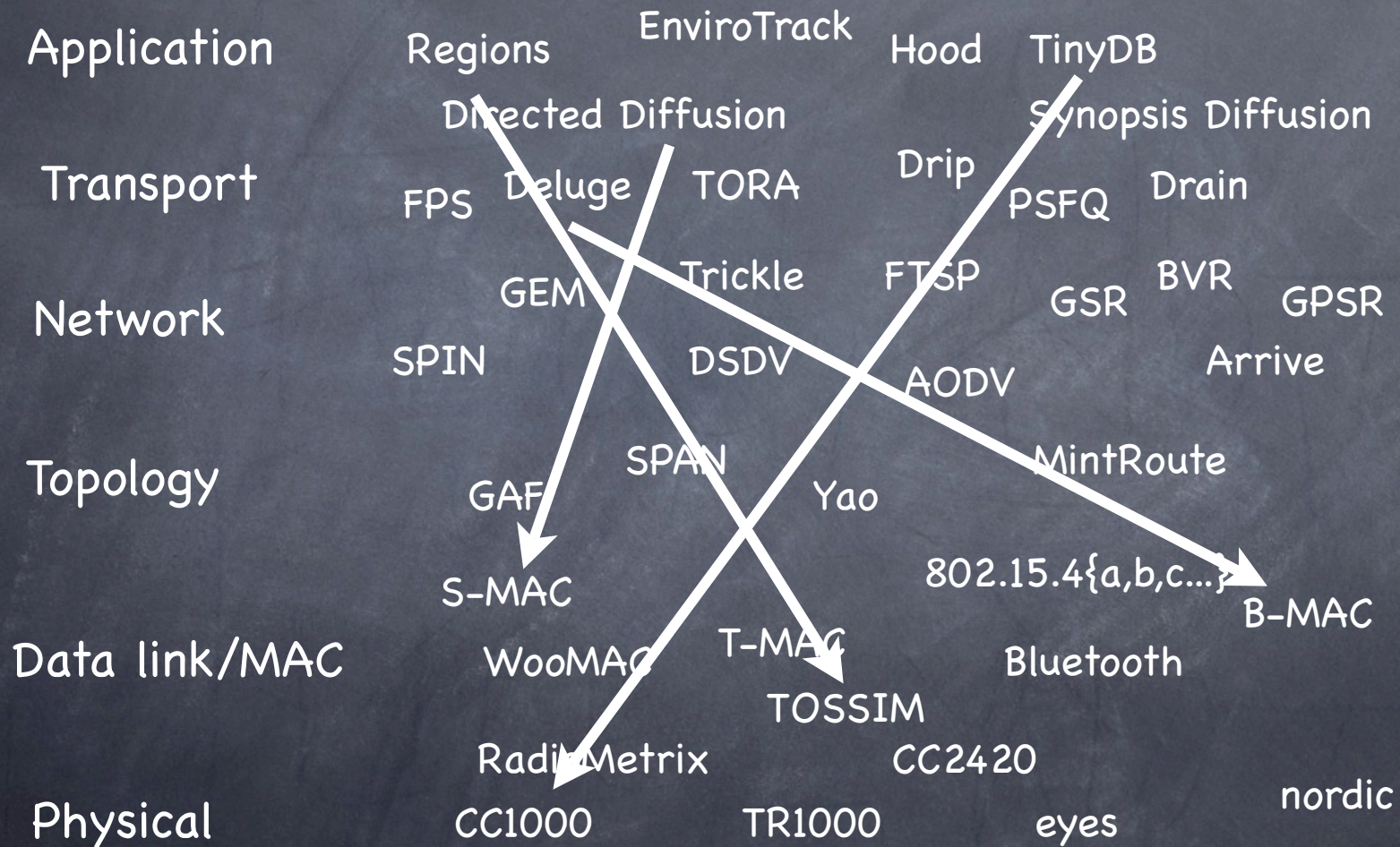


Towards a Sensor Network Architecture

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Sensor Network Research



Research Today

- Broad spectrum of protocols and abstractions
- Vertical integration is common
- Every piece is very efficient, but completely incompatible with almost anything else
- Building up is hard, so we spin in place instead.



