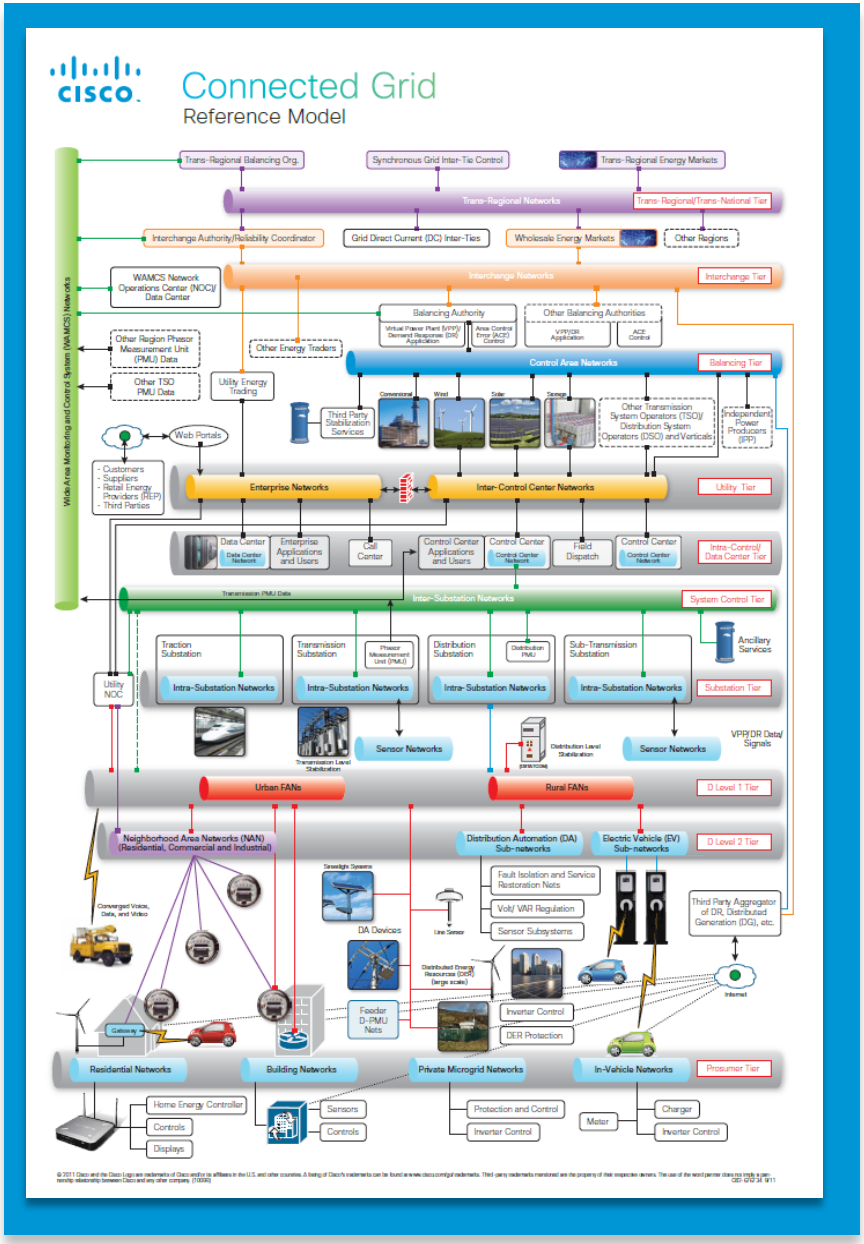
Cisco Connected Energy Network Field Area Network Overview

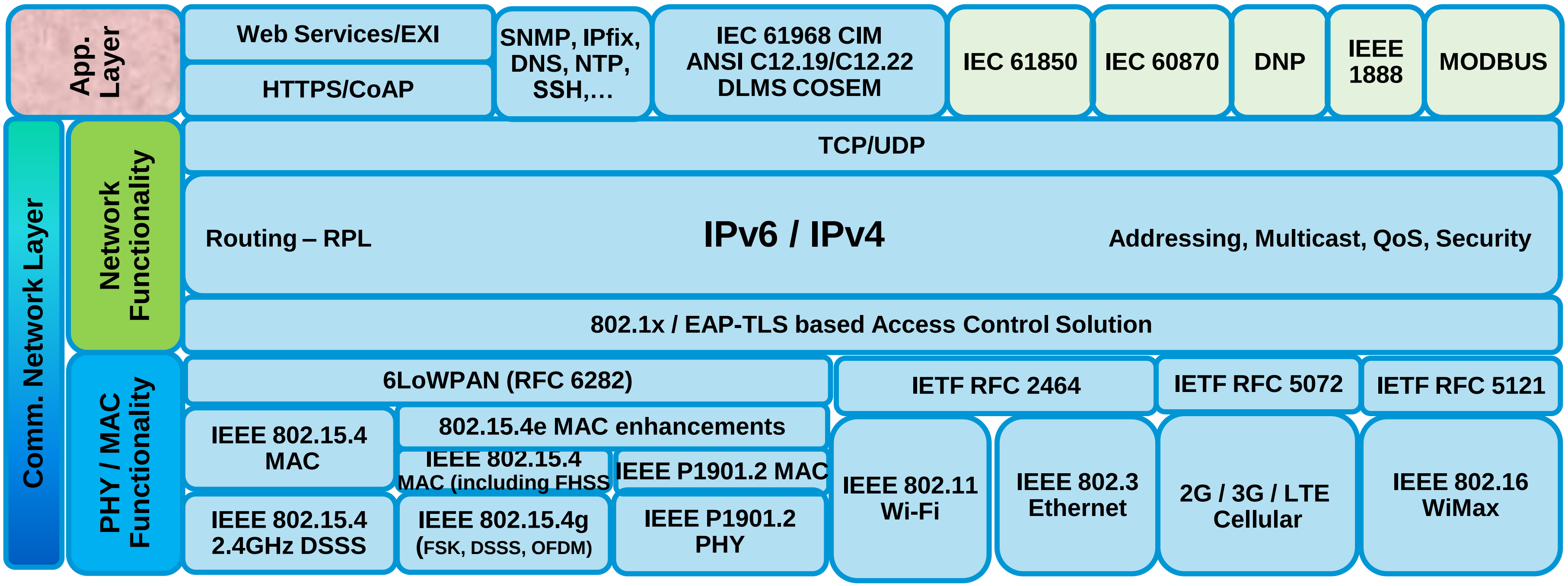
GridBlocks™ Reference Model

- Describes the power delivery chain
- Architectures detail networking each of the eleven tiers in this model
- Results in a complete end-to-end architecture for converged power delivery chain communications
- Framework for
    - Integrating legacy devices
    - Using existing products in new ways
    - Integrating new ecosystem partners
    - Developing new products and services
- Provides a platform for innovation



