Adapting Radio Transmit Power in Wireless Body Area Sensor Networks

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Outline

- Application: medical monitoring
- Platform: “Digital Plaster”
- Objective: optimize transmit power to save energy
  - – Why adapt transmit power?
  - – How much energy can we save?
  - – How practical is it to do?
- Summary: opportunities and limitations

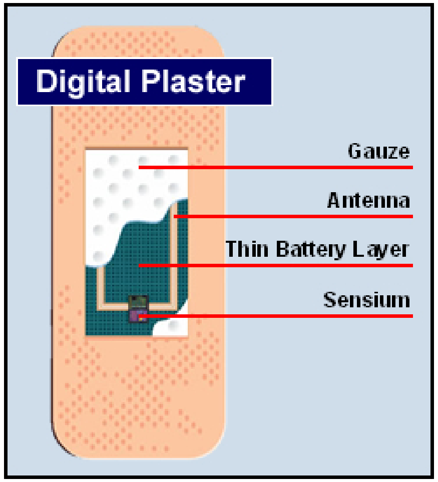
Application

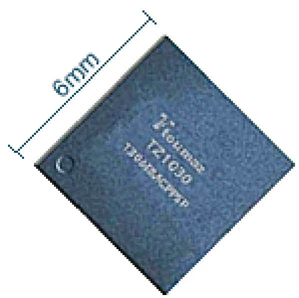
- Chronic disease (diabetes, heart conditions) on the rise
  - Obesity
  - Poor diet
  - Sedentary lifestyle
  - Ageing population

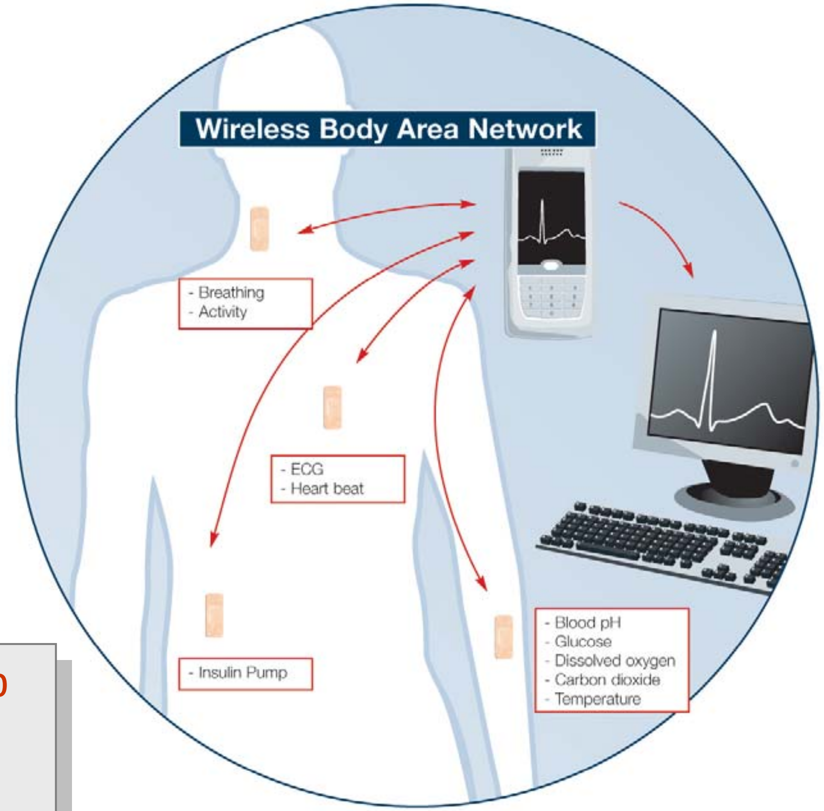


- Today's healthcare systems
  - Deal with acute illness (infections, injury)
  - Already overstretched
  - Cannot cope with long-term conditions
  - Need shift from hospital to home

