Advanced architectures for WSN
Aerospace application : SACER

Daniela Dragomirescu, Pascal Berthou, Robert Plana

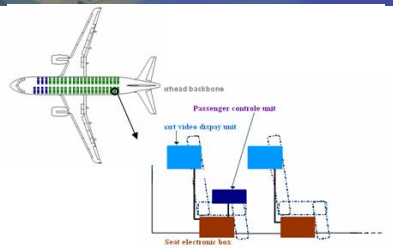
Groupes MINC and OLC

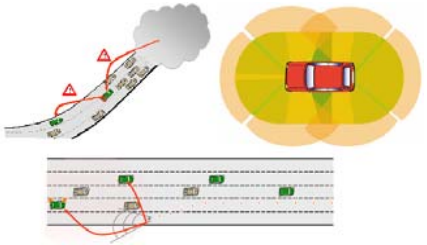
LAAS-CNRS
University of Toulouse
France

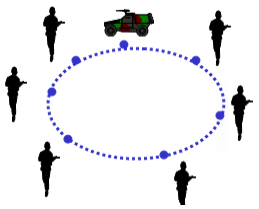
October 2008

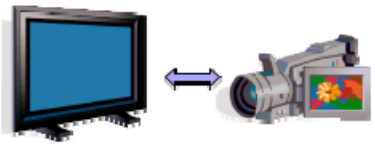
Motivations

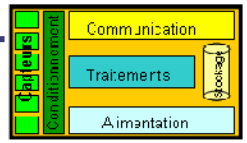
- Wireless Sensor Network Context
  - Small area
  - A large number of nodes
  - Autonomy
- Constraints on radio interface :
  - Low cost
  - Low power
  - Small size
  - Simplicity
  - Application dependent constraints
    - Data rate
    - Radio range
    - BER
    - Spectrum occupation



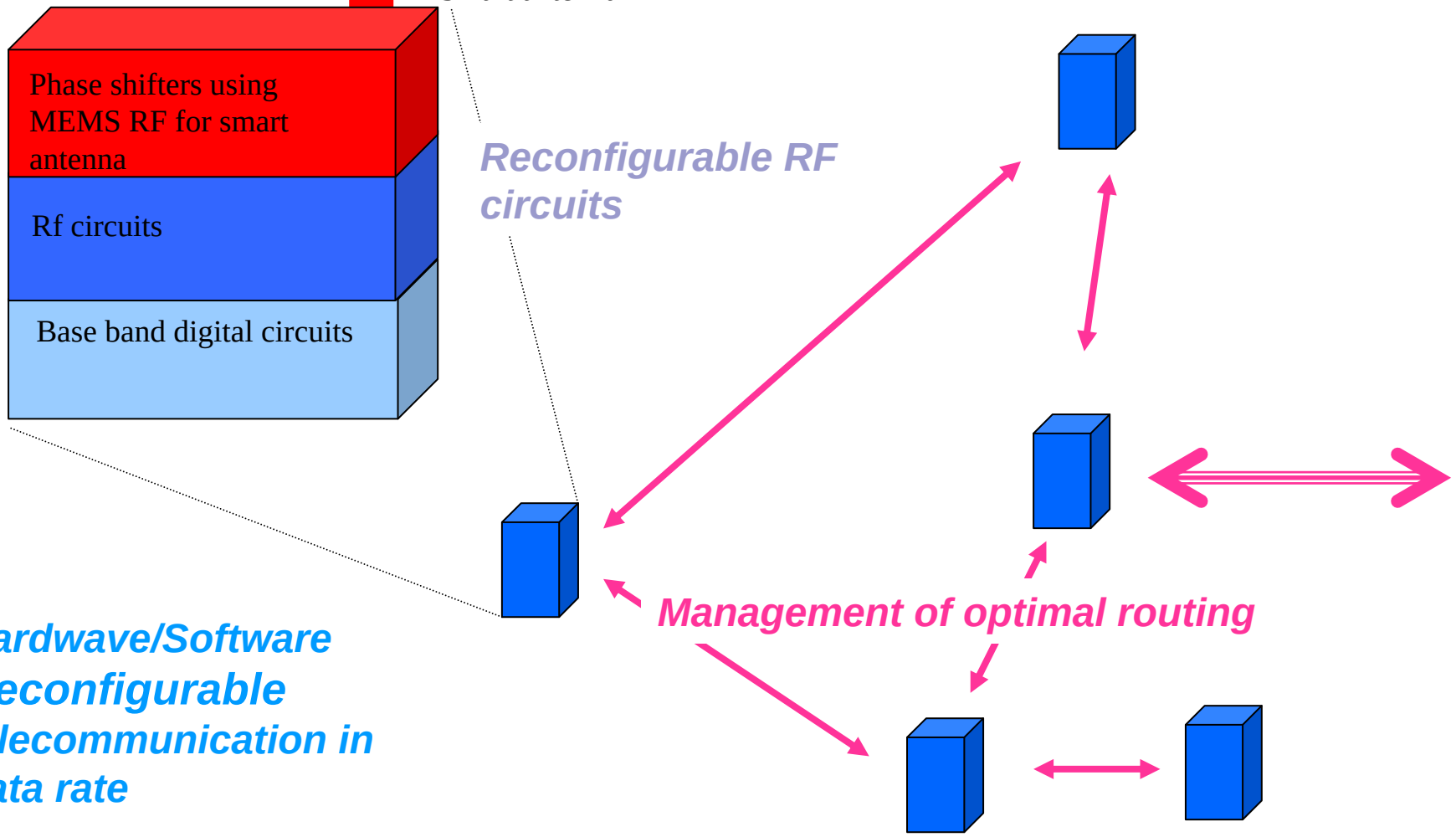








Reconfigurable antenna using MEMS RF



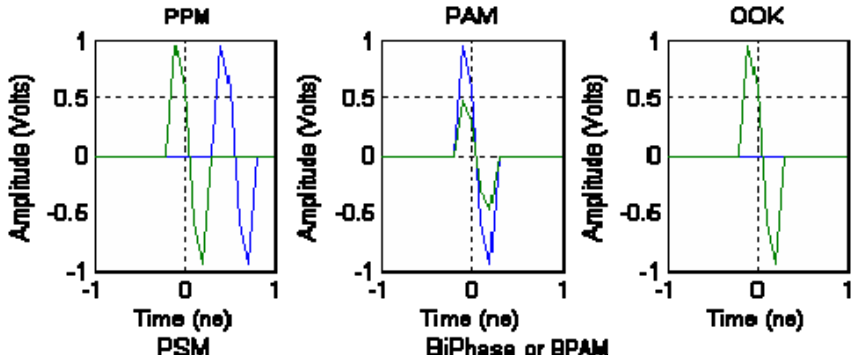
How to use the reconfigurable antenna to obtain optimal routing and optimal power consumption ?

Research fields

- UWB transmission
  - IR-UWB
  - OFDM / SC-FDMA / SC-FDE
  - 60 GHz
- Smart antenna
  - Beam-forming using phase shifter
- Cross-layering architecture
  - D802.15.4 →MAC Protocol using smart antenna
- Aerospace application : SACER
- Perspectives : instrument the hospitals, health field

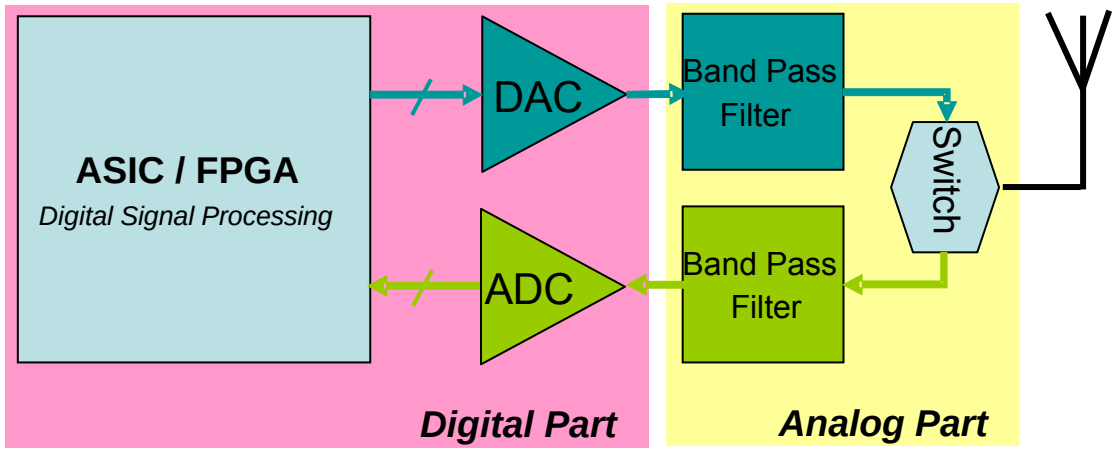
IR-UWB

- IR-UWB



  - Emitter – receiver architecture
    - Mixed architecture : digital – analog RF front end → 60GHz
    - Mostly Digital architecture → high reconfigurability
  - High data rate →
    - channel capacity → directive antenna and 60GHz
    - transceiver architecture
  - BER
  - MAC layer for IR-UWB