Open Standards Reference Model

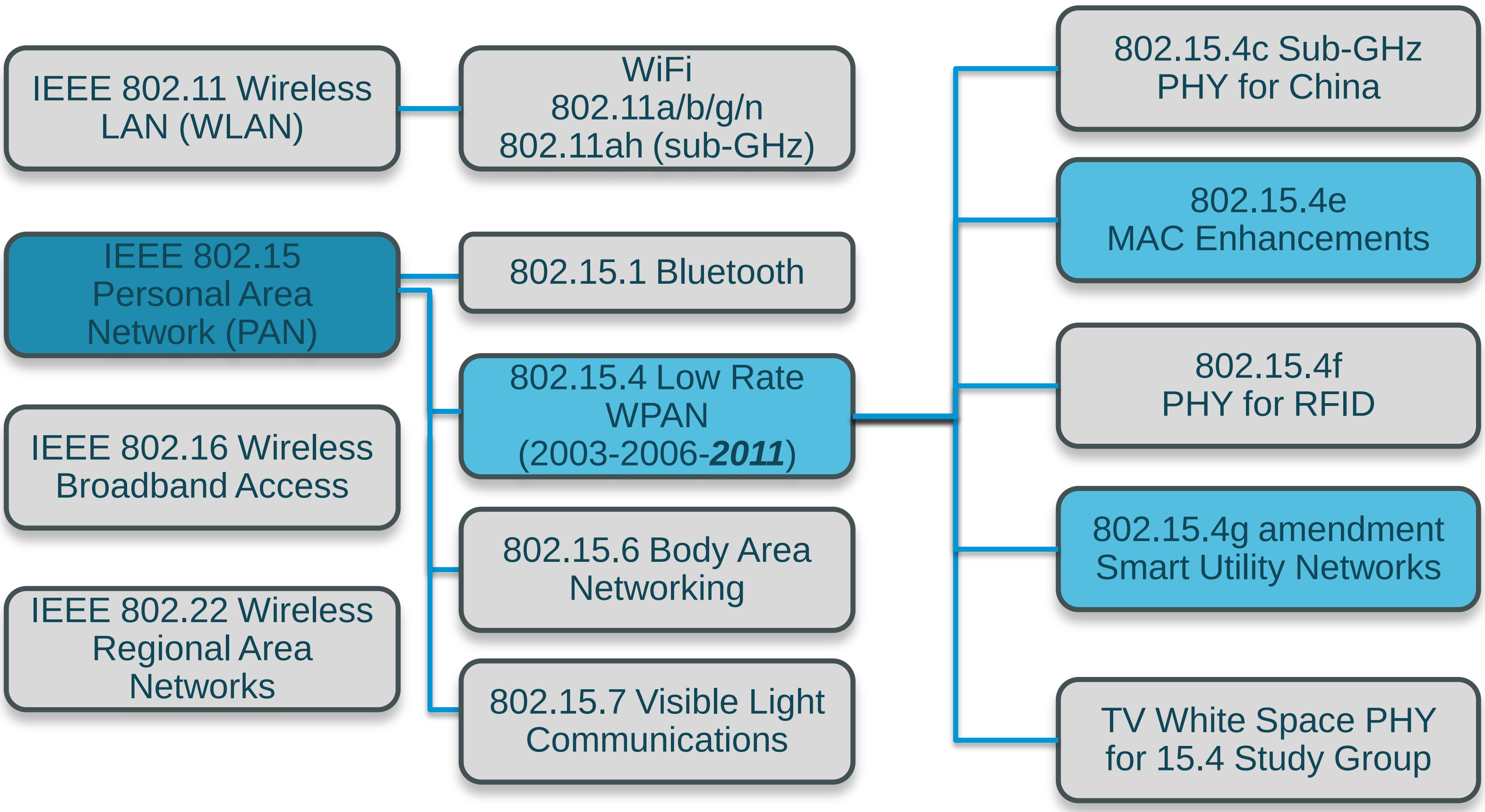
弊社では以下プロトコルがSmartGridでは最適と考え、国内外含め適用に関して活動しております。



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

IEEE Wireless Standards

無線区間部分では、干渉や到達性、安全性、消費電力の改善等を目指した802.15.4の適用が最適と考えます。



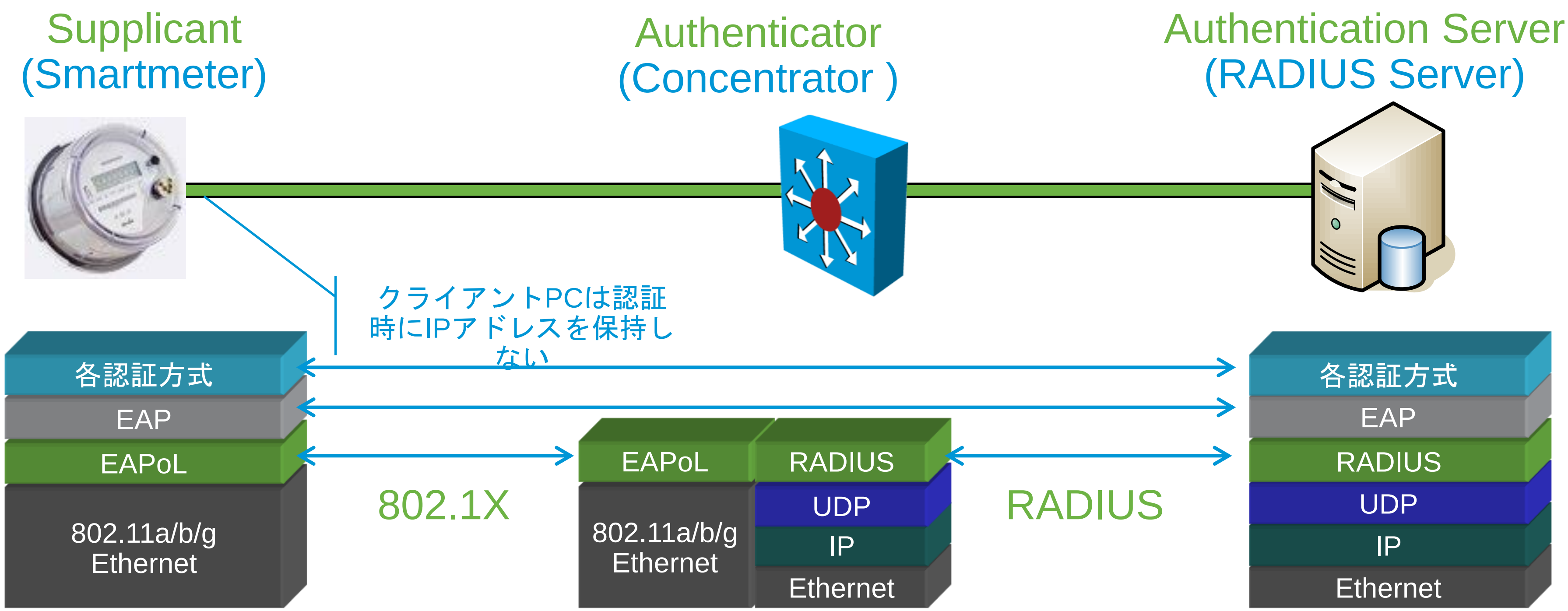
IEEE 802.15.4g – Smart Utility Networks

- SUN 802.15.4g-compliant devices shall at least implement one of these 3 new PHYs modes
  - multi-rate and multi-regional frequency shift keying (MR-FSK) PHY,
  - scalable orthogonal frequency division multiplexing (OFDM) PHY
  - multi-rate and multi-regional offset quadrature phase-shift keying (MR-O-QPSK) PHY.
- 15.4g addresses regional regulations by adding support for new frequencies including sub-GHz frequency bands, also increasing the channel numbering capability defined in 802.15.4-2006
  - 868–868.6 MHz, 902–928 MHz, 2400–2483.5 MHz,
  - 314–316 MHz, 430–434 MHz, and 779–787 MHz band for LR-WPAN systems in China,
  - 915-928 MHz in Japan (Effective in July 2012) Previously 950–956 MHz in Japan.
- Over-the-air data rate of at least 40 kb/s but not more than 1000 kb/s
  - dependent from the radio frequency and coding of each PHY
- Simultaneous operation for at least 3 co-located orthogonal networks
- PHY frame sizes can now be up to 2047 bytes and 32 bits CRC

IEEE 802.15.4e

- Amendment to the 802.15.4-2006 MAC needed for the applications served by
  - 802.15.4f PHY Amendment for Active RFID
  - 802.15.4g PHY Amendment for Smart Utility Networks
  - Industrial applications (such as those addressed by HART 7 and the ISA100 standards)
- **Security**: support for secured ack
- **Low Energy MAC extension** – Coordinated Sampled Listening (CSL
- **Channel Hopping** – but not built-in, as to get designed by vendor
- **New Frame Types**
  - Enhanced (secure) Acknowledgement (EACK)
  - Enhanced Beacon and Beacon Request (EB and EBR)
  - Optional Information Elements (IE)