The Argument and Question

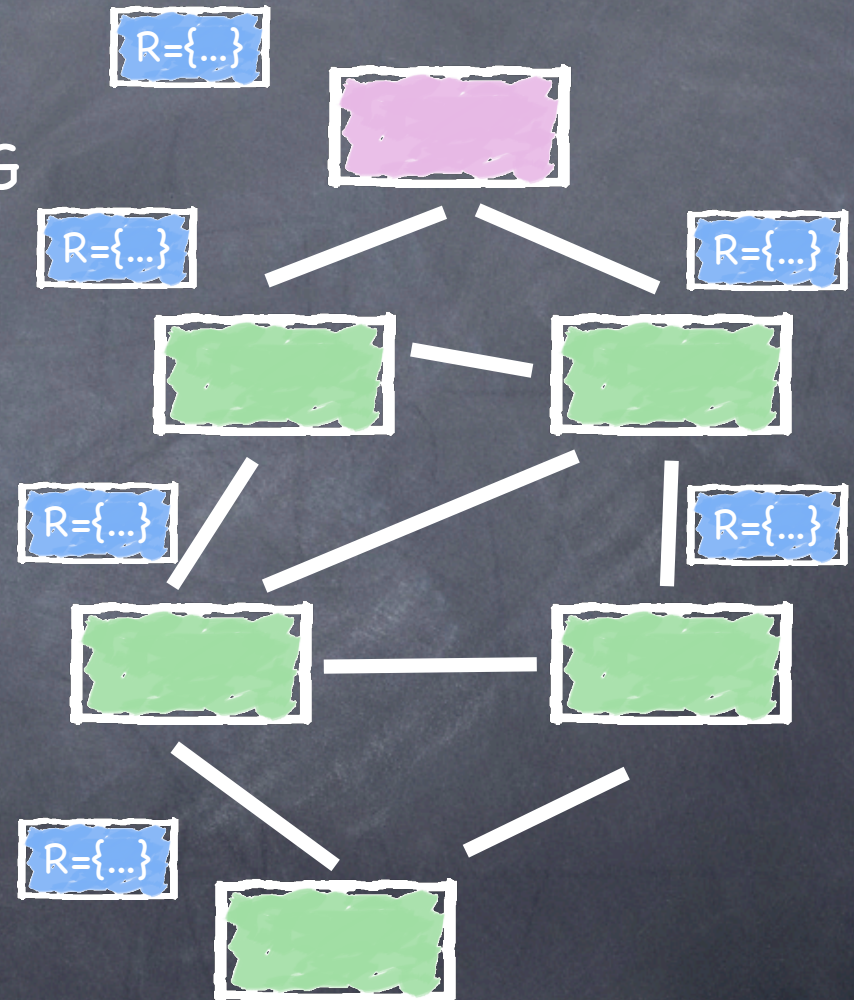
- The primary limiting factor to upwards progress in sensornet research is the lack of an architecture.
- Providing a structure in which to place the pieces can separate concerns and promote composition.
- But what would a sensornet architecture be?
 - What are its design principles? Layers? Encapsulation?
 - What does it define? Packet formats? Protocols?
 - What is it indifferent to? Resources? Heterogeneity?

