Tiny Web Services: Design and Implementation of Interoperable and Evolvable Sensor Networks (Priyantha, Kansal, Goraczko, Zhao, 2008)

Dominique Im Obersteg
Distributed Systems Seminar 2011, ETH Zurich

Evolutionary sensornets

Image: http://www.robotshop.com/blog/images/internet-of-things.jpg

Evolutionary sensornets

- Single confined physical space (office, home,…)
- Heterogeneous sensors
- No direct access to sensor capabilities

Home security system

Medical alert system

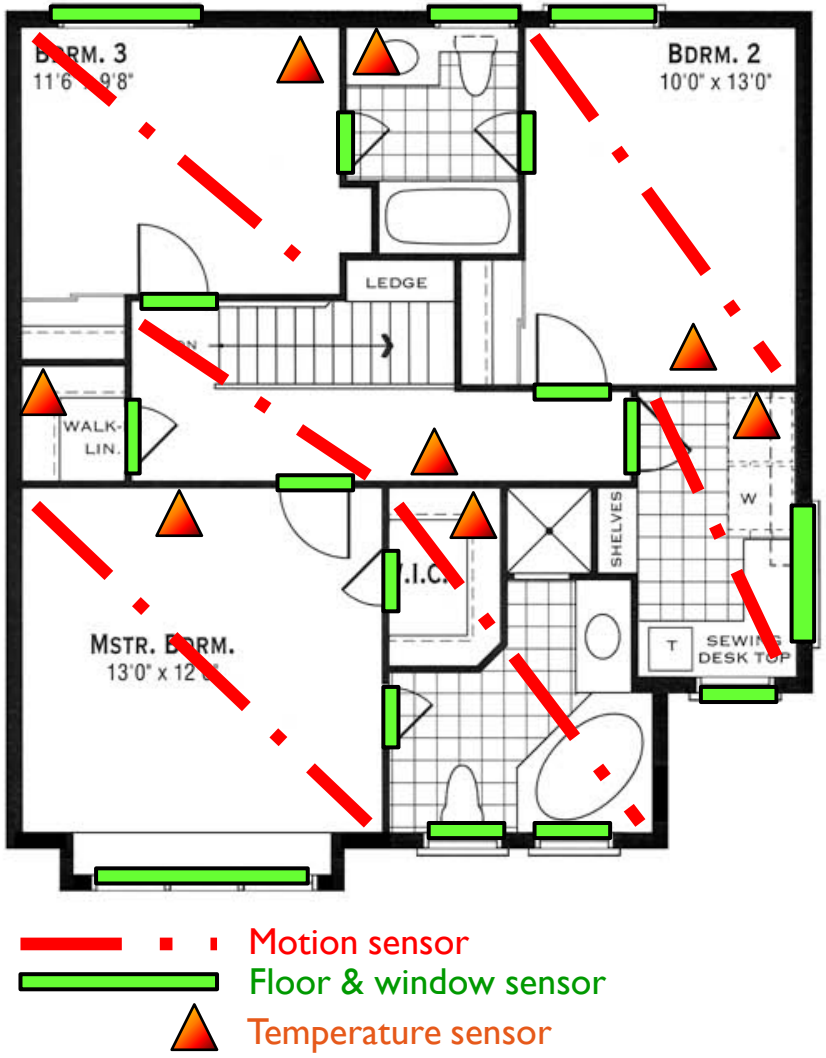
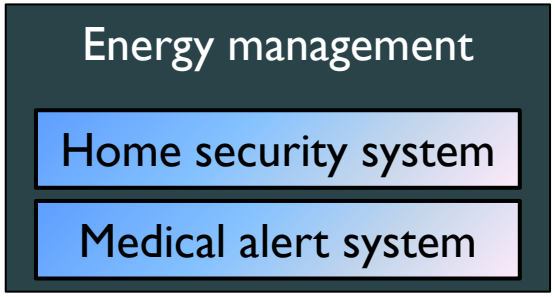


Image: http://aycan.ca/house/plans/house-plan.jpg

Evolutionary sensornets

- Augment & evolve existing sensing infrastructure using soft- and hardware
- New sensors may be added after deployment