802.1X/EAP-TLS



Smartmeterと 認証サーバ 間での認証情報の交換には EAP を利用(証明書を使う場合はEAP-TLS)

EAP は IEEE802.11b やイーサネット、無線などの上で運ばれる

EAP は RADIUS プロトコルの上で運ばれる

What is 6LoWPAN

- IETF WG – IPv6 over Low power Wireless Personal Area Networks
  - Adaptation layer for IPv6 over IEEE 802.15.4
  - Also adopted by IEEE P1901.2 PLC, Bluetooth Low Energy, DECT Ultra Low Energy (ULE)
- Header Compression Format for IPv6 Datagrams in 6LoWPAN Networks
  - Before 15.4g, 15.4 only supports 127 bytes frame size
  - Even if 15.4g enables larger frame size, bandwidth optimization is still required
  - RFC 6282 obsoletes RFC 4944
- Fragmentation
  - on IPv6, fragmentation is handled on end-nodes or by Layer 2

IEEE 802.15.4上でIPv6を使用するための規格。以下機能を策定
・パケット断片化/再構成
・ヘッダ圧縮 (40バイトが最大3バイト)
・近隣発見の最適化(Multicastの抑制)

6LoWPAN – RFC 6282

- LoWPAN_IPHC = IPv6 Header Compression
  - Use additional 5 bits from Dispatch
  - 2 bytes for basic compression, 3 bytes with Context encoding
- LoWPAN_NHC = Next Header Compression
  - Currently defined IPv6 option and UDP (1 byte) headers

Dispatch + LoWPAN_IPHC	In-line IPv6 header	LoWPAN_NHC encoding	In-line Next Header Field	Payload

- Other 6LoWPAN WG items
  - RFC 4919 – Overview, Assumptions, Problem Statement, and Goals
  - draft-ietf-6lowpan-nd-17 – Neighbor Discovery Optimization
  - And more on http://datatracker.ietf.org/wg/6lowpan/
- **CG Endpoint stack implements RFC 6282**

Low Power and Lossy Networks (LLNs)

- Networks made up of many embedded devices with limited power, memory, and processing resources.
  - Such as smart meters, actuators, relays, sensors, etc
- Can be interconnected by a variety of data links, such as
  - IEEE 802.15.4, IEEE P1901.2 PLC, Bluetooth, IEEE 802.11ah, DECT LE, etc.
- LLNs have at least 5 distinguishing characteristics requiring a specific IP routing protocol to be designed
  - LLNs operate with a hard, very small bound on state.
  - In most cases, LLN optimize for saving energy – new routing metric needed
  - Typical traffic patterns are not simply Unicast flows (e.g. in some cases most if not all traffic can be point to multipoint).
  - In most cases, LLNs will be employed over link layers with restricted frame-sizes, thus a routing protocol for LLNs should be specifically adapted for such link layers
  - LLN routing protocols have to be very careful when trading off efficiency for generality; many LLN nodes do not have resources to waste.

IPv6 Routing Protocol for LLNs (RPL)

IETF RoLL WG

コンセントレーター及びスマートメーターに実装して使用する
無線マルチホップ用ルーティングプロトコルです。
現在のところ唯一の標準化技術となります。

- IETF WG Formed in Jan 2008 and already re-chartered
  http://www.ietf.org/html.charters/roll-charter.html
  Co-chairs: JP Vasseur (Cisco), David Culler (UC Berkeley)

- Mission: To define routing solutions for LLNs

- First, documented the Use Cases and Applications requirements
  RFC 5548 – Urban (include Smart Metering)
  RFC 5673 – Industrial
  RFC 5826 – Home Automation
  RFC 5867 – Building Automation

- Then, selected and specified the routing protocol for LLNs
  IPv6 Routing Protocol for LLNs (RPL) adopted as WG document from several proposals

core specは、RFC6550として発行済

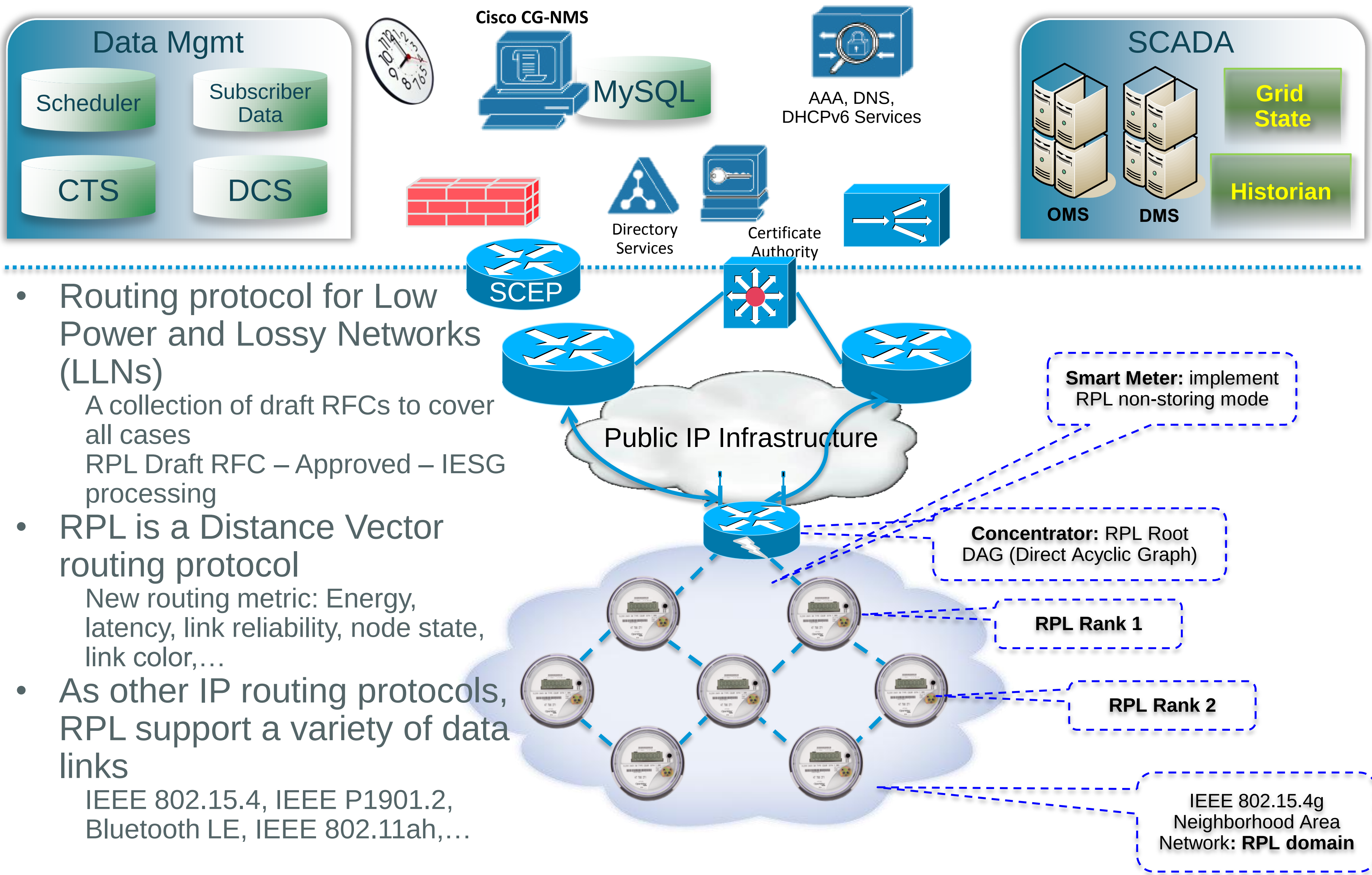
IETF RoLL documents

- RFC 6550 RPL: IPv6 Routing Protocol for Low power and Lossy Networks
- RFC 6206 The Trickle Algorithm
- RFC 6552 RPL Objective Function 0
- RFC 6551 Routing Metrics used for Path Calculation in Low Power and Lossy Networks
- draft-ietf-roll-applicability-ami Applicability Statement for RPL in AMI Networks
- draft-ietf-roll-security-framework A Security Framework for RPL
- draft-tripathi-roll-rpl-simulation-08 Performance Evaluation of RPL
- draft-ietf-roll-terminology Terminology in Low power And Lossy Networks
- draft-ietf-roll-minrank-hysteresis The Minimum Rank Objective Function with Hysteresis

