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
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

<table>
<thead>
<tr>
<th></th>
<th>5 s/packet/node</th>
<th>10 s/packet/node</th>
<th>20 s/packet/node</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 h.</td>
<td>98.04%</td>
<td>99.30%</td>
<td>99.65%</td>
</tr>
<tr>
<td>24 h.</td>
<td></td>
<td>99.56%</td>
<td></td>
</tr>
<tr>
<td>48 h.</td>
<td></td>
<td>99.53%</td>
<td></td>
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</tbody>
</table>
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.

<table>
<thead>
<tr>
<th></th>
<th>Crossbow/ZigBee</th>
<th>Dust/WHART</th>
</tr>
</thead>
<tbody>
<tr>
<td>rate</td>
<td>2 packets/5s/node</td>
<td>1 packet/10s/node</td>
</tr>
<tr>
<td>throughput</td>
<td>99.96%</td>
<td>99.31%</td>
</tr>
</tbody>
</table>
WirelessHART/802.11 Coexistence

802.11
ch .6

802.15.4
ch .11

802.15.4
ch .26
WirelessHART/802.11 Coexistence Test Results

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

<table>
<thead>
<tr>
<th></th>
<th>802.11 g</th>
<th>Dust/WHART</th>
</tr>
</thead>
<tbody>
<tr>
<td>rate</td>
<td>~10.28 Mb/s (^1)</td>
<td>1 packet (80B)/10s/node</td>
</tr>
<tr>
<td>throughput</td>
<td>TCP/IP</td>
<td>83.93% (^2)</td>
</tr>
</tbody>
</table>

\(^1\) 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

802.11
ch .9

802.15.4
ch. 20

802.15.4
ch .11

802.15.4
ch .26
Wireless HART/Zigbee/802.11 Coexistence Test Results

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

<table>
<thead>
<tr>
<th></th>
<th>802.11 g</th>
<th>Crossbow/ZigBee</th>
<th>Dust/WHART</th>
</tr>
</thead>
<tbody>
<tr>
<td>rate</td>
<td>~14.61 Mb/s (^1)</td>
<td>2 packets /5s/node</td>
<td>1 packet (80B)/10s/node</td>
</tr>
<tr>
<td>throughput</td>
<td>TCP/IP</td>
<td>7.96% (^2)</td>
<td>96.92% (^3)</td>
</tr>
</tbody>
</table>

\(^1\) 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)

Absolute Time Alignment Error (1 update every 10s for 3h)

- 70% < 100 µs
- 99% < 1 ms
- max 3.3 ms
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.

<table>
<thead>
<tr>
<th></th>
<th>Tropos</th>
<th>Dust/WHART</th>
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<tbody>
<tr>
<td>rate</td>
<td>live video</td>
<td>1 packet (80B) /20s/node</td>
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<tr>
<td>throughput</td>
<td>n/a</td>
<td>96.67%</td>
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Bionet Network Health Monitoring Application
Bionet Environmental Board Monitoring Application

Graphs

Temperature  Illuminance  Command

Lux

Mote One  Mote Two  Mote Three  Mote Four

Mote Five  Mote Six  Mote Seven  Mote Eight
### Graphs

<table>
<thead>
<tr>
<th>Command</th>
<th>Temperature</th>
<th>Illuminance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mote One</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Toggle</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Mote Two</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Toggle</td>
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<tr>
<td>Mote Three</td>
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<tr>
<td>Toggle</td>
<td>-</td>
<td>-</td>
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<td>Mote Four</td>
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<tr>
<td>Toggle</td>
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<td>Mote Five</td>
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<td>Mote Six</td>
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<td>Toggle</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mote Eight</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Toggle</td>
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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


- JSC Innovation Day 2010, April 28
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

4/28/2010