Putting **IPv6** to work

North American IPv6 Summit

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Rocky Mountain IPv6 Task Force

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Success and Future of IPv6 from an Electrical Utility Perspective

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BC Hydro Smart Metering Program

- BC Hydro is installing the first standards-based multi-services Field Area Network (FAN) with IPv6 802.15.4/RPL mesh to manage the Automated Metering Infrastructure (AMI), Distribution Automation (DA) and other advanced gird applications.
- The design is based on Cisco's Connected Grid Solution utilizing Cisco's Field Area Router (CGR), standards-based Smart Meter FAN technologies, and Itron Openway Centron smart meters.
- BC Hydro is moving to build an IPv6 network capable of supporting over 2 Million routable IPV6 addresses in a secure, resilient, and manageable way.
- Standard-based architecture enables integration of third party new or legacy devices.

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Overview

- Introduction
- Smart metering program
- Deployment strategy
- Unified IPv6 FAN
- Lessons learned
- Test results
- Technology roadmap

BC Hydro

- **Generation**
  - 41 Dam sites, 30 Hydro facilities and 9 Thermal units
- **Transmission**
  - 18,000 km of Transmission lines 300 substations, 22,000 steel towers
  - Two Control Center
  - Consolidation of 4 regional systems (including back-up)
  - Interconnect to Alberta and US
- **Distribution**
  - 56,000 km of Distribution lines
  - Approx. 900K poles, over 300K of transformers
  - Serve 17 Non-integrated areas
- **Approx. 1.9M electric customers**
  - 70% of these customers clustered around the 49th parallel (in greater Vancouver and Victoria)
  - Equal to the area of California, Oregon and Washington state combined

BC hydro
FOR GENERATIONS

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- Crown Corporation
- 1.8 Million Customers
- 51,000 GWh Domestic Load
- 11,300 MW Generation
- Serve 95% of British Columbia
- Triple Bottom Line Performance

BC hydro

FOR GENERATIONS

Powertech Labs

- Founded in 1979, a non-regulated subsidiary of BC Hydro, with extensive knowledge of all aspects of utility industry.
- A large multidisciplinary laboratory, based in Surrey, British Columbia.
- Over 30 years of specialized engineering expertise.
- Global customer base: 300+ customers including many Fortune 500s. BC Hydro is a key customer.
- Established Smart Utility Lab (2012) to address industry's needs in communications and information technology (ICT).
  - Services include network design, interoperability testing and pre-deployment validation to support telecommunication systems, distribution automation and controls.

Powertech

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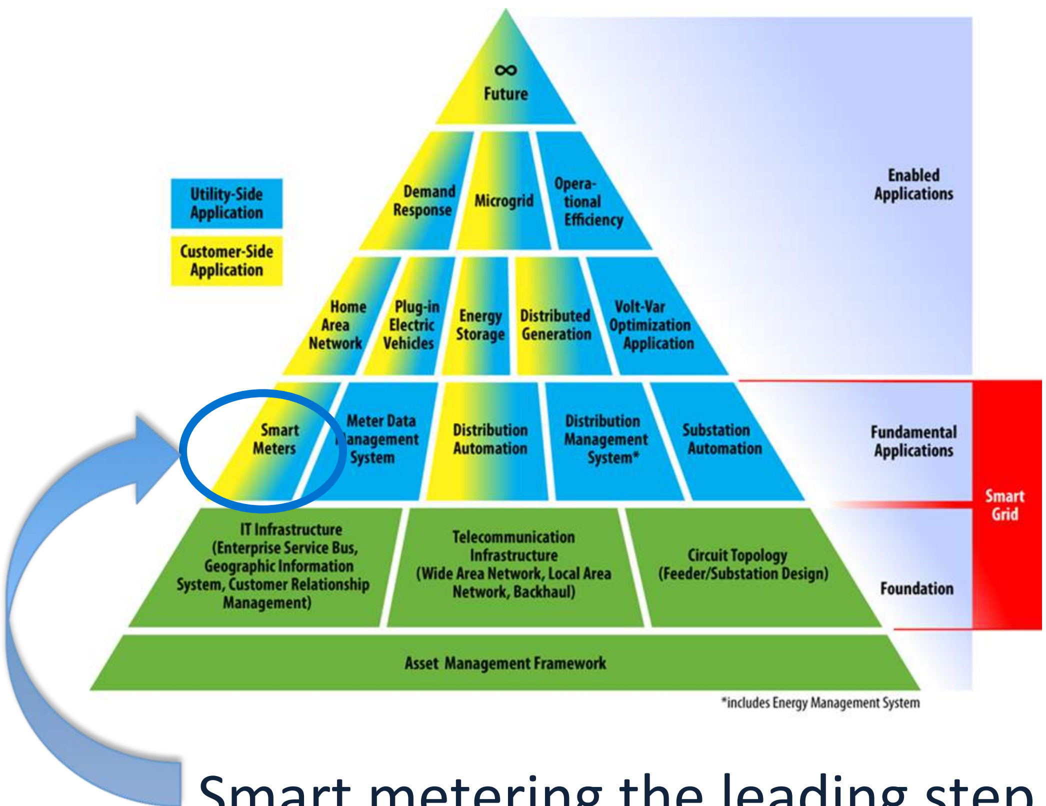
Opportunity to Modernize



Smart metering the leading step in modernizing the grid.

Smart Metering Program Scope

NEW METERS

- Upgrade old meters to smart meters
- Install meter communication network
- Implement automated data collection system



SYSTEM METERING

- Install distribution grid meters
- Develop theft analytics software
- Identify electricity loss, including diversion and theft


IN-HOME FEEDBACK TOOLS

- Launch new conservation website
- Introduce in-home display devices


GRID MODERNIZATION

- Support micro-grids, distributed generation
- Enable an intelligent, self-healing grid that can accommodate two-way flow of electricity



Network Design Philosophy

Reduced Total Cost of Ownership

Interoperability

Scalability

Standard-based

High availability

Multi-vendor

Resilient architecture

Multi-service Networks

Quality of Service

Network security & compliances

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BC Hydro Requirements

Requirements were driven by BC Hydro's service territory's size and remoteness, the ubiquitous coverage and cost of the smart metering network and our desire to do more than just read meters.

