Aalto University
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Energy efficiency in communications

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Most slides by Yu Xiao
Some slides by Mohammad Hoque

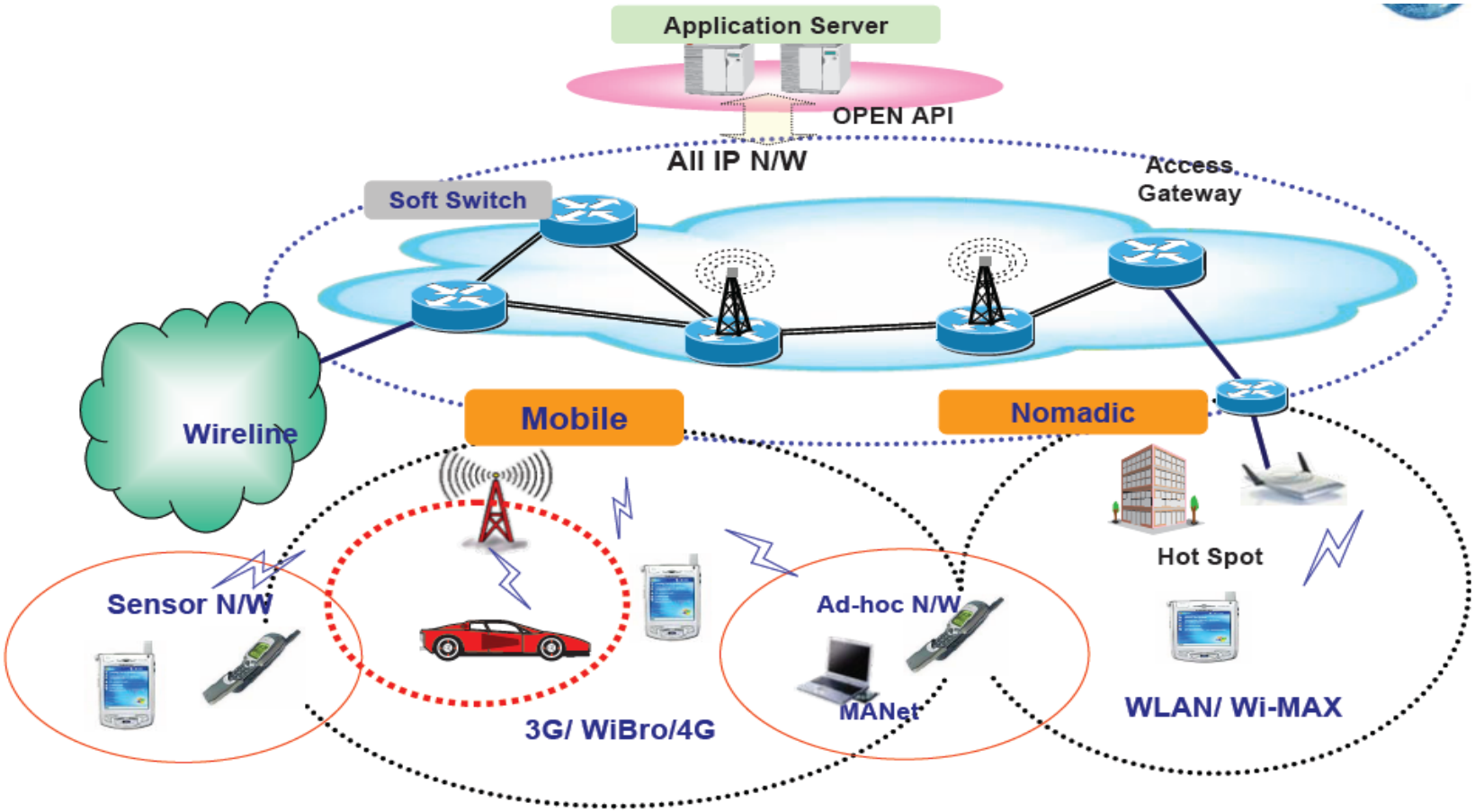
“Green” communications

What is this green stuff?

