WF102: Choosing a Wireless Solution

John Schwartz
Technology Strategist
Agenda

• Design questions
• Chip vs. Module
• Module integration
• Protocol options
• Questions
Design Questions

• How much range do you need?
• What maximum required bandwidth?
• Where will the solution be deployed and under what conditions?
• Will the design be battery powered?
• How often does data need to be transmitted?
• What parameters are flexible and open to design tradeoffs?
Design Questions

• How much range do you need?
  – Frequency considerations
  – Environmental considerations
  – Output power in Europe ~10dBm (10mW)
  – For 0 dBm – 30m indoor, 100m outdoor
  – For 10dBm w/ LNA – 60m indoor, 1km outdoor

• What maximum required bandwidth?
  – 250 kbps over the air, but 125 kbps $\textit{max}$
  – 38.8 kbps more typical for PtP and PtMP networks
  – Slower for mesh technologies
Importance of Frequency Selection

• Where will the solution be deployed and under what conditions?
• Geographic deployment
  – Worldwide vs. Regional
  – Cost considerations
• RF performance
  – Range
  – RF penetration
  – Antenna considerations
License-Free Bands

- 2.4 GHz
- 433 MHz
- 868 MHz
- 5.7 GHz
- 315 MHz
- 420 MHz
- 900 MHz
- 5.7 GHz
- 915 MHz
- 900 MHz
Regulatory Bodies

- FCC (United States)
- IC (Canada)
- ETSI (Europe, some APAC)
- C-Tick (Australia)
- Telec (Japan)
- Anatel (Brazil)
Design Questions

• How often is data transmitted?
  – Affects sleep mode and battery life
  – Determining factor in whether or not mesh can be used
Design Questions

• Battery life calculation example

<table>
<thead>
<tr>
<th>Current in TX (mA)</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current in RX (mA)</td>
<td>45</td>
</tr>
<tr>
<td>Sleep current (mA)</td>
<td>0.035</td>
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<tr>
<td>Time interval (min)</td>
<td>60</td>
</tr>
<tr>
<td>time in TX (ms)</td>
<td>3000</td>
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<tr>
<td>Time in RX (ms)</td>
<td>2000</td>
</tr>
<tr>
<td>% Duty Cycle in TX</td>
<td>0.08%</td>
</tr>
<tr>
<td>% Duty Cycle in RX</td>
<td>0.06%</td>
</tr>
<tr>
<td>% Duty Cycle in sleep</td>
<td>99.86%</td>
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<tr>
<td>Avg current draw</td>
<td>0.093285</td>
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</table>

<table>
<thead>
<tr>
<th>Battery Capacities</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA Alkaline mAh</td>
</tr>
<tr>
<td>AA NiMH</td>
</tr>
<tr>
<td>Lithium</td>
</tr>
<tr>
<td>D Cell Alkaline (typ)</td>
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</table>

<table>
<thead>
<tr>
<th>Alkaline AA</th>
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</thead>
<tbody>
<tr>
<td>Batterylife (hours)</td>
</tr>
<tr>
<td>days</td>
</tr>
<tr>
<td>years</td>
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<th>Lithium</th>
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<td>Batterylife (hours)</td>
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<th>Alkaline D</th>
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<tbody>
<tr>
<td>Batterylife (hours)</td>
</tr>
<tr>
<td>days</td>
</tr>
<tr>
<td>years</td>
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</tbody>
</table>
Design Questions

- What parameters are flexible and open to design tradeoffs?
  - Battery Life vs. Data Rate
  - Battery Life vs. Data Frequency
  - To Mesh or Not to Mesh
  - Placement vs. Range
  - Frequency vs. Homogenous SKUs
Design Questions

• General Considerations
  – Power supply (voltage, current)
  – Battery types
  – Antenna placement/enclosures
  – Data format (transparent/API)
  – Data backhaul or local network?
  – Network topology
RF Development

Components

• Time (development time – opportunity costs)
• Hardware and expertise
  - Development hardware (spectrum analyzer, etc.)
  - RF engineers, antenna design
• Test fixture design
• Certifications
RF Development Timeline & Expense Overview for a ZigBee solution

1. **Timeline Risks (22 - 32 weeks, assuming no major redesigns and all certs pass on first round)**
   a. Hardware development (12 – 19 weeks total)
   b. Software development (22 – 32 weeks total)
   c. Test fixture development (12 – 20 weeks)