RPL Implementation

RPL使用イメージ

コンセントレーター１台当たり最大で5,000台のスマートメーターを収容可能です



- Routing protocol for Low Power and Lossy Networks (LLNs)
  - A collection of draft RFCs to cover all cases
  - RPL Draft RFC – Approved – IESG processing
- RPL is a Distance Vector routing protocol
  - New routing metric: Energy, latency, link reliability, 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,…

Leveraging IPv6 Network Services

IPv6を使用する様々なプロトコルも適用可能と考えます

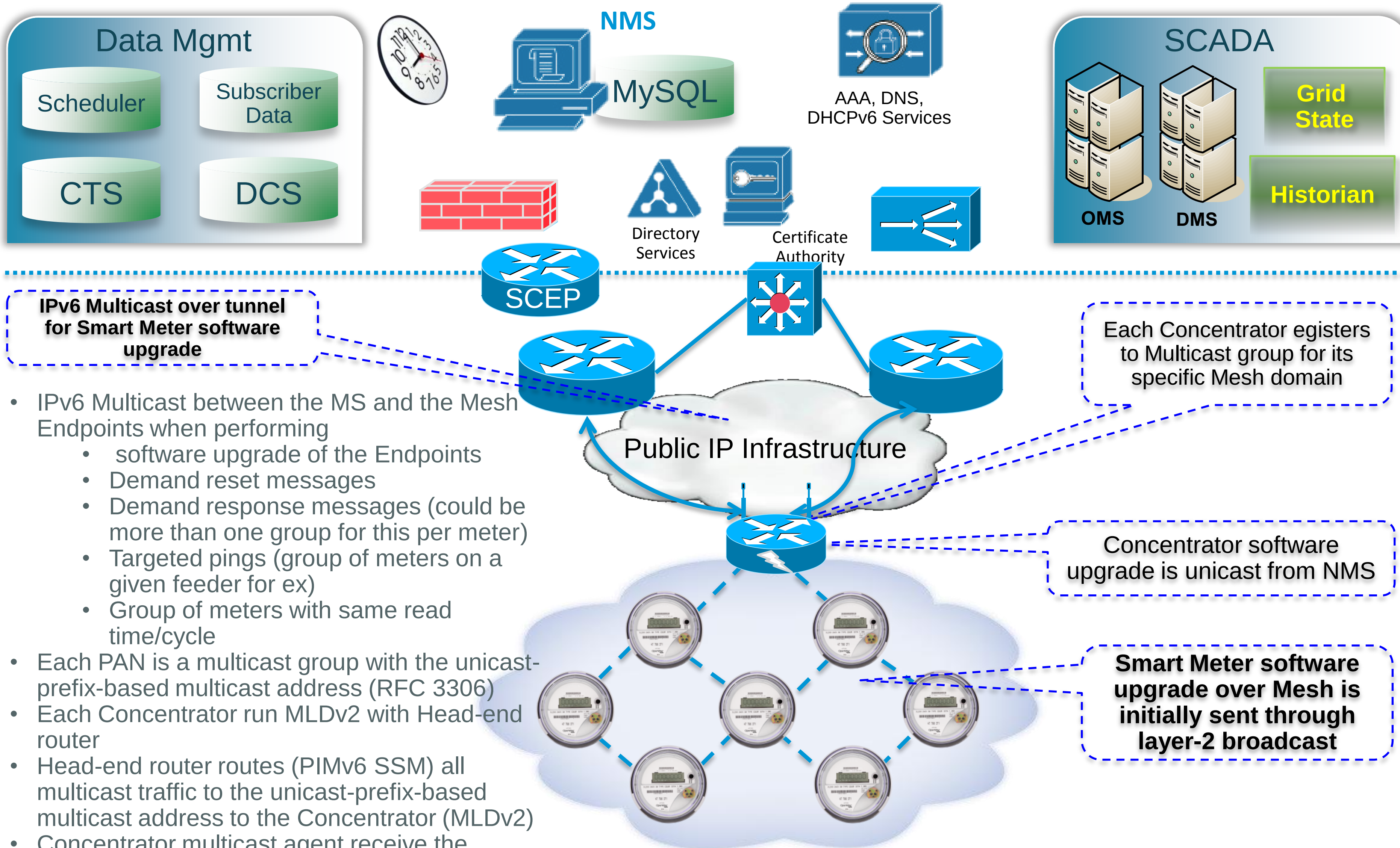
Multi-Services Infrastructure

Non metering functionality migrating out of the application layer to Network services

IP Services	IPv6	Benefits
Addressing	**128 bits, multiple scopes (global, private, link-local,…)**	Large address space, public or private infrastructure
Address Auto-configuration	**Stateless**, DHCP**v6**, **renumbering, DHCPv6 Prefix Delegation**	Zero-touch configuration
Data Link Adaptation layers	Ethernet, WiFi, ATM, FR, PPP, Sonet/SDH, **6LoWPAN (802.15.4g, 1901.2)**,…	Media Diversity
Routing	RIP, OSPF, IS-IS, E-IGRP, MP-BGP, **RPL**	Reachability
IP Network & transport layer Security	IPsec, TLS/DTLS, Filtering (firewall)	Security, Data Integrity
Multicast	**MLD**/PIM/Multicast MP-BGP, **Scope Identifier**	Software upgrade, Demand/Response, Dynamic pricing
QoS	IPv6 QoS Differentiated Service	Multi-Services network, SLA
Time Distribution	NTP version 4	Secured Time Synchronization
Management	DNS, IPfix/PSAMP, SNMP, **CoAP**…	Push/Pull Mgmt model, scalable end-points mgmt

