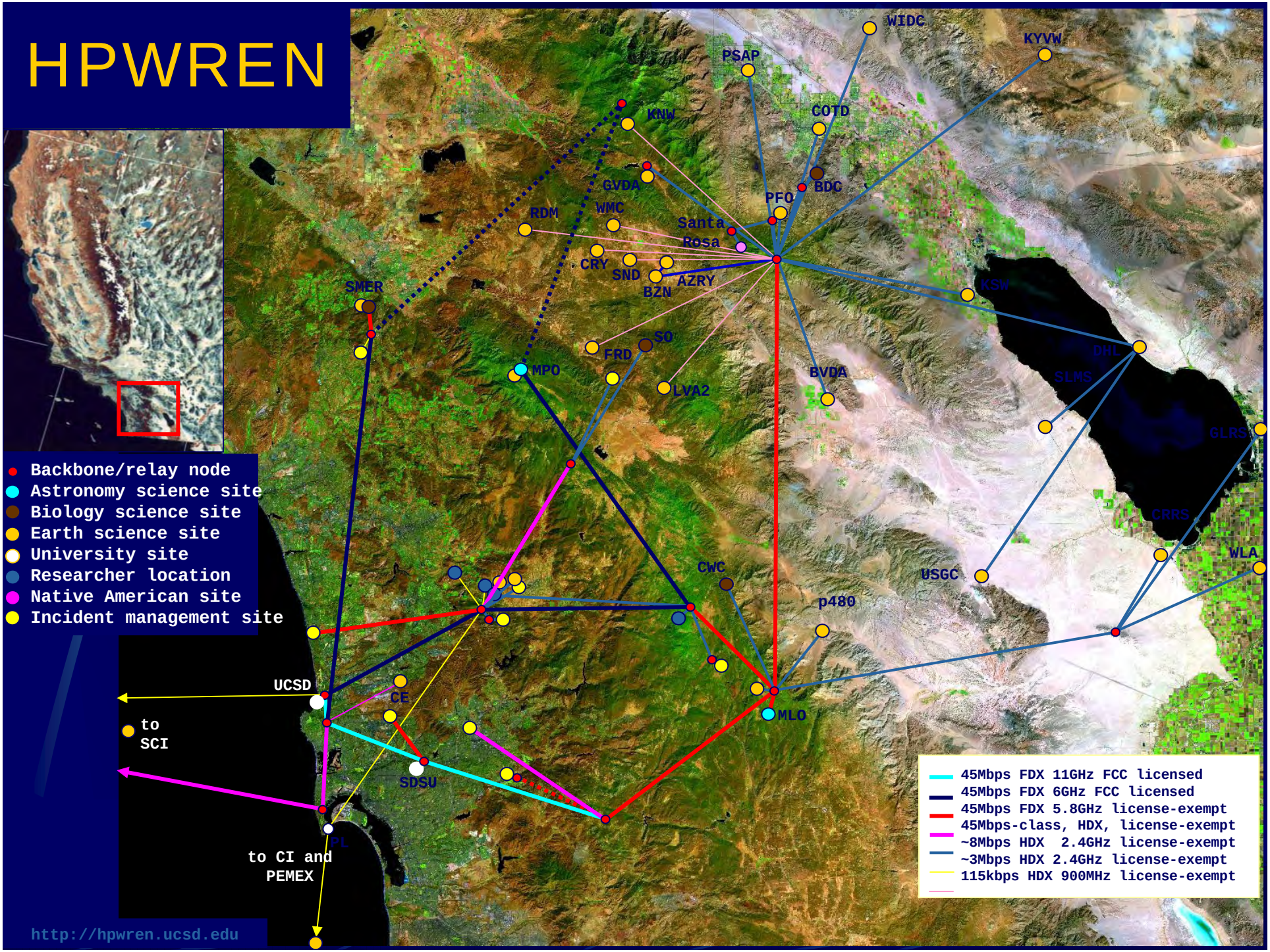
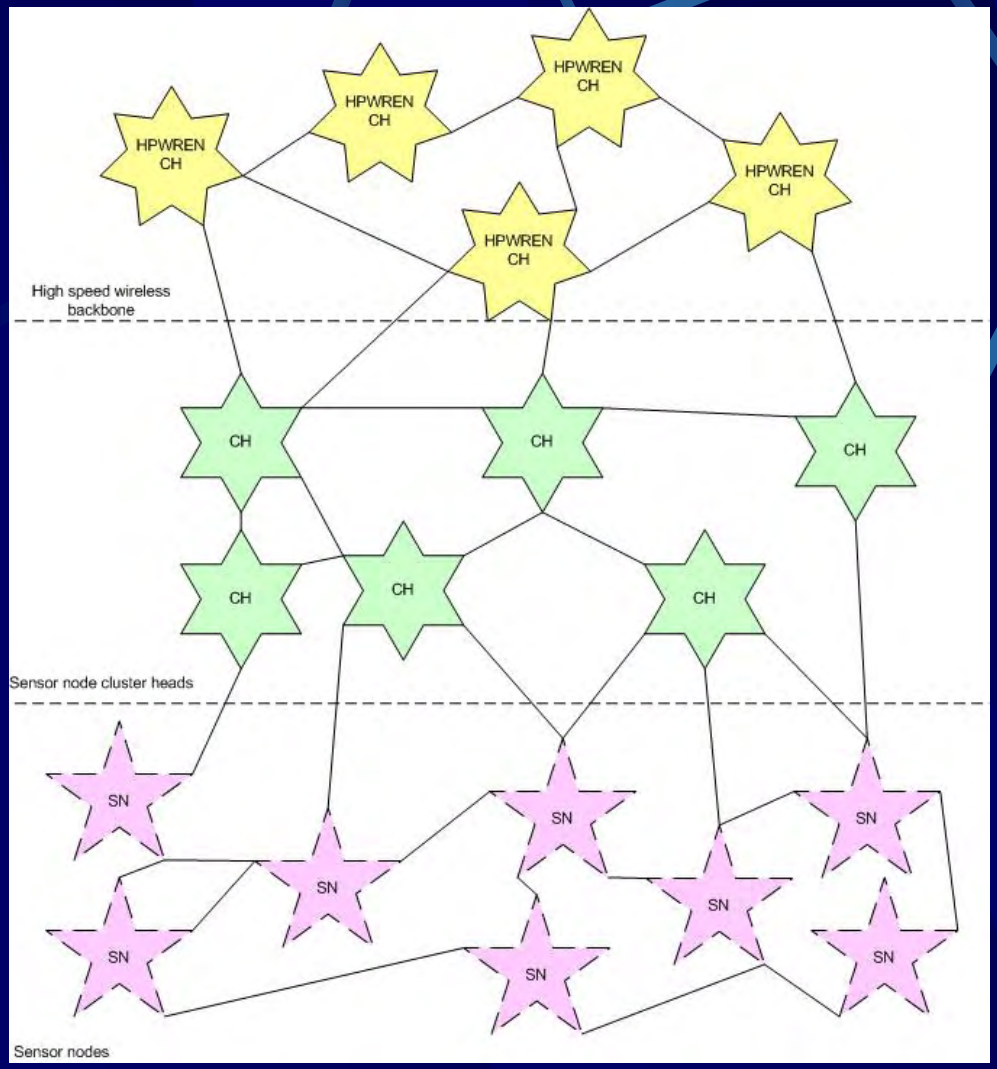
Resource Management of Heterogeneous Wireless Systems

Supported by: NSF, CNS, Sun Micro., Qualcomm, HP


HPWREN
WIDC
KYVW
PSAP
KNW
COTD
GVDA
BDC
PFO
RDM
WMC
Santa
Rosa
CRY
SND
AZRY
BZN
SMER
KSW
SO
FRD
DHL
MPO
BVDA
SLMS
LVA2
GLRS
CRRS
WLA
CWC
USGC
p480
UCSD
CE
MLO
to
SCI
SDSU
PL
to CI and
PEMEX
Backbone/relay node
Astronomy science site
Biology science site
Earth science site
University site
Researcher location
Native American site
Incident management site
45Mbps FDX 11GHz FCC licensed
45Mbps FDX 6GHz FCC licensed
45Mbps FDX 5.8GHz license-exempt
45Mbps-class, HDX, license-exempt
~8Mbps HDX 2.4GHz license-exempt
~3Mbps HDX 2.4GHz license-exempt
115kbps HDX 900MHz license-exempt
http://hpwren.ucsd.edu

