IP-Enabled Smart Objects: The Next Generation of Services

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Green IT Trends

Energy Trends: cost, capacity, environment call for better energy management,

Call for International Actions
Eg. Copenhagen agreement
IP Convergence

Converged Devices and Services
Web 2.0, P2P, VoIP, IP/TV, VoD, “Things”,...

Converged Networks
Data, Audio, Voice, Video, “Things”
Wired, Wireless – Fixed, Mobile

IP Infrastructures
The IP Benefits for “Things”

• The Internet – a demonstration of very large scale IP deployment
  – Critical traffic such as voice and TV already running over IP
  – Most “industrial” (wired) standards support an IP option, ie: Modbus, BACnet and LonWorks
  – Has already demonstrated its capabilities to work over low bandwidth links

• Future proof architecture and extensive interoperability – Interoperability
  – IP runs over any IP network link – wireless (WiFi, 3G, WiMax,….) and wired (Ethernet, Sonet/SDH, serial,….) - Single PHY/DATALINK layer will never fit all of the needs and requirements
  – 6LoWPAN (RFC 4944) defines IP over IEEE 802.15.4

• End-to-end reliability in addition to link reliability – TCP/UDP Transport protocols

• Established application level data model and services
  – HTTP/HTML/XML/SOAP/REST, Application profiles
  – Established naming, addressing, translation, lookup, discovery

• Established network architectures for higher-level services
  – load balancing, caching, mobility

• Established security
  – Network design and policy determines access, not the technology
  – Authentication, access control, and firewall mechanisms

• Established network management tools – Ease management and troubleshooting
  – Ping, Traceroute, SNMP, … OpenView, NetManager, Ganglia, …
IP - an Open Architecture

Applications (Telnet, SSH, SNMP, …)
Web Services (SOAP, XML, REST), CAP, Industry-specific

TCP

UDP

IP (v4, v6)
Routing (OSPF, IS-IS, …)
RoLL

IP over Foo adaptation layer (Ethernet, 6LoWPAN, …)

IEEE 802.15.4
868/915 MHz, 2.4Hz

IEEE 802.11
a/b/g/n/lp WiFi

IEEE 802.3
Ethernet

IEEE 802.16
IP & Wireless Sensor Network

- Network of small-footprint computers
- Optimized for long-life on low power
- Equipped to sense physical data
- Networked using low-power radio

**Function:**
- Sense any measurable physical parameter
  - Light, motion, chemicals, proximity, biometrics
- Form “LoWPAN = Low power Wireless Personal Area Network” and communicate
  - Automatic meshing and routing over radio
- Apply user-defined business logic
  - Sampling, summarizing, reporting events

**Form:**
- Node (Processor, Radio, Storage) + Sensors
- Embedded OS, Networking, Applications
- Servers and Routers interfacing with Enterprise IT systems
Complete Low-Power TCP/IP Stack
Industry’s Smallest Footprint

- 802.15.4e Low Energy extension
- 100s µW

* Production implementation on TI msp430/cc2420

<table>
<thead>
<tr>
<th>Feature</th>
<th>ROM</th>
<th>RAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC2420 Driver</td>
<td>3149</td>
<td>272</td>
</tr>
<tr>
<td>802.15.4 Encryption</td>
<td>1194</td>
<td>101</td>
</tr>
<tr>
<td>Media Access Control</td>
<td>330</td>
<td>9</td>
</tr>
<tr>
<td>Media Management Control</td>
<td>1348</td>
<td>20</td>
</tr>
<tr>
<td>6LoWPAN + IPv6</td>
<td>2550</td>
<td>0</td>
</tr>
<tr>
<td>Checksums</td>
<td>134</td>
<td>0</td>
</tr>
<tr>
<td>SLAAC</td>
<td>216</td>
<td>32</td>
</tr>
<tr>
<td>DHCPv6 Client</td>
<td>212</td>
<td>3</td>
</tr>
<tr>
<td>DHCPv6 Proxy</td>
<td>104</td>
<td>2</td>
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<tr>
<td>ICMPv6</td>
<td>522</td>
<td>0</td>
</tr>
<tr>
<td>Unicast Forwarder</td>
<td>1158</td>
<td>451</td>
</tr>
<tr>
<td>Multicast Forwarder</td>
<td>352</td>
<td>4</td>
</tr>
<tr>
<td>Message Buffers</td>
<td>0</td>
<td>2048</td>
</tr>
<tr>
<td>Router</td>
<td>2050</td>
<td>106</td>
</tr>
<tr>
<td>UDP</td>
<td>450</td>
<td>6</td>
</tr>
<tr>
<td>TCP</td>
<td>1674</td>
<td>50</td>
</tr>
</tbody>
</table>
• Standard IPv6 header (40 bytes) vs Entire 802.15.4 MTU (127 bytes)
  • Often data payload is small, Pay for only what you use
• By virtue of having joined the same 6LoWPAN network, devices share some state.
• The IPv6 header values are expected to be common on 6LoWPAN networks, so the HC1 header has been constructed to efficiently compress them from the onset
• Next header: UDP, TCP, or ICMP in a compressed IPv6 Header
RFC 4944 Header Compression Examples

