

Connectionless Networks Program Overview

Wireless
Network
After Next

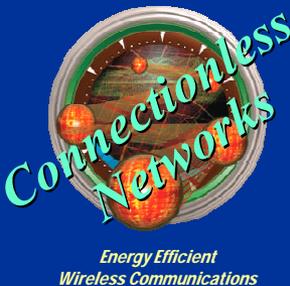
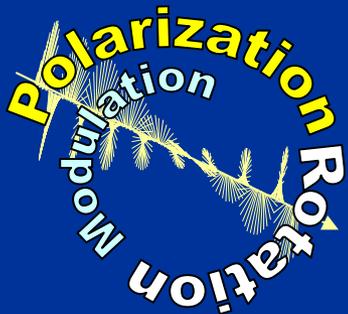
Preston Marshall
preston.marshall@darpa.mil

Rescue
Radio

Radio-Isotope
Micro-power
Sources

Defense Advanced Research Projects Agency
Advanced Technology Office

Retro-Directive
Noise
Correlating
Radar



Opinions expressed are those of the authors, and do not represent the position of DARPA, the Department of Defense, or the United States Government

Next Generation Communications

Are We (Really) Wireless Yet?

These are Wireless . . .



But Not for Long!





Today's Choices in Sensor Networking Technology



- **High Performance (and High Energy)**
 - Wide Dynamic Range Receiver Front Ends
 - High Peak Transfer Rate
- **Low Energy (and Performance)**
 - Limited Dynamic Range Front Ends
 - Constrained Peak Throughput
- **Current Radio Technology Not Appropriate for Intelligent Sensor Networks**
 - Short Message, Bursty Applications
 - Receiver Energy Use Dominated
 - Network “Maintenance” Driven Traffic
- **Available Network/Transport Protocols Poorly Suited to Episodic or Dynamic Environments**

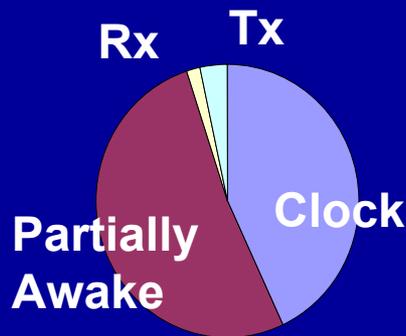
*Neither
Choice
Desirable*



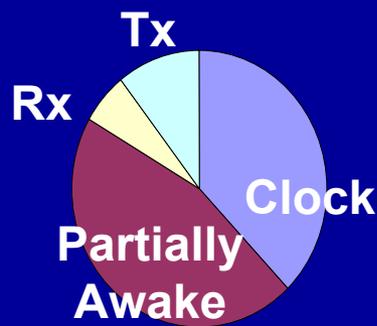
Connectionless Networking



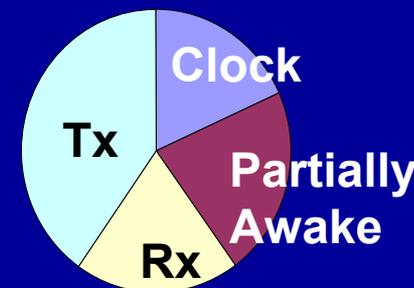
- **Size/Weight/Power of Sensing and RF Components Continue to Drop**
 - Sensing and RF Components Soon to be Able to Leverage MEMS/Nano Technology
 - Digital Processing Power Requirements Drop by 1.6/Year
- **Energy Required to Send a Bit Remains Constant**
 - Driven by Shannon's Law and Physics
- **Energy Required by RF Link and Protocol Design Limits Lifespan, Miniaturization, Covertness, ...**



5 msg/hr



1 msg/min



10 msg/min

**Ad-Hoc, Low Duty Cycle Networks
Require a Different Kind of Radio**



Connectionless Networks Precepts



- **Develop Physical Layer and Protocols Specific to Low Energy Operation**
 - Focus on Receiver Energy (Time) Management
 - Exploit Correlated Nature of Sensor Traffic
 - Adaptive Selection of Network Operating Points
 - Investment Strategy (Energy Cost vs. Efficiency Gains) Driven
- **Leverage Digital Processing to Reconstruct Information Normally Transmitted at PHY Layer**
 - Examine Multiple Hypothesis Regarding Phase Tracking, Block Boundary, Equalization



