Set velocity & direction

5G Core Service - Medical Service

Giga Communication

- **V2I(Vehicle to Infrastructure)**
- **Reliability**

Cloud Server

- **Security**

CLOUD

5G, 100GB/s

5G, 100GB/s

Remote care

- **UHD medical image data**
- **Professional prescription**

Emergency request

- **Real-time**
- **Mobility**

5G Core Service - Education Service

Realistic education services

- Promote efficient education service with 3D
- Education in various fields
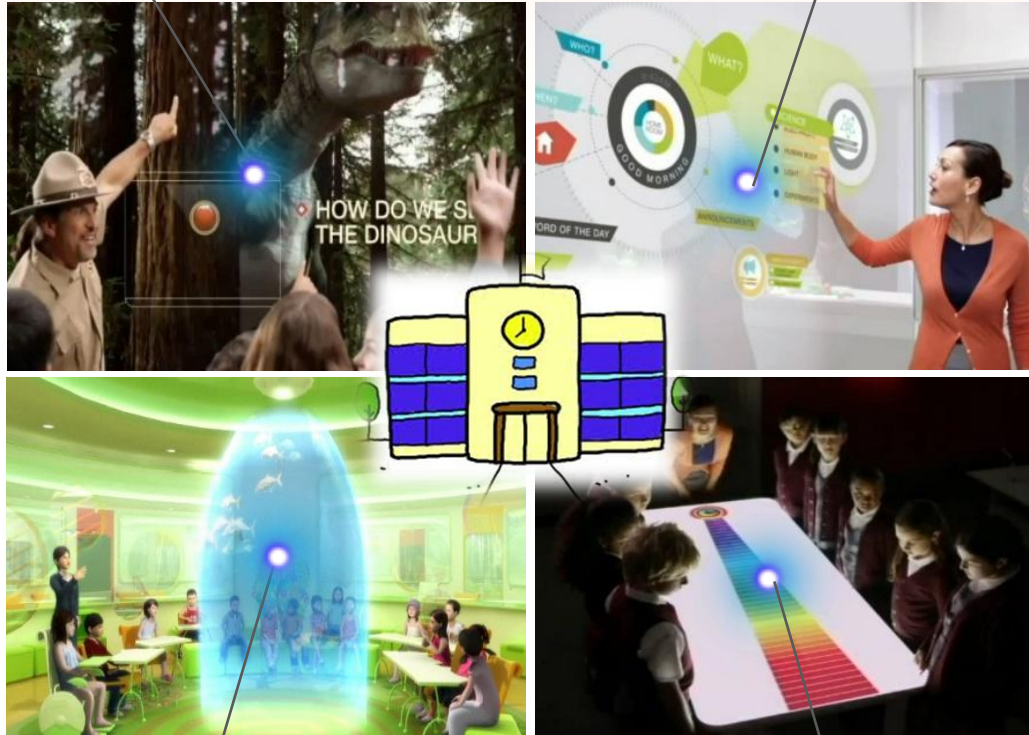
Online education service

- 2-way online education service

Multilateral education service

- Effective simultaneous learning

Smart education infra

- 3D system
- Giga bit communication

Recognition sensor

- **Vision recognition & Situational awareness**

HD Hologram

- **Huge content representation**
- **HDTV hologram implement**
- **50inch hologram display realization**

5G Core Service - Disaster relief Service

Environmental Sensors

- **Measurement & Chemical sensor**
- **HD-CCTV(Closed Circuit Tele-Vision)**

Emergency Service

- **Recognition(Environmental Sensors, Position Information)**
- **Estimation(Situation & Risk)**
- **Action(Service Execution)**

Location Based Service

Position Recognition Technology

High-density User Communication

5G Core Service

Core service	Hyper-reactivity	Hyper-connectivity	Hyper-Low cost	Hyper-reliability	Hyper-realistic	Hyper-energy saving
Smart car	√	√	√	√		√
Medical service	√	√		√	√	
Education service	√	√	√		√	
Game service	√	√		√		√
Disaster relief service	√	√	√	√		√

5G Core/Wireless Network Requirements

High Level Requirements

- **(H1)** **Accommodate Traffic & Bandwidth Explosion**
  - **Traffic volume will be increased 1000 times**
  - **Video Traffic portion will be major**

- **(H2)** **Accommodate Signaling Explosion**
  - **Mobility signaling explosion by Small Cell**
  - **Massive connectivity due to increased number of devices**
  - **Bearer control caused by 'always-on-apps' of OTT (Over-The-Top) services**
  - **Higher paging complexity caused by heterogeneous wireless and wire-line accesses**