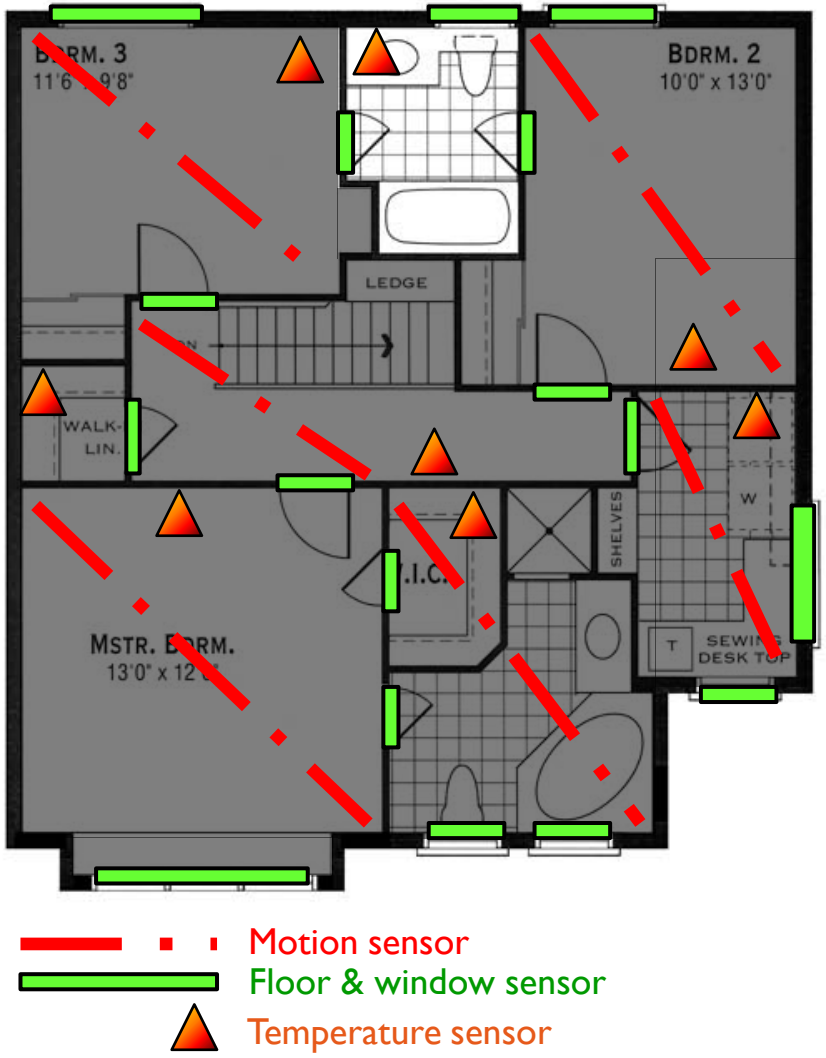


Image: http://aycan.ca/house/plans/house-plan.jpg

Key challenges

- Limited energy
- Limited hardware capabilities
- Sensors should have common API
- Additional data size & processing cost for structured access

Image: http://inventionmachine.com/Portals/56687/images/challenges_ahead.jpg

Research goal

- Quantification of resource cost for providing structured and programmatic access to sensor nodes
- Minimize resource cost
- Trade-off between interface generality and resource efficiency

⇨ Find optimal solution

Image: http://smallbiztrends.com/wp-content/uploads/2011/01/iStock_000004996421XSmall.jpg

