How will 5G be different?
What is 5G?
5G Service Vision

Everything on Cloud
Desktop-like experience on the go

Immersive Experience
Lifelike media everywhere

Ubiquitous Connectivity
An intelligent web of connected things

Telepresence
Real-time remote control of machines
Technical requirements for 5G
5G Rainbow of Requirements

- Peak Data Rate [Gbps]
- Cell Edge Data Rate [Gbps]
- Latency [msec]
- Simultaneous Connection [M/km²]
- Cost Efficiency
- Mobility [km/h]
- Cell Spectral Efficiency [bps/Hz]
Superior User Experience

**Peak Data Rate > 50 Gbps**

- More than x50 over 4G
- 6 Gbps

**1 Gbps Anywhere**

- Cell Edge
- BS Location

**E2E Latency < 5 msec**

- 50 ms

**Air Latency < 1 msec**

- 10 ms

---

[1] Theoretical Peak Data Rate
[2] Data Rate of First Commercial Products

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Enabling Technologies - RAN (1/2)

Disruptive RAN Technologies for Significant Performance Enhancements

- Peak Data Rate
- Cell Edge
- Data Rate
- Cell Spectral Efficiency
- Mobility
- Cost Efficiency
- Simultaneous Connection
- Latency

Technology for Above 6 GHz

Peak Data Rate Increase

- Peak Rate 1 Gbps
- 4G frequencies

- Peak Rate 50 Gbps
- New higher frequencies

Post-OFDM

Spectral Efficiency & Cell Edge Enhancement

Advanced MIMO & BF

Cell Capacity Enhancement

Filter-Bank Multi-Carrier

BF : Beamforming

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Enhancing areal spectral efficiency

Increased density

Wireless backhaul

No cell boundary

Interference alignment

Enhanced D2D

Areal Spectral Efficiency Increase

Advanced Small Cell

Capacity & Cell Edge Enhancement

Interference Management

Cell Edge Data Rate Enhancement

Peak Data Rate

Cell Edge Data Rate

Cell Spectral Efficiency

Mobility

Cost Efficiency

Simultaneous Connection

Latency

D2D : Device-to-Device

Disruptive RAN Technologies for Significant Performance Enhancements
Enabling Technologies - Network

Innovative Network Technologies for Enhanced User Experience and Cost Reduction

Flat Network

- E2E Latency Reduction
- Multi-RAT Interworking
- Radio Capacity Enhancement

Multi-RAT Interworking

- Energy & Cost Efficiency Increase

Mobile SDN

- Peak Data Rate
- Cell Edge Data Rate
- Cell Spectral Efficiency
- Mobility
- Cost Efficiency
- Simultaneous Connection
- Latency

SDN: Software Defined Network

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5G

What we have achieved?
Channel Measurements

Three Types of Environments: In-Building, Campus, and Urban at 28GHz

**In-Building**
- Similar to Indoor Shopping-Mall
  - Five-story Building
  - Spacious Atrium Lobby
- Total 35 Rx Locations
  - Both for LoS and NLoS
  - Tx-Rx Distance: 10m ~ 55m

**Campus**
- Suburban Environments
  - KAIST Outdoor Campus
  - Tx Height 15 meters
- Total 25 Rx Locations
  - Mainly for NLoS
  - Tx-Rx Distance: ~ 270m

**Urban**
- Urban Environments
  - Daejeon City
  - Tx Height 15 meters
- 11 Rx Locations
  - Mainly for NLoS
  - Tx-Rx Distance: ~ 200m

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World’s First 5G mmWave Mobile Technology (May, 2013)
Adaptive array transceiver technology operating in mmWave frequency bands for outdoor cellular

**Base Station**
- Array Antenna
- RF + Array Antenna
- 8x6 (48) Antenna Elements

**Mobile Station**
- Array Antenna
- RF + Array Antenna
- 4x1 (4) Antenna Elements

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<thead>
<tr>
<th></th>
<th>BS</th>
<th>MS</th>
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<tbody>
<tr>
<td>Carrier Frequency</td>
<td>27.925 GHz</td>
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<tr>
<td>Bandwidth</td>
<td>800 MHz</td>
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<tr>
<td>Beamwidth (Half Power)</td>
<td>10°</td>
<td>20° (AZ)/140° (EL)</td>
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World’s First 5G Data Transmission at Highway Speeds (Oct, 2014)
Record-breaking 1.2Gbps data transmission at over 100km/h, and 7.5Gbps in stationary conditions using 28GHz spectrum.
Full-Dimension MIMO
Higher Order MU-MIMO with 3D-Beamforming achieving 3-Fold Capacity Increase

Innovative FD-MIMO Prototype

Macro-Cell eNB
Small-Cell eNB

Indoor Test
Outdoor Test

100 cm
50 cm
30 cm
Device Feasibility - Antenna Implementation for Devices

32 Elements Implemented on Mobile Device with “Zero Area” and 360° Coverage

“Zero Area” Design

- 16 Element Array
- Negligible Area for Antennas In Edges
- < 0.2 mm

Measurement Results

- Normalized Gain (dBi)
- Angle (deg)
- 0°, 10°, 20°, 30°, 45°, 60°, 75°

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mmWave Antenna/RFIC

60GHz Antenna and RFIC Based on IEEE 802.11ad
360° Coverage antenna and 16-chain beamforming CMOS RFIC (Tx/Rx EVM -25 dB)
Global R&D Activities

Current Global 5G Research Initiatives and Samsung’s Active Engagements

- 5G PPP Association (Full Member)
  - Project Leads

- 5GIC Founding Member

- 5G Forum Executive Board Member
- Member of Giga KOREA Project

- 5GIC Founding Member

- IMT-2020 Promotion Group
  - Member of Future Forum
  - Contributor to 863 Project

- NYU Wireless Center (Board Member)
  - Issued NOI on the use of above 24 GHz for Mobile

- ARIB (5G Mobile Promotion Forum)
Expected 5G Timelines

Standards in 3GPP, spectrum allocation in WRC-19, ITU approval in 2020

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<td>3GPP</td>
<td>Rel-13</td>
<td>Rel-14</td>
<td>Rel-15</td>
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<td>Initial 5G Commercialization</td>
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WRC : World Radiocommunications Conferences
ITU-R : International Telecommunication Union Radiocommunication Sector
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Thank You