1. Flexible hardware and software platform that provides the following features to support the move into Smart Grid:
    - Capability for connecting Smart Grid field devices
    - Ability to support dynamic connectivity
    - Future mobile workforce capabilities
    - Multiple interface ports for connecting smart grid field devices including built in serial ports for legacy DA devices
    - Modular hardware with expansion slots for future interfaces and radios such as WiMax and 1901.2 PLC

BC Hydro Requirements

2. Network to be a carrier of multiple applications without having to traverse though metering head ends, including water and gas meters on isolated networks.

3. Security built directly into network layers resulting in a more accessible network for other applications.

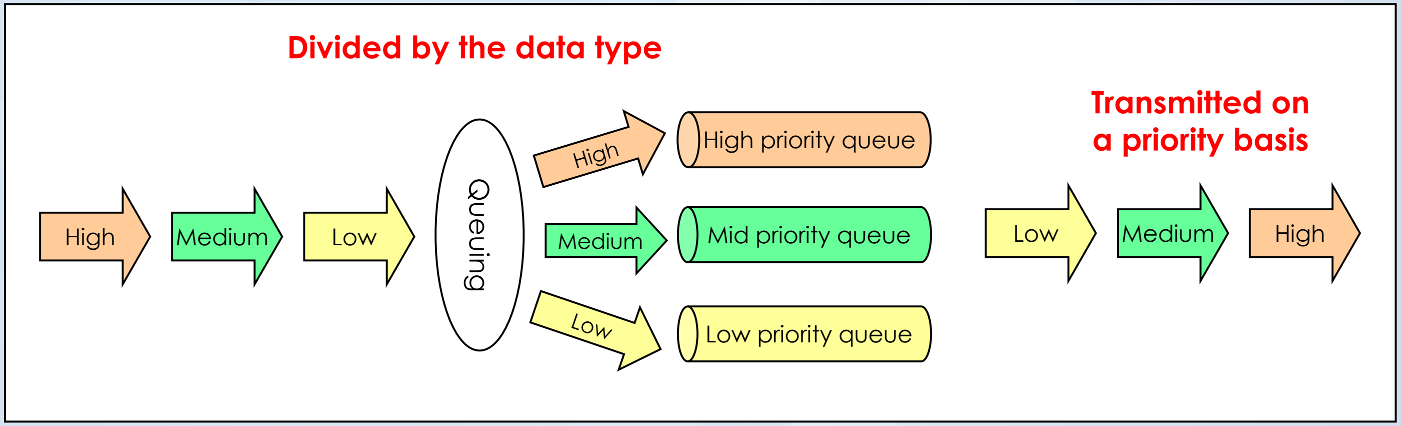
4. Open standards based protocols to future proof and allow network interoperability and development of 3rd party applications.

5. IPv6 capability and experience to move into next generation mesh IP routing protocols.

6. Robust traffic classification, congestion management and traffic conditioning.

BC Hydro Requirements

7. Quality of Service (QoS) to differentiate and prioritize different traffic types. Consistent end-to-end Quality of Service policies required to meet application SLAs.



8. Enhanced Network Management System to include IP management of millions of endpoints.

9. Secure peer-to-peer traffic.

Strategy: A Two Phase Deployment

Phase 1 IPv4:

