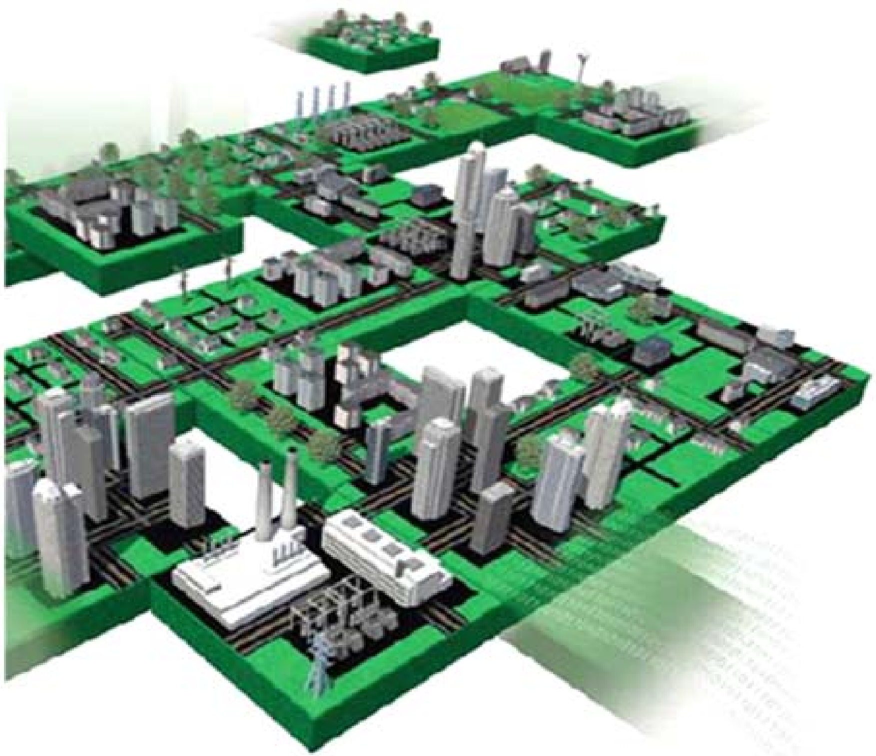
Smart Grid/AMI Intra-system to Inter-system Interoperability using Common IP Standards



