IP is Dead, Long Live IP for Wireless Sensor Networks

Hui, J. W. and Culler, D. E. 2008, SenSys '08

Seminar Talk
Simon Mayer [simon.mayer@inf.ethz.ch]
Distributed Systems Group, ETH Zurich

Topics of this seminar...

- Medium Access Control for WSNs
- Time Synchronization (FTS Protocol)
- Data Dissemination (DIP)
- Collection (CTP Noe / Extended Trickle)
- Localization for Sensor Networks
- Coverage and Connectivity in WSNs

Topics of this seminar...

WSN-specific...

What about the Internet?

What about IP?

Maybe they're not compatible...?

«IP is not suitable for Wireless Sensor Networks»

"Many of the lessons learned from Internet and mobile network design will be applicable to designing sensor network applications."

"However, sensor networks have different enough requirements to at least warrant re-considering the overall structure of applications and services."

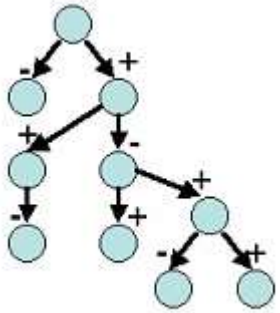
Quotes: Estrin et al. (MobiCom 1999)

«IP is not suitable for Wireless Sensor Networks because...»

- Nodes have limited resources

- Too many devices to rely on broadcast communication

- In-network processing and localized algorithms required



- Nodes don't need identities (i.e., addresses)

«IP is not suitable for Wireless Sensor Networks because...»

WSNs will anyway be tailored to the application at hand...

IP is Dead, Long Live IP for Wireless Sensor Networks

Hui, J. W. and Culler, D. E. 2008, SenSys '08

Jonathan Hui
(UC Berkeley)

David Culler
(UC Berkeley)

- Show that IPv6 and WSNs actually fit well together
- Complete high-performance implementation of an IPv6-compatible network stack for Wireless Sensor Networks

So what has changed since 1999?

- Advances in Wireless Sensor Networks
  - Link Layer: S-MAC, T-MAC, B-MAC, Wise-MAC, ...
  - Network Layer: SPIN, MultihopLQI, CTP
  - Transport: Drip, DIP
- Internet Protocol, Version 6 (IPv6)
  - Larger address space (128 Bit)
  - Optimized headers
  - Autoconfiguration

So what has changed since 1999?

Substantial progress in Internet architecture and WSN research

Revisit assumptions on compatibility of the two...

An optimized IPv6 stack for WSNs

- Feasibility of IP on constrained devices shown by A. Dunkels in 2004
- Hui an Culler adopt a best-of-both-worlds approach: Integration of layered model from networking with elegant mechanisms from WSNs (e.g., Trickle instead of flooding)
- Optimized primarily for energy consumption, scalablility and manageability

An optimized IPv6 stack for WSNs – Issues

- Always-on: Communication with any connected node at any time without prior establishment of a connection

- Best-Effort Reliability: Achieve reliable transport over unreliable links

An optimized IPv6 stack for WSNs – How To

- Exploit IPv6 features
  - Stateless Address Autoconfiguration
  - Optimized headers
- Implement extensions and optimizations
  - Header compression
  - Packet fragmentation
- Make simplifying assumptions
  - Subnet address well-known (can be omitted)

Link Layer: How to minimize idle listening?

- Nodes' radios have to be duty-cycled (energy consumption), but IP requires an always-on link
- Media Management Control
  - Based on B-MAC and WiseMAC
- Hybrid Approach: Scheduling to optimize sampled listening

