



[www.openairinterface.org](http://www.openairinterface.org)  
*Wireless Radio Platforms in a  
Nutshell*

**Mobile Communications  
Department**

**Institut Eurecom**



# Overview

- Intro to [www.openairinterface.org](http://www.openairinterface.org)
- Collaborative Web tools and Development areas
- Current Sources of Funding
- Prototype equipment
- Emulation Methodology
- EMOS Channel Sounding
- OpenAirInterface PHY/MAC

[www.openairinterface.org](http://www.openairinterface.org)

- **OpenAirInterface platforms target innovation in air-interface technologies through experimentation**
- **We rely on the help of**
  - Publicly-funded research initiatives (ANR,ICT,CELTIC)
  - Widespread collaboration with a network of partners using **open-source development and tools**
    - LINUX/RTAI based SW development for PCs
    - LEON3/GRLIB-based HW and eCos-based SW development for FPGA targets
    - LINUX networking environment
  - Experimental Licenses for medium-power **outdoor network deployments**
    - 1.9 GHz TDD, 5 MHz channel bandwidth
    - 2.6 GHz FDD (two channels), 20 MHz channel bandwidth

# Principal Subject Areas

- **Real-time Radio Signal Processing**
  - Hardware/software architectures in support of real-time signal processing (Software Radio, multi-processor system-on-chip)
  - Algorithmic optimizations at the PHY layer (target UMTS-LTE and 802.16m technologies)
  - PHY-layer support for cellular and mesh Network topologies
- **All-IP Wireless Networking**
  - All-IP Cellular mobile network protocols (IPv6 basestation routers, IPv6 mobility management)
  - 802.21
  - IP/MPLS Protocols adapted to MESH topologies
  - Layer 2 Protocols (MAC scheduling, Radio Resource Control, Radio Link Control) for cellular and mesh network topologies
- **Agile RF System Design**
  - Wideband radio design, linear wide-dynamic range receivers
  - "Intelligent" RF (RF/DSP co-design)
- **Design and Simulation Methodologies**
  - Efficient simulation methods (performance, functional and behavioral)
  - Abstraction techniques (hardware modelling, PHY sub-system modelling, traffic modelling, etc.)
  - RF emulation architectures for distributed real-time simulation of wireless networks
- **Propagation and System Measurements and their Analysis (eMOS)**
  - Wideband channel characterization and modelling
  - Real-time measurement collection and offline empirical performance analysis
- **Cognitive Radio**
  - Development of innovative techniques based on sensor networks, that will support the coexistence of licensed and unlicensed wireless users in a same area
  - Design, dimensioning and internetworking of cognitive networks

# Collaborative Web Tools

## ■ OpenAirInterface SVN Repositories

- All development is available through [www.openairinterface.org](http://www.openairinterface.org)'s SVN repository containing
  - OPENAIR0 (open-source real-time HW/SW)
  - OPENAIR1 (open-source real-time and offline SW)
  - OPENAIR2 (open-source real-time and offline SW)
  - OPENAIR3 (open-source Linux SW suite for cellular and MESH networks)
- Partners can access and contribute to our development

