Avionic Systems Division
NASA Johnson Space Center, Houston, Texas

CCSDS Wireless Working Group
Spring 2010 Face-to-Face
JSC Wireless Sensor Network Update

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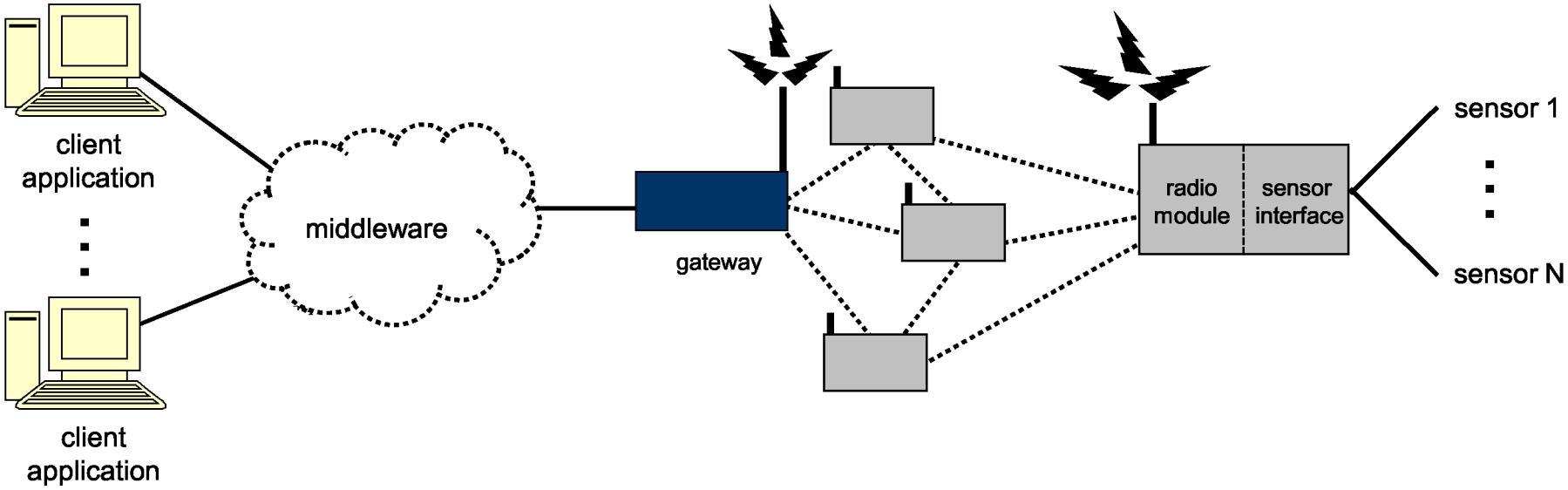
May 3 – May 5, 2010

Overview

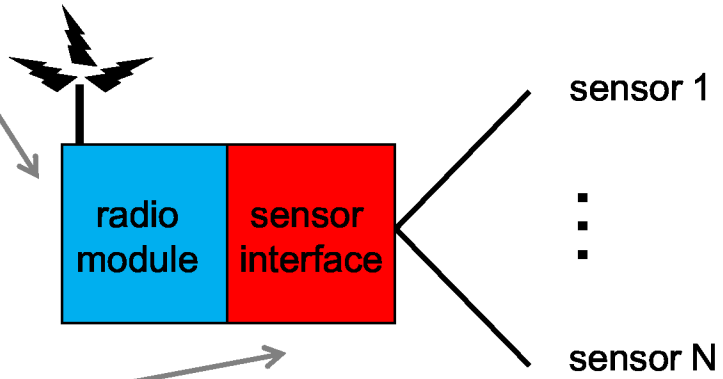
- End-to-end WSN model under consideration
- Standards-based WSN philosophy
- Proposed developmental WSN architecture
- Coexistence tests (Zigbee, 802.11)
- Habitat Demonstration Unit infusion
- Bionet monitoring application development
- JSC node v.2 and ISA100.11a migration
- Ongoing standards evaluation work

General WSN Model



Vision for Standardized WSN Node

- **Standards-based radio module:**
  - Common hardware for all applications
  - Needs certification **only once**
  - "plug and play" into existing network of sensors



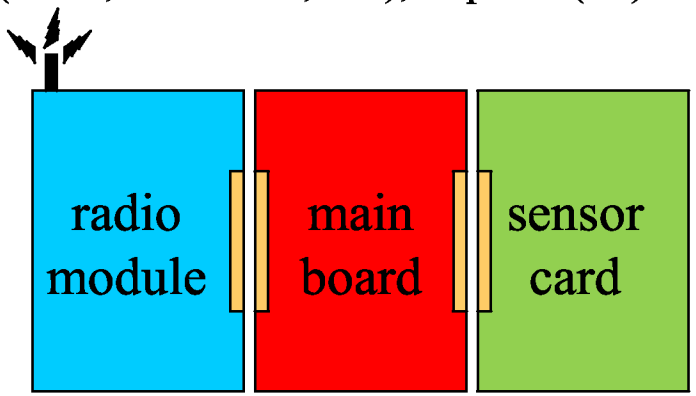
- **Application-specific sensor package:**
  - plug-in "daughter card" with all sensors, data acquisition and processing hardware
  - treats radio module as modem
  - can be swapped out to re-purpose existing hardware for new applications