Web services

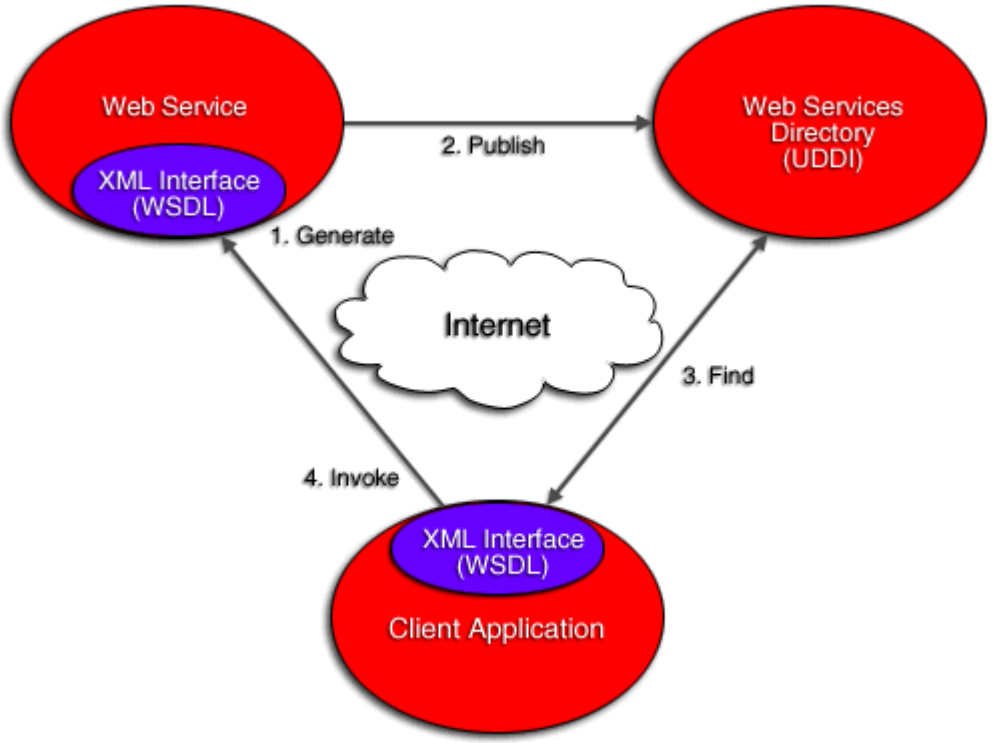


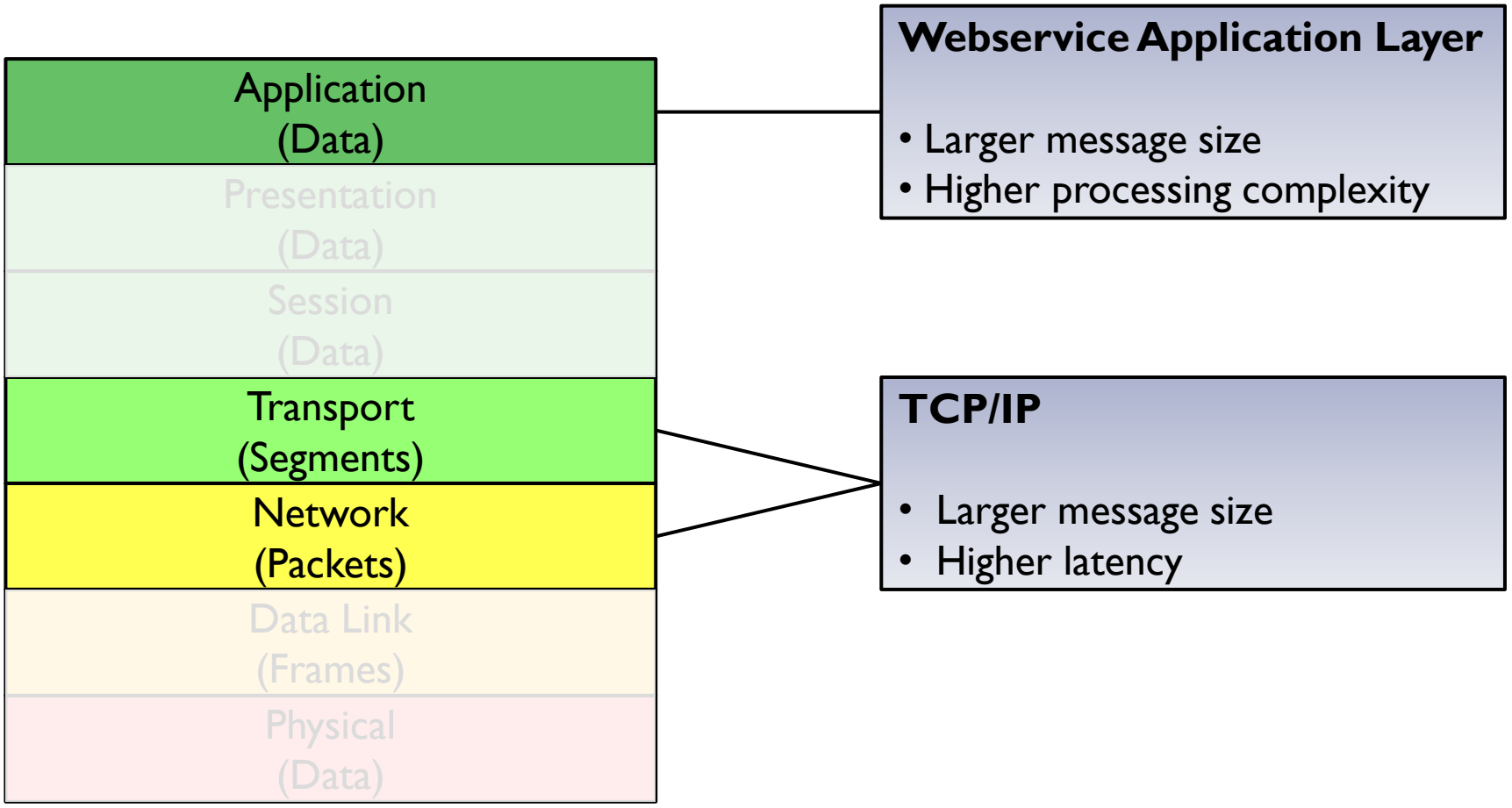
Image: http://download.oracle.com/docs/cd/B10468_13/tour/b10374/img/net2_01.gif

Advantages of web services

- Interoperability
- Improved programmability
- Ease of integration through Internet
- Reduces need for protocol translation

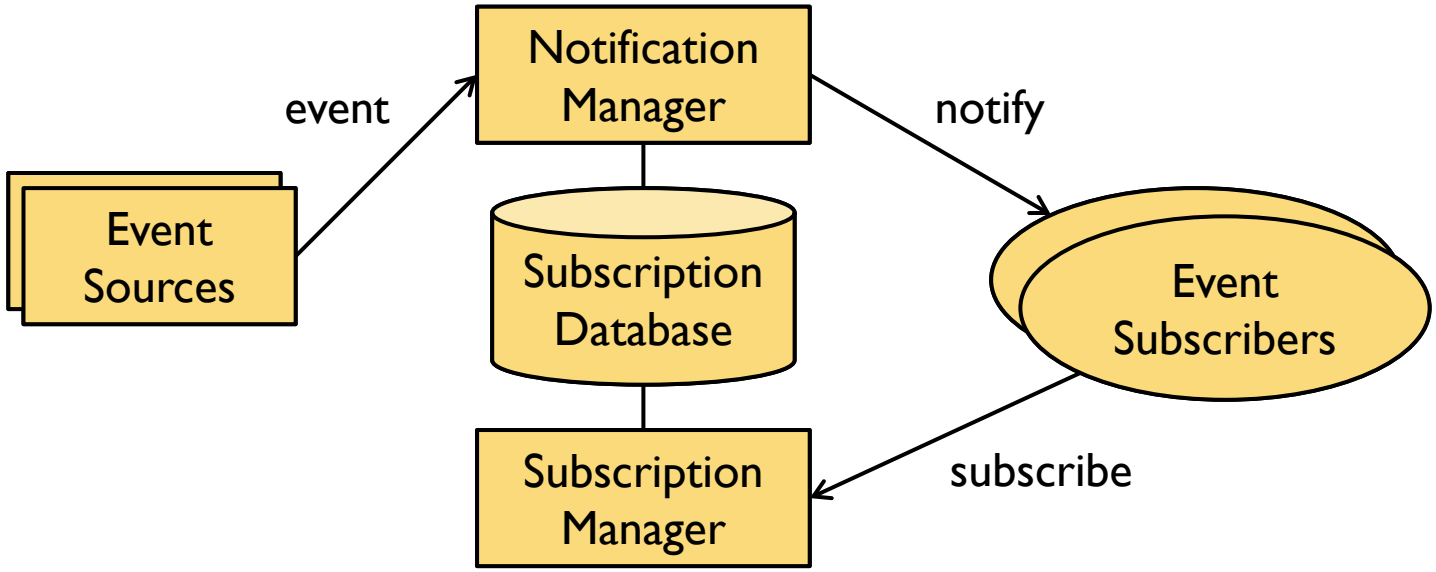
Image: Victorinox

Web service overheads



Web service application design

- Supporting duty cycled nodes



- What about the other direction?