Sampled Listening

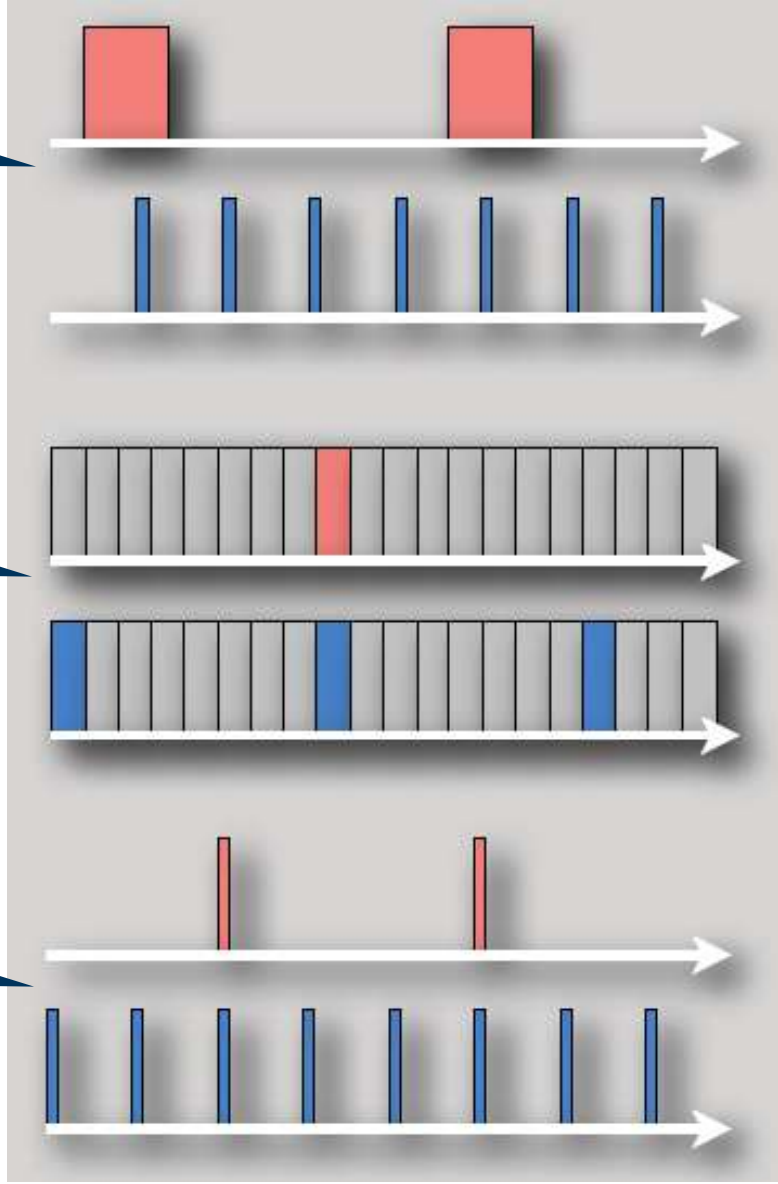
(wake up & listen)

Scheduling

(synchronize listening schedules)

Hybrid

(optimization using scheduling)



J. Hui, Dissertation Talk

Header/Packet Adaptation and Compression

- IEEE 802.15.4 supports 127 Bytes of payload, IPv6 requires a minimum of 1280 Bytes
  - Fragmentation of IPv6 datagrams into multiple frames
- Compression of IPv6 headers to reduce overhead
  - Simplifying Assumptions about IP version, traffic class, hop limit...
  - Entire WSN has common global prefix

- Best case: Reduction of 48 Byte header to 6 Bytes

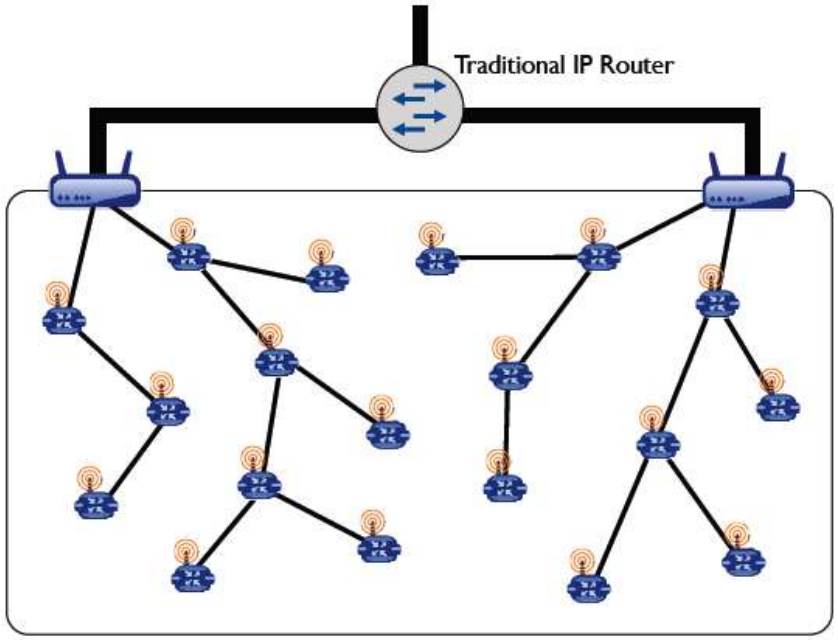
Autoconf – Configuring large numbers of devices

