Millennial Net

Wireless Sensor Networking…Anywhere

Wireless Sensor Networks

- Issues and Applications

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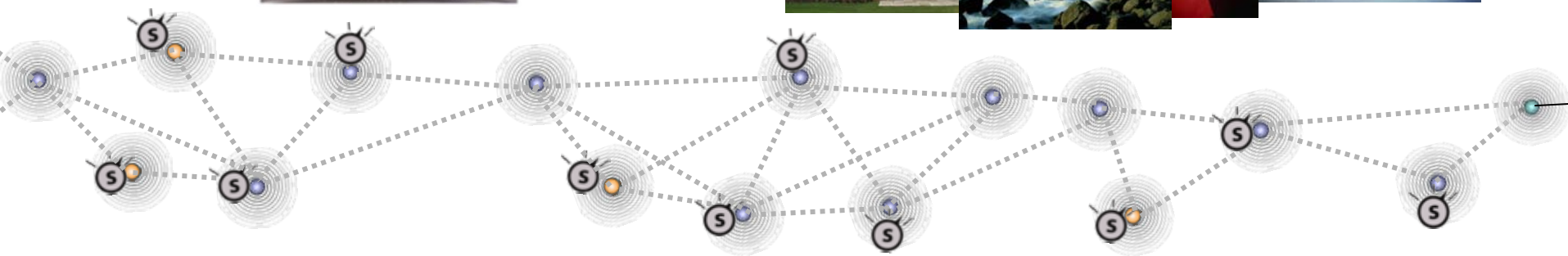
Ultra-efficient, highly scalable, self-organizing **embedded industrial/commercial class wireless networking systems and services for sensing & control applications**

The Premier Sensor Network for Dynamic Systems



- **Founded in 2000 by researchers from MIT**
- **Patented sensor networking technology.**
- **Winner of over a dozen awards for sensor networking innovation.**
- **Based in Burlington, MA.**

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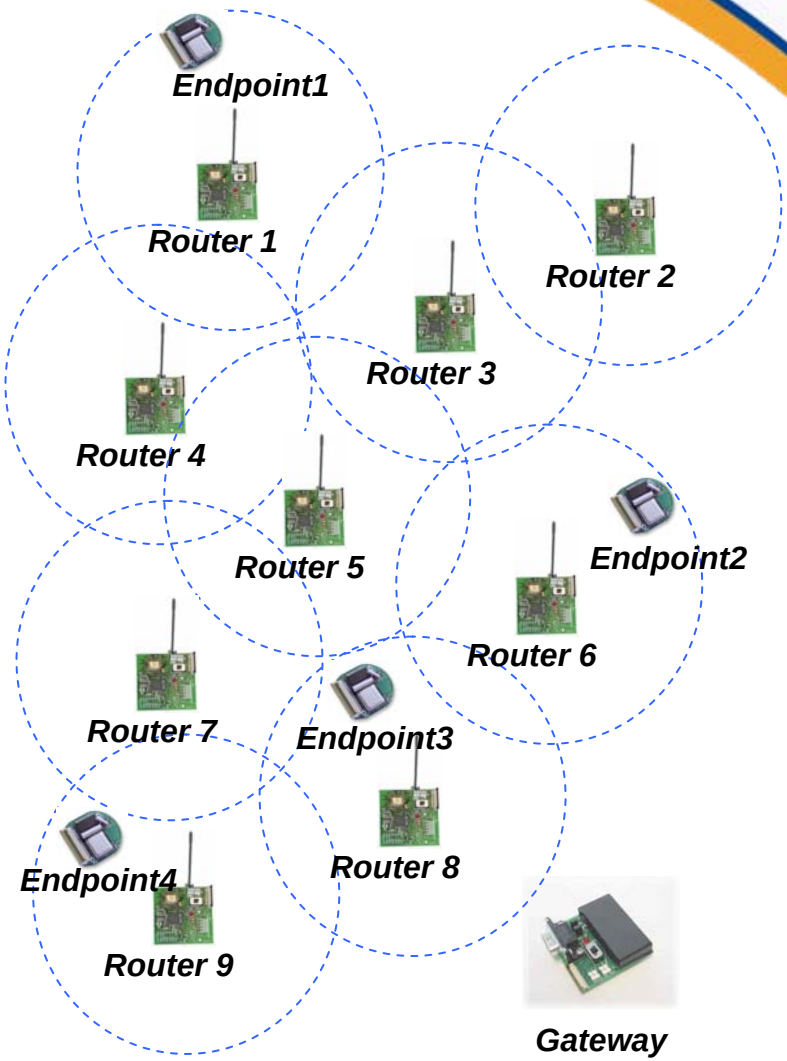
Agenda

- Introduction
- Design Issues and Technologies
- HC-WSN (High Capacity WSN)
- Applications

Wireless Mesh Network

- Ad hoc, self-organizing: Routers and endpoints establish communication network in a completely ad hoc, self-organizing manner. Little human intervention is needed.
- Energy-optimal networking: network devices are constantly activated and deactivated in a highly coordinated manner so that energy consumption is minimized.
- Path-optimal relaying: signals sent by the *endpoint* can be relayed by *routers* to the *base station* via a shortest path.
- Dynamic routing: if one of the *routers* in a data route failed, the data traffic will be automatically re-routed through an alternative *router*.