- **(H3)** **Satisfy Operator's Requirement of Profitable Network Infra**
  - **Legacy network can hardly reduce CAPEX and OPEX**
  - **Need to accommodate new services in the same physical network**

- **(H4)** **Support Various wireless access technologies and fixed access**
  - **Need to support various types of wireless and wire-line access in the same core network**
  - **Need to support new 5G RAT**

Types of Requirements

- **Bottom-Up** Requirement driven by the unique feature of the 5G radio access
- **Top-Down** Requirement to support 5G services
- **Enhancement** Requirement to Overcome fundamental limitation of legacy network, Prevent future potential problems, and Follow the evolution mega trend.

Bottom-Up Requirements

	Brief Description	5G Core Network Requirements	Related HL Req.			
			H1	H2	H3	H4
B1	Seamless Mobility	Shall support seamless mobility regardless of the cell types and RATs in the environment where the macro BS, small cell BS, personal cell, type 1/2 WLAN, and relay station are mixed and overlapped				√
B2	Multiple RAT interworking	Shall have architecture to support 'Flow over Multi-RAT' to provide the high volume service with low cost and guarantee the service continuity in spite of the bandwidth deficiency in a wireless access	√		√	√

H1	Accommodate Traffic & Bandwidth Explosion	**H2**	Accommodate Signaling Explosion	**H3**	Satisfy Operator 's Req. of Profitable Network Infra	**H4**	Support Various wireless access technologies and fixed access

Top Down Requirements

	Brief Description	5G Core Network Requirements	Related HL Req.			
			H1	H2	H3	H4
T1	Wired/wireless terminal switching	Shall support terminal and/or session mobility to provide fast handover between wireless and wire-line terminals		√		√
T2	Network on-demand	Shall be able to build the network based on the QoS/QoE, charging, and service characteristics			√	
T3	Context aware best connection	Shall utilize the various context information (device context, user context, environment context, network context) to provide always best connection/service			√	√
T4	Singe ID for multiple access	Shall recognize a mobile terminal as a single entity regardless of its access network	√			
T5	Fine grained location tracking	Shall have function to trace the mobile terminal location in a fine granularity in order to provide advanced location based service				√

H1 Accommodate Traffic & Bandwidth Explosion	**H2** Accommodate Signaling Explosion	**H3** Satisfy Operator 's Req. of Profitable Network Infra	**H4** Support Various wireless access technologies and fixed access

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Enhancement Requirements

	Brief Description	5G Core Network Requirements	Related HL Req			
			H1	H2	H3	H4
E1	Distributed Architecture	Shall support the distributed network architecture to accommodate anticipated 1000 times of traffic explosion	√	√		
E2	Inter GW mobility	Shall guarantee the service continuity when the change of anchoring GW occurs frequently in the distributed architecture	√			
E3	Flexible Reconfigure & Upgrade	Shall provide virtualization environment and support to reconfigure and upgrade the core network at low cost without changing the physical network infrastructure			√	

|							
H1	Accommodate Traffic & Bandwidth Explosion	**H2**	Accommodate Signaling Explosion	**H3**	Satisfy Operator 's Req. of Profitable Network Infra	**H4**	Support Various wireless access technologies and fixed access

5G Core Network Enabling Technologies

Objective	Enabling Technologies	5G Core Network Requirement									
		T1	T2	T3	T4	T5	B1	B2	E1	E2	E3
Highly Flexible 5G core Infra	Flexible service chaining for future mobile services		√								√
	Optimal virtualization of mobile core control functions		√								√
	Dynamic open control protocol for mobile core									√	√
Flat & Distributed Network	Virtualized logical GW with distributed switch		√						√		
	Dynamic mobility anchoring for seamless inter-GW HO								√	√	
	Signaling mitigation for always-on-app and IoT		√						√		
Converged access control & transport	Unified ID based access control				√						
	Multi-RAT Carrier aggregation			√				√			
	Seamless mobility between wire-line and wireless accesses	√		√		√	√				
	HetNet/Multiple RAT mobility control						√	√			
	Integrated resource management and control				√	√	√	√			
	Access condition awarded content delivery	√		√			√				

Current version of enabling technologies is working draft.