Technologies Being Developed by CN



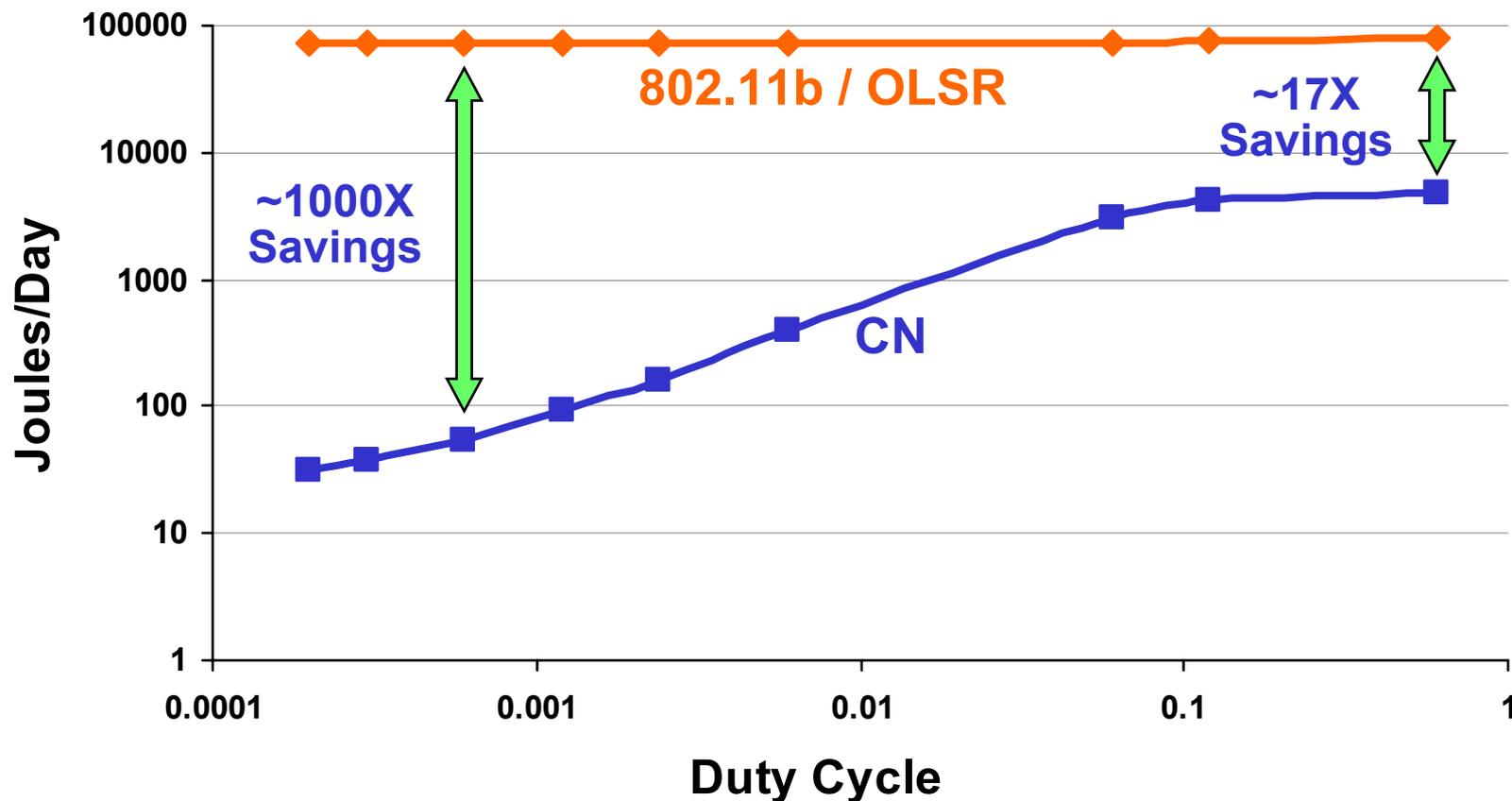
- **Low Power Sleep/Wakeup**
 - Low data rate, energy optimized wakeup waveform
 - High data rate time and frequency hopping data waveform, optimized for packet length
 - Scheduled awake/receive times minimizes receiver energy, which is dominate in low duty cycle applications
- **Cross-Layer Information Sharing**
 - Minimizes redundant over-the-air transmissions
 - Maximizes overhead efficiency
 - E.g. Point-to-point caching of End-to-End information, allowing dynamic re-routing with minimal re-transmissions
- **Hazy Sighted Scoping**
 - Information about distant nodes updated less frequently than nearby nodes
 - Saves energy while retaining the ability to generate near-optimal routes
- **Energy Conserving Multipoint Relaying**
 - Minimizes the aggregate power required for all one-hop broadcasts
 - Metrics based on transmission energy vice topology
- **Energy Efficient Delivery Assurance**
 - Minimizes dropped packets
 - Reduces energy required to reliably transfer data between two end points
 - Reduces overall system energy in the presence of lost nodes



CN Sensor Networking Performance (Simulated)



Energy Usage Per Node Per Day



*25-node simulations



CN - Schedule



Task	FY04	FY05	FY06	FY07
Phase I – Integrated Layer Design and Performance Prediction: - Reduce Acquisition time to 0 seconds - Obtain factor of $10^{2.5}$ reduction in predicted energy usage with a duty cycle of $> 10^{-2}$	 Phase I Simulation Results			
Phase II – Development and Testing: - Obtain at least 1% energy efficiency with a duty cycle of $>10^{-5}$		 Phase II Laboratory Demo		
Phase III – Scalability and Demonstration: - Obtain an efficiency reduction of $> 3\%$ over 3 orders of magnitude of net duty cycle			 Phase III Field Demo	

Today

Transition Targets : Wolfpack, Blue Radio Users, Mobile & Fixed Sensors