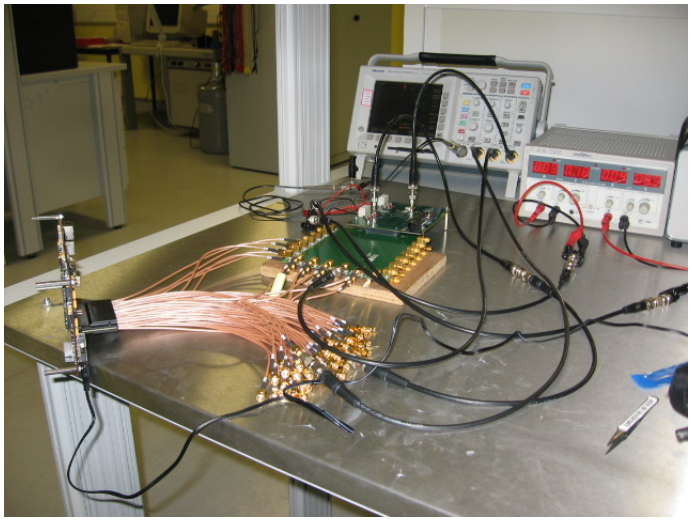
Mostly digital IR-UWB Radio

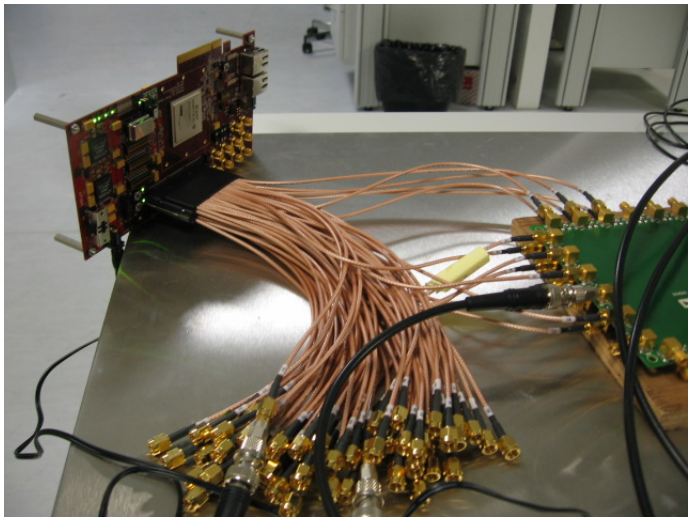


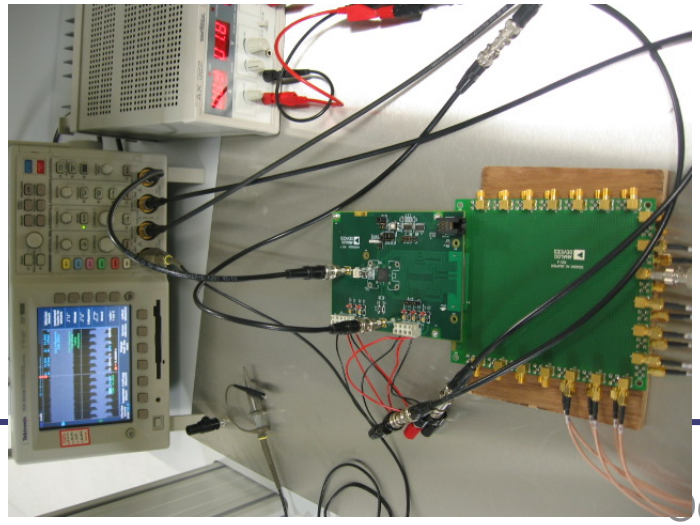
Mostly Digital Radio Architecture

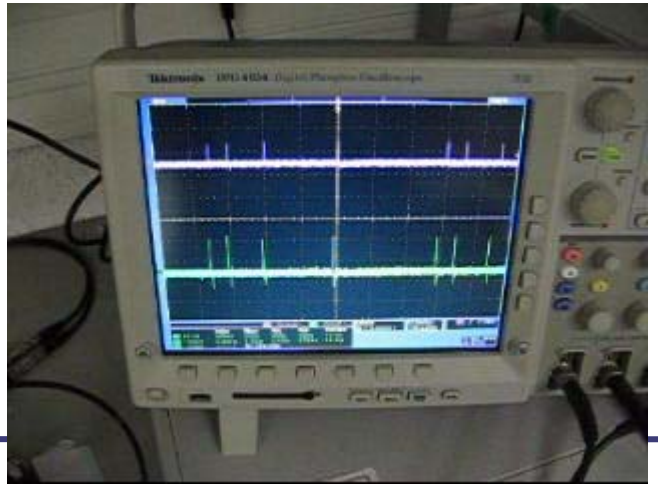
➡ *2 key elements : converters, ASIC/FPGA*

Reconfigurable mostly digital IR-UWB



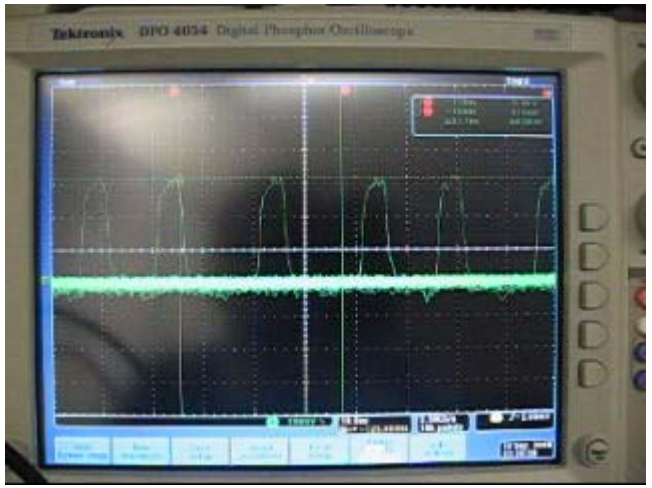






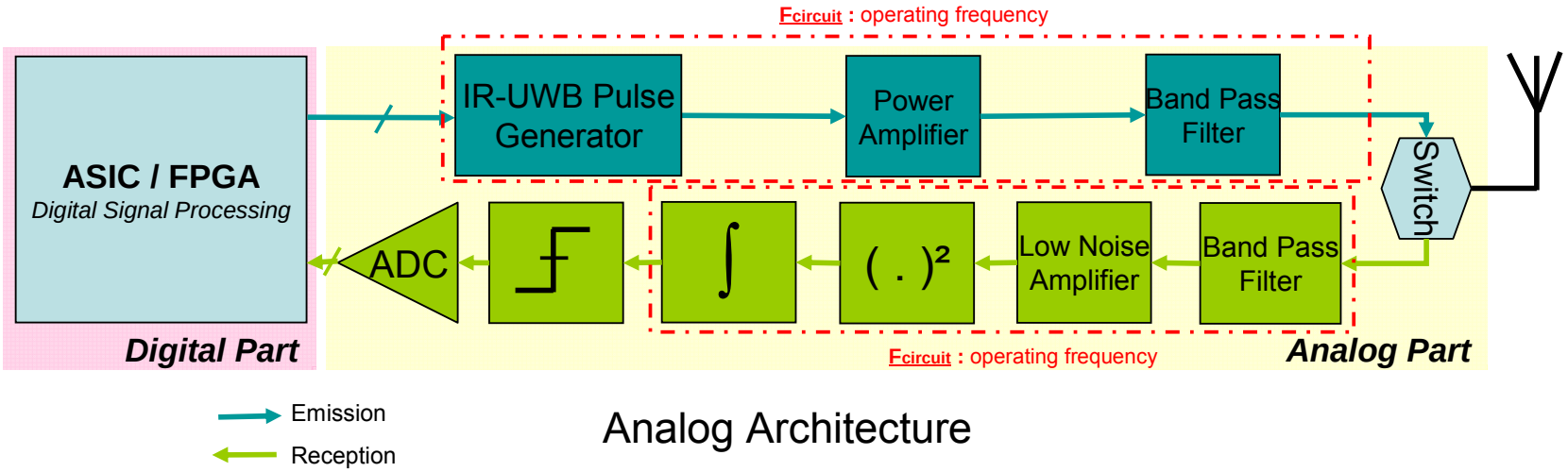
FPGA prototypes

- **IR-UWB Receiver reconfigurable in data rate and user code**
  - **IR-UWB multi user receiver**
  - **IR-UWB receiver with localization function.**
  - **IR-UWB emitter at 250Mb/s**
  - **IR-UWB multi-user emitter**
  - **IR-UWB reconfigurable emitter in modulation, spectral occupation, data rate and user code**