The Big Brother

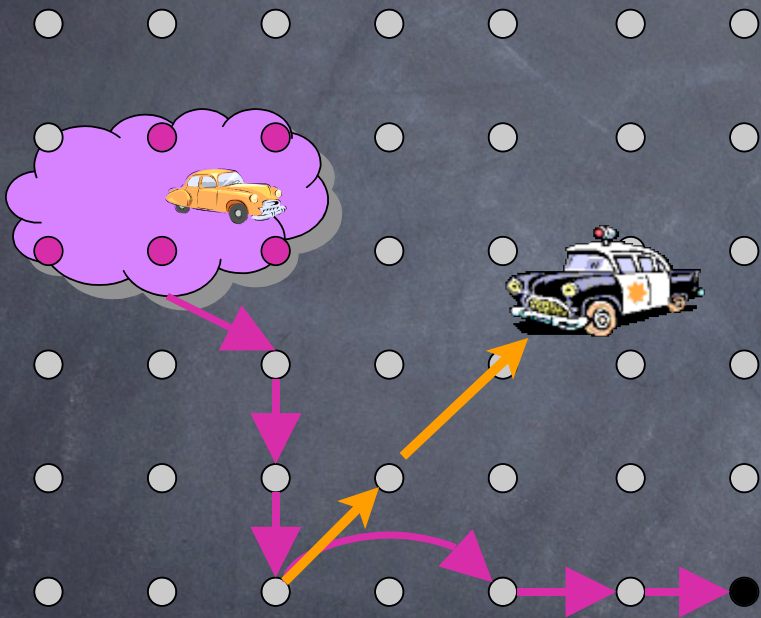
- Devil's advocate: the Internet architecture has been pretty successful. Maybe you should just use that, and call it a day.
- Us: no. Let's look at some sensor network applications, and try to implement them with IP

Test Case: Data Collection

- Stream up a collection DAG
 - Synopsis diffusion, TAG
 - Adapt to network dynamics
- Aggregate on each hop
 - Merge data to save energy
 - $O(n)$, not $O(n\sqrt{n})$ packets
 - End points vs. routers?
- Per-hop IP? μ multicast?



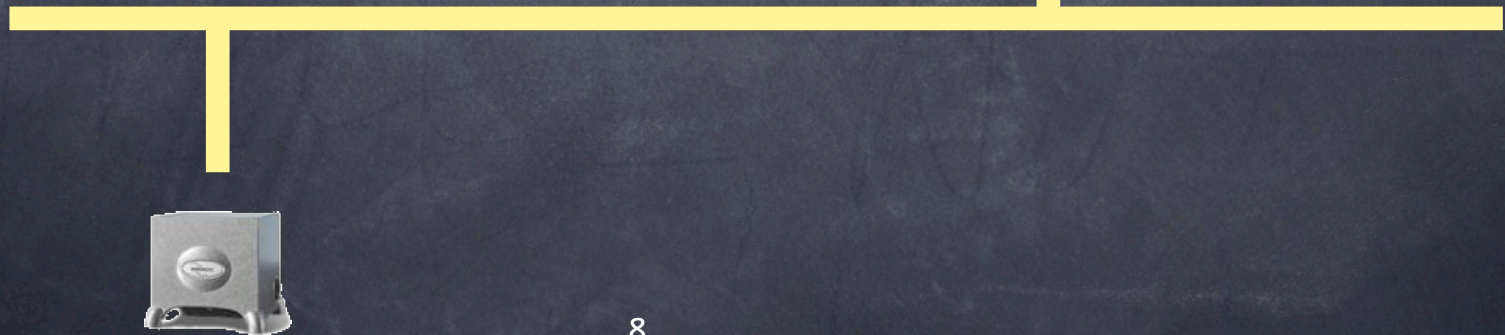
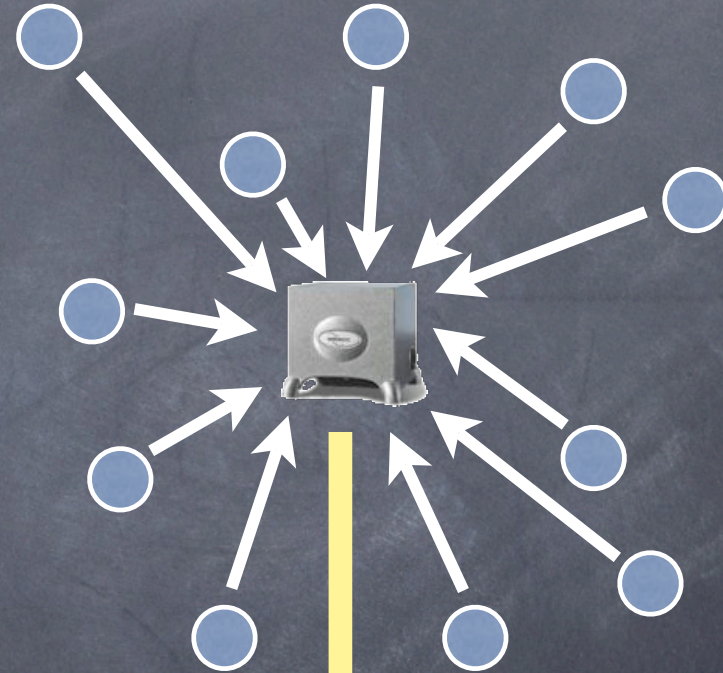
Test Case: Tracking



