Communication Methods for Energy Management

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Architect Cisco EnergyWise
Communication Methods for Energy Management

• Communication Protocols
• Load Side Problem
  Problem Constraints that shaped it
  Clean Slate Smart Load
• Solution Concepts
  Architecture
  Components and Topology
  Communication Method
  Information Model
• What’s Needed Next
Energy Grid

Generation / Transmission / Distribution

SCADA Protocol
- DNP3
- IEC 60870-5
- IEEE 61850

GOOSE / GSSE

Load (Residential, Commercial, Industrial) - RS-485 / IP
- SNMP
- Zigbee
- DeviceNet (CIP)
- BACnet
- Dallas
- Modbus
- C-Bus
- Johnson N2

- Barber-Colman
- ALC WebCTRL SOAP Interface
- Lennox SysBus
- Trane Com3-4
- TCS Basys
- SNRA
- ETC-USAP
- OmniMeter

….and FAX!!
Load Management Overlays

Single Overlay

MoM Overlay

Note: Overlay and multiple connections is repeated for each type and vendor of devices or management solution - shown is just for PC..
Revealing a Network Topology
Network as the Overlay

Single Overlay

MoM Overlay

BUILDING A  BUILDING B  BUILDING C

BUILDING A  BUILDING B  BUILDING C

Core

Distribution

Access
Load Side Problem
Energy Consumption

- Rising energy costs
- IT device proliferation
- Change Behavior

- Regulatory compliance
- Government mandates
- Company requirements

Source: UK Energy Efficiency Best Practice Program; Energy Consumption Guide 19: Energy Use in Offices

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Problem: The Electric Load Curve and Peak Billing

- Passive strategies reduce the curve
- Active strategies shape the curve
- Networked systems will drive efficiency

Available Generation

Load Demand

Danger Zone

California Heat Wave 7/6/07
New Energy Regulatory Mandates

**Canada** Energy Efficiency Act – external power supplies, battery chargers, TV set top boxes, and digital TV adapters

**US** Energy Policy Act of 2005 – battery chargers and external power supplies; EnergyStar for Servers, Storage, UPS, and Data Centers

**Mexico** evaluating efficiency standards for electronic products

**EU EuP Directive** – energy using products, including set top boxes; Data Center Code of Conduct

**Japan** – networking equipment

**China** – TV receivers, set top boxes, and DVD players

**Australia** – DVD players and recorders, hard disk recorders, AV receivers, other audio / video equipment

**US HR 3221** – external power supplies, promote energy efficient data centers.

**HR 6** – energy efficiency labeling for set top boxes and DVR products.
Original Mission: Reduce Energy Usage for Network Devices

BUT… Looking at a Device…. 

Power per port of attached devices in a Cisco Test Building

**How much of the power for a switch is used to actually do switching?**

- Between 40-150W to do switching - based on model, load and/or rate (GE v 10GE)

**What percentage of a switch’s power is used to power attached devices?**

- 70% of Power supply on average used to power PoE

**What’s the average aggregate power consumption of devices connected to a switch?**

- 48 port switch has on average 3392W connected to it

**What’s the average per port power usage?**

- ~70W per port - TODAY!
Redefined the Problem

• **Smart Load**
  Add E to FCAPS for Network Management (FCAPS+E)
  Network plus attached devices can be a smart load

• **Monitor**
  Awareness of energy (usage, context, demand, quality)
  Fast Protocol for collection and aggregation

• **Control**
  Normalized information over common interface
  Fast Protocol for control especially peak demand

• **Interact**
  Interface to Smart Grid / Control / Procurement (ADR)
Clean Slate view of a Smart Load

• Needs Communication and Semantics

• Communication
  
  Create a scalable grid computer from a selection of devices to be managed
  
  Self organize into a domain via discovery
  
  Nodes in the domain should implement distributed hash maps
  
  Nodes will aggregate data for subtended or associated endpoints
  
  Use a broadcast protocol for message propagation
    
    Layer 3 ISIS type flooding (why not multicast you ask)
  
  Responses to broadcast can be aggregated and reduced
    
    Adds aggregation, map / reduce, search
    
    Fast response for requests to collect or control
    
    No single point of failure, registry, or aggregation

• Semantics
  
  Information Model for Energy with Context
  
  Control Interface
Solution Architecture Goals

- Use the network to measure, monitor and manage energy.
- Allow the network nodes to be the command and control plane for power management.
- Network Node is an arbiter or timer for energy management.
- Use the nodes to aggregate power usage reporting.
- Allow the network to provide secure, reliable energy management.
- Develop an eco-system to manage anything connecting to the network.
- No Technology Religion – Everything that draws power controlled using lowest common denominator.