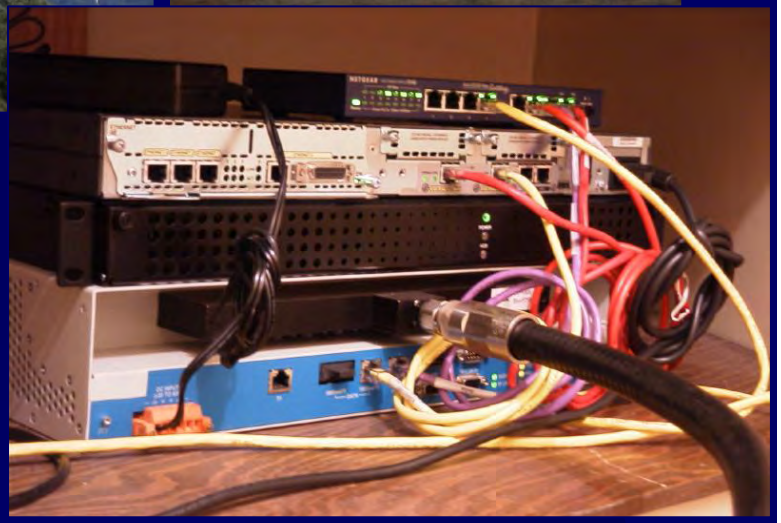
HPWREN - three tier network



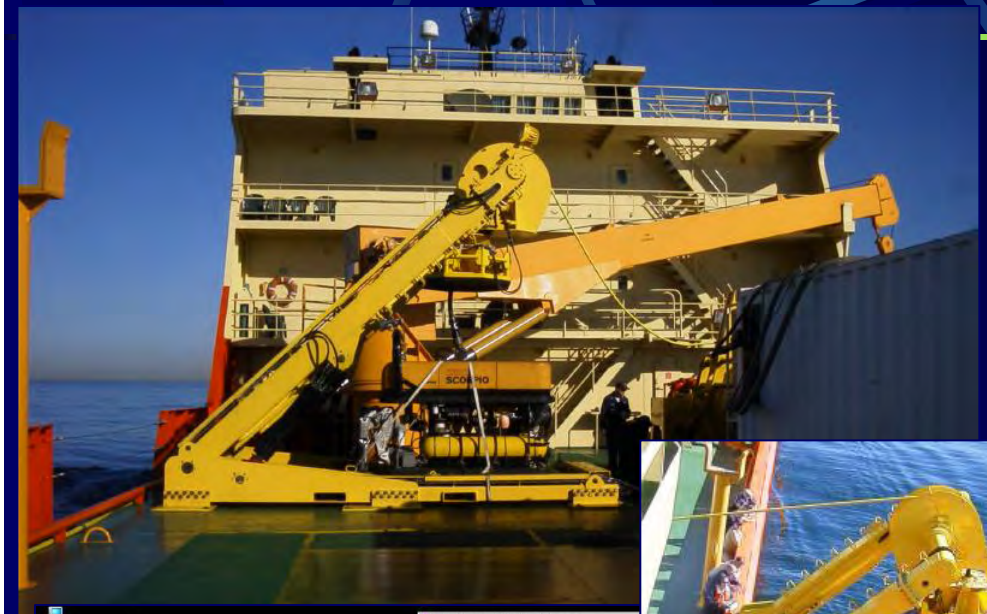
- Wireless MESH
  - QoS scheduling and routing
  - Fast wireless connectivity
- Sensor Cluster Heads
  - Key issue:
    - Delivering good QoS
    - With long battery lifetime
  - Use faster radio to support QoS requirements
- Sensor Network
  - QoS
    - not considered in traditional sensor net research
  - Battery lifetime

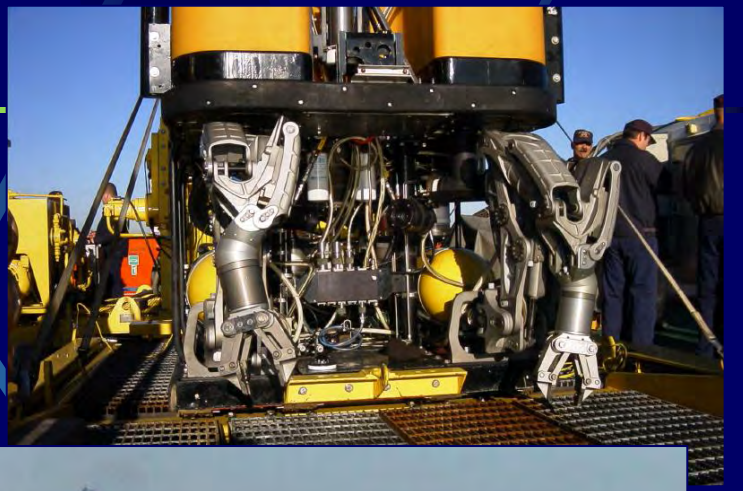
Earthquake sensors in the desert – 10kbps

Palomar Observatory – 150 Mbps



U.S. Navy Deep Submergence Unit





http://www.csp.navy.mil/csda5/dsu/dsu.htm

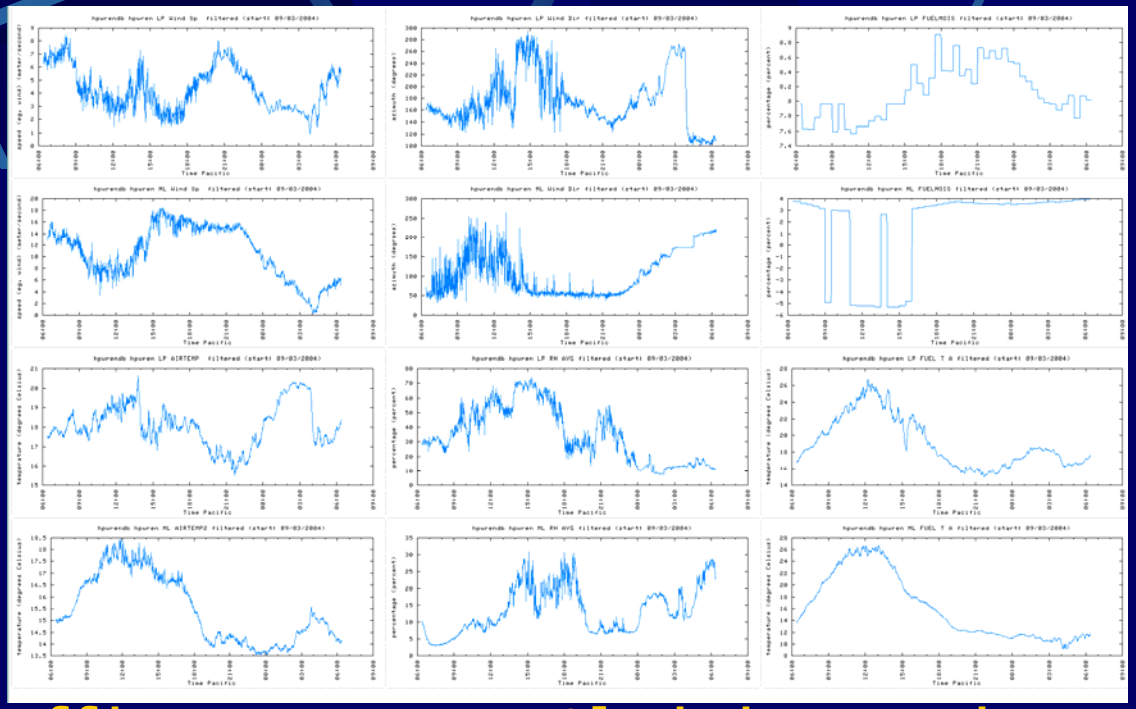
Volcan Fire HPWREN connection, September 2005

Real-time data based alerts

Trigger email/pager/….
if:

