

# Cooperative Communications in Body Area Networks

Paul Ferrand, Claire Goursaud, Jean-Marie Gorce

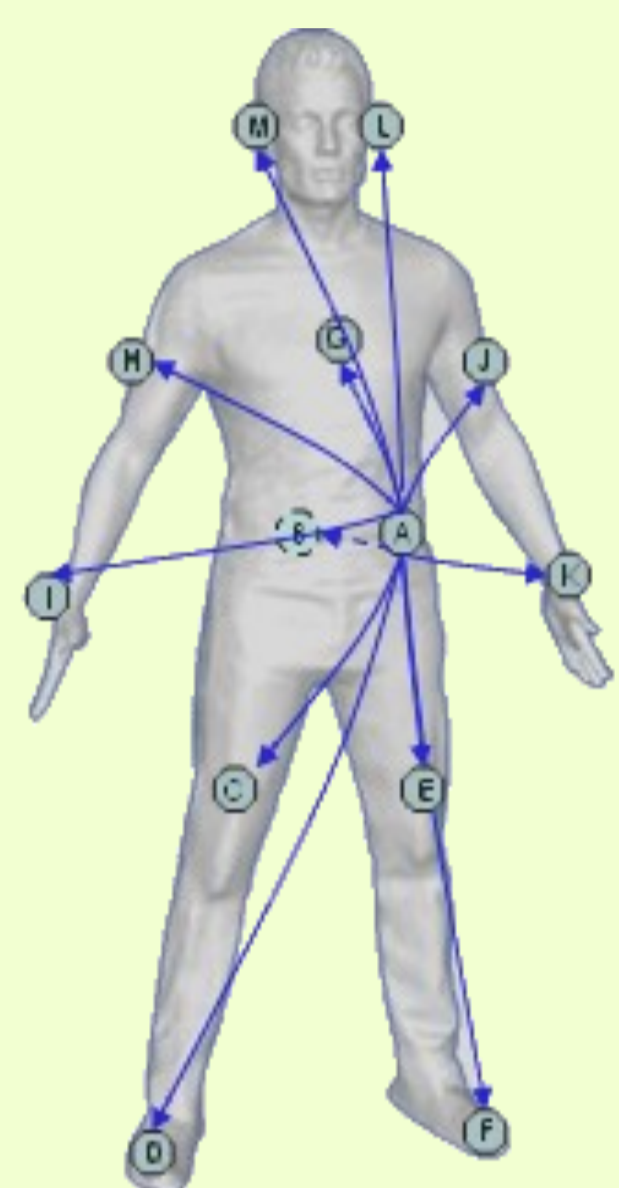
Université de Lyon, INRIA

INSA-Lyon, CITI, F-69621, Villeurbanne, France

CITI Centre d'Innovation  
en Télécommunications et Intégration de Services

## Context

### Body Area Networks



- Wireless sensor networks located in or in close proximity to the human body
- Main uses :
  - Medical Field
  - Sports
  - Entertainment Field
- The future is filled with an increasing number of appliances communicating around the body, possibly with each other

- Common limitations with WSNs (Energy, memory, size)
- Yet very different (very few nodes, ergonomics constraints, health concerns and the transported information is often very sensitive)
- Model used : **12 nodes and 1 sink on the hip**