Close to 3000 W attached to a 48 port switch consuming about 100 W.
Solution Concepts
Cisco EnergyWise Architecture

MANAGEMENT / SMART LOAD APPLICATIONS

Energy Management Applications
Network Management Applications
Building Management Systems

EnergyWise Management API

Cisco Catalyst Switching Network

Management API
SDK

Gateways

EnergyWise SDK – PARTNER DEVICES
POE / POE+ / UPOE
Building Protocols/Devices

IT DEVICES
BUILDING DEVICES

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Use the network to create a Smart Load

- Logical grouping of devices that are managed as one power consuming unit
- **Self organize** to form a grid for communication
- Members can **propagate messages** within the domain
- Domain members create neighbor relationships with each other and parent child relationships with endpoints
- The domain is a **single unit of energy management**

Cisco EnergyWise Domain
Network Devices can Self Organize

- Neighbor relationships are discovered through Cisco® Discovery Protocol, LLDP, or User Datagram Protocol (UDP) handshakes

- Alternatively, can establish static neighbors
Endpoints

- Endpoints connect to a parent for aggregation, control (query or time of day)
- Pattern exists for PoE, PDU, Lighting, Utility-Building, etc.
- Endpoints respond to command and control queries but do not forward them.
- Endpoints could speak many different protocols
  - BACNET, MOD-BUS, Zigby, SNMP, LonBus, CIP
Communication
Scaling

- Need a protocol that is fast and can scale as a domain grows
- Adding more management stations to process does not scale
- Use the natural order and scale of internetworking
- Group network communities to form a smart load with attached devices

Point to Point from Central Management

Processing done by single management station. Requires more messages sent and not parallel

Broadcasting within a Domain

Internetworking adds processing as grid increases in size. Less messages sent and parallel
Query and Messaging

A domain becomes a virtual distributed power information database
Provides the ability to query this database for information similar to SQL

Question : What is the power consumed by building X?

**SQL Query :**
Select sum(usage) from MyDomain where importance <= 100 and name like "BldgX%";

**Cisco EnergyWise Query:**
Switch# energywise query importance 100 name BldgX* sum usage
Message Propagation

Requests are flooded at Layer 3 (Similar to ISIS)

Only local trimming needed (No routing tables)

Leverage the usage pattern (Not a chatty protocol)

Efficient for Broadcast (not Point-to-Point)
Queries

Data is TLV based and provides distributed hash map

Allows for aggregation and map/reduce type processing

- **Set**: Change power levels of devices using Cisco® EnergyWise query
- **Sum**: Get the aggregated power consumption of all the devices searched
- **Collect**: Get a list of individual power consumptions of all the devices searched

Query: What is the power consumed by the domain bldg 19?

Response: 596 Watts
Minimal and Expandable Information Model

- **Identification**
  - Class: Make/Model (species)
  - Instance: Unique identifier within domain (UUID)

- **Security**
  - Authentication: message Digest
  - Authorization: with Access
  - Encryption: Not addressed. Deferred to network.

- **Energy**
  - Power: instantaneous reading
  - Energy: Odometer
  - Demand / Quality: optional based on existing standards
  - Levels: monitor and control interface
  - Caliber: characteristics of a measurement

- **Context**
  - Domain: management community
  - Role: use in the deployment
  - Keyword: tagging for arbitrary organization
  - Importance: local setting rolled up to relative rating
Security

Management Secret
Authenticates communication from a management station

Domain Secret
Authenticates communication between members

Endpoint Secret
Authenticates communication between domain endpoints.
Semantics & Control Interface
Energy Awareness…

Energy (W) is a resource that enables work to be done
Power (P) is the rate of converting energy to work per unit of time
Demand (kW) is the average rate of energy consumed per interval of time

- US Utilities charge for the highest interval demand in a month
  Demand is figured at each main incoming meter
  Demand acknowledges equipment capability to absorb short-time overloads
  Demand charges add penalty and uncertainty to cost forecast
Context: Keywords, Roles, Importance

<table>
<thead>
<tr>
<th>ExampleLight:</th>
<th>ExampleWorkStation:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong> – Light</td>
<td><strong>Type</strong> – Workstation</td>
</tr>
<tr>
<td><strong>Role</strong> – Decorative</td>
<td><strong>Role</strong> – Equities Trading</td>
</tr>
<tr>
<td><strong>Keyword</strong> – Lobby, Public</td>
<td><strong>Keyword</strong> – Trading, Restricted</td>
</tr>
<tr>
<td><strong>Importance</strong> – 20</td>
<td><strong>Importance</strong> – 90</td>
</tr>
</tbody>
</table>

Importance…
- 90 to 100 Emergency response
- 80 to 90 Executive or business critical
- 70 to 79 General or Average
- 60 to 69 Staff or support
- 40 to 59 Public or guest
- 1 to 39 Decorative or hospitality
## Control Interface
Representation of device power states