- IPv6 features + «Every node is a router» design decision
- Neighbor Discovery
  - IPv6 Router Advertisements (RAs)
  - RA frequency managed using Trickle timer
- Address Autoconfiguration
  - Stateful DHCPv6 better suited than stateless address autoconf
  - Uniqueness of IP addresses can be guaranteed easily

Stateful:	Server maintains registry
Stateless:	Server disseminates parameters

Packet Routing: Constructing the Routing Graph

- Focus on most common communication patterns in WSNs
  - Node-to-border router:
  - Border router-to-node:
  - Direct single hop:



Packet Routing: Constructing the Routing Graph

- Focus on most common communication patterns in WSNs
  - Node-to-border router: Single default route
  - Border router-to-node: Border router learns default route graph and reverses the links
  - Direct single hop: Next hop information for neighbors

Packet Routing: Default route selection

Route Selection Algorithm

1. Router Advertisements used to discover candidate routes
2. Node puts potential routes into routing table
   - Each transmission on a route updates its PRR
3. Node sorts routing table and selects default route

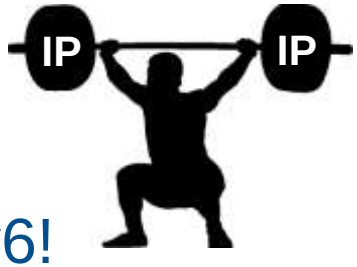
- Maintaining route consistency
  - Detection of routing loops and inefficiencies
  - Remedy: More frequent Router Advertisements (Trickle timer)

Evaluation

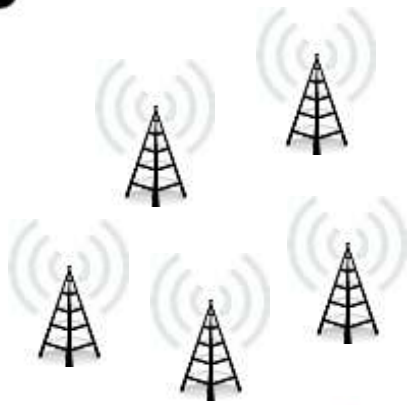
- TelosB nodes within real-world data collection application

- IPv6 solution outperforms existing systems (e.g., Dozer)
  - Extremely low duty cycle (0.65%) → Low power consumption
  - Very low latency: 125ms (on average)
  - Reliability near 100% (98.98%)

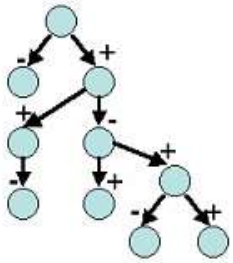
Conclusions



- Nodes have limited resources
  But still, we can implement IPv6!



- Too many devices to rely on broadcast communication
  WSN is no single broadcast domain!



- In-network processing and localized algorithms required
  These are not constrained by the IPv6 architecture!

- Nodes don't need identities (i.e., addresses)
  But it does not hurt… and can be done well in IPv6!

