5G Evolution and 6G powered by IOWN

NTT DOCOMO, INC.
5G Evolution & 6G

Cyber-space

AI

Extreme high data rate / capacity
Extreme coverage
Extreme low energy & cost

5G & 6G

Physical-space

Devices/IoT

Extreme low latency
Extreme high reliability
Extreme massive connectivity & Sensing
Technologies for 5G Evolution and 6G
Technological development and research areas

- Deployment of new radio network topology
- Coverage extension, including non-terrestrial networks
- Ultra-reliable and low latency communications (URLLC) and industrial networks
- Integration of various wireless technologies
- Broader frequency domain and advanced frequency utilization
- Advanced massive MIMO and wireless transmission
- Multi-functionalization of wireless communication systems and utilization of AI technology
- Advanced network architecture
Technologies for coverage extension

- NTN/HAPS
- Underwater acoustic communications
## Coverage Extension with NTN

<table>
<thead>
<tr>
<th></th>
<th>GEO</th>
<th>LEO</th>
<th>HAPS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Altitude</strong></td>
<td>36,000 km (191.9 dB)</td>
<td>1,000 km (160.7 dB)</td>
<td>20 km (126.8 dB)</td>
</tr>
<tr>
<td>(free space path loss)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Latency (one-way)</strong></td>
<td>120 msec</td>
<td>3.3 msec</td>
<td>0.066 msec</td>
</tr>
<tr>
<td><strong>Number to cover Japan</strong></td>
<td>1</td>
<td>Many (need to support entire of earth)</td>
<td>Around 50</td>
</tr>
</tbody>
</table>

### (Example) Current DOCOMO’s business case

- **N-STAR d**
- Spectrum bands: 2.5/2.6GHz (FDD)
- Limited data rate
  - Downlink: 384 kbps
  - Uplink: 144 kbps

HAPS can support more business use cases **with following benefits**
- Higher data rate
- Lower latency
- Smaller terminals
- Flexibility of NW deployments

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Variety of Use Cases with HAPS

- Effective for **many industrial use cases** in 5G evolution & 6G as well as **public safety**

**Challenges of wireless technology**
- Radio interface for long-distance communication
- Efficient frequency utilization scheme between HAPS and ground network
- Network design for efficient interworking between HAPS and ground network
HAPS simulator

- HAPS simulator for airborne coverage
- Newly added functions for uplink, UE direct link, and interference reduction

HAPS simulator for evaluating ultra-coverage performance

- After setting radio-communication parameters, the HAPS simulator calculates system capacity according to the communication environment on the ground.
- Communication parameters can be calculated for location-specific HAPS uses.

Simulator specifications (simplified version)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Feeder link</th>
<th>Service link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>38 GHz</td>
<td></td>
</tr>
<tr>
<td>Bandwidth</td>
<td>≥100MHz</td>
<td></td>
</tr>
<tr>
<td>Transmission power</td>
<td>34 dBm</td>
<td></td>
</tr>
<tr>
<td>Tx peak gain</td>
<td>50 dBi</td>
<td>30 dBi</td>
</tr>
<tr>
<td>Rx peak gain</td>
<td>30 dBi</td>
<td></td>
</tr>
<tr>
<td>Pass loss model</td>
<td>Free space pass loss</td>
<td></td>
</tr>
<tr>
<td>Rain attenuation</td>
<td>20 dB (if rainy)</td>
<td></td>
</tr>
<tr>
<td>Atmospheric absorption loss</td>
<td>1 dB</td>
<td></td>
</tr>
</tbody>
</table>

Application of interference avoidance technology
- HAPS does not beam near ground gNB
HAPS simulator

gNB/HAPS (fc=38GHz)
Coverage will be extended to undersea areas unexplored for high-speed wireless communications.

Spatio-temporal equalization technology that compensates for severe waveform distortion undersea has achieved underwater acoustic communications of more than 1 Mbit/s, enabling video transmissions from underwater drones.

Current initiatives are focusing on bidirectional communication, improved stability and smaller, more power-efficient equipment, for achieving wireless remote control of underwater drones.

### Positioning of our technology

- **Visible-light communication**
- **Resource development**
- **Underwater construction**
- **Fisheries**

### Acoustic MIMO transmission

- **Real-time high-definition video transmission**
- **Compensate waveform distortion by spatio-temporal equalization**
- **Real-time monitoring**

**Target**

- **Communication distance (m)**
  - Throughput (bit/s)
    - 100M
    - 10M
    - 1M
    - 100k
    - 10k

**Conventional acoustic communication**

**Prototype ROV**

**Video of experiment by NTT Network Innovation Laboratories**
Terahertz frequency

■ 6G simulator
6G Spectrum Extension

- 5G NR supports frequency bands up to 52.6 GHz, and extension to approximately 90 GHz for future release.
- 6G exploits higher frequency bands than 5G such as “millimeter wave” and “terahertz wave” (~300 GHz), and remarkably wider bandwidth can achieve extreme high data rates exceeding 100 Gbps.