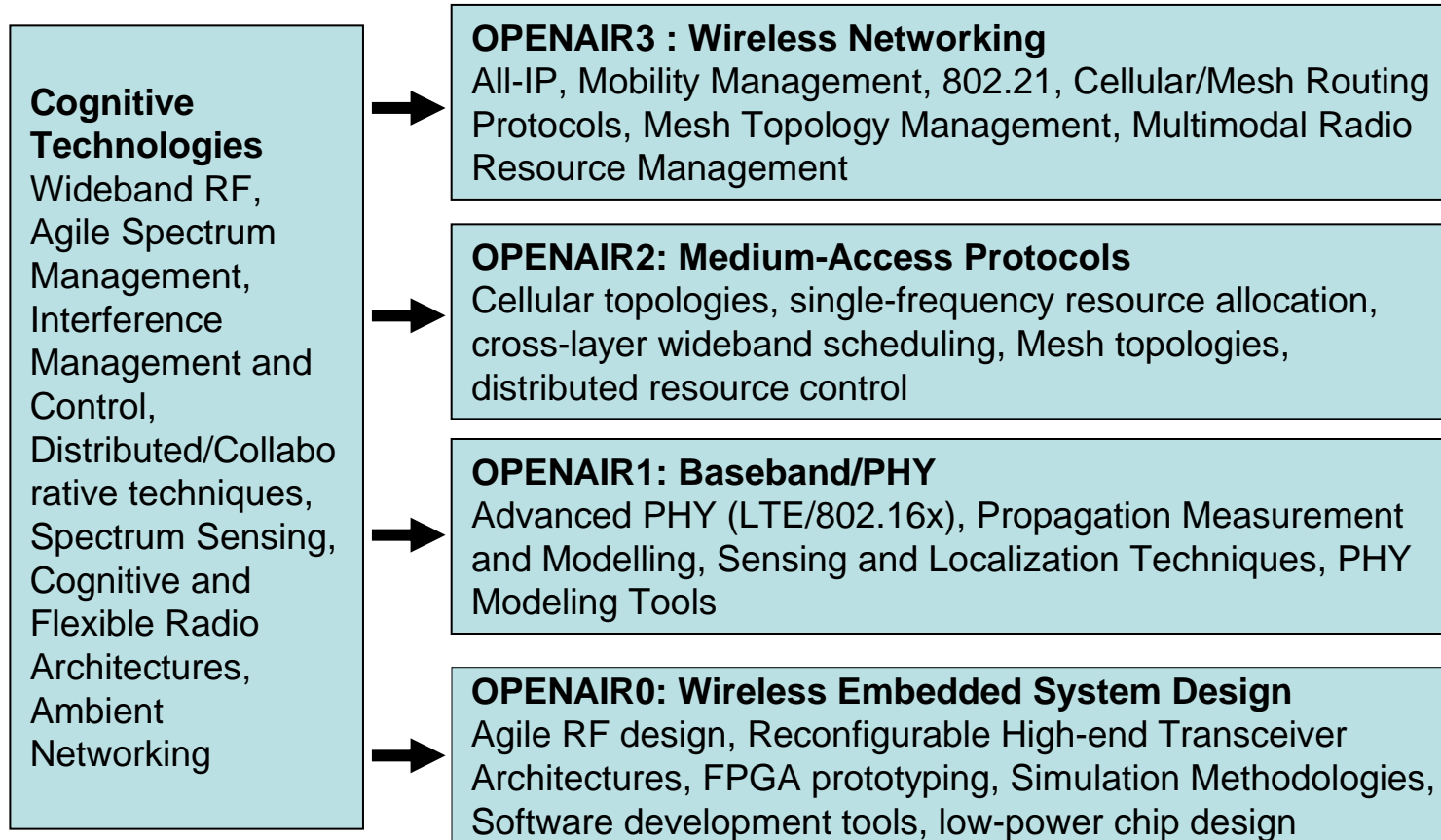
## ■ OpenAirInterface TWIKI

- A TWIKI site for quick access by partners to our development via a collaborative HOW-TO

## ■ phpBB Forum

- external support services

# OpenAirInterface Development Areas

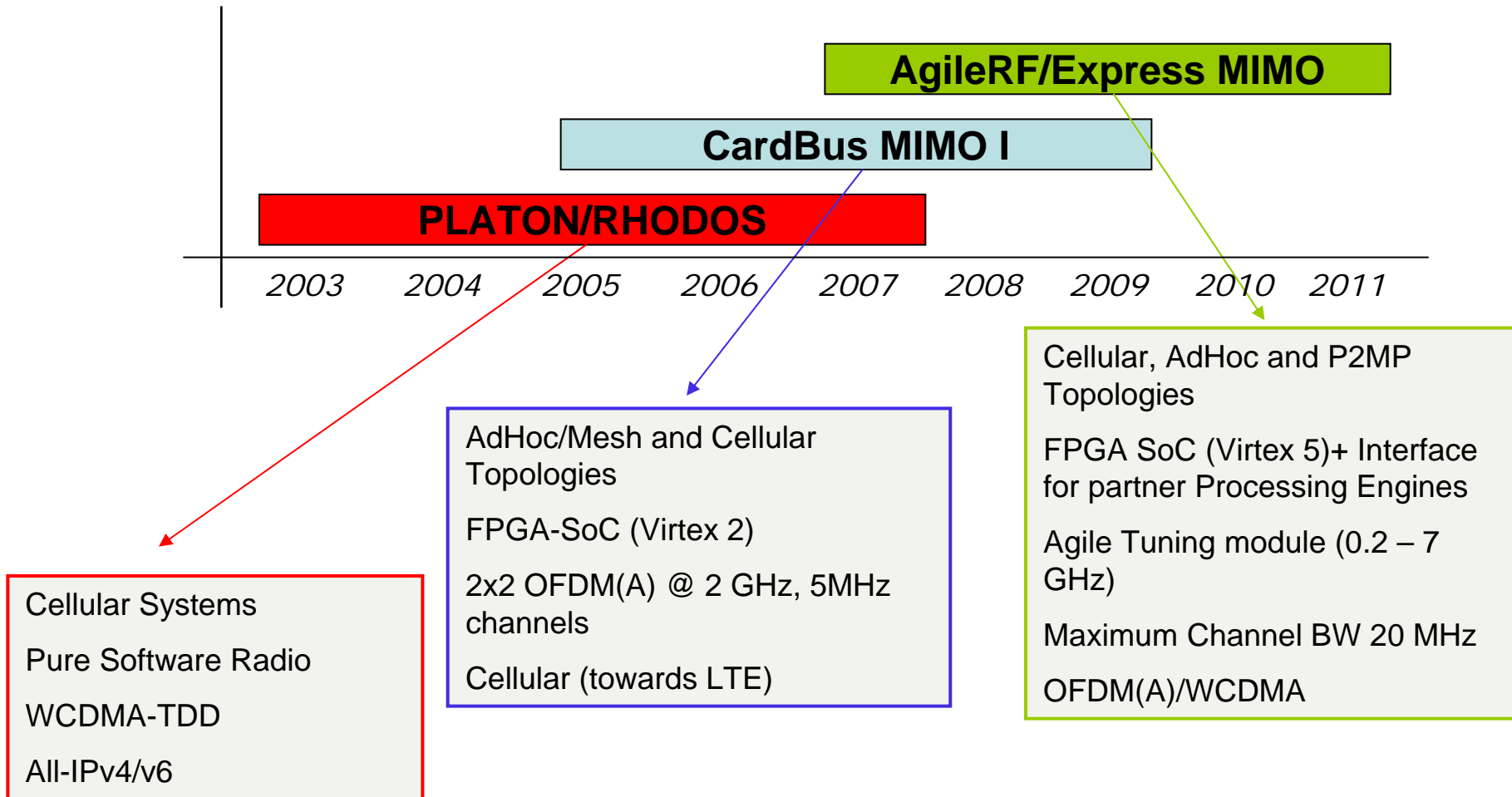


# Current Sources of Funding

Over **1M€**/year **research funding** related to experimental platform development activities

