Millimetre-Wave Small-Cell Access and Backhauling for 5G

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Agenda

- Introduction
  - Requirements for 5G Heterogeneous Networks

- mmW Mobile Access
  - mmW Spectrum, 60 GHz Technologies, Challenges

- mmW Mobile Backhaul
  - E-Band Channel

- Conclusions
Key Objectives for 5G

Higher capacity
- Larger volumes of data per user, larger number of users/devices
  - multi-Gbps mobile access, >10 Gbps backhaul,
  - more spectrum, dense access points distribution (small cells).

Higher flexibility
- easy deployment of capacity where/when it is needed.
  - Wireless backhaul, self-organizing network.

Green radios:
- Low power consumption per bit transmitted
  - mmW radios, directive antennas, short distance links

Low EM exposure:
- lower EM field density (lower Tx power), focused radiation
mmW Het Net

- **Heterogeneous networks**: small cells within macro cells
  - Improve user data rate near the access point
  - Offload data from the macro cell to the small cell
  - Reduce transmit power (terminal and BS)
  - Flexible deployment in dense areas

- **Millimeter-wave small cells**
  - **Spectrum resources** available worldwide (60 GHz, 71-86 GHz)
  - **Multi-Gbps data rates**
  - **No interference** with macro cell
mmW spectrum

Large spectrum resources from 30 to 300 GHz

- dense spectrum re-use
- spatial multiplexing
- compact equipments, easy to fit in urban appliances.
**mmW technology**

![Graph showing Application Frequency (GHz) vs. Year with different technologies and bands like 60 GHz WLAN, 77 GHz Auto Radar, 24 GHz Auto Radar, LMDS, etc.]

**mmW IC technology is ready...**

Source: TeraHertz Communication lab (www.tcl.tu-bs.de).
Some challenges for mmW access

Radio
- Lower Tx power and Rx sensitivity

Antennas
- Directive antennas with beamforming

Propagation
- building penetration, blockage effects, foliage, precipitation
mmW Mobile Access

- Other initiatives: Experimental campaigns at 28/38 GHz in NY univ., univ. of Texas, Samsung.

60-GHz ISM Band

US (57.05-64.00)

Canada (57.05-66.00)

Korea (57.00-66.00)

Japan (59.00-66.00)

Europe (57.00-66.00)

Australia (59.40-62.90)
First commercial WiGiG products coming up

60 GHz Radio for User Terminal

60-GHz Transceiver module on HR silicon (CEA-LETI)

- Compact size: 6.5×6.5×0.6 mm³,
- HR silicon integration with integrated antennas
- CMOS transceiver (CMOS 65 nm)

60 GHz Radio for User Terminal

60-GHz Transceiver module on HR silicon (CEA-LETI)
- Compact size: 6.5×6.5×0.6 mm³,
- Wireless HD std: 7 Gbps (OFDM 16QAM)
- Operates over the 4 IEEE channels between 57 and 66 GHz.
Multi-module architecture

- Frequency multiplexing: inter and intra channels
- Spatial multiplexing: simultaneous multiple beams
- Scalability: capacity, range, power consumption, size
Mobile backhaul

- Mobile backhaul
  - connection between cell sites
  - core network (controller site)
Future Networks: C-RAN

- CPRI rates
  - 9.830 Gb/s
  - 6.144 Gb/s
  - 3.072 Gb/s
  - 2.4576 Gb/s
  - 1.2288 Gb/s
  - 0.6144 Gb/s

Communication between RRH and BBU require a capacity in the order of Gbps.
Backhaul network challenges

- **Network scale/densification**
  - The introduction of Small cells
    - vast expansion of the backhaul network and the number of sites that must be connected and managed.
  - Short link length backhaul will be predominant.

- **Network capacity**
  - The transition to 5G, and the addition of small cells are all strategies to address growing capacity demand.
  - The backhaul network must also scale in capacity or risk becoming a bottleneck.

- **Network Architecture**
  - C-RAN poses big challenges to the backhaul mainly for Capacity and latency requirements.

  **Capacity up to 10 Gbps must be backhauled**
Mobile Backhaul

- Possible technologies:
  - Fiber
    - It has the capacity and latency requirements of CPRI.
    - High CAPEX
      - Fiber deployment seems to be prohibitively expensive in the coming years.
  - Copper
    - It does not have enough capacity and presents an excessive latency to address the requirements of CPRI interconnect.
  - Radio
    - Best when looking at both the OPEX and CAPEX.
Mobile backhaul connection by Radio will be more than 50% in 2016.