Web service application design

- Web service method encapsulation
  - Specified by Web Service Description Language (WSDL)
- XML parsing on sensor nodes
  - Only when URL encapsulation insufficient
- XML Compression and optimization
  - LZW, XML-specific compression, method name encoding (single byte)

Web service application design

- Brief summary
  - Overheads due increased message size and processing complexity
  - Duty cycled nodes to save resources
  - WSDL
  - If XML is needed, use compression/optimization

Network and transport layer design

- Use persistent TCP connections
  - Only overhead is heartbeat message
  - Works only for HTTP 1.1
- Disable delayed TCP acknowledgments
  - Delayed TCP ACKs reduce number of messages but introduce latency overhead
- Use link layer retransmissions
  - Don't wait for TCP timeouts

Network and transport layer design

- Use low-power mode between TCP messages
  - Fixed minimum delay due to link capacities, hop count and packet size
  - Calculate or measure
- Use 6lowpan to connect sensor nodes to IPv6 network
  - Provides way to transmit IPv6 packet over 802.15.4
- Use link layer fragmentation
  - Split data in several TCP segments, acquire channel and send packet burst to reduce overhead

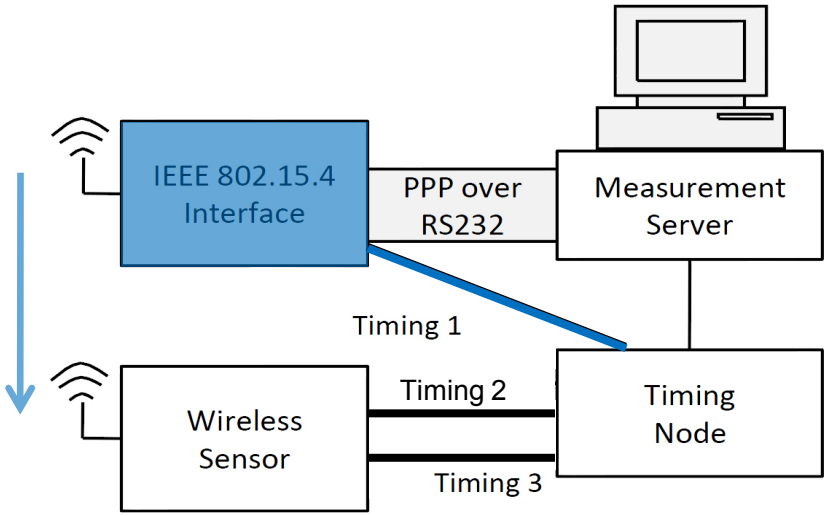
Network & transport layer design

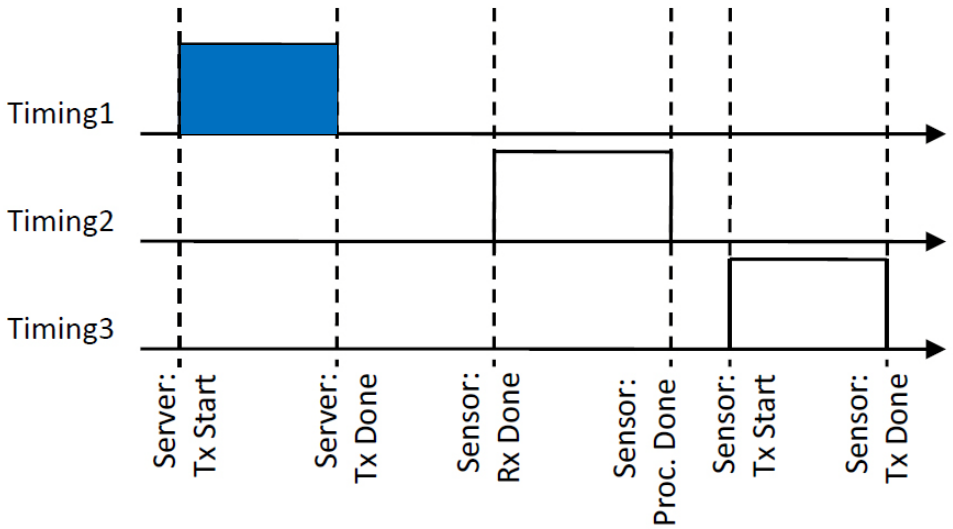
- Brief summary
  - Use persistent TCP connections (if possible)
  - Disable delayed TCP ACKs
  - Don‘t wait for TCP timeouts – use link layer retransmissions
  - Try to save energy between TCP messages
  - Use link layer fragmentation

Experiment

Image: http://class7technology.wikispaces.com/file/view/stopwatch.jpg/78629245/stopwatch.jpg

