Dynamic On-Body Channel Model

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Outlines

- Background
  - IEEE802.15.6
- Experimental investigation of the dynamic features of time-varying on-body channels
  - Measurement setup
  - Time-varying relative path gain
- Statistic analysis of dynamic on-body channel
  - Fading depth and level crossing rate
  - Channel dwelling time
- 5-state Fritchman model
- Summary

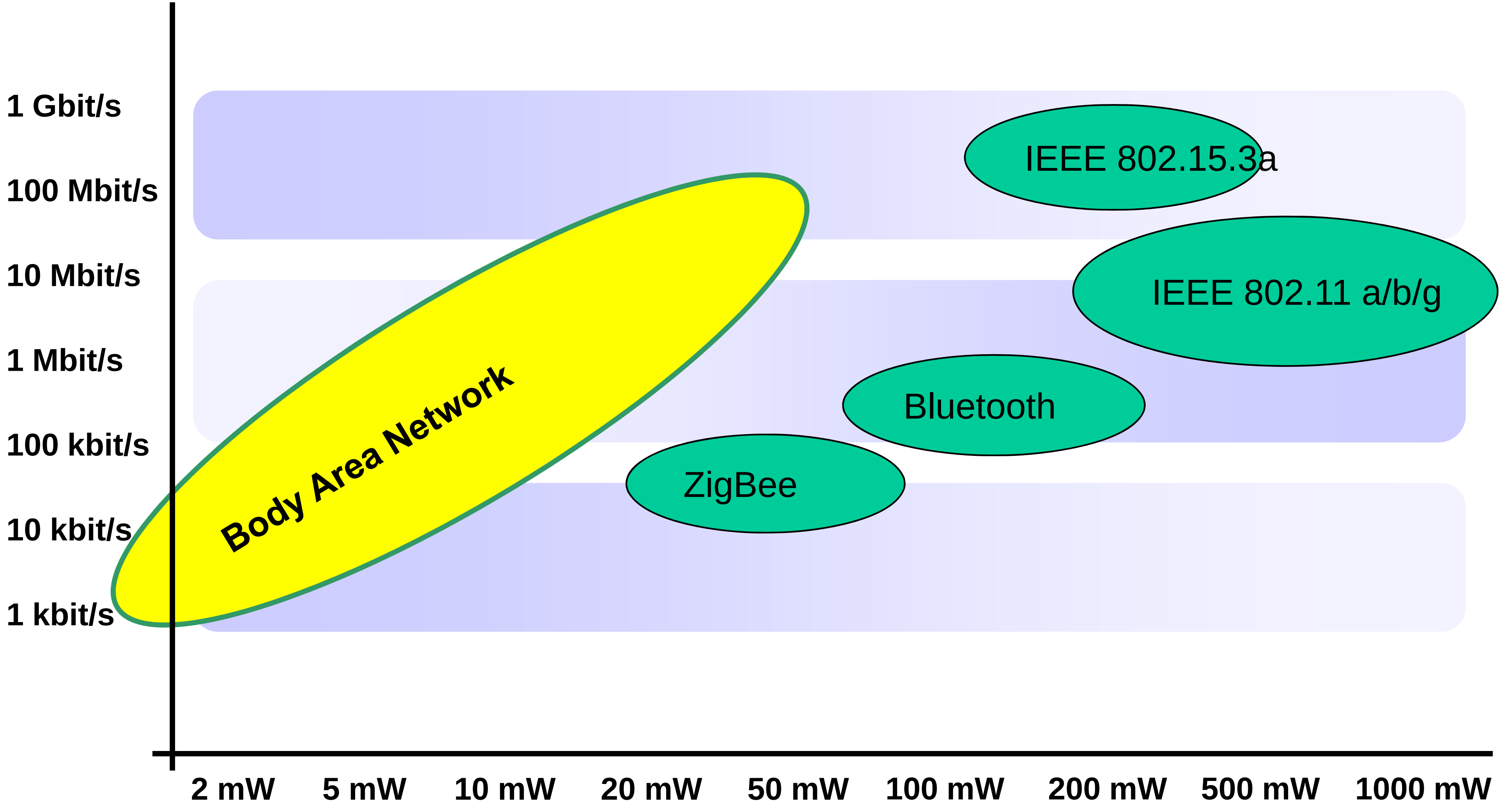
About Body Area Network

- Definition :
  - Short range wireless communication in the vicinity of, or inside, a human body
- Smaller area than PAN (Personal Area Network) → IEEE802.15.6 TG BAN
- Applications
  - Medical / Healthcare
  - Consumer Electrics (Entertainment, Fashion)