NO NEED to reinvent networking

JSC Sensor Node Architecture

Sensor nodes composed of three basic components…

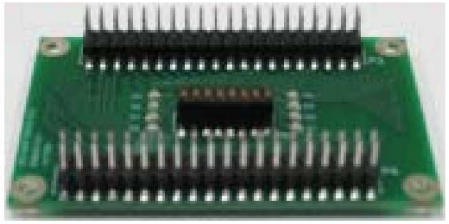
- **radio module:**
  - – COTS radio module implementing standardized WSN protocol; treated as WSN "modem" by main board
- **main board:**
  - – contains application processor (TI MSP430 microcontroller), memory, power supply; responsible for sensor data acquisition, pre-processing, and task scheduling; re-used in every application with growing library of embedded C code
- **sensor card:**
  - – contains application-specific sensors, data conditioning hardware, and any advanced hardware not built into main board (DSPs, faster A/D, etc.); requires (re-) development for each application



JSC WSN Node v.1

- **EV2/EV4–produced WSN node:**
  - DUST/RFM radio module with WirelessHART-variant protocol
  - TI MSP430 application processor
  - MicroSD card slot
  - separate power board (DC, AA)
  - 18 made so far, 20 more being assembled
- **Sensor cards:**

environmental
(light, 3-axis accel., temp.)

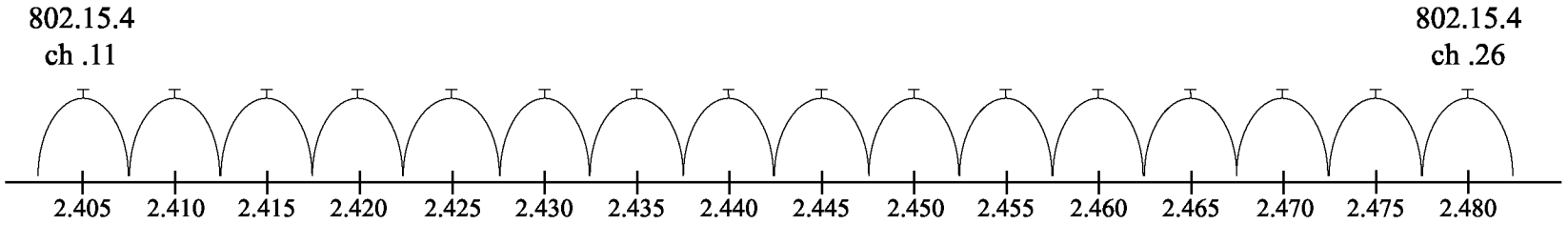


prototype/debug

(in assembly)

HDU:
(10-channel 4-20 mA)

802.15.4, 2.4 GHz Operating Frequencies

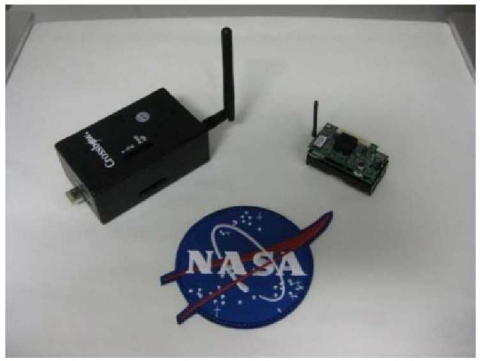


Throughput Tests

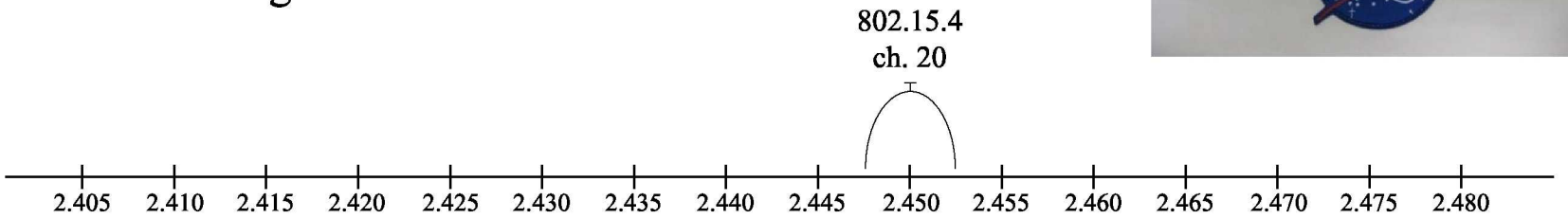
- Dust/WirelessHART protocol
- 5-node mesh network
- 80B counter packets
- sealed in JSC Habitat Wireless Testbed

	5 s/packet/node	10 s/packet/node	20 s/packet/node
12 h.	98.04%	99.30%	99.65%
24 h.		99.56%	
48 h.		99.53%	

