The Use of Wireless Sensor Networks for Mapping Environmental Conditions in Buildings

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Outline

- Motivation for using wireless technology
- Sensor network topology
- Standards issues

Motivation

- Environmental monitoring in buildings
  - Security issues (e.g. chemical sensing)
    - Many different possible sensors
    - Changing needs over time
  - Detection of moisture problems
    - Relative humidity
    - Temperature
    - Liquid moisture sensors

Moisture Monitoring

- Need sensors in many locations….usually don't know beforehand where moisture damage will occur
- Often need to embed sensors within walls
- Need way to make sense of vast amount of sensor data

Monitoring moisture in walls leads to a desire to know source of moisture intrusion…..

Creates monitoring needs for:
-- HVAC System performance
-- Outdoor conditions
-- Ventilation

Resulting Needs for Building Monitoring

- Many sensors
- A variety of sensors
- Ability to add sensors at a later time as results indicate problem areas in a building
- Sensors that survive for an extended period of time (> 1 year)

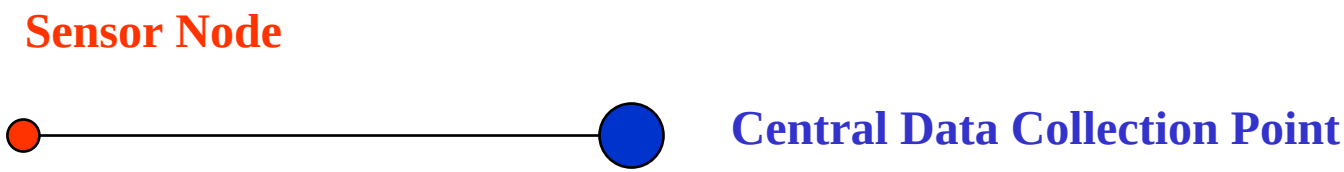
How can wireless sensors fit into the toolbox for such an application?

What are the advantages and disadvantages of wireless sensors?

What standardization issues arise when dealing with wireless sensor networks?

Sensor Network Options: Point-to-Point

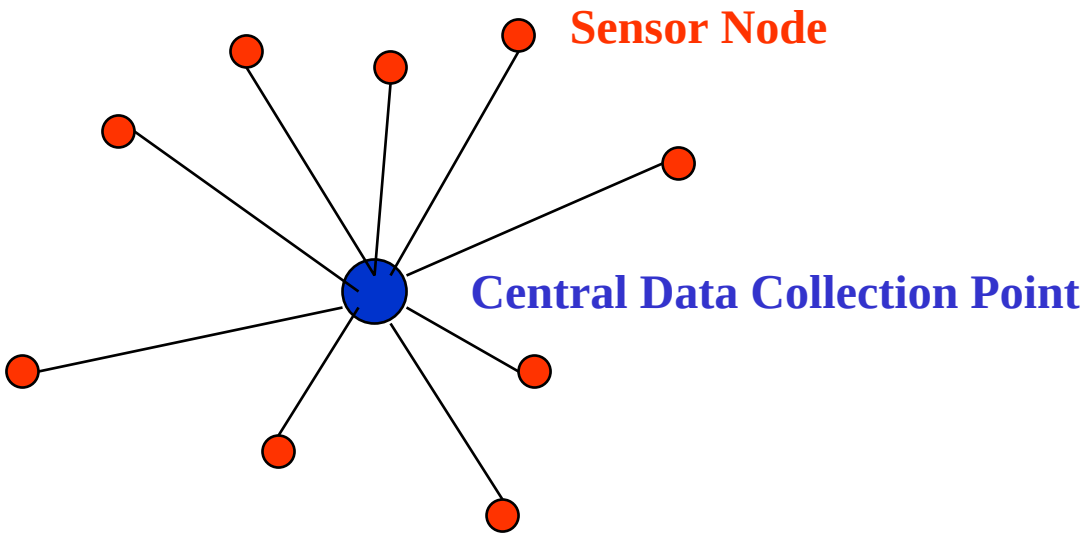
- Replace a conventional cable link between two instruments with a wireless link:



- Many commercially available options
- Is it really a network?

