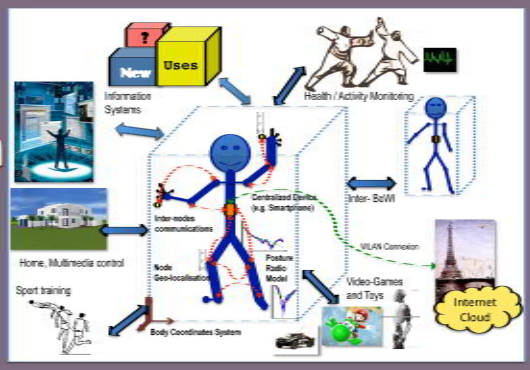
BoWI: Body World Interaction

Lab-STICC (CNRS, UBS, Telecom Bretagne)
IRISA (CNRS, INRIA, UR1)
IETR (CNRS, UR1)



Summary

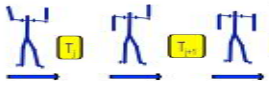
- New wireless, low cost & wearable solutions for posture and gesture recognition
- In- or out-door, everyday environment, without additional equipment
- Cross-layer approach, combining techniques (antennas, wireless, protocols, hw, sw)

Achievements: 1) First demonstration of the interest to use radio signature to improve posture identification **2)** Development of two hardware prototypes (Zyggie V1/V2) and a simulator **3)** Proposition of a posture library and 3 main application scenarios **4)** Channel propagation modeling at 2.4GHz and millimeter-wave **5)** Energy efficiency of distributed precoding for BAN-BS communications **6)** First results distributed power management and energy-proportional architecture **7)** On-body propagation studies in the 60-GHz band.

Usage

- Proposal of an alphabet of postures (Head, Arm, Back, Legs) > 2000 postures
- Three uses cases:

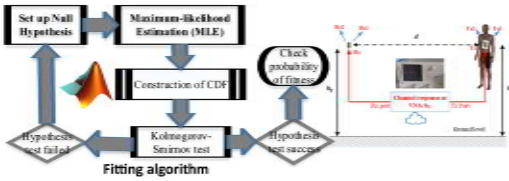
1. Static postures: posture recognition game
2. Gestures = timed sequence of postures: Therapist rehabilitation exercises
3. Motion capture: sport, game, etc.

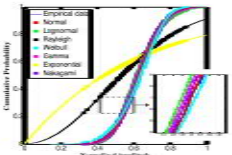

(1)

(2)

(3)

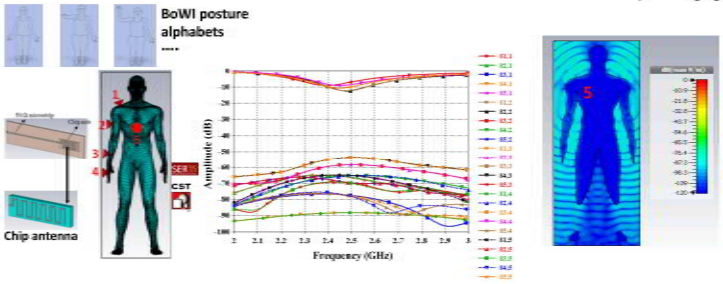
Radio

- Off-body diversity channel analysis (**delay profile, delay spread, channel capacity**)
- A **robust fitting algorithm** to find the optimum **channel model** applied to various **off-body** and **on-body** channel measurements using **Zyggie**
- **Numerical channel simulator** using commercial tool (**POSER®**) with **CST®**
- Miniature **chip antenna** design + impact of antenna polarization/pattern





Normal distribution for LoS off-body channel detected by the **fitting algorithm**

