

The Internet vs. Sensor Nets

5/5/04

Philip Levis

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The Internet vs. Sensor Nets

What they've learned,

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The Internet vs. Sensor Nets

What they've learned,
and we've forgotten.

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What we've learned,

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The Internet vs. Sensor Nets

What they've learned,
and we've forgotten.

What we've learned,
and they've ignored.

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The Internet vs. Sensor Nets

What they've learned,
and we've forgotten.

(BIG)

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What we've learned,
and they've ignored.

(small)

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Usage Patterns and Assumptions

Internet

- Independent hosts
- End to end flows
- Two-tier architecture
- Wired (generally)
- Latency
- Throughput
- Bandwidth is relatively cheap
- Limited in-network state

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Sensor Net

- Single, collaborative use
- Collect, disseminate, and others
- Ad-hoc (more homogenous)
- Low power wireless
- Wake time
- Very low utilization
- Bandwidth is expensive
- RAM is limiting physical resource

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A lot of differences...

Network Architecture

Internet

- Interconnect separate networks
- Resilience to loss and failure
- Support many comm. services
- Accommodate variety
- Distributed management
- Cost effective
- Low effort attachment
- Resource accountability

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Sensor Net

- Dense real world monitoring
- Resilience to loss, failure and noise
- Support many applications
- Scale to large, small, long
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...but many of the same principles apply.

Similar, but Different

- Very different purposes
 - But similar architectural principles
- Problems are different in the details, similar at a high level
- Sensor network problems probably have Internet analogues
 - Need a new solution, but probably similar to existing ones
- Converse: Internet paradigm doesn't work for sensor nets
 - Wireless vs. wired
 - Usage models: what are the key issues?

Outline

- Similar but different
- Phil and Scott: A Dialogue
- How can IP Solutions Fall Short?
- A Sensor Network Architecture
- Conclusion

Phil and Scott: A Dialogue

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Scott

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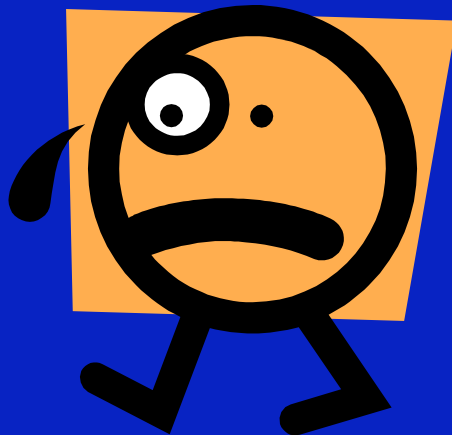
Philip Levis, Neil Patel, David Culler and Scott Shenker.
Trickle: A Self-Regulating Algorithm for Code Propagation and Maintenance in Wireless Sensor Networks. NSDI 2004.

What I Learned

- Internet solutions generally don't apply to sensor networks
- Their underlying techniques do
- Apply, change and adapt to the peculiarities of sensor networks

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- Internet solutions generally don't apply to sensor networks
- Their underlying techniques do
- Apply, change and adapt to the peculiarities of sensor networks
- I thought I had read the literature of my community already!
 - SIGCOMM has been around a long while....