Platform



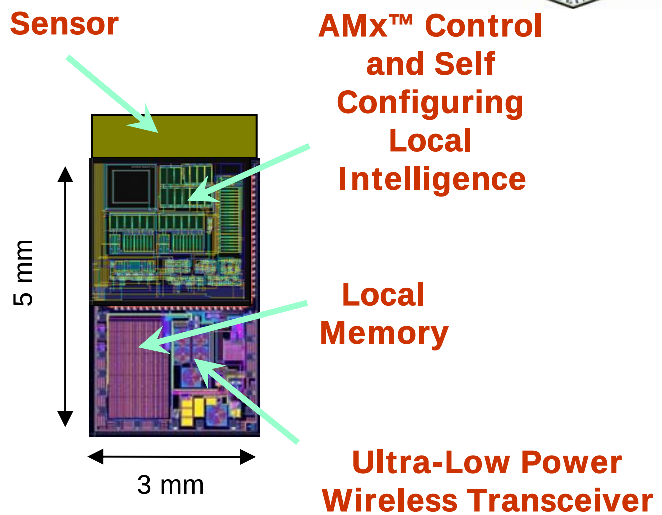




- low cost, disposable integrated sensor chip
- ultra low power – 10 to 100 times less
- tiny, non-intrusive module
- generic wireless sensor
- locally intelligent

Digital Plaster

- Integrated; truly wearable
- Proprietary radio:
  - – Short range: up to 10m
  - – Low-rate link: ~50 Kbps
  - – Ultra-low-power:
    - 2.7mW for -7dBm output (MicaZ radio ~22.5mW)
- Printed battery: ~20mW-hours
  - – AA batteries on motes: ~few Watt-hours
  - – Energy is very precious!
  - – Target life-span: 3-4 days



How to Save Energy?

- Save energy in communication:
  - Proprietary radio design
  - Proprietary MAC protocol
  - This work: adapt transmit power
    - Lower transmit power saves energy
    - Higher transmit power increases reliability