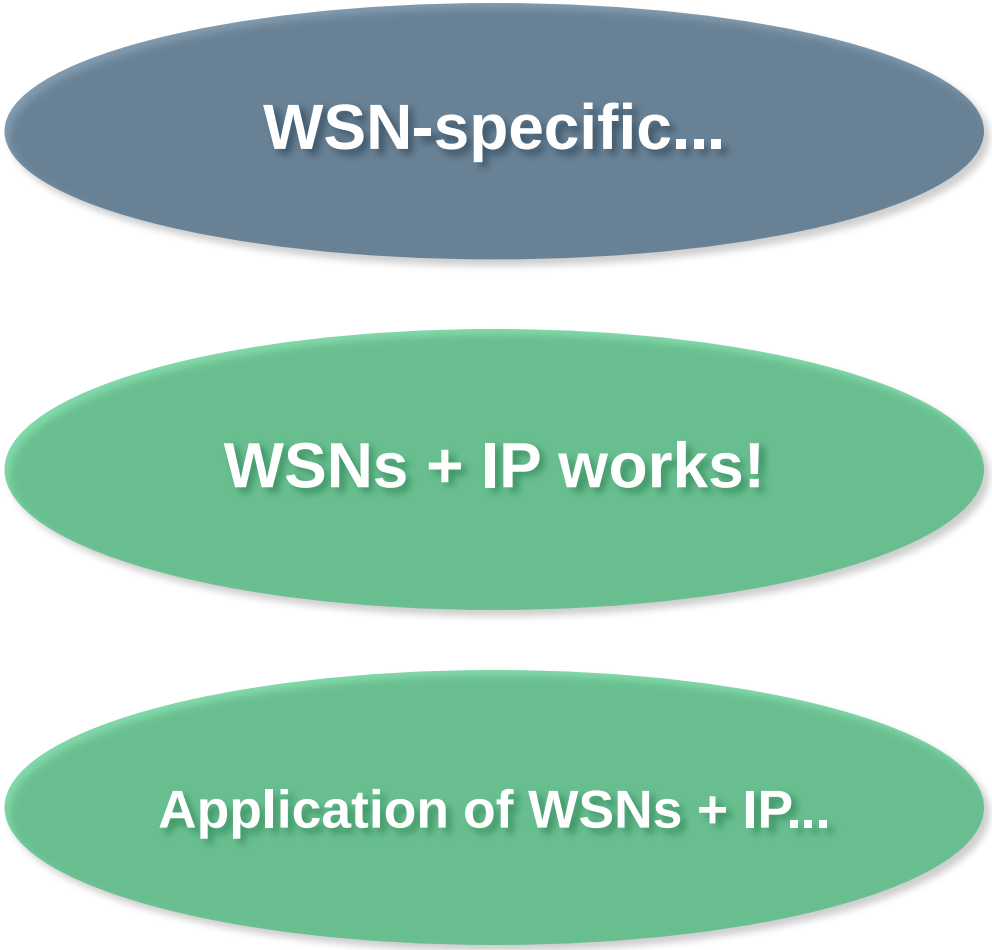
Outlook: Topics of this seminar...

- Medium Access Control for WSNs
- Time Synchronization (FTS Protocol)
- Data Dissemination (DIP)
- Collection (CTP Noe / Extended Trickle)
- Localization for Sensor Networks
- Coverage and Connectivity in WSNs

- Over soon: «IP for Wireless Sensor Networks»

- Next (D. Landtwing): «Energy Monitoring using WSNs»

Outlook: Topics of this seminar...



Thank you for your attention!

Sources

- **Jonathan W. Hui and David E. Culler**.

  IP is Dead, Long Live IP for Wireless Sensor Networks.
  Proceedings of the 6th ACM Conference on Embedded Networked Sensor Systems (SenSys 2008), Raleigh (NC), USA, November 2008.

- **Jonathan W. Hui and David E. Culler.**

  Extending IP to Low-Power, Wireless Personal Area Networks.
  Internet Computing, Volume 12, Number 4, pp. 37-45, July/August 2008.

Image Sources

- http://www.jarvislab.net/Bioinformatics.html
- http://www.heimwerker-test.de
- http://www.servitokss.com/question-marks/
- http://digitaldeutsch.com/Adjektive.html
- http://www.polkadotsalmon.co.uk/broadcastProgrammes.htm