IR-UWB digital base band ASIC prototype → tape out: end of November

Mixed Implementation



Analog Architecture

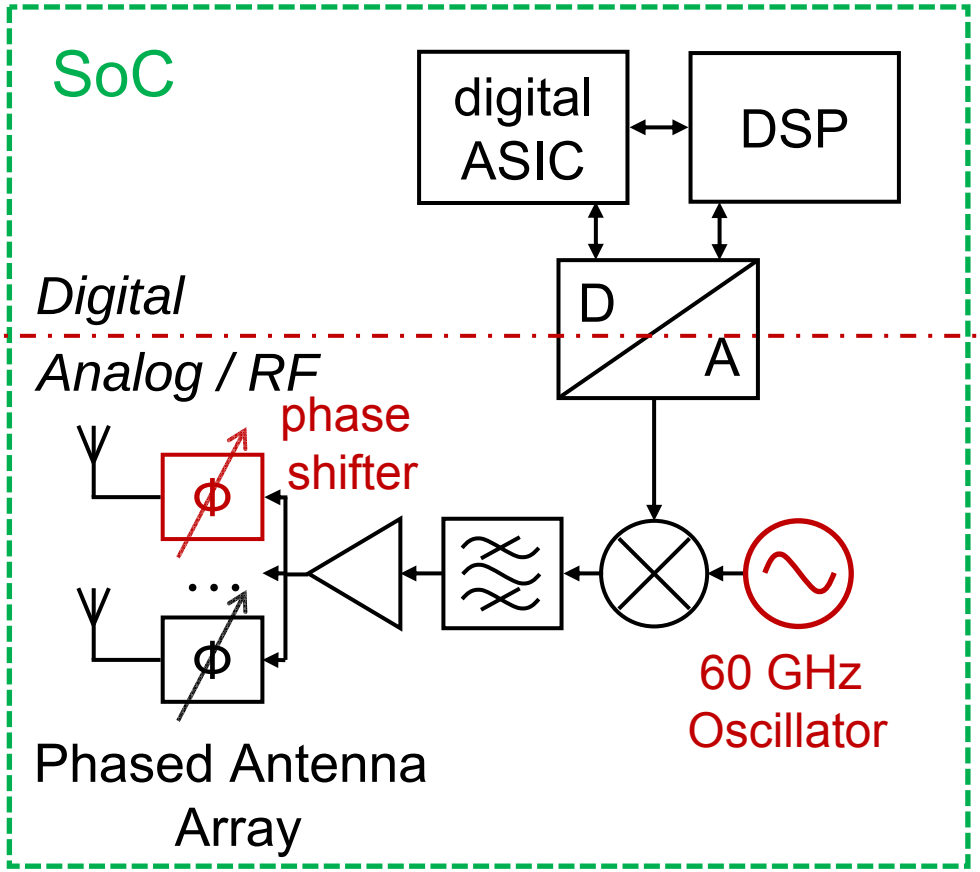
Architecture for 60GHz implementation

VCO ASIC prototype @ 60GHz → tape out : end of November

IR-UWB systems @ 60GHz

Behavioral model
in VHDL

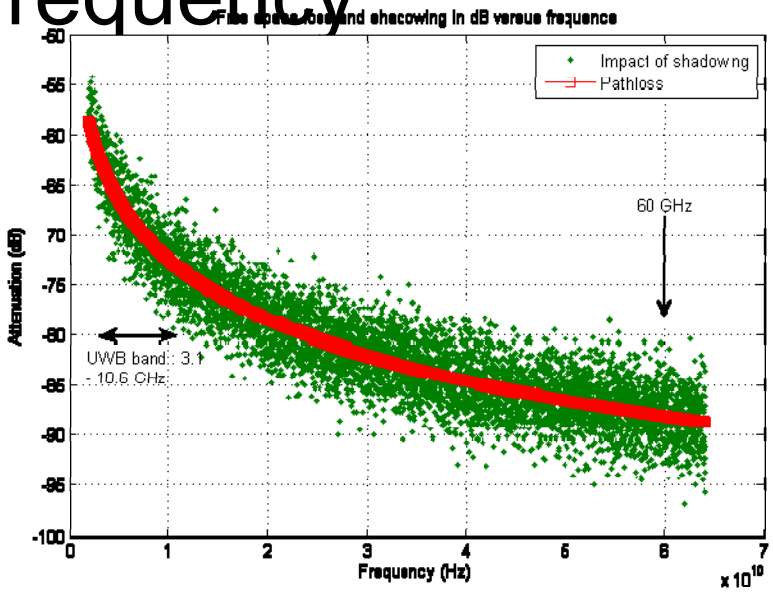
Behavioral model
in VHDL-AMS



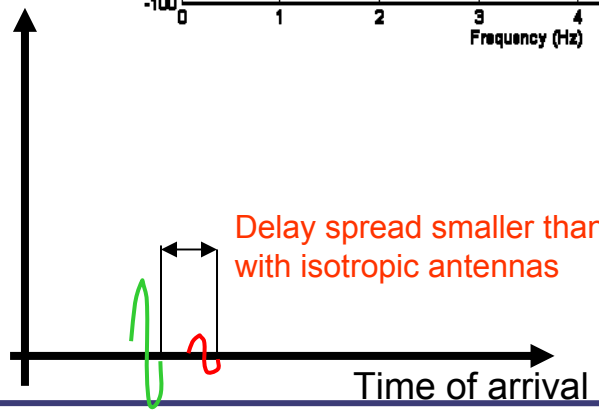
➢ Modeling of entire heterogeneous system by connection of blocks described in VHDL-AMS

IR-UWB Channel Capacity for Mixed Implementation

- Profit from high operating frequency
  - M-ary modulations
    - x 2, x 3 / data rate
  - Wavelength decrease
    - Higher pathloss
    - Delay spread decrease
    - Directive antennas