MeshScape Core Elements

The Most Complete Wireless Sensor Networking System in the Industry

Application Classes

- **Collect**
  - Event Driven
  - Periodic Sampling
  - Store & Forward
- **Broadcast**
  - Burst
  - Stream
- **Dialog**
  - Polling
  - On Demand

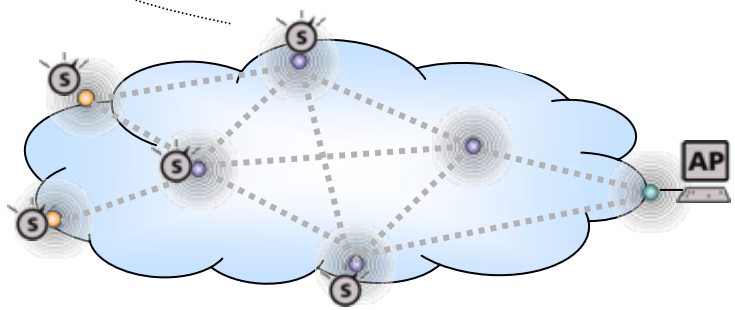
Network Monitor **Application APIs**

***MeshScape* Networking Software**
w/ Persistent Dynamic Routing™

Hardware

ISM Bands
- <1GHz
- 2.4 GHz

Modules & Assemblies
- Gateways
- Meshnodes
- Endpoints



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Design Challenges in Wireless Sensor Networks

- Scalability and efficiency of the network
- Robustness and reliability
- Low power consumption
- Responsiveness (Latency)
- Load balancing and congestion control
- Network management
- Interference avoidance
- Deployment planning and provisioning

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Robustness vs. Communication Overhead

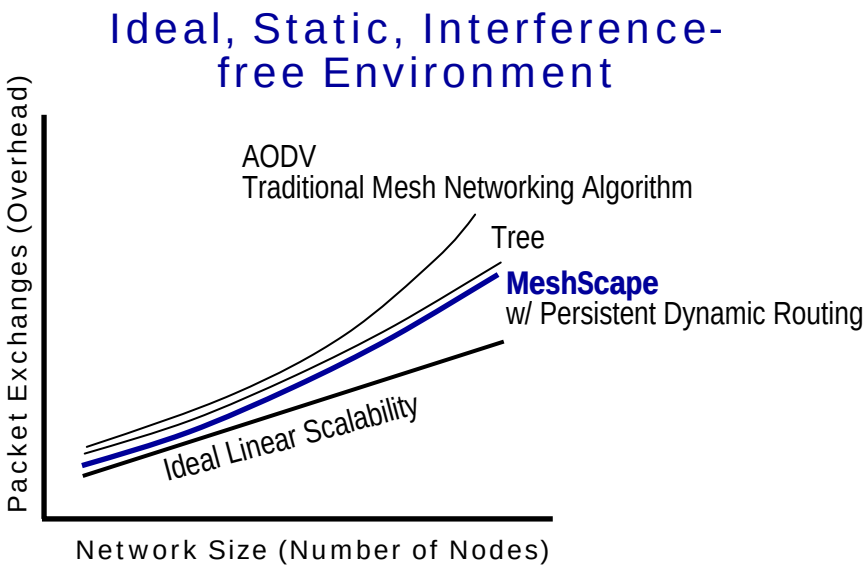
- By definition of ad-hoc mesh networks, the wireless sensor network is more robust than point-to-point communications
- However, to guarantee the robustness, more overhead is required
- The issue of robustness in mesh networks comes down to the following issue :

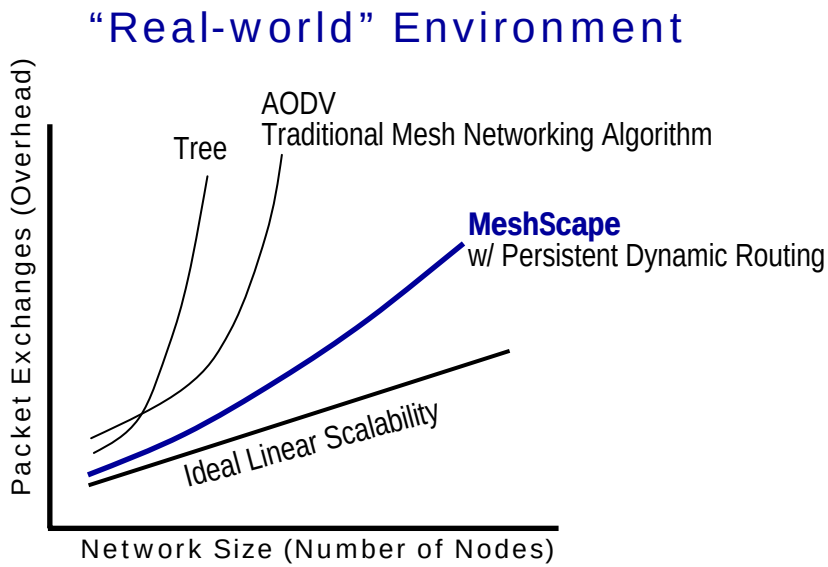
“How can we minimize the communication overhead of mesh networking, and still maintain the robustness of the network?”