condition A +
condition B +
condition C

occurs

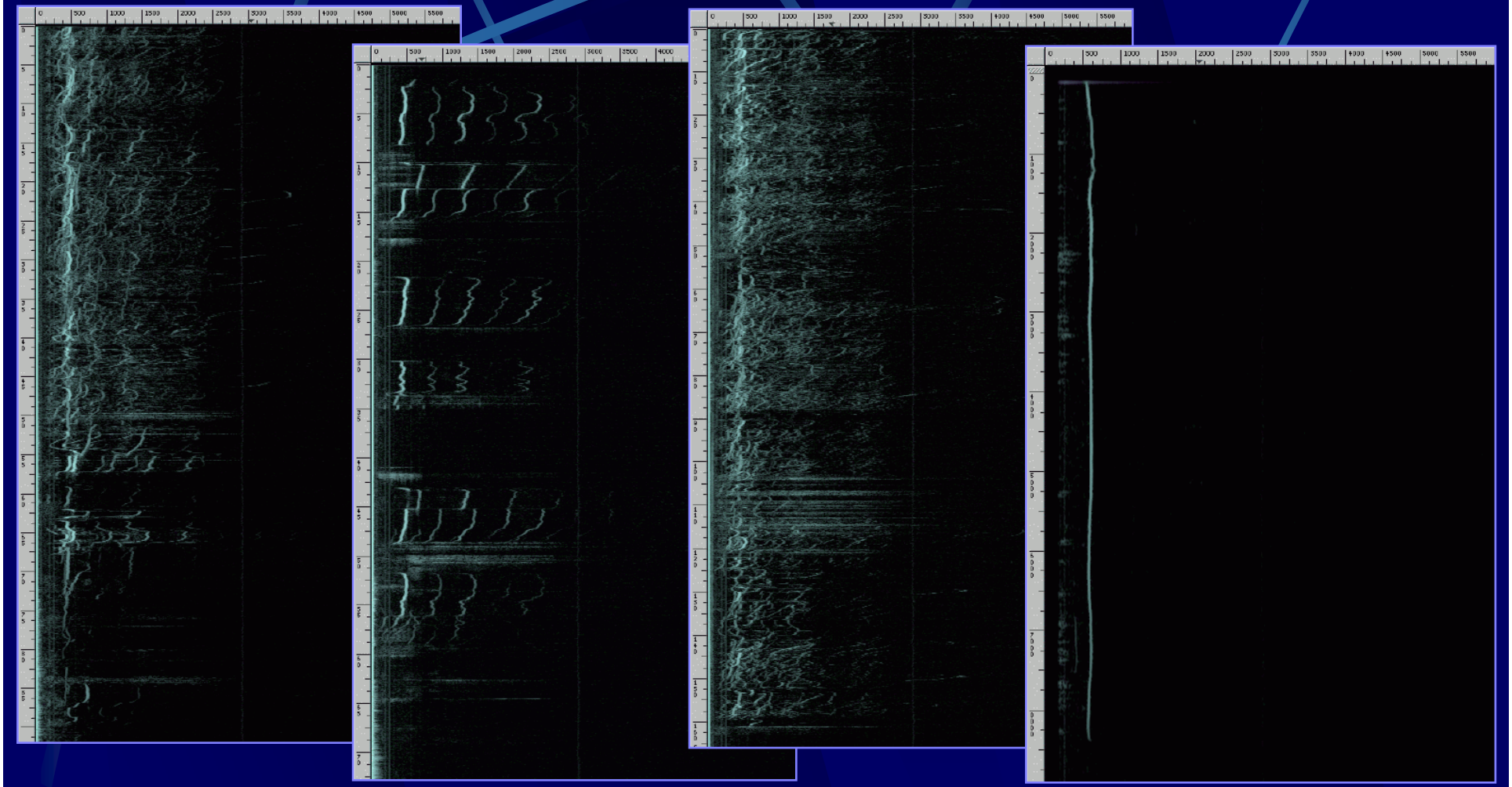


several San Diego fire officers are currently being paged during alarm conditions, based on HPWREN data parameterization by a CDF Division Chief

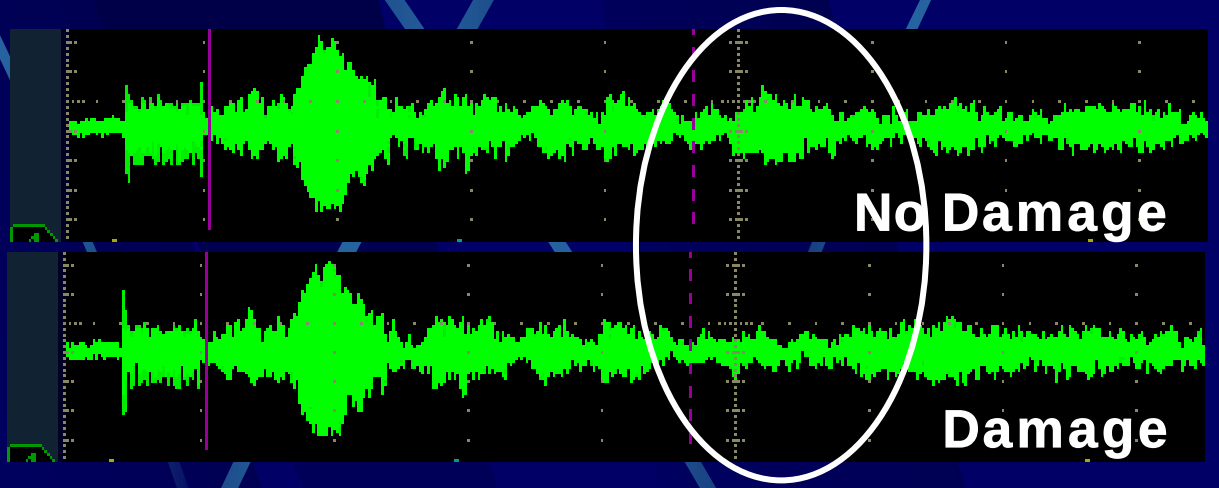
Mountain fire video camera

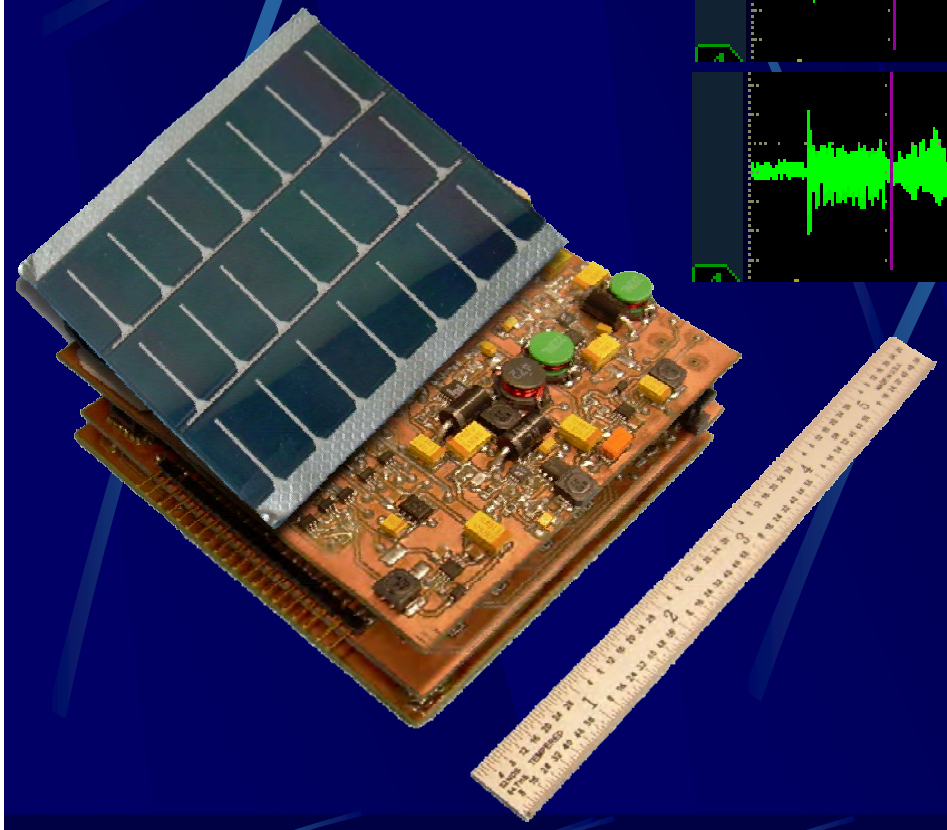
Motion detect camera

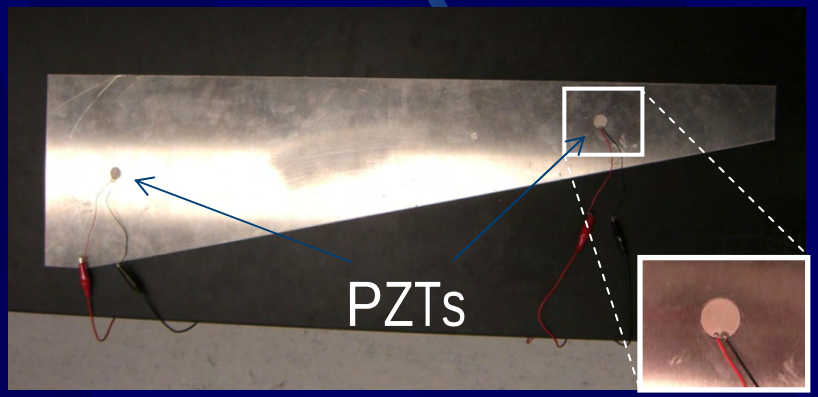
Acoustic sensors:
Wolf howls at the California Wolf Center



