IPv6 for the World of IoT

Robert Barton, P.Eng
Principal Systems Engineer
@MrRobbarto
CCIE #6660
CCDE #2013::6
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Agenda

1. How IPv6 fits into an IoT Architecture
2. Adapting IPv6 for Constrained IoT Networks
3. RPL – IPv6 Routing for IoT
4. Time Sensitive (Deterministic) Networking in IoT
5. Supporting Non-IPv6 Endpoints
6. Network Management Communications Protocols
7. Smart Grid Case Study
Chapter 1: How IPv6 Fits into an IoT Architecture
The Importance of Architecture
(These different buildings require different architectures and skills to build)
IoT: A Driving Factor for IPv6 Adoption

Rapid adoption rate of digital infrastructure 5 x faster than electricity & telephony

Consumer IoT vs. Industrial IoT

- IoT doesn’t mean the same thing to all people . . .
- Personal / Home IoT (e.g. Google Nest) it not typically the domain of IPv6
- However, IPv6 is becoming critical in industrial IoT
IT and OT Are Converging Towards IP

- Sensing
- Ventilation
- Lighting
- BACnet
- Coax
- PBX


Cloud Management and Analytics

Experiences

OpEx

Data Network

IP Telephony

IP Cameras

Building Management Systems Using Low-Voltage PoE

IP Building Systems on low-voltage PoE
Cisco Canada HQ Digital Ceiling Example

Challenge
• Build an innovative, energy-efficient workspace

Digital Transformation
• PoE-powered lighting with Cisco switches
• Sensor-based access to workspaces
• Analytics with fixture-level visibility

Why IPv6?
• Scale of lights to wired ports is ~6:1
• Address exhaustion of IPv4 is limitation to deployment

Cisco Head Quarters Building, Toronto, Canada
- 4 Floors
- 1400 LED / IoT Lights
- 2200 HVAC endpoints
- Distributed Deployment Model
Example – PoE LED Lights in Cisco Office
Digital Ceiling’s Requirements

Catalyst Digital Building Switch (DBS-8)

- UPOE and PoE+
- Perpetual PoE
- Fast PoE
- Fanless
- CoAP protocol support
- Energy monitoring

Stateless DHCPv6: Address assignment comes from SLAAC and DNS and other options from the DHCP pool

```
ipv6 unicast-routing
.
ipv6 dhcp pool STATELESS
dns-server 2001:4860:4860::8888
domain-name smartbuilding.com
.
interface Vlan102 no ip address
description IPv6-SLAAC
ipv6 address 2001:db8:700:1::1/64
no ipv6 nd managed-config-flag exit
```
IPv6 is the foundation that can meet these requirements, unifying IoT systems.

IoT Requirements for Industry

IPv6 is the Glue Between IoT Systems

- Massive Scale – mostly wireless
- Convergence of IT and OT
- Interoperability between networks, APIs, and management protocols
- Lots of legacy gear needs to be connected
- Distributed Computing and Analytics Systems (Fog and Edge)
IPv6 Helps Unite the Heterogeneous Nature of IoT

- Sensor Networks can be interconnected by a variety of data links, such as
  - IEEE 802.15.4, IEEE P1901.2 PLC, Bluetooth LE, IEEE 802.11ah, DECT LE, etc.

IPv6 offers a common network layer for end-to-end communications
IoT World Forum (IoTWF) Reference Model

Levels

7. **Collaboration & Processes**  
   (Involving People & Business Processes)

6. **Application**  
   (Reporting, Analytics, Control)

5. **Data Abstraction**  
   (Aggregation & Access)

4. **Data Accumulation**  
   (Storage)

3. **Fog Computing**  
   (Data Element Analysis & Transformation)

2. **Connectivity**  
   (Communication & Processing Units)

1. **Physical Devices & Controllers**  
   (The “Things” in IoT)

---

Center

Edge

Sensors, Devices, Machines,  
Intelligent Edge Nodes of all types

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IoTWF Reference Model – Separation of IT & OT

Levels

1. Sensors, Devices, Machines, Intelligent Edge Nodes of all types

2. Edge

3. Traditionally IPv4 World, but needs to embrace IPv6

4. This is an IPv6 World!

5. Query Based

6. Data at Rest

7. Non-real Time

IT

OT

Query Based

Data at Rest

Non-real Time

Event Based

Data in Motion

Real Time

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Chapter 2: Adapting IPv6 for IoT Networks
IoT Use of Open Standards