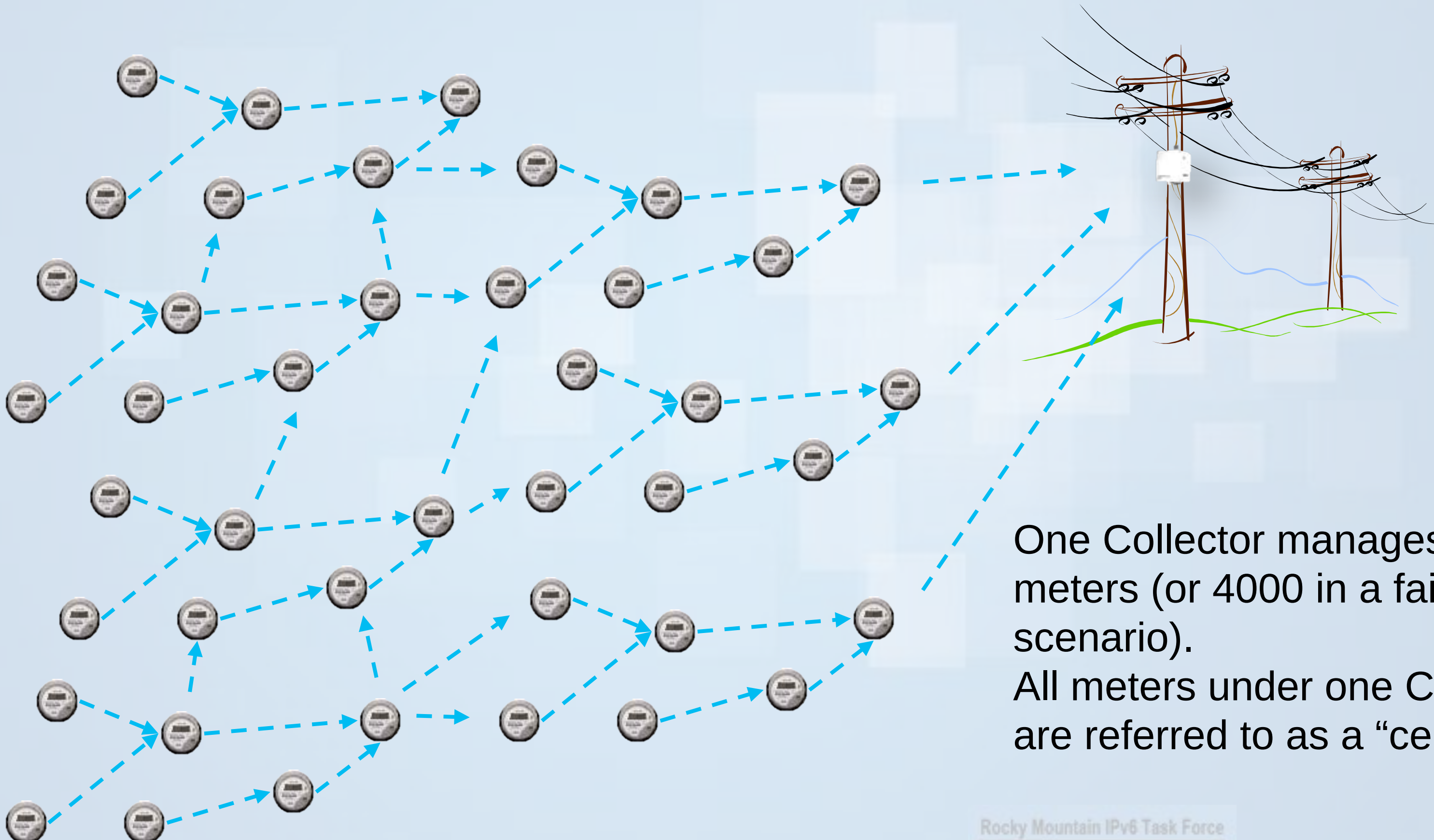
Complete

- CGRs deployed using IPv4 on WAN Backhaul and Head-end infrastructure
- Smart Meters mesh is proprietary non-IP 900Mhz in this phase
- The CGR act as an IPv4 proxy to the Itron Openway management system (ANSI C12.22 is encapsulated in IP by the CGR.)

Phase 2: IPv6

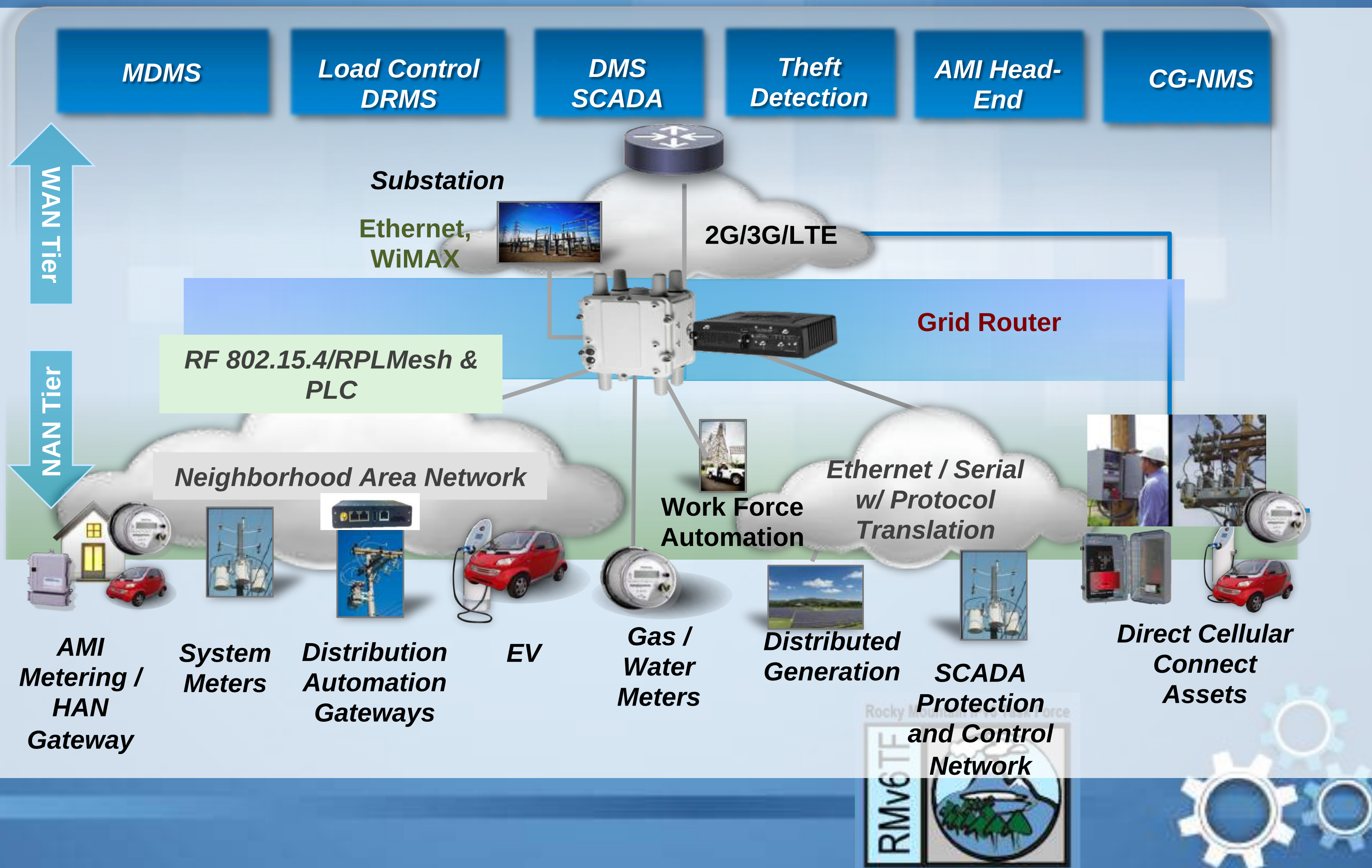
- Sets the stage for advanced business application – Distribution Automation, Volt VAR optimization, Energy Diversion Detection.
- Smart Meters will form a standards-based IPv6 IEEE 802.15.4g, RPL mesh.
- IPv6 traffic from will be tunneled over the IPv4 WAN backhaul to the head-end.
- Head-end will support dual stack.