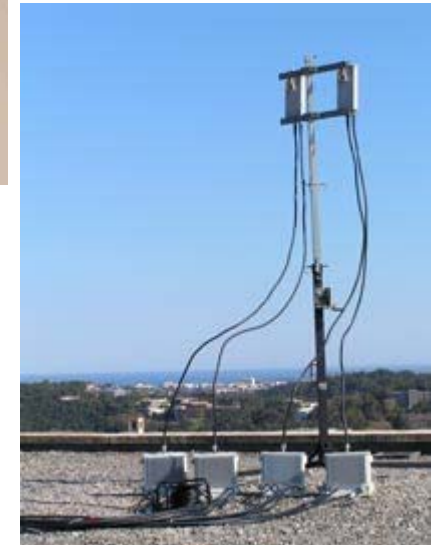
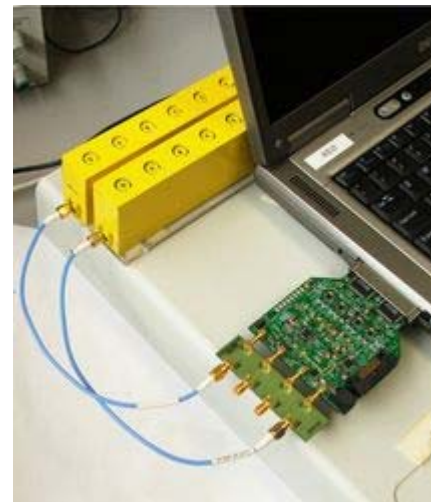
- **IDROMEL** (ANR 2006-2009), **PFMM** (Pole SCS (PACA)-DGE 2007-2009) (**openair0/openair1/openair2/openair3**)
  - Primary Partners: Thales Communications, NXP, 3-ROAM
- **APOGEE** (ANR 2008-2009): (**openair2**)
  - Primary Industrial Partners: France Telecom R+D, Mitsubishi ITE
- **CHORIST** (IST/FP6 2006-2009) : (**openair1/openair2/openair3**)
  - Primary Industrial Partners: Thales Communications, EADS
- **DAIDALOS2** (IST/FP6 2005-2008), **UNITE** (IST/FP6 2006-2009), **AIRNET** (ANR 2006-2009) : (**openair2/openair3**)
  - Primary Industrial Partners: T-Mobile R+D, NEC, Thales Communications,
- **SFR-MIMO** (private contract) : (**openair1**)
  - Primary Industrial Partners: SFR/Vodafone
- **SENDORA** (ICT/FP7 2007-2010): (**openair1/openair2**)
  - Primary Industrial Partners: Thales Communications, TeleNor
- **WHERE** (ICT/FP6 2007-2010): (**openair1**)
  - Primary Industrial Partners: German Aerospace (DLR)
- **HNPS** (CELTIC 2008-2011): (**openair3**)
  - Primary Industrial Partners: Alcatel-Lucent, Thales Communications, EADS

# Prototype Equipment Timeline



# CardBus MIMO 1

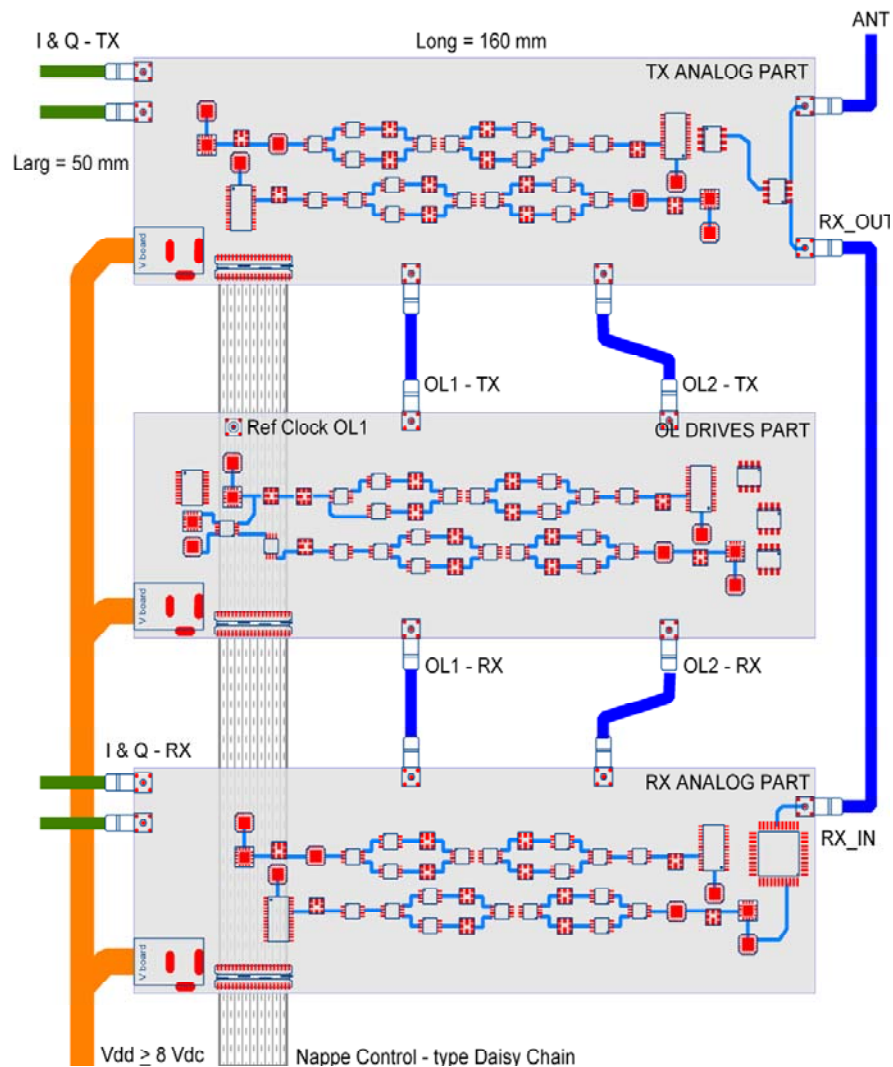
- **Current platform for application experimentation and test network deployments**
  - 5 MHz channel bandwidth TDD@1900 MHz
  - PCMCIA-CardBus form-factor
  - 2x2 MIMO-OFDMA, LTE-like waveform
  - Two-way communications
  - Full Software Radio under RTAI/Linux on x86 architectures
- **Cellular Deployments**
- **MESH deployments**
- **EMOS Channel sounding**
- **20 CBMIMO1 cards fabricated, with partner labs (Thales Communications)**
- **Interconnection with Rooftop high-power installation**



