An interdisciplinary collaboration for research and infrastructure

University of California, San Diego:
San Diego Supercomputer Center
Scripps Institution of Oceanography

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high performance wireless research and education network
http://hpwren.ucsd.edu
HPWREN project objectives

• wide area wireless high performance networking
• focus on access networks for research and education applications
• fixed or temporary/ad-hoc installations
• emphasis on interdisciplinary collaboration
• non-commercial prototype platform to demonstrate feasibility
• connection of sensor networks
• research to understand application performance requirements
• QoS and PBR research

http://hpwren.ucsd.edu
Project participants and collaborator examples

- Led by UCSD’s San Diego Supercomputer Center and Scripps Institution of Oceanography
- Science applications
  - Scripps Institution of Oceanography:
    - Geophysics -- earthquake sensors
  - San Diego State University, Astronomy department
    - Mt. Laguna Observatory
  - San Diego State University, Field Station Programs
    - Santa Margarita Ecological Reserve and Sky Oaks Field Station
  - Lawrence Berkeley National Laboratory and California Institute of Technology
    - Palomar Observatory
  - UC Natural Reserve System
    - Boyd Deep Canyon
  - UC San Diego
    - School of Engineering Bridge sensors (Coronado Bridge and desert highway bridge)
    - Laboratory for Atmospheric Acoustics
  - UC Santa Barbara – Institute for Crustal Studies
- Education applications
  - Originally: Pala, La Jolla, and Rincon Indian Reservations
  - Tribal Digital Village Network
  - California Wolf Center
- First responders and other agencies
  - San Diego Sheriff’s department
  - California Department of Forestry and Fire Protection
  - SSC
to Mount Woodson Area

to Cuyamaca Mountain

to Red Mountain

to UCSD

to Dan Cayan

to Doug Bartlett

to Indian Reservations

Hans Werner Braun
Technology and data collection
Network architecture

• high performance backbone network
  • commercially available 5.8GHz or 6GHz 45Mbps duplex point-to-point radios
    • WMux Tsunami, Interwave CX, Redline AN-50, or licensed Stratex DXR768
    • interconnected by IP routers
  • backbone nodes at “quality” locations, including UPS
  • fairly large antennas (10’, 8’, 6’, or 4’)
  • network performance monitors at backbone sites

• high speed access links
  • commercially available 2.4GHz spread spectrum radios
    • Lucent/etc. 802.11b and Wi-LAN VIP 110-24
  • some 5.8GHz 45Mbps access links
  • point-to-point or point-to-multipoint
  • commonly small (~2’ X ~3’) grid antennas for 2.4GHz
  • some sites include local performance monitors

• network statistics available at http://stat.hpwren.ucsd.edu/

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HPWREN backbone node architecture

- router
- switch
- 45Mbps backbone radio
- 45Mbps backbone radio
- 45Mbps backbone radio
- sensors e.g. video, met
- access radio
- access radio
- access radio
- access radio
- uninterruptible power supply
- passive & active measurements

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Data sources for centralized server

- SNMP/MIB data (router, switch, radio, UPS, traps)
  - e.g., generates daily automated backbone performance data
- reachability tests
- regular inter-node matrix throughput tests
  - generates daily automated summary
- netflow data for HPWREN-external traffic
- DoS attack detection machine at HPWREN-external interface
- sensor data (e.g., weather, cameras)
NLANR PMA 24/7 traffic trace collection

Long-term HPSS data server at the San Diego Supercomputer Center

NLANR Passive Measurement and Analysis traffic trace web server:
http://pma.nlanr.net/Special/hpwren.html

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Persistent Connectivity for research, education, and first responders
45Mbps HPWREN backbone

- Palomar Observatory
- Mt. Woodson
- Guyamaca Mountain
- Mt. Laguna
- Toro Peak
- UCSD/SDSC
- Mt. Soledad
- Mt. Laguna Observatory
- Fallbrook

network
Example earthquake sensors in the desert

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Earthquake sensor and data collector on Toro Peak

http://epicenter.ucsd.edu/ANZA/

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Palomar Observatory, July 2001

http://www.astro.caltech.edu/palomarpublic/
http://snfactory.lbl.gov/
http://neat.jpl.nasa.gov/

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Link to the Santa Margarita Ecological Reserve, September 2001

http://www.scec.sdsu.edu/SMER/SMER.html

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Link to San Clemente Island, October 2002

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CDF Fallbrook connection
August 2002

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Collaborative agency connections

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http://hpwren.ucsd.edu
August 2005, Gillespie Helitack Base connection

high performance wireless research and education network
http://hpwren.ucsd.edu
Bridge connection near Salton Sea
Nov 2002

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Garner Valley Downhole Array and NEES site

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CDF La Cima connection in the Cedar Fire post-burn area

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June 2005, Native American collaboration at Mesa Grande