Field Area Network Mesh Starting Point

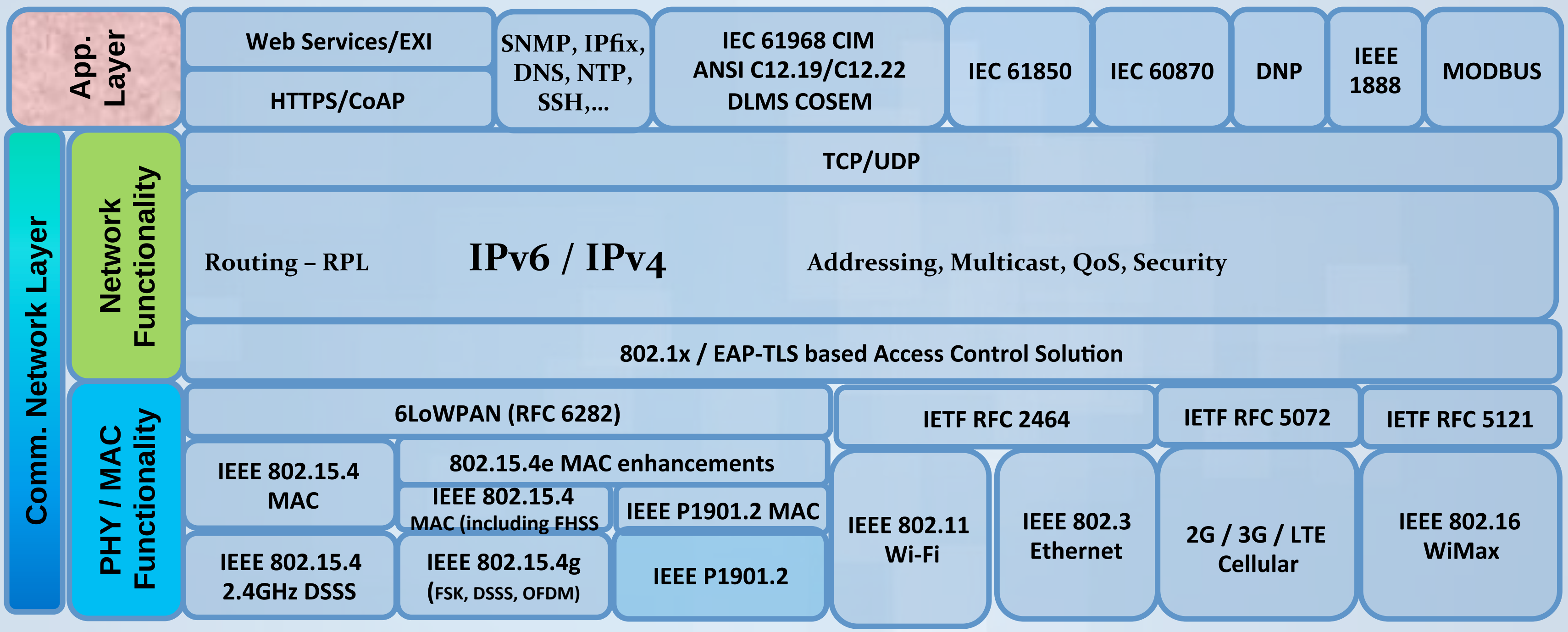


One Collector manages 2000 meters (or 4000 in a failover scenario).
All meters under one Collector are referred to as a “cell”.