Green means a lot

- Energy
  - About 12% of global power consumption (ICT)
  - 60billion KWh wasted by inefficient computing every year
  - Telecom data volume increases approximately by a factor of 10 every 5 years, which corresponds to an increase of the associated energy consumption of 16-20% every year
- CO2
  - At least 2% of global CO2 emission
  - As much as airplanes, and ¼ of cars
- ~~€€¥££~~
  - Half of operators' operating cost

Networking


Application Server
OPEN API
All IP N/W
Access
Gateway
Soft Switch
Wireline
Mobile
Nomadic
Sensor N/W
3G/ WiBro/4G
Ad-hoc N/W
MANet
Hot Spot
WLAN/ Wi-MAX

Questions, questions, …

- Lot of different stuff
  - In network equipment
    - Routers, switches, wireless access points, …
  - At the edge
    - PCs, mobile phones, data centers, set-top boxes,...
- How much energy does all this stuff consume?
- How much could we save? … in network equipment?... at the edge? And how do we do it?
- Where does the energy go?
  - Transmission
  - Computation
  - Cooling

Mobile devices energy consumption

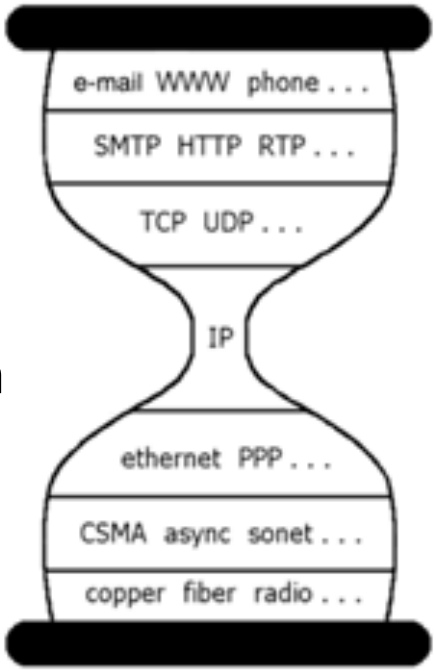
- Battery life time is an important issue
- Mostly a question of QoS, not really “greenness”
- This is currently the main focus of our research

Low power hardware or better batteries?

- No, not really
- We don’t fiddle with the hardware
  - We are software guys
- We are not chemists either
  - Leave the batteries alone…
- Our focus:
  - All layers in communication protocol stack above the physical layer
  - Somewhat also other software in the device
    - E.g. operating system

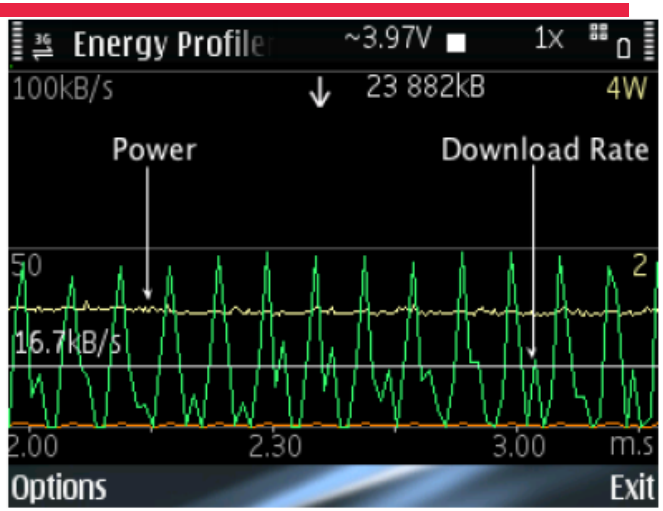
So, what is it about?

- Goals:
  - Maximize bits per Joule
  - Deliver service with as few Joules as possible
    - Maybe trade off some QoS
- How?
  - Optimization of protocols for energy efficiency
    - Across the whole stack
  - Optimize power management to cooperate with protocols
- Necessary activities for doing this:
  - Power measurements
  - Power modeling