- Standardization at all levels to ensure interoperability, reduce cost and risk
- Enables common application layer services over various wired and wireless communication technologies
6LoWPAN (RFC 4944)

• IPv6 over Low power Wireless Personal Area Networks
  • 6LoWPAN defines the transmission of IPv6 over IEEE 802.15.4

• Header Compression Format for IPv6 Datagrams in 6LoWPAN Networks
  • 802.15.4 only supports 127 bytes frame size!
  • Normal IPv6 MTU = 1280 bytes

• Why such a small MTU for IEEE 802.15.4?
  • Networks made up of many embedded devices with limited power, memory, and processing resources
  • Networks are very lossy, and bandwidth is limited (e.g. 150 Kbps)
  • Used for smart meters, actuators, street lighting, intelligent sensors

• Solution: We need an IPv6 Adaptation Layer!
The 6LoWPAN IPv6 Adaptation Layer

- **Physical Layer**
  - Wired/Wireless

- **Data Link Layer**
  - Including 802.15.4g, 802.15.4e

- **Network Layer**
  - IPv6/IPv4

- **Transport Layer**
  - TCP/UDP
6LoWPAN Header Compression

**6LoWPAN Without Header Compression**

- 127 Byte IEEE 802.15.4 Frame
- 802.15.4 Header
- IPv6
- UDP
- Payload
- FCS

**6LoWPAN With IPv6 and UDP Header Compression**

- 127 Byte IEEE 802.15.4 Frame
- 802.15.4 Header
- UDP
- Payload
- FCS

6LoWPAN Header with Compressed IPv6 Header
Evolution of 6LoWPAN to 6Lo

- 6LoWPAN has been generalizing to a wide array of LLN technologies with generic abstractions
- 6Lo now chartered to define IPv6 over IoT Links:

  Bluetooth Low Energy        RFC 7668
  DECT Ultra Low Energy       draft-ietf-6lo-dect-ule
  PLC                          draft-popa-6lo-6loplc-ipv6-over-ieee19012-networks
  Near Field Comms (NFC)      draft-ietf-6lo-nfc-05
  BACnet                      draft-ietf-6lo-6lobac-06
  802.15.4e TSCH               draft-ietf-6tisch-6top-protocol-03
What About IPv6 for LPWA? (Long Power Wireless Access)

Designed for Low Power Consumption, Low Data Rate and Long Distance IoT Use Case

- Fill the gap between local wireless and cellular wireless technologies
- End-device with battery life lasting 10+ years
- Over-the-air distance over 15+ km
- Low cost module at sub-$5
- Technology branches from utilized spectrum
  - Licensed band - 3GPP NB-IOT on LTE/5G Public Mobile SP
  - Unlicensed band - LoRaWAN and SigFox on ISM radio

Use Cases

- Water and Gas Metering
- Public Security
- Street Lighting
- Smart Parking
- Location Tracking
- Leak Detection
- Disaster Precaution
- Livestock
- Environment Monitoring
- Smart Energy
- Waste Management
- Agriculture
LoRaWAN Constraints Limit IPv6

Adaptive Data Rate is the procedure by which the network instructs a node to perform a rate adaptation by using a requested DR (e.g. DR0), a requested TX Power (e.g. 11 dBm)

SF12 14km 10km 8km 6km 4km

SF7

2D simulation (flat environment)

By way of comparison:
Sigfox = max of 100bps (200 KHz channel)
The LoRa Stack

Application

LoRa® MAC

MAC options

Class A (Baseline)

Class B (Baseline)

Class C (Continuous)

LoRa® Modulation

Regional ISM band

EU 868

EU 433

US 915

AS 430

LoRa Alliance Specifications

Semtech modulation

LoRa Alliance Regional Profiles
Network Communications in LoRaWAN

LoRaWAN terminates MAC at the Network Server (transported over IP tunnel from gateway)

L2 is Tunneled Through IP Network (cellular backhaul)