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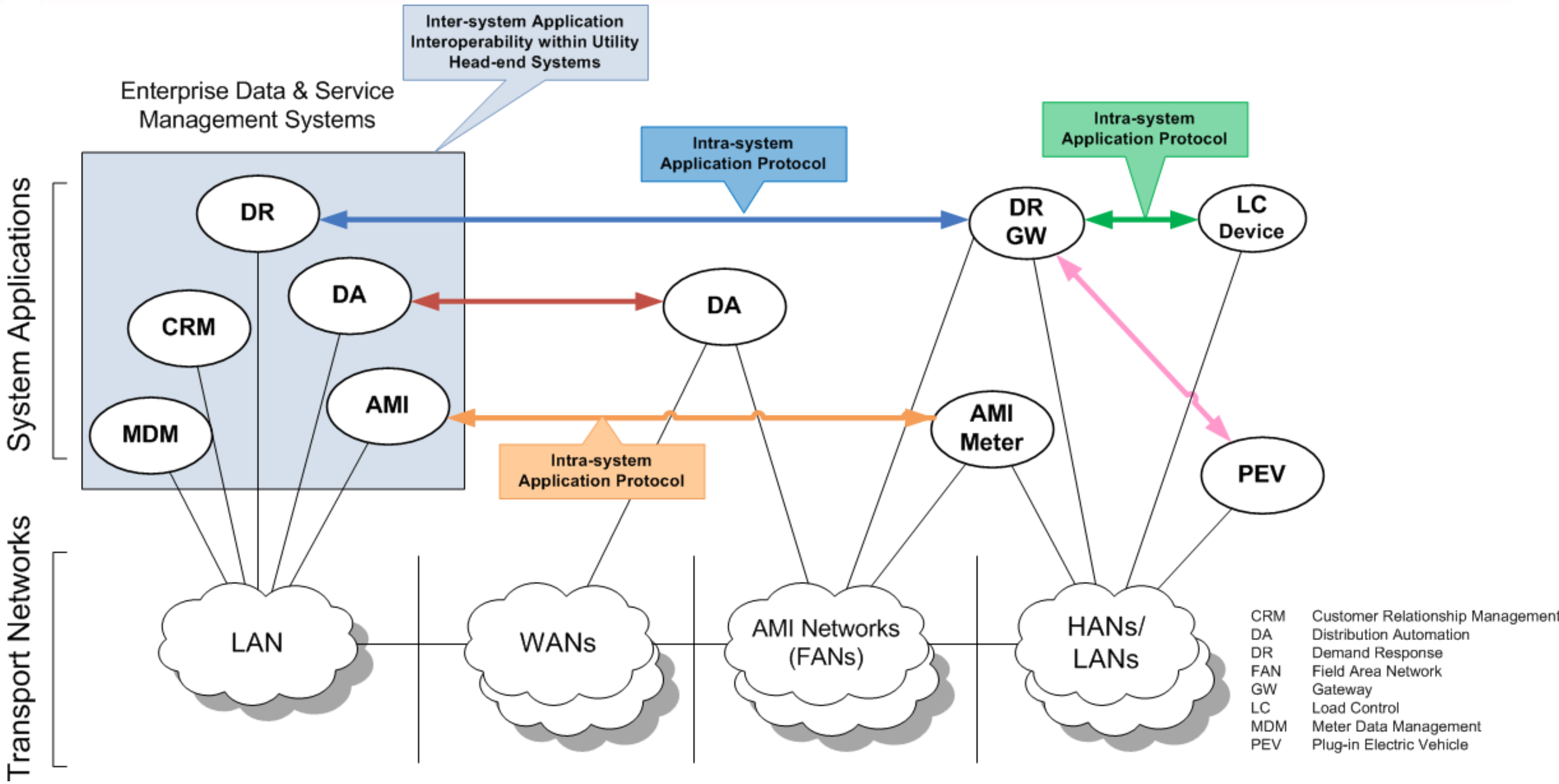
Background

- Various utility systems and networks currently exist (AMI, HAN, DA,…)
  – These different systems are supported by various application protocols and associated transport networks
- IP and IPv6 in particular provides an appropriate key technology target for intra- and inter-system network interoperability
  – There are direct, tangible benefits to this open standards model both for future interoperability and future application development
- To achieve the desired network interoperability goal there must be clear standard specifications to be applied
  – These already exist and can be supported even for AMI end devices
  – An established interoperability certification process also exists
- Discussion is needed on what should be occurring within systems as work is on-going to achieve intra- and inter-system interoperability via IPv6
  – In particular, focus on core utility application protocol development
  – Where applicable, develop adaptation mechanisms to support application protocol migration from existing transport networks to IPv6 networks

