System Architecture Challenges in the Home M2M Network

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M2M Background

• M2M Communications
  – Machine-to-Machine or Machine-to-Man

• The Machine usually includes a sensor or an actuator.
  – Health Care Applications
  – Smart Grid
  – Environmental, Industrial, and Home Monitoring and Automation
Agenda

• Home M2M Networking Roadmap
  – How is today’s home network different than the home network of 2020?

• Network Protocols in the home M2M Network
  – What protocols exist and what protocol enhancements are needed?

• The Converged M2M Home Gateway
  – What are the challenges in the system design of a centralized gateway?
The Home M2M Network

- ZigBee Network
- Wi-Fi Network
- Bluetooth Network
- Ethernet
- Wi-Fi Router
- ZigBee Gateway
- Modem
# M2M Network Protocols

<table>
<thead>
<tr>
<th></th>
<th>802.15.4 (ZigBee / 6LoWPAN)</th>
<th>Bluetooth Low Energy</th>
<th>Bluetooth</th>
<th>802.11 (Wi-Fi)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Max Data Rate</strong></td>
<td>250 kb/s</td>
<td>1 Mb/s</td>
<td>3 Mb/s (Enhanced)</td>
<td>22 Mb/s* (802.11g)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1 Mb/s (Basic)</td>
<td>144 Mb/s* (802.11n)</td>
</tr>
<tr>
<td><strong>Indoor Range</strong></td>
<td>10 m – 20 m (Extended via multi-hop routing)</td>
<td>5 to 15m</td>
<td>1 m, 10 m and 100 m classes</td>
<td>45 m (802.11g)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70 m (802.11n)</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td><strong>Battery Life</strong></td>
<td>Years</td>
<td>Years</td>
<td>Days</td>
<td>Hours</td>
</tr>
<tr>
<td><strong>Frequency Band</strong></td>
<td>2.4 GHz, 868 MHz, and 915MHz</td>
<td>2.4 GHz</td>
<td>2.4 GHz</td>
<td>2.4 GHz, 3.6 GHz, and 5 GHz</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Smart Appliances, Smart Meters, Lighting Control, Home Security</td>
<td>Health / Sports Monitors, Watches, Keyboard</td>
<td>Voice, Data Transfers, Keyboard, Game Control</td>
<td>Networking, Digital Audio, Voice, Digital Video</td>
</tr>
</tbody>
</table>

*At reduced indoor range*
• How is Home Network in 2020 different than that of 2010? Many “M2M” devices are already available.
  – Advancements in key enabling technologies will enable new devices and will make other devices more practical.
The Home M2M Network

• Key Enablers
  – Energy Harvesting
    • Vibration, Electromagnetic, Thermal, Solar
  – Energy Storage
    • Thin Film Batteries, Printed Batteries, and Super Capacitors.
  – Moore’s Law
    • Semiconductor power requirements have lowered to the point where we can power a device with energy harvesting or a thin film.
  – Low Power Network Protocols
M2M Network Protocols

• No single protocol will satisfy all applications.
• The home M2M network will need to support multiple physical links and protocol stacks.
• The high data rate ("fun stuff") has received much attention. (Wi-Fi, Bluetooth, Cellular)
• Low power protocols require special attention.
Low Power M2M Network Protocols

- IEEE 802.15.4
  - The defacto standard M2M Phy and MAC layer
  - 8 bit Microprocessor
  - Low Cost Transceiver
  - Less than 4 Kbytes of SRAM
  - Defines peer-to-peer communications
  - Flexible! The stack on top of 802.15.4 can be tailored to the application
  - Data Rates up to 250 kbps
  - 10m – 20m Transmission range
Low Power M2M Network Protocols

• ZigBee
  – Runs on top of 802.15.4
  – Network Layer, Transport Layer, and APIs
  – Self Healing Mesh Networking
  – 802.15.4 Addressing
Low Power M2M Network Protocols

- WirelessHART and ISA 100.11a
  - 802.15.4 MAC and PHY
  - Self Healing Wireless Mesh networking
  - Both target industrial applications and are working towards converging