Source: Infonetics Research (September 2012)
Frequency Band and spectrum resources for Point-to-point link

Traditional Microwave

Millimetre - E-Band

60 GHz - Unlicensed
The most popular channel sizes are 28MHz and 56MHz.

In some Frequency bands channel aggregation is permitted:

i.e.: 71-76 & 81-86GHz up to 4,75GHz

i.e.: 59-64GHz up to 2.5GHz
E-Band Regulation

- **E-Band (71-76 GHz and 81-86 GHz):**
  - Largest segment of spectrum licensed by FCC (FCC R&O 03-248) and CEPT (ECC/REC/(05)07)
    - Wireless fronthaul, backhaul and network extension
      - Point-to-point fixed wireless system
    - “light license”
  - **E-band Channel: Rec. ITU-R F.2006**
    - Channels of size multiple of 250 MHz
    - FDD or TDD arrangement
    - Duplex separation of 2.5 GHz or 10 GHz.
Examples of implementations (Rec. ITU-R F.2006):

- FDD Duplex separation of 10 GHz.

- FDD Duplex separation of 2.5 GHz.

- FDD Duplex separation of 10GHz, aggregating multiple 250 MHz channels.
### Commercial E-band backhaul links

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Freq. (GHz)</th>
<th>Capacity (Gbps)</th>
<th>Range (Km)</th>
<th>Mod.</th>
<th>Output Power (dBm)</th>
<th>Transceiver power consumption (W)</th>
<th>Country</th>
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<tbody>
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<td>Cablefree</td>
<td>71-76</td>
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<td>-----</td>
<td>10</td>
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<td>Proxim wireless</td>
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<td>2</td>
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<td>DBPSK</td>
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Backhaul Requirements

- **E- Band transceiver:**

<table>
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<th>Frequency Bands</th>
<th>GHz</th>
<th>71-76 Go 81-86 return</th>
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<td>RF interface</td>
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<tr>
<td>Capacity</td>
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<td>10</td>
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<tr>
<td>Network Interface</td>
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<td>Ethernet 10 Gbps</td>
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<td>Latency</td>
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<td>Availability at 1km</td>
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Annex Ea: Frequency bands 71 GHz - 86 GHz

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<th>Channel separation (MHz)</th>
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<th>500</th>
<th>750</th>
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<th>1 500</th>
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<td>285</td>
<td>427</td>
<td>570</td>
<td>712</td>
<td>855</td>
<td>997</td>
<td>1 140</td>
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<td>2</td>
<td>285</td>
<td>570</td>
<td>855</td>
<td>1 140</td>
<td>1 425</td>
<td>1 710</td>
<td>1 995</td>
<td>2 280</td>
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<tr>
<td>3</td>
<td>425</td>
<td>850</td>
<td>1 275</td>
<td>1 700</td>
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<tr>
<td>4</td>
<td>570</td>
<td>1 140(note 1)</td>
<td>1 710</td>
<td>2 280 (note 1)</td>
<td>2 850</td>
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<td>5</td>
<td>875</td>
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<td>2 100(note 1)</td>
<td>3 150(note 1)</td>
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<tr>
<td>8</td>
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<td>2 800</td>
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<td>-</td>
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</table>

NOTE 1: RIC rounded down to closest multiple of 1 Gbit/s rate shall also be considered valid.
NOTE 2: For equipment assessment with different base band interfaces see annex F.

E3Network transceiver will increase spectral efficiency
Commercial backhaul links

- State-of-the-art E-band transceivers: GaAs

- E3Network: SiGe-based highly-integrated FE
  - SiGe: Cheaper cost of mm²
  - SiGe has less defect density -> higher integration
    - Simplify assembly process and improve reliability
  - Self-healing techniques to reduce power consumption
Challenges in E-band backhaul

- High bandwidth (2 GHz)
  - Challenging DBB implementation in FPGA
  - High sampling frequency in ADC/DAC
  - Hard requirements for the base-band analogue filters

**Graph:**
- 33dBc @ 1.8GHz
- 10dBc from DAC response
High order modulation (64QAM)

- Very sensitive to transmission impairments
  - Phase noise
  - I/Q imbalance

- Challenging requirements for SiGe based analogue components
  - Compensation techniques must be applied in a mixed-signal approach
    - self-healing algorithms required
Conclusions

- Millimetre-wave links have the potential to provide the capacity and latency needed by the backhaul and small cells of the Future Networks.
- SiGe technology is ready to be used in millimetre-wave links.
- 60-GHz beamforming technology is needed for small-dell access.
- MiWaveS and E3Network are building the millimetre-wave transceivers for the future backhaul and small cells.
Projects Outlook

MiWaveS

- Beyond 2020 **Heterogeneous Wireless Network** with **Millimeter-Wave** Small-Cell **Access** and **Backhauling**
- 15 partners

E3Network

- Energy Efficient **E-band transceiver for backhaul** of the future networks
- STREP, Dec. 2012- Nov. 2015
- 9 partners
Thank you for your attention