An Active Sensing Platform for Wireless Structural Health Monitoring



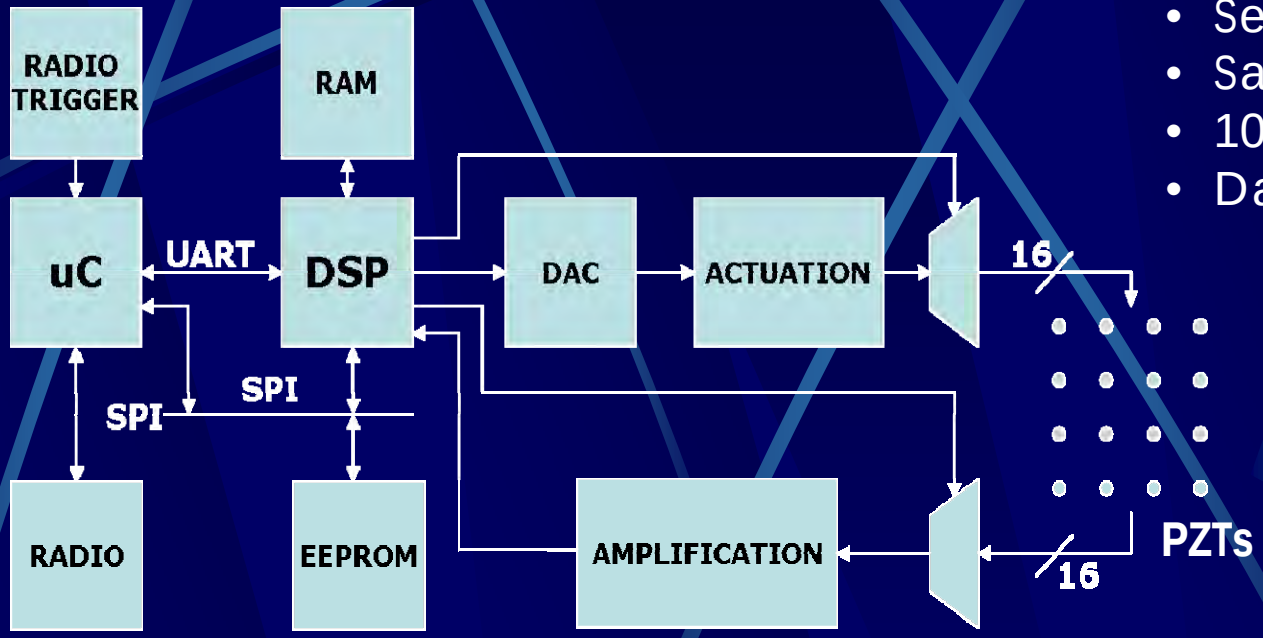




A pair of PZTs: actuator & sensor

Sponsored by LANL
In collaboration with Uof Bologna

Hardware Architecture



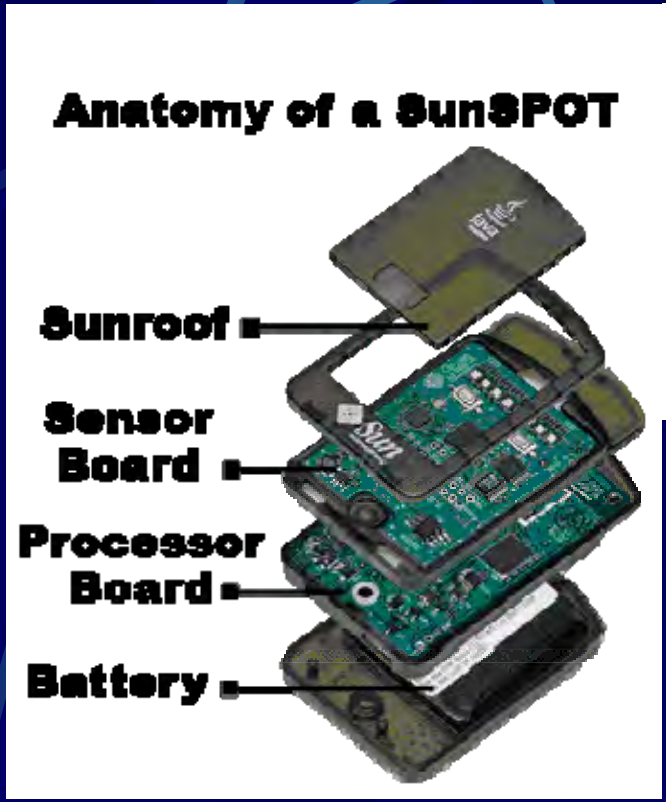
- Sensing – 10ms
- Sampling– 10MSPS
- 10K samples
- Data occupies 20KB

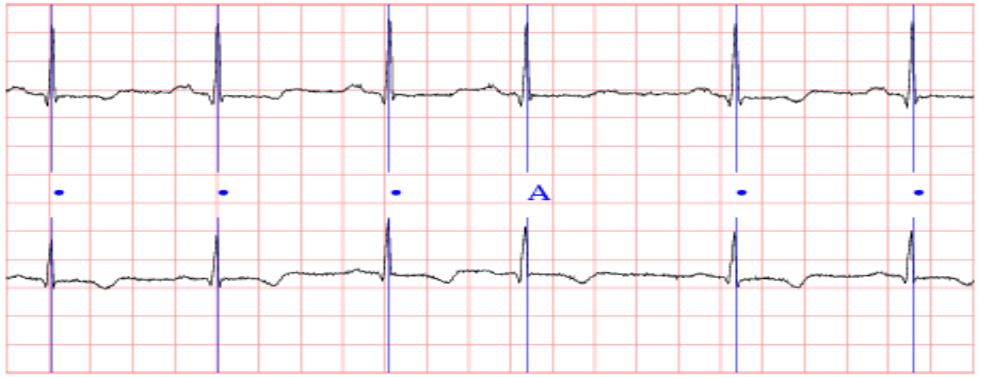
To charge a 100F super capacitor using 100 cm^2 solar panel takes **less than 90 min**

Time to analyze of a pair of PZTs = **3.5 seconds**

DSP can process up to 260 2xPZT at 150MIPS with one charge

EKG Monitoring with SunSPOT





- Reconfigurable
- Low Power
- Easily Programmable
- Simple Hardware Integration

Joint with EPFL and IMEC
Supported by Sun Microsystems

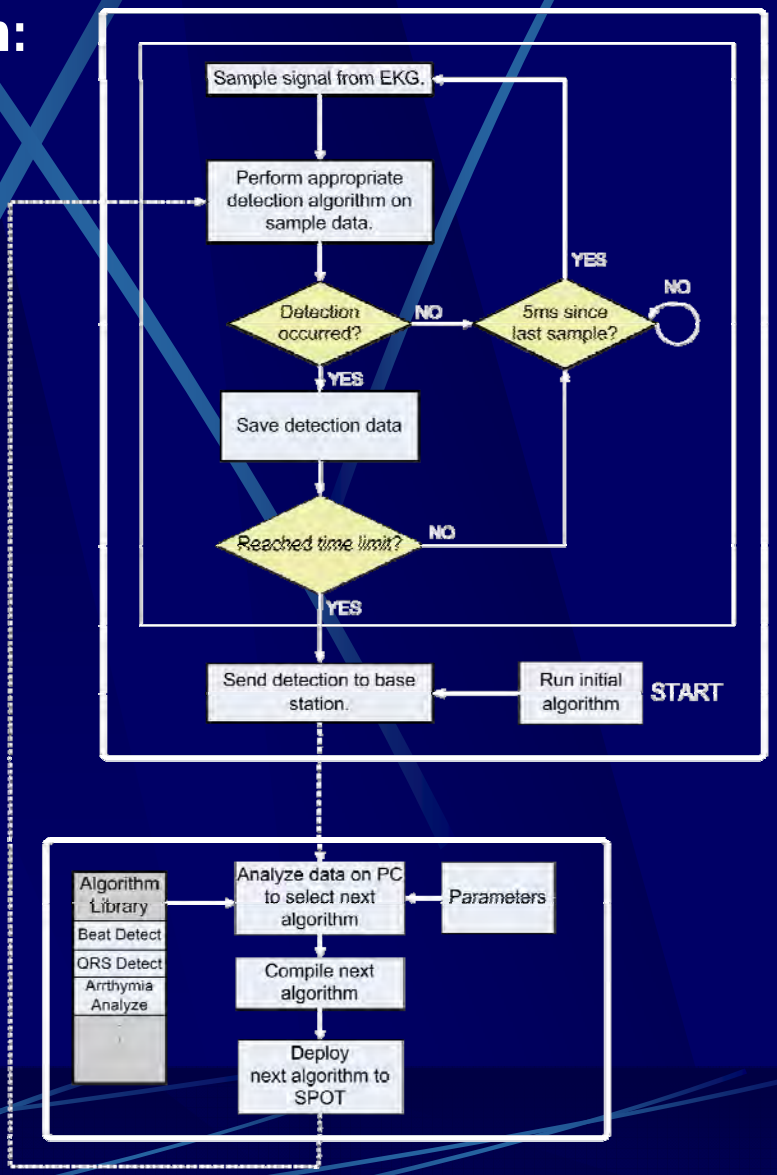
Reconfigurability in EKG Monitoring with SunSPOT

Reconfigurable Programming Paradigm:

- Library of functions
- General code template
- Real-time compilation
- Reconfigurable intelligence
- Transmission Cleanup

Application Library

- **Selector**
- **Beat Detection and Classify**
  - **PC**
  - **SPOT**
- **QRS Detection**
  - **PC**
  - **SPOT**
- **Arrhythmia Detect**
- **Ventricular Flutter**
- **Irregular SVT**