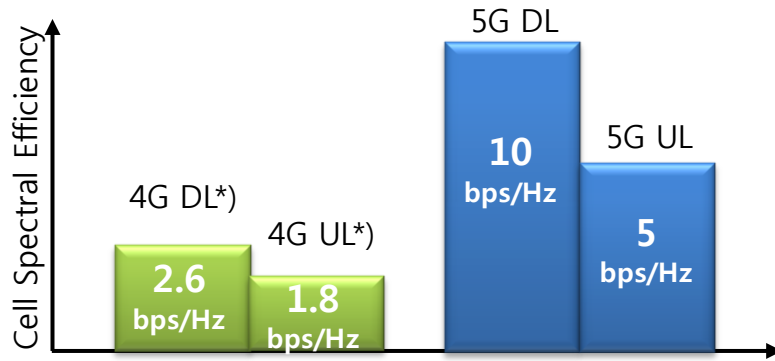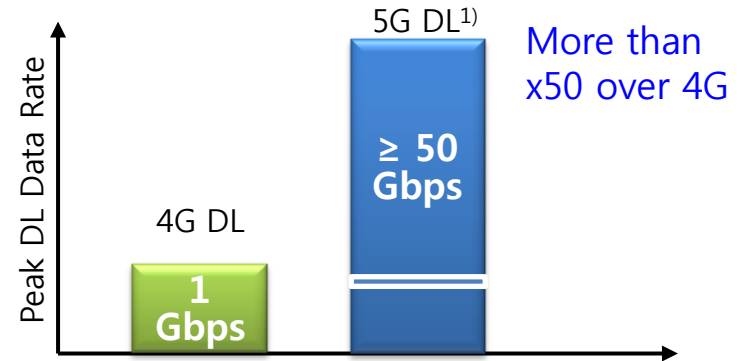|									
T1	Wired and wireless terminal switching	T2	Network on-demand	T3	Context aware best connection	T4	Singe ID for multiple access	T5	Fine grained location tracking
B1	Seamless Mobility	B2	Multiple RAT interworking	E1	Distributed Architecture	E2	Inter GW mobility	E3	Flexible Reconfigure & Upgrade

5G Network Architecture (Example)
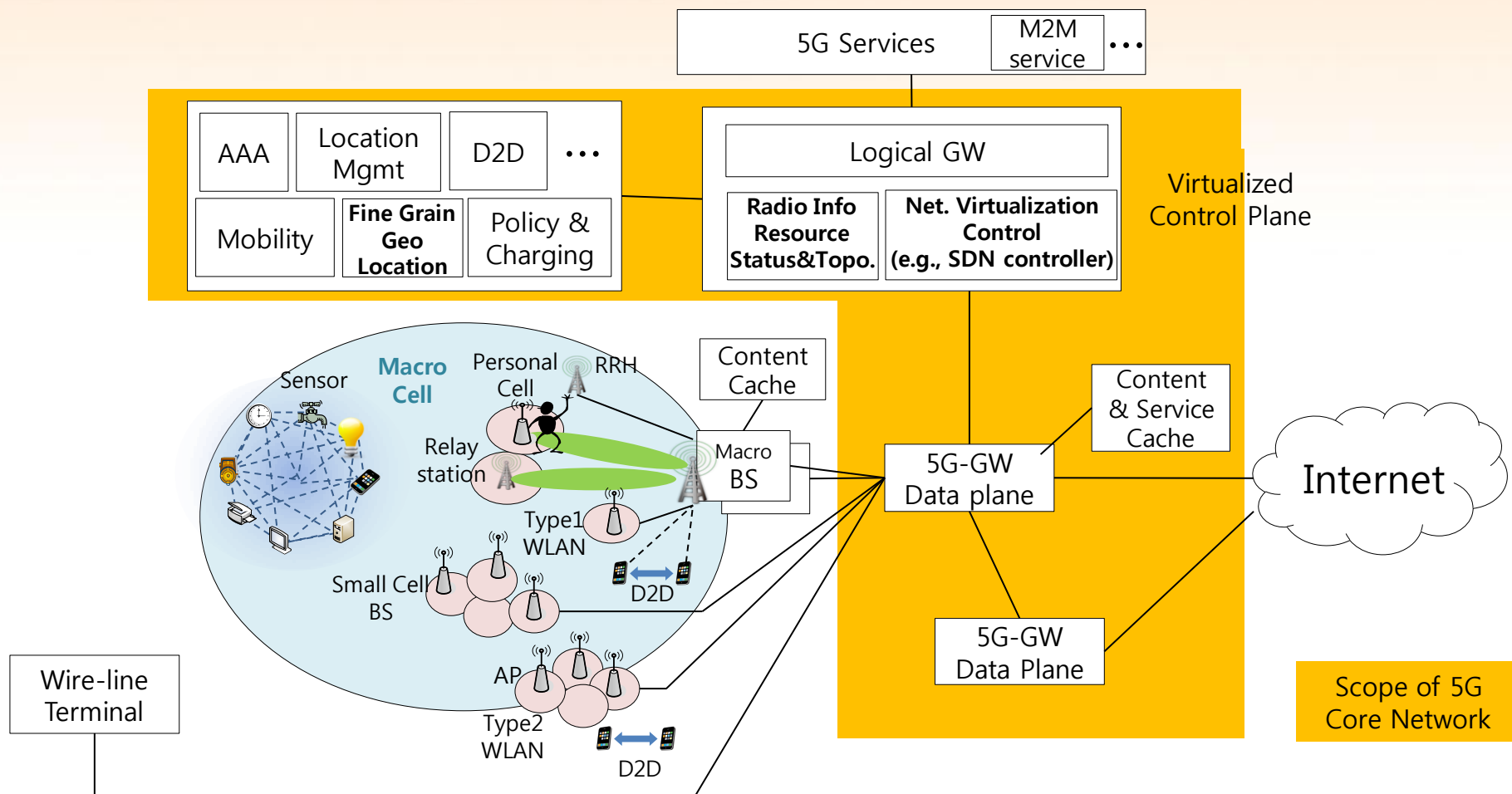
- **5G core network covers both wire-line and wireless accesses**
- **Control plane is separated from the data plane and implemented in a virtualized environment**
- **Fully distributed network architecture with single level of hierarchy**
- **GW to GW interface to support seamless mobility between 5G-GW**
- **Traffic of the same flow can be delivered over multiple RAT**

