Toward 5G Deployment in 2020 and Beyond

NTT DOCOMO, INC.
Takehiro Nakamura
Outline

☐ 5G Concept
☐ Timeline for 5G development
☐ 5G technologies and deployment
☐ 5G experimental trials
5G CONCEPT
5G Global Trend

Future IMT Vision in ITU-R WP5D
National/international projects on 5G

Special sessions on 5G in international conferences

Global initiative to define operator requirements for 5G

Vision2020/ Network2020

5G Workshop in Sep. 2015

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Toward 5G Deployment in 2020 and Beyond
Mobile Communications in 2020 and Beyond

Everything connected by wireless

- Multiple personal devices
- Transportation (Car/Bus/Train)
- Consumer electronics
- Watch/jewelry/clothes
- House
- Sensors
- Cloud computing

Extended and enriched wireless services

- Video streaming
- New types of terminal/HI
- Healthcare
- Education
- Safety and lifeline system
5G Target Performance

5G radio access will provide a total solution for a wider range of requirements in 2020 and beyond.

- **Higher system capacity**
  - 1000x capacity/km²

- **Higher data rate**
  - Typical data rate: 100x faster (Peak data rate: > 10Gbps)

- **Reduced latency**
  - RAN latency: < 1ms

- **Massive device connectivity**
  - 100x more connected devices (e.g., Crowded areas, M2M services)

- **Energy savings & cost reductions**
  - Energy savings for NW & terminals
  - Reduced NW costs, incl. backhaul
Directions of Evolution: “The Cube”

A set of radio access technologies is required to satisfy future requirements

**Spectrum efficiency (S.E.)**

- Current performance
- Traffic offloading
- Network density

**Required Performance**

- Non-orthogonal multiple access
- Study for new interference scenarios
- Tx-Rx cooperative access technologies

**New dimensions for S.E. enhancements**

- Efficient use of higher spectrum bands
- Exploitation of higher frequency bands

**Spectrum extension**

- Existing cellular bands
- Higher/wider frequency bands

**Cost-efficient NW densification**

- New cellular concept for cost/energy-efficient dense deployments

- C/U plane split (Phantom cell)
- Cellular network assists local area radio access
- Exploitation of higher frequency bands

- Efficient use of higher spectrum bands

**Traffic offloading**

- Cellular network assists local area radio access
- Exploitation of higher frequency bands

- Efficient use of higher spectrum bands

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- Study for new interference scenarios

- Tx-Rx cooperative access technologies

**Network density**

- Hotspot
- Dense urban
- Shopping mall

**3D/Massive MIMO, Advanced receiver**

**WiFi**

**Traffic offloading**

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TIME LINE FOR 5G DEVELOPMENT
5G Work Plan in ITU-R

ITU-R is targeting completion of 5G specification development in 2020.
5G Commercial Requirements

Japan is targeting **5G commercial launch in 2020**

## Time Plan for 5G and 5G+

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<tbody>
<tr>
<td><strong>WRC15</strong></td>
<td>Workshop</td>
<td><strong>WRC19</strong></td>
<td><strong>5G launch</strong></td>
<td><strong>5G+ launch</strong></td>
<td><strong>Commercial system development for 5G in 2020</strong></td>
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### Key Points:
- **Rel. 13**
  - Channel Model SI
  - Requirement SI
  - Technology SI
- **Rel. 14**
  - Proposals
- **Rel. 15**
  - Specifications
- **Rel. 16**
  - WIs
  - WIs
Emerging consensus that there should be two phases for the normative work:

- Phase 1 to be completed by H2 2018 to address a more urgent subset of the commercial needs (to be agreed)
- Phase 2 to be completed by Dec 2019 for the IMT 2020 submission and to address all identified usecases & requirements

The above implies the following, tentative, release timing:

- Rel-14
- Rel-15
- Rel-16

*NOTE: Dates above refer to “stage-3 functional freeze” of specs. ASN.1 freeze is typically one quarter after that.
5G TECHNOLOGIES AND DEPLOYMENT
DOCOMO 5G Technical Concept

Existing frequency bands (Saturated)

Higher frequency bands (Higher data rates using wider bands)

- Wide (e.g. > 3GHz)
- Super-wide (e.g. > 10GHz)

Connectivity and mobility maintained using lower frequency bands

Efficient high data rates transmission using higher/wider frequency bands

Further cellular enhancements
Non-orthogonal multiple access (NOMA), etc.

Exploitation of higher frequency bands
Massive MIMO, Dynamic TDD, etc.

 Frequency agnostic enhancements
Phantom cell concept
Radio frame design for reduced latency & M2M, etc.
5G Phased Realization

5G will evolve by incorporating new freq. bands and technologies
⇒ Future compatibility is key for system design to continue evolution

Introduction of 5G New RAT (Tight interworking with LTE)
- Existing frequency bands
- New bands licensed by 2019
- Unlicensed bands

Peak: Several Gbps

More higher & wider freq. bands
+ New bands licensed after 2020

More advanced technologies (e.g., Massive MIMO with higher number of antenna elements)

Peak: Above 10Gbps

Evolution

Future Compatibility

Freq.
In 2020, **5G** will be launched initially from areas, where higher performance is required, e.g., dense urban area.