IEEE 802.15.4 header (22 bytes)

<table>
<thead>
<tr>
<th>Dst PAN ID</th>
<th>Source EUI-64</th>
<th>Src PAN ID</th>
<th>Source EUI-64</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>00-17-3B-00-33-33-44-44</td>
<td>00-17-3B-00-11-11-22-22</td>
<td></td>
</tr>
</tbody>
</table>

Compressed IPv6/UDP header (7 bytes)  
FE80::0217:3B00:1111:2222 -> FE80::0217:3B00:3333:4444

<table>
<thead>
<tr>
<th>DSP</th>
<th>HC1</th>
<th>HC2</th>
<th>Hop Limit</th>
<th>UDP ports</th>
<th>UDP Cksm</th>
</tr>
</thead>
</table>

Compressed IPv6/UDP header (23 bytes)  
FE80::0217:3B00:1111:2222 -> FF02::1

<table>
<thead>
<tr>
<th>DSP</th>
<th>HC1</th>
<th>HC2</th>
<th>Hop Limit</th>
<th>Destination address (FF02::1)</th>
<th>UDP ports</th>
<th>UDP Cksm</th>
</tr>
</thead>
</table>

Compressed IPv6/UDP header (31 bytes)

<table>
<thead>
<tr>
<th>DSP</th>
<th>HC1</th>
<th>HC2</th>
<th>Hop Limit</th>
<th>Source Prefix 2001:0db8:cafe:cafe::/64</th>
<th>Destination Prefix 2001:0db8:beef:beef::/64</th>
<th>Destination IID 0221:1234:5678:6543</th>
<th>UDP ports</th>
<th>UDP Cksm</th>
</tr>
</thead>
</table>

Enhanced 6LoWPAN Header Compression Examples

IEEE 802.15.4 header (22 bytes)

<table>
<thead>
<tr>
<th>Dst PAN ID</th>
<th>Source EUI-64</th>
<th>Src PAN ID</th>
<th>Source EUI-64</th>
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<td>00-17-3B-00-11-11-22-22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Compressed IPv6/UDP header (6 bytes)

FE80::0217:3B00:1111:2222 -> FE80::0217:3B00:3333:4444

Compressed IPv6/UDP header (7 bytes)

FE80::0217:3B00:1111:2222 -> FF02::1

Compressed IPv6/UDP header (9-10 bytes)

IP WSN Eco-System

Solutions

Arch Rock Energy Optimizer (AREO)

Eco-System Partners
Environmental
Municipal streets,
High-end agriculture

Building Data Center Wiring Closet

Applications

Data Presentation and Analysis
Software as a Service and Appliance solutions
Open and standard file formats, eg. Energy
Monitoring, thermal monitoring, air quality,…

Data Collection, Temporary Storage, and Export layer

Data & Network Management

6LoWPAN routers and Relay Nodes
Low power meshed network, IPv4 & IPv6
Flexibility, Scalability, Availability, Security, Manageability

Infrastructure

Sensor-specific nodes
Expandable nodes
Embeddable OEM nodes

Sensing Nodes

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Key Drivers of Fine-Grained and Real-Time Energy Visibility

• Cutting energy spending
  – *Ongoing resource reduction translates to real, substantial savings*