- Wireless HART
  - Network Addresses assigned by network manager
  - API that is backwards compatible to HART

- ISA 100.11a
  - Internally generated 128 bit network address
The Home M2M Network

- Lacks scalability
  - NAT and power management on multiple gateways
- Cumbersome Management
  - The homeowner is required to maintain multiple gateways
- Inefficient Use of Resources
  - The value of a home network grows with the number of devices that can connect and communicate – In order to increase value, we want to communicate across local networks.
M2M Network Protocols

Gateway

Specialized Translation Application

TCP/UDP
IPv6
IEEE 802.2 LLC
Ethernet MAC
Ethernet PHY

TCP/UDP
IPv6
IPv6 Adaption Layer
IEEE 802.15.4 MAC
IEEE 802.15.4 PHY

Ethernet

IEEE 802.3 Ethernet
MAC
PHY
IEEE 802.15.4

ZigBee

Proprietary Protocol

Gateway
The IPv6 Adaption Layer

- IETF 6LoWPAN – RFC4944
- IPv6 Headers and IPv6 Packet Sizes (min 1280 Bytes) are large relative to 802.15.4 packet sizes (128 Bytes).
- 6LoWPAN defines a method for IPv6 header compression and packet segmentation
M2M Network Protocols

• Existing routing, transport, and application protocols are too expensive for low power devices.
  – IETF ROLL and IEEE 802.15.5
    • Routing protocols that are efficient in low resource networks.
  – IETF 6LoWApp - CoRE
    • Constrained Application Protocol (CoAP) – Lightweight HTTP over UDP
Low Power M2M Network Protocols

- ZigBee (Core Stack WG)
  - Smart Metering, Demand Response, and Energy Control
  - IPv6 Addressing
  - Leveraging standards from IEEE and IETF
Low Power M2M Network Protocols

- Bluetooth Low Energy
  - Power requirements that are competitive with 802.15.4
  - Not backwards compatible with existing Bluetooth technology.
  - Transmission distances in the 5 to 15 m range.
Low Power M2M Network Protocols

- Low Power Wi-Fi
  - Standards compliant solutions.
  - Lower Data Rates
  - Reduce the amount of time that they listen to the channel.
  - Take advantage of sleep opportunities by shutting off high speed clocks, etc.
  - Not as efficient as 802.15.4 for low power applications, but it has an enormous infrastructure.
Legacy Home M2M Network

- ZigBee Network
- Wi-Fi Network
- Bluetooth Network
- Ethernet
- Wi-Fi Router
- ZigBee Gateway
- Modem
Gateway-Based Home M2M Network

IP Addressable 802.15.4 Network

Wi-Fi Network

Bluetooth Network

M2M Home Gateway

- Ethernet
- 802.15.4
- 802.11
- Bluetooth
Gateway-Based Home M2M Network

• M2M Gateway
  – A single entity that intelligently manages the resources of the entire network.
  – Maintains a registry of all network services.
  – Maintains a reachability registry.
  – Assist with power management (caching).
  – Homeowner’s single point of management.
  – The fact that devices are multiple physical links is hidden from the application layer and from the homeowner.
The Roll of Software Defined Radio (SDR)

- M2M Gateway and SDR
  - SDR – Multicarrier / Multiband solutions can simultaneously use different protocols in different bands.
  - SDR architectures simplify protocol modifications and general software upgrades.
  - Increases device lifetimes
Combined Femotcell / Home Gateway

- IP Addressable 802.15.4 Network
- Wi-Fi Network
- Bluetooth Network
- Cellular Network
- Ethernet
- Cellular Core Network

M2M Home Gateway/Femtocell
Combined Femotcell / Home Gateway

• Femtocells – A miniature base station with an IP-based backhaul.
  – Provides better cellular coverage.
  – Increased capacity.
  – Allows for higher data rates.
  – Improves battery lifetime.
The Home M2M Network

- Consolidating the management of the entire home network makes it more manageable for the average homeowner.
- By adding IP addressability, the network becomes more valuable (to everyone).
- New services/applications present new opportunities for homeowners, device manufacturers, and service provider.