Wireless Sensor Network

Data Acquisition Network

3d ultrasonic anemometer

Animal Monitoring

Precipitation

Temperature, humidity

In-flight camera

Stationary camera

Solar radiation

Ship Monitoring

HPWREN

Weather station

Seismic

Data Distribution Network

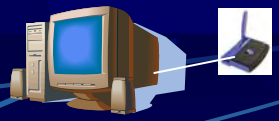
PDA

Mobile and Stationary Operations

Storage

Notebook

Cellular Phone

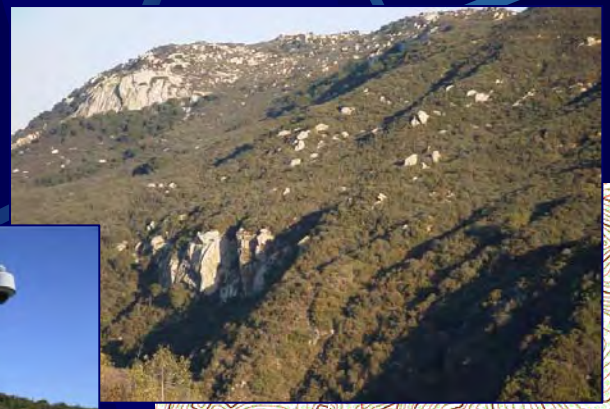


PC

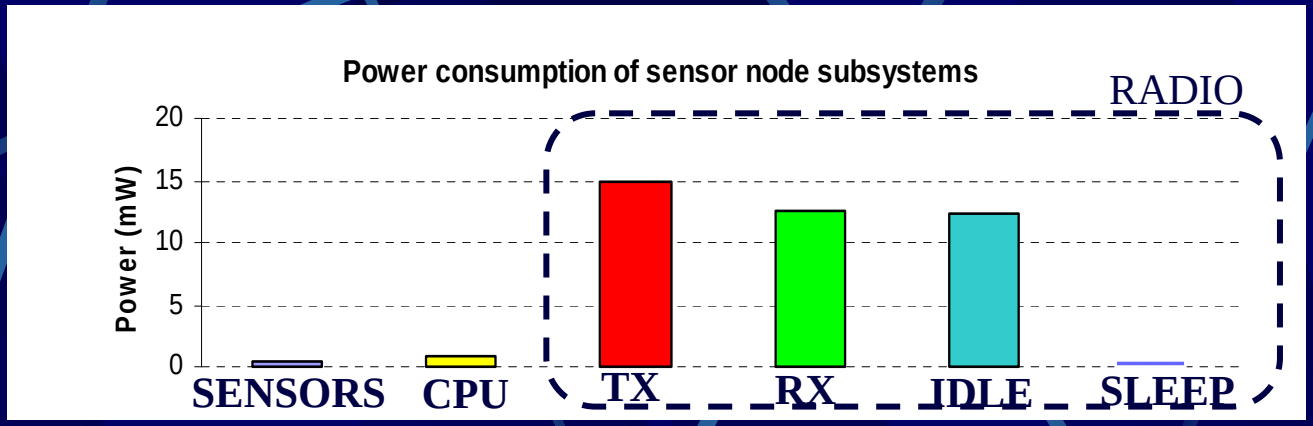
Research Topics: Energy-efficient & QoS-aware Scheduling & Routing

- Objective:
  - Design an adaptive, distributed and low power QoS scheduling & routing methodology
- Main Challenges:
  - Devise a good scheduler:
    - Understand and characterize the incoming traffic
    - Improve delay and throughput
    - Reduce the power consumption
  - Devise a good routing algorithm:
    - Characterize and devise simple & accurate metrics
    - Low power -> route changes occur frequently -> fast adaptation

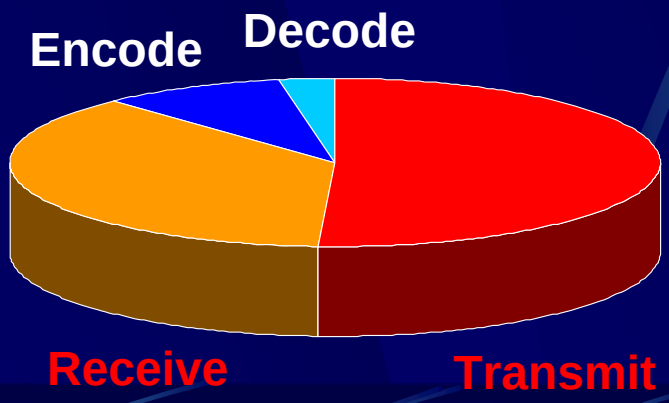
Initial Project Testbed - SMER:
Santa Margarita Ecological Reserve



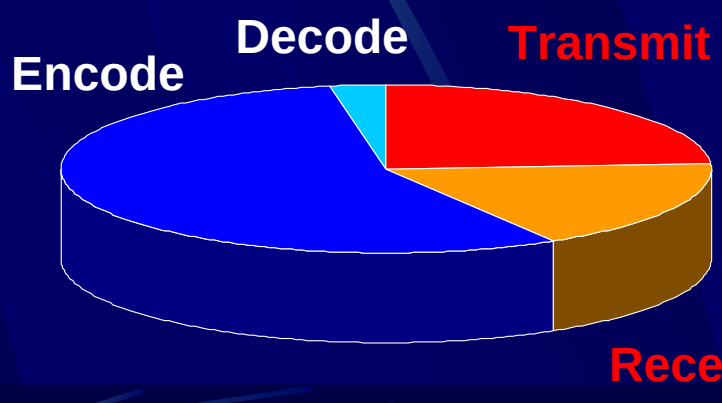
Sensor Node and Cluster Head Power Consumption