## Packet error analysis



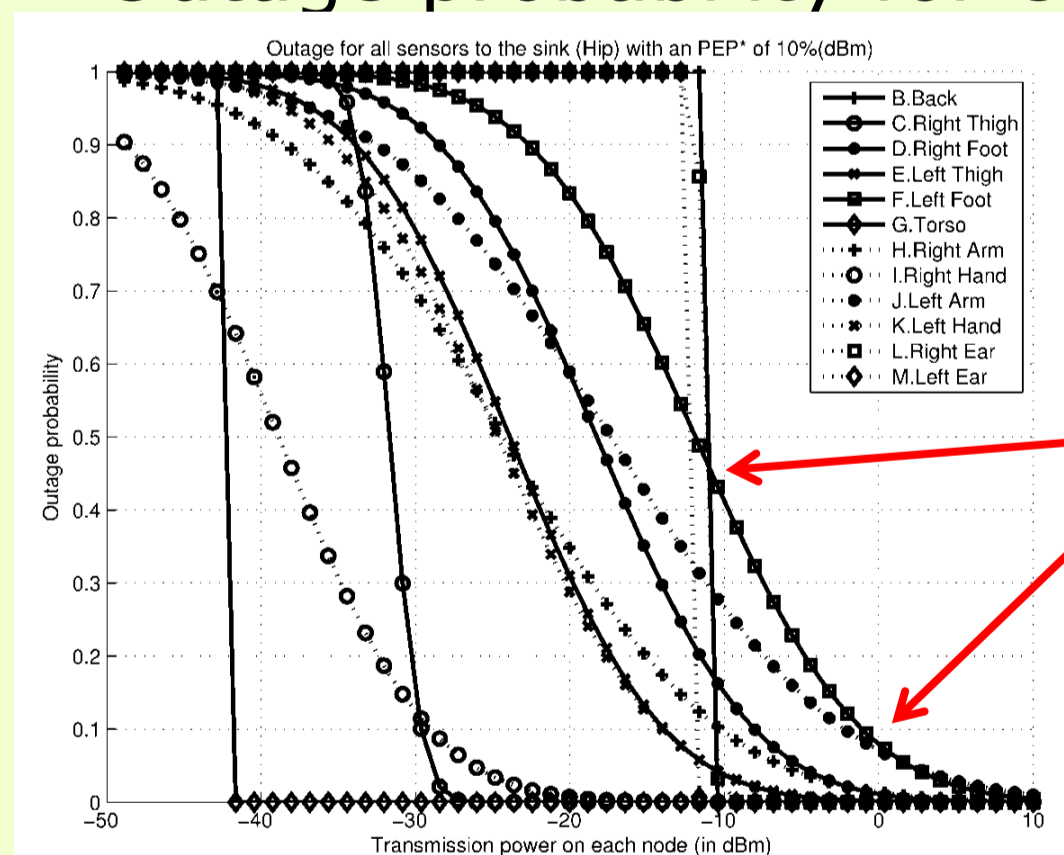
- Due to variation in the channel gain, the mean Packet Error Rate or instantaneous PER are not interesting metrics
- Outage Probability :

$$\Pr(O) = \Pr(\text{PER} > x) \quad x : \text{outage threshold}$$

- Integrate fading statistics into a « short-term » PER