NTT DOCOMO’s Views on 5G
Network/Communication Society in 2020 and Beyond

**Everything Connected by Wireless**

- **Monitor/collect information & control devices**
  - *Multiple personal devices*
  - *Transportation (Car/Bus/Train)*
  - *Watch/jewelry/cloth*
  - *House*
  - *Sensors*
  - *Cloud computing*

**Extension/enrichment of wireless services**

- **Deliver rich contents in real-time & ensure safety**
  - *Video streaming*
  - *New types of terminal/Hi*
  - *Healthcare*
  - *Education*
  - *Safety and lifeline system*

### Examples

- **Monitor/collect information & control devices**
  - **Multiple personal devices**
  - **Transportation (Car/Bus/Train)**
  - **Watch/jewelry/cloth**
  - **House**
  - **Sensors**
  - **Cloud computing**

- **Extension/enrichment of wireless services**
  - **Video streaming**
  - **New types of terminal/Hi**
  - **Healthcare**
  - **Education**
  - **Safety and lifeline system**

### Applications

- **Consumer electronics**
  - Remote operation using personal terminal
- **Watch/jewelry/cloth**
  - Human interface and healthcare sensors
- **House**
  - Remote control of facilities
  - House security
- **Sensors**
  - Smart power grid
  - Agriculture and farming
  - Factory automation
  - Weather/Environment
- **Cloud computing**
  - All kinds of services supported by the mobile personal cloud
Future radio access (FRA) to provide a total solution to satisfy the wider range of requirements of the 5G era (2020s)

- 1000x capacity/km²

**Higher data rate**
- 10-100x data rates (Even for high mobility)

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

**Massive device connectivity**
- 100x connected devices (Even in crowded areas)

**Energy saving & cost reduction**
- Energy saving for NW & terminals
- Reduced NW cost incl. backhaul
Directions of Evolution: “The Cube”

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

Required performance

Spectrum efficiency

Traffic offloading

Network densification

Spectrum extension

Current capacity

New cellular concept for cost/energy-efficient dense deployments

Efficient use of higher spectrum bands

Existing cellular bands

Higher/wider frequency bands

Very wide

Super wide

Frequency

Current capacity

Non-orthogonal multiple access

3D/Massive MIMO, Advanced receiver

Study for new interference scenarios

Tx-Rx cooperative access technologies

Controller

TRx

Controller

TRx

TRx

TRx

TRx

TRx

TRx

Cellular network assists local area radio access

Hotspot

Dense urban

Shopping mall

WiFi

Traffic offloading
5G Technical Concept

Combined usage of lower and higher frequency bands

Higher frequency bands become useful and beneficial!

- Higher frequency bands (wider bandwidth for high data rate)
- No coverage issue any more
- Can provide very high throughput using wider bandwidth
- Big offloading gain from existing cellular bands

Existing cellular bands (high power density for coverage)

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

5G technical concept

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

Exploitation of higher frequency bands
- Phantom cell concept (C/U plane split)
- Massive MIMO, Numerology/frame design, etc.
Phantom Cell Concept

- **Proposed architecture to utilize higher frequency bands**

  “Phantom cell” – Split of C-plane & U-plane between macro and small cells in different frequency bands [1, 2]

- **Existing cellular bands**

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

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

- **Higher frequency bands**

  **New RAT** will be required to exploit higher frequency bands for 5G (e.g. > 10GHz)

New RAT – Some Design Criteria (1)

- Significant gains to justify the “5G”
  - Higher data rate – Greater than 10Gbps
    - Wider bandwidth (Several 100MHz ~ GHz order)
  - Very low latency
    - Shorter TTI (~ 0.1ms order)

- Adaptation to higher frequency bands
  - Consider scalability of LTE numerology
    - Low complexity implementation for LTE/new RAT dual-mode terminals
    - Easy support of dual connectivity & carrier aggregation between LTE and new RAT
  - Robustness against phase noise
    - e.g. by applying wider subcarrier spacing
New RAT – Some Design Criteria (2)

• Signal waveform candidates:
  – OFDM as baseline
    • High affinity with MIMO transmission technologies in multi-path fading environments
  – Other alternatives:
    • Single carrier waveform including DFT-Spread OFDM
      » OFDM vs. Single carrier for data rate vs. coverage tradeoff
    • Advanced multi-carrier waveforms such as FBMC, FTN, etc.

