Beyond 2020 Heterogeneous Wireless Networks with Millimeter-Wave Small Cell Access and Backhauling

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Workshop on Millimetre-Wave Technology for High-Speed Broadband Wireless Networks

www.miwaves.eu
MiWaveS vision

- **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** and **x1000 user density**
  - **Low interferences**
S&T Objectives

- **Objective 1:** mobile access with up to 5 Gbps data rate through mmW radios and above 10 Gbps aggregate capacity for backhaul.
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- **Objective 2**: reduction of the overall EMF exposure
  - Reduction of 3G/4G traffic through offloading (WP2)
  - High directivity antennas (WP4)
  - EMF exposure assessment in WP4
S&T Objectives

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- **Objective 2**: reduction of the overall EMF exposure

- **Objective 3**: reduction of the power consumption per bit transmitted (access and backhaul) (green radio)
  - Offloading to small-cell access points (short range comm.) (WP2)
  - mmWave radios (WP3)
  - Directive antennas (WP4)
  - Smart activation of BS/APs w.r.t. network load (WP2)
S&T Objectives

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- **Objective 2:** reduction of the overall EMF exposure

- **Objective 3:** reduction of the power consumption per bit transmitted (access and backhaul) (green radio)

- **Objective 4:** improvement of flexibility, QoS, robustness for operator networks
  - Split of data and signaling traffic, priority traffic on the 3G/4G network (WP2)
  - self-organizing network (WP2)
  - mmW directive and short-range access links (WP3, WP4)
Targeted results

- **Definition** and **specification** of an heterogeneous wireless network with mmW access and backhaul.

- Proof of concept of **networking functions and algorithms** for mmW access and backhaul (Data routing, antenna beam-steering and beam-forming).

- Demonstration of the **radio** and **antenna technologies** for 60 GHz and E-band communications.

- **EMF exposure** assessment of users.

- Demonstration of an heterogeneous network prototype with mmW backhaul and access links.

- Contribution to **standards, regulation** and **scientific dissemination**.
Project structure

WP8: Project management

WP1: Heterogeneous wireless network with mmW small-cell access and backhauling

WP2: Network mechanisms and algorithms

WP3: Radio technology

WP4: Antenna technology and EMF exposure

WP5: Integration of analog frontend, implementation of baseband algorithms, and prototyping

WP6: MmW access and backhauling proof of concept for heterogeneous wireless networks

WP7: Dissemination, standardisation, exploitation
Use cases and requirements

- **Use cases**
  1. Massive public events and gatherings
  2. Hotspot in shopping malls
  3. Urban street-level outdoor mobile access and backhaul
  4. Indoor wireless networking and coverage from outdoor
  5. Rural detached small-cell zones and villages

- **Requirements**
  - High end-user capacity (multi-Gbps data rate) and site capacity (>10 Gbps aggregated capacity)
  - Ease of small-cell APs installation, configuration and management
  - Interconnection of APs by short backhaul hops, achievable with reasonable antenna sizes, energy consumption and equipment cost
Dynamic self-organising network
functional description and algorithms

- Scenarios and requirements for the self-organized heterogeneous network with mmW small cells, integrated backhaul and access link.
- Overall heterogeneous network design with flexible small cell-macro cell–relationships and dedicated mmW multi-hop backhaul network.
- Radio resource management (RRM) theoretical aspects and algorithms with respect to heterogeneous networks (HetNet) with multi-hop backhaul link.
- Function description and algorithms for the backhaul link and multi-hop relay, and for the access link.
- Principles and functions for power consumption optimization
Antenna beamsteering and beamforming

- **Access**: Practical beamforming and beam tracking algorithms for restricted antenna designs are investigated. Also, beam tracking for mobility scenario is taken into account.
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- **Backhaul**: Beam switching as a potential solution for high throughput point to multipoint transmission; code-book design, channel estimation algorithm
Antenna beamsteering and beamforming

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- **Backhaul**: Beam switching as a potential solution for high throughput point to multipoint transmission; code-book design, channel estimation algorithm
- **Backhaul**: typical small-cell installation mast movement measurements and analysis.
**User Terminal:** V-band Tx/Rx module (57-66 GHz)
- LCP multi-layer substrate
- Single antenna (fixed beam), linear polarization
- Transceiver flip-chipped on the bottom side
- Module flip-chipped on the terminal board
- Interface: baseband I/Q signals, digital controls
**Access point:** V-band Tx/Rx phased array

- Same technology blocks developed for the User Terminal: transceiver chip, antenna elements, multi-layer stack-up
- Add Tx/Rx switch, power splitter, and active phase-shifter circuits
- Targeted antenna array: 1x4, 2x4 or 4x4 elements
- Gain: 12 dBi, 15 dBi or 18 dBi.