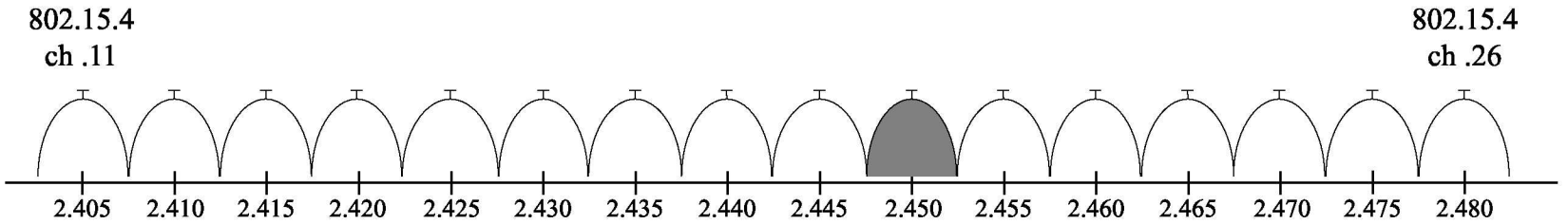
WirelessHART/Zigbee Coexistence



Crossbow/Zigbee channel:



Dust/WHART channels:

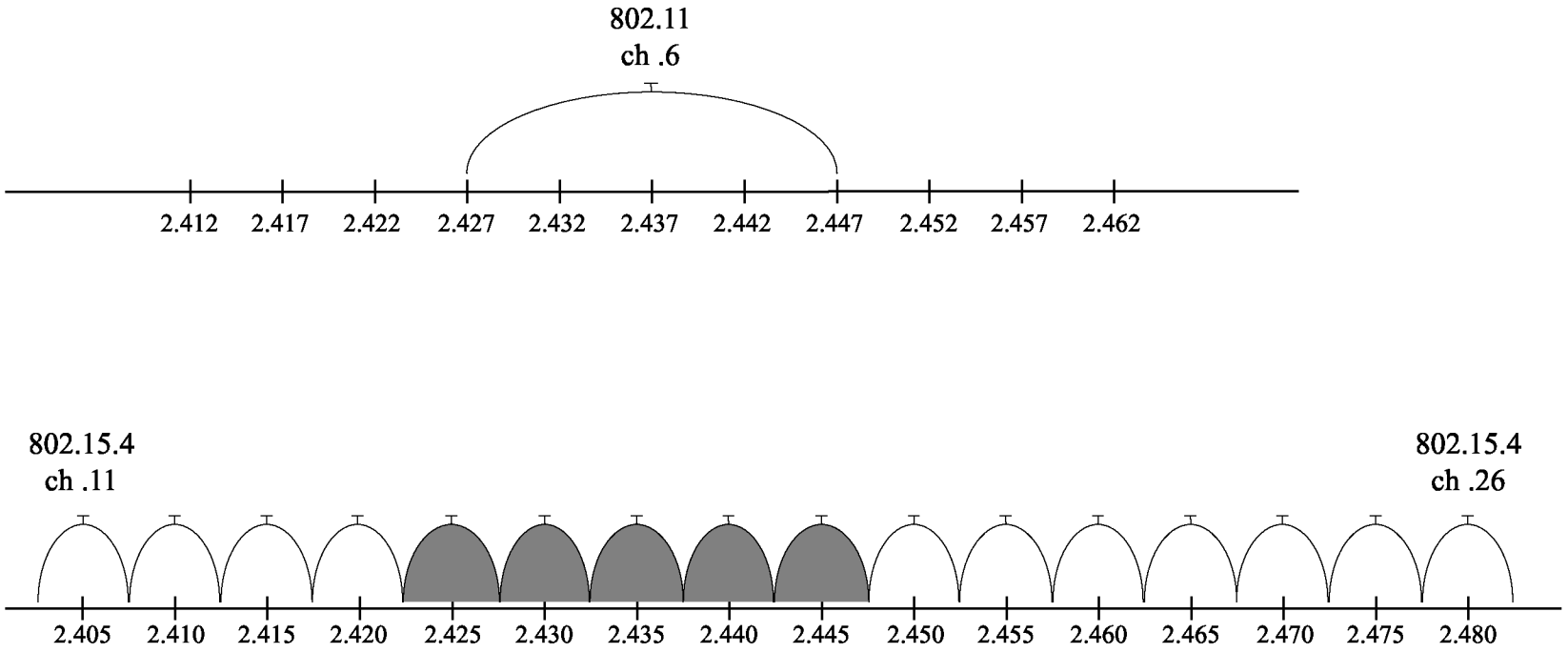


WirelessHART/Zigbee Coexistence Test Results

- 5 Crossbow nodes configured in star topology with 802.15.4 PHY and MAC (CSMA-CA); 5 Dust nodes
- two classes of packets sent: data (light, temp, humidity, 3-axis accel.), status
- data collected over 12 hrs.

	Crossbow/ZigBee	Dust/WHART
rate	2 packets/5s/node	1 packet/10s/node
throughput	99.96%	99.31%