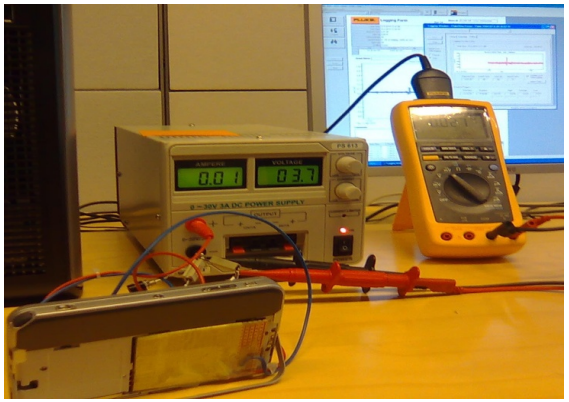


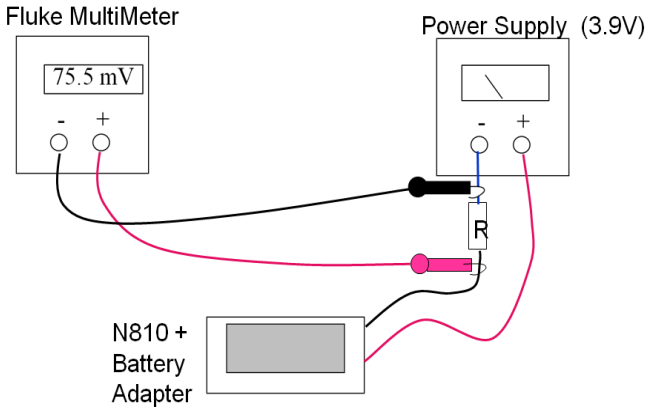
Measuring power

- Nokia Energy Profiler
- Easy to use
- Sampling frequency: 4Hz
- Only for Nokia

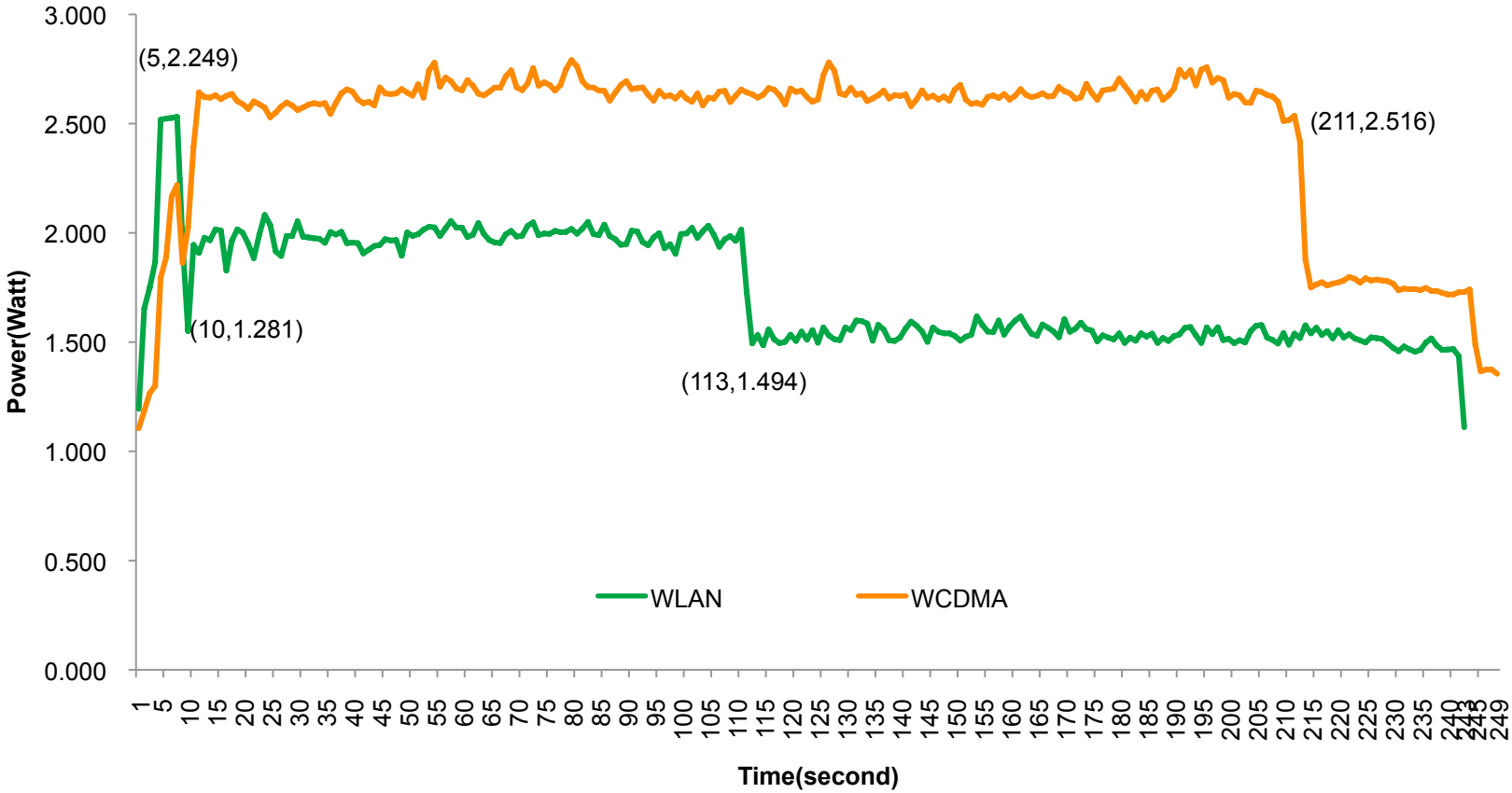


- Hardware measurements
- Can have much higher Hz
- No software overhead





Glance at the power consumption



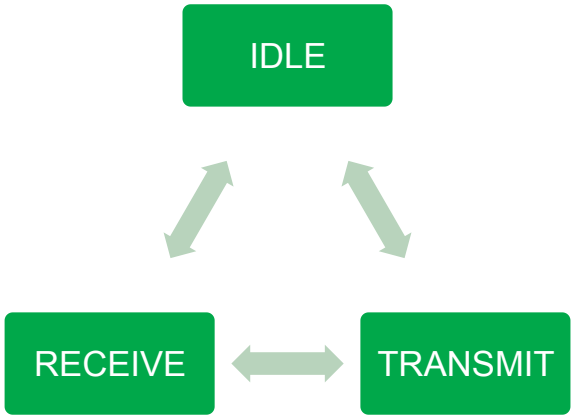
Watching YouTube from N95

Basic questions