→ Waveform & bandwidth may depend on applied frequency bands

**Frequency bands**

- e.g. < 10GHz
- e.g. 10-30GHz
- e.g. > 30GHz

**Bandwidth**

- e.g. < 100MHz
- e.g. 100-1000MHz
- e.g. >1000MHz

**Waveform**

- OFDM (or advanced multi-carrier waveform)
- Single carrier
New RAT – Some Design Criteria (3)

- Flexibility to support **variable scenarios** (D2D, wireless backhaul, multi-hop, etc.)
  ➔ **RAT design considering DL/UL symmetry**

- **Flexible Duplex (FleD)** – Associated with carrier aggregation / dual connectivity functionality
  – Joint operation of FDD & TDD (or one-way link, i.e., DL/UL only)
  – Opportunistic carrier selection including unlicensed bands

**Carrier aggregation / Dual connectivity**

**Existing cellular bands** ↔ **Higher frequency bands**

- **Opportunistic carrier selection**
  - UL only carrier
  - DL only carrier
  - TDD carrier (Unlicensed)

Commonly connected to anchor carrier/RAT
Massive MIMO in Higher Frequency

- **Massive MIMO** – Beamforming using massive antenna elements in higher frequency bands
  - *Essential technology to extend effective cell range*

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<thead>
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<th>Antenna element spacing (d)</th>
<th>3.5 GHz ((\lambda = 8.6) cm)</th>
<th>10 GHz ((\lambda = 3) cm)</th>
<th>20 GHz ((\lambda = 1.5) cm)</th>
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→ Compensation of increased path loss & Improved spectrum efficiency

Cell range extension by beamforming gain

Improved spectrum efficiency with (multi-user) spatial multiplexing
Massive MIMO: Coverage Extension

Comparison of effective cell ranges

Carrier frequency ($f$):
- $f = 3.5$GHz
- $f = 10$GHz
- $f = 20$GHz

Evaluation assumptions:
- Tx power: 33 dBm
- Tx bandwidth: 100 MHz
- Target Rx SNR: -4 dB
- Antenna gain per antenna element: 5 dBi
- Path loss model:
  - ITU-R Urban Micro
  - NLOS
  - BS antenna height: 10m
- Shadowing margin: 4 dB
- Penetration loss: 0 dB (outdoor user)
- Rx noise figure: 9 dB
Massive MIMO in Higher Frequency

- **Support of wireless backhaul and group mobility**
  - Larger number of Rx antennas can be applied in relay node compared to UE
  - Wireless backhaul links with super high data rates

UEs inside the bus served by WiFi or Small cell
5G Simulator Demo: Key Technologies for Small Cell Enhancements
## DOCOMO’s Views on Standardization

### Time Plan for 5G

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- **WRC15**
  - Spectrum < 6GHz

- **WRC18/19**
  - Spectrum > 6GHz

**Questions**:
- Can/should we start specification work for spectrum above 6GHz before WRC18/19?
DOCOMO 5G Experimental Trials

Existing Frequency Bands
- UHF
  - Ex. 800MHz, 2GHz

Wideband Transmission Over Higher Frequency Bands
- Low SHF
  - 3–6GHz
- High SHF
  - 6–30GHz
- EHF
  - > 30GHz

- **Ericsson**
  - Experiments on new radio interface concept and Massive MIMO (15GHz Band)

- **NSN**
  - Experiments on super-wideband single carrier transmission and beamforming (70GHz Band)

- **Alcatel-Lucent**
  - Experiments on candidate waveforms to support mobile broadband & M2M

- **Fujitsu**
  - Experiments on coordinated scheduling for super dense base stations using RRE

- **NEC**
  - Experiments on time-domain beamforming with very large number of antennas (5GHz Band)

- **Samsung**
  - Experiments on super-wideband hybrid beamforming and beam tracking (28GHz Band)