WirelessHART/802.11 Coexistence



WirelessHART/802.11 Coexistence Test Results

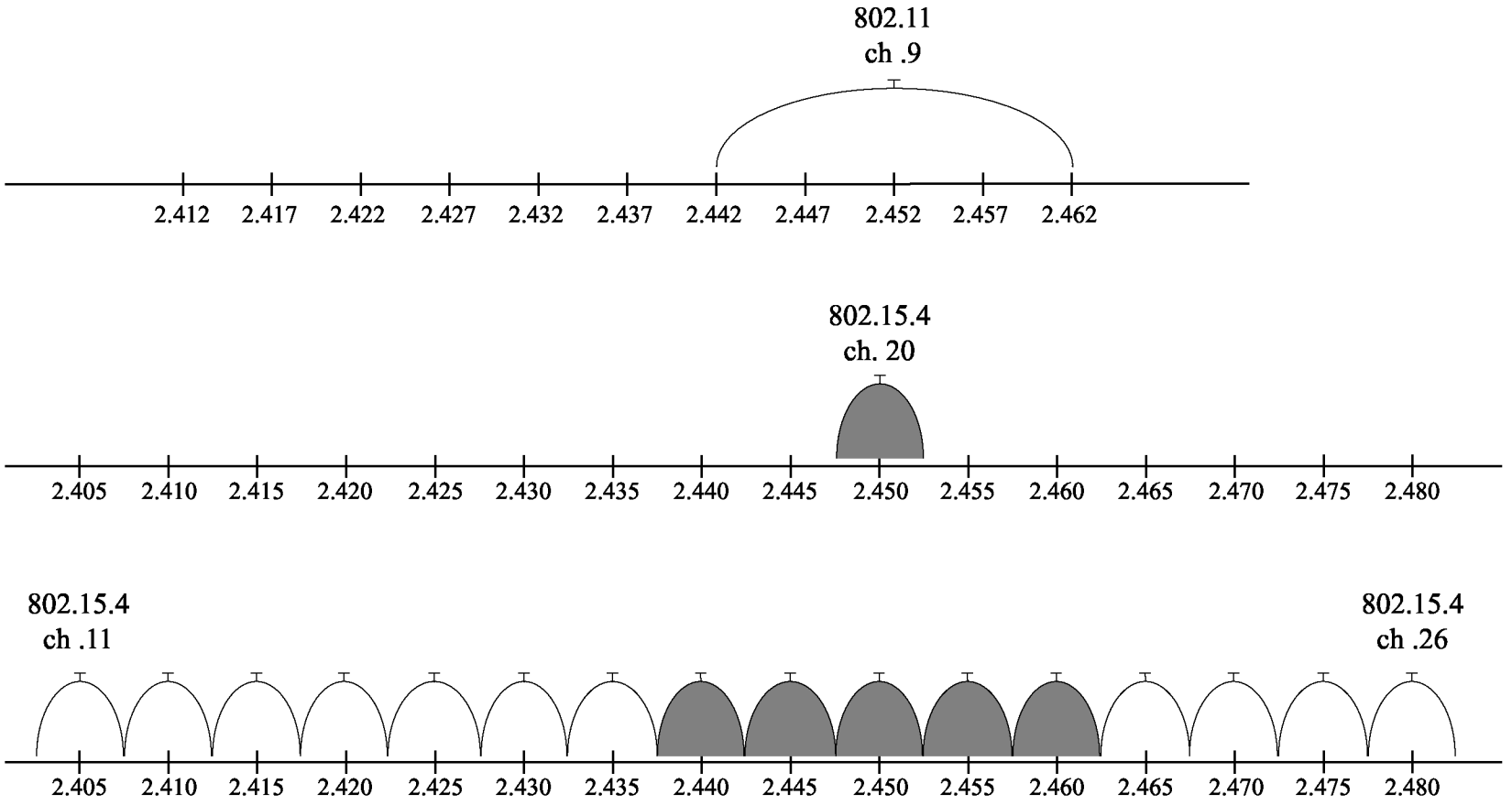
- 5 dust nodes, 1 laptop (802.11g)
- data collected over 12 hrs.

	802.11 g	Dust/WHART
rate	**~ 10.28 Mb/s [1]**	**1 packet (80B)/10s/node**
throughput	**TCP/IP**	**83.93% [2]**

[1] iperf TCP/IP flow, average over 12h.

[2] 16.07% of packets not delivered, but 15.53% of packets never sent per queuing rules

WirelessHART/Zigbee/802.11 Coexistence



WirelessHART/Zigbee/802.11 Coexistence Test Results

- 4 Dust nodes, 6 Crossbow nodes, 1 laptop (802.11g)
- data collected over 12 hrs.