- Local sensing/
aggregation
 - Evader location estimate
- Mobile-to-mobile
routing (landmark)
- μ multicast? AODV?
DSDV?

Test Case: Leaf Network

- Simplest mote network deployment
 - No network protocols
- Motes broadcast to energy-rich gateways



Why Not IP

- Arbitrary node-to-node routing isn't common
 - And it requires a lot of state
- Protocols aren't always end-to-end
 - There are many network protocols, not just one
- We could give nodes unique 32-bit identifiers...

Usage Patterns and Assumptions

Internet

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

Sensornet

Collaborative use
Collect, disseminate, etc.
Ad-hoc (more homogenous)
Low power wireless
Wake time
Very low utilization
Bandwidth is expensive

IP costs a lot, and it isn't
what we need...

resource

Network Design Goals

Internet

Interconnect separate networks

Resilience to loss and failure

Support many protocols

Accommodate variety

Distributed management

Cost effective

Low effort attachment

Resource accountability

Sensornet

Dense real world monitoring

Resilience to loss, failure and noise

Support many applications

Scale to large, small, and long

Cost effective

Evolvable in resources

Composable

Security

... but many of the same
architectural principles apply

Key Architectural Principle

- IP: the Internet Protocol
- The narrow waist
 - Separate above (transport) from below (data link)
 - Allow parallel and independent development
- Specify the interface between the two

SP: The Sensor Protocol

- SP is the narrow waist of sensor networks
 - Single hop protocol
 - A common abstraction of many data link layers
- Decouples network and data link protocols
- Needs a richer interface than just send