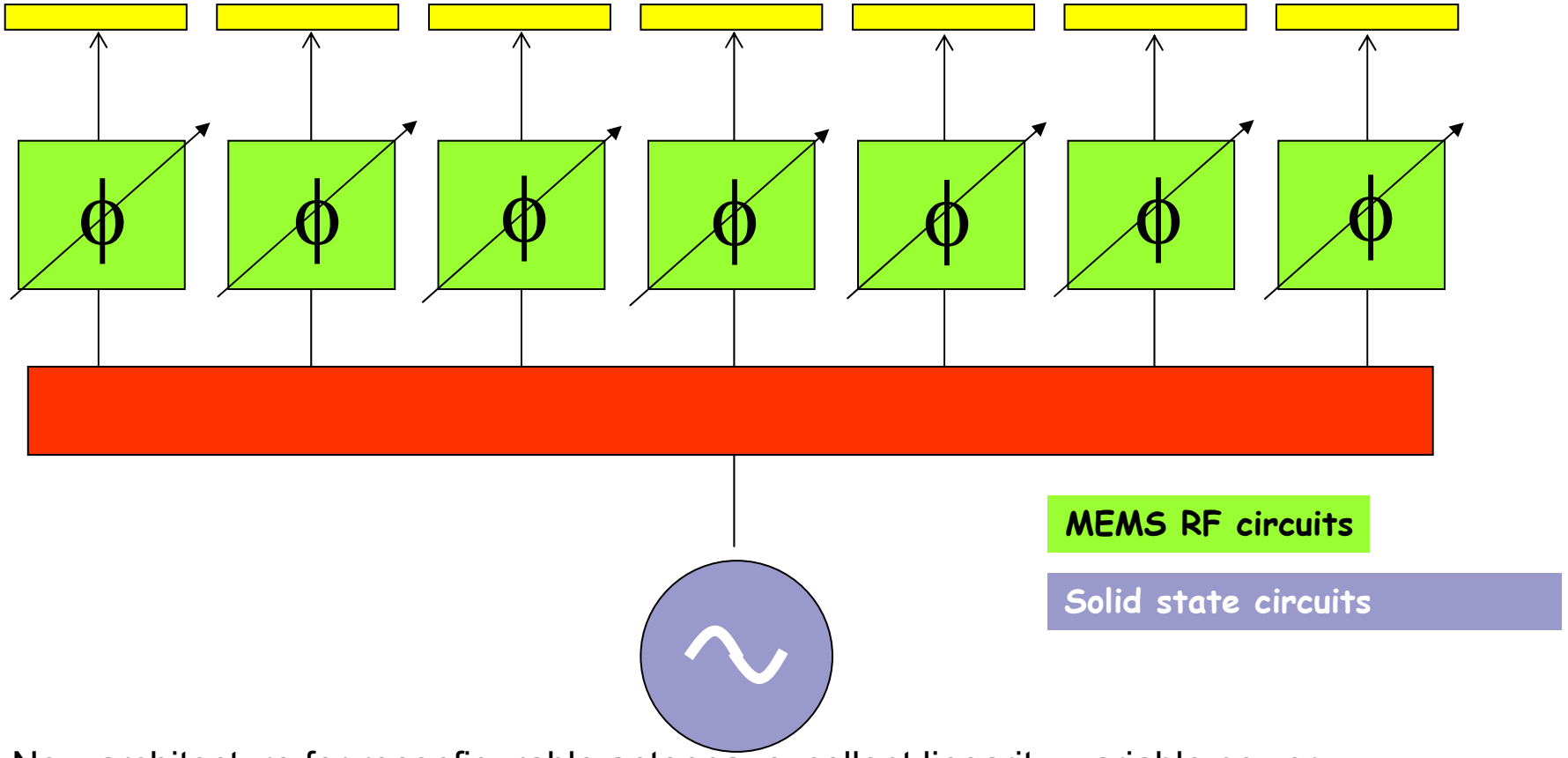


Directive antennas



Smart antenna : reconfigurable circuits @ 60GHz

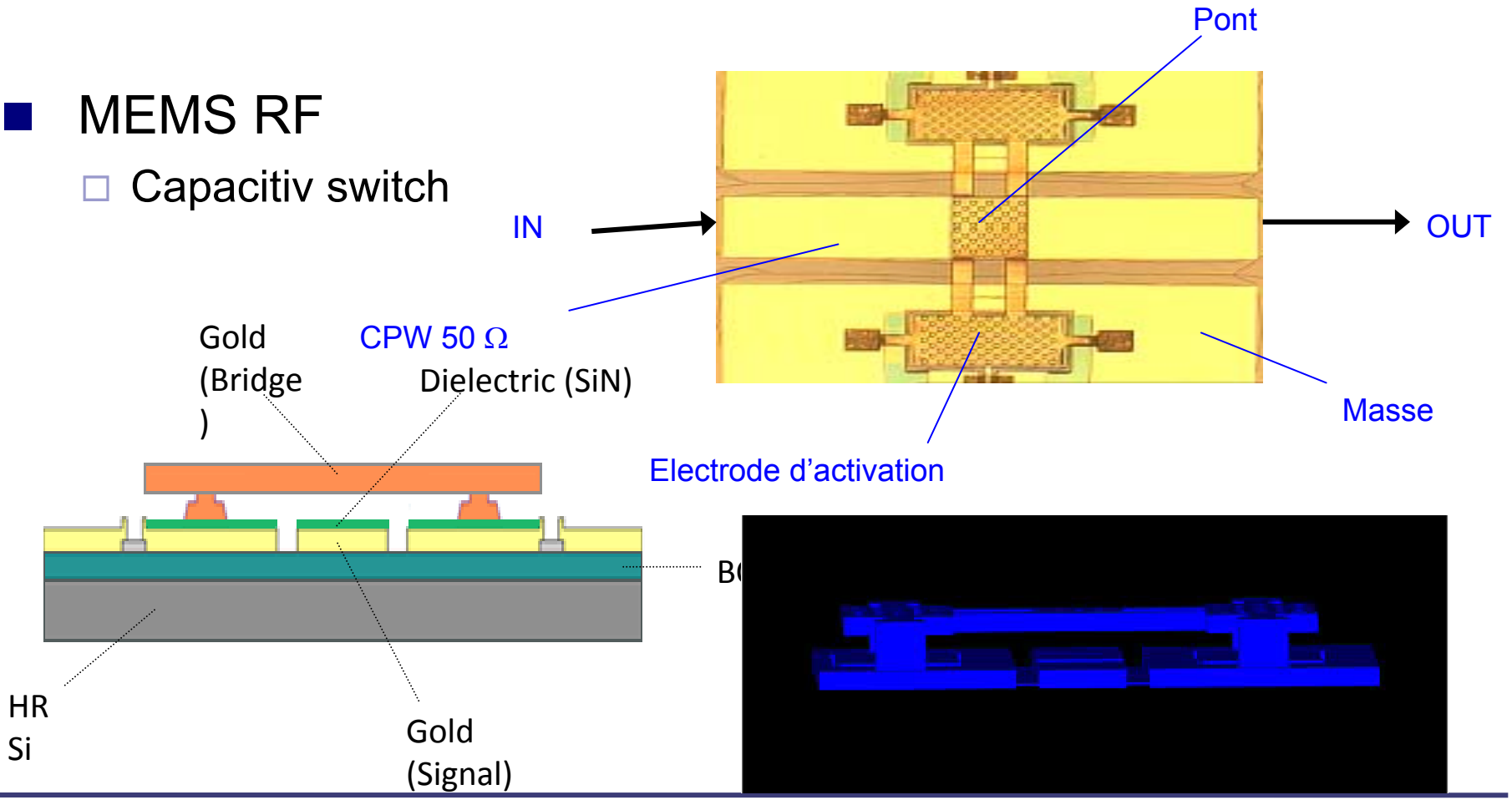
- Reconfigurable antenna in emission diagram and pointing direction.



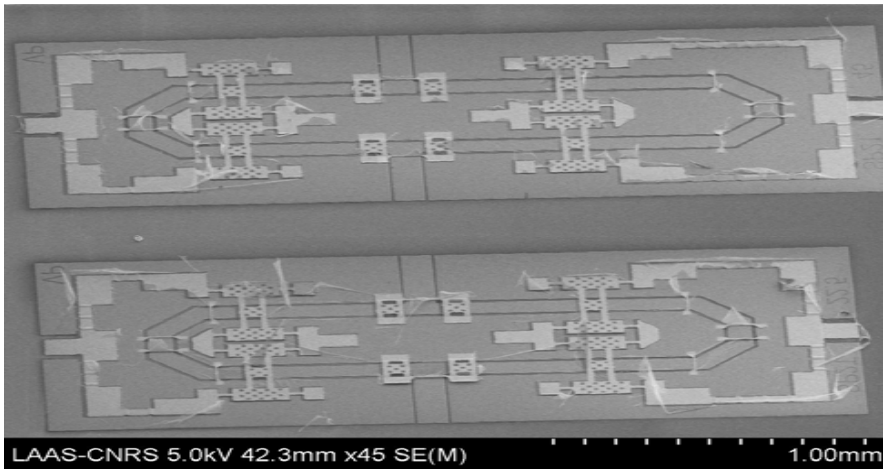
New architecture for reconfigurable antenna: excellent linearity, variable power, integration with the antenna possible