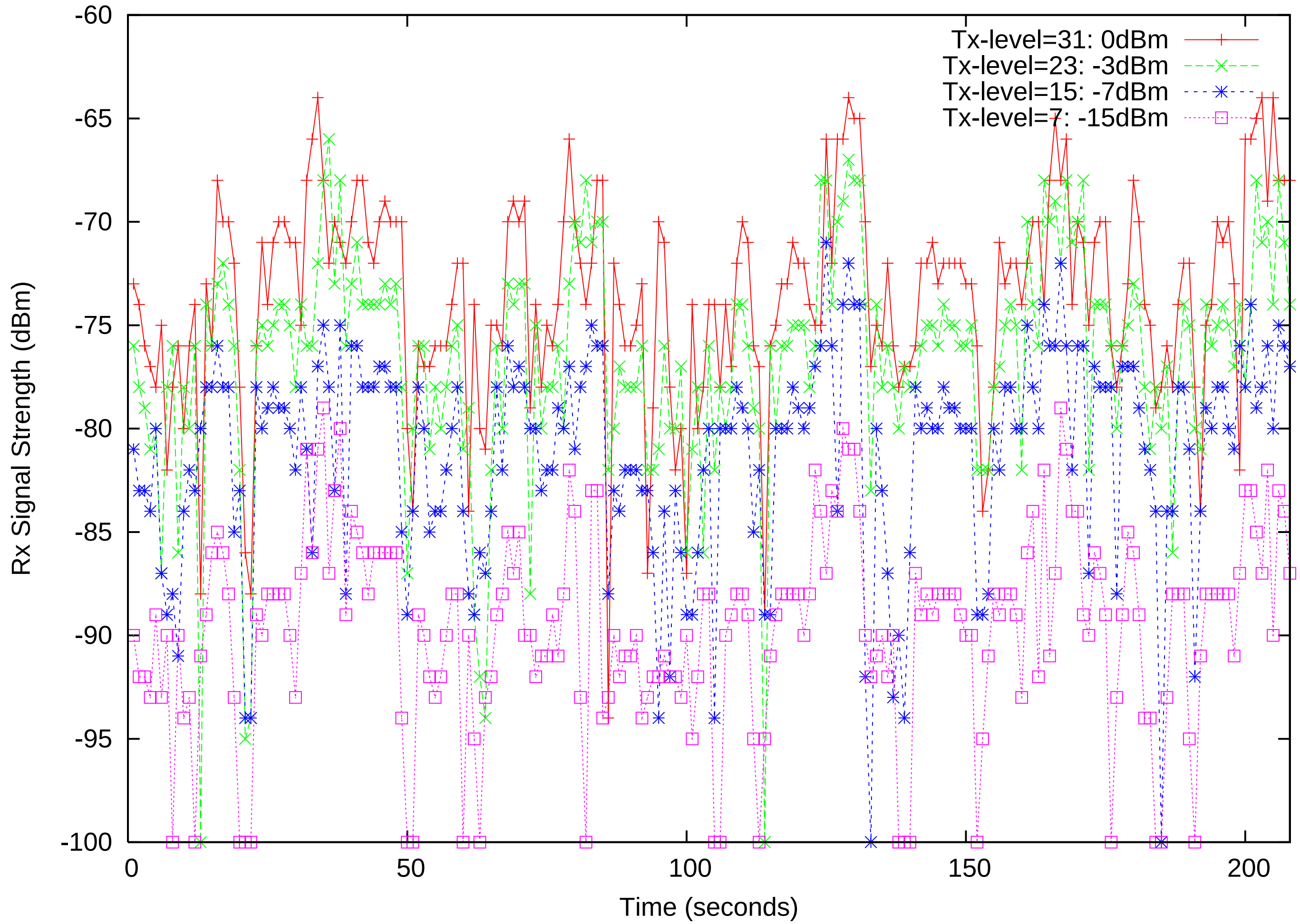
transmit level	output power (dBm)	power draw (mW)
31	0	31.3
27	-1	29.7
23	-3	27.4
19	-5	25.0
15	-7	22.5
11	-10	20.2
7	-15	17.9
3	-25	15.3

CC2420 radio

transmit level	output power	energy consumption rate
7	-6 dBm	2.8 mW
6	-7 dBm	2.7 mW
5	-9 dBm	2.6 mW
4	-10 dBm	2.5 mW
3	-12 dBm	2.4 mW
2	-15 dBm	2.2 mW
1	-18 dBm	2.0 mW
0	-22 dBm	1.8 mW

