01  Mobile Communication Trend
02  5G Service Vision
03  5G System Requirement
04  5G Forum, Korea
Mobile Communication Trend

**Smart Devices Explosion**
- x10 ~ x1000
- 5Billion to 5Trillion

**Super-fast Hyper Connection**
- Connecting all devices derives new business models

**Cost Effective Systems**
- Need New Solution to resolve ARPU reduction over CAPEX/OPEX

**Giga Service Demand**
- Driven by display tech. & Giga networks (AR, Hologram, UHD)

**Welfare Infra Demand**
- National wide knowledge based service for all people in need
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)
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

  Display Trend
  - Size Reduction
  - High Definition & Real Image
  - The Digital Age comes true

  Slim & High Resolution
  Real 3D Display
  Holographic
  Flexible Display
Global Exponential Mobile Data Traffic Increase
(Growth Rate: $\approx 2x$ per year, $\approx 1000x$ 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
Traffic Explosion

Status of Mobile Subscribers (Korea)

- Total Number of Subscribers: 54,514,397
- Number of Smartphone Subscribers: 38,160,077
- Number of LTE Subscribers By Mobile Carrier: 23,993,469

Unit: person

[Source: Ministry of Science, ICT & Future Planning, Nov. 2013]
# Korea Mobile Trend

## 1G Carrier Operating
- Only voice call
- 1984’ service start

![first cellphone]

## 2G Government Leading
- Voice call, SMS, e-mail (data transmission)
- 1996’ service start
- IS-95 (USA, Synchronous)
- GSM (Europe)

![2G phone]

## 3G Carrier Leading
- Voice data, non voice data transmission
- 2003’ service start
- Composite
- IMT-2000
  - WCDMA, CDMA2000, TD-SCDMA

![WCDMA]

## 4G Manufacturer Leading
- Fast data rate, High quality HD visual phone
- 2011’ service start
- LTE, LTE-A (2013’)

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

![5GForum]
5G Mobile Systems Environment

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

Highly secured

Realistic applied service

Highly reliable

Very fast, High traffic data

Millisecond latency
5G Service Vision

5G

Hyper-reactivity
Fast, low latency, real-time response.

Hyper-connectivity
Connection for everything on wireless/wired.

Hyper-realistic
Augmented reality service, hologram service.

Hyper-low cost
Cost effective infrastructure for device & network.

Hyper-energy saving
Energy efficiency and power-saving system & service.

Hyper-reliability
Error-free service for medical service, public safety, etc.
5G Core Service - Smart Car

Measuring/Position Sensor
- Sensor Requirement
  - GPS
  - Camera
  - 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

5G, 100GB/s

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

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

Cloud

5G Core Service - Smart Car

- RADAR
- LIDAR
- Camera
- GPS
5G Core Service - Medical Service

- Giga Communication
  - V2I (Vehicle to Infrastructure)
  - Reliability

- Remote care
  - UHD medical image data
  - Professional prescription

- Cloud Server
  - Security

- 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
5G Core Service - Game Service

**Recognition sensor**
- Vision recognition & Situational awareness

**HD Hologram**
- Huge content representation
- HDTV hologram implement
- 50inch hologram display realization
5G Core Service - Disaster relief Service

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

Location Based Service
Position Recognition Technology

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

High-density User Communication
## 5G Core Service

<table>
<thead>
<tr>
<th>Core service</th>
<th>Hyper-reactivity</th>
<th>Hyper-connectivity</th>
<th>Hyper-Low cost</th>
<th>Hyper-reliability</th>
<th>Hyper-realistic</th>
<th>Hyper-energy saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart car</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Medical service</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Education service</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td></td>
<td>✓</td>
</tr>
<tr>
<td>Game service</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Disaster relief service</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>
(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
## 5G Core Network Requirements (1/3)

### 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

<table>
<thead>
<tr>
<th>Brief Description</th>
<th>5G Core Network Requirements</th>
<th>Related HL Req.</th>
</tr>
</thead>
</table>
| **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 | H1, H2, H3, H4
| **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, H2, H3, H4

### Related Requirements

- **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 Requirements (2/3)

### Top Down Requirements

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

**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 Requirements (3/3)

### Enhancement Requirements

<table>
<thead>
<tr>
<th>Brief Description</th>
<th>5G Core Network Requirements</th>
<th>Related HL Req</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E1</strong> Distributed Architecture</td>
<td>Shall support the distributed network architecture to accommodate anticipated 1000 times of traffic explosion</td>
<td>√ √</td>
</tr>
<tr>
<td><strong>E2</strong> Inter GW mobility</td>
<td>Shall guarantee the service continuity when the change of anchoring GW occurs frequently in the distributed architecture</td>
<td>√</td>
</tr>
<tr>
<td><strong>E3</strong> Flexible Reconfigure &amp; Upgrade</td>
<td>Shall provide virtualization environment and support to reconfigure and upgrade the core network at low cost without changing the physical network infrastructure</td>
<td>√</td>
</tr>
</tbody>
</table>

### Related HL Requirements

- **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

<table>
<thead>
<tr>
<th>Objective</th>
<th>Enabling Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly Flexible 5G core Infra</td>
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<td></td>
<td>Flexible service chaining for future mobile services</td>
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<tr>
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<td>Optimal virtualization of mobile core control functions</td>
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<td></td>
<td>Dynamic open control protocol for mobile core</td>
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<tr>
<td>Flat &amp; Distributed Network</td>
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<td></td>
<td>Virtualized logical GW with distributed switch</td>
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<td>Dynamic mobility anchoring for seamless inter-GW HO</td>
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<td></td>
<td>Signaling mitigation for always-on-app and IoT</td>
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<td>Converged access control &amp; transport</td>
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<td></td>
<td>Unified ID based access control</td>
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<tr>
<td></td>
<td>Multi-RAT Carrier aggregation</td>
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<td></td>
<td>Seamless mobility between wire-line and wireless accesses</td>
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<tr>
<td></td>
<td>HetNet/Multiple RAT mobility control</td>
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<tr>
<td></td>
<td>Integrated resource management and control</td>
</tr>
<tr>
<td></td>
<td>Access condition awarded content delivery</td>
</tr>
</tbody>
</table>

Current version of enabling technologies is working draft.