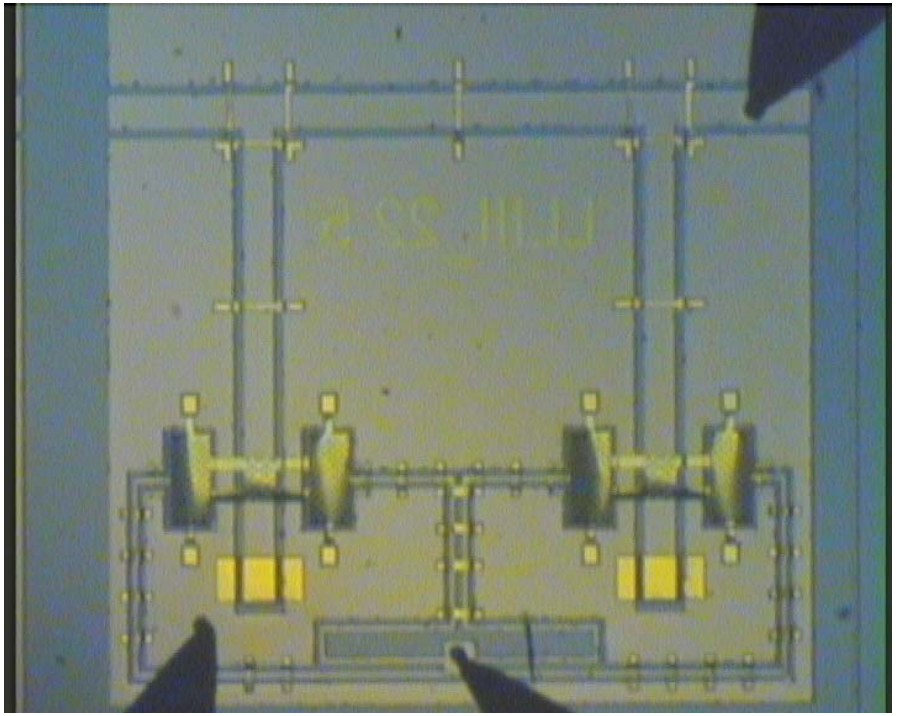
MEMS @ 60GHz

- MEMS RF
  - Capacitiv switch



Fabricated Phase Shifter @ 60GHz





Cross-layering architecture

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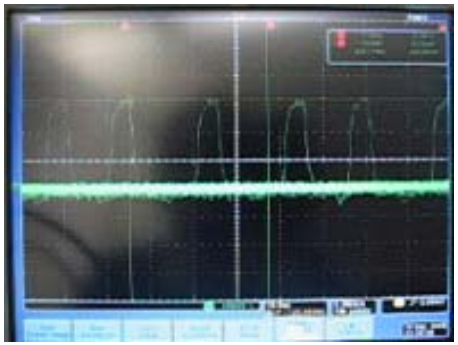
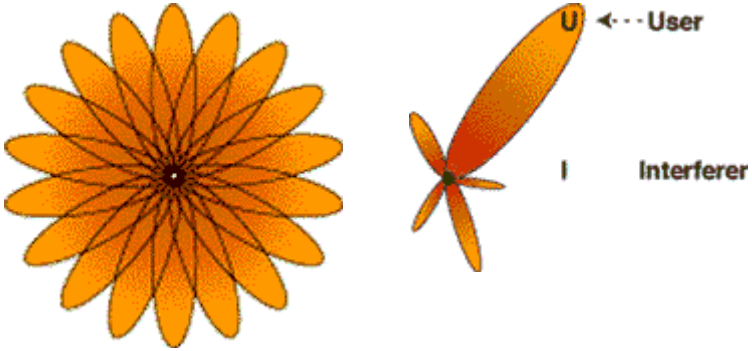
Motivation

- New reconfigurable transceiver
  - Modulation, Spectral Efficiency, Data rate, User code …



- New reconfigurable antennas
  - Improving the BER, Reducing interferences
  - Switch Antennas vs Adaptive Ant.

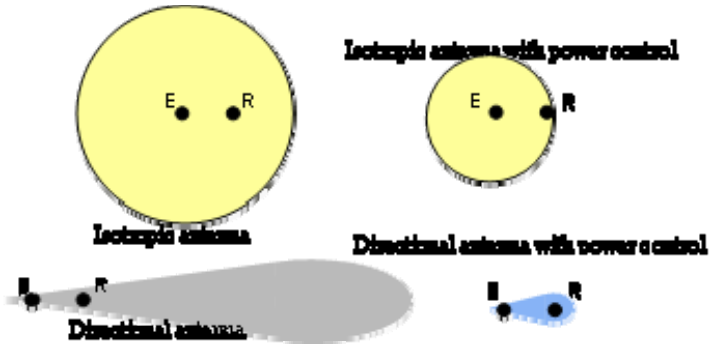


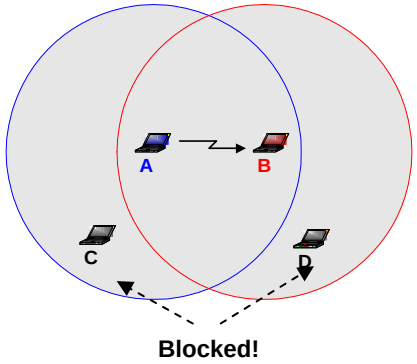
- New Services are needed
  - Localization
  - Synchronization
  - Broadband

- **Idea : Take benefit of the highly reconfigurability of lower layers to the high layers**

Example : benefits of smart antennas on routing protocols

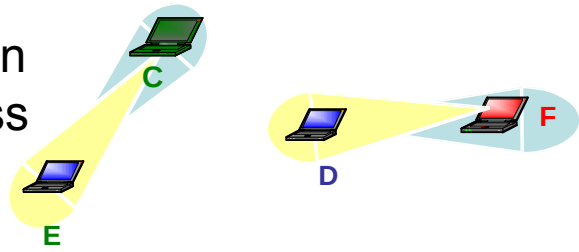
- Smart antenna :
  - **Beam Direction :** Focus on the receiver, avoid interferences
  - **Power Control** :Power consumption and autonomy
  - Better ratio : energy transmitted / energy for reaching the receiver





Double pair problem ?

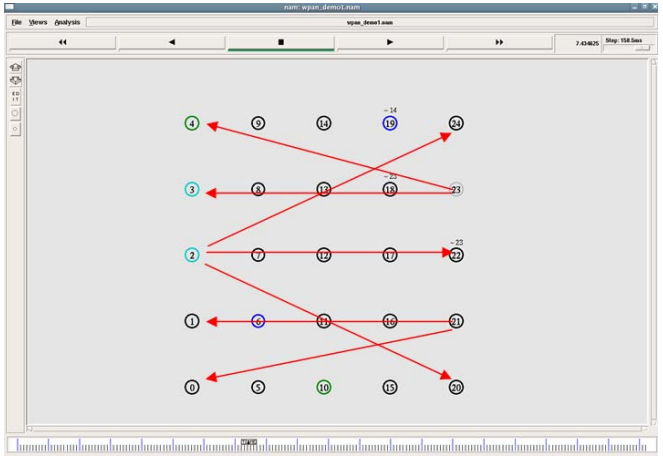
Spatial Division Multiple Access Solution !

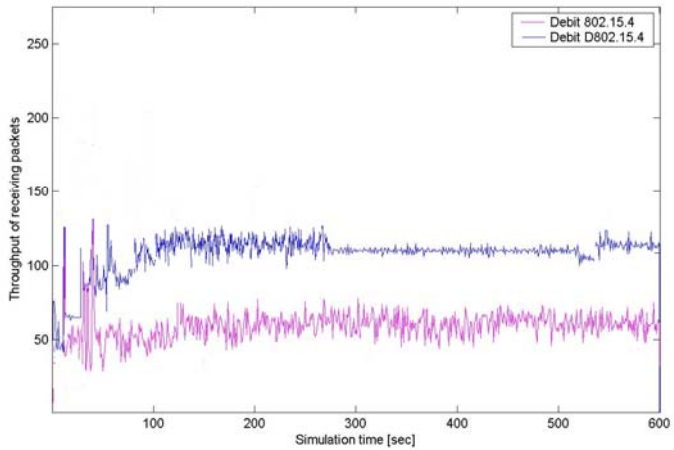


- **Rethink MAC & Network Layer !**

Directional 802.15.4

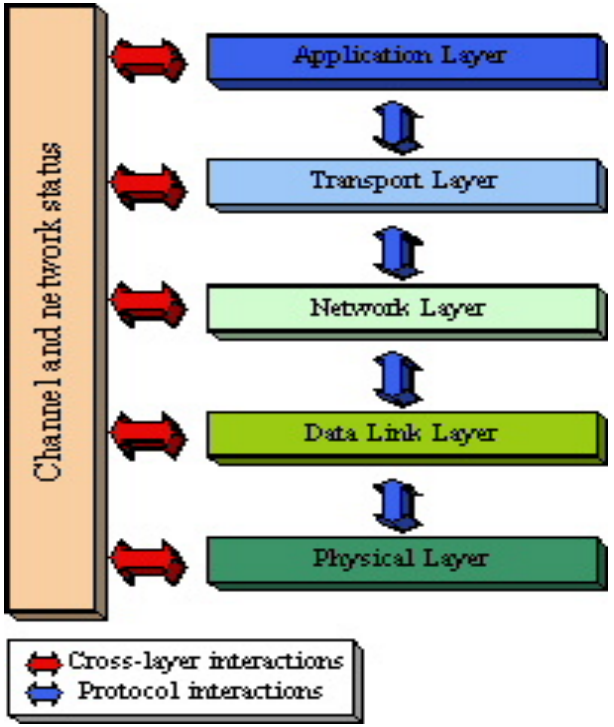
- Extension of Zigbee to use smart antennas (4)
  - Antennas selection according to the receiver estimated position
  - When broadcast is needed :activates the 4 antennas
- NS-2 Model
  - Shows better throughput and lower end to end delay
  - UWB extension is envisaged (802.15.4a)





Cross-layering: architecture

- **Transversal multi-layer communication architecture** with new integrated services
  - Definition of a **MIB (management information base)** with new services
  - Definition of **rules** to use these services
- **First prototype released**
  - Available for linux 2.6.18
  - Tested with 802.11 & TCP