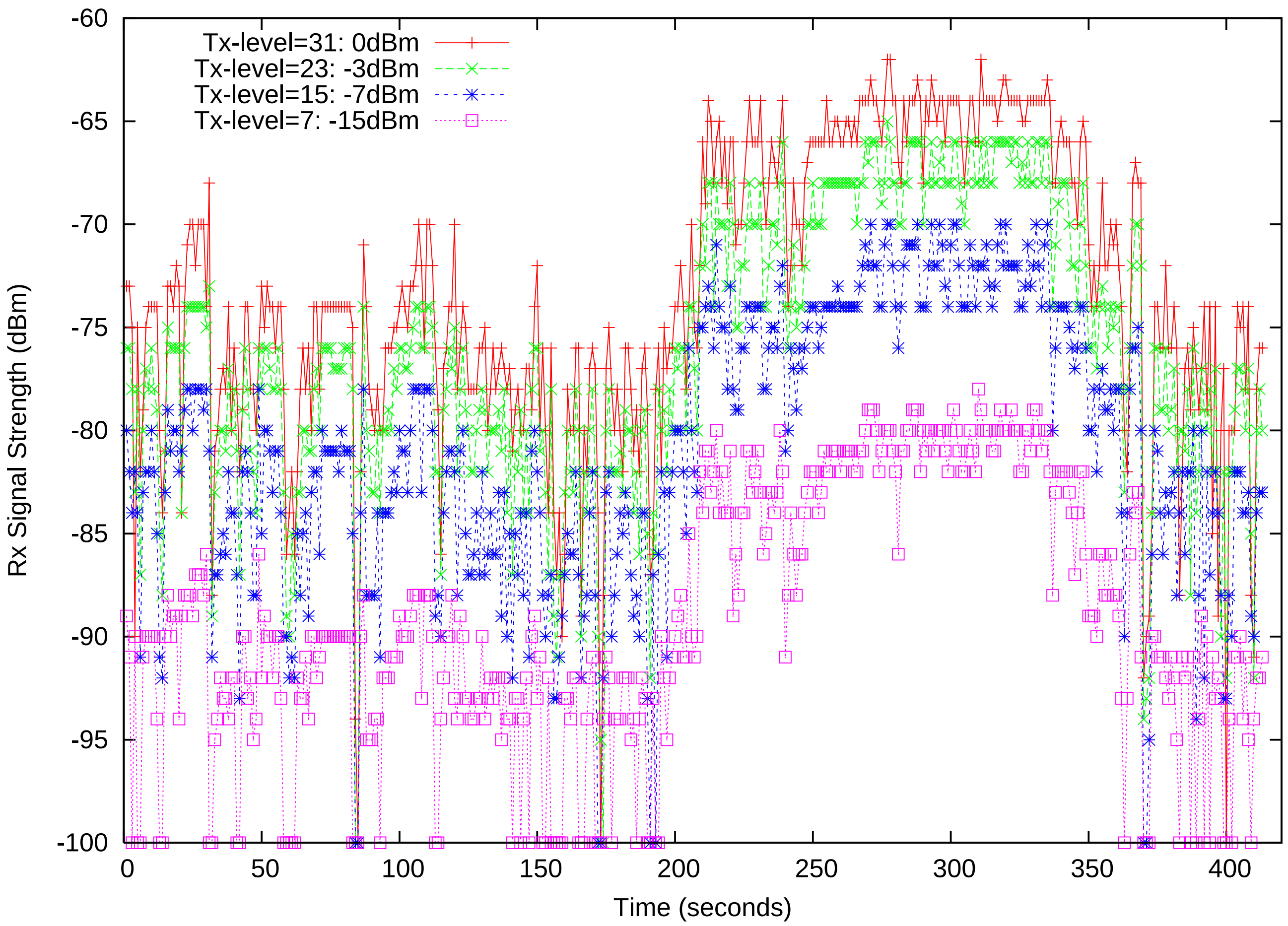
Sensium radio

Fixed Transmit Power: Normal Walk



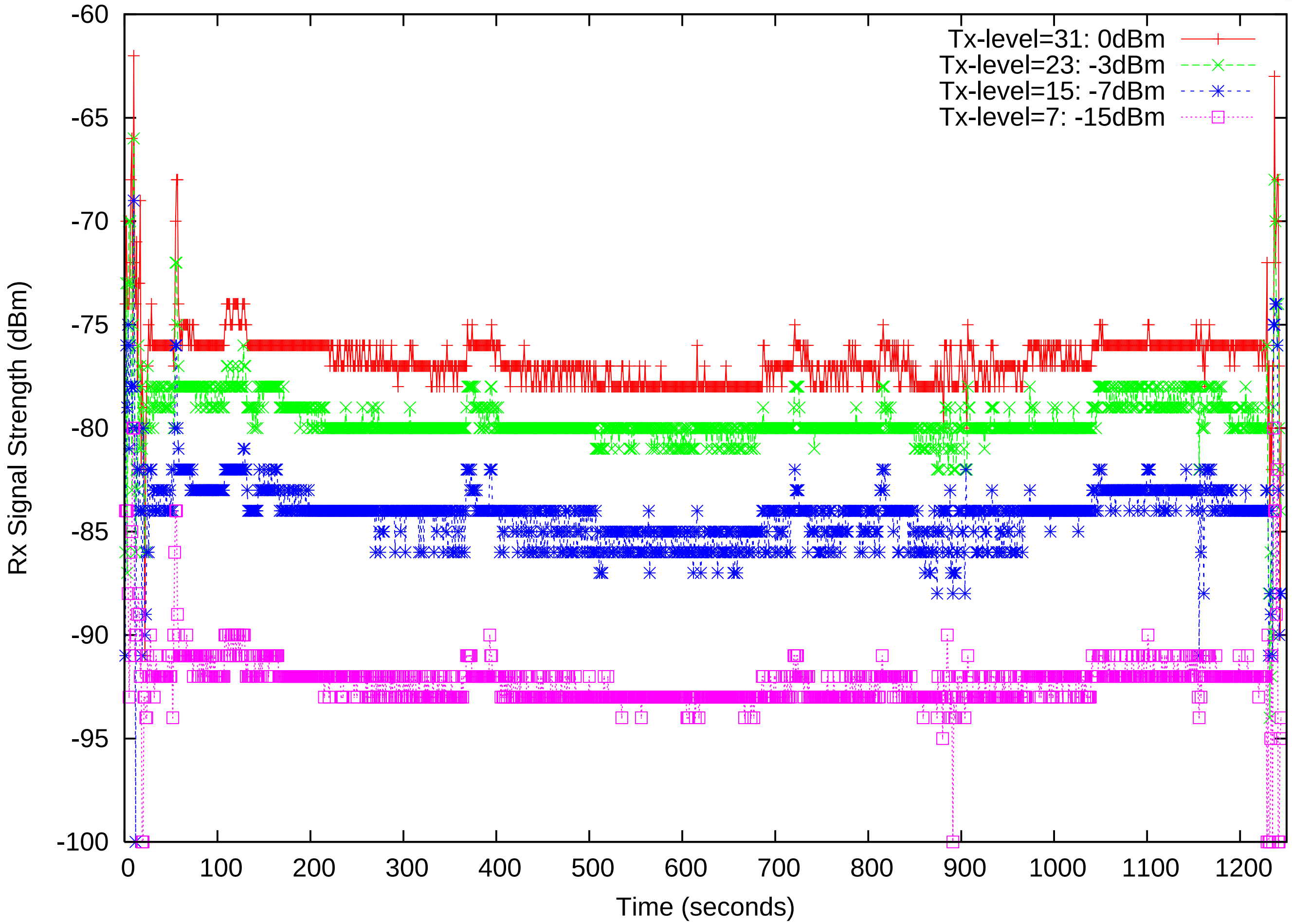
Normally walking patient

Fixed Transmit Power: Slow Walk



Slowly walking patient

Fixed Transmit Power: Resting



