DOCOMO’s 5G Trials Using Variety of Spectrum Bands

Yoshihisa Kishiyama
NTT DOCOMO, INC.
## Time Plan for 5G and 5G+

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<td><strong>Standardization</strong></td>
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<td><strong>NTT DOCOMO Trials</strong></td>
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<td><strong>NTT DOCOMO Commercial System development</strong></td>
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### Standardization
- **ITU**
- WRC15

- **Rel. 13**
  - **Study Item**
- **Rel. 14**
  - **Work Item**
  - **Phase 1**
- **Rel. 15**
  - **Work Item**
  - **Phase 2**
- **Rel. 16**
  - **Proposals**
  - **Specifications**
  - **Enhancement to 5G+**

### Research Project
- **EU Projects**
- **5G National Project in Japan**
- **5GMF PoC Trials**

### NTT DOCOMO Trials
- **Trials for 5G key technologies**
- **System Trials @ Tokyo**
- **5G commercial system development**
- **5G commercial launch**
- **Enhancement to 5G+**

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**Deployment/Migration Scenarios**

- **In 2020**, 5G will be deployed initially from areas, where higher performance and necessary features are required
  - Both New RAT (NR) and enhanced LTE (eLTE) introduced to realize tight interworking between lower and higher frequency bands

- **In beyond 2020**, deployment areas for 5G will be gradually expanded while introducing additional technologies and frequency bands (= 5G+)
  - LTE (or LTE-Advanced) cell can be continuously used as eLTE cell for a long-time
  - Stand-alone NR might be also deployed

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**Before 2020**

- LTE

**2020**

- 5G
  - New RAT
  - eLTE

**202x**

- 5G+
  - New RAT
  - eLTE
  - Special use cases?

**Urban Area**

**Suburban/rural Area**

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5G will support both eMBB and IoT use cases together with LTE evolution.

New RAT will mainly focus on eMBB.

New RAT will be enhanced for all use cases.
## 5G Frequency Band Candidates

<table>
<thead>
<tr>
<th>Frequency band</th>
<th>Bandwidth</th>
<th>For eMBB</th>
<th>Device availability</th>
<th>Spectrum availability</th>
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<tbody>
<tr>
<td></td>
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<td></td>
<td>Europe</td>
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<tr>
<td><strong>Below 6 GHz</strong></td>
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<tr>
<td>3.4-3.8GHz</td>
<td>400MHz</td>
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<td>🎈</td>
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<tr>
<td>3.8-4.2GHz</td>
<td>400MHz</td>
<td>🙁</td>
<td>🎈</td>
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</tr>
<tr>
<td>4.4-4.99GHz</td>
<td>500MHz</td>
<td>🙁</td>
<td>🎈</td>
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<tr>
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<tr>
<td><strong>Above 6 GHz</strong></td>
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</tr>
<tr>
<td>24.25-27.5GHz</td>
<td>3,250MHz</td>
<td>🙁</td>
<td>?</td>
<td>🎈</td>
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<tr>
<td>27.5-29.5GHz</td>
<td>2,000MHz</td>
<td>🙁</td>
<td>?</td>
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*Unlicensed frequency bands, which are mainly used for Wireless LAN now.*
NTT DOCOMO 5G Trials
5G Experimental Trials 【w/ 13 vendors】

5G experimental trials are being started since Q4 of 2014

**Existing bands**
- UHF bands
  - Ex. 800MHz, 2GHz

**Exploitation of higher frequency bands**
- Low SHF bands
  - 3-6GHz
- High SHF bands
  - 6-30GHz
- EHF bands
  - > 30GHz

System solution vendor
- Huawei
- Fujitsu
- NEC
- Ericsson
- Samsung
- Mitsubishi Electric
- Nokia

Key devices/Chip sets vendors
- Panasonic
- Intel
- MediaTek
- Qualcomm
- Keysight Technologies
- Rohde & Schwarz

Measuring instruments vendors
5G Capacity Test @ 4.5GHz with Huawei

Trial Environment in Yokohama, Japan

Yokohama Media Tower (base station)

NLOS
5G Capacity Test @ 4.5GHz with Huawei

Experimental Equipment

| Number of antennas | BS: 64 TRX  
UE: 8 TRX  |
|---------------------|------------------|
| Antenna spacing     | BS: 3.72cm x 5.21cm  
UE: 11cm  |
| Antenna tilting     | 16.4°  |
| Antenna height      | BS: 108m  
UE: 3.2m  |
| Maximum transmit power | BS: 46dBm  
UE: 23dBm  |