Scalability

MeshScape → Low Overhead Yields High Scalability

Add Dynamics (interference, mobility, "reconfiguration flexibility")
Interference = environmental changes, active RF noise, passive blockage of RF link,





Other Trade-offs

- Responsiveness and mobility
  - High responsiveness requires more control packets to be transmitted
  - Mobile nodes need high responsiveness to handle mobility
- Power efficiency
  - Common approach to minimize power consumption is to reduce node duty cycle
  - Drawback
    - Longer sleep cycles can decrease network responsiveness (higher latency)
    - More complicated synchronization can affect scalability

Next Trend ? - High-Capacity Wireless Sensor Networks (HC-WSN)

- Increasing Capacity
  - Increasing capacity is a way to increase scalability
  - Higher capacity can serve wider range of applications
  - Still need to keep the advantage of WSN – low power, mobility, small size, low cost, etc

HC-WSN Approaches

- Multiple Gateways
  - Many existing wireless sensor networks use one gateway
  - Can add additional gateways to increase capacity
  - Advantage: each data packet takes fewer hops, more data packets can be transmitted
  - Tradeoff: requires gateways to be connected via fatter pipe (Ethernet, 802.11)

- Multiple Frequency System
  - Use multiple channels though channel hopping , MIMO, or dynamic channel switching
  - Advantage: send more data through multiple frequency bands
  - Tradeoff: power and responsiveness Data Aggregation

- Data Aggregation
  - Multiple data packets are aggregated into one
  - Advantage: minimize number of data packets sent through network maximizing throughput
  - Tradeoff: responsiveness

Making Wireless Mesh a Reality

Application Characterization Drives Network Topology and Functionality

Power:	A/C Power Available	→	Battery for 10+ Years
Scalability:	<10 Nodes	→	>500 Nodes
Data Rate:	1 sample per day	→	1 sample per second
Range:	1 meter	→	100s of meters
Mobility:	Sensors stationary	→	Sensors extremely mobile
Integration:	Wall mount temp sensor	→	Intrinsically Safe Process Control Sensors

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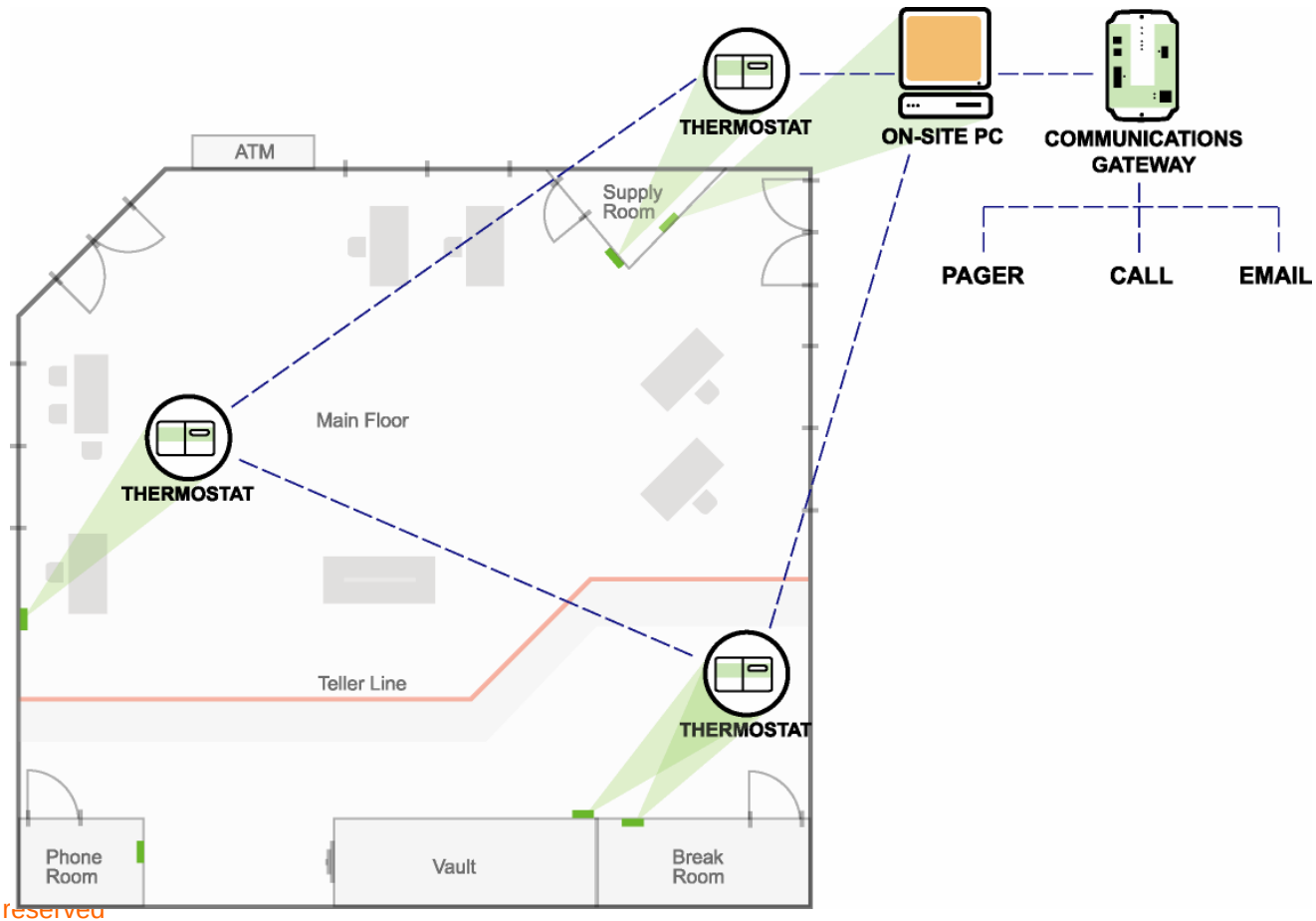
Case Studies