2. **Development Expense ($349,500 - $572,500, assuming no major redesigns, all certs pass on first round and excludes opportunity cost)**
   a. Tools – $99,500 - $225,500 total
      i. Compiler & tools – $2,500
      ii. Spectrum analyzer – $45,000 - $90,000 (could be leased)
      iii. Network analyzer – $45,000 - $90,000 (could be leased)
      iv. Testing software – $3,000 - $5,000
      v. SE/Certicom tools 7 licenses – $30,000 Annually
      vi. SE test harness – $4,000 - $8,000
   b. Engineering time – $126,000 – $191,000 total
      i. Hardware – $60,000 (12 wks @ $5K/wk) - $95,000 (19 wks @ 5K/wk)
      ii. Software – $66,000 (22 wks @ $3K/wk) - $96,000 (32 wks @ 3K/wk)
   c. Certification – $20,000
      i. Worldwide certifications $20,000 every two-to-three years (recertify as major components rev)
   d. Test Fixture – $104,000 - $136,000
      i. Hardware – $60,000 (12 wks @ $5K/wk) - $100,000 (20 wks @ $5K/wk)
      ii. Software – $24,000 (8 wks @ $3K/wk) - $36,000 (12 wks @ $3K/wk)

Assumptions:
1. Timeline assumes developers have equal RF experience as Digi RF engineers.
2. Timeline assumes developers have considerable ZigBee Smart Energy expertise.
3. Timeline assumes development is done in parallel by multiple assets (e.g. there are independent teams for Test Fixture Hardware, and Test Fixture Software).
4. Tool needs assume all fundamental RF Design & Test tools must be acquired/developed.
5. Engineering Time expenses assume cost for single engineer + overhead for given period.
6. No significant design challenges—a poorly designed board could add another 3 months in design time to pass FCC certification; getting calibration right between a thermostat product, a different load controller, and a smart meter could add another month. In our own experience,
Chip vs. Module - TTM

Development Cost and Time

$ in thousands

$0 $50 $100 $150 $200 $250 $300 $350 $400

1 2 3 4 5 6 7 8

Months

Blue line: Chip
Pink line: Module
Chip vs Module...cost

Cost of Development and Material

- Xbee Module
- Chip

$ in thousands vs Units

www.digi.com
Chips and Modules

• Chip Advantages
  - Size
  - Customization
  - It’s mine!
  - Cost (large volumes)

• Disadvantages
  - Certification
  - Chip & design re-spins

• Module Advantages
  - Ease of integration (time-to-market)
  - Certifications
  - One design may support multiple topologies
  - Managed hardware changes
  - Cost (other volumes)
Module Integration

• Typical hardware features and issues
  – 3.3V UART interface
  – Requires only
    • VCC, GND, DIN, DOUT
  – Component placement
  – Packaging
  – Antenna selection
Module Integration

• Antennas
  – Chip Antennas
    • Best mechanically
    • Lowest range
  – Wire Antenna
    • ¼ wave 1.8 dBi gain
    • Used w/ Plastic/fiberglass enclosures
  – RPSMA
    • Connects to external dipole
  – U.FL
Module Integration

Antennas
Module Integration

Antennas
Wireless Choices

ZigBee  Bluetooth  UWB
Cellular  Wi-Fi  6LoWPAN
## Wireless Standards Comparison

<table>
<thead>
<tr>
<th>Feature(s)</th>
<th>IEEE 802.11b</th>
<th>Bluetooth</th>
<th>ZigBee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Life</td>
<td>Hours</td>
<td>Days</td>
<td>Years</td>
</tr>
<tr>
<td>Complexity</td>
<td>Very complex</td>
<td>Complex</td>
<td>Simple</td>
</tr>
<tr>
<td>Nodes/Master</td>
<td>32</td>
<td>7</td>
<td>64000</td>
</tr>
<tr>
<td>Latency</td>
<td>Enumeration up to 3 seconds</td>
<td>Enumeration up to 10 seconds</td>
<td>Enumeration up to 30 milliseconds</td>
</tr>
<tr>
<td>Range</td>
<td>100m-1000m</td>
<td>10m</td>
<td>70m-1600m</td>
</tr>
<tr>
<td>Extendability</td>
<td>Roaming possible</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>RF Data Rate</td>
<td>11Mbps</td>
<td>1Mbps</td>
<td>250Kbps</td>
</tr>
<tr>
<td>Security</td>
<td>Authentication Service Set ID (SSID)</td>
<td>64-bit, 128-bit</td>
<td>128-bit AES and application layer user defined</td>
</tr>
</tbody>
</table>
ZigBee

- Low cost
- Low power
- Security-enabled
- Reliable
- Initial target markets were AMR, building automation, and industrial automation (M2M Comms)
- Digi is a member of the ZigBee Alliance
Wi-Fi (802.11)

- 2.4 GHz
- Most popular
  - 802.11b = 11 Mbps
  - 802.11g = 54 Mbps
    - backwards compatible with 802.11b
- Range – a few hundred feet (~100 m)
- Can be infrastructure standard
Cellular

- 3G / 2.5G
- Data rates – in the few hundred kbps range and below
- Costs, carrier fees
  - ~$.10-.50 per MB
  - ~$50-60 per month unlimited
Conclusion

• Ways to judge wireless options
  – Frequency
  – Range
  – Throughput
  – Costs
  – Interference
  – Power requirements
  – Features