Network Servers (terminates MAC Layer)
The Future of IPv6 and LPWAN Technologies

- The desire is to have IPv6 support in LPWA technologies, but is a challenge.
- Existing technologies have little ability to alter frame formats, making IETF 6Lo application difficult – requires a new adaptation layer.
- IETF LPWAN Working Group
  - LPWAN Static Context Header Compression (SCHC) and fragmentation for IPv6 and UDP
- Similar to 6Lo, will use ROCH (Robust Header Compression) and allows an insertion of the IPv6 stack into a variety of LPWAN technologies (especially LoRaWAN).
Chapter 3: RPL – IPv6 Routing for IoT
Routing over Low Power Lossy Networks (RoLL):

- **Existing IP routing protocols are poorly suited for IoT**
  - Lossy connections and will lose state too easily
  - Only consider link cost, not node type or other constraints
  - Lack of routing flexibility when different objective functions are required

- **RFC 6550** defines RPL: *IPv6 Routing Protocol for Low-Power and Lossy Networks*

- RPL is a Distance Vector routing protocol
  - New routing metrics (Objective Functions): Energy, latency, link reliability (ETX), node state, link color,…

- As other IP routing protocols, RPL support a variety of data links
  - IEEE 802.15.4, IEEE P1901.2, Bluetooth LE, IEEE 802.11ah,…
RPL Definitions

- *Directed Acyclic Graph (DAG)* – a directed graph where no cycle exists
- *Destination Oriented DAG (DODAG)* – a DAG rooted in one location
RPL Tree DODAG Structure

Dag Information Object (DIO) Messages advertise upward routes downward from CGR

DAG Advertisement Object (DAO) Messages advertise routes to parents

The Rank is a rough approximation of how “close” a node is to the Root and serves to avoid routing loops
RPL Objective Functions

• An Objective Function (OF) defines how metrics are used to select routes and establish a node’s Rank.

• Metrics include:
  • Expected Transmission (ETX) – how reliable the link is
  • Hop Count
  • Latency
  • Node Energy

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Parent node = Path with lowest $\sum_{Rank=n}^{0} ETX$
Routing Around Battery Powered Nodes

- RPL Objective Function allows routing around battery-powered nodes when necessary
- End to end IP infrastructure can help reduce battery usage

Battery lifetime is a critical design criteria in IoT
Example: Routing with ETX Objective Function

Choose route with lowest path $\sum_{\text{Rank}=n}^{0} ETX$

Path $ETX =$
- Left: 2
- Middle: 3
- Right: 2.5
Final RPL Topology
Example of Multiple DAGs in Single Physical Mesh
Physical Topology (IPv6 Link Local connection between nodes is possible)
Example of Multiple DAGs in Single Physical Mesh

Different DAGs for Different Objective Functions

DAG With Low ETX OF

DAG with Energy Conservation OF
Example: Cisco CGR 1000 WPAN RPL Table
In practice, this is called the Field Area Network (FAN)

```
CGR# show wpan 3/1 rpl tree
CGR1000_JAD1843000D#show wpan 4/1 rpl tree
------------------------------- WPAN RPL TREE FIGURE [4] -----------------------------

[2620:175:F00:100::1] (4/12) ➞ Rank 0 (the CGR router)
  \--- 2620:175:F00:100:5C71:CA79:791D:A52 ➞ Rank 1
  \--- 2620:175:F00:100:787B:876E:8B52:2692 (4) ➞ Rank 1
    \--- 2620:175:F00:100:58B8:CC09:85A2:529E ➞ Rank 2
    \--- 2620:175:F00:100:FC6C:F5F2:5E2C:BC88 ➞ Rank 2
  \--- 2620:175:F00:100:95A7:E3B8:E818:B349 ➞ Rank 2
  \--- 2620:175:F00:100:C11B:F90E:C1F1:9C7 (4) ➞ Rank 2
    \--- 2620:175:F00:100:25FC:C9D3:682C:3418 ➞ Rank 2
    \--- 2620:175:F00:100:4D80:B8F2:4A1F:67C4 ➞ Rank 2
    \--- 2620:175:F00:100:D06C:6C65:E465:97 ➞ Rank 2
    \--- 2620:175:F00:100:E4E0:EE1F:BBD3:4A56 ➞ Rank 2
```
Chapter 4: Non-IPv6 Endpoints in an IPv6 FAN
Multi-Service Grid Network Involves Legacy Devices

Mesh Gateway Router (IR510)

Serial Interface on RTU

Street Light

IP WAN

CGR 1000

Mesh Domain

SCADA/DMS server & application
Native Raw Socket or IP/Serial Redirector SW
IPv6 MAP-T (RFC 7599)