Target Positioning

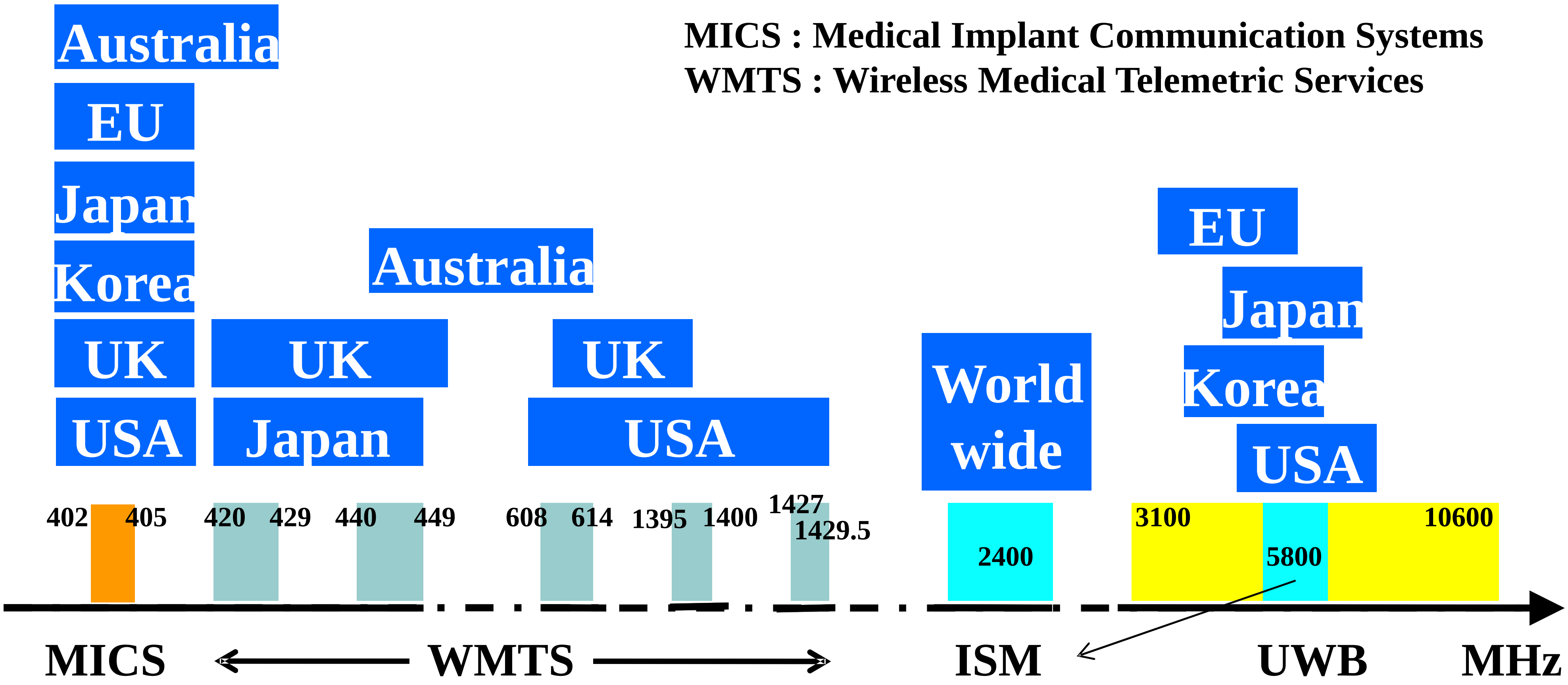
Average power consumption, sustained data rate

< IEEE 802.15-05-0694r0 >



Candidate Frequency Bands (0034-06-0006)

MICS : Medical Implant Communication Systems
WMTS : Wireless Medical Telemetric Services



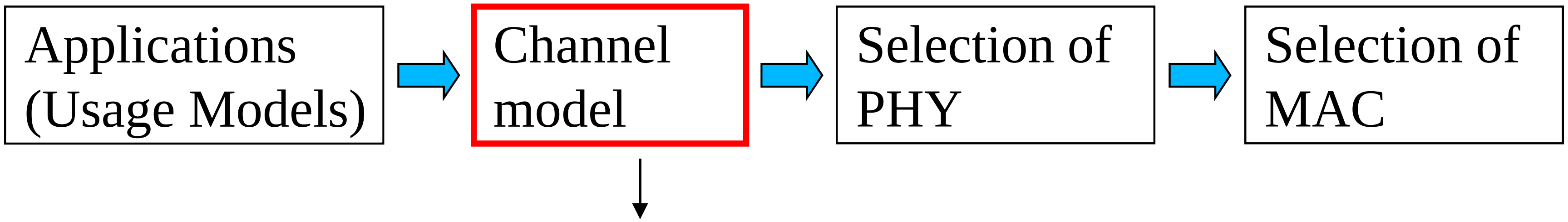
Requirement of BAN System

- Self recoverable from link & node failure
- Support for Quality of Services (QoS)
- Very low power consumption
- Data rates
  - Some tens of kbps (in most cases)
  - up to 10 Mbps
- Coexistence between BANs and other technologies
- SAR (specific absorption rate) should satisfy relevant regulatory requirement

Channel Model

- Useful for link budget calculation
  - Propagation path loss
- Usage scenarios
- Transmission simulation at PHY, MAC layer
  - Monte Carlo simulation of dynamic channel impulse responses

< Standardization Process >



TG6 Channel Model Document has been reviewed and approved (Nov. 13, 2008)

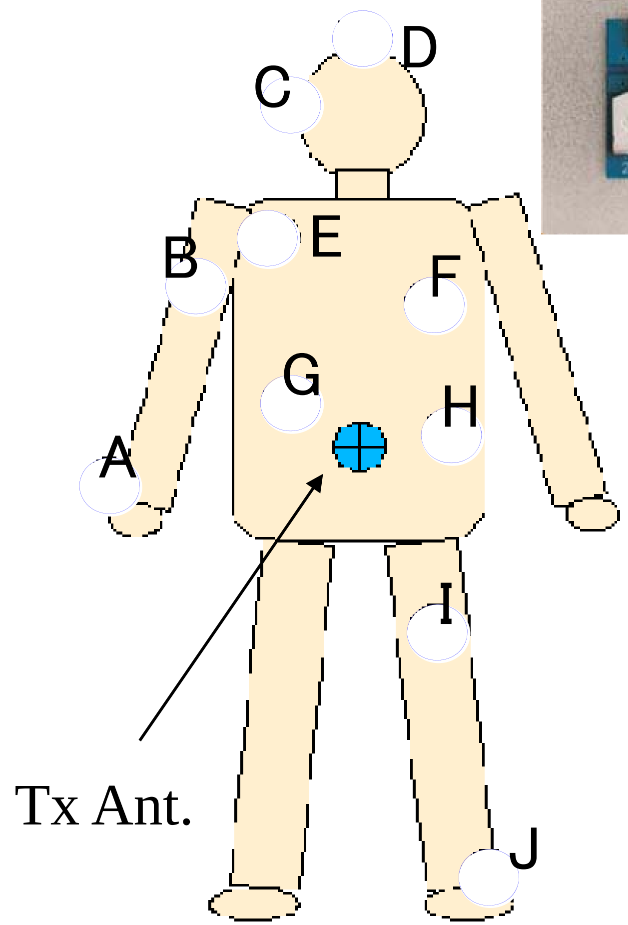
Motivations for dynamic on-body channels

