



Sensor Network Challenges for Intelligent Buildings

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Introduction

- Sensor Networks will play a fundamental role in future intelligent buildings:
 - Energy Conservation
 - Security
- SN technology has several advantages:
 - Low energy consumption, long lifetime
 - Possible to retrofit old buildings for monitoring, interconnect with HVAC systems in new buildings
 - Capture spatial-temporal phenomena at a much finer granularity than other technologies



Challenges

- **Hardware Cost**
 - COTS platforms are still too expensive ~\$100
 - More capable sensors (vision) are even more expensive
- **System Architecture**
 - No defined system architecture
 - Applications are vertically integrated
- **Wireless Communication**
 - Unpredictable wireless links, in particular in indoor buildings
 - Long spatial and temporal correlations, diverse sources of interferences
- **Security**
 - Authentication and integrity of the data (use for control)
 - Data collected must not be spoofed since it affects privacy
- **Programmability**
 - Energy and communication constraints



Research Needs

■ Long Term Deployments

- **New motto: No more demo-ware!**
- Must drive the cost down to allow cheap deployments
- Some good advances, mote-on-a-chip (spec)... still too costly. Drive the cost to $> \$10/\text{unit}$ (50 nodes == 1 desktop)
- Solve the packaging issues, no more grad students ad-hoc solutions.

■ System Architecture

- **Unclear** what should be the system architecture
- We believe experience with multiple applications is invaluable
 - Architecture based on common functionality needed by group of applications
 - Synthesis at the lower levels of the stack
 - Tiered architectures: *one size does not fit all*



Research Needs

■ Wireless Communication

- Need new communication models for low-power RF transceivers
- Understand temporal and spatial properties of the wireless links
- New routing and data dissemination algorithms based on the real wireless communication properties

■ Security

- Some ongoing work on authentication and integrity at packet level
- Not enough work at system level security. Less crypto, more security.

■ Programmability

- Low level re-programmability: TinyOS, SOS, Virtual Machine, ELF-16 models
- User-level programming: meta-languages, databases, parallelization
- Scaling issues: > 10000, we may need new paradigms (statistical mechanics?)