Unified Field Area Network Architecture

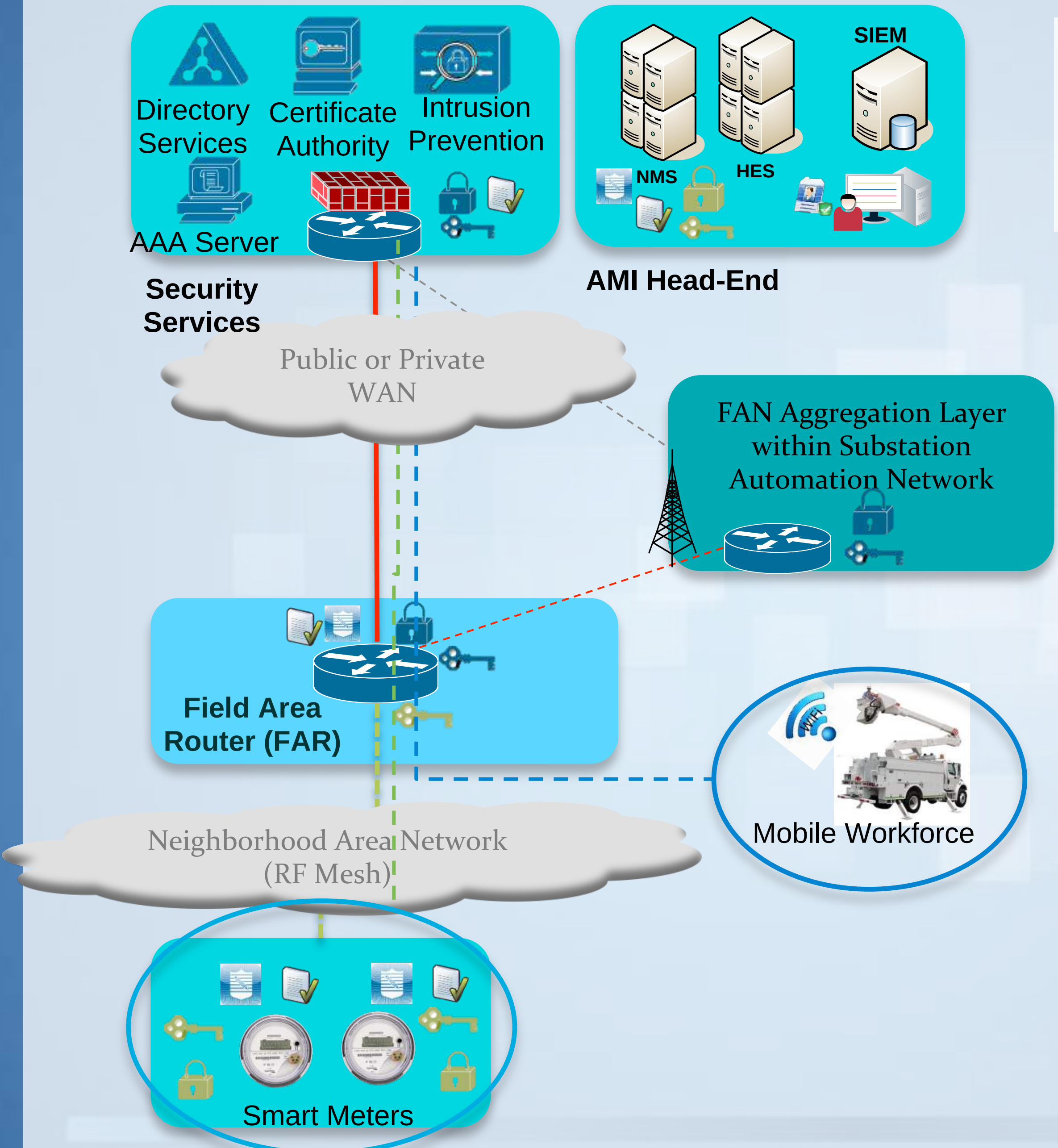


Open Standards Reference Model



- Standardization at all levels to ensure interoperability and reduce technology risk.
- Enables common application layer services over various wired and wireless communication technologies.

Security Architecture



- Secure storage for encryption keys
- Secure encryption keys
- Network-layer encryption (IPSec)
- Link-layer encryption (AES)
- Secure Device Identity via Digital Certificates
- Strong user identities with Role-Based Access
- Time-stamped logs, correlation at SIEM
- Separation of AMI vs. non-AMI traffic, segmentation

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Security Highlights

- Certificate-based identities, user names & passwords
- Role based Access Control
- 802.1x-based access control for meters, routers, grid devices
- Link-layer encryption in RF Mesh
- Group-based key generation and management (mesh)
- Network-layer encryption for WAN Backhaul (IPSec)

Current Project Progress

- Migration to IPv6
  - Gradual transition (completion planned for Q2 2015)
  - To date three cells have successfully migrated.
- WAN
  - WAN backhaul deployed with 3G cellular and BGAN satellite
  - Operationalizing 1.8Ghz WiMAX (and SCADA over WiMAX)
- Transition to multiservice grid network (MSGN)
  - Feeder meter and transformer meter are in field trial.
  - Developing Energy Analytics Suite for utilizing smart grid data starting with theft detection.
  - Testing DA use cases on IPv6 RF mesh ongoing in Smart Utility Lab.

Lessons Learned **Planning General**

- Ensure all licensing and agreements are in place with all vendors.
- Know what skillsets are needed and clear points of escalation with all vendors.
- Planning deployment process minimizing field technical requirements.
- Rigorous end-to-end testing in non-production environments.
- Early application testing in lab environment.

Lessons Learned Planning IPv6

- Provide IPv6 training to the broad project team members.
  - Practical training to cover differences with IPv4 world particularly on subnet masking.
- Device audits:
  - Ensure all network devices REALLY support IPv6. Many older devices do not support ALL IPv6 options such as multicast.
  - Expect and test for bugs in firmware and applications.
- Planning MTU size
  - Multiple layers add headers to increase the size of packets and fragmentation reduces efficiency.

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Lessons Learned **Architecture**

- Understand differentiation between the neighborhood area network (NAN) and wide area network (WAN)
- IP address plan
  - Develop an IPv6 address plan that satisfies all existing scenarios interfacing with corporate and operations network and evolves in the future.
  - Avoid just mapping your existing IPv4 plan to IPv6 and relying heavily on NAT solutions (except for integration of legacy assets).
- Dual stack in back end (servers and data centers)
- Develop a comprehensive routing plan
  - OSPF is used in data centers and BGP was selected for efficiency and BGP over OSPF IPv6 routing plan was developed.
- Build resilience and high availability particularly in back end.

Lessons Learned

Implementation and Operation

- Increased complexity for implementation and operations with Information, Telecom and Operating technologies
- Creativity a must with schedule- Learn to decouple and move forward
- Strict change management and stack alignment process to handle concurrent project and production
- Network management:
  - Platform compatibility may be an issue
  - Several management platforms complicates sustainment
- Challenging to upgrade a living system with such large scale that is constantly changing

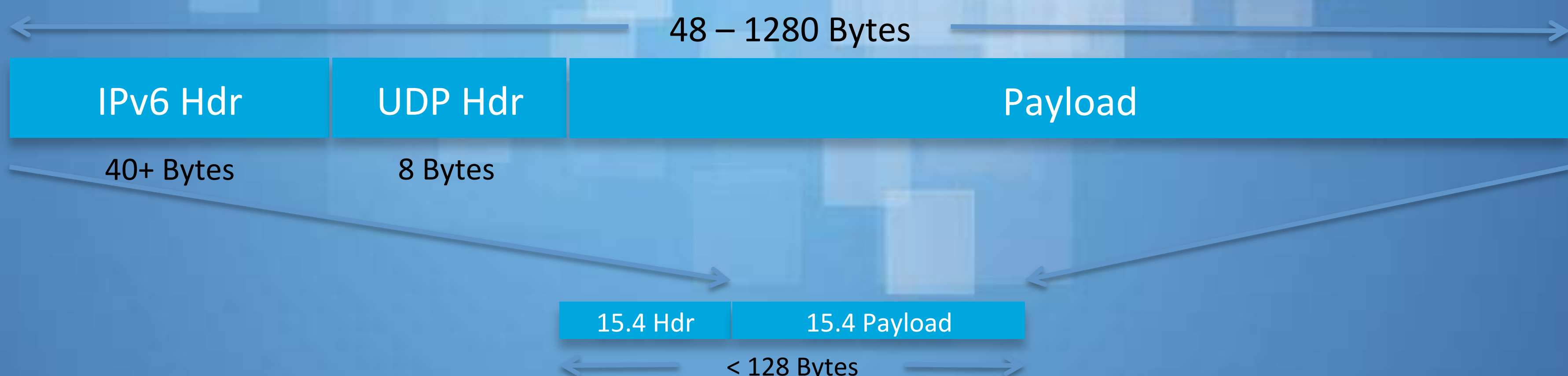
IPv6 Mesh Network Testing

- Packet size is extremely important to performance
- 6LowPAN introduces fragmentation
- The performance of the mesh depends on many factors including hop count and packet size
- Distribution Automation Devices is possible but understanding the traffic is key