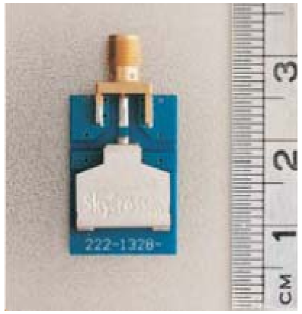
- Body itself is a main part of the propagation channel → Big difference from conventional radio systems
- The on-body propagation between two points is not stationary
  - The whole body or part of the body can be in movement
  - Intended movements like walking, running
  - Unintentional movements like breath
- Understanding on-body channel is necessary

Measurement Campaign

- Anechoic chamber
- 120MHz signal at 4.5GHz
- Antenna
  - Skycross SMT-3TO10-M-A
  - 10 Rx positions
- Regular actions in 10s
  - standing still (reference)
  - Actions: walking, standing up and sitting down
- Channel sample per 1ms by channel sounder

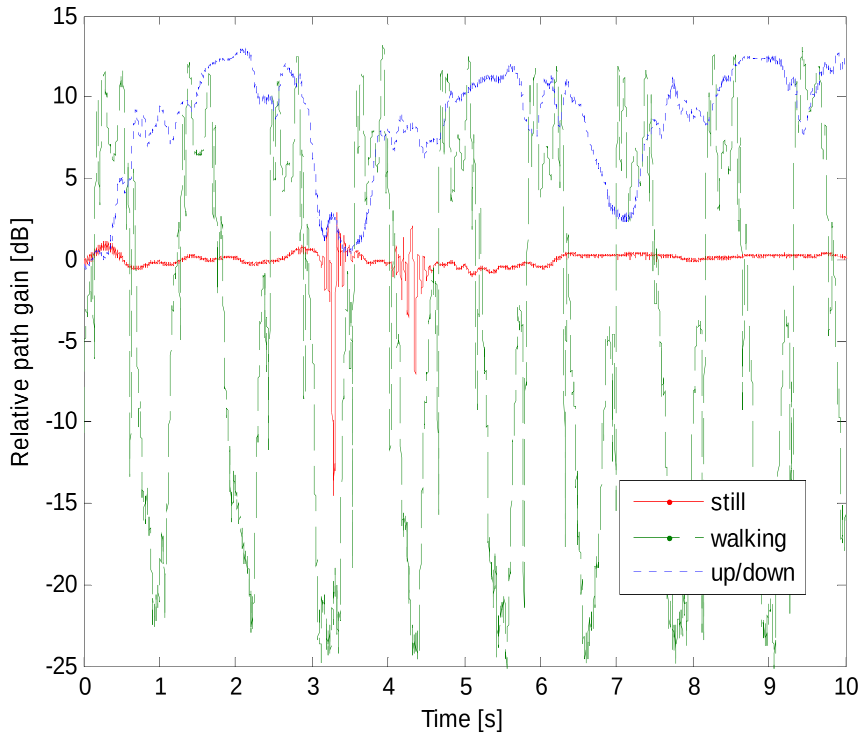
Rx Antenna locations



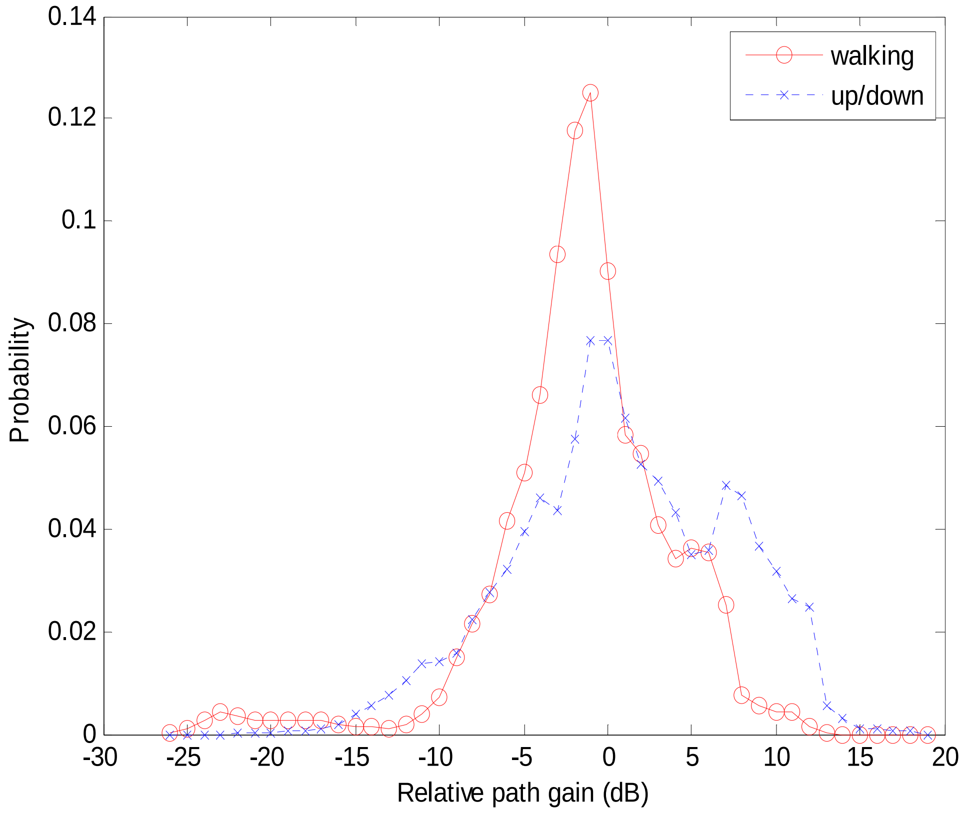


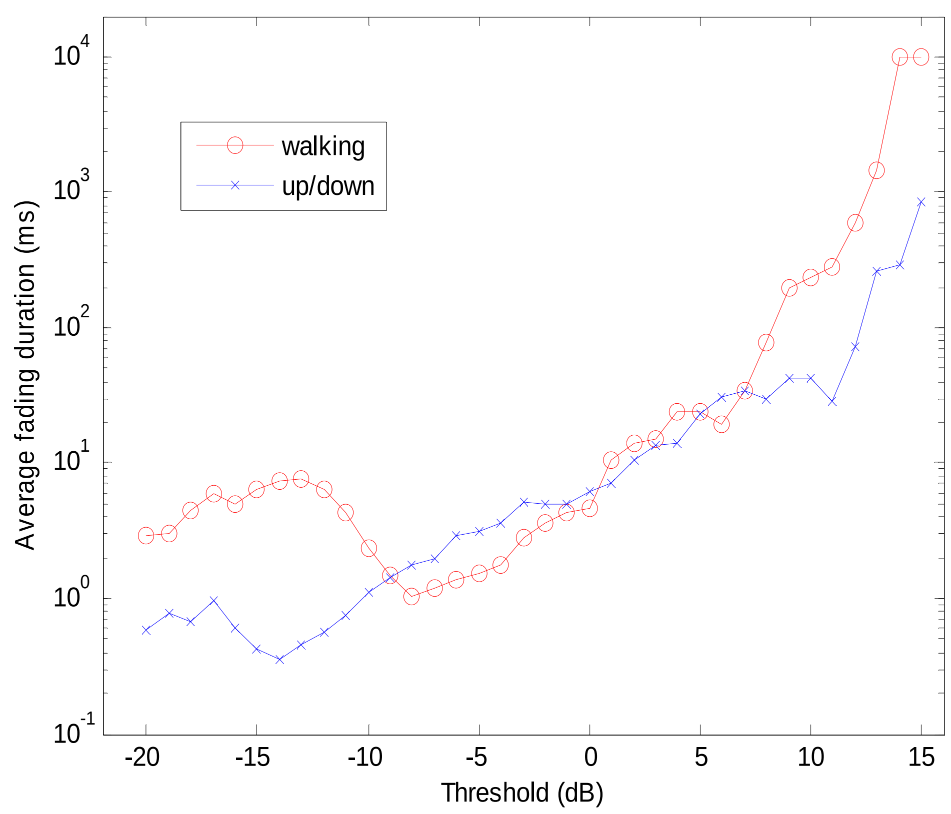
Relative path gain

- Path gain averaged in frequency domain
- Reference path gain
  - For each Rx position in reference scenario
- Relative path gain in the two dynamic scenarios