Motivation

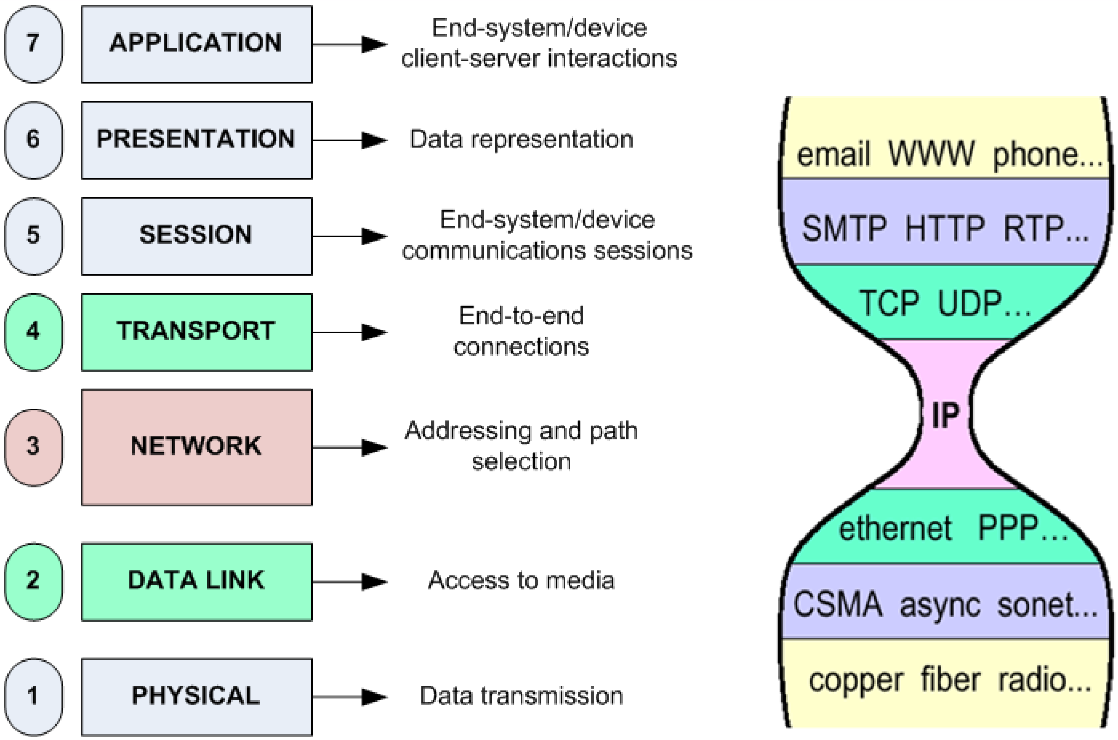
- Opportunity to highlight how IETF networking standards can be incorporated within the Smart Grid development roadmap to accelerate overall standards adoption
  - Using established, vetted requirements and best practices
  - Using defined certification processes
- Opportunity to consider utilities' standards adoption principles through use of IETF communications standards:
  - Openness, Separation of duties, Generational Compliance, and Loose Coupling as applied to AMI/HAN networks
- Opportunity to provide background on benefits of IP and increase awareness of existing standards for defining and certifying interoperable IP networks

AMI/HAN Application Interoperability & Interconnection



- Application layer modeling and protocol interoperability should be defined more separately from the underlying transport network

Common IP Network Layer



- **"Everything on IP and IP on Everything"**
  - Allows focus on application development with standard transport layers (TCP, UDP,…) providing connection services not offered by connection-less IP
  - Lots of standard networking equipment to support lower layer interconnection

Benefits of IP

- The power of IP lies in a common convergence layer that can be assumed when developing new application services
  – “Everything on IP” captures the flexibility to develop application services using standardized transport protocols (UDP, TCP, SCTP) and APIs
  – “IP over Everything” reflects the successful model of IP networking across a wide array of communications link technologies – Ethernet, ATM, FDDI, RF, etc.
- A common, interoperable IP network layer will allow the development and introduction of services not yet imagined
  – For e.g. applications can be developed for smart meters, DA sensors, controllers, HAN gateways, etc. without specific reference to the transport networks (LAN, WAN, FAN, HAN) other than performance, reliability, QoS, etc.
  – Benefit of application intelligence distributed to network edges
- IP convergence allows interoperability to be focused at the application layer with standard network devices handling lower layer interworking
  – Existing utility-specific application development can be reused and continuing effort can be applied to enhance or introduce new applications
  – With standard application QoS differentiation mechanisms available (Diffserv, MPLS, ...)

A Word on the IETF that leads IP Standardization

- Internet Engineering Task Force (IETF) is an international organization focused on developing Internet technical standards
  - Standards are published in the form of RFCs (Request for Comments)
  - RFCs are the specifications output used for developing interoperable products and are freely available to everyone for download to build products
- It is an open standards organization with no formal membership or membership requirements
  - Anyone can participate and the work effort is voluntary (company paid)
  - Private and public companies of all sizes, academic and government institutions, etc.
  - IETF activity is organized around technical working groups with chairs drawn from technical leaders in the field
- It is a technical standards organization working by ‘rough consensus’ where the criteria is technical merit
  - The IETF does not engage in marketing or product promotion
  - The process is driven by collaboration of technical experts
  - The Internet’s success is a testament to this open technical standards model

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What does it mean to support IP?