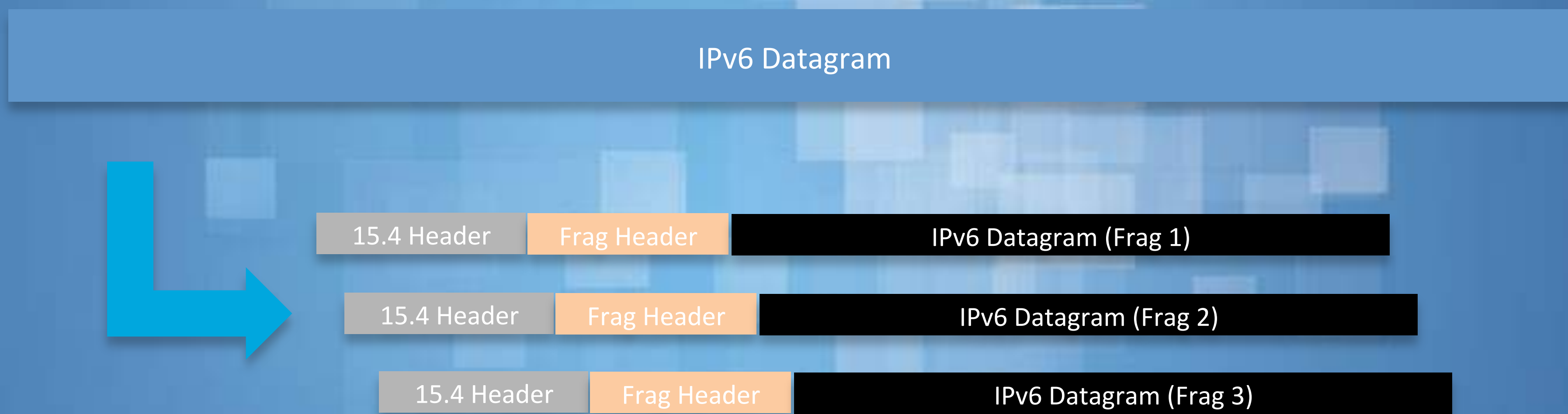
6LowPAN

Small IEEE 802.15.4 Link Frames

- RFC 2460 requires 1280 byte link MTU
- Relatively large UDP/IPv6 header (at least 48 bytes)



6LowPAN Fragmentation



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RPL – Routing for Sensor Networks

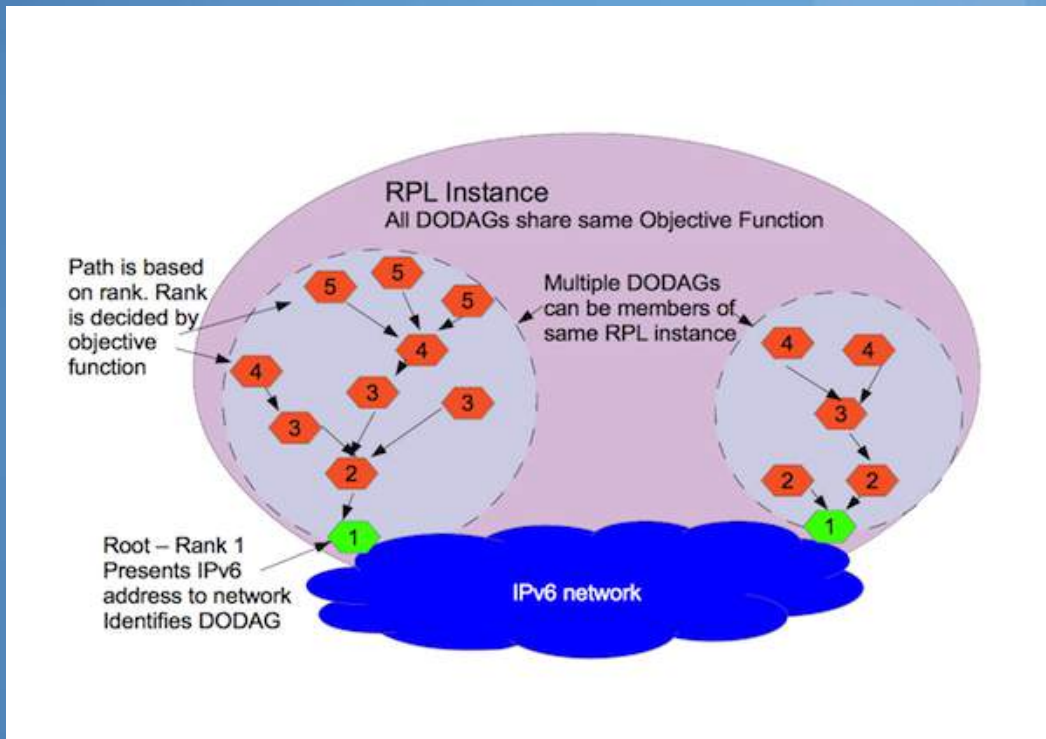
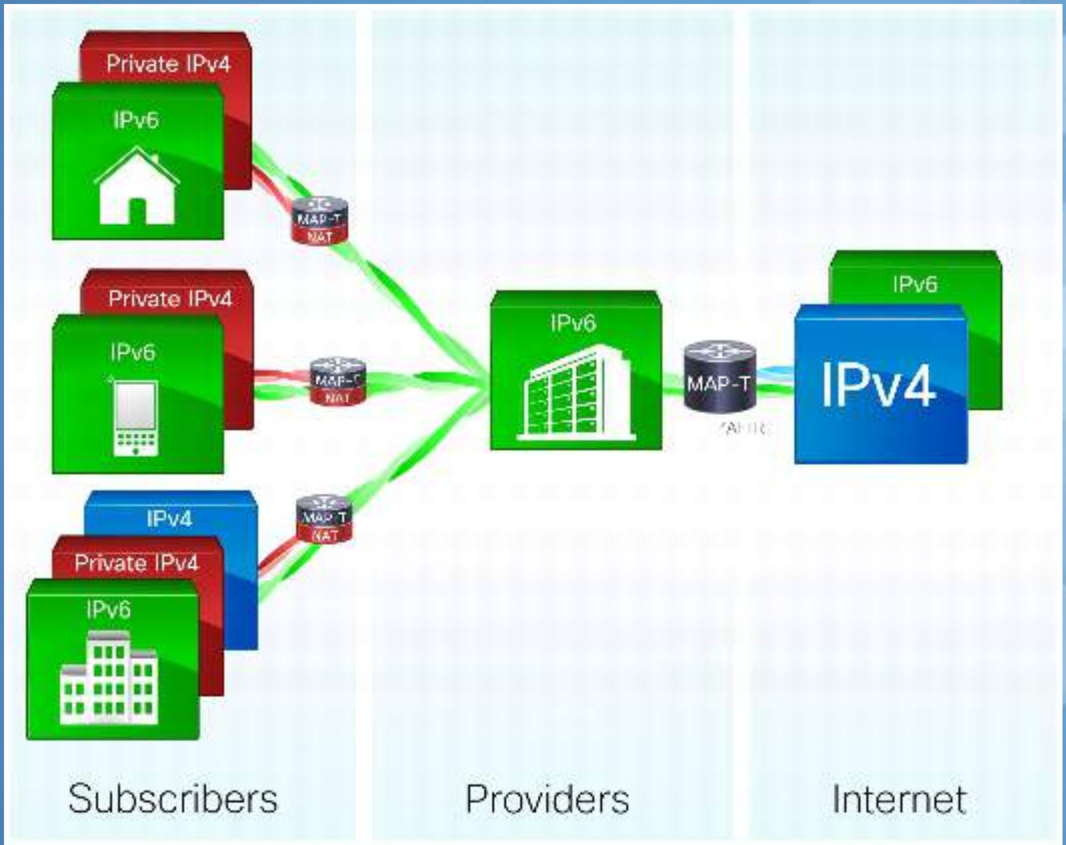