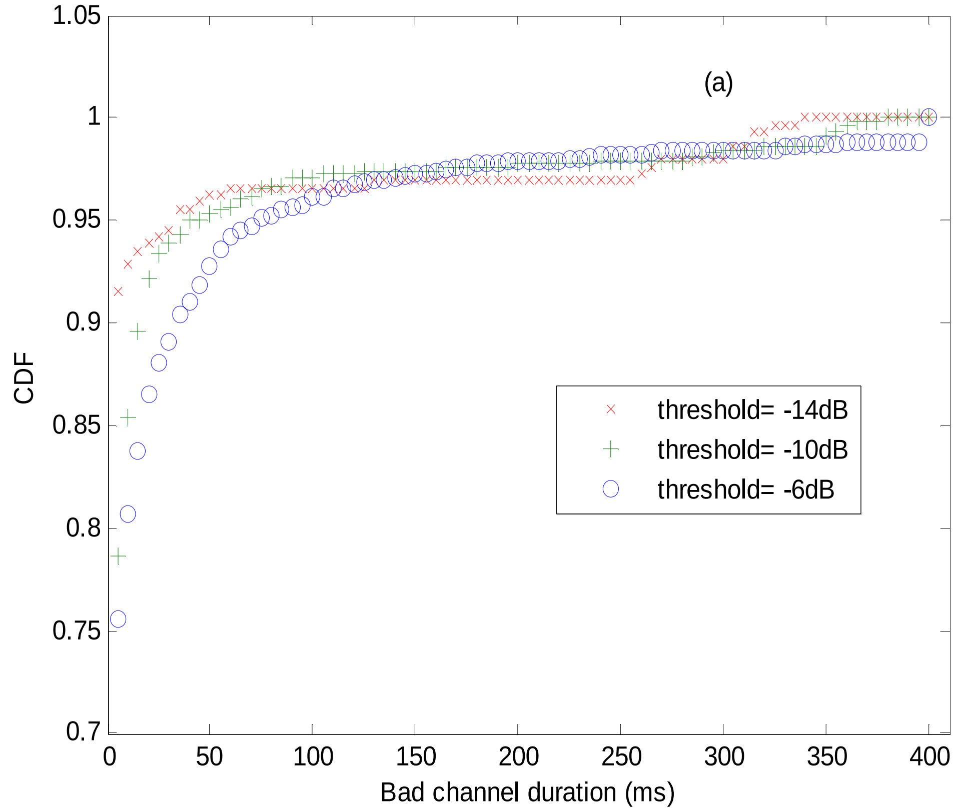
Statistic analysis

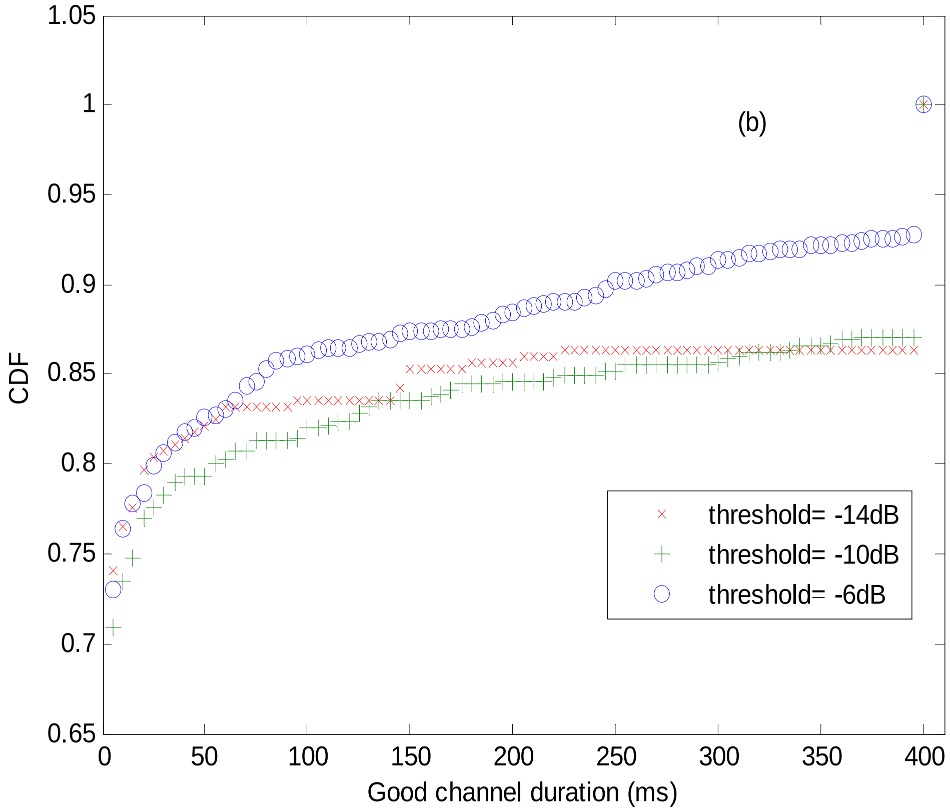




- Medical sensors prefer simple modulations without complex error coding
  - For the reason of complexity, cost and power consumption
- The performance deteriorates significantly when the SNR is lower than a threshold value