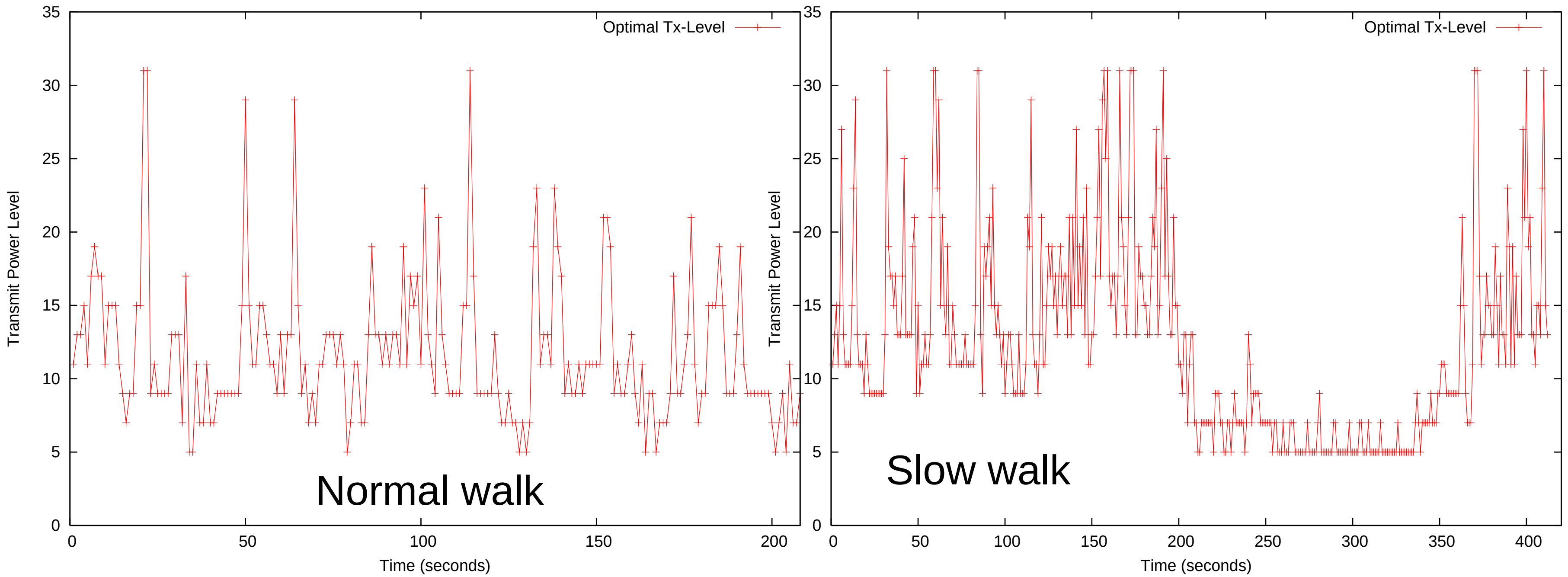
Resting patient

Q1: Why Vary Transmit Power?

- Wireless channel fluctuations:
  - Heavily depend on patient movement and orientation
  - Can be rapid (order of seconds)
  - Can be slow (order of hours)
- Transmit power control
  - An opportunity to save energy during quiescent periods and improve reliability during noisy periods
  - A challenge given the harsh radio environment and demanding application requirements

Q2: How much energy can be saved?