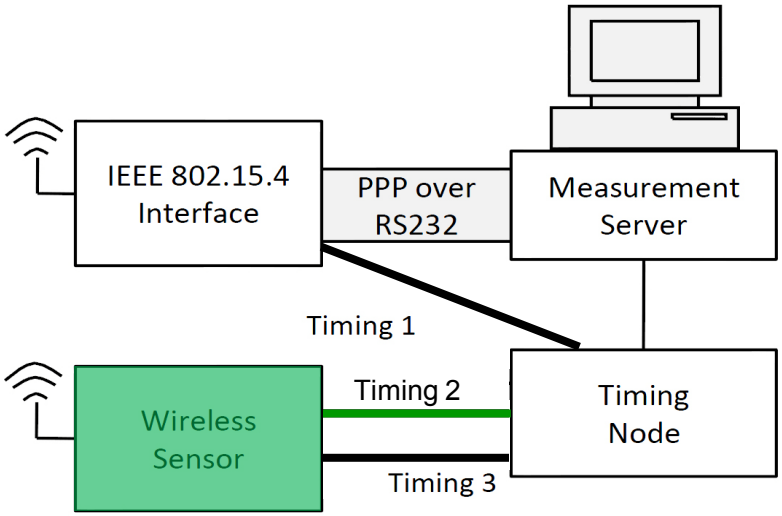
Experiment

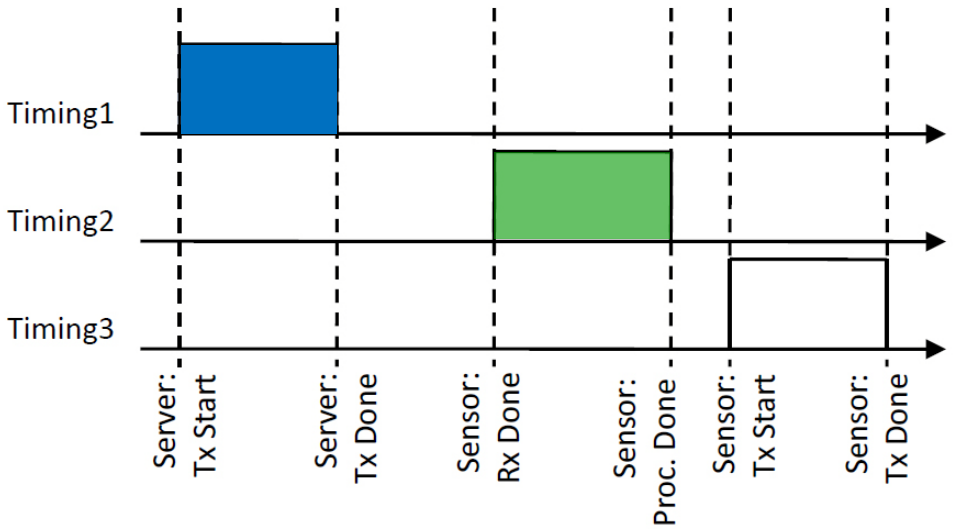




Time (ms)	Event	TCP Action
0.00	Server Tx start	TCP data
6.19	Server Tx done	(74 byte request)
9.68	Sensor Rx done	
10.67	Packet processed	
10.68	Sensor Tx start	TCP ACK
11.71	Sensor Tx done	
29.29	Server Tx start	TCP data
33.35	Server Tx done	(27 byte request)
35.53	Sensor Rx done	
36.35	Packet processed	
36.36	Sensor Tx start	TCP data
37.78	Sensor Tx done	(37 byte reply)

Experiment





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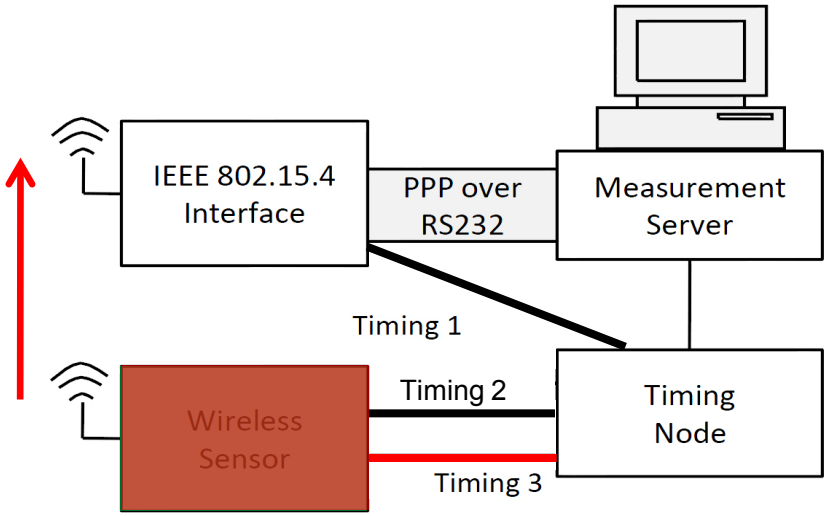