Energy breakdown for voice



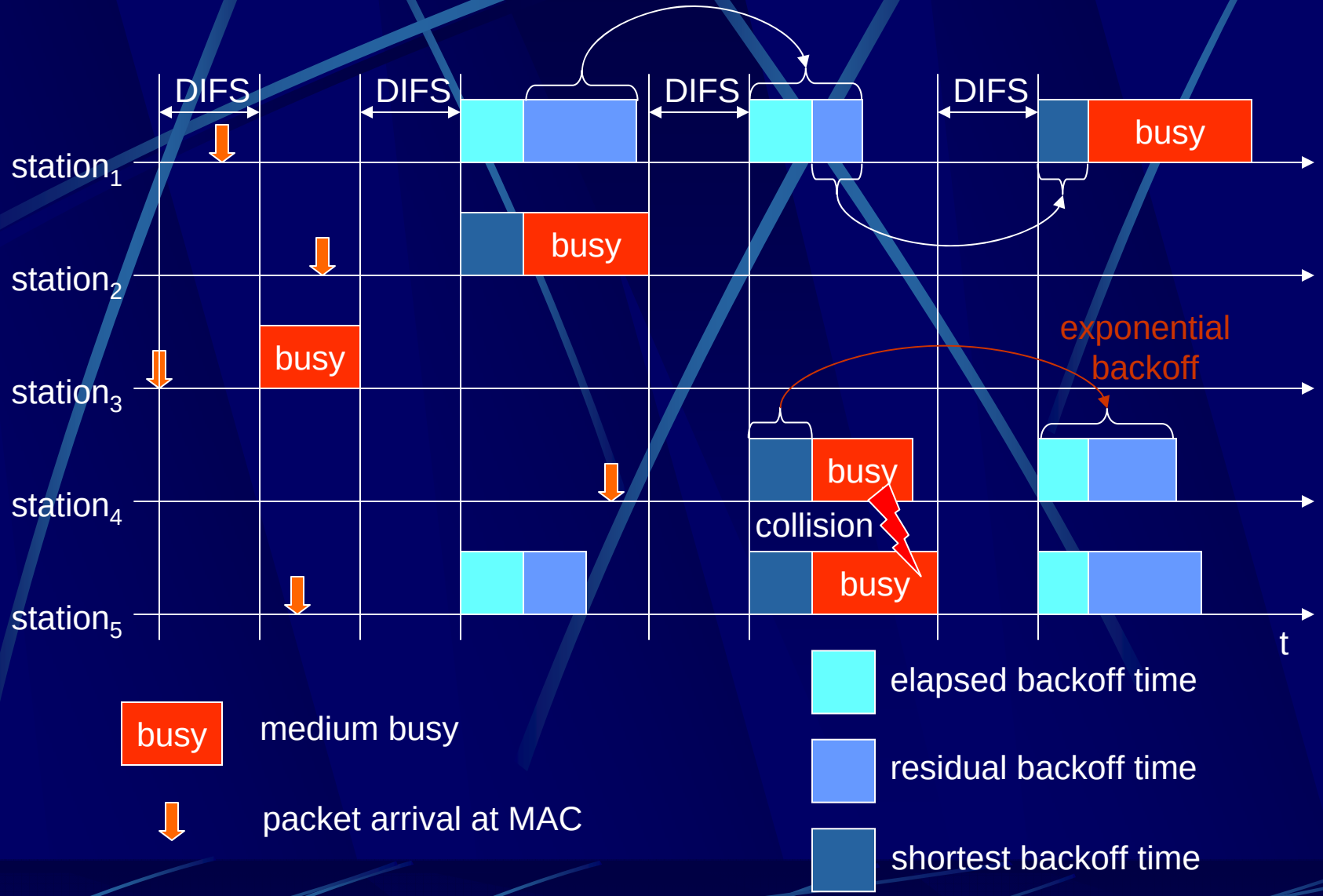
Energy breakdown for MPEG video



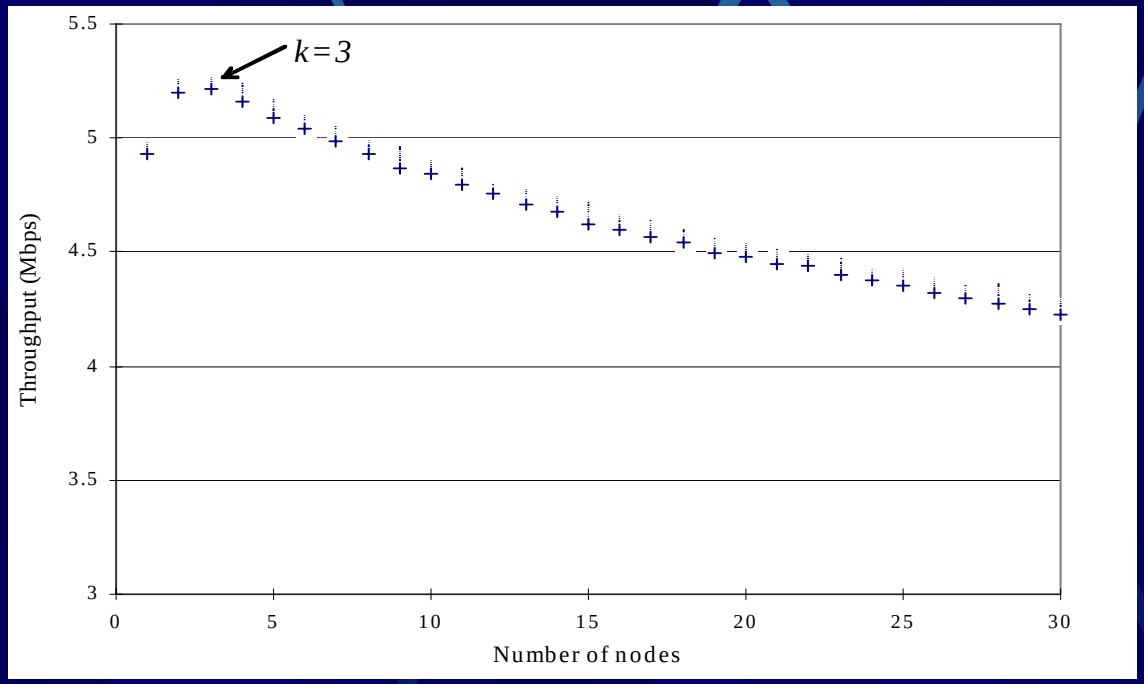
Lucent WLAN & SA-1100 CPU at 150 MPIS

Source : Mobicom'01 SensorsTutorial

QoS issues: 802.11 contention



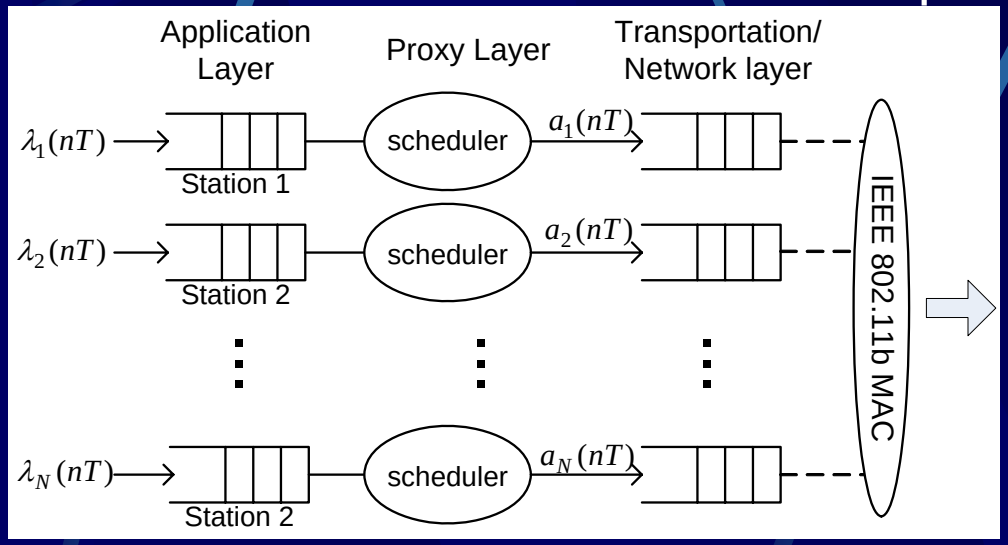
WLAN Bandwidth vs. Contention

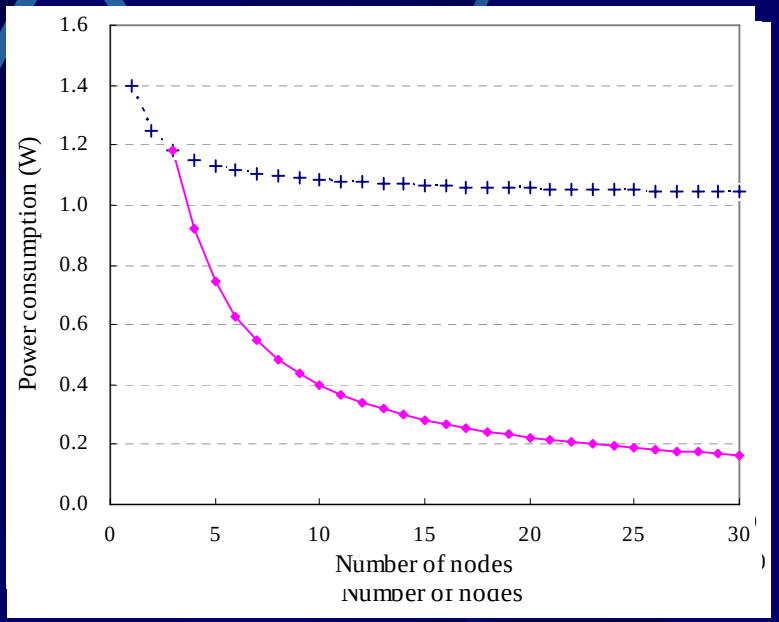


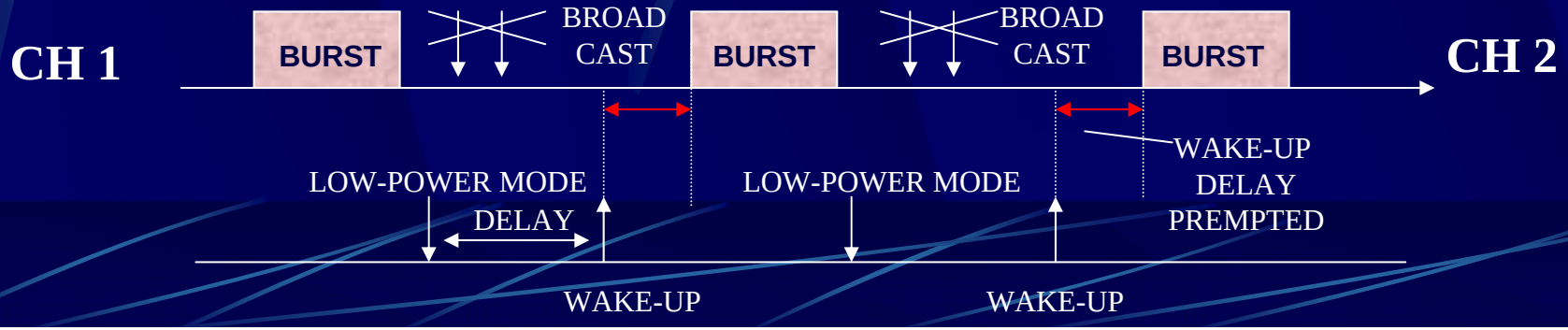
- This suggests that in finite traffic:
  - Throughput improvements are possible with bursts of packets
  - Scheduling k clients at a time can be beneficial

TDMA with CBR on WLAN

- Proposed TDM fixes contenders at 2-4
  - Lower contention means higher throughput
  - Another benefit is more sleep

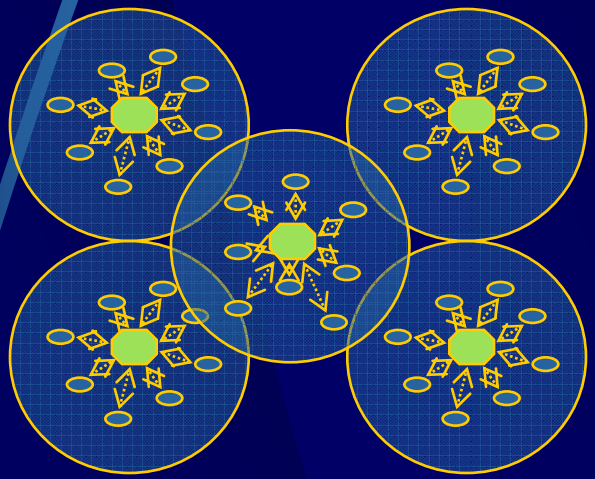




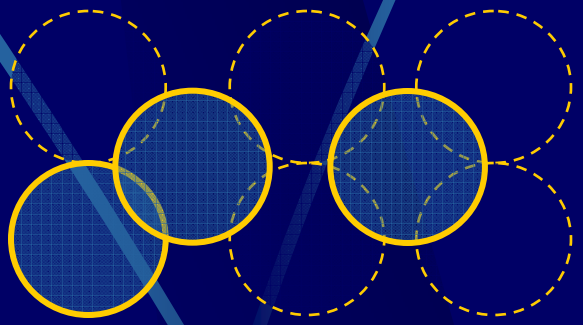


Hybrid distributed scheduling

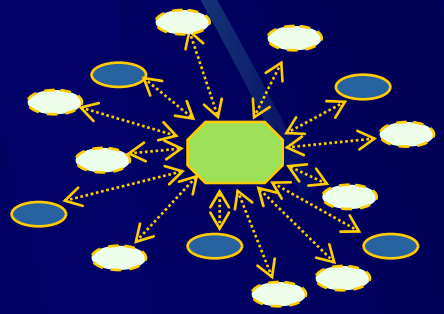
- Combines cell and node level scheduling