1. Energy Management
2. Hotel Guest Room Control
3. Building Environmental Monitoring
4. Industrial Process Monitoring
5. Medical Monitoring
6. Electric Sub-metering

Case1: Energy Management

Problem Description:

Reduce cost, complexity and time of deployment of commercial building energy management systems.



Energy Management

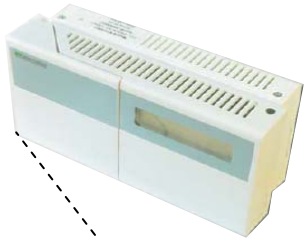
Design Requirements

Power:	❑ External power source
Scalability:	❑ 10-30 thermostats per building ❑ Additional “Peel & Stick” sensors to be added
Data Rate:	❑ Continually polled RS-485 system.
Range:	❑ 10 to 30 meters
Integration:	❑ Integration of Basys Thermostat with Mesh Node ❑ Emulate RS-485 wiring via command-response polling

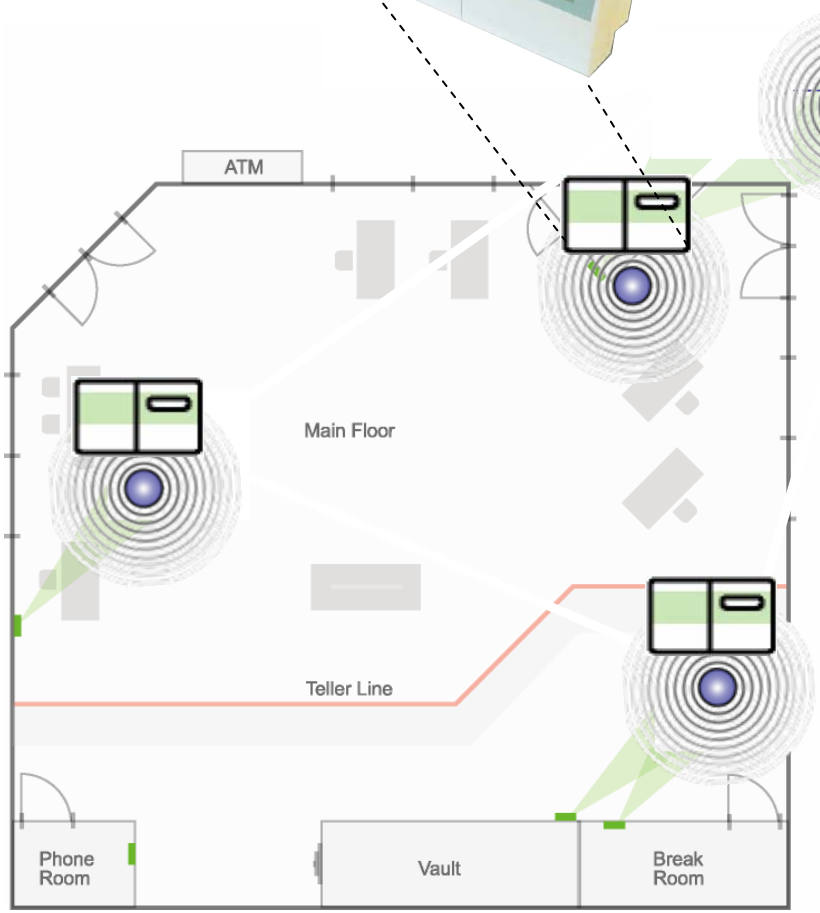
Energy Management

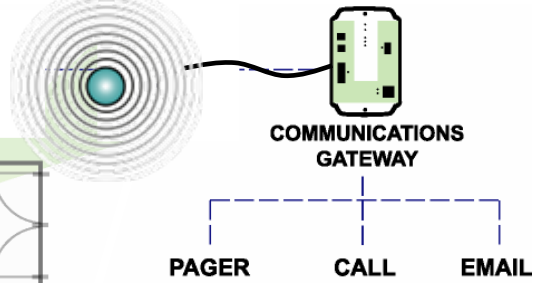
Solution Implementation – Wireless

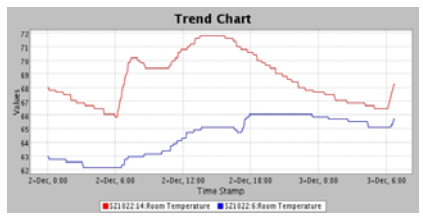
Integration of Basys Thermostat with Mesh Node