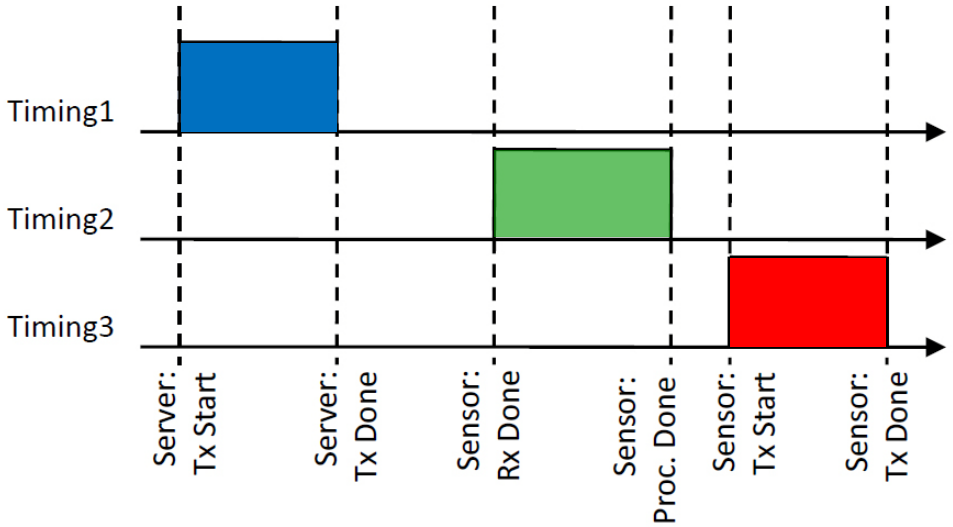

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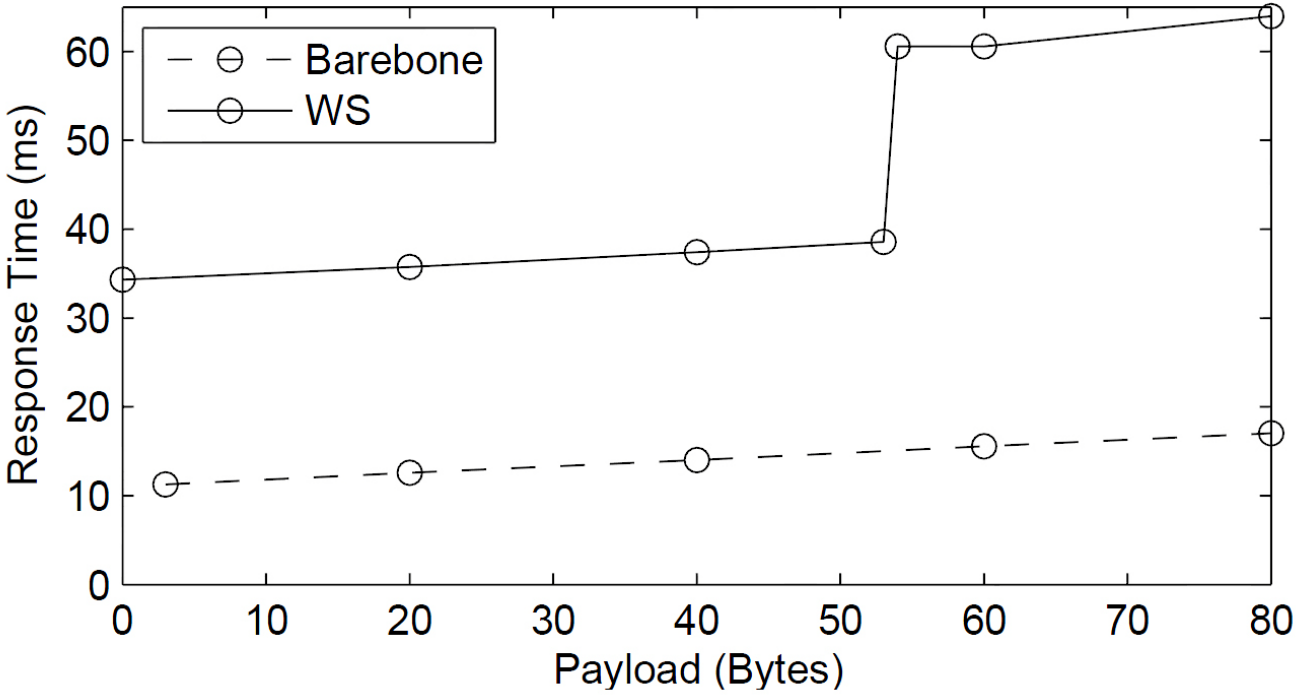
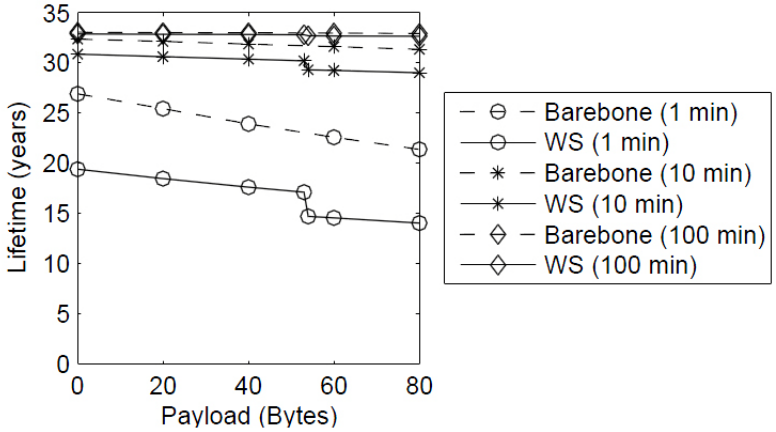
Response time

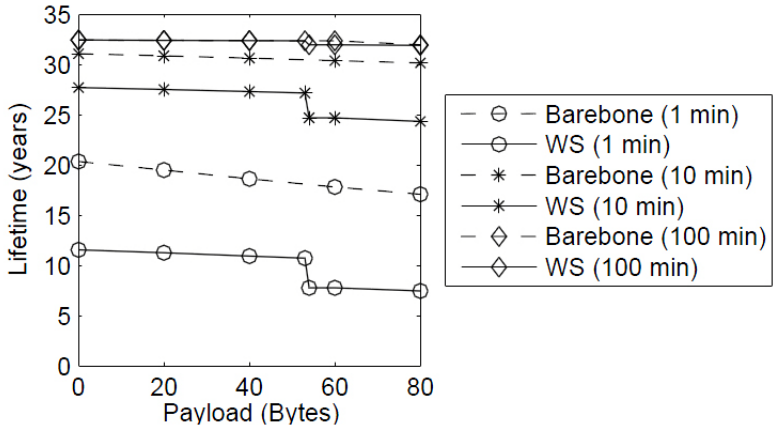


- Increased response time (~20 ms), still acceptable
- Significant increase when payload is split in multiple packets

Energy consumption



Radio off during TCP msg transmission gaps



Radio always on

- Additional cost relatively small when message fits in a single packet
- Frequent message exchanges significantly reduce lifetime
- Lifetime computation based on timing and hardware data