Image: Cisco, The Register

RPL assumes that:

- The sensors need to construct paths back to a control point of some kind;
- Some or all of the sensors are power-constrained; and
- Some sensors will lack a direct path to the control point, and will need other sensors to pass on their messages.

MAP-T IPv4 Legacy on IPv6



- utilizes stateless IPv4 to IPv6 translation (i.e. NAT64)
- customers see IPv6 and IPv4 services simultaneously
- MAP-T is attractive to those utilities with many IPv4 legacy devices

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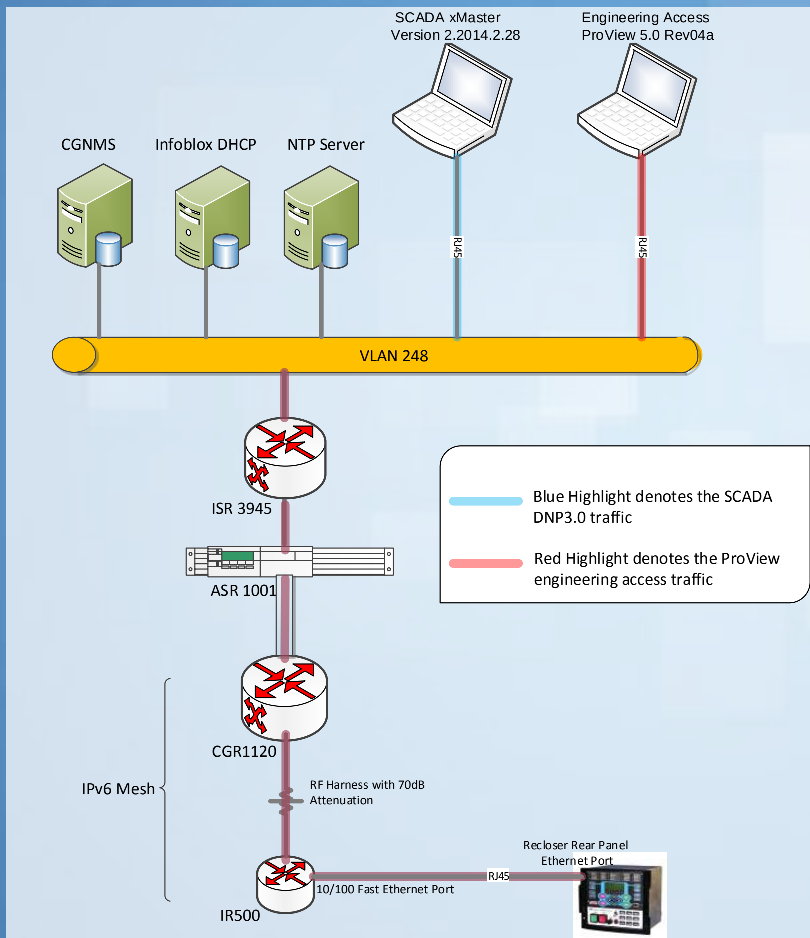
Distribution Automation Test Network



Conversion of IPv4 to IPv6 was necessary for the Distribution Automation devices to work.

