5G and Wireless Measurements

DOCOMO Innovations, Inc.
## History

<table>
<thead>
<tr>
<th>Year</th>
<th>1G</th>
<th>2G</th>
<th>3G</th>
<th>4G</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>Analogue Cellular</td>
<td>TDMA Concept</td>
<td>Paper by Dr. Kinoshita</td>
<td>100M-1Gbps Experiments</td>
</tr>
<tr>
<td>1985</td>
<td>1980s</td>
<td>WCDMA</td>
<td>OFDMA/SCFDMA</td>
<td>100M-1Gbps Experiments</td>
</tr>
<tr>
<td>1990</td>
<td>2G</td>
<td>WCDMA</td>
<td>OFDMA/SCFDMA</td>
<td>100M-1Gbps Experiments</td>
</tr>
<tr>
<td>1995</td>
<td>1990s</td>
<td>2Mbps Experiments</td>
<td>Super3G Concept</td>
<td>1Gbps Experiments</td>
</tr>
<tr>
<td>2000</td>
<td>3G</td>
<td>2G</td>
<td>WCDMA</td>
<td>LTE/LTE-Advanced</td>
</tr>
<tr>
<td>2005</td>
<td>2000s</td>
<td>3G</td>
<td>3G</td>
<td>LTE/LTE-Advanced</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td>4G</td>
<td></td>
</tr>
</tbody>
</table>
It’s time to think about **5G**

<table>
<thead>
<tr>
<th>Year</th>
<th>1G</th>
<th>2G</th>
<th>3G</th>
<th>4G</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>Analogue Cellular</td>
<td>TDMA Concept</td>
<td>WCDMA Experiments</td>
<td>OFDMA/SCFDMA 100M-1Gbps Experiments</td>
</tr>
<tr>
<td>1985</td>
<td></td>
<td></td>
<td>2Mbps Experiments</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td></td>
<td></td>
<td></td>
<td>CDMA concept</td>
</tr>
<tr>
<td>1990s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**:5G?**

Paper by Dr. Kinoshita
ICC’81 and IEEE Trans. VT, 1982
Future Radio Access towards 5G

Our vision of 1000x capacity and 10-100x data rates will bring dramatic UX improvement for users in 2020.

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

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

- **5G in 2020**
  - Reduced latency
    - Reduced 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
Keys for 5G

Our Conventional Business

No Room!!

A lot of Space

BUT, No one knows how to use higher frequency bands as Cellular

How should we use Higher Frequency Bands???
FRA (Future Radio Access): Combined usage of lower and higher frequency bands

**Existing cellular bands**
- (high power density for coverage)

**Higher frequency bands**
- (wider bandwidth for high data rate)
  - Very wide (e.g. > 3GHz)
  - Super wide (e.g. > 10GHz)

**DOCOMO’s 5G 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.
In Summary

Massive MIMO

Spectrum Efficiency

Current Capacity

Network Density

Spectrum Extension

Higher frequency bands

700MHz~

Small Cells (Phantom Cells)

© 2014 DOCOMO Innovations, Inc. All rights reserved.
From a Deployment point of view

- No one knows where/how future small cells/massive MIMO cells should be deployed in 5G NW.
- Operation cost would increase as the number of cells increases.
That is,

**Deployments** would be more and more important in 5G NW.

↓

Conventional wireless measurements would not be good enough for 5G deployments.

↓

Future Wireless Measurements should be targeted to 5G NW and 5G deployments.
BACKUP SLIDES
Phantom Cell Concept: DOCOMO proposed this architecture to utilize higher frequency bands through splitting macro and small cells for C-plane and U-plane in different frequency bands \([1, 2]\)


**C-plane:**
- Macro cell maintains good connectivity and mobility using lower frequency bands

**U-plane:**
- Small cell provides higher throughput and more flexible/cost-energy efficient operations using higher/wider frequency bands
Massive MIMO (Multiple-Input Multiple-Output)

**Massive MIMO:** Beamforming using massive antenna elements in higher frequency band for gain and capacity improvement

- 4G LTE (today): 2 antennas (at device) x 2 antennas (at base station)
- **5G:** hundreds of antennas at base station!

### Antenna element spacing

<table>
<thead>
<tr>
<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>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 ( \lambda )</td>
<td>16</td>
<td>169</td>
<td>676</td>
</tr>
<tr>
<td>0.7 ( \lambda )</td>
<td>9</td>
<td>81</td>
<td>361</td>
</tr>
</tbody>
</table>

Migration of Massive MIMO

Cell range extension by beamforming gain

Improved spectrum efficiency with (multi-user) spatial multiplexing