Multicasting in Mesh

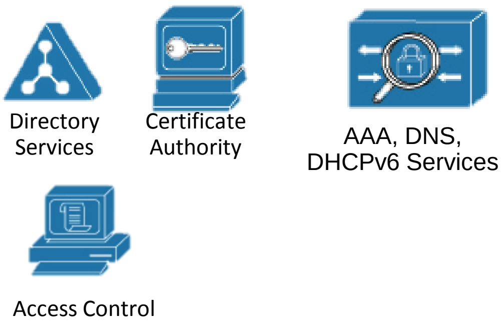
Multicastを使用したソフトウェア更新の例

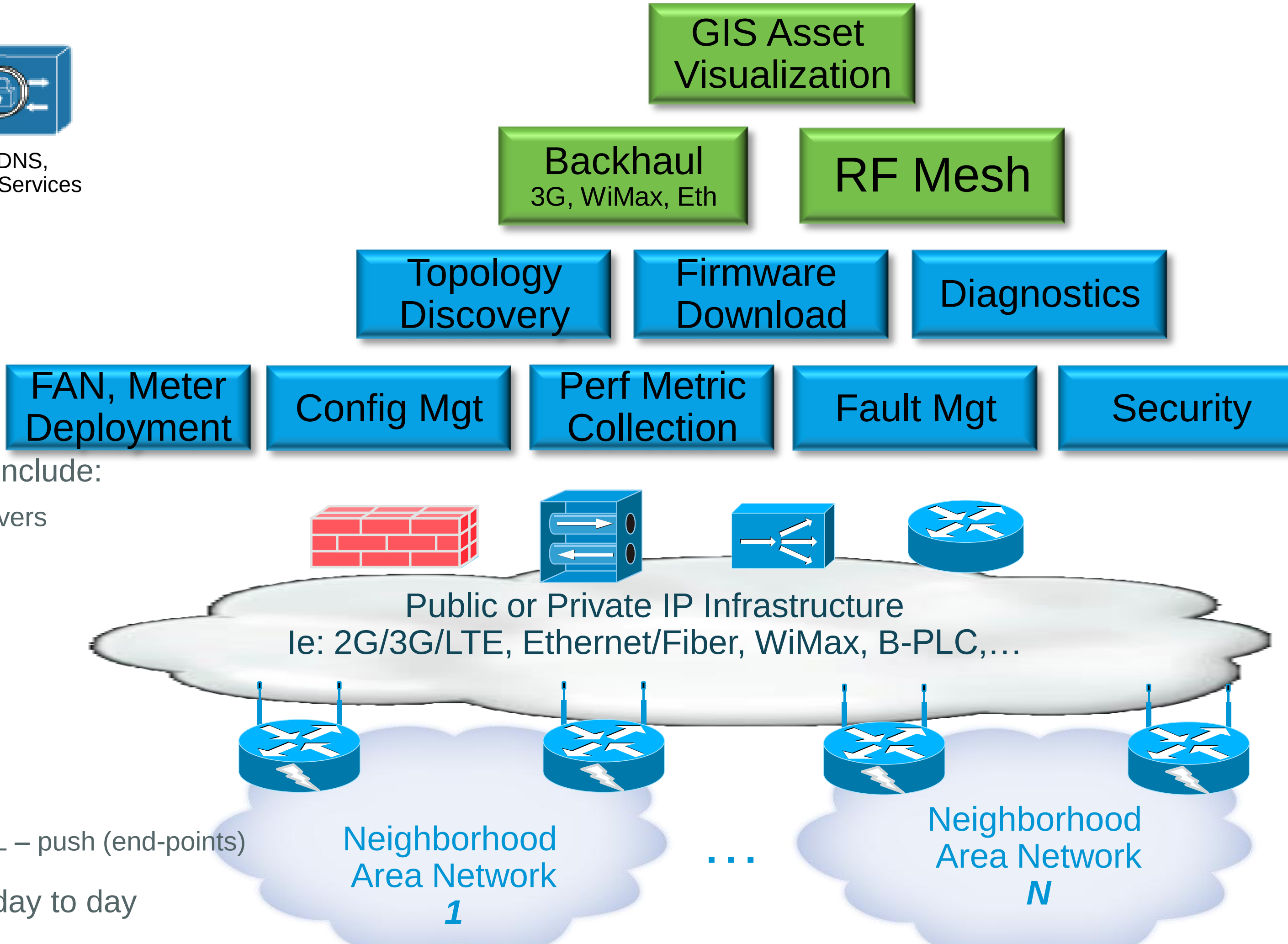


- IPv6 Multicast between the MS and the Mesh Endpoints when performing
  - software upgrade of the Endpoints
  - Demand reset messages
  - Demand response messages (could be more than one group for this per meter)
  - Targeted pings (group of meters on a given feeder for ex)
  - Group of meters with same read time/cycle
- Each PAN is a multicast group with the unicast-prefix-based multicast address (RFC 3306)
- Each Concentrator run MLDv2 with Head-end router
- Head-end router routes (PIMv6 SSM) all multicast traffic to the unicast-prefix-based multicast address to the Concentrator (MLDv2)
- Concentrator multicast agent receive the multicast packets and Layer 2 broadcast into the mesh

Network Management

SNMPベースの管理に加え、無線区間に最適化された標準プロトコルCoAPベースの管理もご検討すべきと考えます



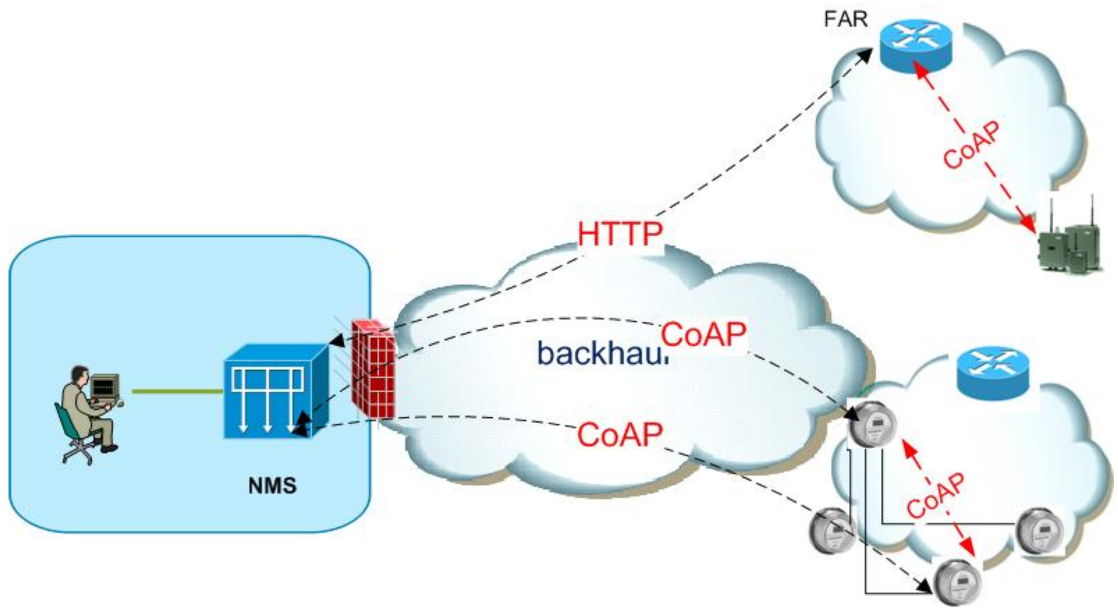


- Information System must include:
  - Scalable DNS/DHCPv6 Servers
  - AAA server
  - CA/RA server
  - NMS
  - NTP source & server
- Push vs Pull mode
  - SNMP – pull (router)
  - IPFix/PSAMP or COAP/XML – push (end-points)
- Basic IP tools simplifying day to day operations
  - Ping, Traceroute,…