Aerospace application : SACER project

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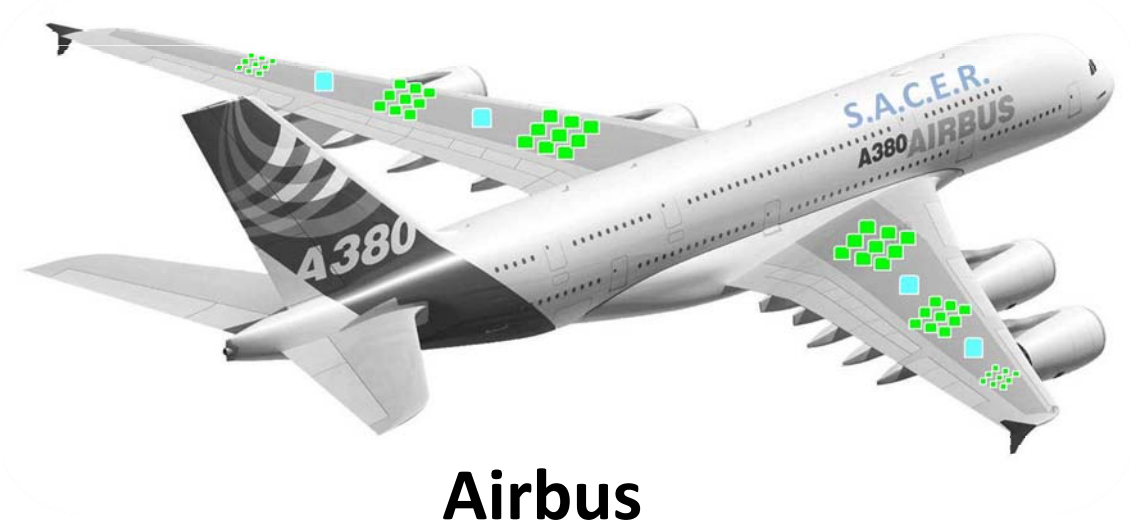
Objectives

SACER is an answer to the Airbus and Intespace needs to dispose data describing the behavior of aircraft and satellite before commercialization.

- To fulfill this need, wireless equipments are requested in order to bring advantages such as
  - less weight
  - less cost
  - Less wire congestion
- The wireless sensor network will replace the existing test equipments whose sensors are still connected by wires

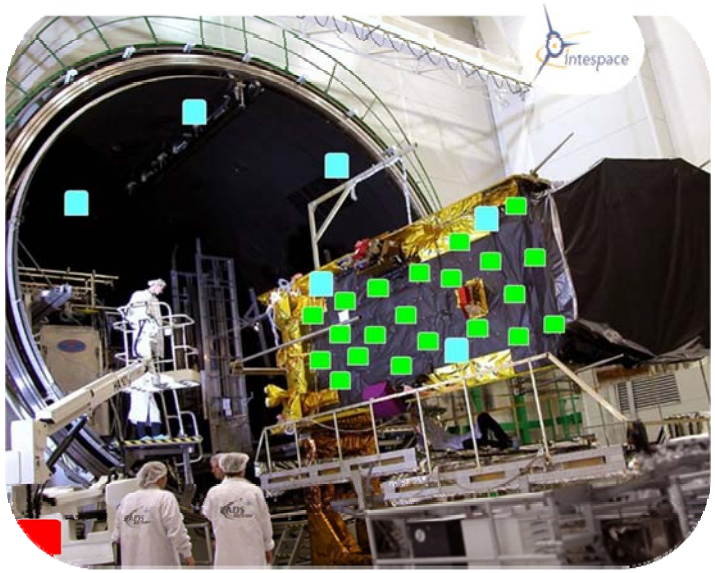
Objectives



Airbus

- Real time measurement of the wings pressure profile
- Verifying and validating results of virtual wind tunnels model

Intespace



- Real time description of the behavior of mechanical structure such as satellites during dynamic tests.
- Gather the structure deformation at different points where strain gauges and accelerometers are implemented

Radio Interface

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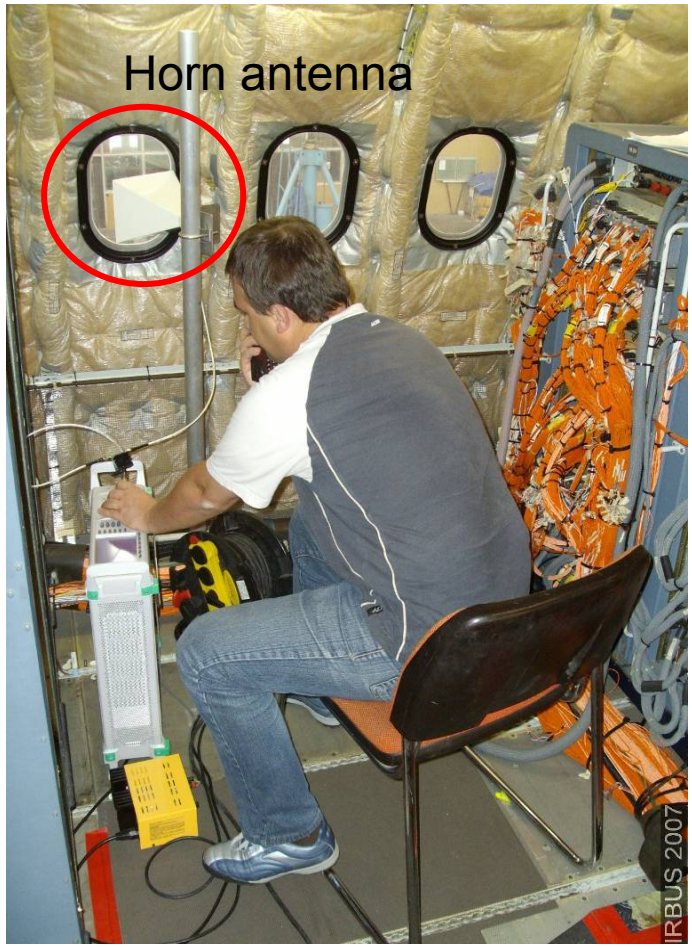
Radio link characterization

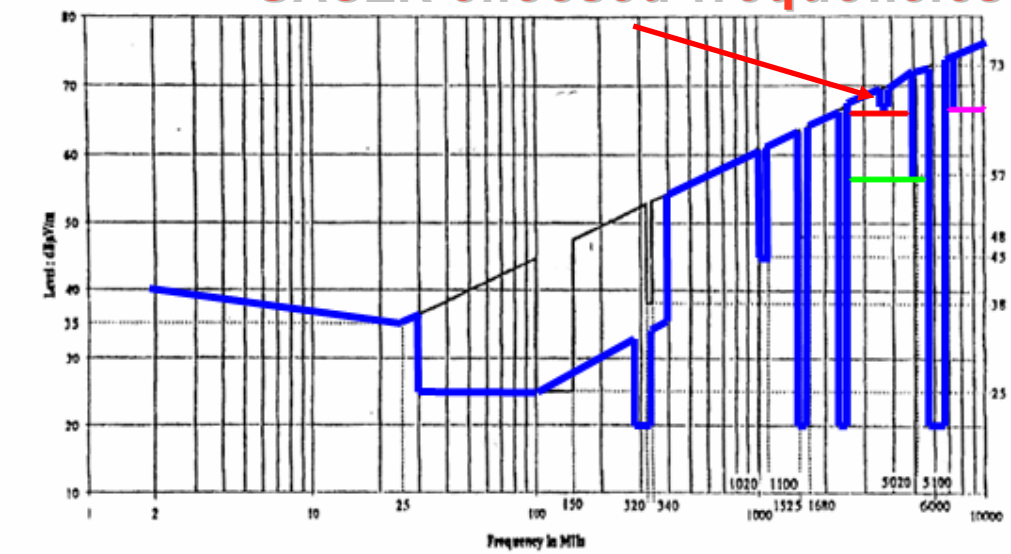


A340 wing

Channel Model : Close to ground propagation !

Limits of usual solutions

SACER choosed frequencies



Aerospace Frequency Regulation

- For low power WSN, the transceiver has to remain as simple as possible : FSK/PSK modulation

But too large bandwidth and to high radiated power : interference with avionics' systems

- UWB communications are an obvious choice for both applications

Tranceiver choice : IR-UWB or MB-OFDM (SC-FDMA)