<table>
<thead>
<tr>
<th>Category</th>
<th>Color</th>
<th>Code</th>
<th>Color</th>
<th>Level</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operational (1)</strong></td>
<td>FF0000</td>
<td>Red</td>
<td></td>
<td>10</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FFFF00</td>
<td>HighMinus</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FFFF00</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td>MediumMinus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00FF00</td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>LowMinus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>00FF00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><strong>Standby (0)</strong></td>
<td>0000FF</td>
<td>Blue</td>
<td></td>
<td>4</td>
<td>Ready</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0000FF</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>Standby</td>
</tr>
<tr>
<td></td>
<td>A52A2A</td>
<td>Brown</td>
<td></td>
<td>2</td>
<td>Sleep</td>
</tr>
<tr>
<td><strong>Nonoperational (-1)</strong></td>
<td>000000</td>
<td>Black</td>
<td></td>
<td>1</td>
<td>Hibernate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>000000</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>Off/SoftOff</td>
</tr>
</tbody>
</table>
# Standards based levels

<table>
<thead>
<tr>
<th>State</th>
<th>DMTF Power</th>
<th>ACPI State</th>
<th>MIB Power State</th>
<th>EW/IETF State Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-operational states:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Off-Hard</td>
<td>G3, S5</td>
<td>Shut/Mech Off</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Off-Soft</td>
<td>G2, S5</td>
<td>Shut/Soft Off</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Hibernate</td>
<td>G1, S4</td>
<td>Hibernate/Hibernate</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Sleep-Deep</td>
<td>G1, S3</td>
<td>Sleep/Sleep</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sleep-Light</td>
<td>G1, S2</td>
<td>Standby/Standby</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Sleep-Light</td>
<td>G1, S1</td>
<td>Ready/Ready</td>
<td></td>
</tr>
<tr>
<td>Operational states:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>On</td>
<td>G0, S0, P5</td>
<td>Low/LowMinus</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>On</td>
<td>G0, S0, P4</td>
<td>Frugal/Low</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>On</td>
<td>G0, S0, P3</td>
<td>Medium/MediumMinus</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>On</td>
<td>G0, S0, P2</td>
<td>Reduced/Medium</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>On</td>
<td>G0, S0, P1</td>
<td>High/HighMinus</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>On</td>
<td>G0, S0, P0</td>
<td>Full/High</td>
<td></td>
</tr>
</tbody>
</table>
Queries: Sums and Deltas

Summing can give the total possible power change in the domain based on present configuration options.

Switch# `energywise query importance 50 keyword 'Decorative' sum delta`

EnergyWise query, timeout is 3 seconds:

<table>
<thead>
<tr>
<th>Level</th>
<th>Label</th>
<th>Delta Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Shut</td>
<td>-723.8</td>
</tr>
<tr>
<td>1</td>
<td>Hibernate</td>
<td>-610.3</td>
</tr>
<tr>
<td>2</td>
<td>Sleep</td>
<td>-520.3</td>
</tr>
<tr>
<td>3</td>
<td>Standby</td>
<td>-520.3</td>
</tr>
<tr>
<td>4</td>
<td>Ready</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>Low Minus</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>Low</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>Medium Minus</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>Medium</td>
<td>0.0</td>
</tr>
<tr>
<td>9</td>
<td>High Minus</td>
<td>+223.8</td>
</tr>
<tr>
<td>10</td>
<td>High</td>
<td>+223.8</td>
</tr>
</tbody>
</table>

Queried: 48  Responded: 48  Time: 0.15 seconds
Deployments
Metering and Sub-metering

- **Midsize Branch Office**: 1 or More Meters or Submeters
- **Small Branch Office**: 1 Submeter
- **Large Campus Building**: Many Meters or Submeters
Typical Metering

Energy Domain Metered

![Graph showing energy usage over time]
Match Energy Domains to Electrical Distribution
Add Business Context
Details From Domain Estimating True Metering

Energy Domain Business Context

Energy Domain Details
What's Needed Next…
Eco-System

Management – Energy, Network, Others

End Devices

BMS, Gateways

Services, Regional, Other Value-add
Standards Work

- Established IETF EMAN working Group
  - Leading effort for Energy over IP
  - Standardizing Information Model first
  - Specifying Architecture
  - Working with Existing bodies such as DMTF, IEC, IEEE, ASHRAE etc

- ODVA work with CIP for Industrial Automation

- Integration via 802.3az (EEE)
Areas for Research

- Power distribution like VOIP (power setup, power route, QoS)
  • Negotiating Power, Energy, and Demand over Electrical lines
    Identification of devices based on power characteristics
  • Sleeping a device and proxy presence
  • Broadcast communication
    Storm prevention within a palatable multicast
    How to add Point-to-Point easily (registry?)
  • Estimating and Characterizing Measurements (virtual devices)
  • Protocol translations and routing (mediation)
  • Accounting / Negotiating overlapping measurements
  • Track energy cost of packet / routing based on cost
  • Predicting MTTR and/or Maintenance based on energy usage
http://books.google.com/books?isbn=9780470607251
References

John Parello - jparrello@cisco.com
Tirth Ghose - tirghose@cisco.com

Reduced / Free for Academic Research:

- Cisco EnergyWise Validated Design Guide

- Cisco EnergyWise fundamentals Video Tutorial
  - http://www.youtube.com/watch?v=hGf6DADO468

- Cisco EnergyWise concepts and summary paper
Thank you.