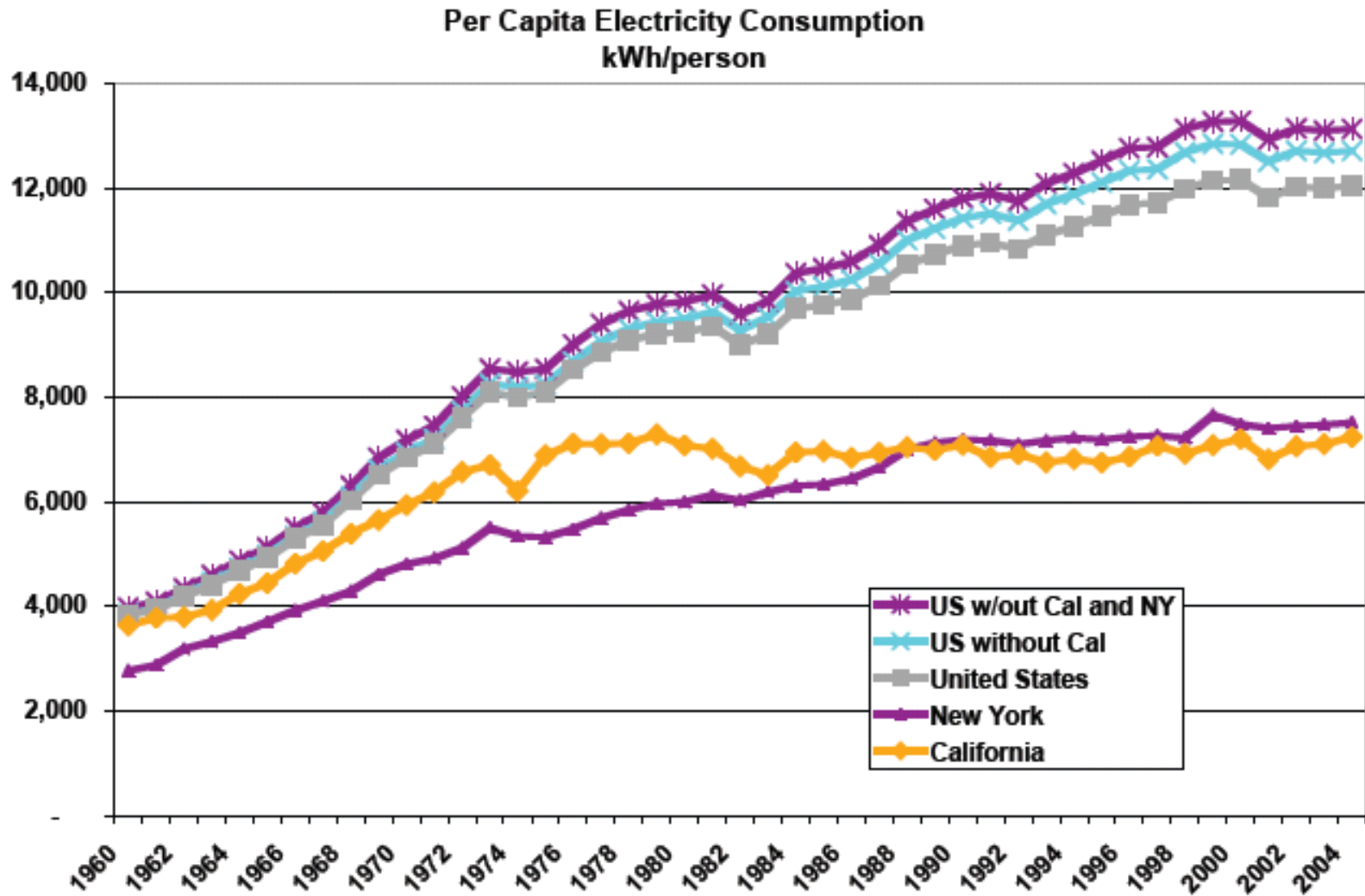
Thank you



Back Up Slides



Why is this important?