[R1] Cell Spectral Efficiency

5G DL

5G UL

4G DL*)

4G UL*)

Cell Spectral Efficiency

2.6 bps/Hz

1.8 bps/Hz

10 bps/Hz

5 bps/Hz

[R2] Peak Data Rate

Peak DL Data Rate

5G DL[1]

4G DL

1 Gbps

≥ 50 Gbps
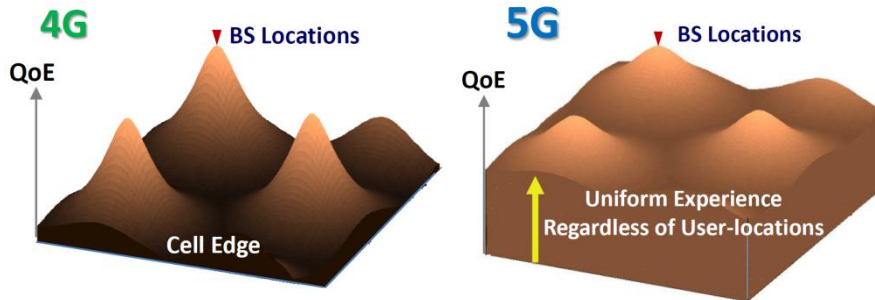
More than x50 over 4G

1) 5G Peak UL data rate: a half of Peak DL data rate

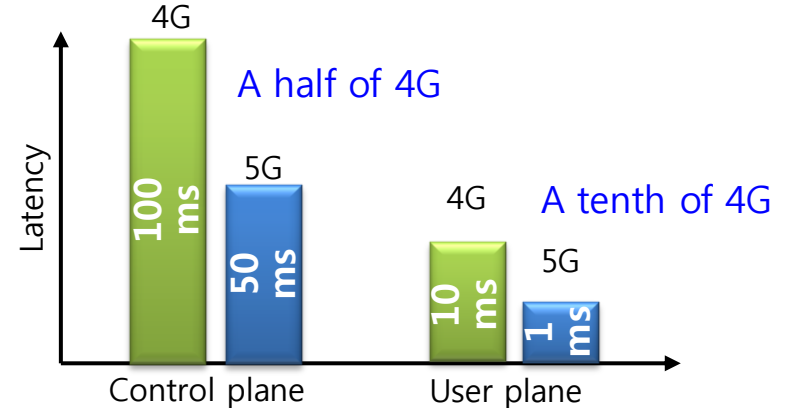## [R3] Cell Edge User Data Rate

DL*): 0.075 bps/Hz/cell
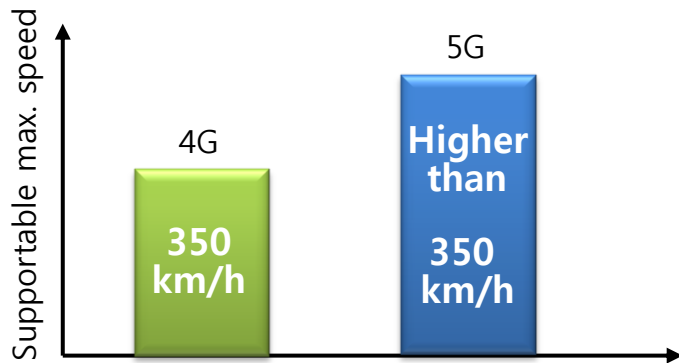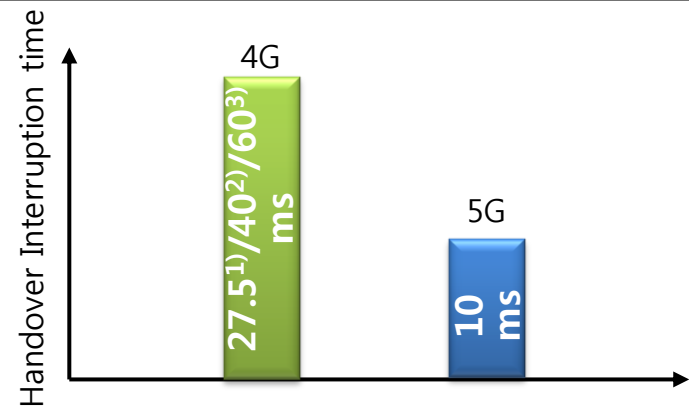UL*): 0.05 bps/Hz/cell

Anywhere DL 1 Gbps
Anywhere UL 0.5 Gbps

4G QoE ▼ BS Locations Cell Edge

5G QoE ▼ BS Locations Uniform Experience Regardless of User-locations

[R4] Latency

Latency

4G

5G

100 ms

50 ms

A half of 4G

4G

5G

10 ms

1 ms

A tenth of 4G

Control plane   User plane

*) IMT-A Req. in 10-30 km/h test environment

[R5] Mobility

Supportable max. speed

4G: **350 km/h**

5G: **Higher than 350 km/h**

[R6] Handover Interruption Time

Handover Interruption time

4G: **27.5[1]/40[2]/60[3] ms**

5G: **10 ms**

1) Intra-frequency, 2) inter-frequency within a spectrum band
3) inter-frequency between spectrum bands

[R7] Areal Capacity

- In order to accommodate the explosive increase of future mobile data traffic, 5G RAN should be able to scale-up system capacity by adding more cells in a target area

- If necessary, a metric value in unit of bps/km^2 may be specified.

[R8] Energy Efficiency

- 5G radio access technology design should aim for higher energy efficiency against increased device/network energy consumption required on 5G wireless communications.

- If necessary, a metric value in unit of J/bit may be specified.

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Wireless Network Requirements

