Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Sleeping channel measurements for body area networks]
Date Submitted: [November, 2009]
Source: [Dino Miniutti[12], David Smith[12], Leif Hanlen[12], Andrew Zhang[12], Athanassios Boulis[1], David Rodda[1], Ben Gilbert[1]] Company [NICTA[1], The Australian National University[2]]
Address [7 London Circuit, Canberra, ACT, 2600, Australia]
Voice:[+61-2-6267-6256], FAX: [+61-2-6267-6220], E-Mail:[dino.miniutti@nicta.com.au]

Abstract: [300+ hours of sleeping BAN channel measurements with characterisation of data in terms of outages with respect to receiver sensitivity. Showing that channel outages are greater than 10% with -100 dBm receiver sensitivity.]

Purpose: [To help design and evaluate BAN systems.]

Sleeping channel measurements for BAN

NICTA & The Australian National University
Dino Miniutti, David Smith, Leif Hanlen, Andrew Zhang

NICTA
Athanassios Boulis, David Rodda, Ben Gilbert

Outline

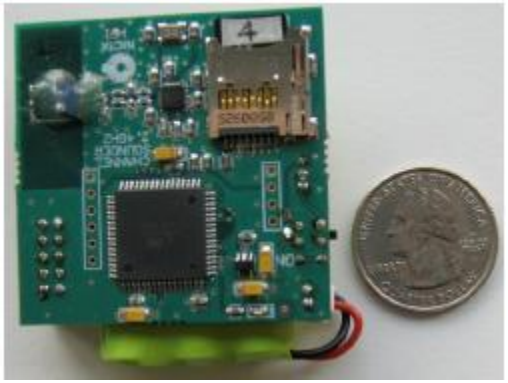
- **Motivation:** People have asked about what happens to the BAN channel when people are sleeping
  - Have done some sleeping measurements
  - People at home in bed (not hospital)

- Analysis:
  - Channel gain distribution
  - Outage probability
  - Outage duration

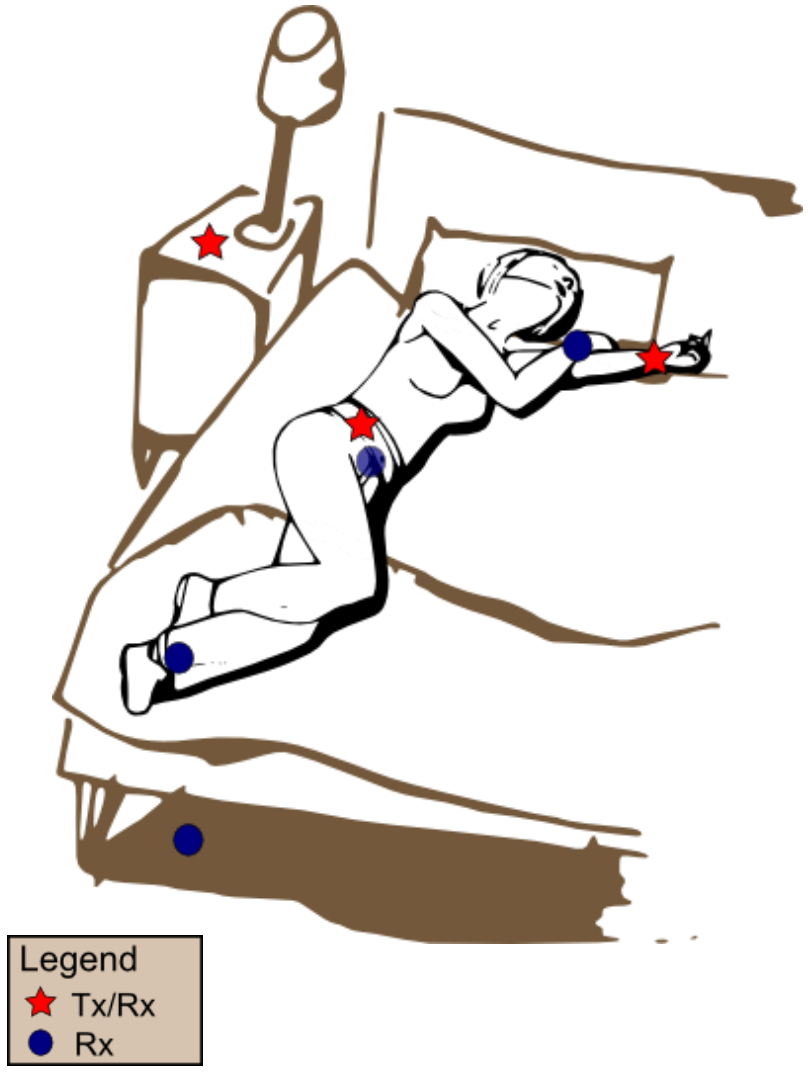
- *Outage = Received power < Receiver sensitivity*