corresponding to a packet size, and calculate the probability this PER goes beyond a given threshold
- Hardly tractable result :

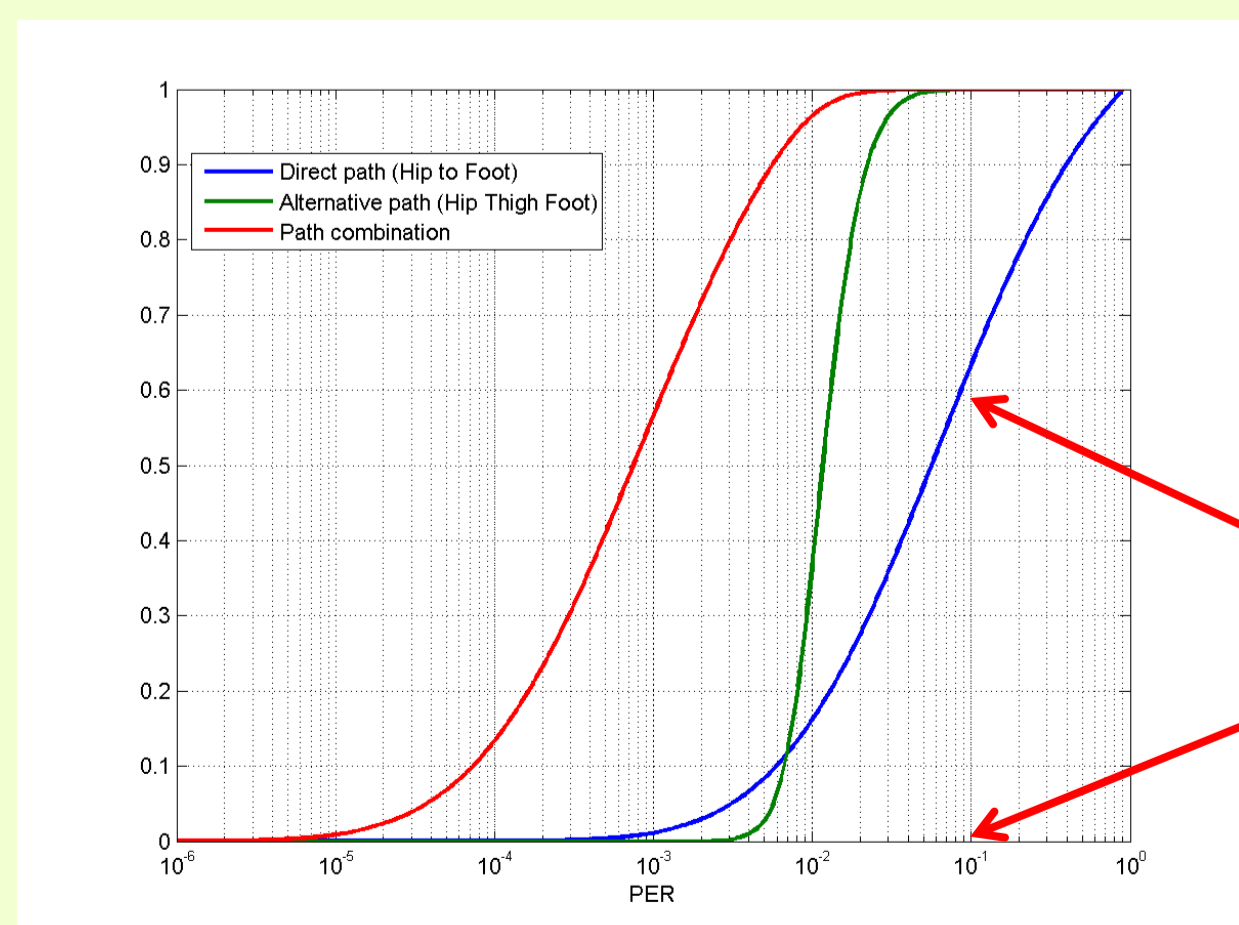
$$\Pr(E|\bar{\gamma}) = \int_0^{\infty} Q\left(\frac{\sqrt{\gamma}}{2}\right)^N \frac{(1+K)e^{-K}}{\bar{\gamma}} \exp\left(-\frac{(1+K)\gamma}{\bar{\gamma}}\right) d\gamma$$