	Brief Description	5G Wireless Network Requirements	Related HL Req.			
			H1	H2	H3	H4
R1	Cell spectral efficiency	the aggregate throughput of all users divided by the channel bandwidth divided by the number of cells **(DL: 10 bps/Hz/cell, UL: 5 bps/Hz/cell)**	√		√	√
R2	Peak data rate	the maximum theoretically achievable data rate which can be assigned to a single mobile station assuming error-free conditions when all the available radio resources are utilized for the corresponding link **(DL: 50 Gbps, UL: 25 Gbps)**	√		√	√
R3	Cell edge user data rate	5% point of the cumulative distribution function (CDF) of the user data rate **(DL: 1 Gbps, UL: 0.5 Gbps)**	√		√	√

H1 Accommodate Traffic & Bandwidth Explosion	**H2** Accommodate Signaling Explosion	**H3** Satisfy Operator 's Req. of Profitable Network Infra	**H4** Support Various wireless access technologies and fixed access

Wireless Network Requirements

	Brief Description	5G Wireless Network Requirements	Related HL Req.			
			H1	H2	H3	H4
R4	Latency	**Control plane latency**: typically measured as transition time from different connection modes, e.g. from idle to active state. **(50 ms)** **User plane latency**: the one-way transit time between an SDU packet being available at the IP layer in the user terminal/base station and the availability of this packet (PDU) at IP layer in the base station/user terminal. **(1 ms)**			√	√
R5	Mobility	A mobility class is supported if the traffic channel link can be maintained when the user is moving at the maximum speed in that mobility class. **(higher than 350km/h)**		√	√	√
R6	Handover interruption time	the time duration during which a user terminal cannot exchange user plane packets with any base station. **(10 ms)**		√	√	√