- No RS-485 wiring
- Fast Installation
- Flexible Wireless Network







Case 2: Hotel Guest Room Control

Problem Description

Need economical way to provide hotel-wide improved guest experience through hotel-wide guest room control

Hotel Guest Room Control

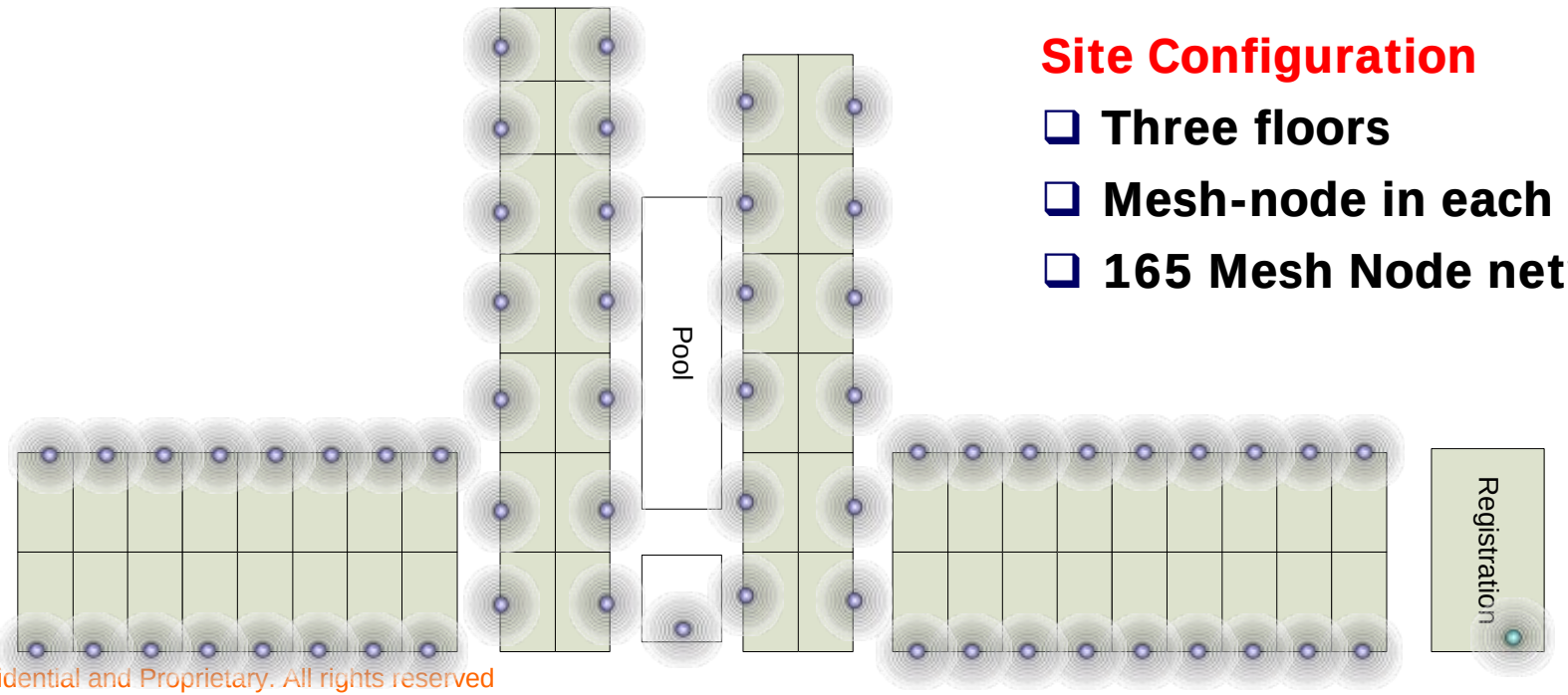
Design Requirements

Power:	❑ External power
Scalability:	❑ 150+ mesh nodes/network
Data Rate:	❑ One measurement per minute
Range:	❑ 50 feet minimum in-building (steel, aluminum, reinforced concrete) ❑ 150 feet minimum outside
Integration:	❑ Mesh node integrated with room control device (RJ11 to UART interface)

Hotel Guest Room Control

Solution Objective

- Easily installable, fully redundant, property-wide wireless mesh network to provide two-way monitoring and control of guest room systems
- Lower cost, faster installation, minimal interruption to guest experience