- Numerical approximation for the outage computation
- Outage probability for each node:

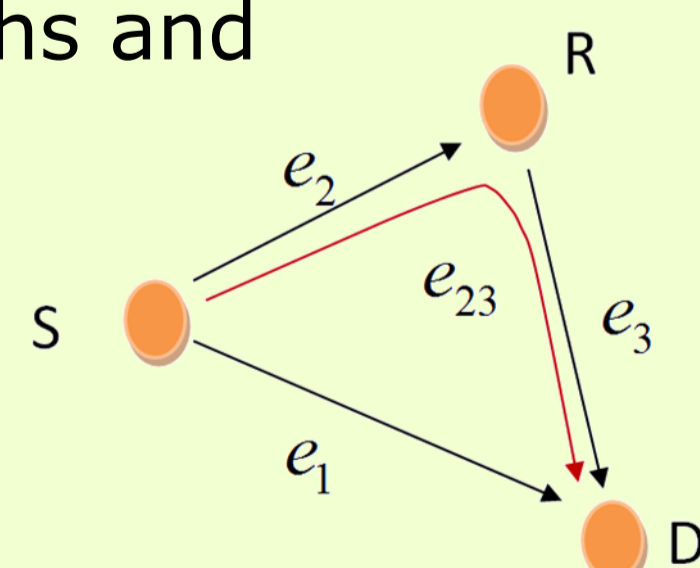


At 0 dBm and -10 dBm, some extreme nodes still have a high outage probability

- Relaying on the Foot->Thigh->Hip paths and cumulative outage of the network

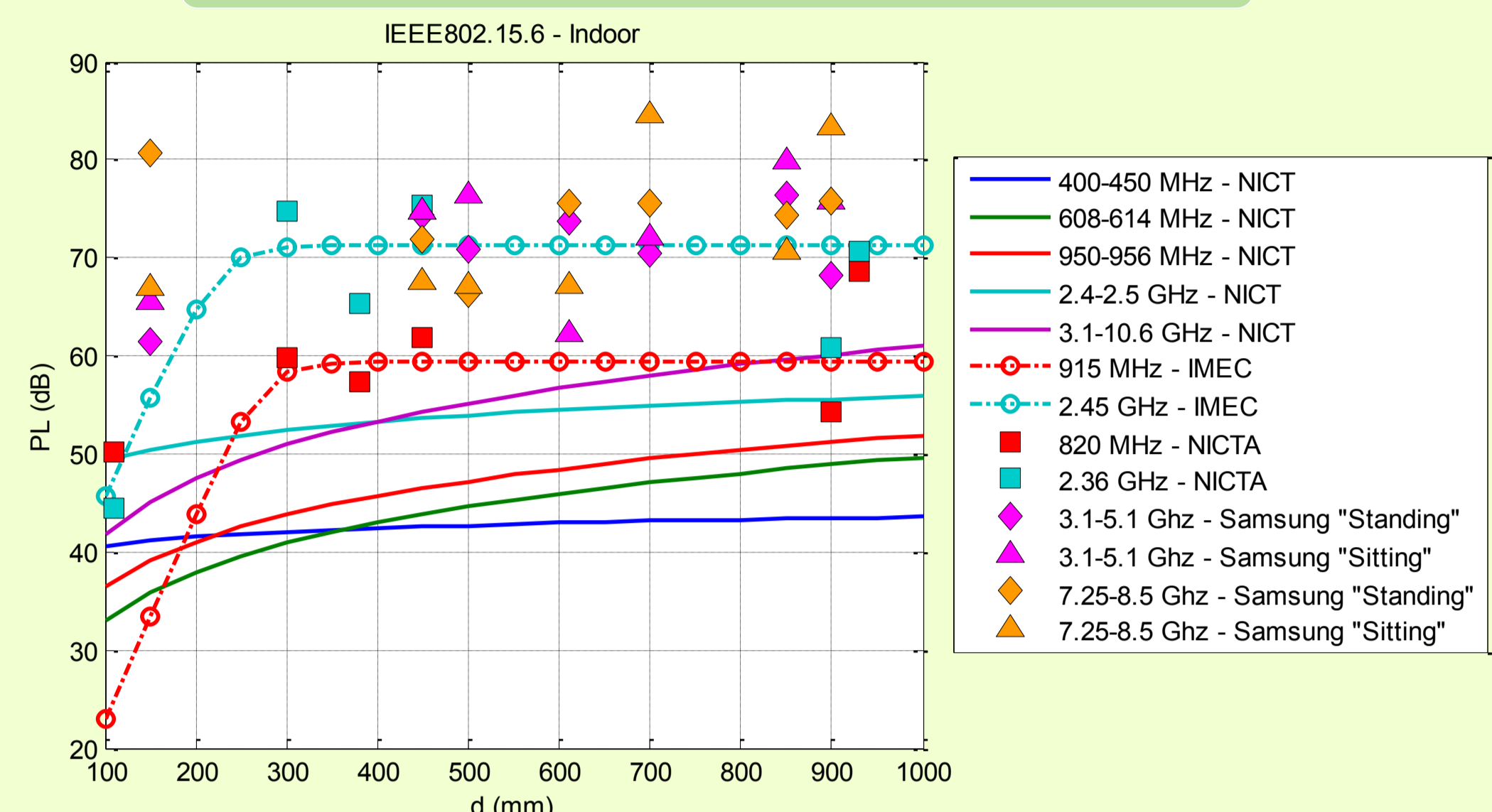


Threshold for the outage at 10%  
→ Link in outage 40% of the time



- Using relays greatly increases the link stability

## A specific channel model



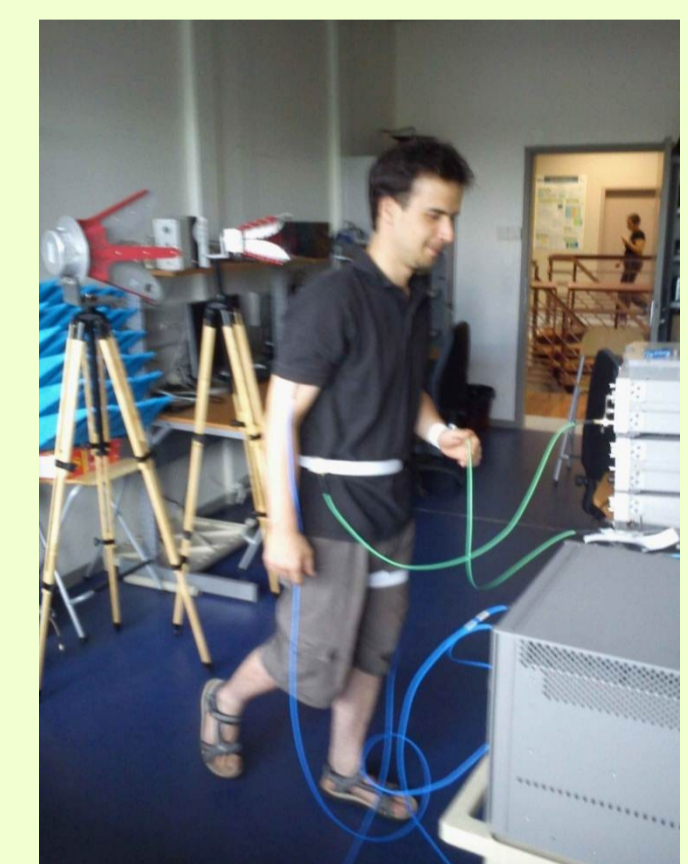
- The path loss in indoor environments does not depend on distance (**saturation model**)
- Virtually no propagation through the body
  - Body movements create a strong shadowing effect
- Consequently, the fading strength is very dependent on the current body position
  - With LOS between nodes the fading is weak
  - Without LOS between nodes the fading is very strong
- Specific time-variant topology
  - Nodes near the sink (the hip in our models) will have stable links
  - Others will be unstable
  - ... But not necessarily between each other!