# AgileRF/ExpressMIMO

- **IDROMEL reconfigurable radio architectures**
  - Agile RF and ExpressMIMO\_fully reconfigurable RF and baseband DSP
    - Across the entire spectrum of systems with channel bandwidth from 10kHz to 20 MHz
    - “developer-friendly” tools for real-time MODEM development and validation
  - Processing issues related to multimodality and concurrency of radio standards on a common processing architecture
  - Heterogeneity in networking protocols
- **Primary goal: provide a demonstrator (up to and include UMTS-LTE, 802.16m) highlighting the challenges and difficulties in truly reconfigurable radio architectures**
  - RF based on high-end discrete components
  - BB DSP based on state-of-the-art FPGA prototyping technologies
  - Open-source development (BB DSP)

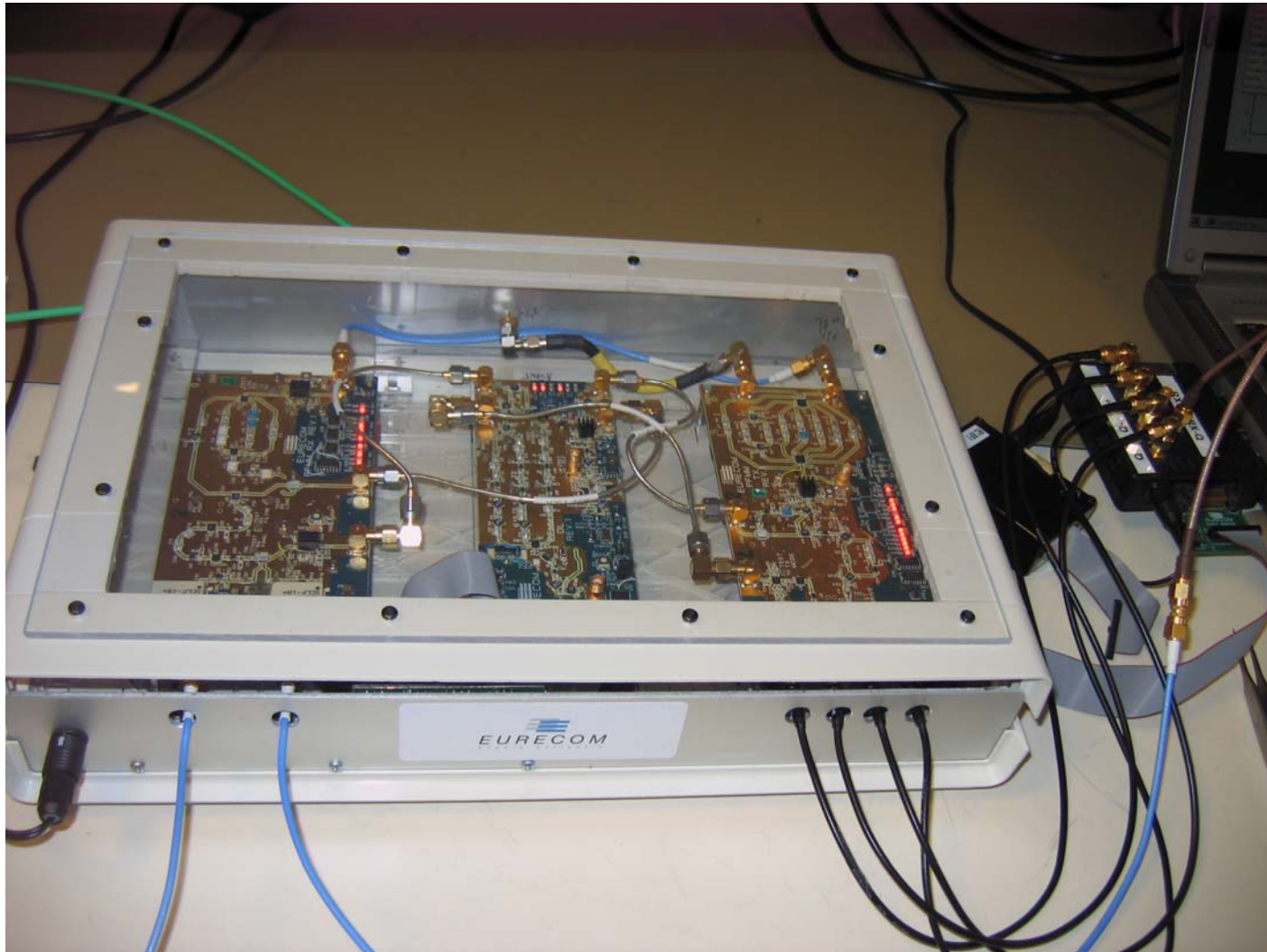
# AgileRF



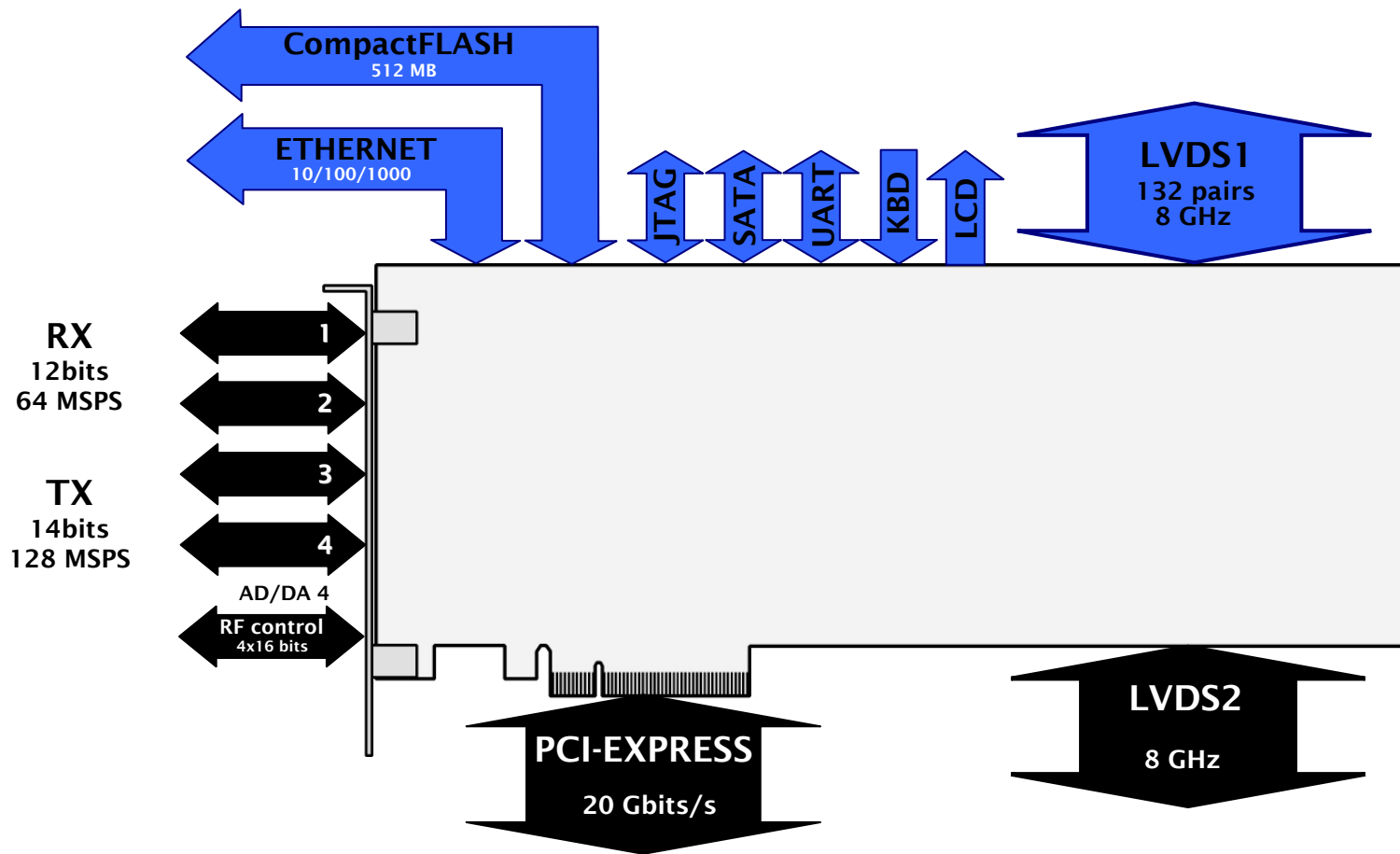
## Characteristics:

- Frequency band: 200 MHz – 7.5 GHz
- 500 kHz raster
- Baseband channel BW: 20 MHz
- Tx : +15 dBm (35 dB ACLR)
- Rx NF : 8 dB