Multi-cell wireless network



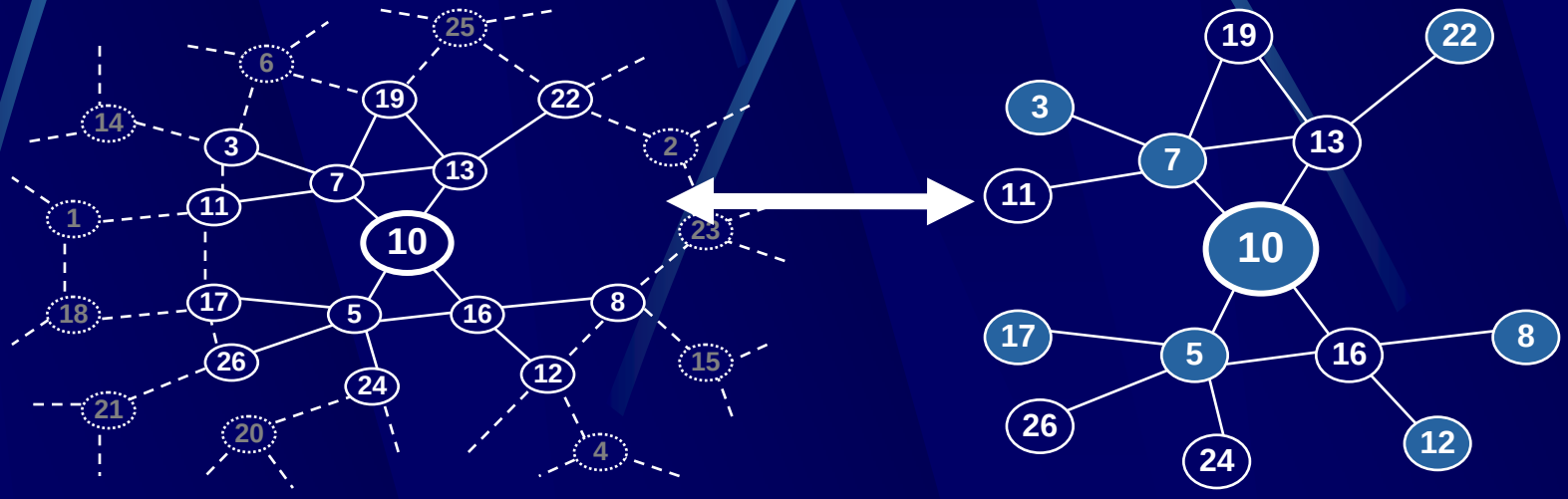
Cell-level scheduling



Node scheduling in a cell

Distributed node scheduling

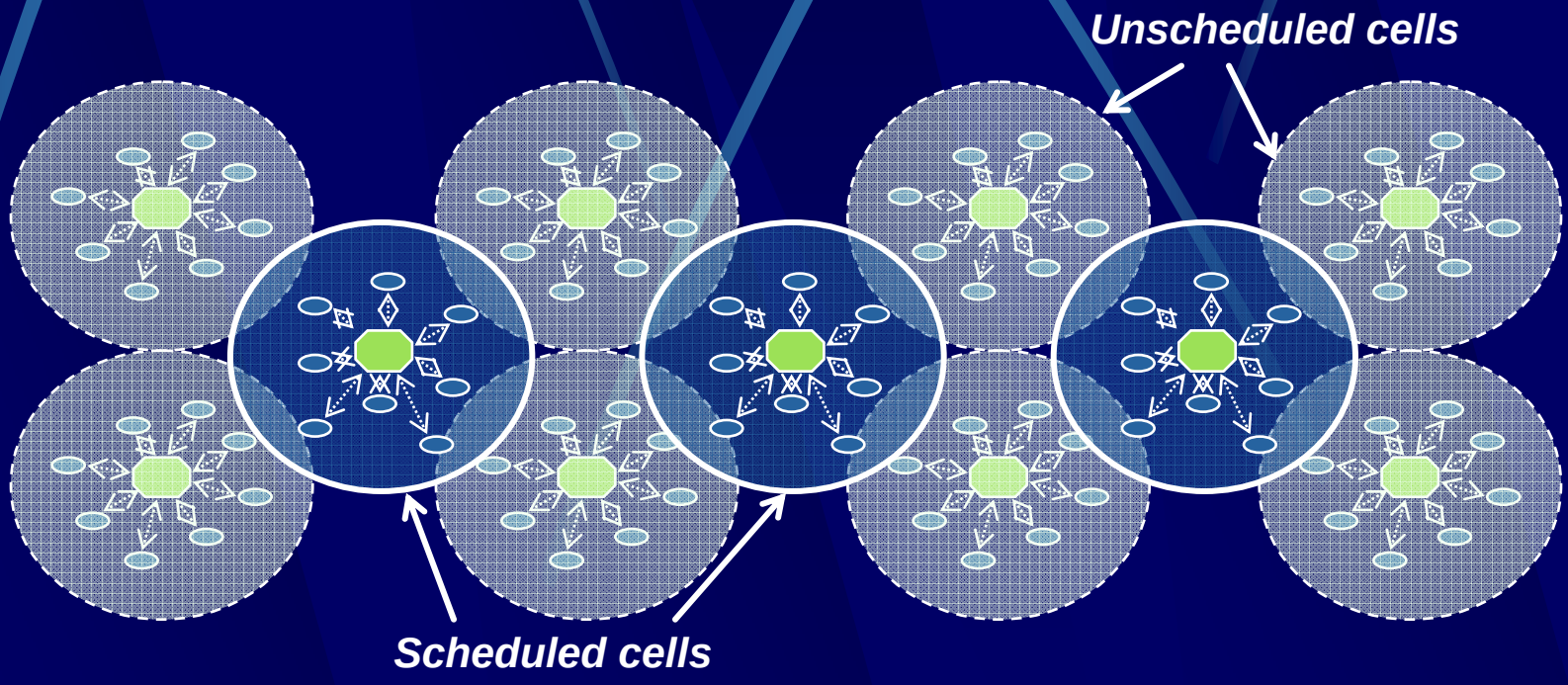
- Distributed scheduling with minimal overhead
  - Less vulnerable to a node failure
  - Flexible to the change of network topology
  - Requires two-hop connectivity information



Distributed cell scheduling

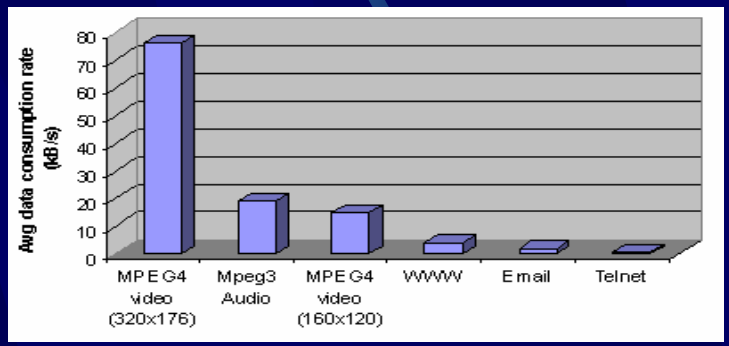
- Activate cells that will not interfere with each other

  → *Improve the overall throughput*



Recent results

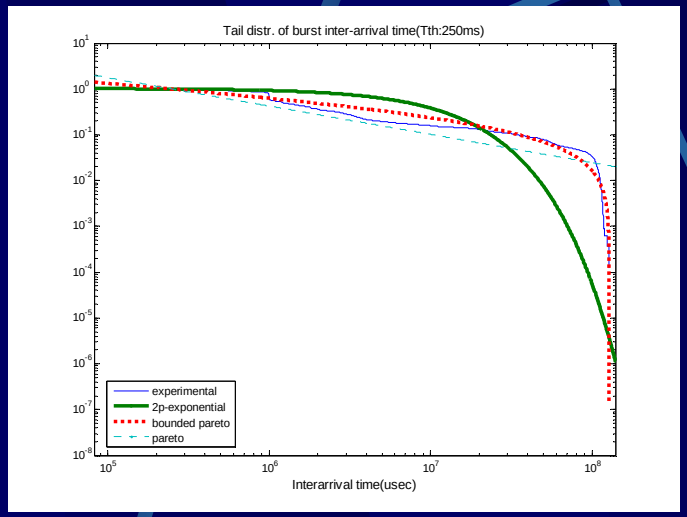
- XScale PXA27x DVK representing sensor node cluster heads (CH)
- NS2 simulator for multiple nodes
- The applications used are
  - Various sensor traffic from SMER/HPWREN
  - MPEG4 video
  - MP3 audio
  - Email, Telnet, WWW



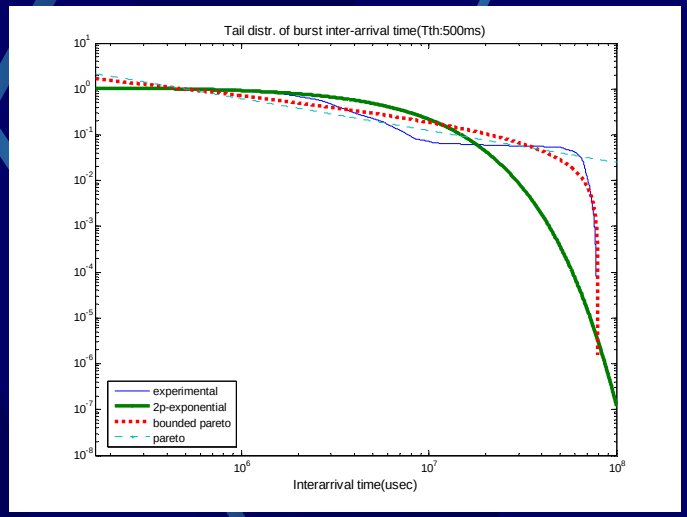
Data consumption rate of applications kbps