  - Links switch between stable and unstable periodically (due to repeated body movements like walking or running)

## Very prone to opportunistic relaying

## Ongoing work

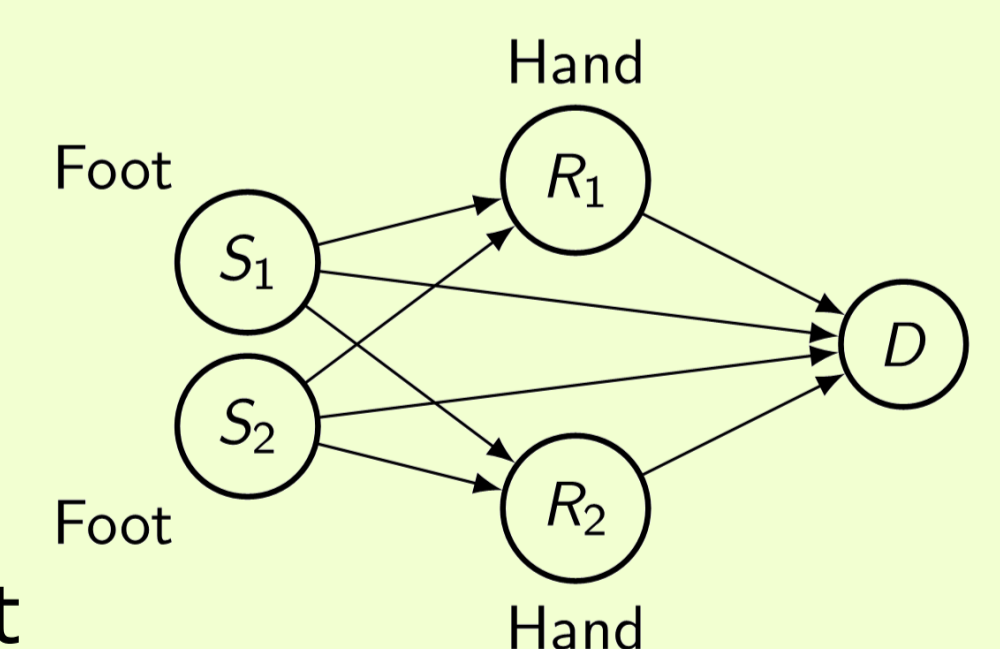
### Channel sounding

- 2 emitters and 2 receivers simultaneously (characterize the correlation of the links)
- Shadowing temporal correlation characterization and modelling
- Improving the CITI network simulator with realistic BAN propagation layers



### Network model

- Simplify the network and derive the capacity
- Develop versatile techniques to improve reliability and capacity while minimizing the energy consumption, using the fact that we can predict the channel



### Cross-layer protocol design

- Manage the predictions and perform regressions to adapt the models of the PHY layer
- Triggering a relay operation automatically, based on the prediction of the state of another link
- Adapt coding rates to increase the spectral efficiency of the network as a whole, and to ensure that latency constraints are met