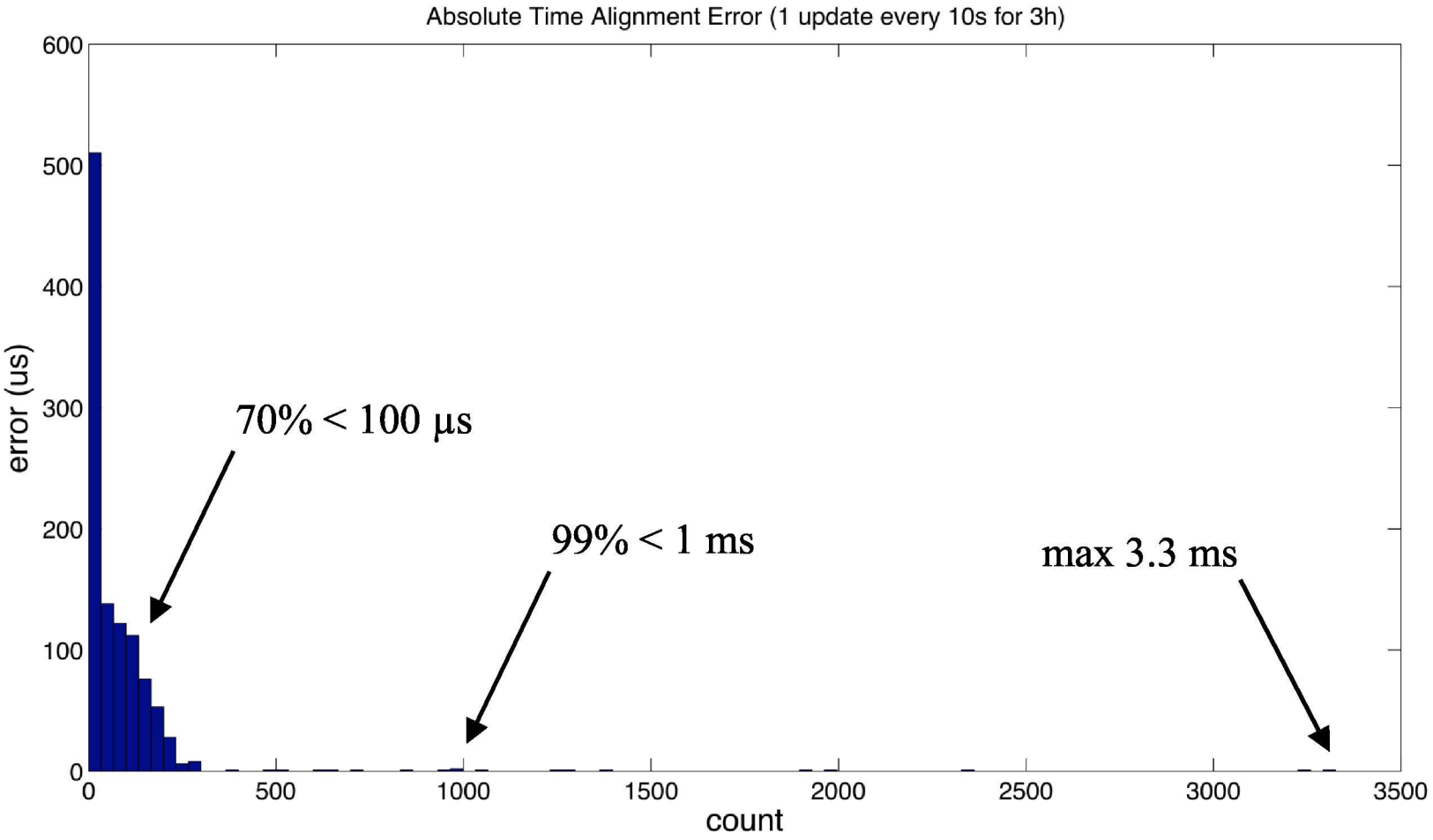
	802.11 g	Crossbow/ZigBee	Dust/WHART
rate	**~ 14.61 Mb/s [1]**	**2 packets /5s/node**	**1 packet (80B)/10s/node**
throughput	**TCP/IP**	**7.96% [2]**	**96.92% [3]**

[1] iperf TCP/IP flow to laptop, average over 12h.

[2] no reports from Crossbow for last ~2 hrs; throughput prior assumed to be representative

[3] 3.08% of packets not delivered, but 2.51% of packets never sent per queuing rules

Timing Test Results (Dust / WirelessHART)



Habitat Demonstration Unit (HDU)

HDU Participating in DesertRATS 2010 Exercises in August:

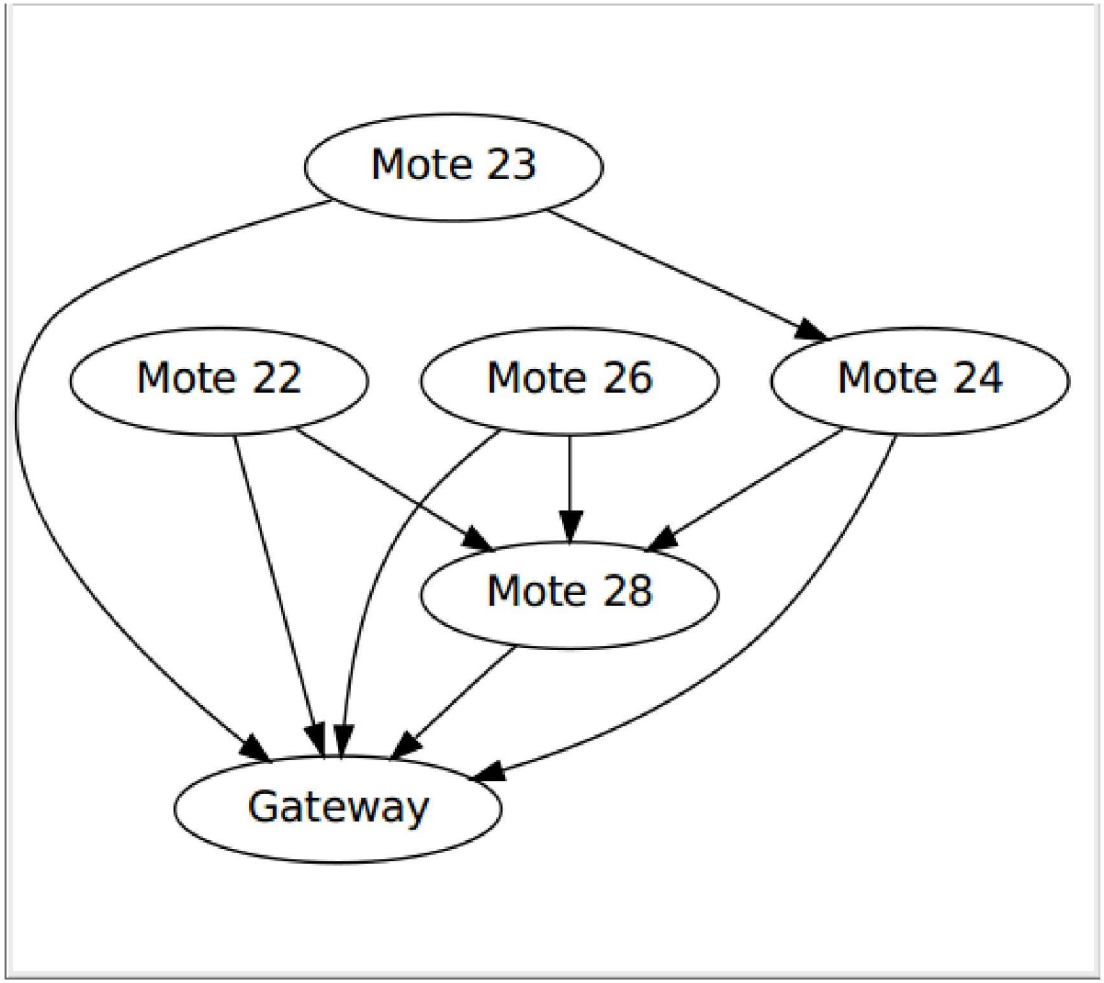
- 11 JSC Dust/WHART nodes providing wireless instrumentation
- Up to 10 channels of data gathered per node
  - temperature
  - humidity
  - differential pressure
- Requires coexistence with multiple wireless systems in an operational environment:
  - 802.11g
  - Tropos (extended-range .11n)