H1 Accommodate Traffic & Bandwidth Explosion	**H2** Accommodate Signaling Explosion	**H3** Satisfy Operator 's Req. of Profitable Network Infra	**H4** Support Various wireless access technologies and fixed access

Wireless Network Requirements

	Brief Description	5G Wireless Network Requirements	Related HL Req.			
			H1	H2	H3	H4
R7	Areal capacity	In order to accommodate the explosive increase of future mobile data traffic, 5G RAN should be able to scale-up system capacity by adding more cells in a target area.	√	√	√	√
R8	Energy efficiency	5G radio access technology design should aim for higher energy efficiency against increased device/network energy consumption required on 5G wireless communications.			√	√

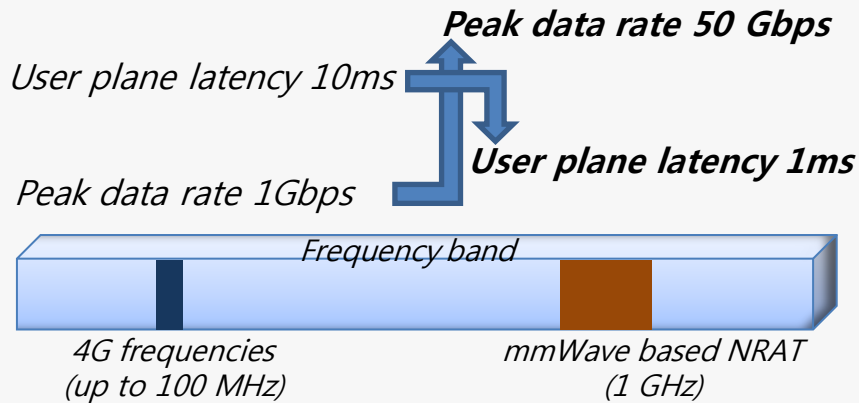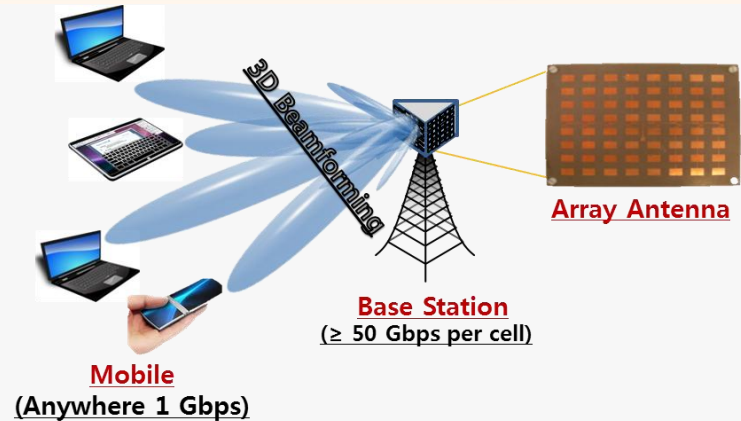**H1** Accommodate Traffic & Bandwidth Explosion   **H2** Accommodate Signaling Explosion   **H3** Satisfy Operator 's Req. of Profitable Network Infra   **H4** Support Various wireless access technologies and fixed access

mmWave Higher Bandwidth

Peak data rate 50 Gbps

User plane latency 10ms

User plane latency 1ms

Peak data rate 1Gbps

Frequency band

4G frequencies
(up to 100 MHz)

mmWave based NRAT
(1 GHz)

Large Scale Antenna

3D Beamforming

Array Antenna

Base Station
(≥ 50 Gbps per cell)

Mobile
(Anywhere 1 Gbps)

Advanced Multiple Access

OFDM

MS 1
MS 3
MS 2
BS

Subcarrier Index (Frequency)

Much Lower Sidelobe

FBMC

Non-Orthogonal Multiple Access

Power

MS 3

MS 2

MS 1

Subcarrier Index (Frequency)

Subcarrier Index (Frequency)