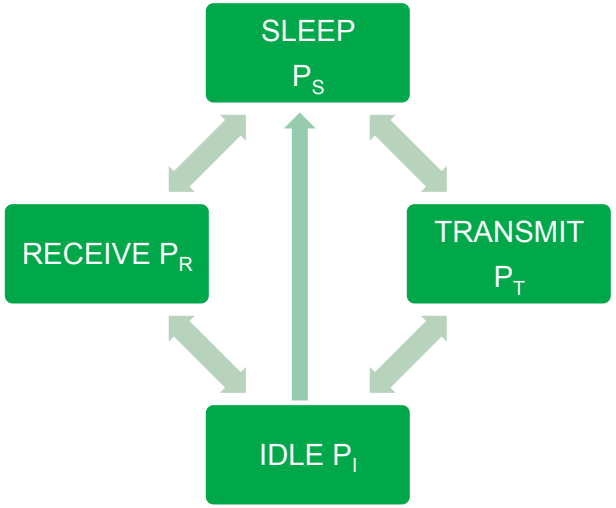
- How many Joules are needed for transmitting or receiving one bit?
  - Hardware dependent
  - Radio technology dependent
  - Context/environment dependent
  - Protocol dependent
- How many bits do you need to transmit or receive?
  - Depends on protocol and service design
  - Depends on context/environment

Example: WLAN

- Not a simple On/Off
- Multiple operating modes



Continously Active Mode (CAM)