Sensor Network Options: Star Network

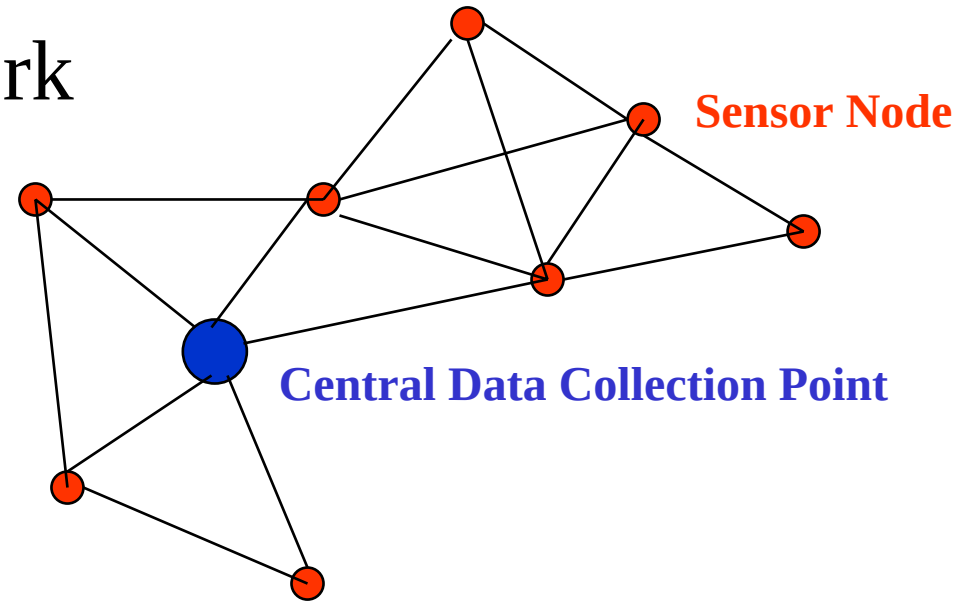
- Star Network:



  - Communication between central point and each sensor
  - No communication between sensors
  - Many proprietary systems are sold using this topology

Sensor Network Options: Mesh Topology

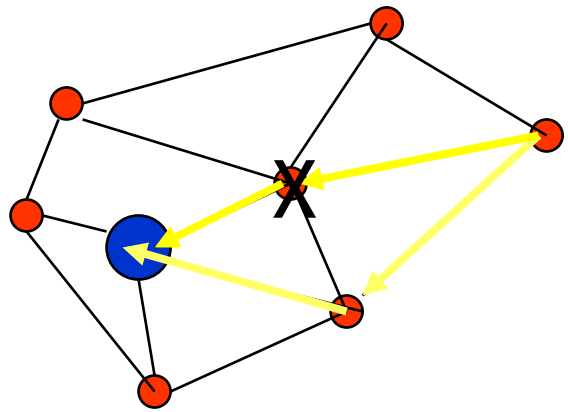
- Mesh network



- Communication between nodes that are within “hearing” distance.
- Multihop transfer of messages to route data from one end of mesh to other
- Ideal systems can be set up in an ad-hoc manner

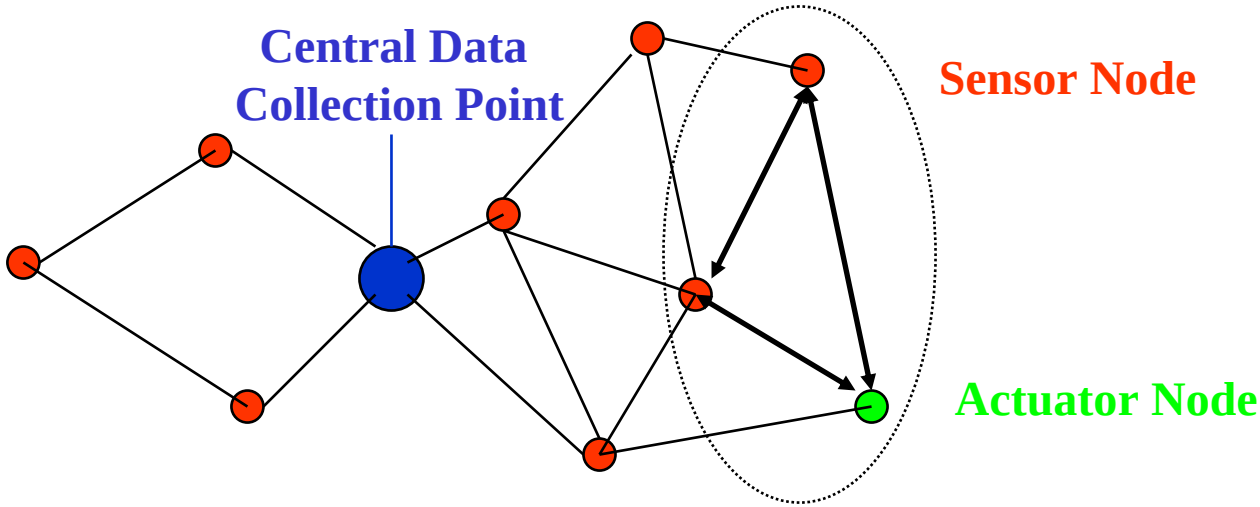
Advantages of Mesh Topology

- Self-configuring
- Self-healing
- Not dependent upon one link
- Expandable
- Sensor nodes serve as repeaters – no need to specially set up repeaters