**Preliminary layout (19x19 mm²)**

![RFFE](https://via.placeholder.com/150)

**Cross section**

Courtesy CEA-LETI
Access point: V-band Tx/Rx phased array

- High antenna gain (20-30 dBi)
- Beamsteering capability over a wide angular sector
- Spatial multiplexing
- Hybrid architectures with beam-steering sub-arrays

Courtesy CEA-LETI
Radio and antenna technologies

**Backhauling:** V-band and E-band arrays and lenses
- Low cost dielectric lens and printed focal array (fixed beam)

Courtesy STMicroelectronics
Radio and antenna technologies

**Backhauling:** V-band and E-band arrays and lenses

- Low cost dielectric lens and printed focal array (fixed beam)
- Discrete lens antenna array with switched focal array (switched beams)

Courtesy VTT & CEA-LETI
Radio and antenna technologies

Backhauling: V-band and E-band arrays and lenses

- Low cost dielectric lens and printed focal array (fixed beam)
- Discrete lens antenna array with switched focal array (switched beams)
- Continuous Transverse Stub antenna (fixed beam)

Courtesy Univ. Rennes.
Demonstrations

**KPIs:** Max. throughput, Power cons., Beamforming perf., Latency, etc.
Demonstrations

WP3 (SIV, CEA, ST-F)

WP4 (UR1, CEA, ST-F, VTT)

WP5 (NI, TUD, UNIS)
Impacting standardisation bodies

Workshop on candidate technologies for IMT-2020

New ITU-R recommendation for IMT-2020

Perf requirements, eval criteria, methodology of new IMT radio

Proposal phase

Global mmWave Spectrum Allocation, Proposals Eval

WRC 2015

WRC 2018/2019

Recommendation ITU-R M.[IMT.VISION]
Report ITU-R M.[IMT.FUTURE TECHNOLOGY TRENDS]
Report ITU-R M.[IMT.ABOVE 6 GHz]

Use cases, Algo. Analysis RF / Ant opt.

Integration, Measurements

Support Rel 13 study items (SI)

First mmWave SI / WI

Main mmWave SI / WI

Provide basis for Rel 14 work items

MiWaves Mulit-Gbit/s mmWave Backhaul and Access Link Demonstrator

Conclusion

**MiWaveS** is developing **key technologies for mm-wave wireless access and backhaul in future 5G heterogeneous mobile networks.**

- Definition and specification of an **heterogeneous wireless network with mmWave access and backhaul**
- **Networking functions and algorithms** (Data routing, antenna beam-steering and beam-forming).
- Demonstration of **radio and antenna technologies** in V band and E band
- **EMF exposure** assessment of users
- Contribution to **standards, regulation and scientific dissemination**
Thank you for your attention
MiWaveS at a Glance

- **Large scale integrating project (IP), 15 partners**
- **Project coordinator:** Dr. Laurent Dussopt (CEA-LETI, Fr).
- **Project officer:** Pertti Jauhiainen (EC).
- **Call:** FP7-ICT-2013-11, **Objective:** ICT-2013.1.1 Future networks
- **Contract:** CNECT-ICT-619563
- **Total cost:** 11 349 195 €; **EC funding:** 7 358 113 €

**Communication:**
- **Web:** [www.miwaves.eu](http://www.miwaves.eu)
- **Twitter:** [https://twitter.com/FP7_MiWaveS](https://twitter.com/FP7_MiWaveS)
- **LinkedIn:** [www.linkedin.com/groups/FP7-MiWaveS-6694097](http://www.linkedin.com/groups/FP7-MiWaveS-6694097)