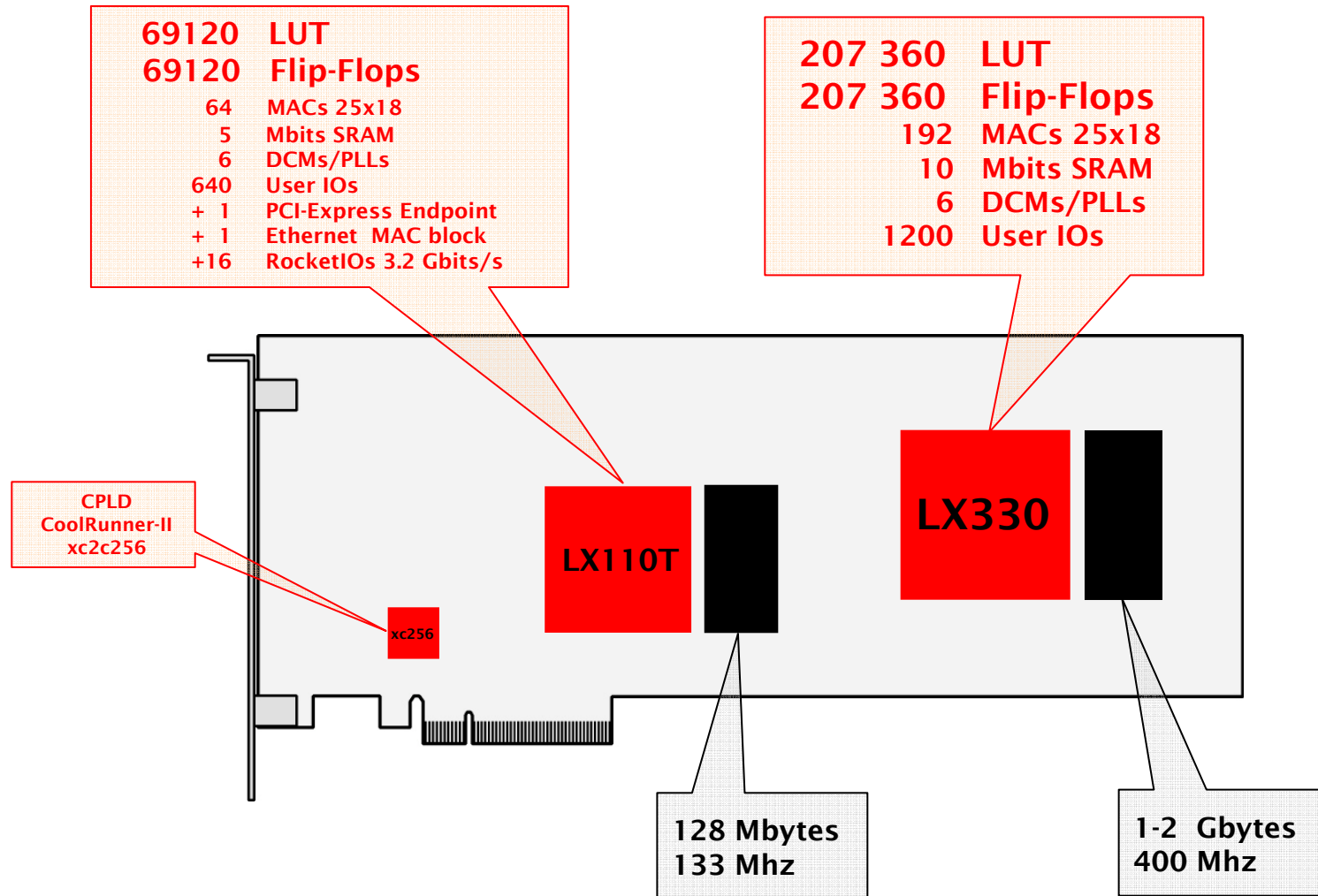
# AgileRF Prototype (March 2008)



# Express-MIMO: Interfaces



# ExpressMIMO: Logic & memory resources



# Targets for AgileRF/ExpressMIMO

- **LTE networks**

- [www.openairinterface.org](http://www.openairinterface.org) PHY/MAC is quite close to LTE
- IPv6-based protocol stack
- “high-speed” receiver design

- **MESH networks**

- Small-scale MESH networks for public-safety
- Relays between cellular and LAN's