- IETF RFC 4294, "**IPv6 Node Requirements**" defines through RFC technical compliance what it means to support IP
  - RFC 4294 (and RFC 2460 - IPv6 Specification) define the requirements that IPv6 nodes (Hosts and Routers) must support to ensure IP interoperability
  - Only through RFC compliance can there be IP that is fully "**Open, Standard and Interoperable**"
  - IPv6 compliance must also be meaningfully validated through appropriate interoperability certification (Global IPv6 Ready)

IP Layer Requirements

IPv6 Node (Host/Router) Requirements	Applicable RFC Support Level			
	MUST	SHOULD	MAY	SHOULD NOT
Base				
Internet Protocol, Version 6 (IPv6) Specification [RFC-2460]*	X			
Addressing				
IPv6 Addressing Architecture [RFC-4291]	X			
Default Address Selection for IPv6 [RFC-3484]	X			
Address Configuration & Discovery				
Stateless Address Autoconfiguration [RFC-4862]	X			
Link Local Address Generation/Duplicate Address Detection [RFC-4862]	X			
Privacy Extensions for Stateless Address Autoconfiguration [RFC-4941]		X		
Stateful Address Autoconfiguration [RFC-3315], [RFC-4361]			X	
Neighbor Discovery [RFC-4861]		X		
Router and Prefix Discovery [RFC-4861]	X			
Router Solicitations, Receiving/Processing Router Advertisements [RFC-4861]	X			
Redirect functionality – Routers [RFC-4861]	X			
IP Control				
Internet Control Message Protocol [RFC-4443]	X			
DNS and DHCP				
DNS stub-resolver functionality [RFC-1034]		X		
Dynamic Host Configuration Protocol (DHCP) [RFC-3315], [RFC-4361]			X	
Other Node Configuration (Stateless DHCP) [RFC-3736]			X	

IP Layer Requirements cont'd

IPv6 Node (Host/Router) Requirements	Applicable RFC Support Level			
	MUST	SHOULD	MAY	SHOULD NOT
Security				
Security Architecture [RFC-4301]	X			
Authentication Header (AH) [RFC-4302]	X			
Encapsulated Security Payload (ESP) [RFC-4303]	X			
NULL encryption algorithm [RFC-2410]	X			
NULL authentication algorithm [RFC-4303]	X			
AES-128-CBC algorithm within ESP [RFC-3602]	X			
3DES-CBC encryption algorithm within ESP [RFC-2451]	X			
DES-CBC encryption algorithm within ESP [RFC-2405]				X
HMAC-SHA-1-96 algorithm within AH and ESP [RFC-2404]	X			
HMAC-MD5-96 algorithm within AH and ESP [RFC-2403]			X	
Packet Sizes/Types				
Support for IPv6 Packet Size of 1280 bytes [RFC-2460]*	X			
Path MTU Discovery [RFC-1981]		X		
Jumbograms (> 65535 bytes) [RFC-2675]		X		
Internet Protocol version 4 Support [RFC-791]			X	
Network Management				
Management Information Base for IPv6 [RFC-2465]			X	
IP Forwarding Table MIB for nodes that support an SNMP agent [RFC-4292]		X		
IP MIB for nodes that support an SNMP agent [RFC-4293]		X		

* RFC 2460 (IPv6 Specification–defined) requirement not directly referenced in RFC 4294

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IP Layer Requirements cont'd