Richer than Send

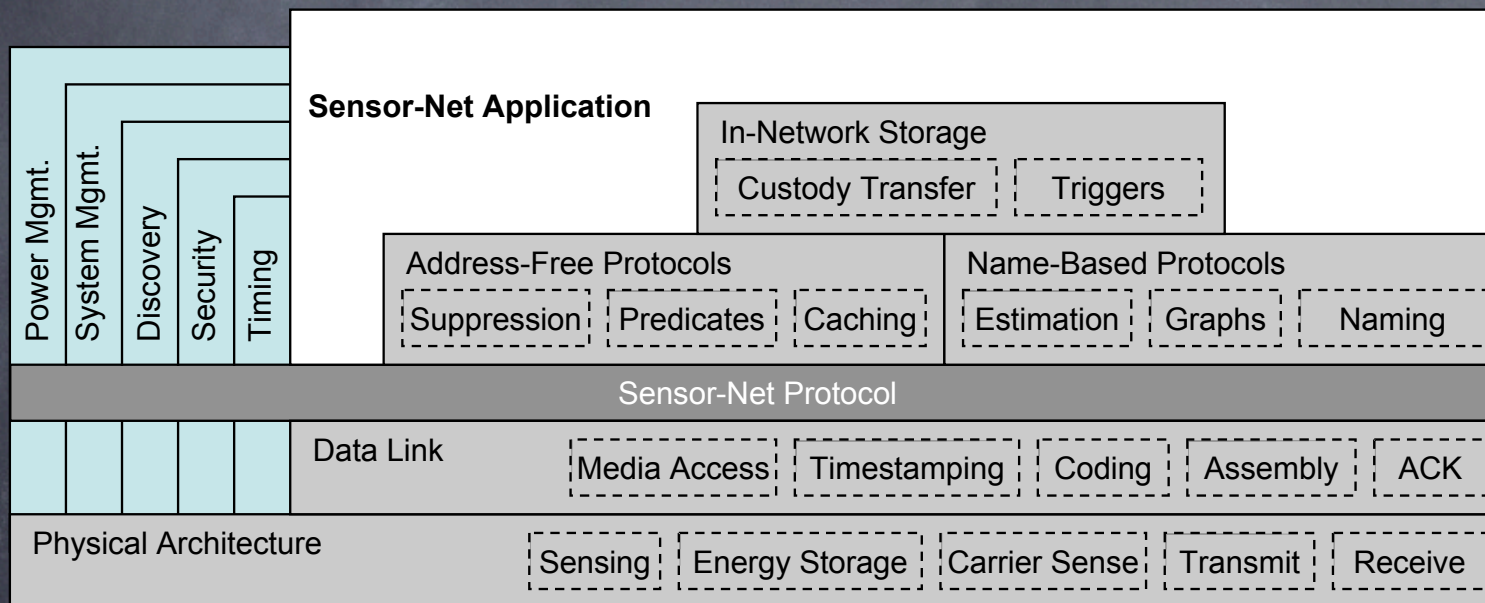
- Support a range of network protocols, each with their own timing, reliability, and other requirements
- Provide feedback from the data link layer to network layers and vice versa
 - Link estimation
 - Reliability
 - Packets outstanding
- Allow network layers to opaquely cooperate, improving efficiency



Not a Typical “Protocol”

- SP does not specify a wire, er, wireless format
 - Requires certain header fields, which can be implemented differently depending on the data link
- It is an abstraction of many data link protocols, rather than a specific protocol

Proposed Architecture



Address Free Protocols

- Many sensor network protocols are address-free
 - Flood, disseminate, tree collection
- Broadcast based protocols can build on top of basic data link layer
- Implicit address protocols (unicast) can build on top of data link addressing

Name-Based Protocols

- Wide range of naming needs
 - Individual nodes (single hop)
 - Individual nodes (multihop): logical coordinate spaces
 - Groups of nodes
 - Node structures (e.g., which tree)
- Protocols distinguished by naming schema

The Forwarding Predicate

- Flooding: always
- Broadcast: never
- Routing: if I am the next hop
- Forwarding does not have to follow the end-to-end principle: in-network processing is critical
 - TAG aggregation, synopsis diffusion

Cross Layer Services

- Some functionality cannot be cleanly abstracted in a layered model: concerns cross layers
- Power management
 - Network, transport, and application protocols all care
 - Complete layer encapsulation doesn't work well
- Provide a uniform interface that many layer interact with
 - Specify protocol timing, urgency, number of packets

Some Other Parts

- Programming architecture
- Physical architecture: mote gateway protocols
 - Use an IP proxy: argument is against using IP within the network. An external IP interface is critical.
- Scaling and adapting to network heterogeneity

A Working Proposal

- Evaluate and adapt designs based on use
- Deployment model makes iteration acceptable
 - Sensor nets are often autonomous domains: cross-system compatibility is not a major requirement
- The free-for-all of the past few years has shed light on where the boundaries should lie: let's start to try to codify them.

Questions