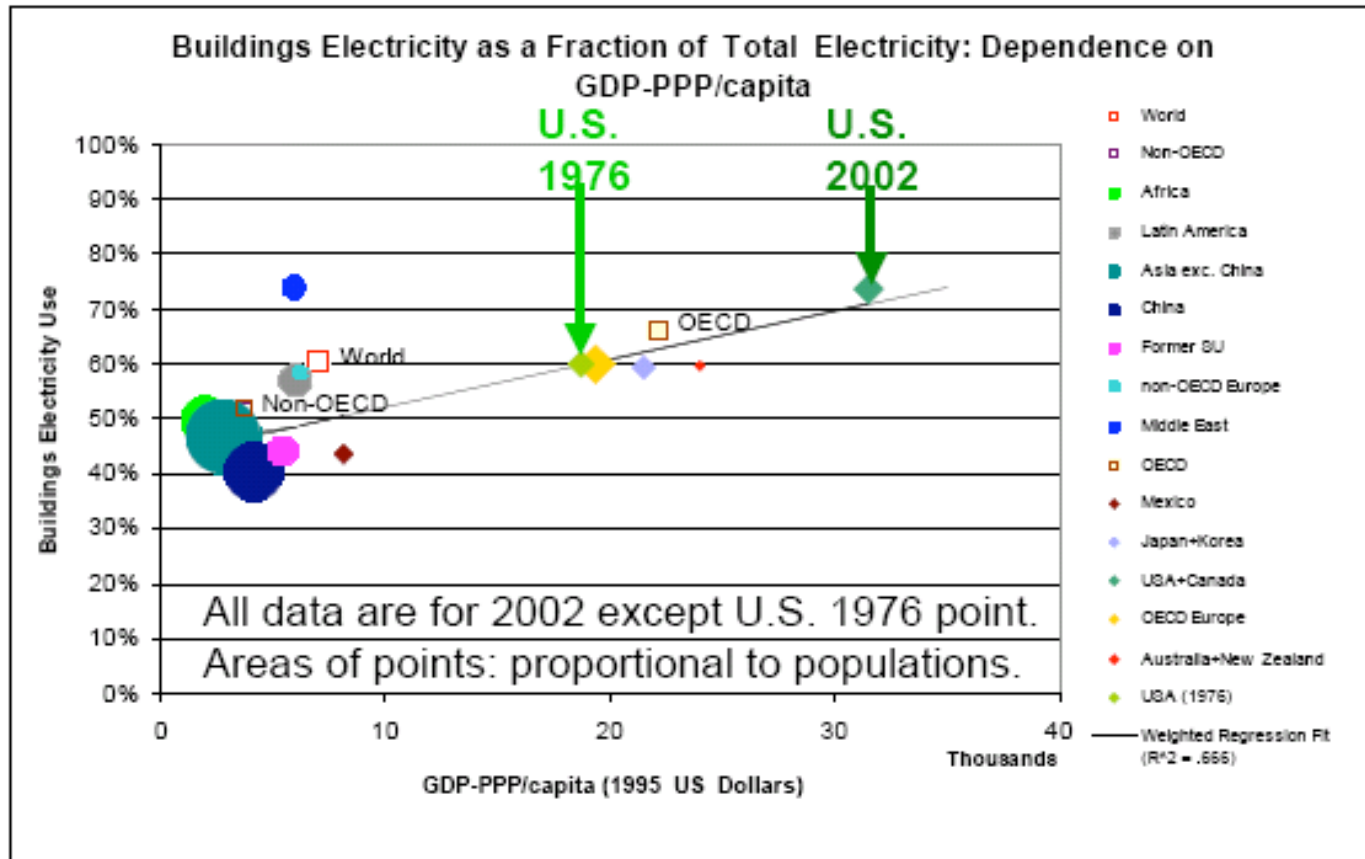


Source: California Energy Commission



Economic Impact

A larger fraction of electricity goes to buildings in rich countries!



“Buildings Electricity” = 100% Commercial and Residential + 15% Industrial + 10% Agricultural.

Data provided by Paul Waide, graphics by Shoibal Chakravarty, from Robert Scollow



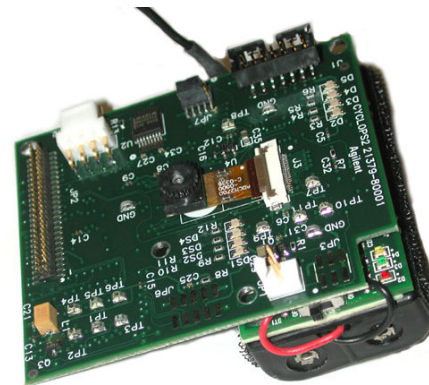
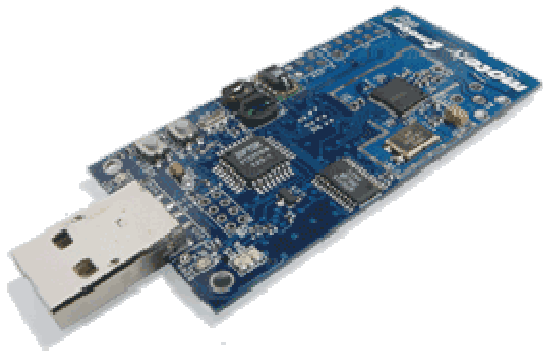
Design Goals

- Self-configuration, long lifetime
- Small and light weight, easy to integrate into existing buildings' ceilings
- Non intrusive; no special infrastructure needed
- Power and memory efficient
- Economical
- Meets security and privacy requirements

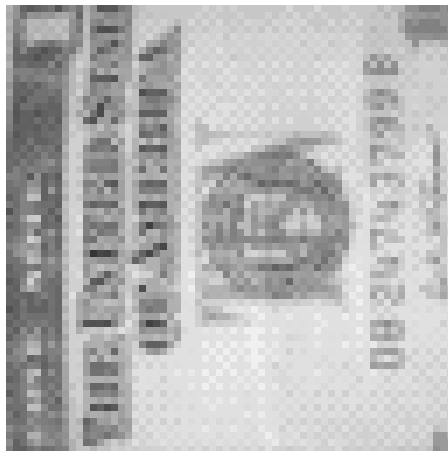
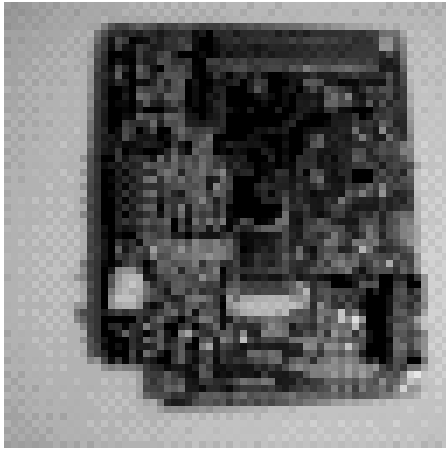


Technology: Vision Sensor Networks

- Based on new generation Telos mote
- Ultra-low power-consumption Cyclops camera
- Close the loop: actuate by controlling HVAC systems in real time



Ceiling Array



Technical Challenges

- RF propagation quite unpredictable in indoors
- Camera is a power hungry sensor (lifetime)
- No precise enough models of the phenomena
- New distributed algorithms for optimal routing and adaptive data sampling
- Distributed control with nondeterministic delays