Outline

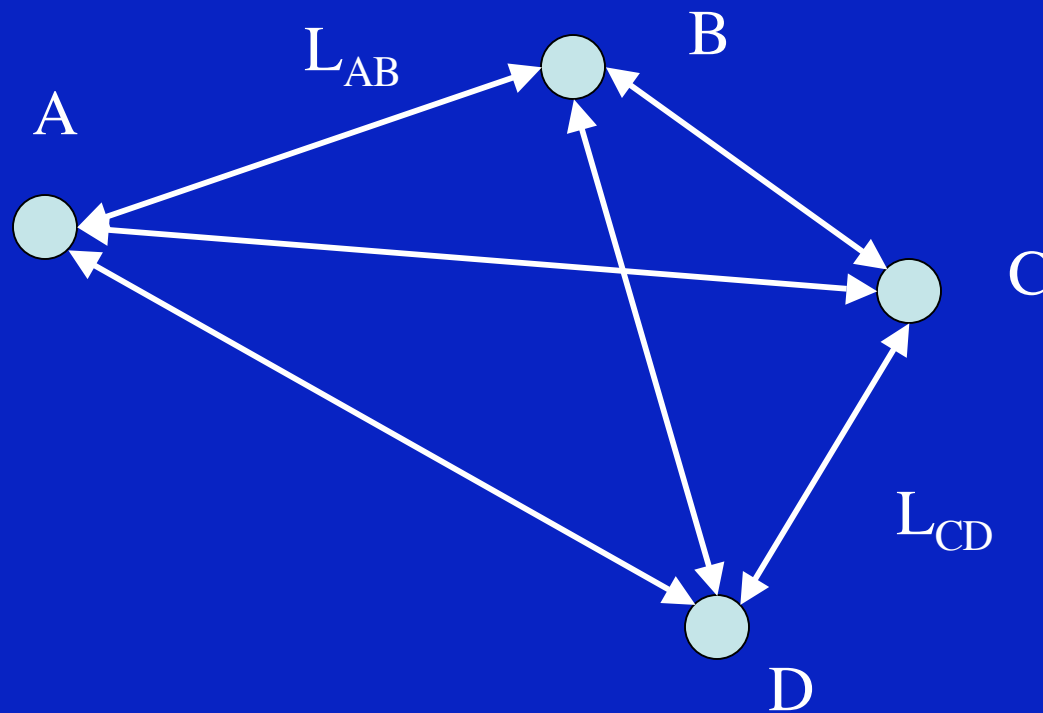
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How Can Current IP Solutions Fall Short?

- Assumptions of behavior
 - Hari: The problem with any-to-any routing is your bandwidth goes to zero as the network size increases. Robert has a paper on this in Mobicom.
 - Phil: But GDI uses less than 0.2% of the network bandwidth....
- Assumptions of environment (control)
 - Stability (can it hose my network?) vs. optimality (can it go faster?)
 - Sensor nets are a walled garden, but you're outside....
- Wireless networks aren't a graph
 - There is wireless IP, but...

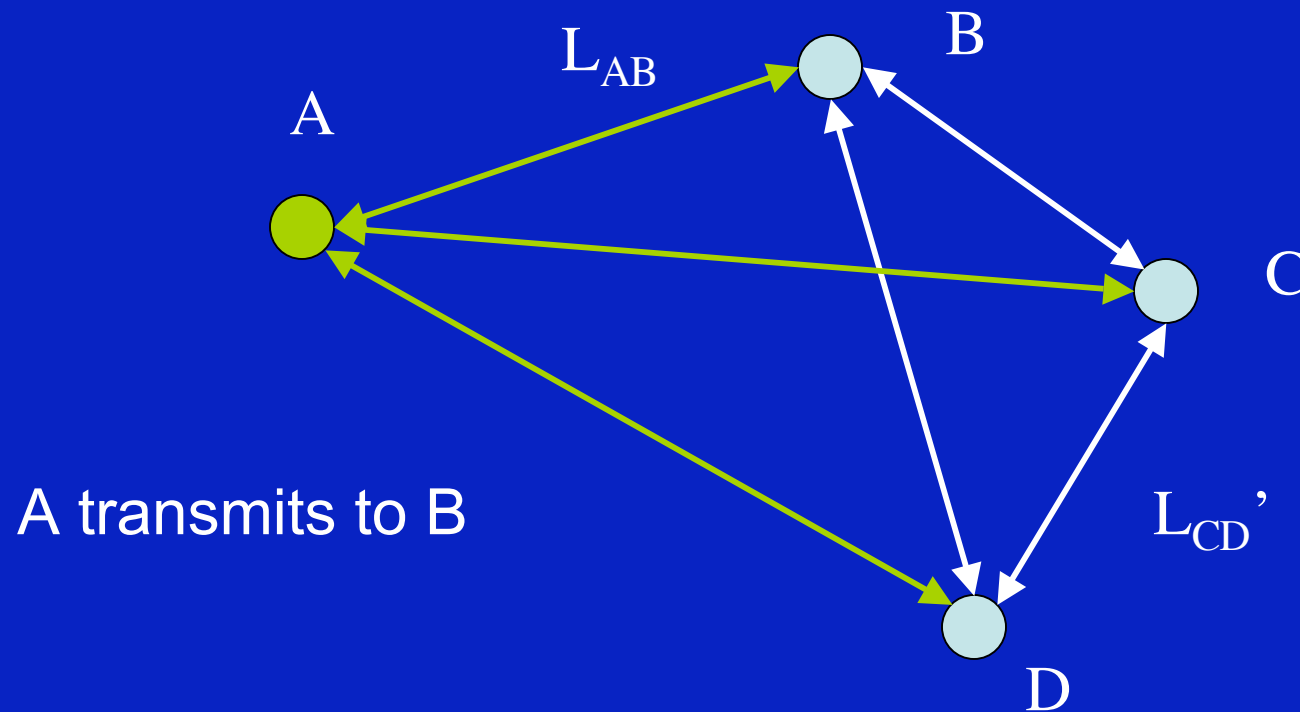
Wireless Networks Aren't a Graph

- A graph assumes link independence
- In a wireless network, transmissions can affect distant nodes
- This is not necessarily a binary relationship