• Leveraging utility tariffs
  – *Time-of-use, demand ratchet avoidance, demand/response readiness*

• Extending life of facilities
  – *Leverage the complete potential of existing power or cooling capacity*

• Complying with mandates
  – *US (EISA 07, EPAct 05), CA (AB32), FR (Environmental “Grenelle”)…*

• Achieving certifications
  – *Ongoing adherence to building standards: EnergyStar, LEED, THPE…*

• Committing to sustainability
  – *Brand strength, stake-holder loyalty and cultivation of goodwill*
AR Energy Optimizer Architecture

- Sensing Points
  - AC Power
  - Gas
  - Temp, Humidity, Flow
  - Outdoor Temp, Light

- Sensing Nodes
  - IPpower™
  - IPsensor™
  - IPsensorN4X™
  - IPthermal™

- Infrastructure
  - PhyNet Router
  - PhyNet Server
  - IP Backbone

- Data Acquisition
  - WSN Management

- Data Presentation and Analysis
  - Standard Data API
  - Arch Rock EVP
  - Ecosystem Partner App
  - WSN Lifecycle Management

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Arch Rock Energy Optimizer

- Dashboard, Budget Tracker
- Key Performance Indicators
- PUE, DCiE, Industry Metrics
- Circuit or Rack Level Spend
- Spatial or Functional Views
- Real-Time Energy Views
- Itemized Load Profiles
- Impact Analysis

- Activity Log
- Cause/Effect
- “What If”
- Alert Trail

- Daily $ Spent
- Utility $ Rate
- kW versus $

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AREO Energy Monitoring

15-MINUTE AVERAGE ENERGY DEMAND FOR MAY 2009

Click and drag on the chart to zoom in. Click the check-marks to hide lines.

Peak demand for May 2009: 345.282 kW

- HVAC
- Lighting
- Line 1
- 208V Production Loads
- Line 2
- Office 120V Loads
- Line 3
- Paste/Screen
- 2nd Up
- Other

Energy Real-Time monitoring chart
AREO in Building-wide Facilities

- AC power submeters
- IP power nodes
- Gas/Water submeters
- IP sensor nodes
- Temp, Hum., Light
- IP sensor nodes
- Outdoor Temp
- IP sensor N4X
- IP relay nodes
- Routers
- Internet
AREO in the Data Center

IPpower:
- PDUs
- Racks
- CRAHs

IPthermal:
- T, H

IPthermal-XT:
- Rack Intake T
- Rack Output T

IPthermal-HT:
- CRAH Air Supply T
- CRAH Air Return T

IPthermal-AC:
- CRAH Water Supply T
- CRAH Water Return T
- CRAH Water Flow Rate T, H

IPpressure:
- T, H
- Diff. Pressure

PhyNet Router:
- Mesh Aggregation and Ingress/Egress

Intranet
Operations Center
Arch Rock Energy Optimizer portal

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IP WSN in Municipal Streets Services

• Embedding IP WSN nodes in Parking meters reducing overall cost of operation and enabling new services.
  – IP WSN GPRS or WiFi routers to connect a cluster of parking meters to a central office
  – IPRelay Power Amplifier nodes when required
• Additional sensor nodes detecting vehicles and advertising free parking slots through City’s services
• City’s environmental air quality could be added through additional sensor nodes
  – Alarms, surveillance, treaty verification
IP WSN in High-end Agriculture

Winery fine-tuning of irrigation process, grow quality grapes

Real-time Vineyard Data, Correlated and Analyzed Remotely, Saves Time, Makes Decision-making More Accurate

How is transpiration affected by various weather conditions?
Collaborative Internet Sensors Communities

• Web 2.0 – Collaboration – Cloud Computing
  – Education & Research, Interest Groups, Public Information
• Let’s get your imagination developing the usage!
Take Away

• IP infrastructures are in place
  – Services, management, routing
• Nodes may have to store data, then forward when network is available
  – Not different from known applications such as e-mails
• Scaling access to data
  – Node vs server level
• Analysis of data is really what adds value
References

- http://www.archrock.com
- http://www.ipso-alliance.org
- Global IPv6 Strategies case study
  - http://www.globalipv6strategies.com