Network architecture

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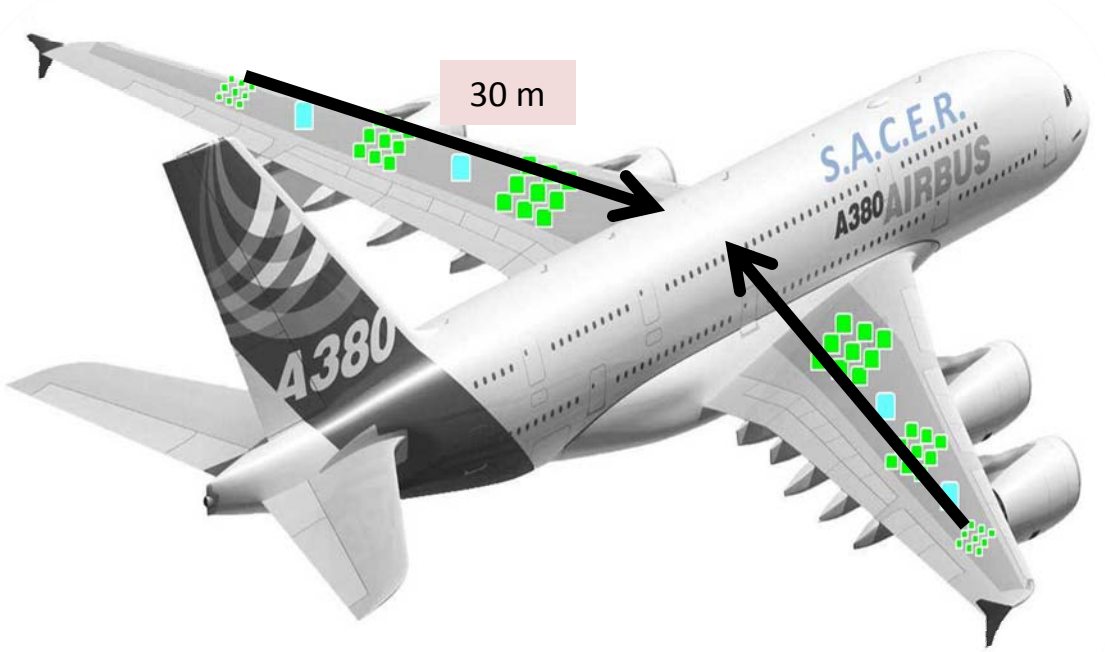
Airbus Specifications

- Hundreds of sensors stuck on the wings (Pressure, Temperature)
- High sensibility and sampling rates
- Precise synchronization of the measures
- Small Packet Error Rate



Possible Architectures

Star network

Mesh network

Tree network

Ring network

- No external power for node and sensor
- 28 V connectors on the wing for routers - repeaters

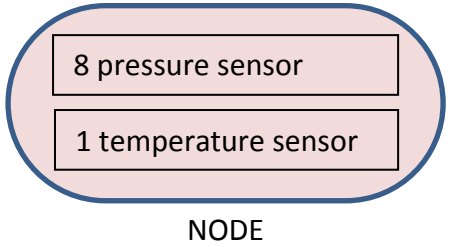
Not enough energy available to allow a direct communication (star network) between node and concentrator

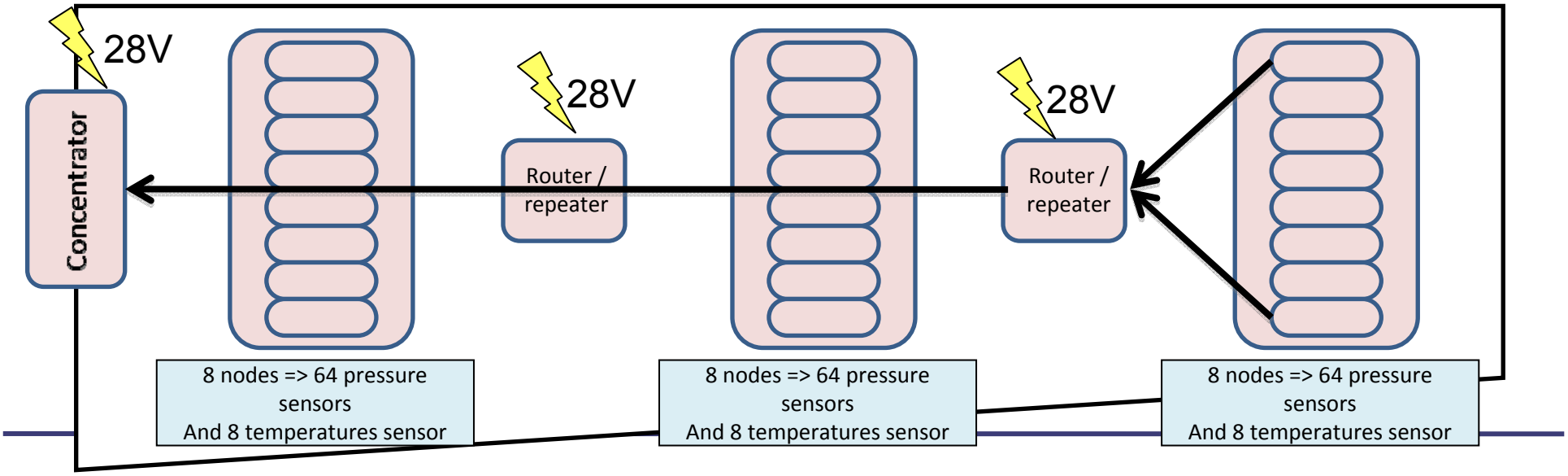
→ Some router - repeater are needed (Tree network with clustered nodes) to decrease the distance between emitter and receiver

Proposed architecture

- 8 pressure sensors per node
- 1 temperature sensors per node

Packaged in a platics gloves stuck over the wings (wired connection between sensors and node)





Proposed architecture

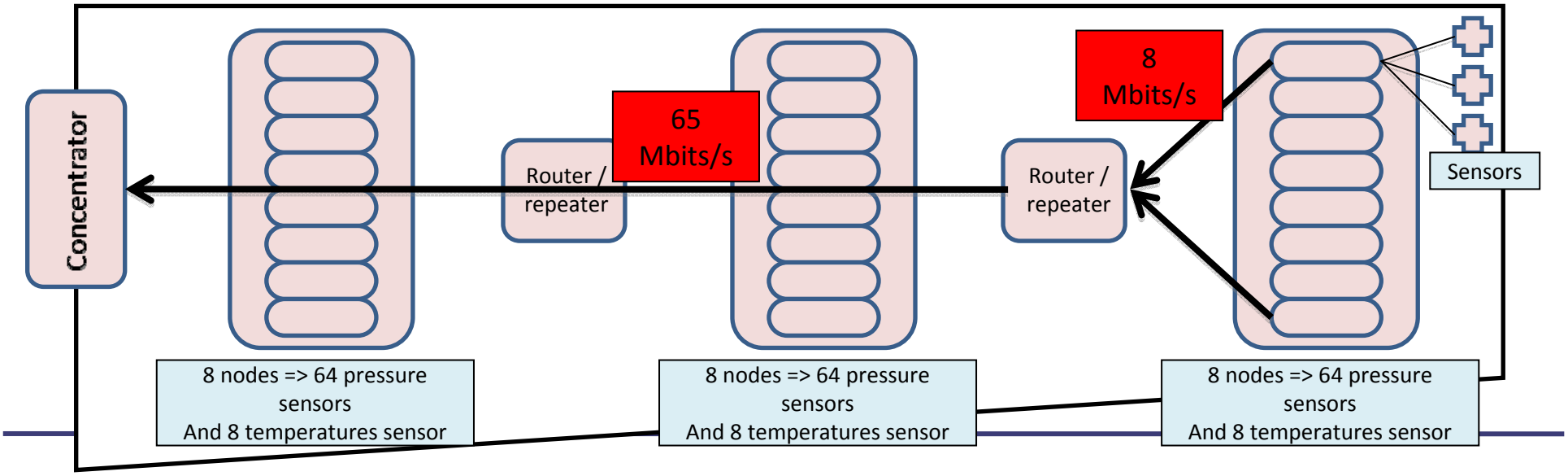
- 8 pressure sensors per node
- 1 temperature sensors per node

- 8 nodes per router

- 3 routers per concentrator

2 concentr. per wings

- Data rate between sensor and node: < 1 Mbits/s (Worst case)
- Data rate between node and router : < 8 x 1 Mbits/s
- Data rate between router and concentrator: < 65 Mbits/s