Base Station (BS)
- E-cart (including 2 UEs)

User Equipment (UE)
- RF/BBU
- 8 TRx

Experimental setup includes:
- Base band unit
- Indoor facility
- Test vehicle
- Optical fiber
5G Capacity Test @ 4.5GHz with Huawei

Successful large-scale 24-layer MU-MIMO Trial using TDD channel reciprocity

- DL SU-MIMO (1s average) = 1.5 Gbps (200MHz BW, 3 layers)
- DL total user throughput (1s average) = 11.29 Gbps (200MHz BW and 23 UEs*)
- DL peak spectral efficiency (1s average) = 79.82 bps/Hz/cell

* Number of connected UEs: 23 UEs / 200MHz (11 UEs using lower 100MHz, 11 UEs using upper 100MHz, & 1 UE using 200MHz)
* Number of spatial layers: 24 layers / 100MHz (12 user & 2 layers/user)
5G Throughput Test @ 15GHz with Ericsson

- Achieved over 15 Gbps per UE and over 25 Gbps per cell (2 UEs) with 800 MHz bandwidth, 256QAM, and 4-layer MIMO per UE
- Based on improvement of UE chip set performance, peak data rate of 5 Gbps (in 2020) and 10 Gbps (in 202x) are expected

Frequency: 15GHz band
Frequency BW: 720MHz
BS Antenna elements: 128 (64x2 polarized)
5G Throughput Test @ 15GHz with Ericsson

- Achieved high throughput performance up to 15 Gbps over trial area using distributed MIMO
5G Throughput Test @ 15GHz with Ericsson

- Achieved 12 Gbps at mobile speed of 10 km/h with distributed MIMO using 4 TPs mounted on top of building.
We have successfully achieved a data speed of more than 2.5 Gbps on a vehicle travelling at a speed over 150 km/h.

Major specifications:

- **Freq. band**: 28 GHz band (800 MHz bandwidth)
- **BS**:
  - 96 antenna elements
  - Support up to 2 stream MIMO transmission with 2 beams
- **UE**:
  - 8 antenna elements
  - 2 beams reception
5G Coverage Test @ 39GHz with Huawei

BS antenna height = 108m

UE antenna height = 3.5m

Either H or V Pol.

ARU: Analog Radio Unit

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<tbody>
<tr>
<td>System bandwidth</td>
<td>1.4 GHz (200MHz/CC)</td>
</tr>
<tr>
<td>Tx power per ARU</td>
<td>19 dBm</td>
</tr>
<tr>
<td>Antenna gain</td>
<td>31 dBi (Lens antenna)</td>
</tr>
</tbody>
</table>
5G Coverage Test @ 39GHz with Huawei

Successful long range 5G transmission (> 1km) even with mmW

- Far UE: 1.3 Gbps
- Near UE: 2.11 Gbps
- BS @ Yokohama Media Tower

1.5km
0.3km
5G Experimental Trials: List of Publications

- 5G Trials with Ericsson (15+13)
- 5G Trials with Huawei (13+8)
- 5G Trials with Nokia (9+7)
- 5G Trials with Fujitsu (2+12)
- 5G Trials with NEC (2+8)
- 5G Trials with Mitsubishi Electric (2+10)
- 5G Trials with Samsung Electronics (7+4)
- 5G Trials with Rohde & Schwarz (0+1)

The 5G Trial Sites will be offered mainly in two distinct of Tokyo, the Odaiba waterfront and Tokyo SKYTREE TOWN from May, 2017

- The Odaiba waterfront area
- Tokyo SKYTREE TOWN area

**DOCOMO Cloud services**

- Connect to a 5G cell at 5G area
- Support mobility between 5G cells
- Connect to a LTE cell at out of 5G area
- Support mobility between LTE and 5G
- Support mobility between 5G and commercial LTE NW

**Users can experience 5G higher performances, higher data rate and lower latency at 5G area**

**Features**

- DOCOMO Cloud services are available via LTE NW even at out of 5G area
- Utilize 28 GHz and 4.5 GHz frequency bands
5G Experiments @ 28GHz with Ericsson

- DOCOMO x Ericsson 5G trial at 28 GHz for DOCOMO 5G Trial Sites
- Achieved over 10 Gbps in Odaiba