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high performance wireless research and education network
http://hpwren.ucsd.edu
June 2005, SDSU Sky Oaks Field Station connection

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Initial Pala Indian Reservation connection
September 2000

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http://hpwren.ucsd.edu
La Jolla Indian Reservation connection, January 2001
Native American connections

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Tribal Digital Village network project

- Native American activity building up on HPWREN
- Funded by Hewlett Packard
- Awarded to the Southern California Tribal Chairmen’s Association
- HPWREN is collaborator, and not the service provider
- Objective of a utility architected and operated by Native Americans
Mt Woodson to Pala, Rincon and La Jolla Indian Reservations

- Pala Firestation
  - Pala LC
  - Rincon TANF
  - Rincon EdCtr
- La Jolla EdCtr
- C1-2-relay
- C1-1-relay
- MW-C1
  - Ethernet switch
  - router
- MW-LJ

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TDVnet Cluster1/Cluster2 – eight reservations

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July 2005, post-fire at Adams Road, Pala Indian Reservation

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La Jolla relay site on Palomar Mountain January 2001

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http://hpwren.ucsd.edu
Cuyamaca Mountain 2.4GHz antenna

http://hpwren.ucsd.edu
Ad-hoc Connectivity
CENIC networking conference
May 2001

Paradise Point conference site
Mt. Soledad relay site

http://www.cenic.org/

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CENIC networking conference
May 2002

http://hpwren.ucsd.edu

Mt. Soledad relay site

Paradise Point conference site
temporary 45Mbps connection

http://www.cenic.org/

http://www.cenic.org/

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HPWREN - Fire Chiefs Association meeting
Nov 2002

High performance wireless research and education network
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Anza-Borrego demo

3D ultrasonic anemometer

High performance wireless research and education network

http://hpwren.ucsd.edu
HPWREN ICP connections concept, using one or more radio relays

Mountain-top HPWREN Backbone site

Line-of-sight radio relay site

Incident Command Post site

Line-of-sight radio relay site

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Coyote Fire HPWREN connection

Palomar Mountain relay

Fire operations relay

Operations camp

July 2003

Cuyamaca Mountain
HPWREN backbone site

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Eagle Fire HPWREN connection, May 2004

HPWREN access at SDSU/SMER

Incident Command Post

Preparation for relay battery transport at the ICP site

Local SAM connection at the ICP

Eagle Fire as seen from HWY79 on May 3rd, 2004

http://hpwren.ucsd.edu
Mataguay Fire HPWREN connection, July 2004

- Cuyamaca Mountain backbone site
- Palomar Mountain relay site
- Incident Command Post relay site
- Incident Command Post

http://hpwren.ucsd.edu
Volcan Fire HPWREN connection, September 2005

Incident Command Post site

Volcan relay site

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Border 50  Fire HPWREN connection, October 2005

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May 2005 joint exercise with CDF and San Diego Sheriff’s Department

Equipment preparation

Deployed wireless relay and sensors

CDF staff guiding the slingshot load of the Sheriff’s helicopter

Equipment return

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Ad-hoc firefighter Incident Command Post capability at Dos Picos

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http://hpwren.ucsd.edu
Demonstrations and Exercises
Santa Margarita Ecological Reserve
May 2001

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Researchers in the field

- antenna mounted on tripod
- connected to laptop PCMCIA card
- no external power or equipment

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Yagi antenna on tripod

- yagi antenna
- amplifier
- tripod
- antenna cable to power injector
CDF demonstration
February 2001

http://www.fire.ca.gov/

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Multi-agency crisis management demo
28 August 2001

State Highway 163 scene

Mobile weather station

Network-controllable video camera

Sharp Hospital relay site

Inmarsat satellite

64kbps ISDN link

DARPA ENCOMPASS Server at SSC

Sharp Hospital satellite antenna

UCSD HPWREN Internet connection at SDSC

National Guard Armory

SSC Deployable Communications Support Terminal

Inmarsat satellite antenna
U.S. Navy Deep Submergence Unit – SIO SeaLab II site
February 2002


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http://hpwren.ucsd.edu
Flight communications test, ground tracked
April 2002

Ramona overflight area

SDSU GCRG airplane

Data communications antenna

Ground station

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Flight communications test, fixed antenna
August 2002

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2048 X 1536 sized image taken from the ground via a network-accessible camera in the airplane
Coronado bridge demonstration topology

UCSD

~3 miles

Mt. Soledad

~12 miles

Coronado Bridge

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Coronado bridge communications test, April 2002

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15 May 2002 Coronado bridge telemetry demonstration

- Wireless 802.11b connection
- 360 degree camera
- Video camera and web server
- Seismic sensor
- Seismic data logger
- Radio box and Ethernet switch
- 3 megapixel still camera
- Seismic sensor (structural engineering)
Cameras
Video cameras

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Mountain fire stills, observed by stationary p/t/z video camera

