Future Radio Access for 5G

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Outline
- High-level Vision
  - Phantom cell concept
- Key Technologies
  - Small cell enhancements
  - Massive MIMO
  - Non-orthogonal multiple access (NOMA)
- 5G Simulator Demo

High-level Vision

Network/Communication Society in 2020 and Beyond

Everything Connected by Wireless
Monitor/collect information & control devices
- Multiple personal devices
  - Interaction across multiple devices
- Transportation (Car/Bus/Train)
  - Entertainment, Navigation
    - Traffic information
- Consumer electronics
  - Remote operation using personal terminal
- Watch/jewelry/cloth
  - Human interface and healthcare sensors
- Cloud computing
  - All kinds of services supported by the mobile personal cloud

Extension/enrichment of wireless services
Deliver rich contents in real-time & ensure safety
- Video streaming
  - 4K/8K video resolutions
  - Video on newspapers
- Background video
- New types of terminal/Hi
  - Glasses/Touch internet
- Healthcare
  - Remote health check & counseling
- Education
  - Distance (remote) learning
    - Any lesson anywhere/anytime
- Safety and lifeline system
  - Prevention of accidents
  - Robustness to disasters
FRA concept and requirements

Various requirements for network/communication society in 2020 and beyond

- **Support for traffic explosion**
  - 1000x capacity/km²

- **QoE for various applications**
  - 10-100x data rates
  - Reduced latency to < 1ms
  - Support of high mobility
  - Terminal battery saving

- **Massive device connectivity**
  - 100x more connected devices
  - Lower overhead incl. reduced control signaling
  - Enhanced connectivity, e.g., deep inhouse

**Future Radio Access**

Intelligent network with low cost & high robustness

- **Very small/light BS with energy saving**
  - Efficient support for diverse environments incl. emergency cases

FRA will provide a total solution to satisfy the requirements

Directions of evolution: “The Cube”

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

<table>
<thead>
<tr>
<th>Spectrum extension</th>
<th>Current capacity</th>
<th>Traffic offloading</th>
<th>Non-orthogonal multiple access</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study for new interference scenarios</td>
<td>Existing cellular bands</td>
<td>Higher/wider frequency bands</td>
<td>3G Massive MIMO, Advanced router</td>
</tr>
<tr>
<td>Tx-Rx cooperative access technologies</td>
<td>Spectrum efficiency</td>
<td>Required performance</td>
<td>4G LTE, LTE-Advanced</td>
</tr>
<tr>
<td>5G New Radio</td>
<td>6G Advanced</td>
<td><strong>docomo wi-Fi</strong></td>
<td>Traffic offloading</td>
</tr>
</tbody>
</table>

Evolution paths for FRA

- **Further LTE enhancements**
  - Macro-assisted small cell enhancement (Phantom cell)
  - Further general LTE enhancements

- **Potential new RAT**
  - Should prioritize the achievement of more big gains over backward compatibility
  - Consider new spectrum allocations of WRC-15 and beyond
  - Some technical components may be applied to further LTE enhancements

**Phantom Cell**

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]

**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
Combined usage of lower and higher frequency bands → Higher frequency bands become useful and beneficial!

**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)

- No coverage issue any more
- Can provide very high throughput using wider bandwidth
- Big offloading gain from existing cellular bands

**Frequency**

**Further enhancements**

**Exploitation of higher frequency bands**

- Phantom cell concept (C/U plane split)
- Massive MIMO, Numerology/Frame design, etc.

**Non-orthogonal multiple access (NOMA)**, etc.

Proposals for Small Cell Enhancements

**Proposals for LTE Rel-12 SCE**

- **“Dual connectivity”**
  - C/U-plane architecture and related physical layer aspects
  - FDD/TDD joint operation with carrier aggregation and/or dual connectivity

- **Efficient small cell operation**
  - Small cell ON/OFF for energy saving and interference reduction
  - Efficient small cell Discovery
  - Interference coordination and load balancing

- **Proposed macro-assisted discovery**
  - UE can detect OFF (DTX)-state small cells

**Massive MIMO in higher frequency**

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

**Example 2D antenna configuration**

<table>
<thead>
<tr>
<th>Antenna element spacing (d)</th>
<th>3.5 GHz (kHz = 8.6 cm)</th>
<th>10 GHz (kHz = 3 cm)</th>
<th>20 GHz (kHz = 1.5 cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 λ</td>
<td>16</td>
<td>169</td>
<td>676</td>
</tr>
<tr>
<td>0.7 λ</td>
<td>9</td>
<td>81</td>
<td>361</td>
</tr>
</tbody>
</table>

→ Compensation of increased path loss & Improved spectrum efficiency

Cell range extension by beamforming gain

Improved spectrum efficiency with (multi-user) spatial multiplexing
Beamforming Gain vs. Path loss

- Problem: In higher frequency bands, path-loss scales with $20\log(f)$ \[^1\]

\[^1\] Oda et al., IEEE VTC2001-Spring

One digit increase of carrier frequency (e.g., 2GHz $\rightarrow$ 20GHz) is approximately equivalent to 20dB power loss.

Macro-assisted Massive MIMO

- Key issue – Coverage for common channels (system information, paging, synchronization signal, etc.)

“an excellent feature”

The combination of Massive MIMO and Macro-assisted (Phantom) cell will provide adequate cell coverage even with higher frequency bands.

Macro-assisted discovery for Massive MIMO

- Discovery function is a key to achieve advanced multi-site operations for Massive MIMO
  - Multi-site cooperative beamforming
  - Beamforming for load balancing among cells

$\Rightarrow$ Macro-assisted discovery is an effective approach.

Non-Orthogonal Multiple Access (NOMA)

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

Processing power in Devices

Intentional Non-orthogonality

Effort for Orthogonality

Effort for Interference Mitigation

FDMA, TDMA, CDMA, OFDMA

Equalizer, C canceller

NOMA

Cell Throughput (Mbps) vs. UE Speed (km/h)

30% gains
Application to wireless backhaul

- Flexible support for access & backhaul links
  - Support for moving cell as well
- Massive MIMO and NOMA will be effective also for increasing capacity of wireless backhaul

5G Simulator Demo

Real-time Simulator of 5G World

Simulator of high capacity and high data rate 5G world

- Real-time evaluation of system performance and demonstration of download & play of high resolution movie (4K)
- Confirmation of DOCOMO candidate 5G technologies in real propagation environment (Shinjuku area)
Summary

- We presented our views on vision, requirements and potential key technologies for Future Radio Access (FRA):
  - Macro-assisted small cell, i.e., Phantom cell, and Massive MIMO are promising in the long-term future for higher/wider frequency bands
  - Non-orthogonal multiple access (NOMA) is a promising technology for future cellular enhancements
  - Other technologies, e.g. new numerology/frame structure, new waveform, contention based UL and flexible NW need to be further studied

FRA technical concept

- Combined usage of lower and higher frequency bands
- Future cellular enhancements
- Exploitation of higher frequency bands
- Non-orthogonal multiple access (NOMA), etc.
- Phantom cell concept (C/U plane split)
- Massive MIMO, numerology/frame design, etc.