Local Communications in Mesh Network

- Could limit communication to local set of nodes



For example: Temperature sensor controlling damper doesn't need to broadcast signal to entire network, only to the damper

→ **Less network traffic**

Disadvantages of Mesh Topology

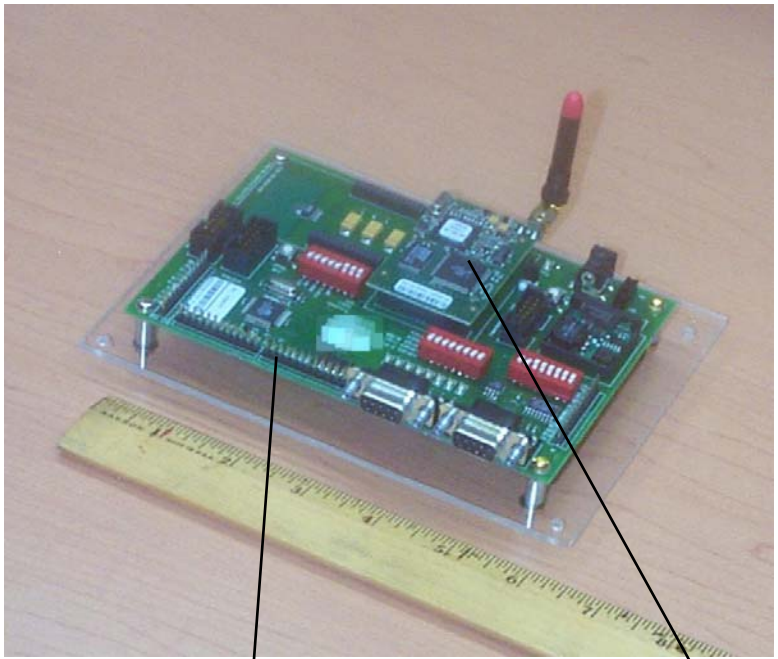
- Limited bandwidth
  - Each sensor node may be called upon to send data from many different sensors
- Power issues
  - Sensor nodes may transmit signals from many adjacent nodes
- Cost
  - Software and hardware needed for routing algorithms on each sensor node

Decision to Go with Mesh Network

- Allow expandable sensor network
  - Sensors can easily be added after initial investigations
- Commercially available kit
  - 8 wireless boards, each can take 8 analog signals
  - Wireless routing embedded on nodes
  - Flash memory on board to process signals
  - Analog sensors can be wired to board – provides generality
  - Provided wireless networking component – user provides sensor