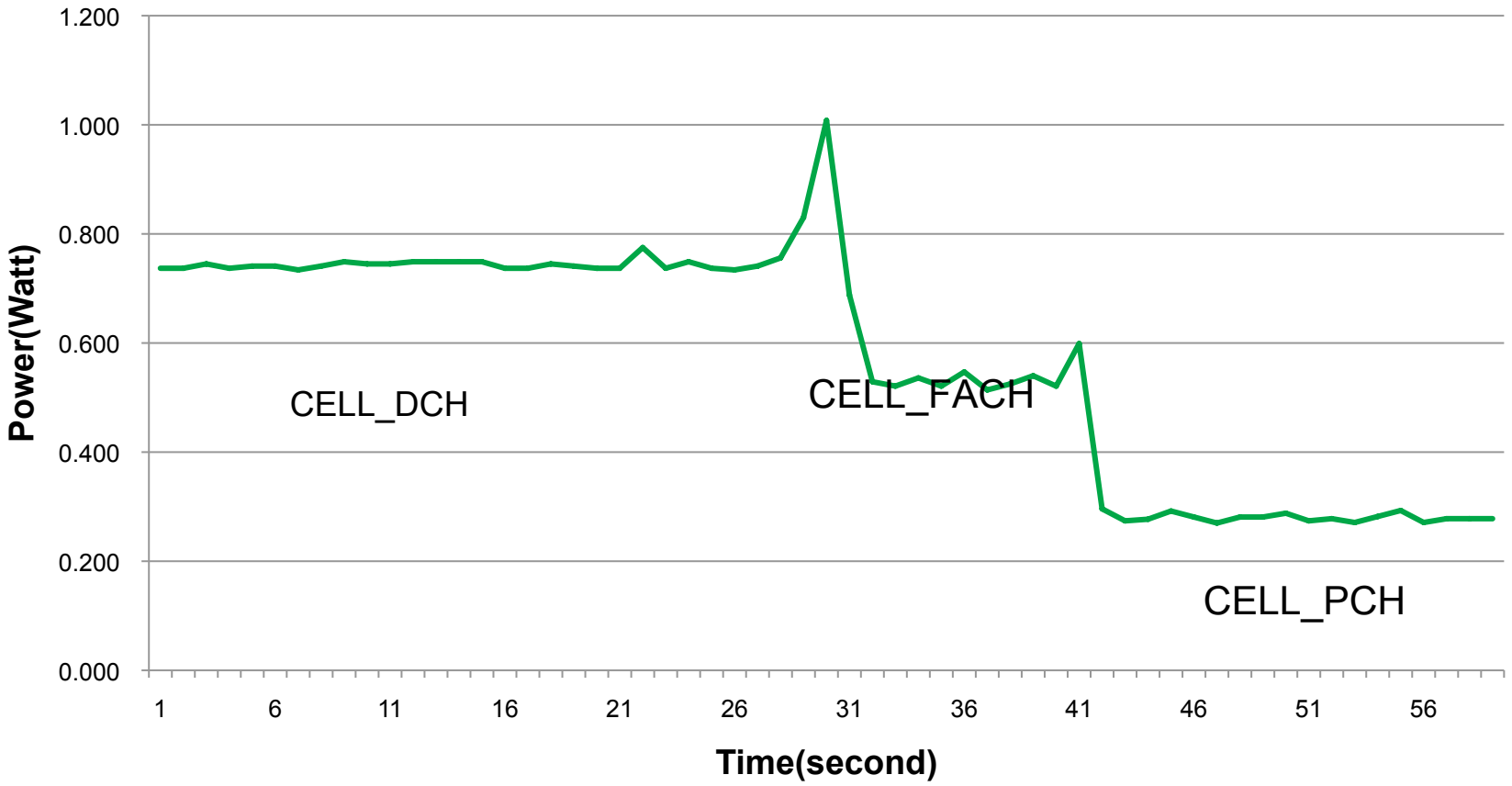
Power Saving Mode(PSM)

WLAN

- Power consumption ~ WNI operating mode

WNI operating mode	Average Power (W)		
	Nokia N810	HTC G1	Nokia N95
IDLE	0.884	0.650	1.038
SLEEP	0.042	0.068	0.088
TRANSMIT	1.258	1.097	1.687
RECEIVE	1.181	0.900	1.585

3G WCDMA


1.200
1.000
0.800
0.600
0.400
0.200
0.000
Power(Watt)
CELL_DCH
CELL_FACH
CELL_PCH
1
6
11
16
21
26
31
36
41
46
51
56
Time(second)