- **Cognitive Radio Networks**

- Demonstrate AgileRF capabilities
- Wideband spectrum sensing

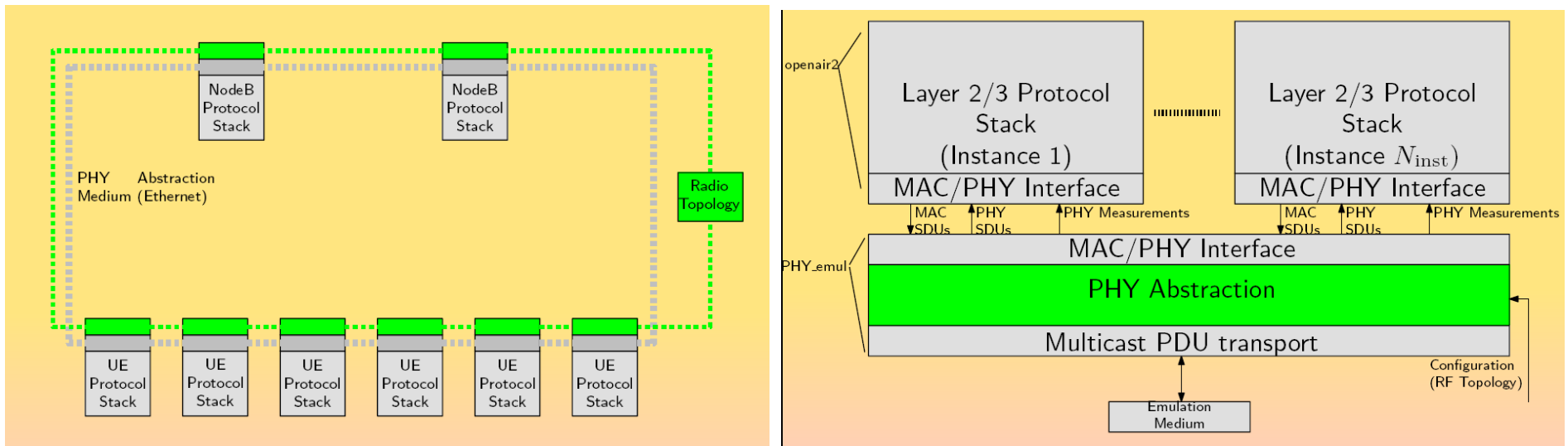
- **Prototyping step for Baseband SoC DSP processor**

- Medium-term vision -> produce a chip based on Idromel architecture

# Emulation Platform

- **Protocol Implementation Validation**
  - Enables developers of L2/L3 and applications to test their implementation in a real-time setting without the need for RF equipment
  - This can include completely repeatable experiments
- **System Performance Evaluation**
  - For L2/L3 protocol assessment using accurate PHY abstraction models
- **Possibility of using real channel measurement traces as stimulus (input from EMOS)**
- **Measurement collection for modelling of L2**

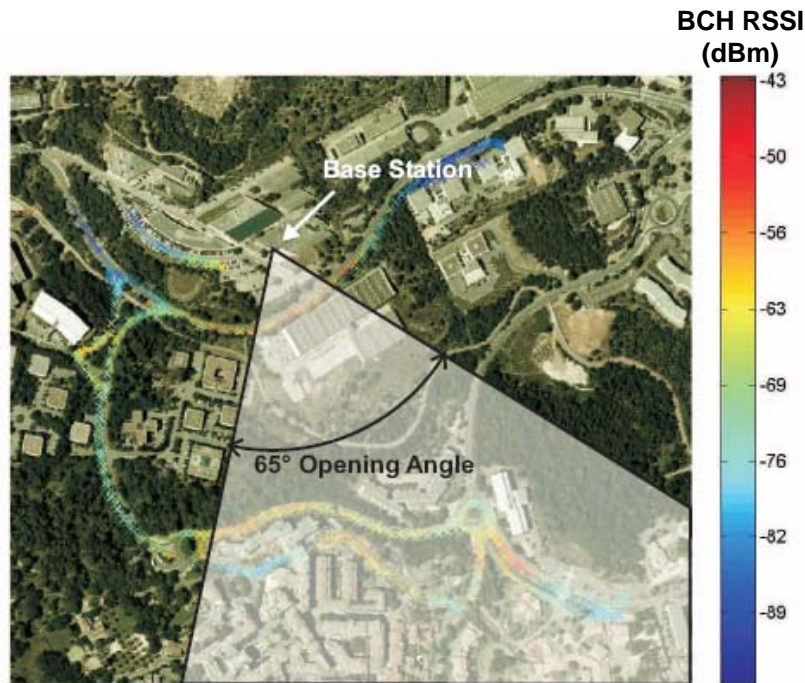
# Emulation Methodology (2)