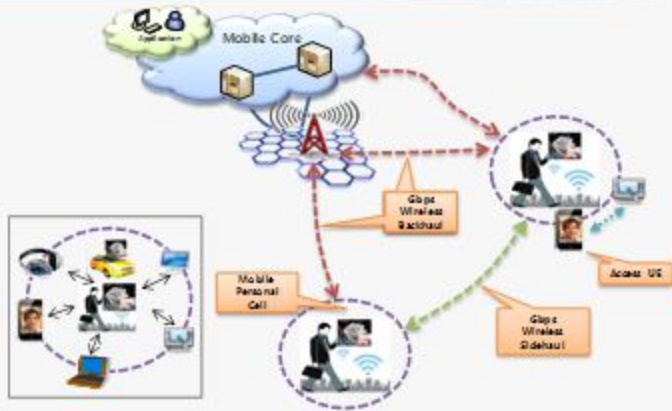## Modulation & Coding

4-QAM

S_2 S_1

S_3 S_4

4-FSK

Freq

16-FQAM

256 QAM
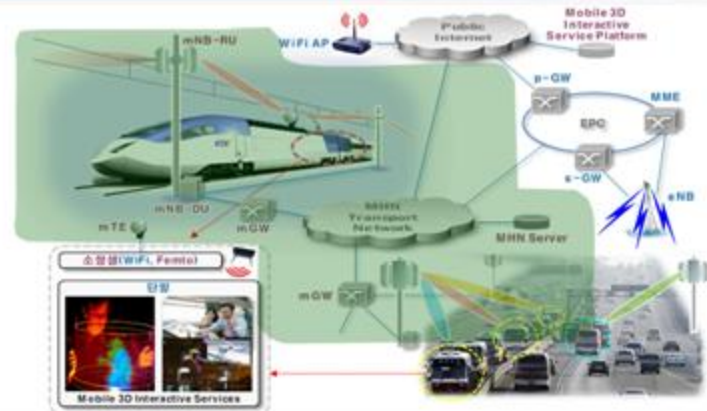
NRAT: New Radio Access Technology, FBMC: Filter-Bank Multi-Carrier
FQAM: Frequency, Quadrature Amplitude Modulation

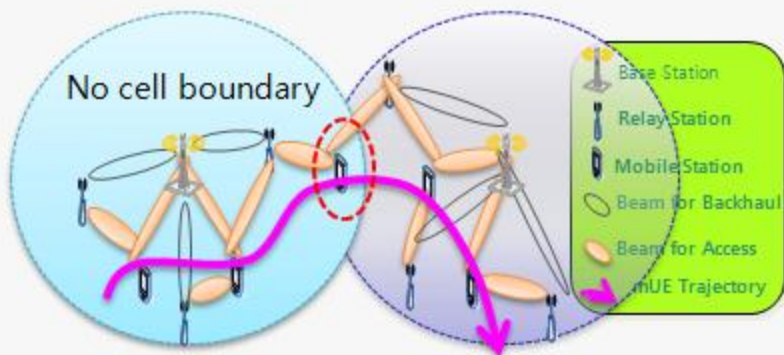| Objective	Enabling Technologies	5G RAN Requirements							
		R1	R2	R3	R4	R5	R6	R7	R8
Throughput Enhancement	mmWave's higher bandwidth	✓	✓		✓				
	Advanced carrier aggregation	✓	✓						
	Cognitive Radio	✓						✓	✓
	Advanced small cell							✓	✓
	Large scale antenna (3D beamforming, Massive MIMO, …)	✓	✓	✓					
	Modulation and coding (Higher order modulation, FQAM, advanced channel coding, …)	✓	✓						
	Advanced Multiple Access (NOMA, FBMC, FTN, …)	✓		✓					
	Advanced Interference Management (Networking Coding, Cooperated Tx/Rx, SIC, interference alignment, …)	✓		✓					
Flexible Topology	Advanced Relay (full-duplexing, Relay-based networking coding, …)	✓		✓					
	Wireless Backhaul, Moving Network, Personal Cell			✓					
	Virtual Cellular (Fast and Seamless handover)				✓	✓	✓		
Low cost and Low power	Integrated Tx/Rx with WLAN and WPAN							✓	✓
	Device-to-Device (D2D) communication, …							✓	✓