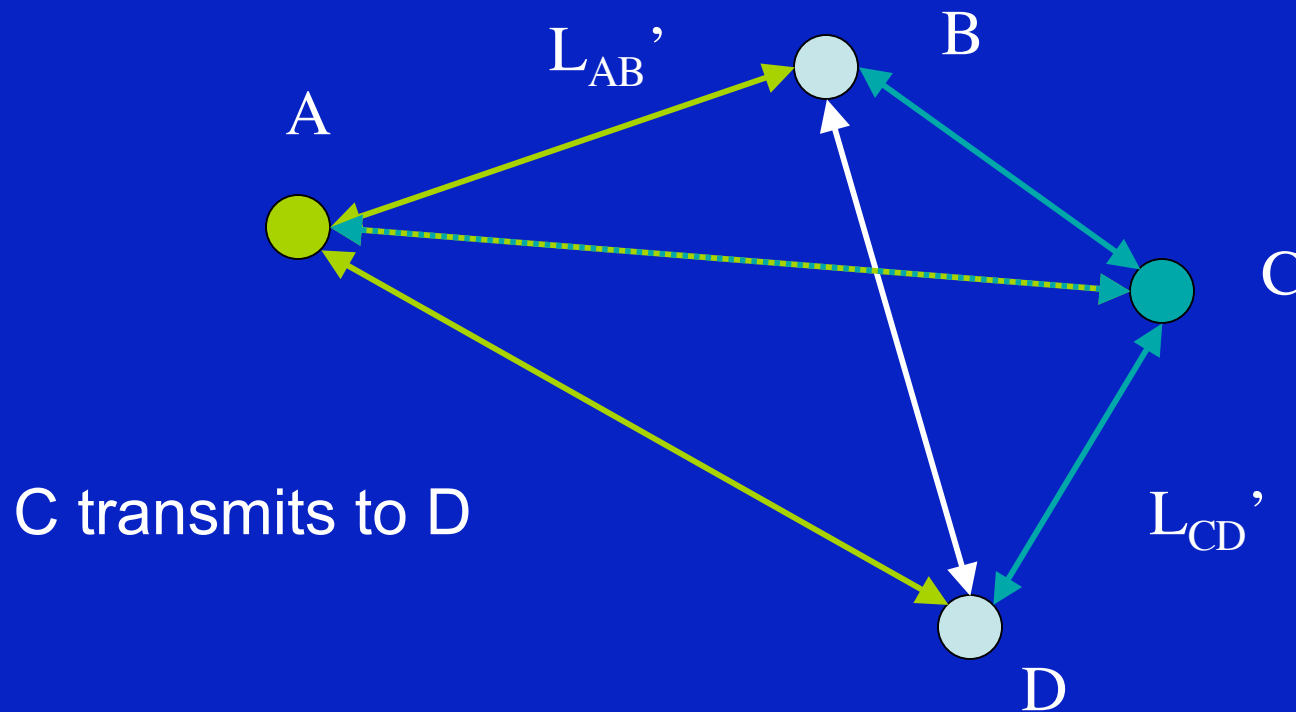
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What Constitutes Inteference?

- Depends on the keying
- OOK, ASK, FSK, QPSK, etc.
- Example: CC1000 (mica2 nodes), 1 bit/ baud FSK radio
- Experiment: One node transmits
 - Immediately, two nodes respond, no media access
 - What does the first node hear?

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 - What does the first node hear?
 - One node, deterministically (the FM capture effect)
 - Move the nodes slightly, which of the two may change
 - ASK/OOK (mica, rene) behaves completely differently
- What about Telos, micaZ (802.15.4, QPSK)?

If Not a Graph, Then What?

