Spectrum Sensing with USRP and GNURadio

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Mobile Computing

Topics Discussed

• 1. Motivation: Software Defined Radio and Cognitive Radio
• 2. Experimental Setup: Spectrum Sensing on CSU Wireless Network (802.11a/g, 2.4 GHz)
• 3. Results
• 4. Implications for ‘Smart Grid’
1. Intro: “Cognitive Radio”

- “Intelligent” radios that are adapted to sense spectrum holes and transmit data at those under-utilized frequencies
- Reconfigurability: using software-defined radio, the ‘cognitive radio’ can change its operating parameters: transmit-power, carrier frequency and modulation strategy
- First Task: sense spectrum usage, availability

1. Intro: Unlicensed Radio Spectrum

- Unlicensed spectrum:
  - 902 Mhz – 928 Mhz cordless phones, baby monitors, Wireless LANS
  - 2.4 Ghz – 2.4835 Ghz 802.11, Bluetooth, Microwave oven
  - 5.725 Ghz – 5.785 Ghz unused
2. Experiment: CSU Wireless System Coverage

2.4 GHz band sensing in different CSU buildings (coverage areas), different floors, positions in buildings

2. Gnu Radio as a Spectrum Sensing Device

- Usrp_spectrum_sense.py use with RFX2400 daughterboard to sense 2.4 GHz frequency range coverage
- "Wireless Device B" = USRP + RFX2400;
- "Wireless Device A" = CSU Transmission System
2. 802.11b coverage in a building

2. 802.11 Spectrum Channels

<table>
<thead>
<tr>
<th>Channel</th>
<th>Lower Frequency</th>
<th>Central Frequency</th>
<th>Upper Frequency</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>2.401</td>
<td>2.412</td>
<td>2.423</td>
</tr>
<tr>
<td>2</td>
<td>2.406</td>
<td>2.417</td>
<td>2.428</td>
</tr>
<tr>
<td>3</td>
<td>2.411</td>
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<tr>
<td>4</td>
<td>2.416</td>
<td>2.427</td>
<td>2.438</td>
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<tr>
<td>5</td>
<td>2.421</td>
<td>2.432</td>
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<td>2.426</td>
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<td>2.431</td>
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<td>2.441</td>
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<tr>
<td>10</td>
<td>2.446</td>
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<tr>
<td>11</td>
<td>2.451</td>
<td>2.462</td>
<td>2.473</td>
</tr>
</tbody>
</table>
3. Results: Spectrum Sense Points

- (test on Microwave oven at home)
- Library, Main Classroom (computer center), Stillwell Hall, Rec Center
- Test for channel usage at each of 11 subchannels of 2.4 GHz band (2.412 GHz – 2.462 GHz)
- Use usrp_spectrum_sense.py function

3. Test: Microwave Oven (test)
3. Test Microwave Oven

![Microwave Oven test graph]

3. MC – Computer Center

![Main Classroom 3rd Floor graph]
3. Library 4th Floor

![Graph showing frequency range and strength of signal for Library 4th Floor.]

3. Rec Center

![Graph showing frequency range and strength of signal for Rec Center 3rd Floor.]

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**Strength of Signal vs. Frequency Range (GHz)**

- **Library 4th Floor**
  - Frequency range: 2.41 to 2.47 GHz
  - Strength of signal peaks at different points in the frequency range.

- **Rec Center 3rd Floor**
  - Frequency range: 2.41 to 2.47 GHz
  - Strength of signal peaks sharply at one frequency point, with minimal variation elsewhere.

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This presentation highlights the signal strength variations across different frequencies, emphasizing the unique characteristics of signal intensity at specific floors within the library and rec center environments.
3. Stillwell Hall 3rd Floor

3. SH 1st Floor
3. SH Basement

3. Results Summary

- Distinct Channels observed at various locations
- Channel Utilization over time appears constant
4. Application / Extension: Smart Grid

- A “Smart grid system” is any **two-way communications system** and associated equipment and software, including equipment installed on the electrical delivery system and on the premises of retail end-use customers, that utilizes the electrical delivery system to **provide real-time monitoring, diagnostic, and control information**...
4. Smart Grid Routing Protocols

- Connection of multiple vendor devices, esp. at home metering level ✉️ Need for communication protocol independent of lower layers
- C12.22 application layer protocol for sessionless communication, transfer of table data from meters
- 802.11 (wireless) variants: Bluetooth SIG, WiFi
- 802.15 (Wireless Personal Area Networks or WPAN): Z-Wave, 6LoWPAN, **Zigbee**

4. Zigbee Routing Protocols

- Zigbee for low cost ($1 / transceiver, $3 with processor and memory; vs. $3 for Bluetooth), low power, useful for wireless control/monitoring, ex. home/energy automation
- Routing protocol – AODV typical (battery or not; also ‘cluster tree routing’ if battery operated)
- “Multi Protocol Label Switching” (MPLS) for WAN, assign packets to Equivalence classes when enter network, and thus store all routing info in header to be read.
4. MLPS vs. AODV

- Smart Grid Conference, CMU March, 2009
- Coalton Bennett: Review of Communication Technologies for Smart Grid Automatic Metering Systems (Cornell University)

Questions?

< insert funny picture here>