Prototype

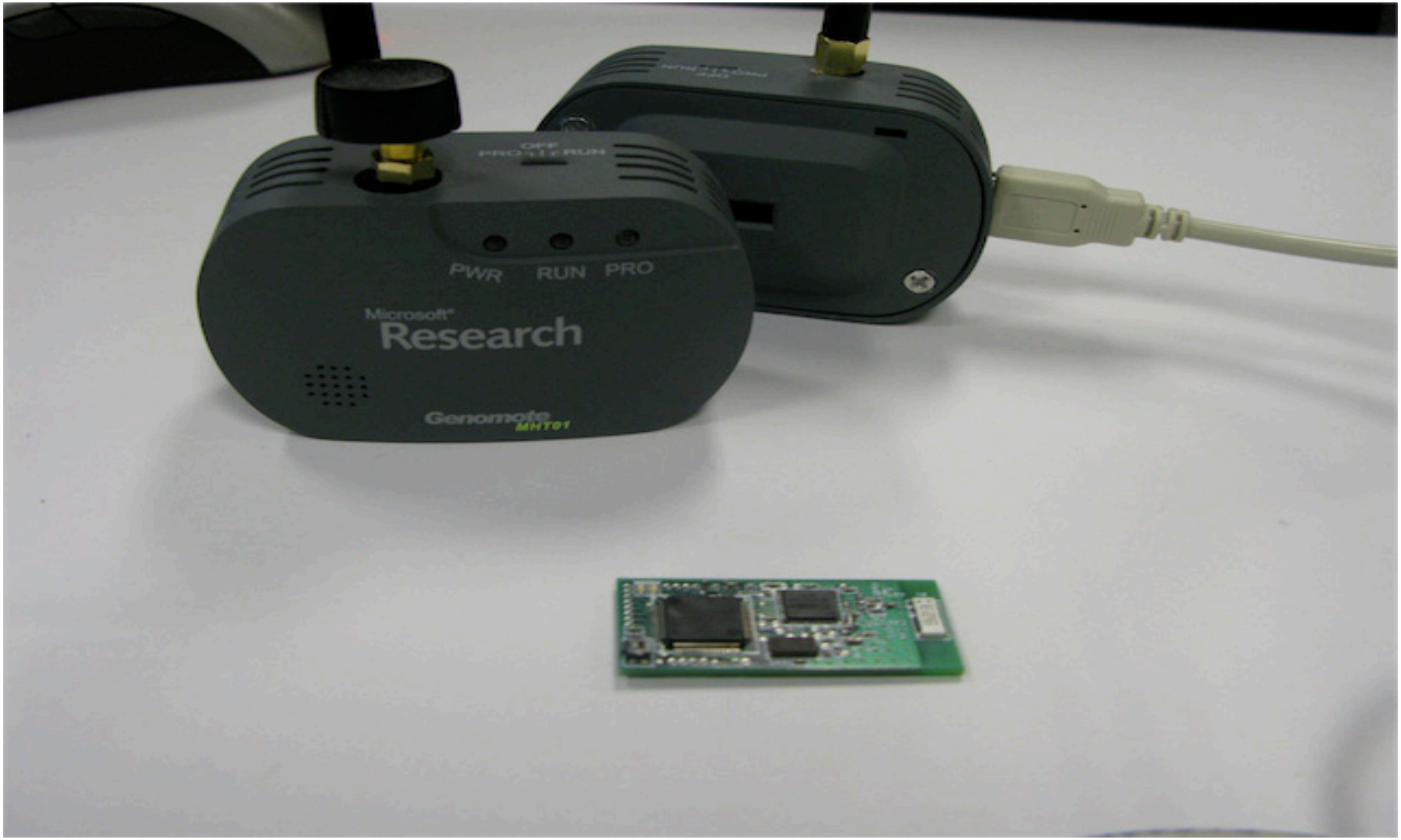
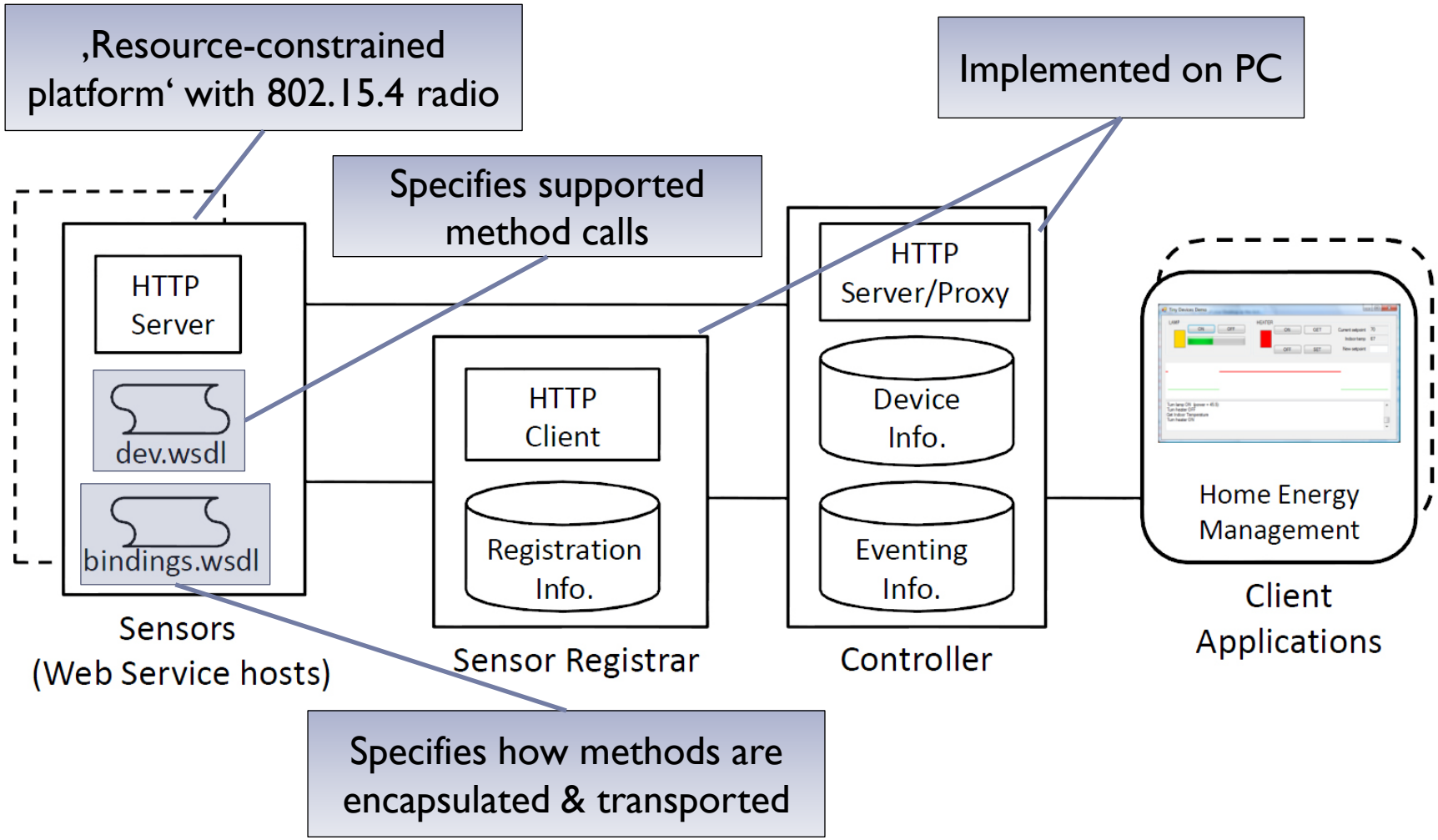


