# Sensor Networks and the Future of Networked Computation

James Aspnes
Yale University

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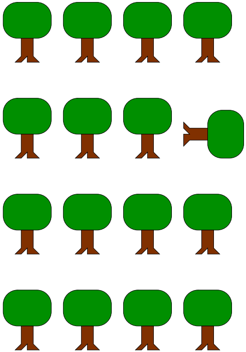
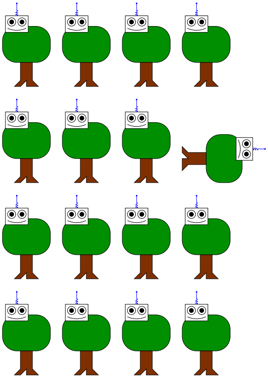
# Why wireless sensor networks?

- Question: If a tree falls in the forest, how do we hear it?



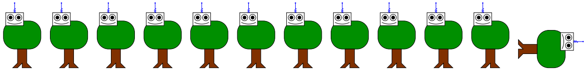
# Why wireless sensor networks?

- Question: If a tree falls in the forest, how do we hear it?
- Answer: nail a **sensor** to every tree.



# The central dogma of sensor networks

- Distributed sensing is necessary to detect rare, localized events.
- Abundant sensors must be cheap.
- Short-hop radio is the obvious communication mechanism.
- The more computation we can do in the network itself, the less communication we need.



# Classical networks

Classical networks are made of big, expensive devices:

- Routers.
- Wires (or equivalent fixed point-to-point connections).
- Power cables running to the routers.
- Network administrators standing next to the routers.

# Sensor networks

Sensor networks are made of small, cheap devices:

- Sensors.
- Short-distance radio broadcast.
- Weak power sources: batteries, solar cells, RF antennas.
- No network administrators!

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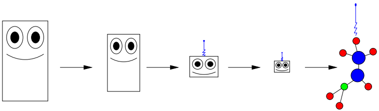
Every feature of sensor networks is likely to become typical of most networked computing devices.

# Where we are evolving from

- Existing sensor network applications.
  - Weather stations.
  - Networks of strain gauges on ships.
  - Ecological sensor networks.
  - B-52-launched tank detectors.
- Active RFID chips.
  - Mostly used for inventory tracking.
  - Many are writable.
  - Some already can record temperature extremes or sudden drops.
- New hardware technologies like **proximity interconnect** and **chip-based networks**.

# Where we are evolving to

- Sensors/RFID chips that talk to each other.
- Computers without wires.
- Cheap sensors everywhere.
- Long view: smart molecules?

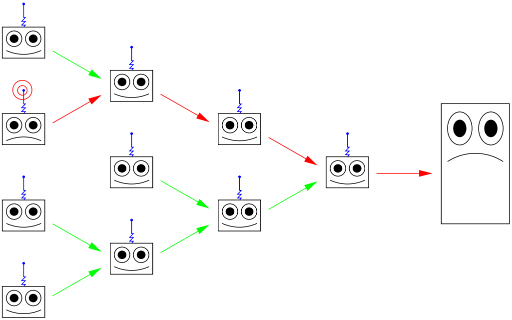


# Classic network problems revisited

- Consensus, leader election, clock synchronization— with severe resource constraints.
- New geographical routing algorithms that require no external configuration and respect sensors' limitations.
- Internet-scale problems on much smaller scales.

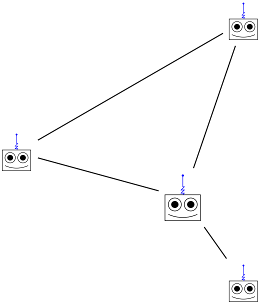
# Data aggregation

- The central problem in sensor networks.
- Still an active area of research.



# Localization

- How do we know where our sensors are?
- Triangulation/trilateration.
- NP-hard in the worst case.
- Good algorithms for dense networks.
- Error propagation still needs work.



# Mobility

- Controlled mobility creates a need for planning.
- Uncontrolled mobility requires tolerance of a rapidly-changing network structure (or maybe *no* consistent network structure).
- Details: see previous talk.

# Security

How do we keep dumb sensors from being hijacked or misused?

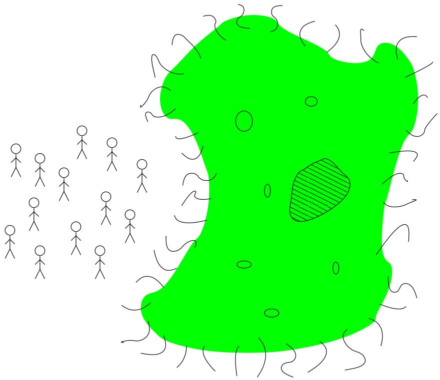
- Controversy over adding RFID tags to US passports exemplifies issues of control.
- Most RFID and sensor network applications rely on physical distance to limit access.
- Such reliance may not be reasonable as sensors become ubiquitous.

# New models

- **Population protocols** model collections of very weak devices using networks of finite-state automata.
  - Unstructured case is now very well understood.
  - Bounded-degree networks are in principle equivalent to LINSPACE Turing machines.
  - Speedy algorithms are still needed.
- Can we build continuous models that are good approximations to discrete physical systems?
- Battery life, geographical constraints, and sensor unreliability need to be incorporated into models at a fundamental level.

# The future

- There are many more bacteria than people (even by weight).
- The same economics suggests we can expect many more tiny computers than big ones.
- Sensor networks are the vanguard of this revolution.



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