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Mountain fires video clips, observed from Mt. Laguna

http://hpwren.ucsd.edu
Mountain fire video clip, Pines Fire from Mt. Laguna
High resolution still camera at SMER

http://hpwren.ucsd.edu
High resolution still camera at SMER, animations

http://hpwren.ucsd.edu
High resolution still camera at La Jolla, February 2002

http://stat.hpwren.ucsd.edu/Imagery/LaJollaCoast/Data/TODAY/CURRENT-large.html

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http://hpwren.ucsd.edu
Motion detect camera, Ramona, January 2003

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http://hpwren.ucsd.edu
Various images
Superbowl, January 2003

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http://hpwren.ucsd.edu
Superbowl, January 2003

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Camera at the California Wolf Center

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Cedar Fire, 28 October 2003, Mt. Laguna looking towards Cuyamaca

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Mt. Laguna 360 degree four cameras, July 2003

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http://hpwren.ucsd.edu
Mt. Laguna 360 degree view cameras

high performance wireless research and education network
http://hpwren.ucsd.edu
Mt. Laguna automatic motion detect capture

http://hpwren.ucsd.edu

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http://hpwren.ucsd.edu
Ramona CDF Air Attack Base

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Ramona CDF Air Attack Base

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Meteorological sensors
Mount Laguna sensor instrumentation

- 3D ultrasonic anemometer
- Temperature
- Relative humidity
- Solar radiation
- Tipping rainbucket
- Fuel moisture
- Fuel temperature
- Data logger
- Barometric pressure
- Pan-tilt-zoom camera
- 3D ultrasonic anemometer
- Solar radiation
- Tipping rainbucket
- Support equipment
- Fuel moisture
- Fuel temperature

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Wind gusts on Mt. Laguna

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Mount Laguna sensor instrumentation

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Mount Laguna sensor instrumentation

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Real-time sensor implementation at an HPWREN backbone site

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Real-time text display with history graphing support

HPWREN multicast weather station data display
20040606 20:57:15 - Mt. Laguna: 32.69N 116.43W 6200'

Air temperature = 18.3C 65.0F degrees
Relative humidity = 16.3 percent
Wind speed = 6.8 meter/sec 13.5 Miles/hr
Wind direction = 223 degrees horizontal
Barometric pressure = 805 millibar
One minute rainfall = 0.0 mm (mm^2)
Solar radiation = 9 watt (mm^2)

Fuel stick temperature = 15.7C 60.3F degrees
Fuel stick moisture = 4.4 percent (this sensor is currently unreliable)

10Hz 3D Anemometer details
using 596 data points over the last 60 seconds:

- 3D Speed (m/sec) avg: 5.91 avg: 7.45 avg: 8.49 avg: 125
- horizontal (degrees) avg: 137 avg: 125 max: 225
- vertical (degrees) avg: -8 avg: 11 max: 17
- sonic temperature (K) avg: 296 avg: 305 max: 317

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Real-time graphics display

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Real-time data based alerts

Trigger email/pager/… if:

condition A + condition B + condition C

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

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July 2005, Fuel stick replacement on Lyons Peak

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Acoustics sensors
Acoustics research with automated data collection

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Wolf howls at the California Wolf Center
Seismic sensors
Interactive spectrum analysis of real-time seismic sensor data
(magnitude 1.6, near Banning, Riverside County, CA)

~59 miles

~73 miles

~34 miles

~75 miles

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Concepts
Multicast real-time sensor data distribution

HPWREN real-time sensor data multicast stream

- Sensor, e.g., meteorological station
- Sensor, e.g., meteorological station
- Sensor, e.g., 10 Hz sonic anemometer
- Sensor, e.g., radiation or seismic
- Site-local processor

- "sensors" data server and web interface
- Data analysis and display
- Data analysis and display
- Data analysis and display
Ramona CDF camera collaborations

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Planned VoIP prototype (e.g., for ICPs)

HPWREN backbone

Centralized phone line access

analog POTS line #1 → FXO #1
analog POTS line #2 → FXO #2
analog POTS line #3 → FXO #3
analog POTS line #4 → FXO #4

e.g., ICP site

FXS Phone #1
FXS Phone #2
FXS Phone #3
FXS Phone #4
Post-incident research concept
Potential incident management scenario concept

Real-time sensor telemetry (video, high resolution stills, ...)

Perimeter weather station

Incident area

Perimeter weather station

Perimeter weather station

operations center

command post

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OV-10 camera concept

high performance wireless research and education network
http://hpwren.ucsd.edu
Annual HPWREN Users Workshop
2004 HPWREN Annual Users Meeting

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Strategies
Backbone focus
Web pages

• main site: http://hpwren.ucsd.edu/
• cameras: http://hpwren.ucsd.edu/cameras
• sensors: http://hpwren.ucsd.edu/Sensors
• statistics: http://stat.hpwren.ucsd.edu/
• various photos: http://hpwren.ucsd.edu/Photos