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**5G NR supporting spectrum up to ~50GHz (52.6GHz)**

**5G Sub-6**

- Initial focus

**5G mmW**

- Initial focus

**5G evolution (up to ~90GHz)**

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**Frequency**

<table>
<thead>
<tr>
<th>1GHz</th>
<th>3GHz</th>
<th>10GHz</th>
<th>30GHz</th>
<th>100GHz</th>
<th>300GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR1</td>
<td>(FR3)</td>
<td>FR2</td>
<td>(FR4)</td>
<td>(FR5)</td>
<td></td>
</tr>
</tbody>
</table>

---

**6G**

- Initial focus

**6G Low/Mid-band**

- Coexistence with existing technologies in lower-frequency spectrum

**6G High-band**

- Possibility to exploit new spectrum, e.g., 10-20GHz
- Exploiting further higher spectrum including above 100GHz (“THz spectrum”)

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Technical difference to be identified
6G simulator

- Real-time system simulator for evaluating ultra-high-speed 100 Gbps 6G communication
- Will support use of terahertz frequency such as 100 GHz, in addition to sub-6 and millimeter waves
- User throughput above 100 Gbps achieved in factory-simulation test using 100 GHz

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center frequency</td>
<td>100GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>8000MHz</td>
</tr>
<tr>
<td>Base station elements</td>
<td>1296</td>
</tr>
<tr>
<td>Base station power</td>
<td>33 dBm</td>
</tr>
<tr>
<td>Mobile station power</td>
<td>23 dBm</td>
</tr>
<tr>
<td>TDD ratio</td>
<td>Changeable</td>
</tr>
</tbody>
</table>

User throughput ratios (DL:UL)

- DL:UL = 10:0
- DL:UL = 5:5
6G simulator
Innovative applications in 6G era
Applications in 6G era

**Main Contribution to Society**

Well-being
- Empathy
- Optimistic

Smart
- Functional improvements
- Increased efficiencies

**Time**

**First wave**
- Adoption of mobile phones
  - 1980: Car phone
  - 1985: Shoulder phone
  - 1990: MOVA 2G Movable phone

**Second wave**
- Mobile multimedia
  - 2000: Information at the tip of fingers
  - 2010: Variety of apps & videos

**Third wave**
- New business value
  - 2020: Solve social issues, Human-centered value creation
  - 2030: Smart

**Advancement of Purpose**
- Emotional and psychological world
- Materialistic and physical world

**BrainTech Human Augment.**
- XR/remote medicine/autonomous driving
- Payment / blockchain / IoT
- Video / apps / game communication
- Website / apps / game communication
- Voice Communication
Human Augmentation through 6G NW!

Ubiquitous body

Go beyond the constraints of space and time

Superhuman

Network

Telepathy and telekinesis through the network

Experience feeling

6G faster than nerve impulses!? Share 5-Senses through the network!
### Human augmentation

#### Sensing
- **Electroencephalogram**
  - EEG sensor
    - Electrical activity in brain
- **Myoelectricity**
  - Myoelectricity sensor
    - Hand and arm movement
- **Physical movement replication**
  - Piezoelectric sensor
    - Gripping force
- **Embodied knowledge**
  - Anthropometric sensors
    - Body movements

#### Platform
- **Human augmentation platform**
  - Register sensor data
  - Reproduce sensor data
  - Interconnectivity
- **Database**
  - Physical data
  - Mapping information
  - Sensor data
  - Operational data

#### Application
- **Robots**
  - Control robot
  - Robots
- **Myoelectricity**
  - Myoelectricity actuator
    - Control prosthesis
  - Physical movement replication
    - Play instrument
- **Embodied knowledge**
  - Replicate physical movements while watching video

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Human augmentation demonstration (1)

Actuation

Sensing
Human augmentation demonstration (2)
Human augmentation demonstration (3)
5G Evolution & 6G powered by IOWN
(Innovative Optical and Wireless Network)
5G Evolution and 6G mobile networks technologies can be combined with IOWN's ultra-high capacity, ultra-low latency and ultra-low power technologies based on breakthrough photonics, to further enhance the next generation ICT infrastructure, and respond to the pressing needs of society.
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See website for details:

DOCOMO 6G White Paper

The Japanese version was released on Nov. 8, 2021
Concept video:
5G Evolution & 6G powered by IOWN

Introducing:
Renewal by combining 5G Evolution & 6G and NTT’s IOWN vision

Please download this concept video:
https://www.nttdocomo.co.jp/english/corporate/technology/whitepaper_6g
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