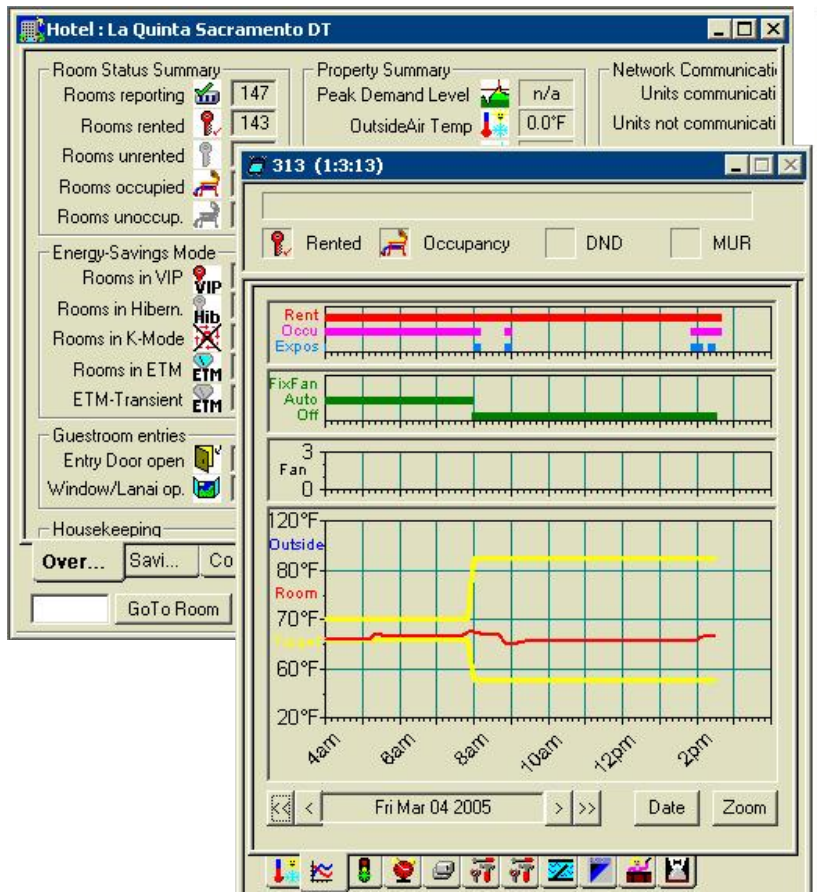
Site Configuration

- Three floors
- Mesh-node in each room
- 165 Mesh Node network

Hotel Guest Room Control

Application Overview

- Temperature Control (PTAC Control)
- Temperature Range Control
- Room Rented Indication
- Room Occupied Indication
- Energy Management
- Future upgrade to door lock management



Case 3: Building Environmental Monitoring

Problem Description

Develop a system to detect and report moisture buildup inside building envelope

- **Mitigate moisture related litigation**
- **Provide a risk management solution to the construction and insurance industry**

Building Environmental Monitoring

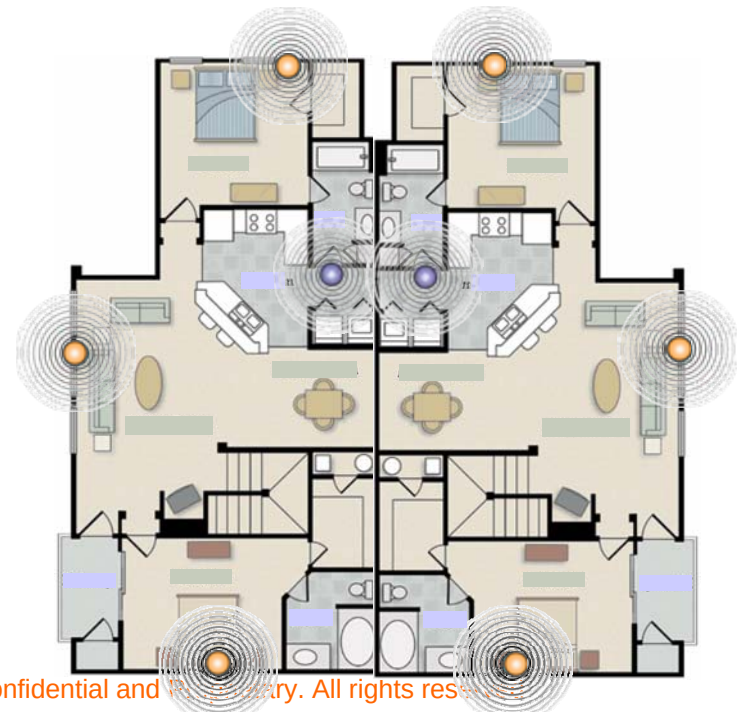
Design Requirements

Power:	❑ 10+ years on single “C” cell to power node and sensor
Scalability:	❑ 15-200 nodes per building
Data Rate:	❑ 2 samples per day
Range:	❑ End-nodes 60-80 ft ❑ Mesh-nodes 100 ft
Integration:	❑ End-node with Sensirion temperature / humidity sensor