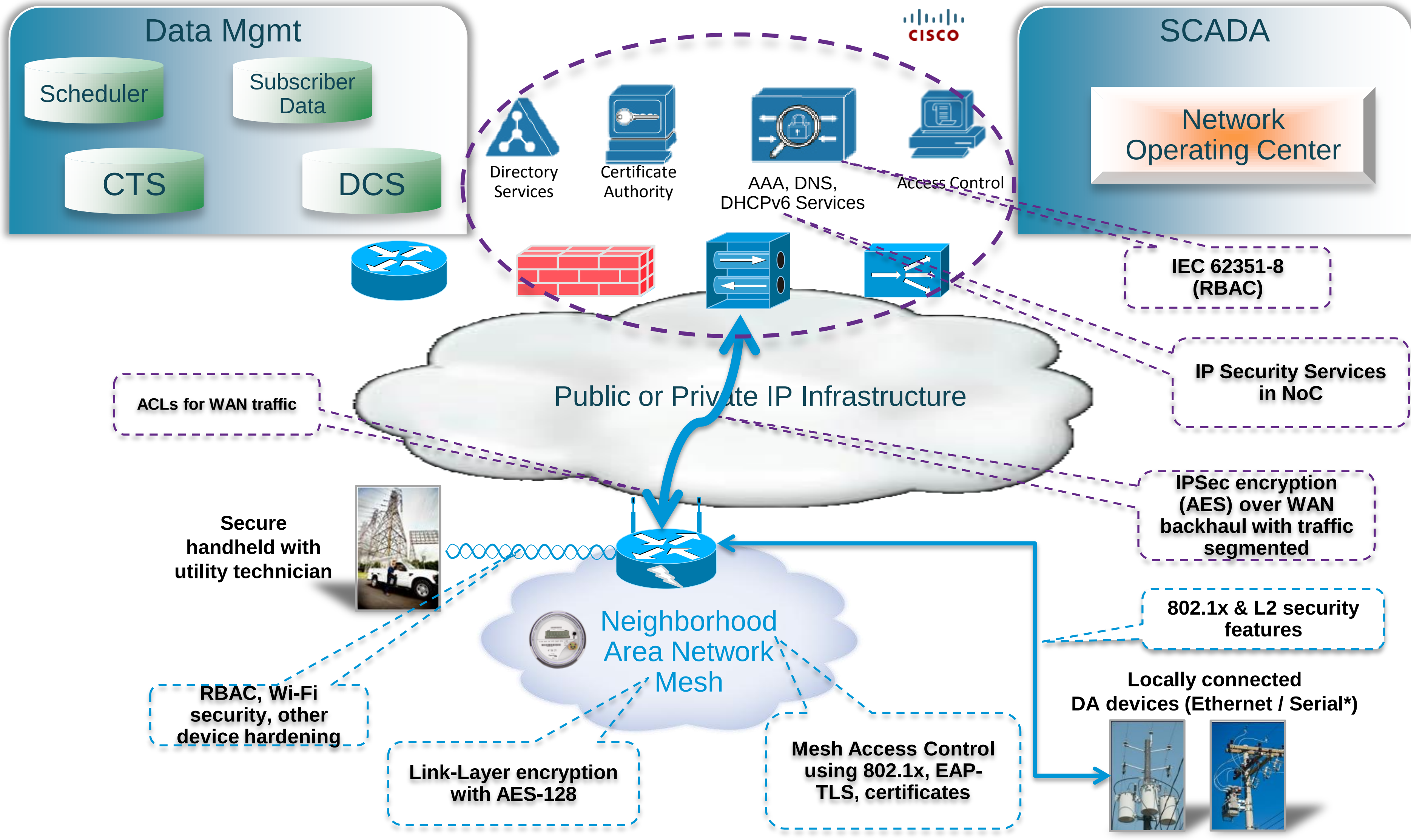
CoAP (Constrained Application Protocol)

- IETF CoRE WG
- Device constraints
  - Microcontrollers
  - Limited RAM and ROM
- Network Constraints
  - Low data rate
- Request/Response
- Small Message Overhead
- Supports Multicast
- Supports Asynchronous Messaging

```
Client              Server      Client              Server
   |                  |            |                  |
   |   CON tid=47     |            |   CON tid=53     |
   |    GET /foo      |            |    GET /baz      |
   +----------------->|            +----------------->|
   |                  |            |                  |
   |   ACK tid=47     |            |   ACK tid=53     |
   |  200 "<temp...   |            |  404 "Not...     |
   |<-----------------+            |<-----------------+
   |                  |            |                  |
```

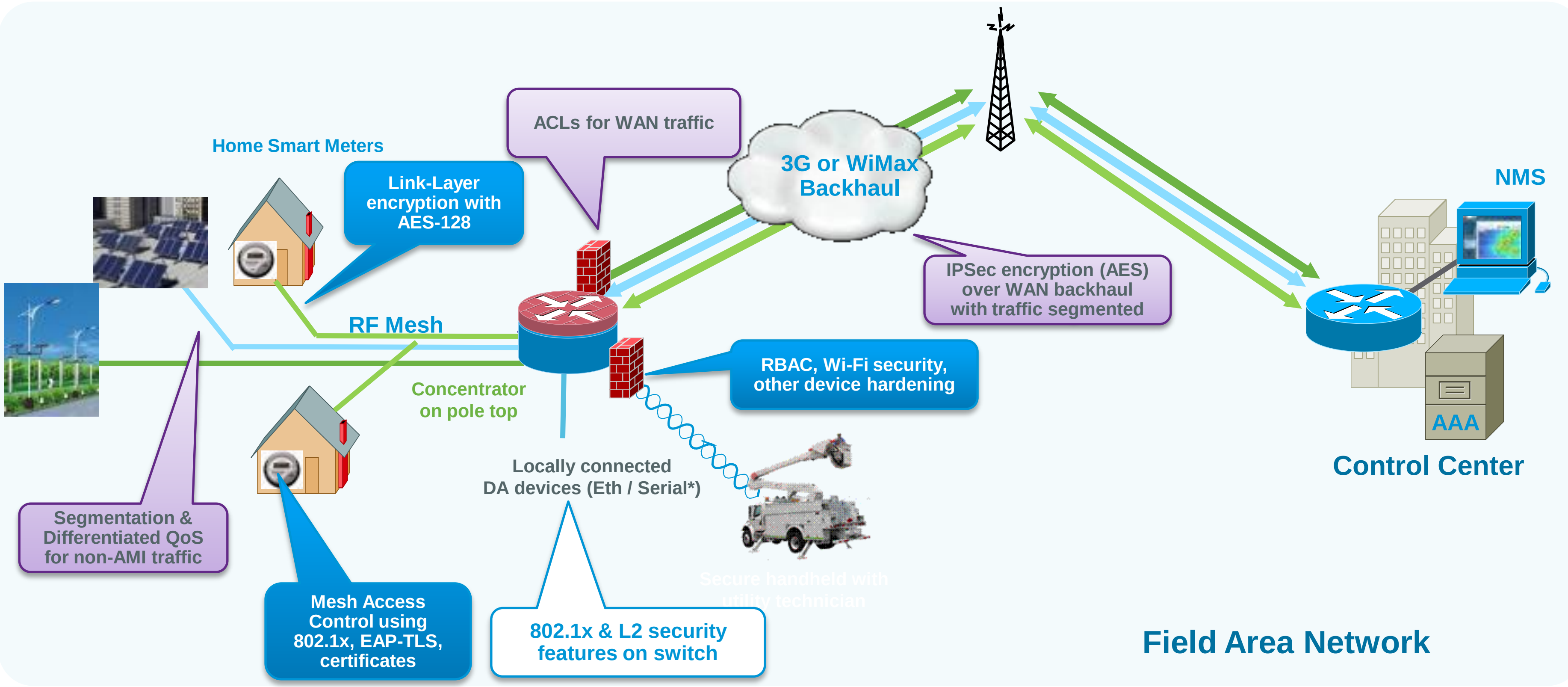


Security & Security Management



L2, L3通信の保護、機器やアプリケーションのアクセスコントロールなど、標準化された技術で実現可能です

Connected Grid Architecture
Security for Field Area Network



- Segmentation & Differentiated QoS for traffic within NAN Mesh & WAN by use of GRE
- Access Control in the mesh using 802.1x, EAP-TLS and Secure Device Identity (X.509 certificates)
- Link-layer encryption using on RF Mesh link towards the meter (AES) using group mesh keys
- Network-layer encryption (IPSec) on 3G backhaul to the utility control center
- 802.1x & L2 security features for devices in secondary substation
- Role-based access control (RBAC), Wi-Fi security on hardened Field Area Router (FAR)
- Access Control Lists to filter traffic between zones in FAN