  - The channel is good when the relative path gain is above the threshold
- The threshold corresponds to fading margin in system design

Channel Dwelling Time





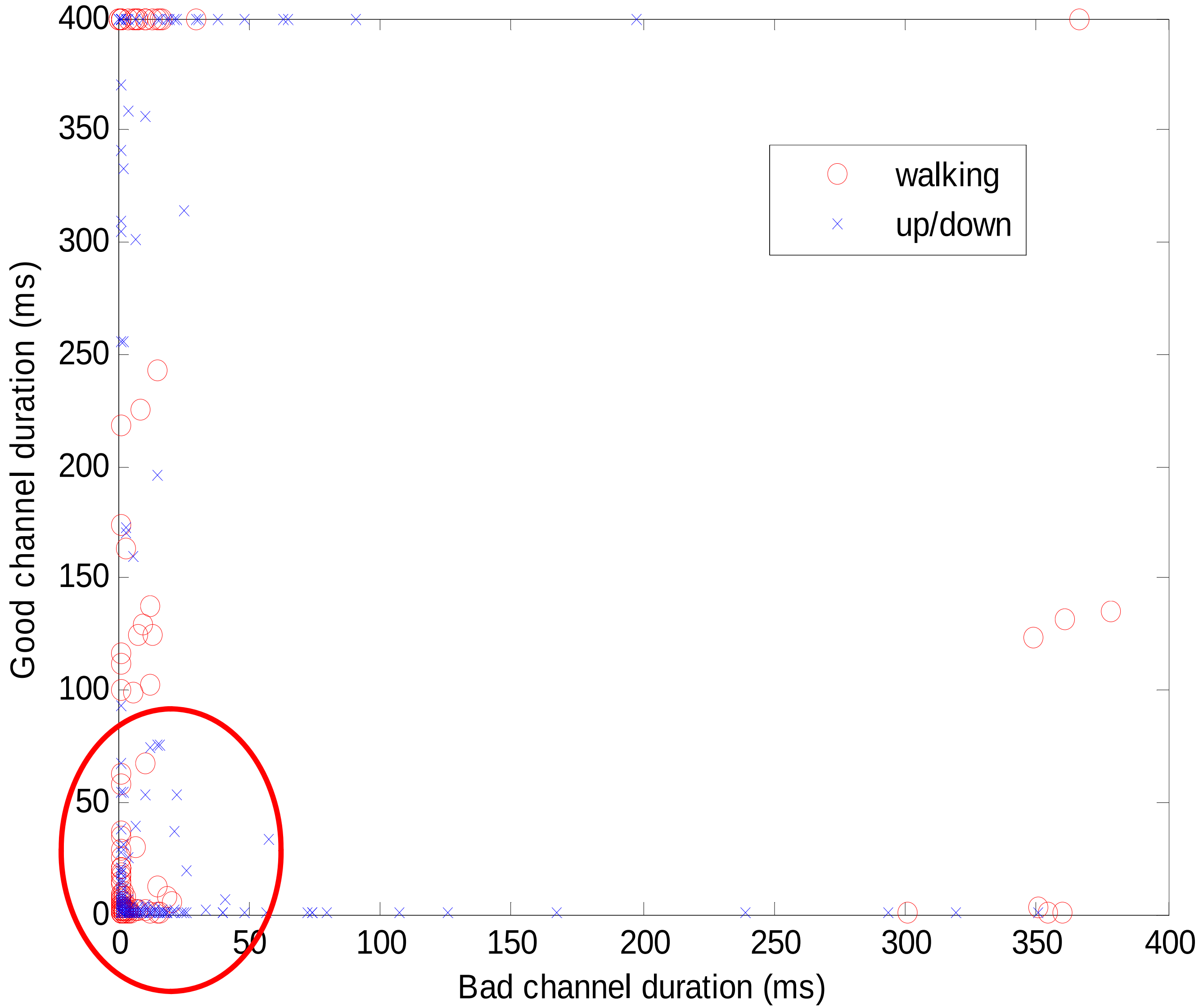
- At -10dB, the duration of approximately 85% of bad channels are shorter than 10 ms
- None of bad channels last longer than 400ms.