Wireless Nodes

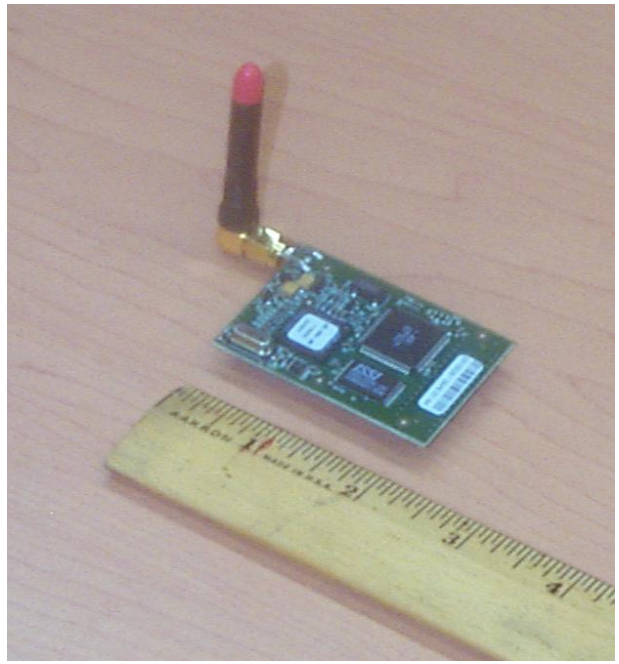
Board



Analog Sensor Connections

Communication node

Communication node



Radio Characteristics

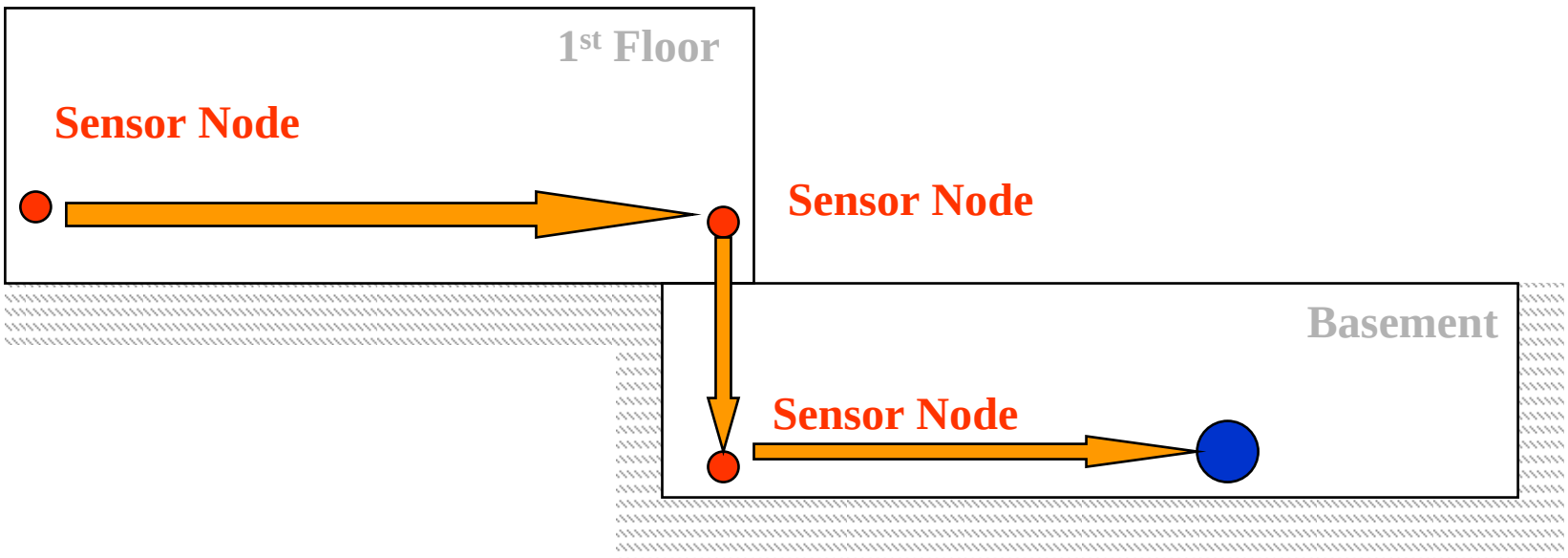
- 9V Power Supply – battery or line power
- 900 Mhz, direct sequence spread spectrum
- 192 kBps between nodes
- 50 kBps across network
- Transmit power: 0 to +20 dBm
- Manufacturer's stated range in open air:
  1000 ft. line of sight

Work to Date

- Connected sensors to board, not node by itself
- Powered by line power
  - Pseudo-wireless
  - For buildings, combination of wired and wireless probably the best approach
  - Wireless component still valuable to avoid signal wires over long distances

Extendable Sensor Network

Desired sensor data from 2 locations
Initially could not receive data
from 1st floor location



Central Data Collection Point

Bottom Line – Time

- Time:
  - Wiring sensors to nodes: ~30 minutes for 8 sensors
  - Programming sensor nodes and receiving station: ~2 hours
  - Initial sensor node deployment: ~10 minutes for 16 sensors
  - Testing and addition of repeater node: ~10 minutes
  - Total time to deploy: ~3 hours
    - Subsequent deployments will take significant less time considering that computer code can be reused

Bottom Line – Cost

- Each sensor node: ~ $1000.
- Sensors were simple potentiometers for demo – negligible cost at present, but other sensors will increase cost
- Sensors for buildings driven by cost…..these currently seem expensive
- Emerging technology….future cost reductions (hopefully)

Next Steps

- Deployment of temperature and moisture sensors in test cases in both residential and office settings
- Map environmental conditions → identify sources of moisture intrusion and temperature breaches
- Advantages over wired networks:
  - Time savings? (expect: yes)
  - Cost savings? (expect: no for hardware, yes for labor)
  - Added features? (expect: no)

Standards Issues

- Wireless Internet standards exist and are becoming widely adopted
- Other wireless communication standards between peripherals are coming into use
  - Focus: Bandwidth, security
  - For sensors, focus is: Power management, security
- Standards in development for sensor networks
  - Trade organizations
  - Industry consortia

Will these be sufficient for sensors that are used in buildings?

Standardization Needs

- Communication interoperability
- Plug-and-Play sensors
- On-board information, e.g. calibration, operating limits
- Test methods for evaluating performance in buildings:
  - Battery life
  - Interference
  - Range

Conclusions

- Wireless is fun!!!! But…..
  - Does it make sensing quantities in buildings easier?
  - Does it reduce costs for installation of sensors?
  - Does it allow us to do more than can be done with a wired system?
- Different sensor network topologies give different benefits
  - Mesh network can ease installation of sensor network when a priori knowledge of sensor locations, numbers, and types are not known
- Standards
  - Building community will need to monitor (and take part in) current development of standards as they relate to wireless sensors.