Mesh Security Features

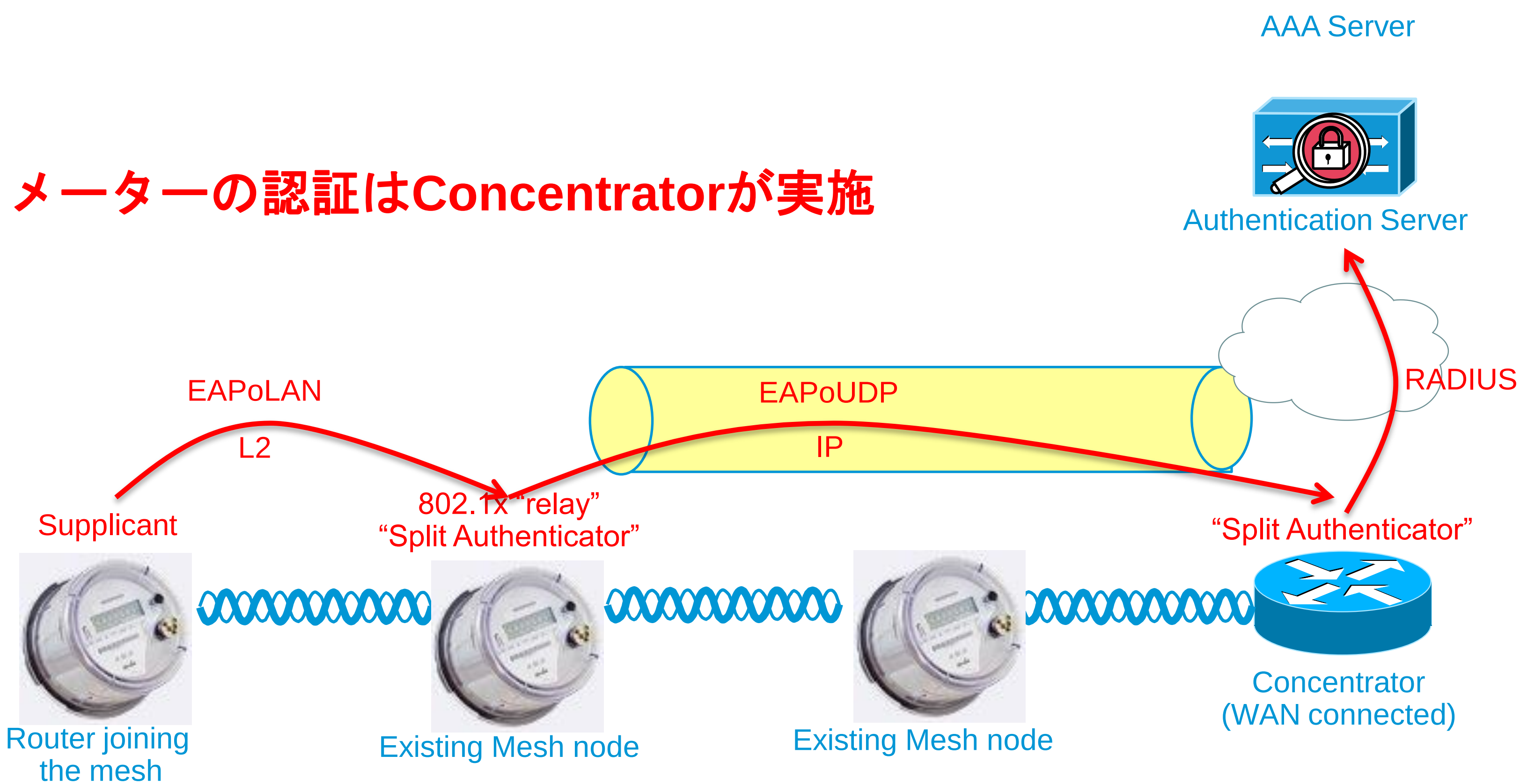
- 802.1x Authenticator on RF Mesh Interface of Concentrator –acts as an intermediary (proxy) between the meter and the authentication server, requesting identity information from the meter, verifying that information with the authentication server, and relaying a response to the meter
- 802.1x Split Authenticator on meters – acts as a client that authenticates to AAA server as well as proxy that relays authentication messages from downstream meters
- Mesh Group Keys – result of 4-way handshake that involves meter, Concentrator and NMS; NMS responsible for generating group keys; used for multiple purposes
  - Forming forwarding adjacencies with neighbors
  - Differentiate between insider and outsider traffic (nodes with access to medium; potentially rogue)
  - Link-layer encryption based on group keys for scalable key management
- Mesh Crypto Infrastructure –generation of group keys, periodic re-keying and distribution in PAN

Meshに組み込まれるメーターは802.1xを使用して認証を行う事が出来ます

mesh node join

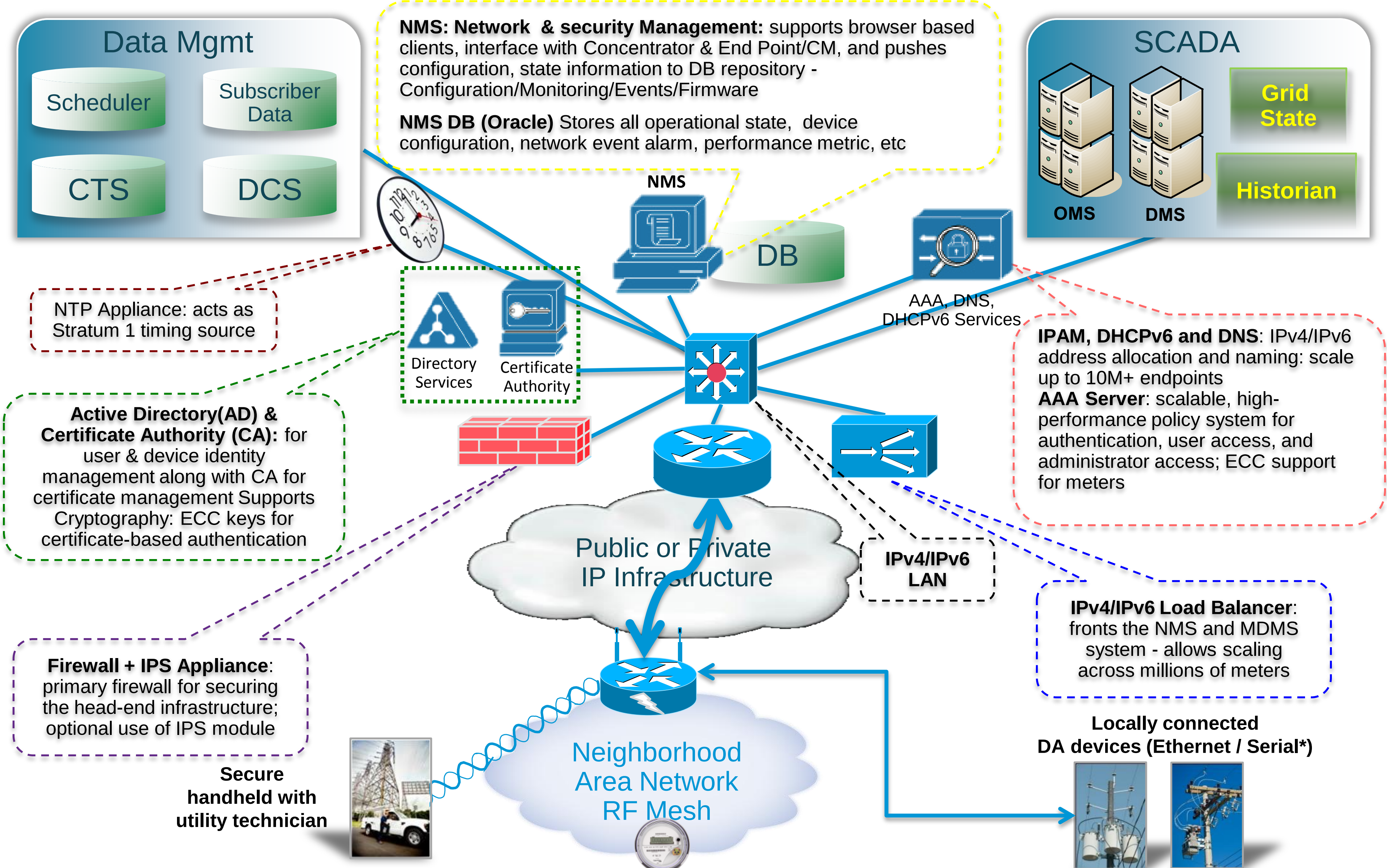
“split authenticator”