<table>
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<tr>
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<th>Wired and wireless terminal switching</th>
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<td>T1</td>
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<tr>
<td>T5</td>
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</tbody>
</table>

<table>
<thead>
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<th>Multiple RAT interworking</th>
<th>Distributed Architecture</th>
<th>Inter GW mobility</th>
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<td>T1</td>
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<td>E1</td>
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<td>E3</td>
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</tbody>
</table>
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
5G Wireless Network Requirements: 4G vs. 5G (1/2)

**[R1] Cell Spectral Efficiency**

<table>
<thead>
<tr>
<th></th>
<th>4G DL*</th>
<th>4G UL*</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL</td>
<td>2.6 bps/Hz</td>
<td>1.8 bps/Hz</td>
</tr>
<tr>
<td>UL</td>
<td>0.075 bps/Hz/cell</td>
<td>0.05 bps/Hz/cell</td>
</tr>
</tbody>
</table>

**[R2] Peak Data Rate**

- **4G DL**: 1 Gbps
- **5G DL**: At least 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**

- **4G DL**: 0.075 bps/Hz/cell
- **4G UL**: 0.05 bps/Hz/cell
- **5G DL**: Uniform Experience Regardless of User-locations
- **5G UL**: Anywhere UL 0.5 Gbps

**[R4] Latency**

- **4G Control plane**: 100 ms
- **5G Control plane**: 50 ms
- **4G User plane**: 10 ms
- **5G User plane**: 1 ms

A half of 4G

A tenth of 4G

*) IMT-A Req. in 10-30 km/h test environment
5G Wireless Network Requirements: 4G vs. 5G (2/2)

[R5] Mobility
- Supportable max. speed
  - 4G
    - 350 km/h
  - 5G
    - Higher than 350 km/h

[R6] Handover Interruption Time
1) Intra-frequency, 2) inter-frequency within a spectrum band
3) inter-frequency between spectrum bands
- 4G
  - 27.5 ms
- 5G
  - 10 ms

[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/km² 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.
## 5G Wireless Network Requirements (1/3)

### Wireless Network Requirements

<table>
<thead>
<tr>
<th>Brief Description</th>
<th>5G Wireless Network Requirements</th>
<th>Related HL Req.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>R1</strong> Cell spectral efficiency</td>
<td>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)</td>
<td>√</td>
</tr>
<tr>
<td><strong>R2</strong> Peak data rate</td>
<td>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)</td>
<td>√</td>
</tr>
<tr>
<td><strong>R3</strong> Cell edge user data rate</td>
<td>5% point of the cumulative distribution function (CDF) of the user data rate (DL: 1 Gbps, UL: 0.5 Gbps)</td>
<td>√</td>
</tr>
</tbody>
</table>

**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 Wireless Network Requirements (2/3)

#### Wireless Network Requirements

<table>
<thead>
<tr>
<th>Brief Description</th>
<th>5G Wireless Network Requirements</th>
<th>Related HL Req.</th>
</tr>
</thead>
</table>
| **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)* | H1  
**H2**  
**H3**  
**H4** |
| **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
## 5G Wireless Network Requirements (3/3)

### Wireless Network Requirements

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<th>Related HL Req.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>R7</strong> Areal capacity</td>
<td>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.</td>
<td>✓ ✓ ✓ ✓</td>
</tr>
<tr>
<td><strong>R8</strong> Energy efficiency</td>
<td>5G radio access technology design should aim for higher energy efficiency against increased device/network energy consumption required on 5G wireless communications.</td>
<td>✓ ✓</td>
</tr>
</tbody>
</table>

### Related HL Req.

- **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 Wireless Network Enabling Technologies (1/3)

**mmWave Higher Bandwidth**

- **Frequency band**
  - 4G frequencies (up to 100 MHz)
  - mmWave based NRAT (1 GHz)
- **Peak data rate**
  - 1Gbps
  - 50 Gbps
- **User plane latency**
  - 10ms
  - 1ms

**Large Scale Antenna**

- **Base Station**
  - (> 50 Gbps per cell)
- **Array Antenna**
  - **Mobile**
    - (Anywhere 1 Gbps)

**Advanced Multiple Access**

- **OFDM**
- **FBMC**

**Modulation & Coding**

- **256 QAM**
- **4-QAM**
- **4-FSK**
- **16-FQAM**

FQAM: Frequency, Quadrature Amplitude Modulation
## 5G Wireless Network Enabling Technologies (3/3)

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

*Current version of enabling technologies is working draft.*

- **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
5G Forum Introduction

• 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
5G Forum Positioning

5G Research Initiative

- National Project A
- Project B
- Project X

5G Forum

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

External Bodies

(2020PG, 2020B AH, ..)

Standard Bodies

- TTA
- 3GPP
- ITU-R

R&D @Industries

White Papers

External Bodies

(2020PG, 2020B AH, ..)