Image: http://www.wired.com/images_blogs/photos/uncategorized/2008/03/04/tiny_web_services1.jpg

Prototype system



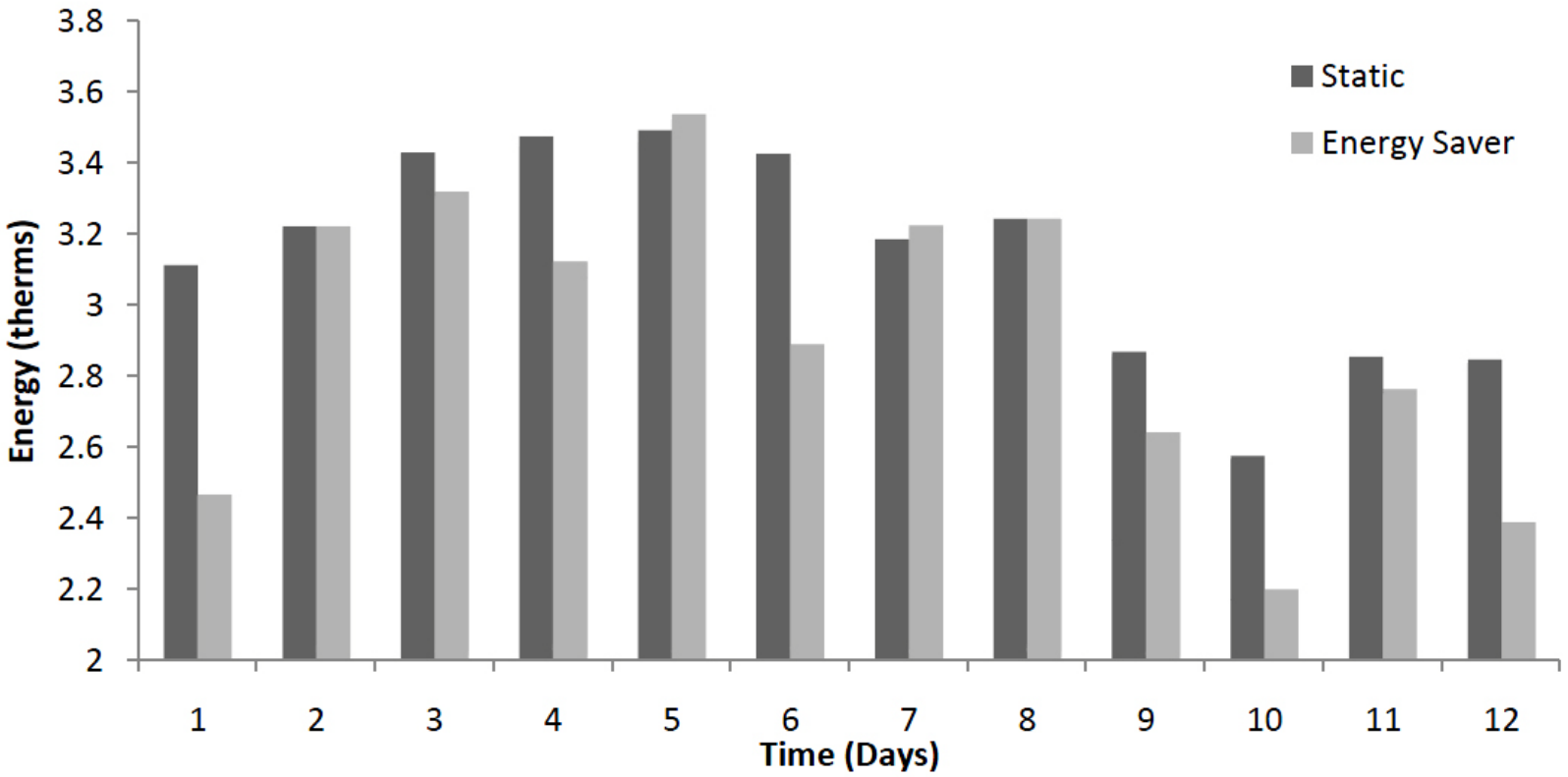
Home energy management application

- 12 day period
- Volunteer family
- Motion sensors in living area, study room and each bedroom

- Use data from home‘s security system
- Smart-sockets on most-used entertainment electronics and lamps

Image: http://www.londonnfp.com/lnfp/images/family.jpg

Home energy management application



- Energy Saver: control heating by motion data

Conclusion

- Web service based evolutionary sensornets are flexible and extensible
- Ease of access leads to many new possibilities
- Proof of concept successful
- More detailed experiments need to be performed to prove efficiency and scalability

Personal opinion & discussion

- Web service application design evaluation
- Low power mode between TCP transmissions
- Battery lifetime
- Multi-hop networks
- Security

Image: http://www.tunezine.com/tunezine98_fichiers/Discussion.gif

Questions?

Image: http://images.huffingtonpost.com/2010-02-04-Questions.jpg