- Most good channels < 10ms
- Short duration (< 20ms) is not sensitive to the threshold.
- More than 10% good channels > 400 ms.
- The channel dwells in good channel for long time.

Summary of observations

- Fading depth
  - Most negative fading depth are less than -16dB
- Fading duration (-10dB threshold)
  - 93% fade duration < 20 ms
- Fading interval
  - 13% fading interval >400ms
  - 77% fading interval < 50ms
- Position dependent fading

From bad channels to good channels



Why Finite State Model?

- On-body channel dwells in bad channel and good channel in different patterns
  - Burst errors
- Finite State Model is an efficient way to evaluate performance of communication systems over time-varying fading channel
- Fritchman model
  - k Good states for those channel gain over the threshold
  - N-k Bad states for those channel gain less than threshold
  - No state transit among good states or bad states

5-state Fritchman model

S5 (unstable bad)
<20ms

S4 (semi-constant bad)
20~400ms

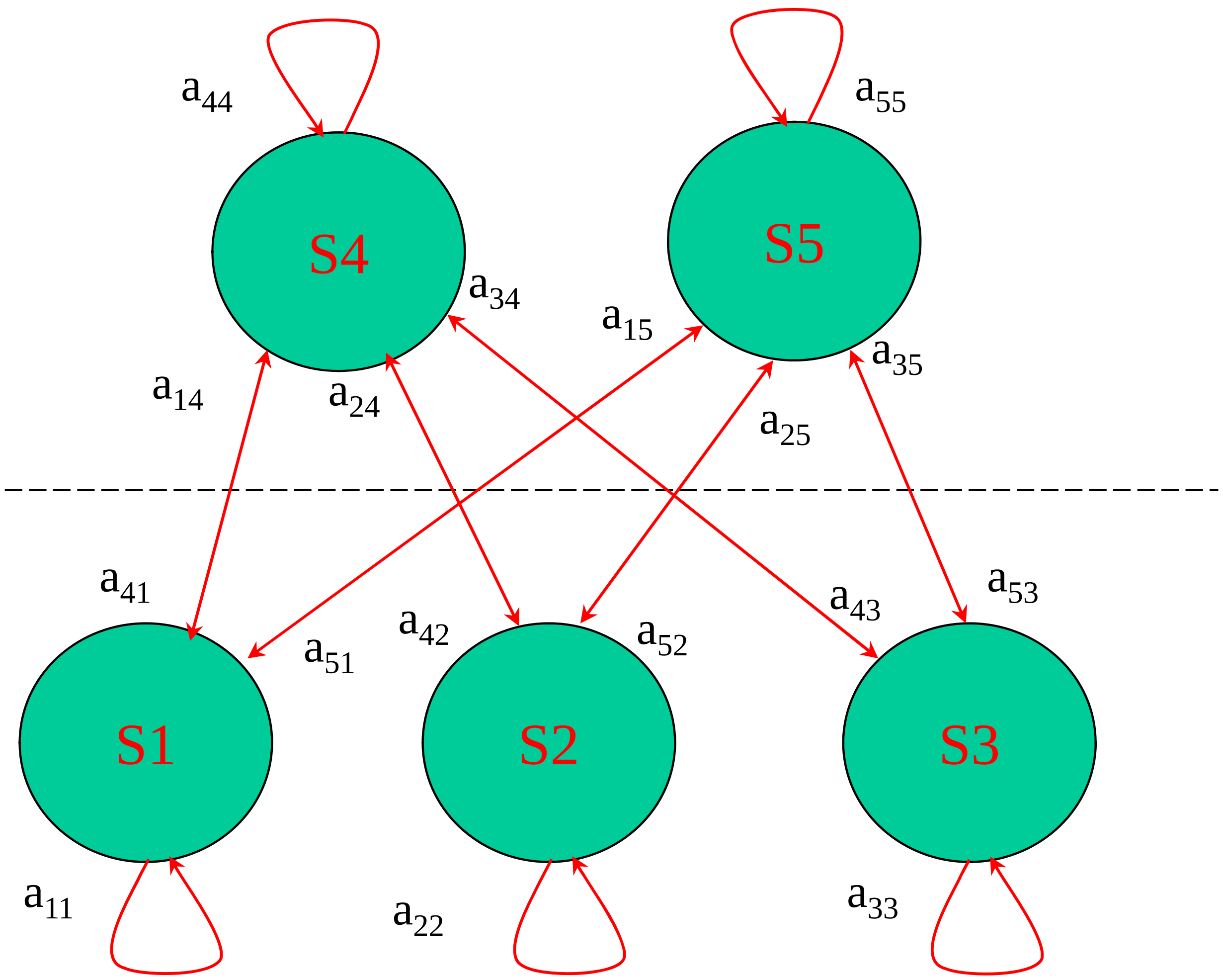
Bad channel

Good channel

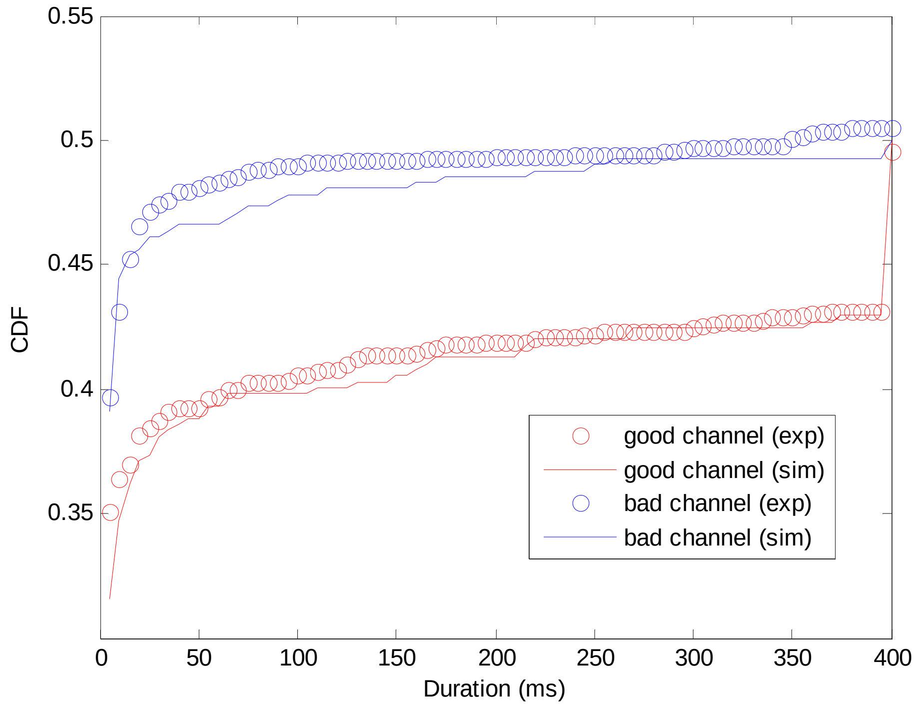
S1 (Unstable good)
(<= 20ms)

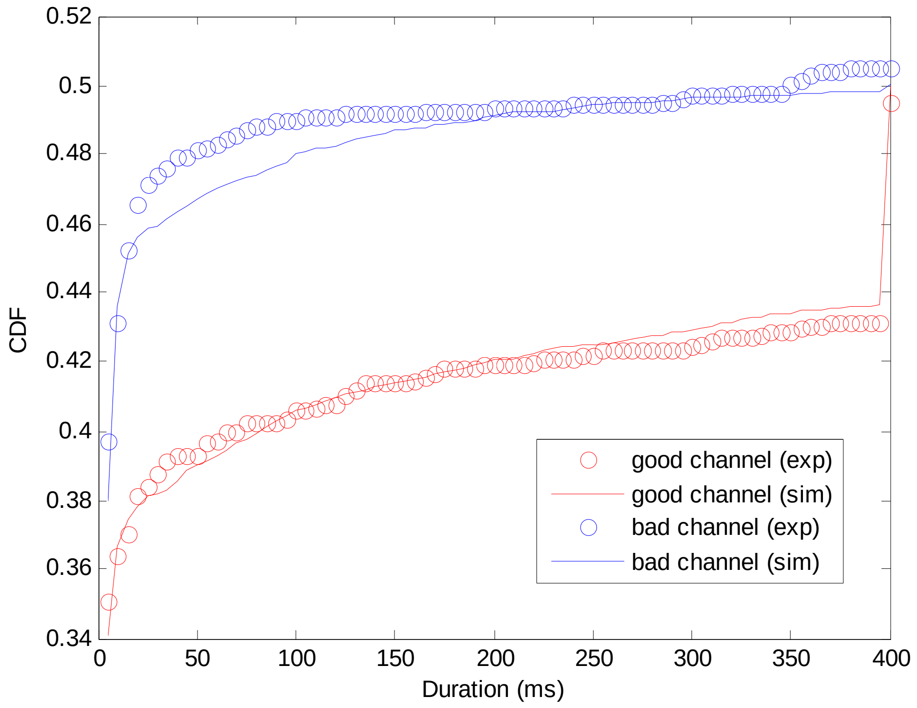
S2 (Semi-constant good)
(20~ 400ms)