Some examples

- Smart data compression

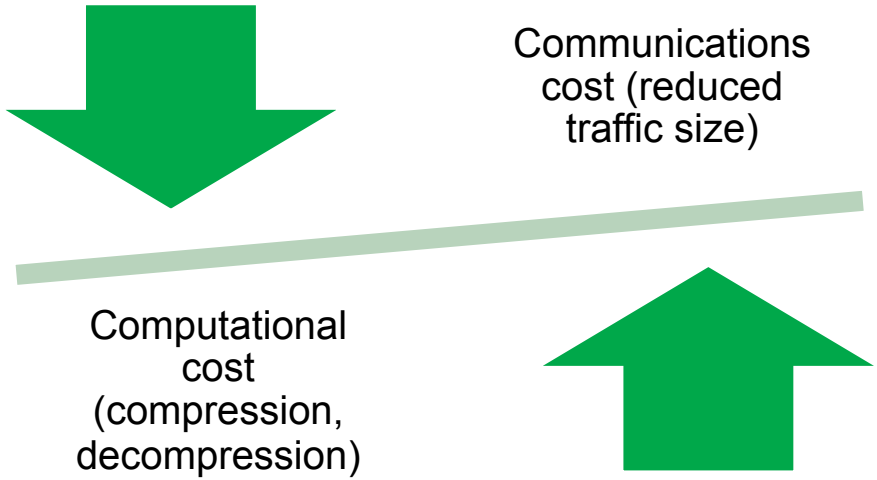
  Yu Xiao, Matti Siekkinen, and Antti Ylä-Jääski. Framework for energy-aware lossless compression in mobile services: the case of E-mail. In Proceedings of the IEEE International Conference on Communications. ICC 2010. May 2010.

- Proxy-based traffic shaping for audio streaming

  Mohammad Hoque, Matti Siekkinen, and Jukka K. Nurminen. On the Energy Efficiency of Proxy-Based Traffic Shaping for Mobile Audio Streaming. To Appear in Proceedings of the 8th Annual IEEE Consumer Communications and Networking Conference (CCNC). January 2011.

Smart data compression

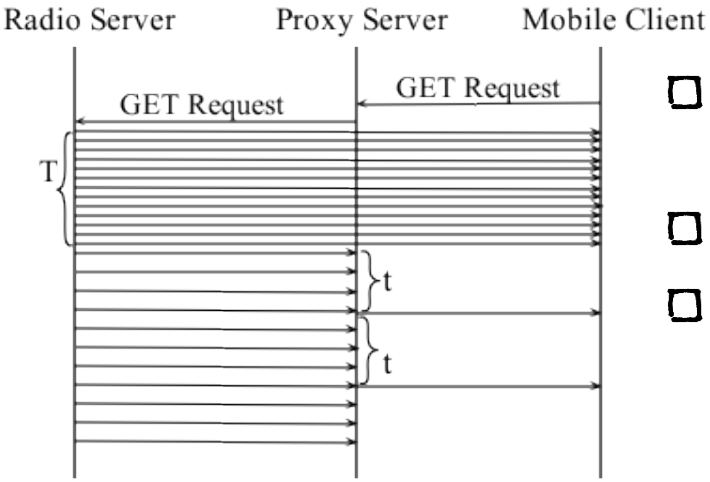
- Energy consumption ~ Traffic size
- Compression technique can help reduce traffic size
- Tradeoff always exists



