Cooperative Communications in Body Area Networks

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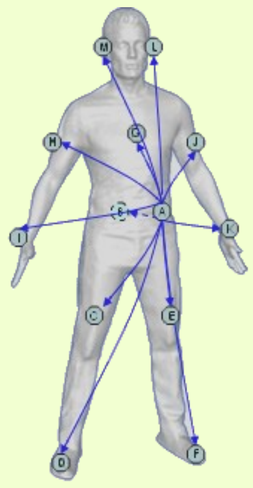
Context

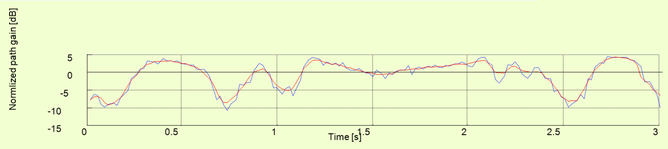
Body Area Networks



- Wireless sensor networks located in or in close proximity to the human body
- Main uses :
  - Medical Field
  - Sports
  - Entertainement 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, ergonomy constraints, health concerns and the transported information is often very sensitive)
- Model used : **12 nodes and 1 sink on the hip**

Packet error analysis



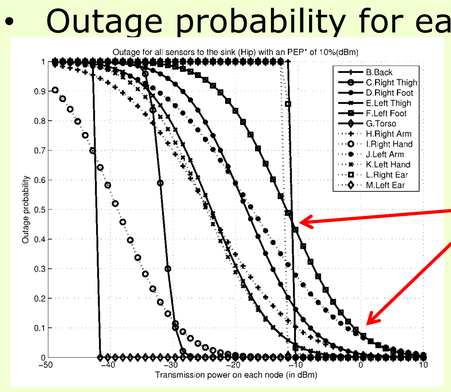
- Due to variation in the channel gain, the mean Packet Error Rate or instantaneous PER are not interesting metrics
- Outage Probability :

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

- 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 :

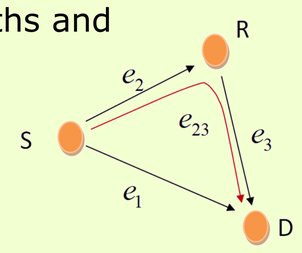
$$\Pr(E|\bar{\gamma}) = \int_0^\infty Q\left(\frac{\sqrt{\gamma}}{2}\right)^N \frac{(1+K)e^{-K}}{\bar{\gamma}} \exp\left(-\frac{(1+K)}{\bar{\gamma}}\gamma\right) d\gamma$$

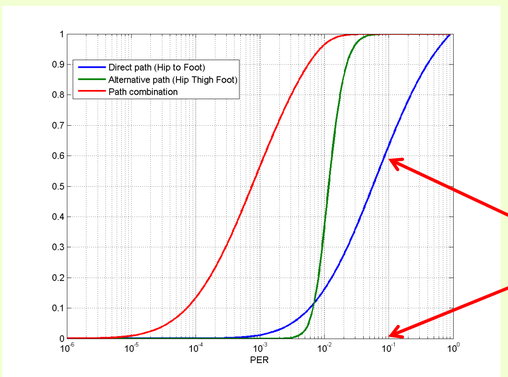
- Numerical approximation for the outage computation
- Outage probability for each node:



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

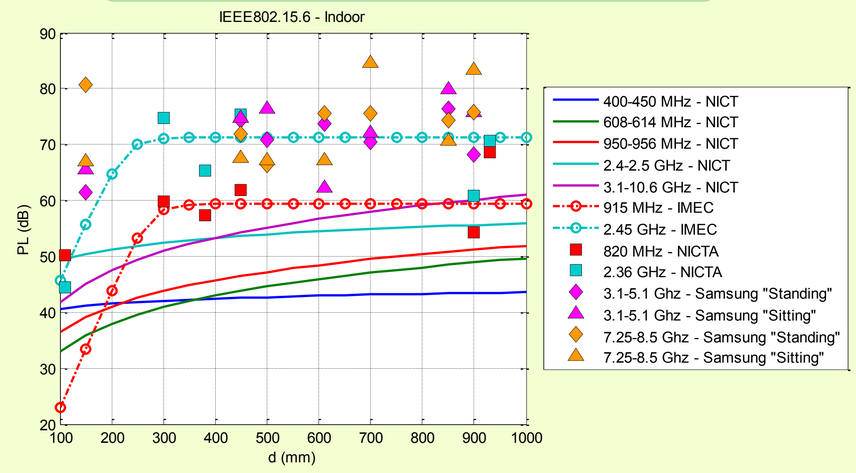




Threshold for the outage at 10%
→ Link in outage 40% of the time

- Using relays greatly increases the link stability

A specific channel model

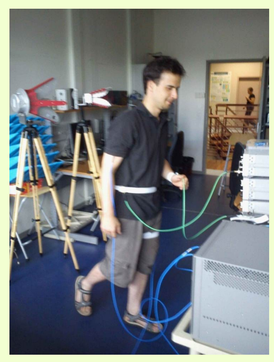


- The path loss in indoor environments does not depend on distance (**saturation model**)
- Virtually no propagation through the body
  - Body movements create a strong shadowing effect
- Consequently, the fading strength is very dependent on the current body position
  - With LOS between nodes the fading 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)

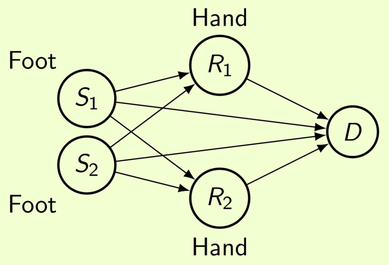
<u>Very prone to opportunistic relaying</u>

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

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