Mapping was done in the IR500 DA Gateway

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Round Trip Time vs Packet Size

6LowPAN Fragmentation Starts {

Packet Size (bytes)	Packet Loss	Round-trip Ave (ms)	Round-trip Min (ms)	Round-trip Max (ms)
40	0%	155	89	688
64	0%	157	101	668
128	0%	235	149	1250
256	0%	423	370	1117
512	0%	457	320	1087
1024	0%	837	759	1415
1200	0%	908	843	1762
1300	0%	996	938	1560
1400	0%	1032	932	1788
1430	0%	1163	996	1963

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Packet Loss vs Hop Count

Packet loss (%) in forward direction

	Attempted Throughput [kbps]								
Packet size [bytes]	5	10	15	25	5	10	15	25	35
	2 hop depth				1 hop depth				
128	0.1%	29.0%	55%	73%	0.0%	0.4%	9%	34%	52%
256	0.0%	0.2%	29.0%	56%	0.2%	0.0%	0.0%	2%	27%
512	0.0%	0.1%	0.4%	34.0%	0.0%	0.1%	0.0%	0.0%	11%
700	0.0%	0.0%	0.7%	45.0%	0.0%	0.2%	0.0%	0.0%	10%

Packet loss color code

- 1%<Pck loss<25%
- 25%<Pck loss<50%
- 50%<Pck loss<75%
- 75%<Pck loss<100%

Attempted packets per second

	Attempted Throughput [kbps]								
	2 hop depth				1 hop depth				
Packet size [bytes]	5	10	15	25	5	10	15	25	35
128	**4.9**	9.8	14.6	24.4	4.9	**9.8**	14.6	24.4	34.2
256	2.4	**4.9**	7.3	12.2	2.4	4.9	**7.3**	12.2	17.1
512	1.2	2.4	**3.7**	6.1	1.2	2.4	3.7	**6.1**	8.5
700	0.9	1.8	**2.7**	4.5	0.9	1.8	2.7	**4.5**	6.3

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TCP vs UDP for Distribution Automation

TCP Traffic between Recloser controller and xMaster	One Integrity Polling Capture	
	TCP	UDP
Total packet number	4	2
Time (sec)	0.501	0.159
Avg. packets/sec	7.979	12.550
Avg. packet size (Bytes)	123.5	175.0
Total transmitted data(Bytes)	494	350
Throughput (Bytes/Sec | kbps)	985	7.7	2196	17.2

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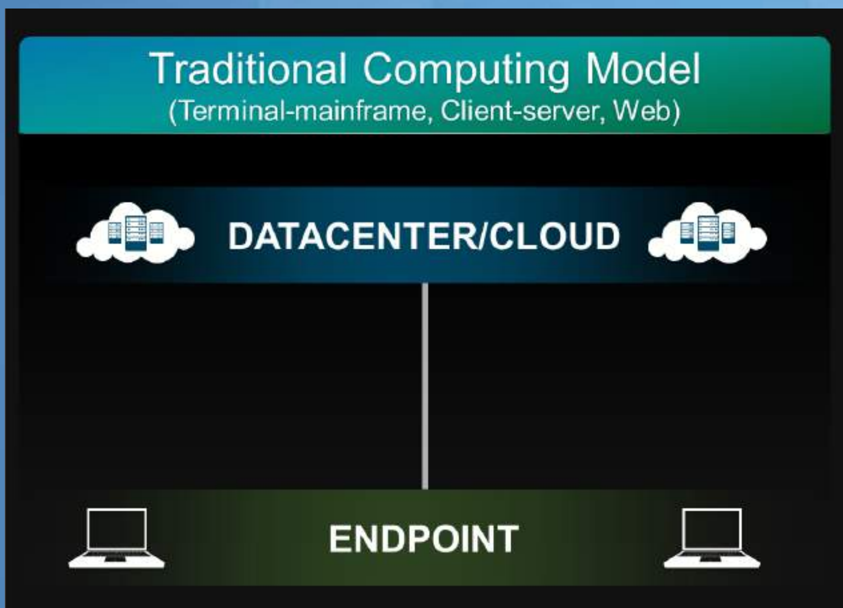
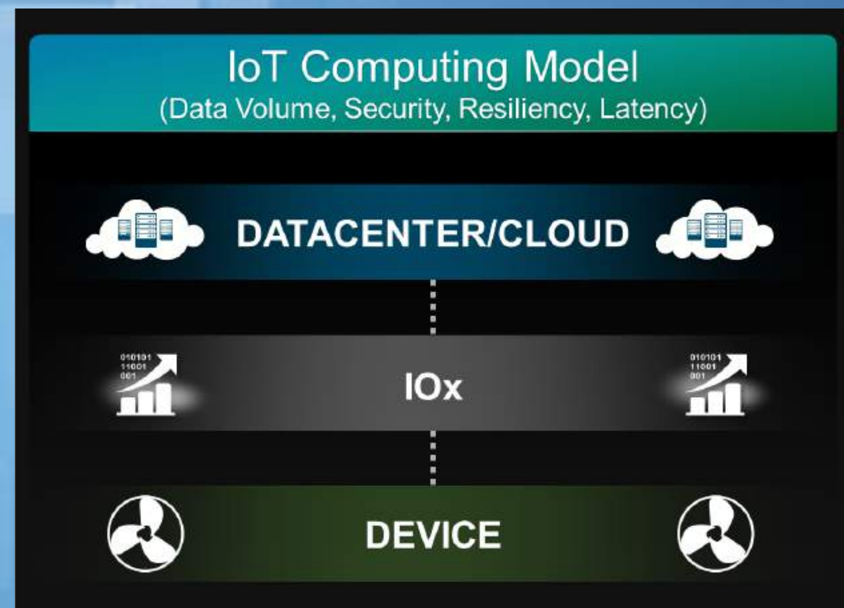
Future of the Mesh for Utilities





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More Logic Near the Edge

- Perform localized/distributed SCADA at the edge
- Test mesh performance from the edge
- Only send back required data to the backend systems

Thank you

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