WirelessHART/Tropos Coexistence Test Results

- 5 Dust/WirelessHART nodes
- data collected over 1 hr.

	Tropos	Dust/WHART
rate	live video	1 packet (80B) /20s/node
throughput	n/a	96.67%

Bionet Network Health Monitoring Application



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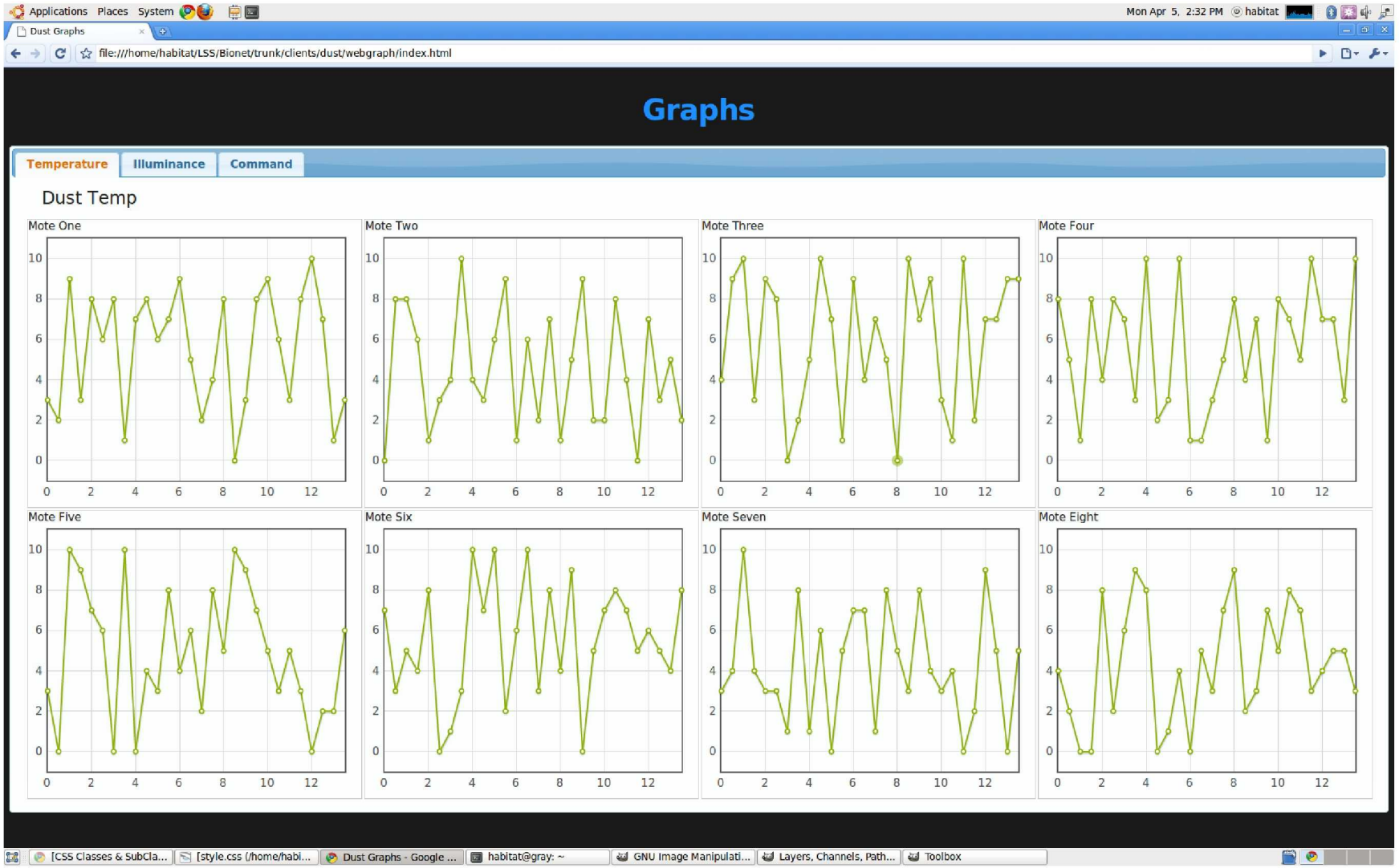
Bionet Environmental Board Monitoring Application