Proxy-based traffic shaping for audio streaming

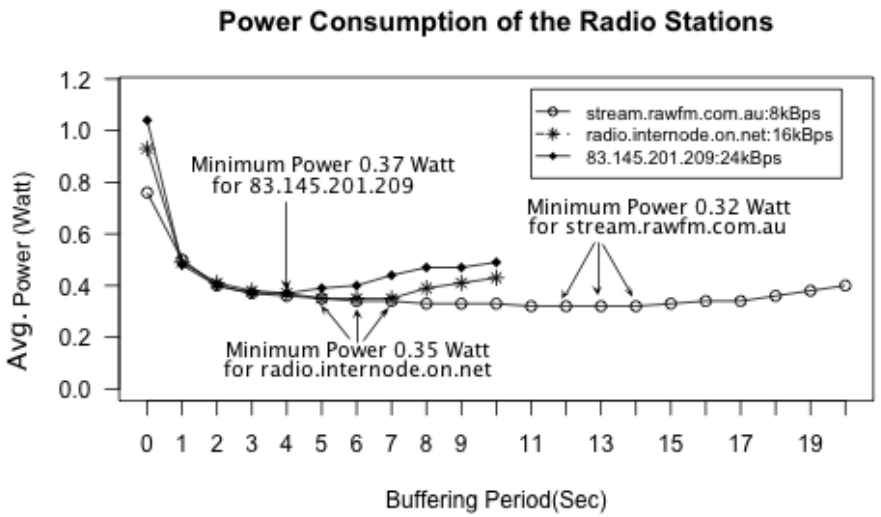
- Audio streaming provides constant flow of incoming packets
  - 802.11 PSM does not work well
- Provide a proxy that shapes streaming traffic into bursts
  - Receive a burst at a time and sleep in between them¨
- How much can we save energy?

Traffic Shaping with Proxy



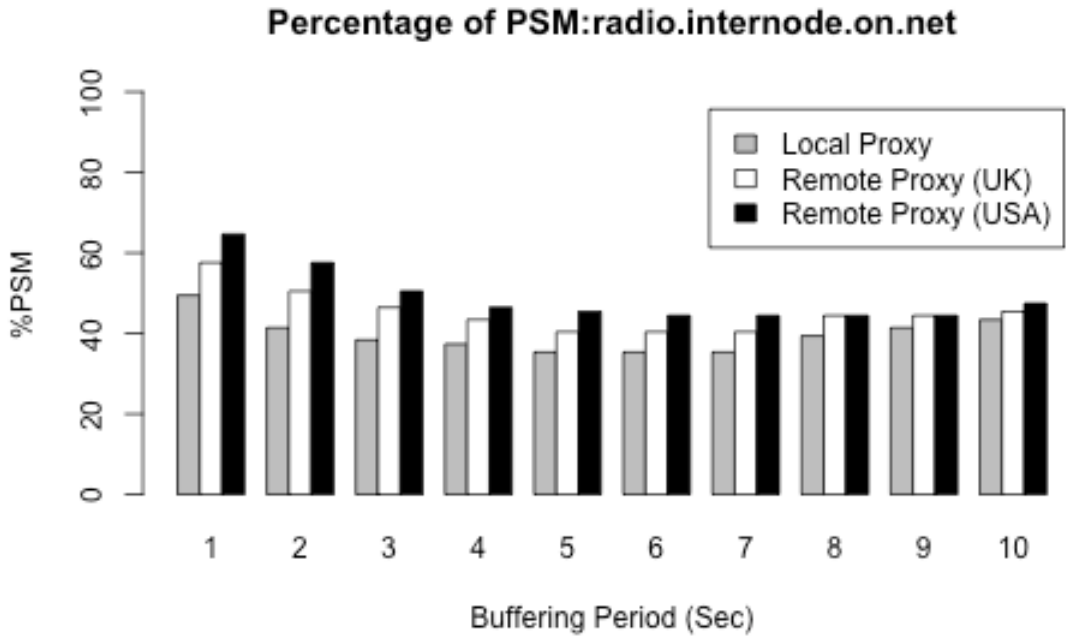
- Initial start-up time (T)
  - Proxy does not buffer radio traffic for T seconds.
- After T expires Proxy buffers traffic for t seconds
- Sends the buffered data in a single burst

Evaluation: Local Proxy over WLAN



- Power consumption decreases with the buffering period.
- The quality of the radio stream remains same throughout the experiments.
- Minimum power consumption is 35% of 0.99Watt for the 16kBps radio.

How much do we save energy?



- Proxy Locations: local (RTT=2ms), UK(RTT=56ms), and USA (RTT=110ms)
- Quality of radio stream unaffected
- Power consumption decreases as buffering period increases
- Minimum power consumption is 35% of 0.99W for the 16kBps radio

Want to learn more?

- Future Internet
  http://www.futureinternet.fi/

- Come talk to us about…

  Doctoral thesis,
  Master thesis
  Special assignment
  Seminar
  ...

Thanks!