An IED makes a connection into the Mesh network via the Cisco IR509 router (either through Serial or Ethernet/IPv4)

The Connected Grid Router (CGR) forwards the IPv6 packet from the Mesh over a VPN tunnel to the headend

The MAP-T CPE Router (e.g. Cisco IR500 series router) NATs the connection into an IPv6 packet

The MAP-T Border Relay, unwraps the IPv6 packet, exposing the original IPv4 packet and sends it toward the SCADA server

The IPv4 SCADA server terminates the connection and accepts incoming SCADA packets

The Connected Grid Router (CGR) forwards the IPv6 packet from the Mesh over a VPN tunnel to the headend

The MAP-T Border Router, unwraps the IPv6 packet, exposing the original IPv4 packet and sends it toward the SCADA server

The IPv4 SCADA server terminates the connection and accepts incoming SCADA packets
IPv6 MAP-T Example: Smart Grid

MAP-T CPE -> CGR 1000 (IP WAN) -> MAP-T Border Relay

6LoWPAN
IPv6
Application Traffic (SCADA)
Native IPv4
MAP-T
Native IPv4
**MAP-T NAT Process**

**IPv4**
- Source: 10.1.0.60
- Destination: 192.168.0.2
- TCP
- Src Port: 20100
- Dst Port: 18999

**IPv6**
- Source: 2610:d0:1200:cafe:a:100:3c00:0
- Destination: 2031:6f8:147e:1001:99:a0a:fe00:0
- TCP
- Src Port: 20100
- Dst Port: 18999

**NAT44 on DA GW**
- Map IPv4 address & port to IPv6 prefix, then replace IPv4 header with IPv6 header

**6LoWPAN/RPL**
- IPv6

**DNP3/IP or Modbus TCP or IEC 60870-5-104**

**Outgoing communication:** Dynamic NAT44

**Incoming communications:** Static NAT44
Chapter 5:
Time Sensitive Networking (TSN) in IoT
(Deterministic Networking)
Time Sensitive (Deterministic) Networking

- Wireless networks (e.g. Wi-Fi) use ISM band and are contention-based
  - They cannot guarantee packet delivery. This is not ideal for critical systems.
  - In Ethernet this is was addressed by IEEE 802.1 Time-Sensitive Networking (TSN)

- **Industrial (manufacturing):** process control, machine control
  - Latency critical to meeting control loop frequency requirements

- **Audio/video:** streams in live production studios
  - One flow is 3 Gb/s now, 12 Gb/s tomorrow

- **Autonomous Guided Vehicles:**
  - Autonomous vehicle control
Making Wireless Deterministic with TSN

- Deterministic Networks require a central controller to orchestrate media access

- Using 802.15.4, schedule every transmission – called Time Slotted Channel Hopping (TSCH)
  - Saves energy by optimizing sleeping periods
  - Reduces frame loss due to interference
  - Optimize bandwidth usage (no wasteful back-offs due to CSMA/CA)

- On LLN Wireless technologies include:
  - WirelessHART (Emerson)
  - ISA100.11a (Honeywell)
Example: Honeywell OneWireless ISA100.11a with Wi-Fi Deployment

Wireless Control Loop

Sensor
Actuator
PLC

802.11 Wireless Mesh Backhaul
ISA100.11a
802.11 Wireless Client

Cisco Wireless Controller
Switch
ISA100.11 Wireless Device Manager

ISA100.11a Field Devices
Mobile Station
Cisco 1552S Access Points
• 6TiSCH puts together 6LoWPAN for IPv6, RPL for Low-Power Routing and TSCH for Deterministic Wireless Networking capability

• 6TiSCH generalizes ISA100.11a and WirelessHART to enable Industrial Internet

• TSCH with Centralized scheduling routing, optimized for Time-Sensitive flows
  • Mission-critical data streams (control loops)

• RPL Distributed Routing and scheduling for large scale monitoring
  • Enabling co-existence with IPv6-based Industrial Internet
  • Separation of resources between deterministic and stochastic, leveraging IEEE/IETF standards (802.15.4, 6LoWPAN …)

• https://datatracker.ietf.org/wg/6tisch/charter/
Chapter 6: IPv6 IoT Network Management
Constrained Application Protocol (CoAP)

