WiZi-Cloud: Application-transparent Dual ZigBee-WiFi Radios for Low Power Internet Access

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Quick Facts

- Mobile devices rapidly evolves in the past few years
- Ever increasing mobile Internet traffic
- Battery bottleneck
Energy Usage Breakdown: Active & Idle

Radios active, screen on:
- WiFi: 1648.2mW (44.5%)
- GSM: 1170.7mW (31.6%)
- BT: 340.3mW (9.2%)
- Screen: 378.4mW (10.2%)
- OS: 164mW (4.4%)

Radios idle, screen off:
- WiFi (PSM): 29.4mW (50%)
- BT: 7.3mW (12%)
- GSM: 19mW (32%)
- OS: 3.4mW (6%)
Reduce Network Energy Usage

- Optimize the network interfaces, WiFi, GSM, BT
  - power efficient protocol design
  - hardware design
- Alternative low power radio interface
  - Keep energy consuming interface off as long as possible, wake up only when needed
  - Low power alternative radio for traffic or signaling
**WiZi-Cloud**

- Dual ZigBee-WiFi radios
- ZigBee has unique features
- Characteristics of energy consumption
- Feasibility study
- Complete design and prototype:
  - Main stream apps well supported
  - 300% energy efficient
  - Good coverage
ZigBee Overview

- Ultra low power
- Low data rate (250Kbps)
What can 250Kbps do?
What can 250Kbps do?

<table>
<thead>
<tr>
<th>BW Usage (Kbps)</th>
<th>Email</th>
<th>Web Browser</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>80</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

ZigBee is eligible to carry traffic for many heavily used mobile network applications.
Outline

- WiZi-Cloud System Design
- Prototype & Observations
- Evaluation
- Conclusion
WiZi-Cloud System Design

1. Intra-device interface handover

![Diagram showing ZigBee and WiFi connections with a beacon.]
WiZi-Cloud System Design

2 inter-AP handover
WiZi-Cloud System Design

3 Signaling on ZigBee
Software Architecture

- Leverage existing HW/SW
- Seamless intra-device/inter-AP handover
- Flexibility for handover policy design
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Client Prototype

- Android G1, with modified Linux kernel, UART support
- User space WiZi stack
- ZigBee USB dongle
AP Prototype

- OpenWrt based (Linux) AP firmware
- On-board serial port, USB port
Observations

- Throughput vs. energy efficiency
- Work with slow data links
- Flow control on ZigBee-Host link is critical
  - Limited MCU and storage capability on ZigBee
  - ZigBee RF link fluctuates
  - Flow control overhead: trade off throughput for reliability
  - Pipeline!!!
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• Evaluation
  ▫ Energy efficiency
  ▫ Throughput
  ▫ Coverage
• Conclusion
Evaluation 1. Energy Efficiency

- Evaluate with real mobile applications
- Test same app with ZigBee & WiFi base performance

<table>
<thead>
<tr>
<th>Sample App.</th>
<th>Latency Sensitivity</th>
<th>Traffic Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>VoIP, stream audio</td>
<td>high</td>
<td>moderate</td>
</tr>
<tr>
<td>Email</td>
<td>moderate</td>
<td>moderate</td>
</tr>
<tr>
<td>Web</td>
<td>low</td>
<td>high</td>
</tr>
</tbody>
</table>
Evaluation 1. Energy Efficiency

- **VoIP & Stream Radio**
  - High delay sensitivity
  - Moderate traffic load
- **Active mode:** reduce energy usage by 50%

![Graph showing current consumption for different scenarios]
Evaluation 1. Energy Efficiency

- VoIP standby time: extended by 3 times!
Evaluation 1. Energy Efficiency

- Web browsing: low delay sensitivity, high traffic load
  - Browse Google Reader on G1
  - Download the top 14 Engadget news feeds, with text and images

<table>
<thead>
<tr>
<th></th>
<th>Avg Current (mA)</th>
<th>Loading time (sec)</th>
<th>Energy (Joule)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WiZi</td>
<td>199.6</td>
<td>239.8</td>
<td>196.2</td>
</tr>
<tr>
<td>WiFi</td>
<td>297.4</td>
<td>93.4</td>
<td>112.9</td>
</tr>
</tbody>
</table>

WiFi preferred for large traffic volume
Evaluation 2. Throughput

- iperf 30 sec test, averaged over 10 runs

Amortize the overhead along the data link

TCP fragments
Overhead vs. potential waste of bw.
Evaluation 3. Coverage

- 3 floor college building
- Broadcast test to measure Packet Loss Rate
- WiFi Ch6 24dBm
- ZigBee Ch26 4dBm / 27dBm

Case for signaling
Evaluation 3. Coverage
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Conclusion

- Energy consuming WiFi is a critical issue for mobile devices
- Designed and implemented WiZi-Cloud prototype (SW/HW)
- Evaluation with real mobile applications
- Great improvement for proper applications
Thanks!

http://www.ccs.neu.edu/home/noubir/wizi