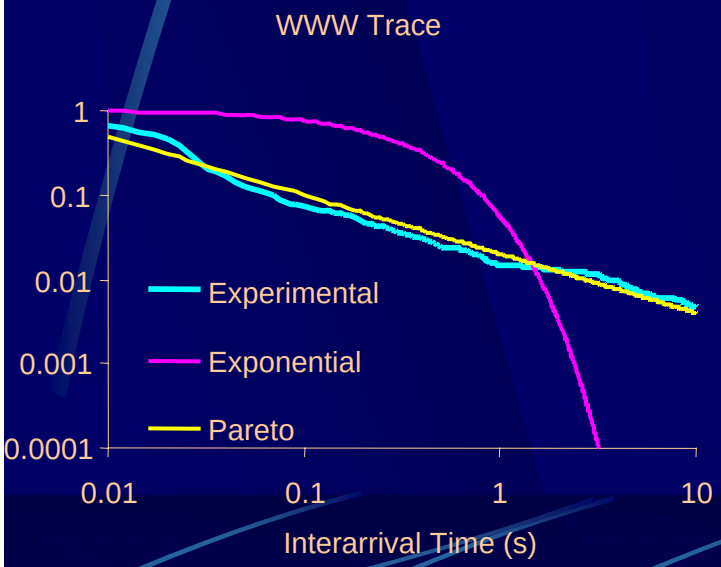
Traffic characterization

Video cluster heads



Sensor cluster heads



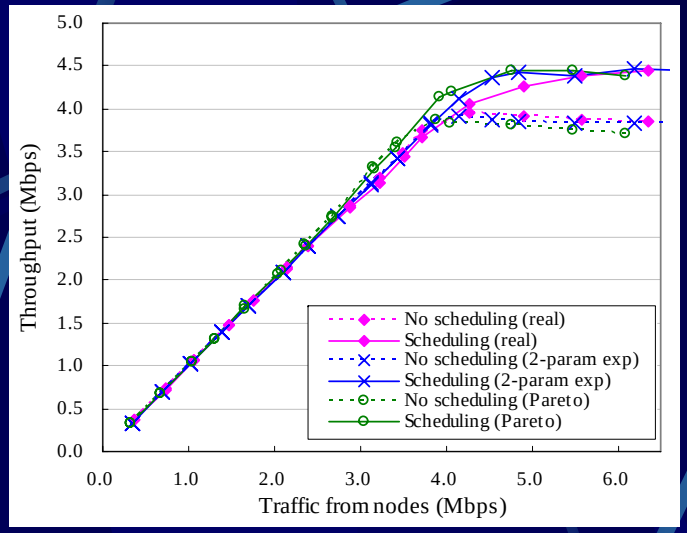


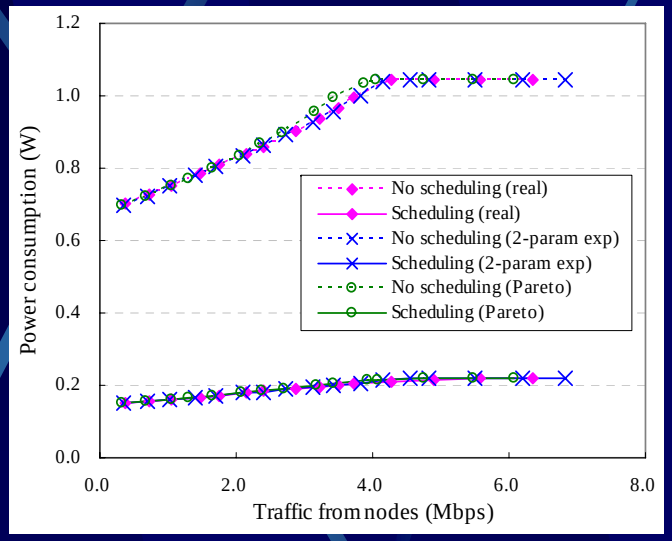
Distributions

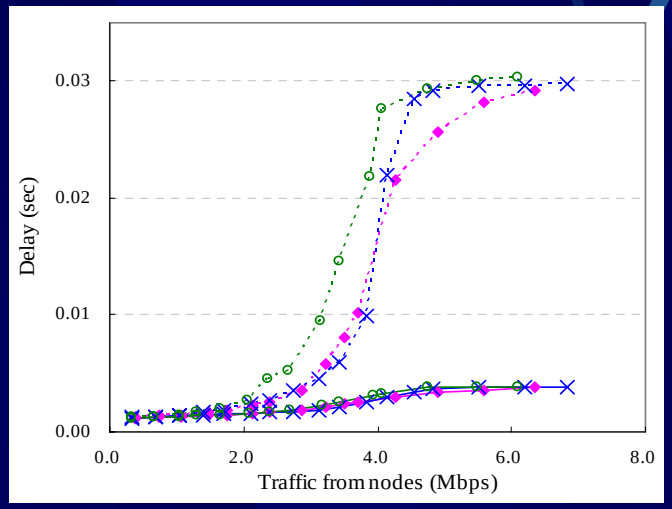
$$Exp = 1 - e^{-\lambda_e t}$$

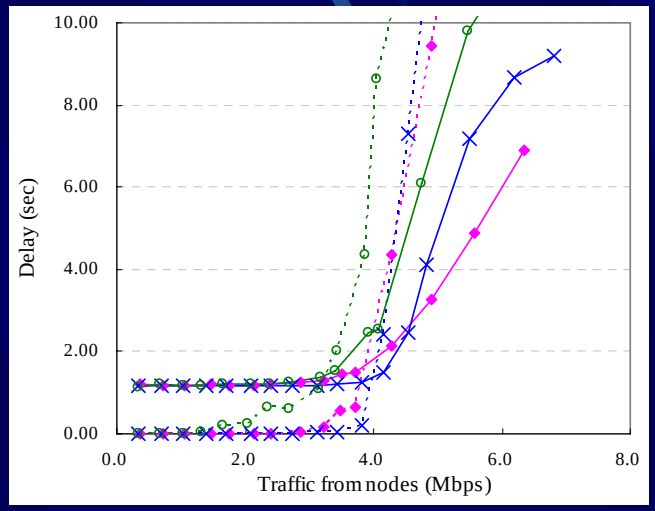
$$Pareto = 1 - b \cdot t^{-a}$$

Node scheduling





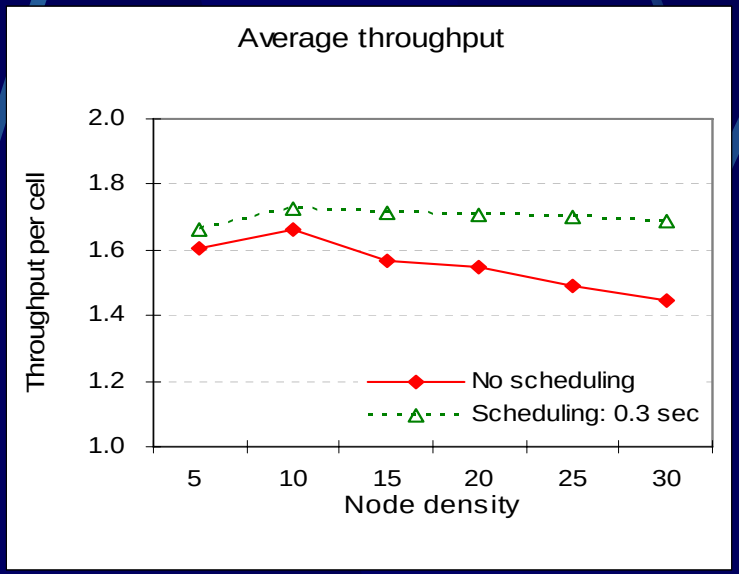


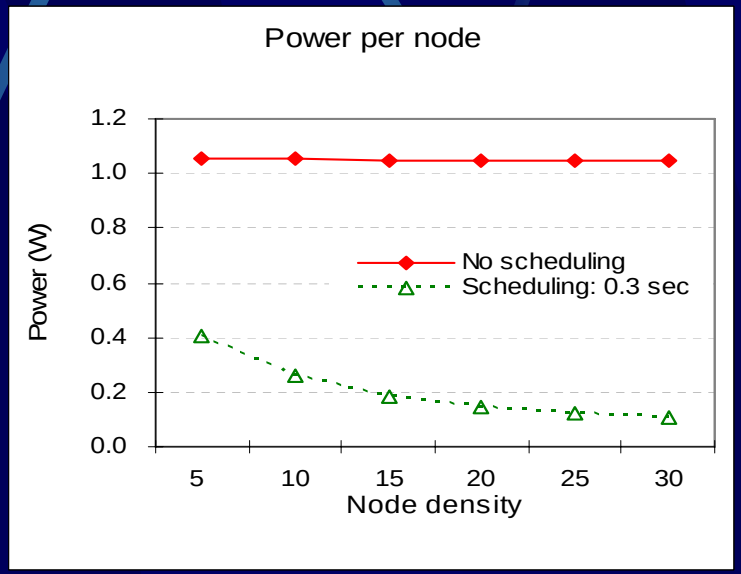


- Significant improvements in throughput, MAC delay and power consumption regardless of the traffic model used

Distributed cell and node scheduling

- Nodes scheduled ***with a distributed algorithm***
- Results show large power savings with throughput improvement





Conclusion

- Scheduling communication at sensor node cluster heads has significant benefits
  - Lower energy consumption
  - Better bandwidth utilization
- Benefits of scheduling measured for
  - Sensor node traffic
  - Multimedia traffic
  - Standard web traffic