- CoAP is a lightweight version of HTTP defined by IETF in the Constrained RESTful Environments (CoRE) standard
  - UDP based with small headers (<10 bytes)
  - Request / Response model (GET, POST, PUT, DELETE)
  - Pub/Sub Model (OBSERVE)
  - Supports block transfer, proxy, caching, resource discovery
CoAP Communication Example

Transmit the command string over CoAP

Retransmit using Exponential back off until reply

coap://my-bright-light.com:5683/foo.xml

CON tid=0x47
GET /foo
CoAP Communication Example

CoAP Communication Example

Transmit the command string over CoAP

Retransmit using Exponential back off until reply

coap://my-bright-light.com:5683/foo.xml

CON tid=0x47
GET /foo

ACK tid=0x47
200 "<bright…

Message ID 0x47
MQTT (Message Queue Telemetry Transport)

• Created in 1999, and is intended to be a publish-subscribe based "light weight" messaging protocol for IoT and M2M
  • TCP Based
• Based on the idea that TCP and HTTP are good protocols (just need to be made lighter):
• Sensor publishes information (MQTT Publisher)
  • Information is published as an address
  • The application that needs to receive the information can be set as the MQTT subscriber
The MQTT Framework

- Publisher publishes “topic” at a given address
  - MQTT Server (MQTT Broker) can retrieve topics from publishers
  - Clients subscribe to topics from a broker or server
  - Broker can distribute topics to clients (subscribers)

Building climate control system
MQTT Broker Deployment Example
Pv6 Building Automation Network

Distances

Temperature /Humidité

Light/Lumière

Arduino

USB Connection

GigaEthernet0 : 2001:1::1

Arduino

USB Connection

GigaEthernet2 : 2001:2::1

Cisco IR809 Router (IPv6 Network)

IPv6

Python Script

MQTTBox Subscriber (Client Station)

MQTTBox

GigaEthernet0 : 2001:1::1

GigaEthernet2 : 2001:2::1

MQTT Broker Mosquitto/Eclipse

Network information

IPv6

Cisco IR809 Router (IPv6 Network)
MQTTBox Subscriber Configuration (the client)

MQTT Client Name: MQTT IPv6

MQTT Client Id: 492280c0-06d4-4c1b-9e

Protocol: mqtt / tcp

Host: [2001:1::89e2:7618:fd14:aa6b]:

Username: Username

Password: Password

Reconnect Period (milliseconds): 1000

Connect Timeout (milliseconds): 30000

KeepAlive (seconds): 10

Will - Topic: Will - Topic

Will - QoS: 0 - Almost Once

Will - Retain: No

Will - Payload: 

Broker is MQTT v3.1.1 compliant? Yes

Auto connect on app launch? Yes

Reschedule Pings? Yes

Queue outgoing QoS zero messages? Yes

Save

Delete
MQTT Client Subscribing to Broker’s Sensor Data
Visualisation with Wireshark

Sniffer trace of MQTT Topics sent from broker to MQTTBox client station

MQTT messages with 3 topics
## Comparing Control Layer Protocols

<table>
<thead>
<tr>
<th></th>
<th>CoAP</th>
<th>MQTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Protocol</td>
<td>IPv6</td>
<td>IPv6</td>
</tr>
<tr>
<td>Transport Protocol</td>
<td>UDP</td>
<td>TCP</td>
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<tr>
<td>Typical Messaging</td>
<td>Request/Response (like http)</td>
<td>Publish/Subscribe</td>
</tr>
<tr>
<td>Effectiveness in LLNs</td>
<td>Excellent</td>
<td>Fair</td>
</tr>
<tr>
<td>Security</td>
<td>DTLS</td>
<td>SSL/TLS</td>
</tr>
<tr>
<td>Scalability</td>
<td>Complex</td>
<td>Simple</td>
</tr>
<tr>
<td>Strengths</td>
<td>Light-weight and fast with low overhead is suitable for constrained networks; Uses RESTful model that is easy to code to; Easy to parse, and process for constrained devices</td>
<td>TCP and QoS options provide robust communications; simple management and scalability using a broker architecture;</td>
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</table>
Chapter 7: Smart Grid Case Study – BC Hydro
Smart Meter Program Scope

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<th>Total</th>
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<tbody>
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<tr>
<td>North Interior</td>
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<td>Victoria</td>
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<tr>
<td>Kootenay</td>
<td>Cranbrook</td>
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</table>