- Every transmission perturbs the graph: links are not independent
- Except when utilization is so low that there are no interactions...
- Link estimates change when there is traffic
- Recent work on a theoretical model for reasoning about wireless networks:
 - Mobicom 2003: Kamal Jain et al., MSR: “Conflict Graphs”
 - Assumes binary interference
- An unanswered question...

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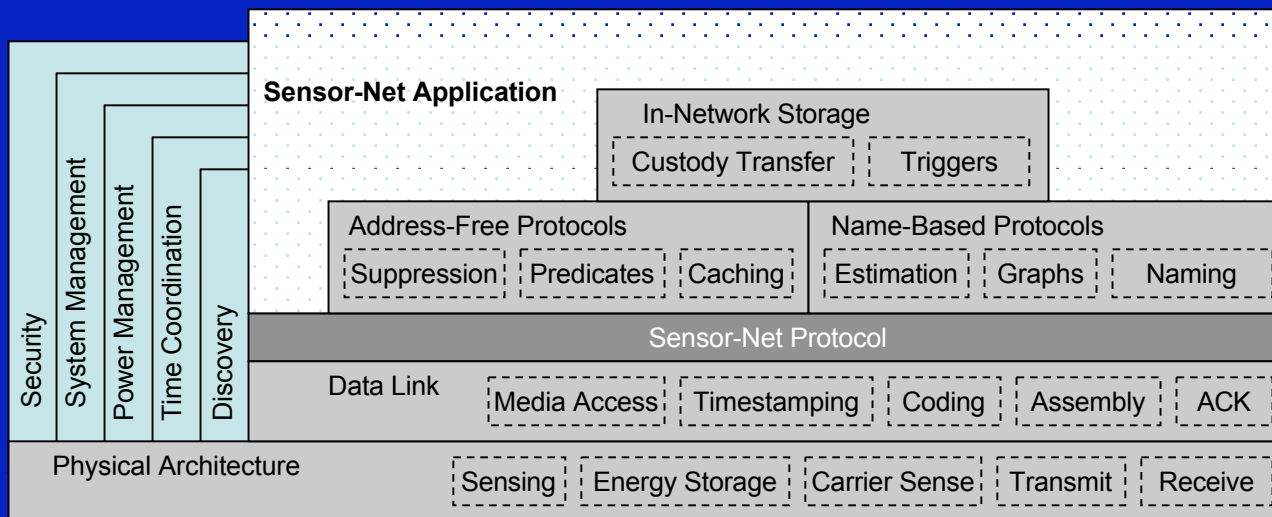
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A Current Sensor Network Flaw

- You can change anything and everything
- No structure to protocols, solutions
 - Great for research, bad for getting things done
- Need *interoperability*
- E.g., diffusion: naming, routing, link estimation, all in one
- Sensor networks need an architectural design

Architectural Proposal

Culler, Shenker, Stoica, et al.



Narrow Waist:
Local broadcast

The Narrow Waist

- Data link instead of network layer
 - Accommodates many network layer protocols
 - Floods, dissemination, routing, diffusion, etc.
- Should be as minimal as possible
 - Address-free, typed, variable length packet
 - Layer addressing/naming on top
- Reflects resource differences
 - In-network processing is desirable
- Ad-hoc nature of the network
 - Not a two-tier architecture

Address-Free Protocols

- A broad class of sensor net protocols do not require addresses
 - Dissemination, local aggregation, code propagation, Trickle
- Use local wireless broadcast as implicit naming scheme
 - Roughly approximates nearby nodes
- A predicate determines whether a node forwards
 - The false predicate: local broadcast
 - The true predicate: full network propagation
 - Predicate defines connected subregions

In-Network Storage

- Distinct from but related to data centric storage
- Not all sensor network traffic is slow and continuous
 - Triggers, high bandwidth events
- Data rate can easily exceed network rate
 - Need to locally store data before forwarding
 - Tree-based aggregation
 - Temporary disconnection
- Flow control, end-to-end delivery
 - Sensor network transport?

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Some Obscure Similarities?

Internet

- Multicast
- High speed packet classification
- High speed TCP

Sensor Net

- Dissemination
- Single hop link estimators
- Media access

Conclusion

- The networking community has solved a LOT of problems
- Some of those solutions are very useful in sensor networks
 - But not all of them: we don't need TCP <insert moniker here>
 - Those that are useful can rarely be taken as is (SPIN, SRM)
- *The research challenge is understanding the important differences and adapting, applying, and inventing as need be.*

Questions

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