メーターの認証はConcentratorが実施



無線区間の認証方式はWPA2　（暗号化アルゴリズムはAES）

Network Operation Center (NOC)



ALLIANCE BUILT ON STRENGTH

Global Customer Base

Complimentary Go-to-Market

Long Term Vision

Open Standards Commitment

Financial and Market Strength

Utility Operational Expertise

Existing scalable AMI / Smart Metering Solution

World-class Ruggedized Manufacturing

Deployment Experience

IT and Telecom Expertise

Network Management and Security Solutions

World-class Networking and Professional Services

Market Transformation Experience

FAN / AMI Case Study

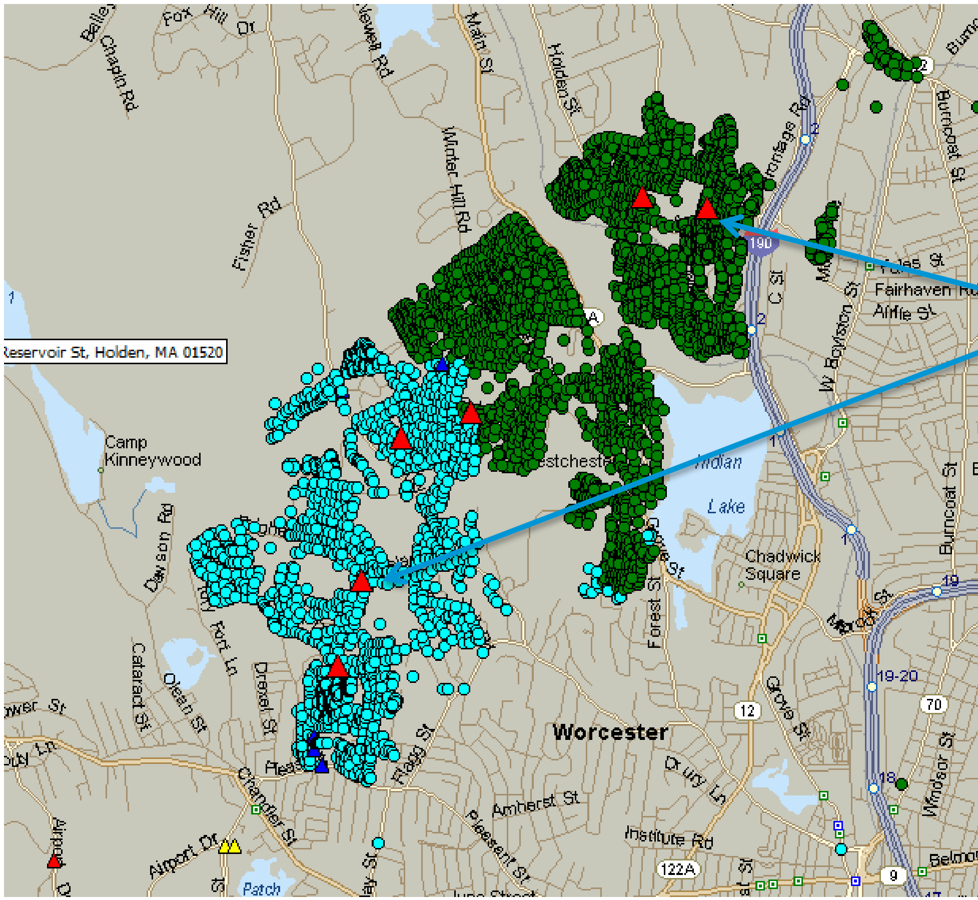
"The Itron-Cisco partnership was a compelling factor why we decided to go with Itron. The partnership is really a game changer. The ability to leverage our infrastructure with Cisco's telecommunications ability is a great stepping stone into smart grid. We'll be able to leverage it for years to come."

Gary Murphy
Chief Project Officer, Smart Metering Program

- 1.8M smart meters to be deployed by the end of 2012
- Itron as supplier of smart metering system and Meter Data Management System (MDMS)
- Cisco for Field Area Network solution
- Itron OpenWay® smart meters, run over a multi-application communication network powered by Cisco
- Multiple WAN backhaul: 2G/3G cellular, 1.8 GHz WiMAX, and Satellite

National Grid AMI Pilot with Itron/Cisco

5,000 meters in Worcester, MA



- AMI and Distribution Automation use cases
- Testing new standards based IPv6 RF Mesh
- 6 Cisco CGR1240 with 3G backhaul
- DA Gateways for Volt/VAR optimization over IPv6 RF Mesh
- Hosted head-end infrastructure at Itron
- Timeline: Feb – June 2012

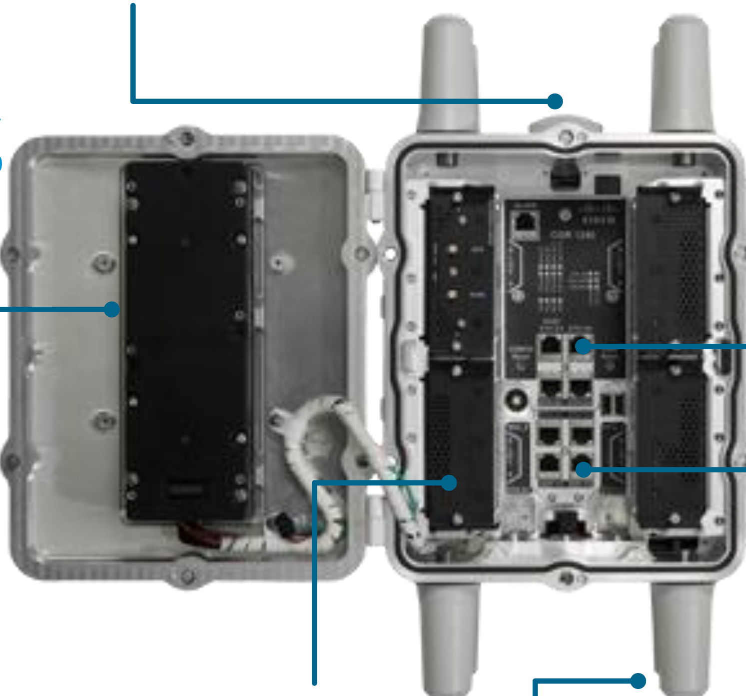
Cisco 1000 Series Connected Grid Routers

CGR1240: Outdoor Model (pole mounted)

ご参考: 標準化技術を採用した弊社製 Concentrator

GPS Antenna

Battery Backup



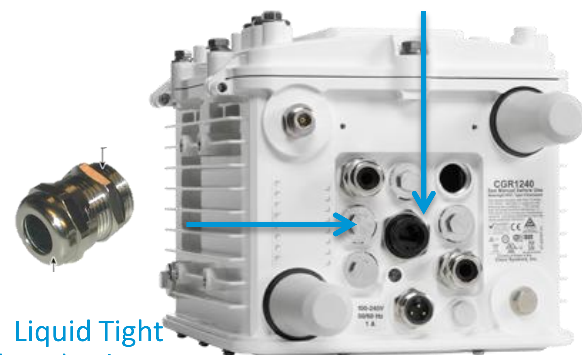
Ethernet Switch 2GE WAN (Cu or SFP), 4FE LAN

2 RS 232 / RS 485 Serial ports

4 Module Slots

Integrated Antennas for: RF Mesh, WiMAX, 2G/3G, WiFi

Ruggedized, IP67 Ethernet (RJ-45) connector



Liquid Tight (IP67) Adapter

- Estimated Dimensions: **30.5 cm (H) x 20.3 cm (W) x 19 cm (D)** = 12” (H) x 8.0” (W) x 7.5” (D
- Antennas shown above are optional; can be deployed with external antennas

Thank you.