TOTAL 1,848,939
The Multi-Service Grid Network Architecture

- Street Lighting Controller
- SCADA Management
- Meter Management

Backhaul Network

IPv6 Mesh Endpoints

RF Mesh Field Area Network (FAN)

- AMI Metering / HAN Gateway
- Transformer Monitoring
- Distribution Automation
- EV Charging Infrastructure
- Direct Load Control
- Gas / Water Meters
- Distributed Generation
- SCADA Network
- Direct Connect AMI Meters

Backhaul

FAN
Anatomy of a Smart Meter

Communications Board with FAN radio

Register board: registers voltage/energy usage, stores load/voltage profile and contains ZigBee radio for HAN

Metrology board: processes voltage and current measurements and converts them to pulses
Customer Portal

Consumption data
Current billing period: Dec 14, 2016 to Jan 13, 2017

Cost to date
$43*

Projected cost at Jan 13
$102*

Daily consumption for Dec 22 – Dec 28, 2016
Smart Grid Network Architecture

- VPN Backhaul Tunnels
- RPL Mesh Network
- Home Area Network (HAN)
Meter farm in an underground concrete vault
Sample RPL Mesh IPv6 Addressing Plan

Assigned Address Block
2021:ABCD:1000::/36

Data Center
/40

Infrastructure
/40

Grid WAN Network
/40

CGR Loopbacks
/48

IPSec Tunnels
/48

RPL Mesh
/40

Mesh 1
/64

Mesh 2
/64

Mesh 3
/64

Mesh n
/64
Case Study: BC Hydro’s Conversion to IPv6

- IPv6 made the mesh **flatter and faster**
  - Before IPv6: Only 20% of meters were within 3 hops of CGR, 60% were 6+ levels deep. Max depth was 30 levels.
  - After IPv6: ~60% of meters within 3 hops of CGR with max depth of 14 levels deep.
## Comparing to Full IPv6 After Conversion

<table>
<thead>
<tr>
<th>Rank</th>
<th>Pre-IPv6</th>
<th>Post-IPv6</th>
<th>Difference between levels (msec)</th>
<th>Average Round Trip Time</th>
<th>Difference between levels (msec)</th>
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<tbody>
<tr>
<td>CGR</td>
<td>2670</td>
<td></td>
<td>0</td>
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<td>Rank 1</td>
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<td>1330</td>
<td>430.5</td>
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<tr>
<td>Rank 2</td>
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<td>1000</td>
<td>716.1</td>
<td>285.7</td>
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<td>2330</td>
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<td>Average</td>
<td>1732</td>
<td></td>
<td>279.69</td>
<td></td>
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</tbody>
</table>
Demand Response (DR) Load Controller

- Power generation and consumption must always be kept in balance
- During periods of high power draw (peaking), energy consumption needs to be reduced to avoid brownouts
- Demand Response allows control of high energy consumption devices on the grid
- The DR device connected to water heater is connected to the FAN mesh (e.g. the meter on the home)
IPv6 Street Lighting
Wrap Up
Further Reading

• **Available Now!**
• Much of this session is based on content from this book
• **Pearson Live Lesson Series:**
IPv6 this week in Barcelona

- BRKIP6-2616 - Beyond Dual-Stack: Using IPv6 like you’ve never imagined – 30 Jan. 16:45
- BRKRST-3304 - Hitchhiker's Guide to Troubleshooting IPv6 - Advanced – 31 Jan. 9:00
- BRKSPG-2602 - IPv4 Exhaustion: NAT and Transition to IPv6 for Service Providers – 31 Jan. 9:00
- BRKIP6-2301 - Enterprise IPv6 Deployment – 31 Jan. 11:30
- LABSPG-3122 - Advanced IPv6 Routing and services lab – 31 Jan 14:00 & 1 Feb. 14:00
- BRKCOL-2020 - IPv6 in Enterprise Unified Communications Networks – 31 Jan. 16:30
- BRKCOC-2388 - Inside Cisco IT: A Tale of Two Protocols - Before Dual Stack to IPv6 Only and Beyond – 2 Feb. 9:00
- BRKIP6-2002 - IPv6 for the World of IoT – 2 Feb. 11:30
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Don’t forget: Cisco Live sessions will be available for viewing on-demand after the event at www.ciscolive.com/global/on-demand-library/.
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