

**Decoupling Synchronization from Communication is Key to Continued Scaling of Indoor Wireless Sensors**

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**Current Building Energy Consumption Is Not Sustainable**

**Figure 1. U.S. Electricity Consumption By Sector, 2008 (DOE 2009a)**

Total Primary U.S. Electricity Use: 40.1 Quadrillion Btu

**EXECUTIVE OFFICE OF THE PRESIDENT**  
**U.S. ENERGY POLICY AND**  
**GLOBAL CHANGE**

"If current trends continue, by 2025 buildings worldwide will be the largest consumer of global energy, more than the transportation and industry sectors combined."

**NIST**  
"A national goal has been set to achieve net-zero energy in 50% of U.S. commercial buildings by 2050 (DOE 2010)."

*measure everything*

Net-Zero Energy, High-Performance Green Buildings – NSTC - 2008  
Measurement Science Roadmap for Net-Zero Energy Buildings – NIST Technical Report 2010

**Pervasive Networks Make This Possible**

Legend:  
↗ Lifetime  
↓ Battery  
↓ Size  
↑ Count

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**Energy Storage Dominates Volume**

$P_{AVG}=750\mu W$  DC=2%

$P_{AVG}=21nW$  DC=0.2%

Low-Power Listening (idle listening)  
DC=2.2%

ULP

R. Szewczyk, A. Minutoli, J. Polastre, D. Culler,  
"An Analysis of a Large Scale Habitat Monitoring Application",  
ACM SenSys'04, November, 2004, Baltimore, MD

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**Synchronization Dominates Power Budget**

**Discovery**  
Low Power Node |--- 1 minute ---|  
Battery Node (Searching) Min 1  
Min 2  
Min 3

**Asynchronous Neighbor Discovery (Disco<sup>a</sup>)**  
 $Discovery \propto (Duty Cycle)^2$

**WiseMAC '04      A-MAC '10  
B-MAC '04      GLOSSY '11  
Adaptive LPL '07    LPB '12**

**Staying Synchronized**  
Local time |--- Guard ---| 1200  $\mu s$  @ 20 ppm  
Real time 300 s  
**Preserving Sync**  
 $\alpha$   
 $C * (Duty Cycle)$

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<sup>a</sup>Prabal Dutta and David Culler. 2008. Practical asynchronous neighbor discovery and rendezvous for mobile sensing applications. In Proceedings of the 6th ACM conference on Embedded network sensor systems (SenSys '08). ACM, New York, NY, USA, 71–82.

**Key Insight: Decouple Synchronization from Communication**

- External synchronization
  - Ambient 60 Hz wave
  - Sudden change in room lighting, or a noise
  - Provide it efficiently?
- Idea: Use visual light as wake-up channel for synchronization
- Synchronization and time-keeping burden is shifted to infrastructure

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