- Optimal Transmit Power for -85dBm RSSI

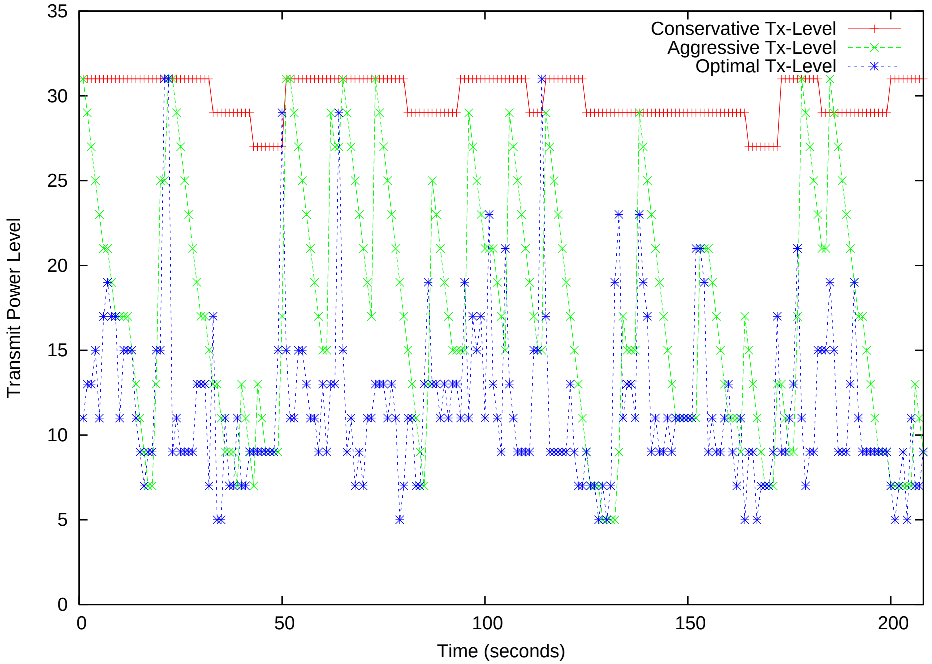


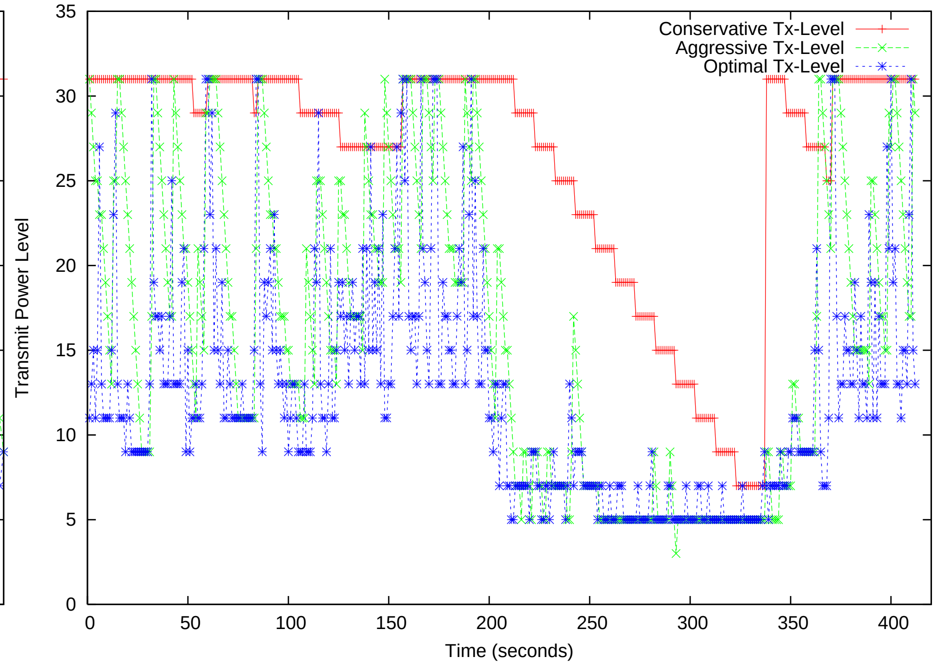
- 34-38% savings in energy (compared to maximum transmit power)

Q3: Would it work in practice?

- Sender obtains RSSI feedback from receiver:
  - Reduces transmit power if RSSI too high
  - Increases transmit power if RSSI too low
- Conservative approach:
  - If feedback is absent or below threshold T_L
    - Increase transmit power to max
  - If N consecutive feedback values are above threshold T_H
    - Decrease transmit power by 1
- Aggressive approach:
  - Maintain running average of feedback values
  - If average is below threshold T_L
    - double transmit power
  - If average is above threshold T_H
    - reduce transmit power by 1

Practical Performance





- Conservative approach:
  - 2-8% energy savings, 1-2% loss
- Aggressive approach:
  - 23-26% energy savings, 7-10% loss

Conclusions

- Adaptive Transmit Power Control in Body Area Networks:
  - Desirable due to large temporal variations in wireless channel of body area networks
  - Can be implemented with simple and practical feedback-based schemes
  - Under ideal conditions can save ~35% energy with minimal loss in reliability
  - Effectiveness will strongly depend on deployment scenario (aged care, athlete monitoring, etc.)

Future Work

- Link asymmetry / loss of feedback
- Generalization of schemes:
  - Conservative, balanced, aggressive, …
- Evaluation on Toumaz Digital Plaster platform