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Bionet Environmental Board Monitoring Application

Applications Places System — Mon Apr 5, 2:33 PM — habitat

Dust Graphs

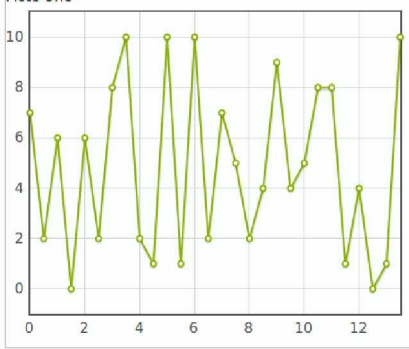
file:///home/habitat/LSS/Bionet/trunk/clients/dust/webgraph/index.html

Graphs

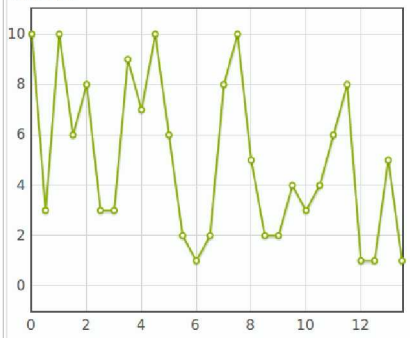
Temperature | Illuminance | Command

Lux

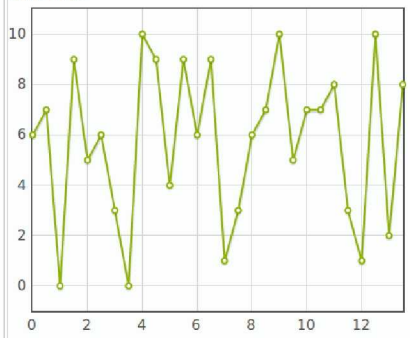
Mote One



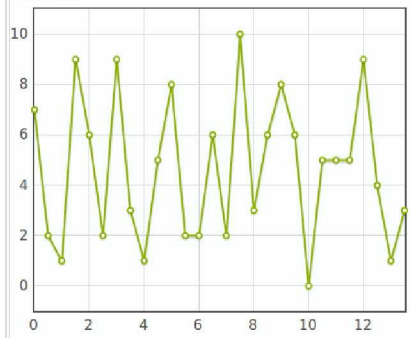
Mote Two



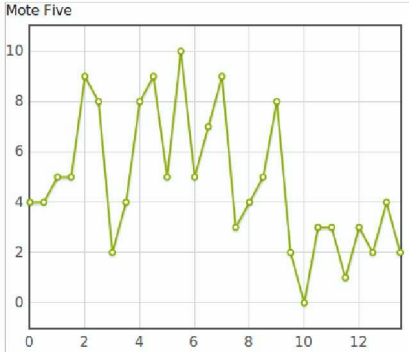
Mote Three



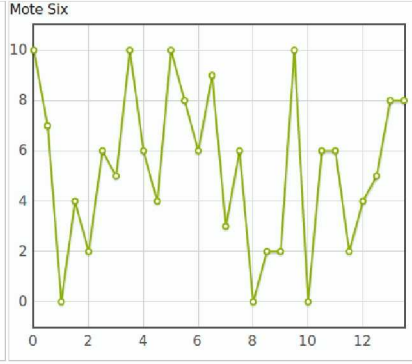
Mote Four



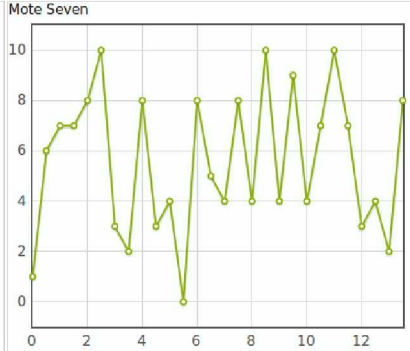
Mote Five



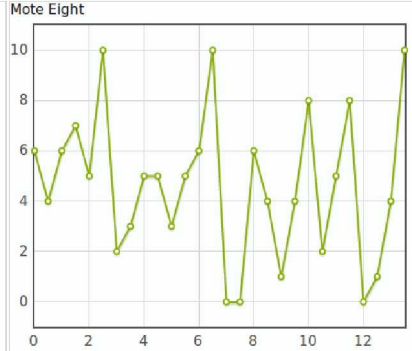
Mote Six



Mote Seven



Mote Eight



[CSS Classes & SubCla... | [style.css (/home/habi... | Dust Graphs - Google ... | habitat@gray: ~ | temp.png-2.0 (RGB, 1 l... | Layers, Channels, Path... | Toolbox