Experiment setup

- Using NICTA's body-worn "channel sounder" (same one used in previous measurements)
- Measured people sleeping/lying in bed
  - Majority of data is for people sleeping
- 12 subject measurements (8 different adults)
  - Each measurement 2 hours or more (over 300 hours in total)
  - Just outside 2.4 GHz ISM band (to avoid ISM interference)
  - 0 dBm transmit power
  - RSSI sampled every 15 ms
  - 183 link measurements
    - 85 on-body to on-body
    - 98 on-body to off-body



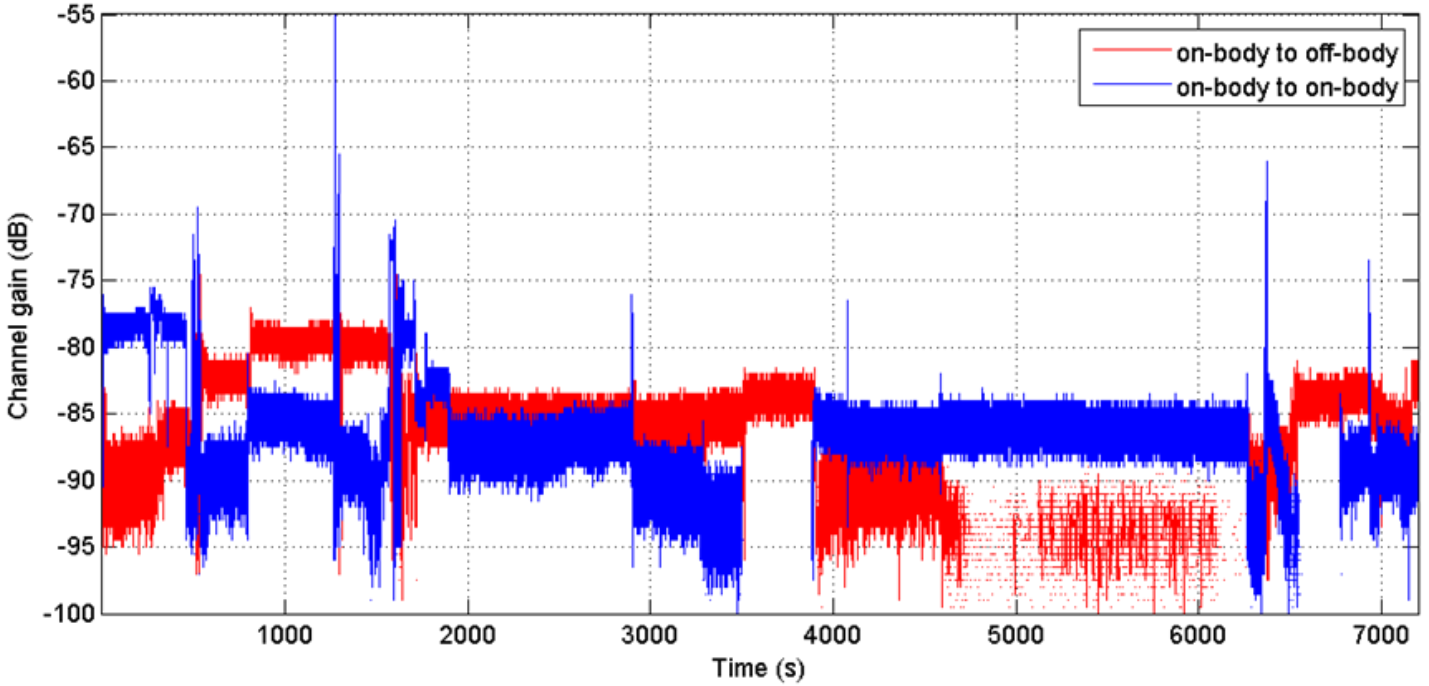
Measurement positions



Device positions	Device type
Next to bed (head)	Tx/Rx
Left wrist	Tx/Rx
Hip (front)	Tx/Rx
Next to bed (foot)	Rx
Right wrist	Rx
Hip (back)	Rx
Left ankle	Rx

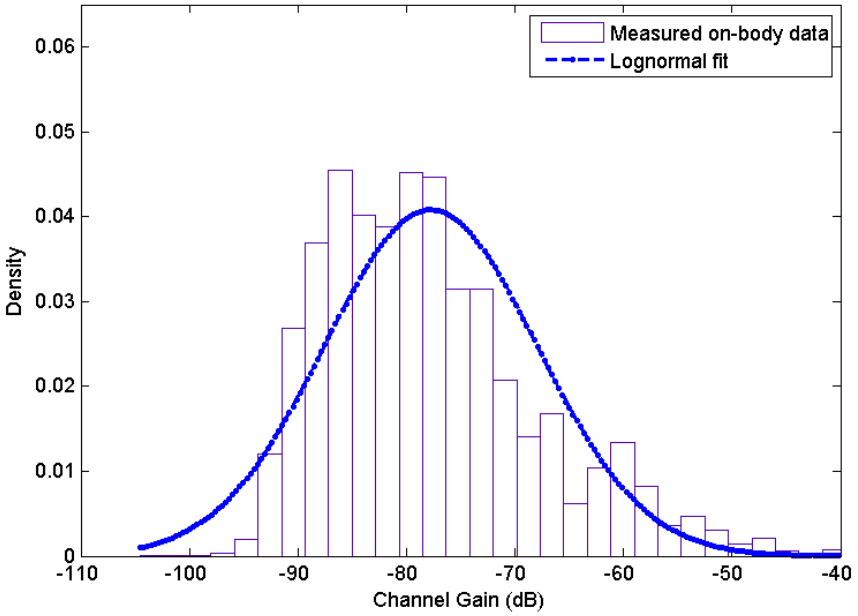
Transmitting devices also receive packets from all other transmitters. Physically they are the same, but they run different firmware

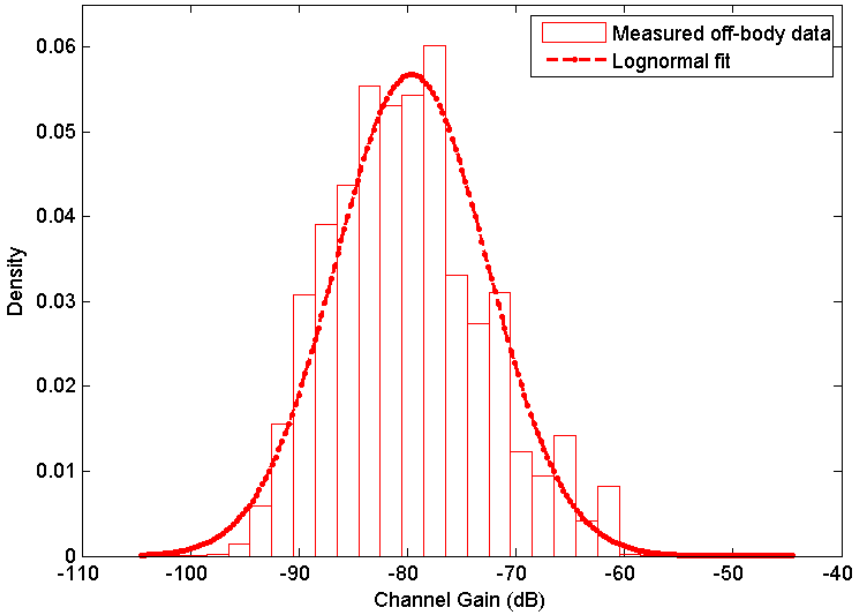
Typical measurement (example)