S3 (Constant good)
(> 400ms)



Generated on-body channels per the 5-state Fritchman model

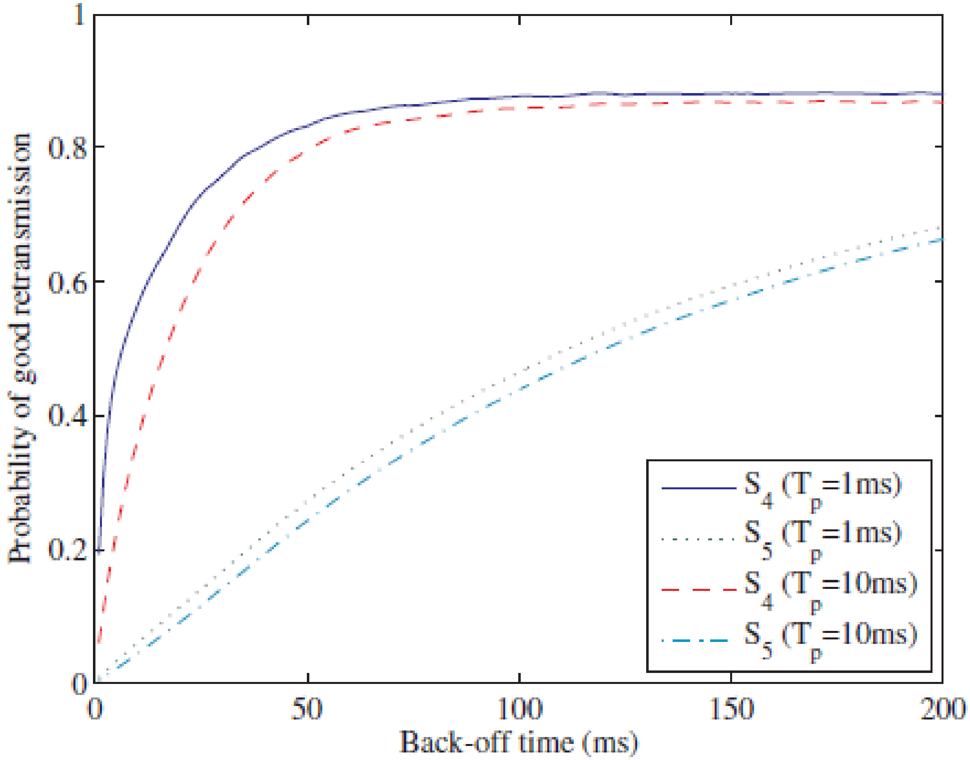


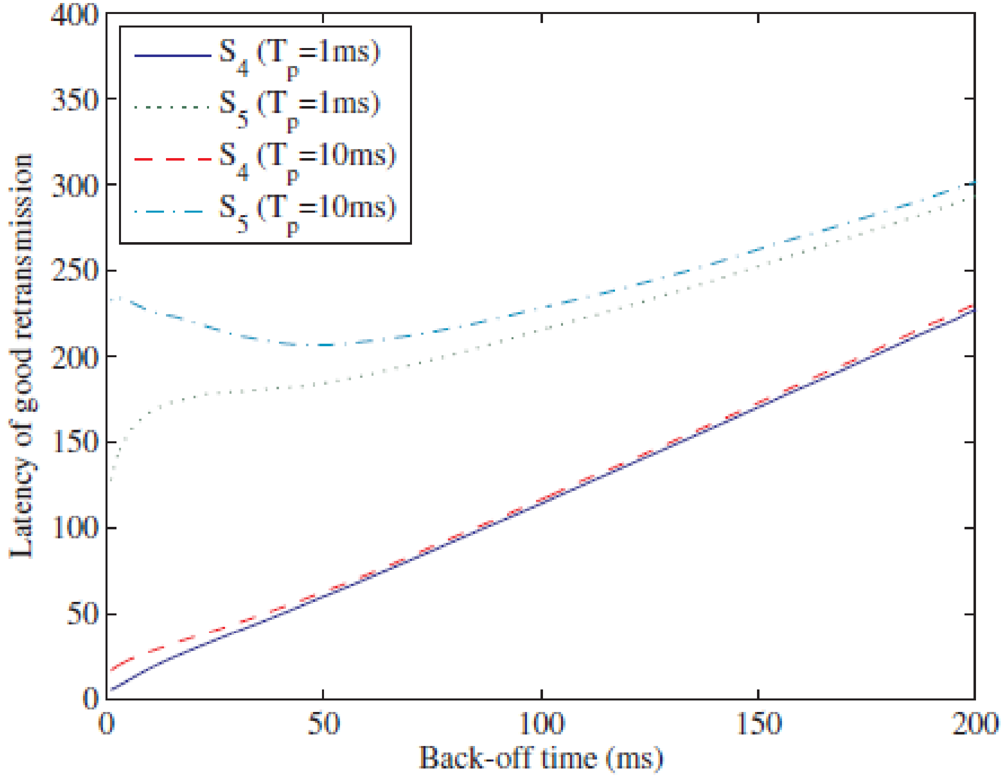


Initial state= S5
(Unstable bad channel)

Initial state= S1
(Unstable good channel)

Retransmission Evaluation





Summary

- Investigation into time-varying dynamic on-body channels by experiment
- Statistical analysis
  - Channel dynamic depends on sensor location and action
  - Channel fading pattern
- 5-state Fritchman model to describe dynamic on-body channels
- The simulated channels and experiment measurements agree well