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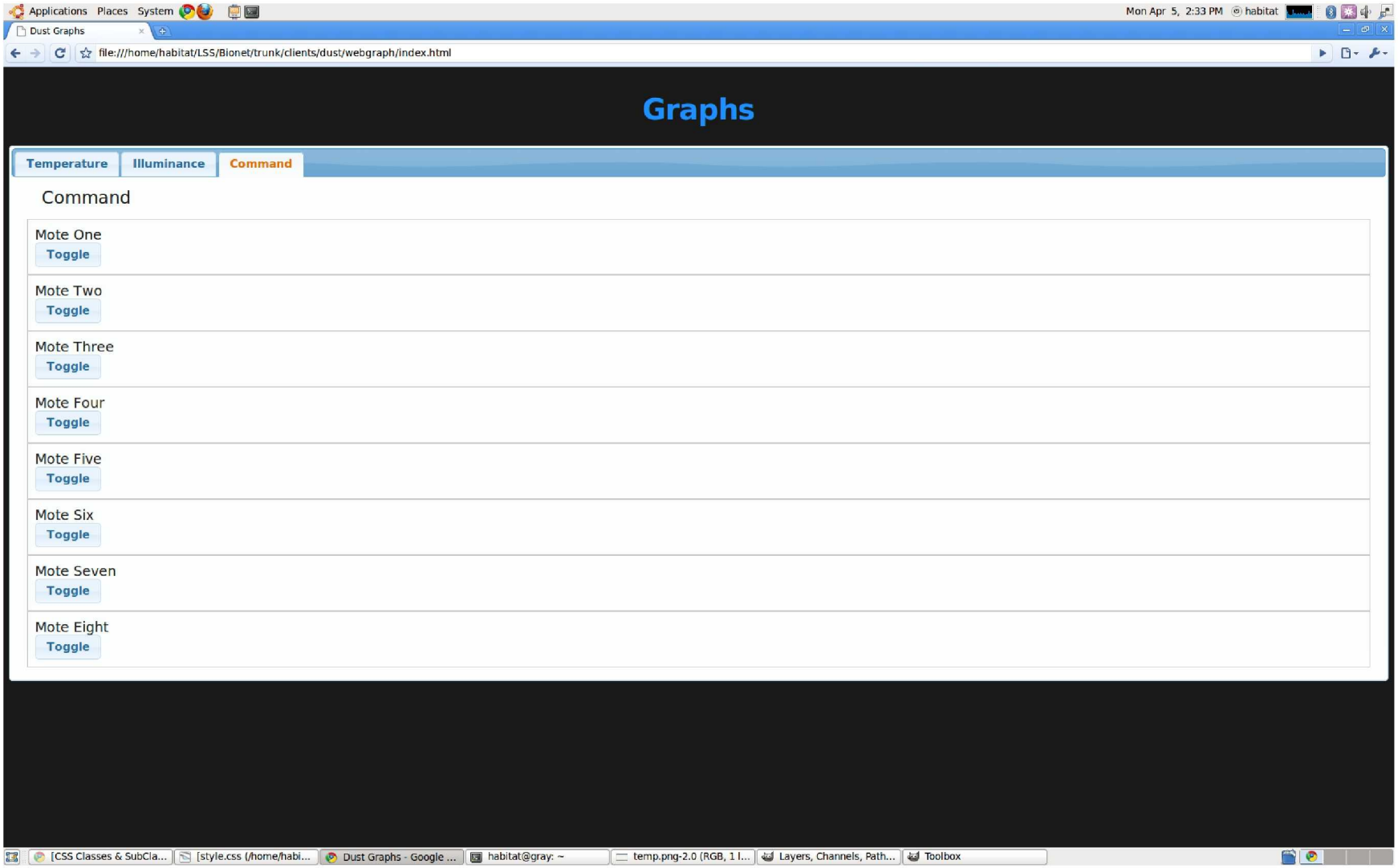
Bionet Environmental Board Monitoring Application



JSC WSN Node v.2: ISA100.11a

Beginning work on ISA100.11a-enabled version of JSC WSN node:

- Integrating development kit hardware from Nivis with v.1 JSC WSN node for early validation
  - using current hardware (w/o Dust module) to validate Nivis implementation
  - gaining familiarity with capabilities of Nivis API's
- Planning development of 2nd-generation node:
  - attending Nivis integration kit workshop (April 2010)
  - allocating funds for hardware purchases, software development
  - folding lessons learned from v.1 node into v.2 node hardware design
- Studying ISA100.11a protocol in greater depth
  - mapping .11a process control language to more generic services, QoS levels

Publications, Talks

- **R. Wagner, "Standards-Based Wireless Sensor Networking Protocols for Spaceflight Applications", IEEE Aerospace Conference, March, 2010, Big Sky, MT.**

- **JSC Innovation Day 2010, April 28**

WSN Standards Forward Work

JSC lunar habitat mockup provides representative environment for WSN testing. Issues to continue investigating include:

- RF issues
  - Data delivery reliability – resistance to multi-path, interference, noise
  - Data throughput rate
  - Interoperability – assess impacts on 2.4 GHz 802.11 WLAN
- Power issues
  - Radio/networking component
    - Low power, full mesh networking
  - Sensing/processing component
    - Scheduled sensing
    - Event-driven sensing
- Application issues
  - Feasibility of sensing transient events
  - Usefulness of MAC-derived application time synchronization
- Protocol issues:
  - extending past ISA100.11a to future protocols
  - incorporating DTN