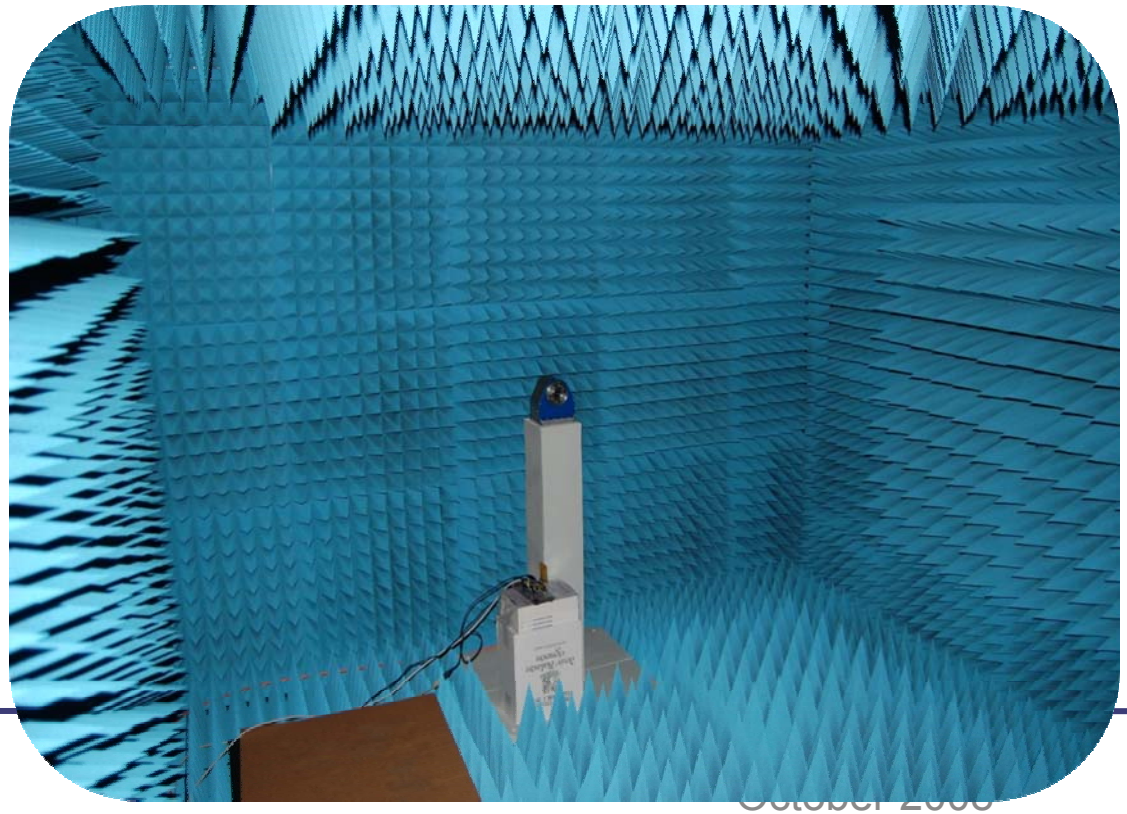
First prototype

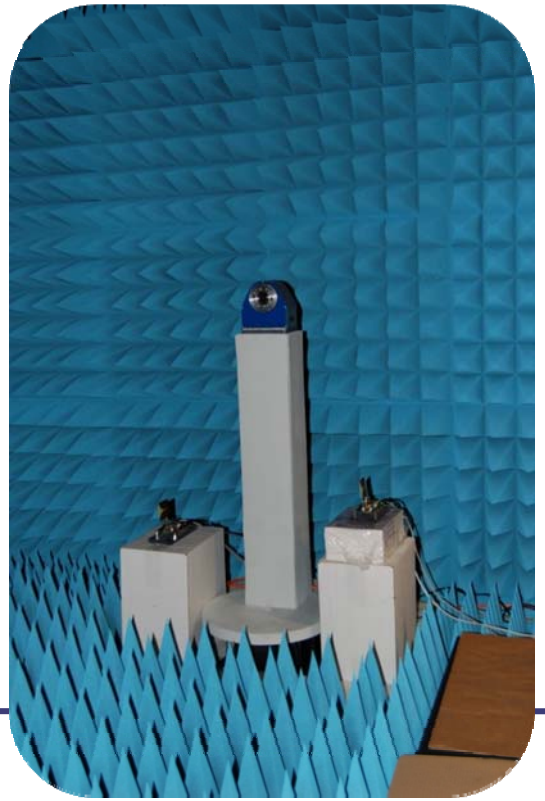
(January 2009)

- To validate a subset of the specifications : 1 concentrator, 1 router, 2 nodes, 16 sensors
- “of the shelves” solution : WIMEDIA cards (UWB)

Measurements in anechoic chamber

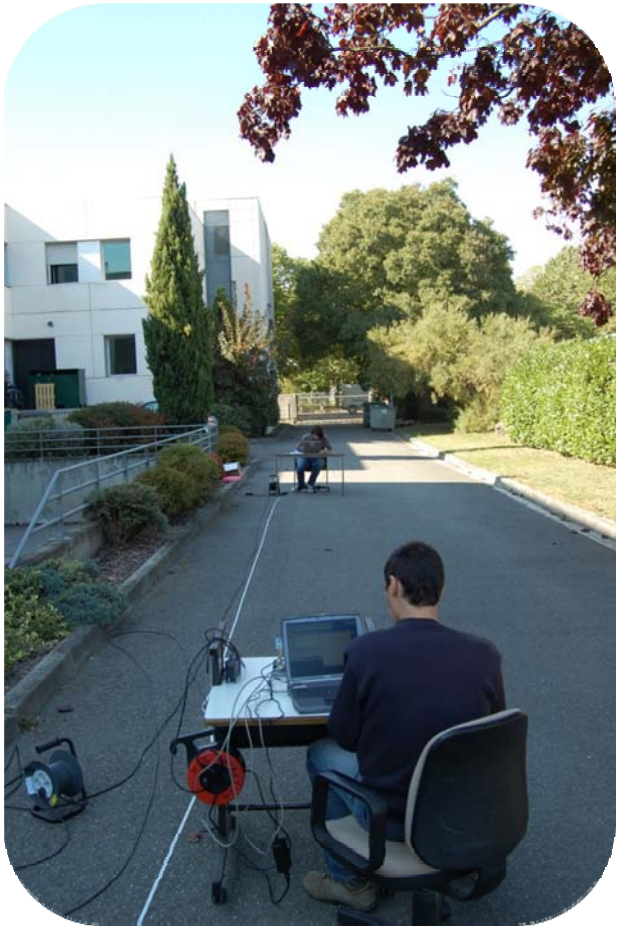
- Wimedia network card : Wisair (MB-OFDM)
  - Point to point measurements
  - No multi-path
  - Distance : 3 meters
  - Throughput reached : 95.7 Mbits/s





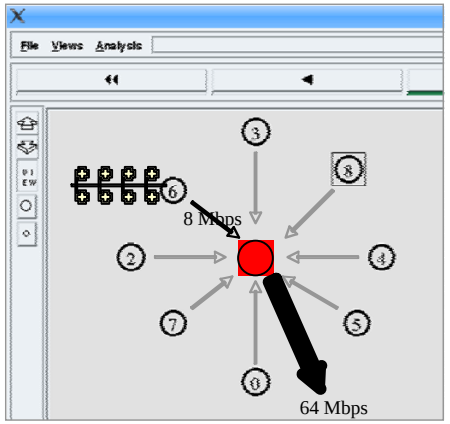
Outdoor measurements

- Point to Point measurement
- Close to the wing model (1 reflexion on ground)
- Distance : 1 – 15 meters
- Throughput reached : 95.7 Mbits/s

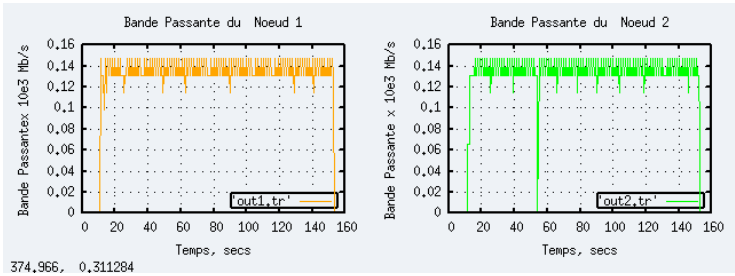


Wimedia NS-2 model

- Prototype modeled with NS-2 :
  - Wimedia model
  - Sacer architecture
- Validation :
  - SACER constraints are respected thanks to Wimedia QoS



Sensor
Node
Router



Conclusion

Conclusion

- SACER project ends in 2011
  - Very constraint application
- Opens perspectives for large application area:
  - demands on hospital monitoring and health applications
- Successful collaboration between hard & soft teams : Cross layering is very promising

WSN Team

- Daniela Dragomirescu (Assoc. Prof.), Herve Aubert (Prof.) ,Robert Plana (Prof.)
- Pascal Berthou (Assoc. Prof.), Thierry Gayraud (Assoc. Prof.), Michel Diaz (D.R.)
  - Vincent Puyal – post-doc – MEMS RF and phase shifter design
  - Christina Villeneuve – post-doc – clean room technology for MEMS and phase shifter
  - Anthony Coustou – research engineer – CAD support and RF circuits design
  - Aubin Lecointre – Ph. D student – PHY and MAC layer for IR-UWB systems
  - Michael Kraemer –Ph.D student – 60GHz transceiver design and system modeling in VHDL-AMS
  - Julien Henaut – Ph.D. student – OFDM systems
  - Ali Kara Omar – Ph.D. student – RF transceiver @ 5GHz
  - Abdoulaye Berthe – Ph.D student – Mac layer
  - Thomas Beluch – Ph.D. student –low power transceivers
  - Roxana Albu – Ph.D. student – cross-layer architecture
  - Akrem Hkiri – Ph.D. student – real-time distributed simulation
  - Ahmed Akl –Ph.D student – aeronautic wireless communication architecture