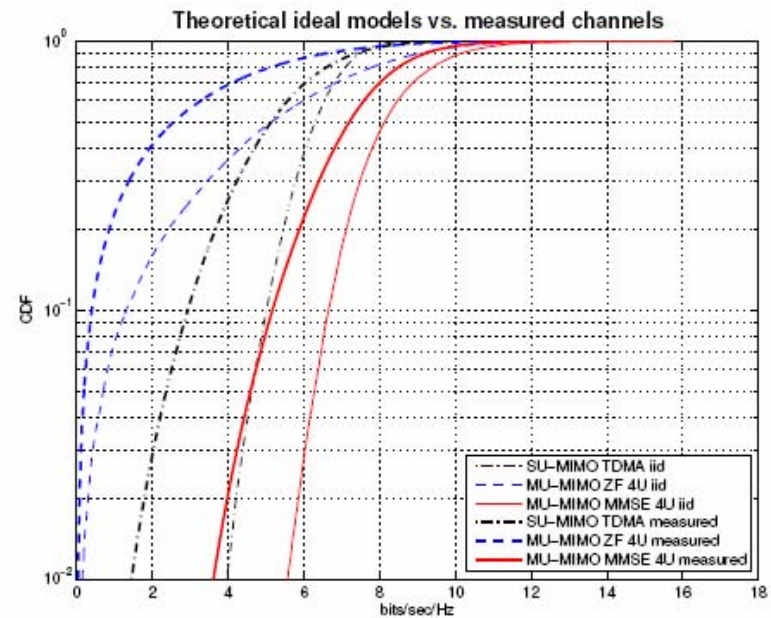
# EMOS Channel Sounding

- **E**urecom **M**IMO **O**penAir**I**nterface **S**ounder (EMOS)
  - **allows for multiuser/two-way MIMO channel measurements in real time**
- **Uses**
  - **Propagation modelling**
  - **Offline System capacity analysis based on real-time measurement data**
  - **Measurement databases for localization algorithm development**
- **Characteristics (today)**
  - **CBMIMO1 hardware**
    - **1.9 GHz (5MHz channel bandwidth) 2x2 MIMO channel sounding**
    - **Full MIMO channel estimate every 2ms dumped in real-time to disk**
    - **GPS location stamp along with channel estimate data**
    - **Measured Bit error-rate on rate  $\frac{1}{2}$  convolutional-coded QPSK (1 bit/s/Hz) OFDM data channel (OpenAirInterface BCH)**
    - **Two-way and multiuser capability**
- **Future (with AgileRF/ExpressMIMO)**
  - **200 MHz->8 GHz, 20 MHz channels 4x4 MIMO**

# EMOS Channel Sounding (2)

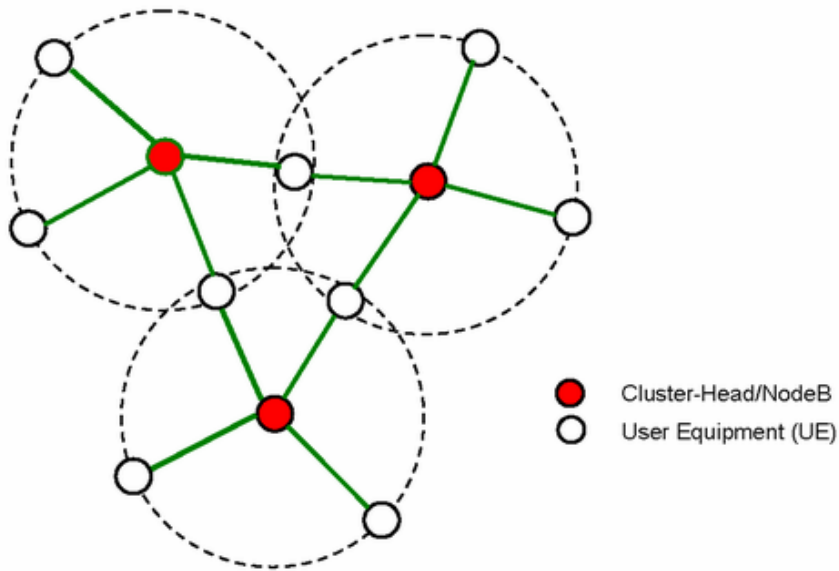


Example Measurement run around EURECOM building (4 terminals in mobility along coloured paths)

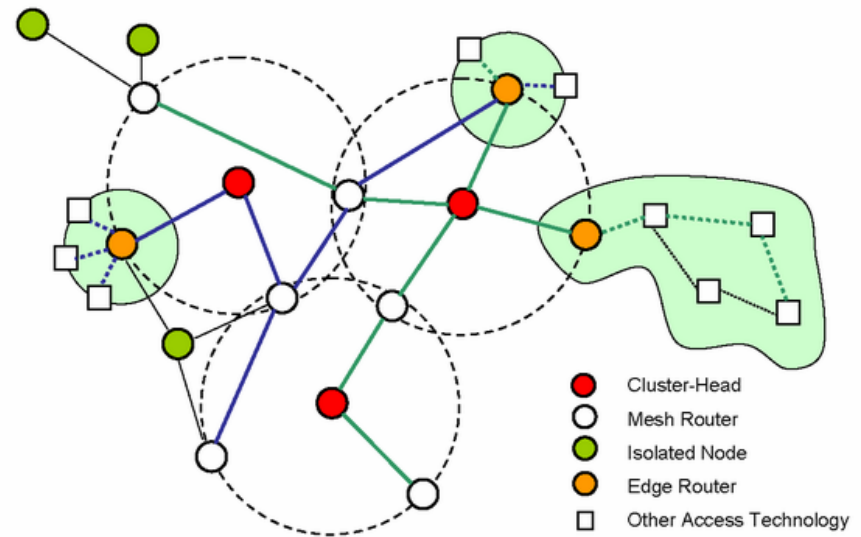


Offline system analysis (here information outage) on measured data

# PHY/MAC Topologies



Cellular Topology



Mesh Topology

# OpenAirInterface PHY/MAC Roadmap

## ■ Current development

- 2x2 MIMO-OFDMA for Single-Frequency deployment
  - BICM-SIC oriented for dual-stream coded-modulation QPSK->64 QAM (6 bits/s/Hz)
  - 802.11/16 convolutional or 3GPP turbo code
- LTE-like MAC for cellular and mesh topologies
  - Shared channels (DL-SCH,UL-SCH)
  - Broadcast support (e-MBMS)
  - Feedback signaling for spatial-subband-CSIT
  - HARQ type I/II
  - 3GPP RLC/PDCP
  - Linux IP/MPLS networking device
  - Mesh and Cellular (3GPP-subset) RRC
- Distributed network synchronization (MESH topology)
- Capacity for distributed MIMO - pilot definitions and coding sub-system
  - Dual-antenna receiver for intercell interference cancellation and distributed MIMO (one stream from each cell)

## ■ Planned developments

- Distributed HARQ for relaying
- MU-MIMO (downlink SDMA)
- 16 bits/s/Hz (!)
- layered-UEP codes for multiresolution broadcast

# OpenAirInterface PHY/MAC Protocol Stack