In beyond 2020, deployment areas for 5G are gradually expanded while introducing additional technologies and frequency bands (= 5G+).
5G Forward/Backward Compatibility

- It is important to make sure 5G continuous evolutions and 5G forward/backward compatibility considering:
  - Unclear spectrum allocation plan especially for mmW
  - Difference in 5G launch timing between countries/regions
5G will support both use cases for enhanced Mobile Broadnand (eMBB) and Machine-Type Communications (MTC) together with LTE evolution.
Data Rate Improvements Toward 2020 and Beyond

Continuous improvement of user experienced throughput toward 5G/5G+

- **2000**: WCDMA
  - Ave. ~2Mbps, Peak 14Mbps
- **2005**: HSDPA
  - Ave. ~24Mbps, Peak 150Mbps
- **2010**: LTE
  - Ave. ~240Mbps, Peak ~600Mbps
- **2015**: LTE-Advanced
- **2020**: 5G
  - Ave. ~1Gbps, Peak ~5Gbps
  - 5G+
    - Ave. ~4Gbps
    - Peak >10Gbps

- Data rate increase will continue (approx. 100x per 10 years) (quasi-Moore law)

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Toward 5G Deployment in 2020 and Beyond

19
5G Key Technologies for 2020 Deployment

New RAT

New numerology with shorter TTI
Wider bandwidth and low latency

Well localized waveform

Lean radio frame
Less inter-cell interference, energy saving, good forward compatibility

Massive MIMO/ beamforming
Cell range extension
Improved spectral efficiency
5G Key Technologies for 2020 Deployment

Tight LTE integration

C/U-plane split (dual connectivity, CA)

Flexible duplex with unlicensed spectrum (e.g. LTE-assisted access)

NOMA on LTE

Further cellular enhancement with massive connectivity

Intentional non-orthogonality

IoT related LTE enhancements

Low cost / Long battery life devices
New numerology and lean radio frame

- **New numerology (radio parameter set)** to support higher frequency bands and lower latency
  - Desired *scalability from LTE numerology*
    - Low complexity implementation for LTE/new RAT dual-mode terminals
    - Easy support of dual connectivity between LTE and new RAT
  - Shorter TTI for low latency (< 1ms)

- **Lean radio frame** with Good forward compatibility
  - Removal of “always-on” signals such as cell-specific reference signal
Waveform

- Flexible waveform design to support both mobile broadband and IoT
- New waveform designs allow for a limited amount of in-band distortion in order to significantly reduce out-of-band leakage
- Trade-off between time and frequency localization of filter response

FBMC (Filter Bank Multi-Carrier) and Filtered-OFDM are studied as alternative waveforms of CP-OFDM.
Massive MIMO

Compensation for path-loss

- Range extension of small cells

Large number of simultaneously connected users

- Smooth connectivity even in crowded areas

More than 100 antenna elements per small cell

2GHz

\[ L \]

\[ \Phi_{min} \]

\[ \lambda/2 \]

20GHz

\[ L \]

\[ \Phi_{min}/10 \]

10G

10x beamforming gain
**C/U-Plane Split (Phantom Cell)**

**U-plane:** Small cell provides higher data rate and more flexible & cost-energy efficient operations.

**C-plane:** Macro cell maintains good connectivity and mobility.

**Cell ON/OFF:** Small cell are put on only when there is traffic.
NOMA

Effort for Orthogonality

OFDMA (LTE)
(or FDMA, TDMA, CDMA)

Effort for Interference Mitigation

Intentional Non-orthogonality

Processing power in Devices

Robust gain against user mobility

e.g., NOMA backhaul for moving cells

Exploitation of power-domain, path loss difference among users, and UE processing power

Under study in LTE Release 13
Radio Technology Components for Phase 1 and Phase 2

<table>
<thead>
<tr>
<th>Technology components</th>
<th>Phase I of new RAT</th>
<th>Phase II of new RAT</th>
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<tbody>
<tr>
<td><strong>Target spectrum</strong></td>
<td>Up to 30 (or 40) GHz</td>
<td>Up to 100 GHz</td>
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<tr>
<td><strong>Target deployments</strong></td>
<td>eMBB (Hotspot, UMi, UMa) Dense urban scenario</td>
<td>All scenarios</td>
</tr>
<tr>
<td><strong>Waveform</strong></td>
<td>OFDM-based</td>
<td>Single carrier (or alternative waveform) ?</td>
</tr>
<tr>
<td><strong>Numerology</strong></td>
<td>Flexible numerology Minimized number of options for target spectrum and target deployments</td>
<td>Optimizations to higher frequency bands and all use cases</td>
</tr>
<tr>
<td><strong>Radio frame design</strong></td>
<td>Low latency (short TTI) Minimized overhead channels Flexible radio frame structure</td>
<td>Extension to support all use cases</td>
</tr>
<tr>
<td><strong>Massive MIMO</strong></td>
<td>Supported Coverage extension and MU–MIMO gain</td>
<td>Possible extensions for higher order array, UE beamforming, etc.</td>
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<tr>
<td><strong>Initial access</strong></td>
<td>Prioritize LTE assisted access</td>
<td>Standalone to be supported</td>
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5G EXPERIMENTAL TRIALS
5G Experimental Trials

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

Key devices/Chip sets vendors
- Alcatel-Lucent
- HUAWEI
- FUJITSU
- NEC
- ERICSSON
- SAMSUNG
- MITSUBISHI ELECTRIC
- NOKIA

System solution vendors
- Intel
- QUALCOMM
- Panasonic
- KEYSIGHT TECHNOLOGIES

Measuring instruments vendors
- Rohde & Schwarz

Toward 5G Deployment in 2020 and Beyond
Experimental trials on DOCOMO proposed NOMA and channel sounder to explore higher frequency bands are also conducted.
Conclusion

- Diverse requirements to be considered for 5G (including MBB and IoT)
- 5G will be about an innovative combination of several technical components
- Now 5G is about to enter standardization phase (3GPP and ITU-R)
- Phased approach is important to introduce 5G technologies considering market needs and realistic spectrum allocation time plan