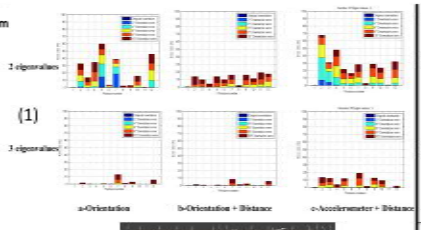


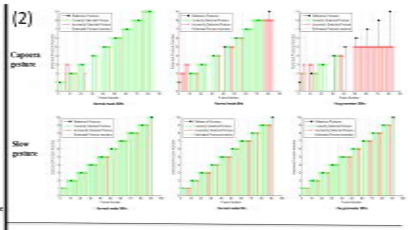
Algorithms

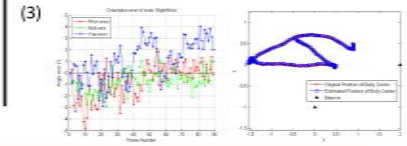
- **Case 1 "Static Postures":** RSSI matrix used as a signature, data fusion based on:

a. Acc + Mag: node orientation M[3x3] => Local basis + PCA + orientation ref. (e.g. manager)
b. Node orientation (Acc + Mag) M[3x3]+RSSI => Improved results or reduced PCA basis
c. If Mag NOK (environment perturbation): Acc + RSSI raw data => No orientation ref. close to a.
d. Two Steps: 1) Acc-based pre-selection 2) reduced PCA
e. Work-in-progress: comparison PCA vs. Artificial Neural Networks vs. K-means

- **Case 2 "Gesture":** linear acceleration => Acc + Mag and Acc + RSSI not usable as in case 1
  - EKF => quaternions => PCA inputs and controlled use of Gyro
  - Classification + timing analysis
- **Case 3 "Motion capture":** orientation + avatar + fixed beacons for geolocation







d. Experimental results with Zyggie V1. 5 persons but only 4 for training, Accelero for selection of 7 main classes + RSSI with limited PCA: recognition rate of 98%

Cooperative communications

- Why choosing distributed MIMO precoding?

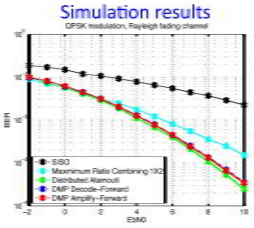
1) Reduce transmission power thanks to the adaptation to the channel
2) Compensate for rate loss (2-slot) with symbol combination (spatial multiplexing)

- Challenges

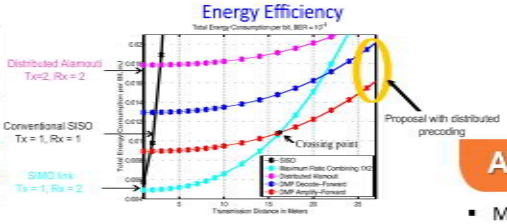
- Take into account the cooperation aspect for the precoder solution
- Design a dedicated MAC protocol
- Deal with the BAN channel characteristics for the local transmission

Distributed precoding via the Amplify-and-Forward protocol

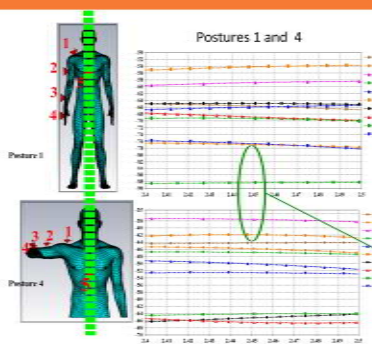
Simulation results



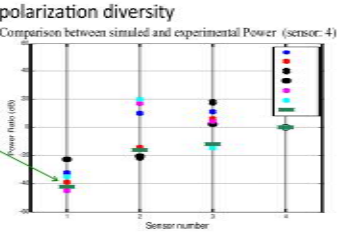
Energy Efficiency



Radio numerical results / Algorithms

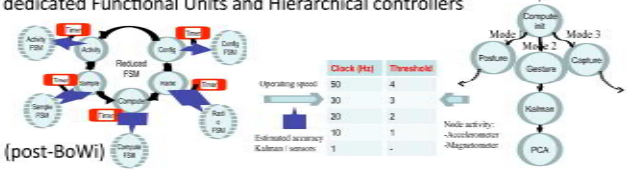


- Training PCA with theoretical values, use PCA eigenvalues in real conditions
- Perspectives: More postures, Design of adaptive antenna for BoWI, Pattern/ polarization diversity



Architecture

- More computation for less communication = Power Savings (1/100 less wireless data # 10^6 MACs)
- Power Management driven by motion and application accuracy needs
- Architecture with dedicated Functional Units and Hierarchical controllers



- ASIC specification (post-BoWi)

Zyggie Prototype

- V1: Motion capture data for simulation, algorithm validation, Android app.
- V2: UWB for local positioning, CORTEX M4 for embedded computing