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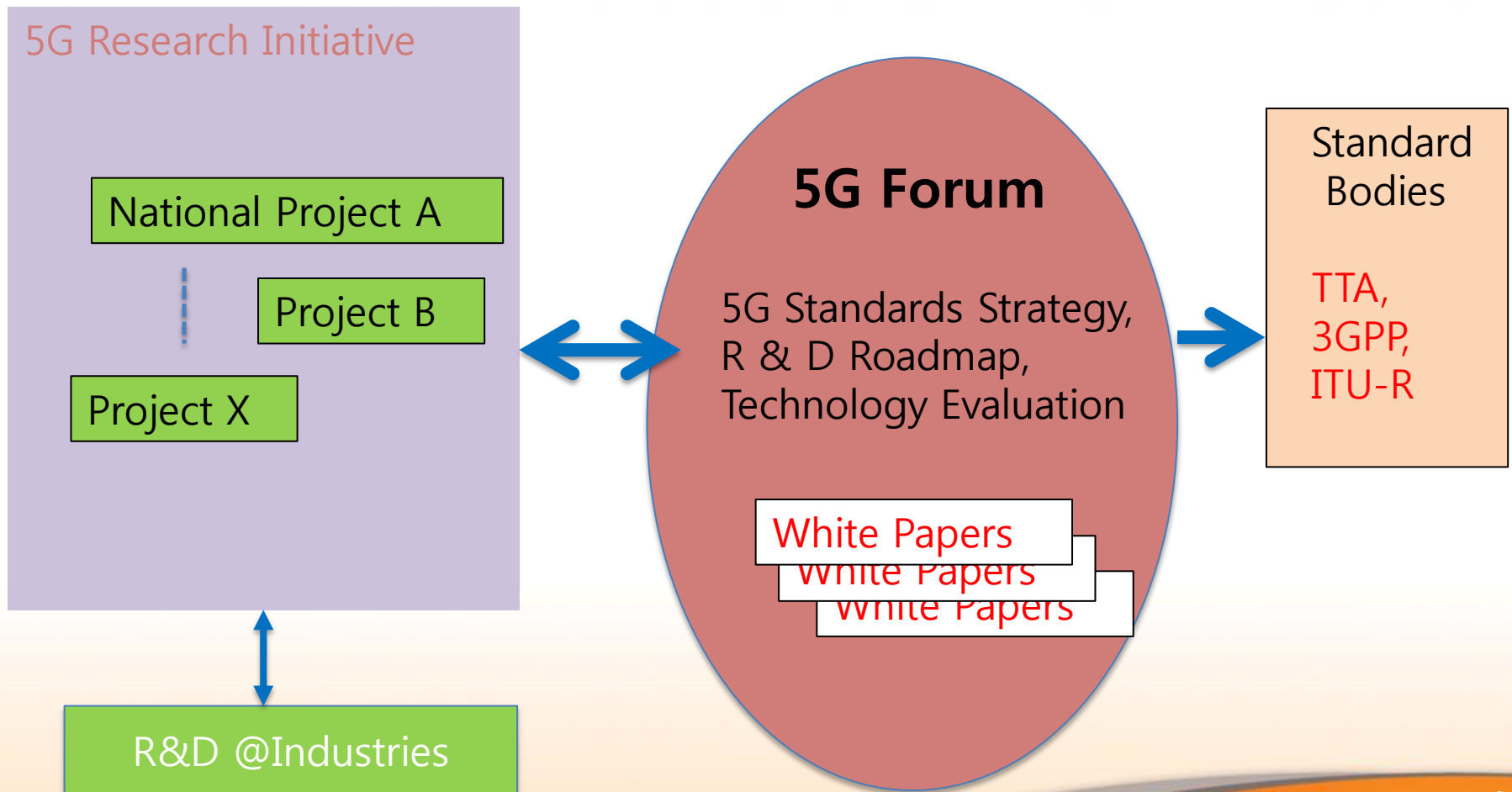
R1 cell spectral efficiency **R2** peak data rate **R3** cell edge user data rate **R4** latency
R5 mobility **R6** handover interruption time **R7** areal capacity **R8** energy efficiency

MIMO: Multiple Input Multiple Output, FQAM: Frequency, Quadrature Amplitude Modulation
NOMA: Non-Orthogonal Multiple Access, FBMC: Filter-Bank Multi-Carrier, FTN: Faster Than Nyquist
SIC: Successive Interference Cancellation

- Birth: May 30, 2013
  - Public Private Partnership

- Objective
  - In pace with wireless technology
  - For a leading country in Technology, Service and Industrialization of 5G Mobile Communication through
    - Mid to Long-term Strategic Planning for Technology Innovation
    - Active Working on Standardization
    - Mobile Service Vision Set-up
    - Establishment of Common Knowledge/Experience amongst People

External Bodies
(2020PG, 2020B AH, ..)

5G Research Initiative

National Project A

Project B

Project X

R&D @Industries

5G Forum

5G Standards Strategy,
R & D Roadmap,
Technology Evaluation

White Papers
White Papers
White Papers

Standard
Bodies

TTA,
3GPP,
ITU-R

5G Forum Organization

Executive Board — Leadership Counsel

Board of Audit/inspection

Steering Committee

International Cooperation/Liaison Sub-Committee

Technology Sub-Committee

Management/ Support Team

Spectrum Aspect Sub-Committee

Service Aspect Sub-Committee