Building Environmental Monitoring

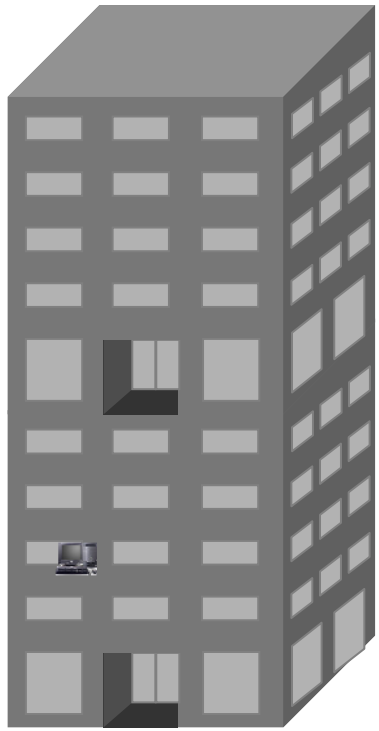
Solution Objective

- Inside wall battery-powered sensor w/ End Node sample 2x/day for 10 years
- Introduction of "BEEMS" – Building Envelope Environmental Monitoring Service



Site Configuration

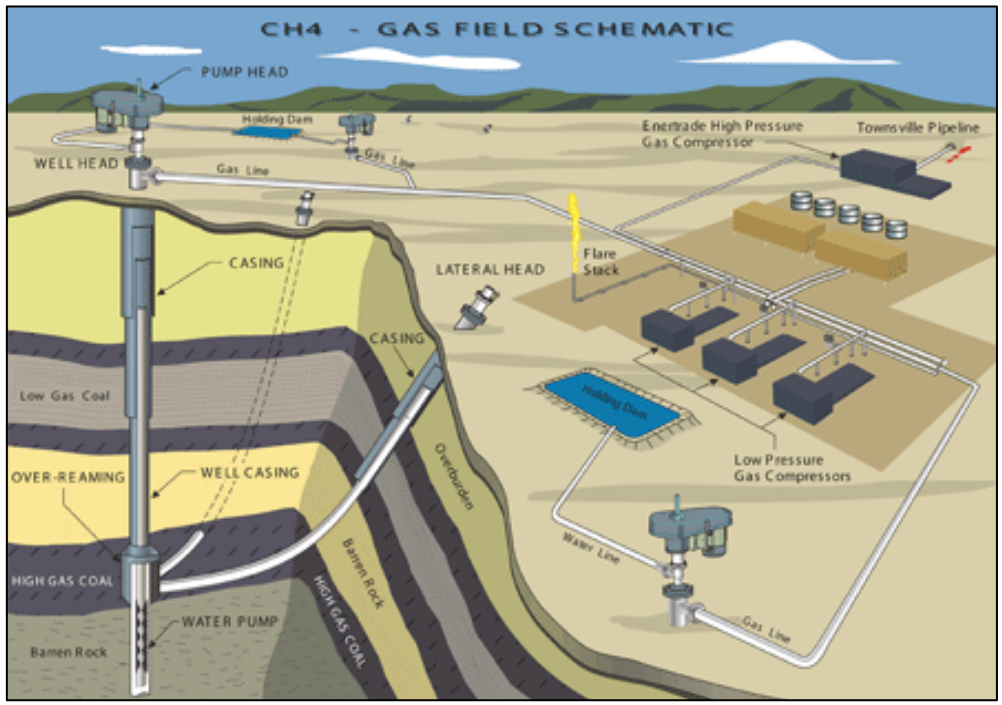
- Hybrid Star-Mesh
- 105 Nodes (30 Mesh Nodes, 75 End Nodes)
- 15 Floor Condo Complex
- Gateway in basement



Case 4: Gas Pad Application

Problem Description

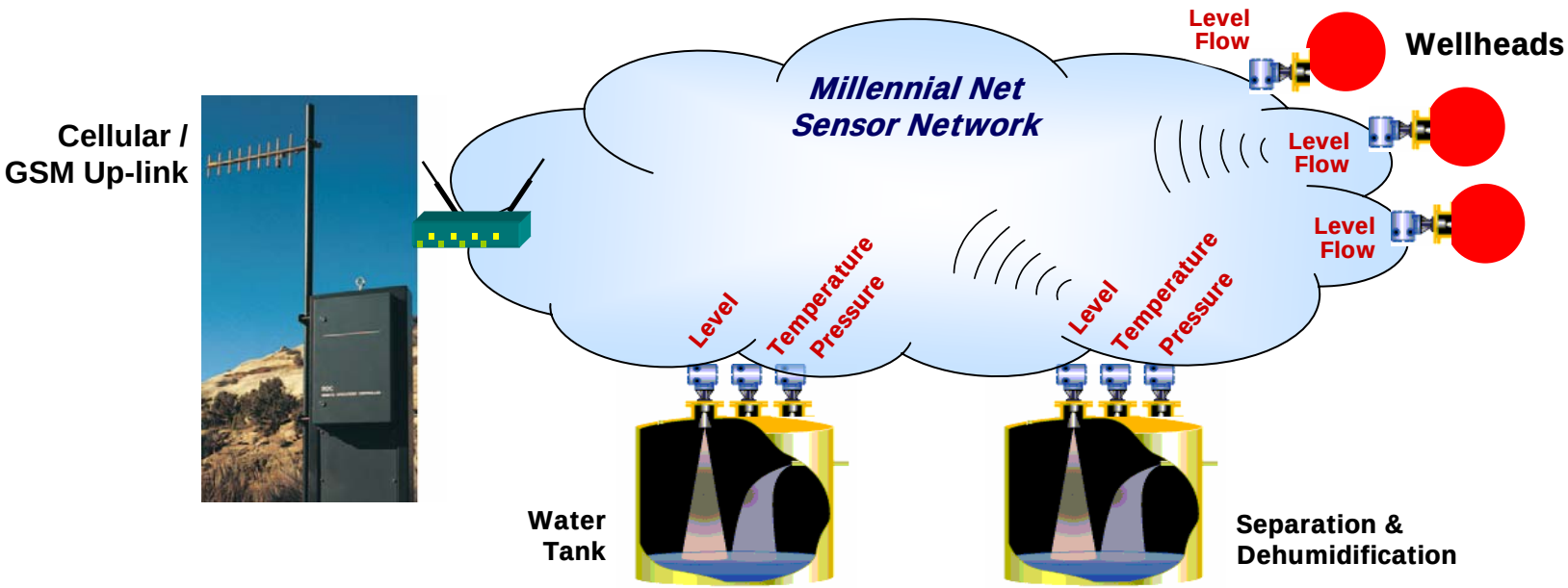
Improve operational efficiency, reduce costs through remote sensing and monitoring of fluid level, pressure, temperature and gas flow