- General trend is for long periods where RSSI is stable
- Gaps in figure correspond to RSSI dropping below channel sounder receive sensitivity (approx: -100 dBm)
  - Including all data, this occurs 14.8% of the time for on-body and 14.9% of the time for off-body channels

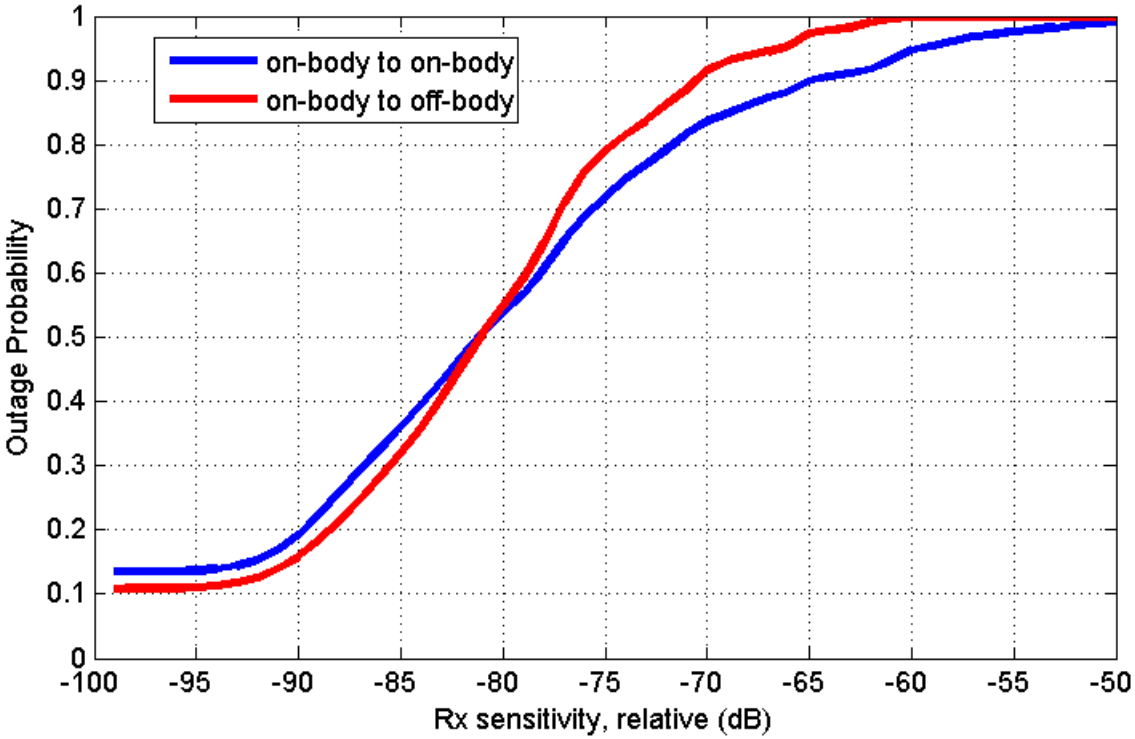
Channel gain distribution





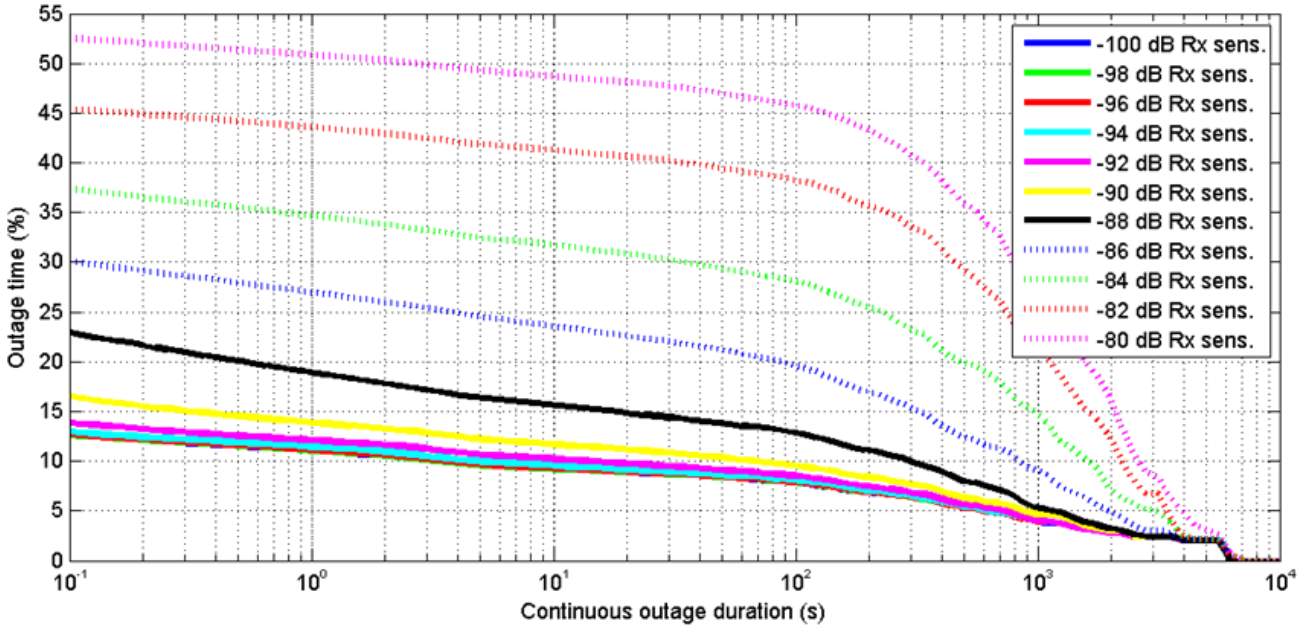
- Lognormal distribution is best fit
- Median channel attenuation:
  - On-body: 79.5 dB
  - Off-body: 81.5 dB
- Generally larger attenuation than non-sleeping channels

Outage probability



- Best case outage probability (attenuation > 100 dB) is more than 10% for both on-body (13.5%) and off-body (10.9%) channels

Outage duration (on-body to on-body only)



- Showing percentage of time that continuous outages of larger than *x* seconds (on horizontal axis) occur in all on-body to on-body measurements
  - Example: A receiver with a sensitivity of -88 dBm will experience outages of larger than 1000 seconds 5% of the time
- Long (duration) outages are infrequent, but because they are long, they take up a large fraction of the total time

Comments

- On-body and off-body results are very similar.
  - Attenuation effects are from the same sources
    - Shadowing from body
    - Antenna orientation
    - Distances are similar (substantially less than 3m)
  - This sort of attenuation is not frequency dependent – can not change channel within same band to avoid

- More attenuation than non-sleeping channels
- Minimum PER > 10% with -100dBm receive sensitivity
- Long outages are infrequent, but they account for a large percentage of the total time