Gas Pad Application

Solution Objective

- Install a **self-sufficient, self-powered wireless sensor network**
- Collect and communicate **vital operational data** to remote monitoring center via satellite to internet backbone



Gas Pad Application

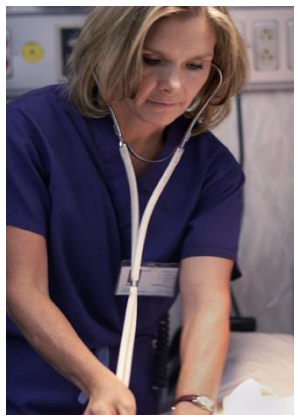
Design Requirements

Power Efficiency	❑ Battery/solar cell powered ❑ Need low-power mesh nodes & gateway
Integration	❑ HW - Integrate into explosion-proof enclosures ❑ SW - Transport HART protocol over wireless
Range	❑ ~100 feet between mesh nodes
Data Rate	❑ One measurement per minute
Scalability	❑ Wireless Mesh - Up to 15 sensors per gas pad

Case 5: Medical Monitoring Application

Problem Description: ➔ Convenient wireless collection of **patient vital signs** in hospital or home

Solution Objective: ➔ **Portable, auto-configuring, wireless sensor network** to monitor **patient vital signs** from medical instrument to PDA or desktop



Blood Pressure

Blood Glucose

Weight

Temperature

Medical Monitoring Application

Design Requirements

Auto-configuring	❑ **Automatically bind mobile gateway to medical devices**
Power Efficiency	❑ **Battery powered – 3 month life**
Integration	❑ **Customized command/response protocol**
Range	❑ **Short - 5 to 10 meters**
Data Rate	❑ **20 messages per hour**
Scalability	❑ **Up to 5 medical instruments per networks**

Medical Monitoring Application

System Design & Development

- **Small wireless module fits inside blood pressure, blood glucose, thermometer, and body fat monitors**

- **Vital signs displayed on medical device LCD screen also sent wirelessly to PDA or PC**

- **Compact Flash Gateway enables mobile monitoring**

Wireless module

Case 6: Electrical Submetering

Problem Description

Develop a system to enable tenant sub-billing

- **Cost allocation based on usage rather than square footage**
- **Allows for contract and bill validation**

Electrical Submetering

Design Requirements

Power:	❑ Generally power provided from electric meters; some solar-powered units on rooftop
Scalability:	❑ 50 - 200 nodes per mall
Data Rate:	❑ Every 15 minutes
Range:	❑ Mesh-nodes: 100 - 150 ft
Integration:	❑ Mesh Nodes integrated with both electric socket meters and low-cost CT clamp meters

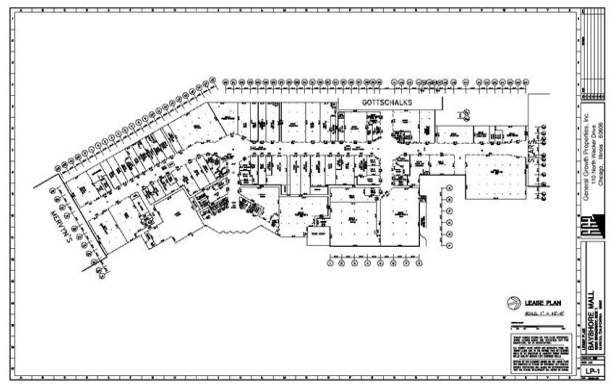
Electric Submetering

Solution Objective

- Easily installable, fully redundant, property-wide wireless mesh network to enable tenant sub-billing
- Lower cost, faster installation, minimal interruption to mall operations and tenants

Site Configuration

- Mesh Topology
- 92 Nodes (Including 3 solar powered repeaters)
- 500,000+ Sq. Foot Mall
- Gateway in facility manager's office



For More Information…

Wireless Sensor Networking Source Book

A Guide to the Fundamentals of Wireless Sensor Networks

by Sokwoo Rhee, Ph.D.
and
Sheng Liu, Ph.D.

Available at
www.millennialnet.com