IPv6 Node (Host/Router) Requirements	Applicable RFC Support Level			
	MUST	SHOULD	MAY	SHOULD NOT
Multicast				
Multicast Listener Discovery MLDv1for IPv6 [RFC-2710]			X	
Node applications needing to Join Multicast Groups – MLDv2 [RFC-3810]		X		
Node applications needing only Any-Source Multicast [RFC-2710]			X	
Node applications supporting Source-Specific Multicast [RFC-3810]	X			
Mobile IP				
Generic mobility-related requirements – Routers [RFC-3775]		X		
Home agent functionality – Routers [RFC-2473], [RFC-3775] and [RFC-3776]			X	
Generic mobility-related requirements – Hosts [RFC-3775]		X		
Route optimization requirements for correspondent nodes – Hosts [RFC-3775]		X		
Mobile node functionality – Hosts [RFC-3775]			X	
Generic packet tunneling – Hosts [RFC-2473]			X	
Secure home agent communications – Hosts [RFC-3776]			X	

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Requirements Below IP Layer

- In accordance with RFC 4294, “An IPv6 node must include support for one or more IPv6 link-layer specifications”. For example,
  - IPv6 over Ethernet [RFC-2464]
  - IPv6 over PPP [RFC-2472]
  - IPv6 over ATM [RFC-2492]
  - IPv6 over FDDI [RFC-2467], etc.
- IPv6 over IEEE 802.15.4 [RFC-4944] comes closest to an applicable specification for IP over low power RF mesh links
  - Some areas of requirement conformance to RFC 2460/RFC 4294 still to be addressed (for ex. 1280 byte size for IPv6 packets)
- Note 1: Requirements for simple (stateless) IP header compression should not constrain network flexibility
  - For ex. current RFC 4944 link local addressing assumes Layer 2 connectivity but other schemes can be developed
- Note 2: IPv6 specifications are predicated on multicast link capability (see RFC 4861) which if achieved or approximated allows many link-specific features to be transparent to network layer

IP in AMI

- "IP" is not an amorphous term to be interpreted as convenient – there are clear requirements and they have to be met
- Requirements were written for computers (hosts) and routers – some AMI nodes do not meet them and probably cannot meet them without further specification development
- Until either the existing standards are met, or new ones are specified, there is no truly "open, interoperable, standard" applicable to AMI
- For eventual inter-system interoperability AMI networks must be committed to IP – done the right way via applicable standards and certifiable IPv6 compliance
  - Vendors can support on-going work at the IETF to get appropriate standards published as related to requirements for low power, and memory and processing constrained devices

Global IPv6 Ready Certification Program

- IPv6 Ready program provides certification for global compliance with core IPv6 specifications needed to guarantee network interoperability
  - http://www.ipv6ready.org/
- Vendors' design and development programs for IPv6 should be focused on achieving Phase 2 certification which covers:
  - RFC 2460
  - RFC 4291
  - RFC 4861
  - RFC 4862
  - RFC 4443
  - RFC 1981*

* IPv6 Path MTU Discovery is to accommodate the prevalent 1500-byte MTU used in Ethernet-based networks

AMI Intra-system Interoperability Roadmap

- Continue focus on application specification and developing interoperable application protocols (including application security)
  - For ex. AMR/AMI, DA, DR-to-HAN interworking which are the core domain competence of the industry
- Define intra-system application protocols with greater independence from underlying transport networks
  - While working towards common IP based transport network
- Identify network performance requirements that must be met for applications to be supported without constraining network type
  - Meter data reading, DA, interactive DR, HAN
- Commit to an evolution path towards full IPv6 networking using standard IETF networking specifications and certification
  - This will support intra-system transport while evolving to permit full inter-system interoperability

Specific AMI/HAN Intra-system Examples

- Within HAN system continue to enhance Smart Energy Profile (SEP) and equivalent HAN application protocols
  - While decoupling SEP and SEP-equivalent applications so that they can operate over other networks, particular IP
  - See for example, Arch Rock's , draft-tolle-cap-00, "UDP/IP Adaptation of the ZigBee Application Protocol" or Z-wave's Z/IP Initiative
- Within AMI system develop specific application protocols that allow information exchanges between head-end DR controllers and HAN interface (gateway) device
  - For ex. load control, price, time/schedule and message delivery exchanges as may be facilitated by C12.19 Decade 19 Tables or other standards-based means
- With focus on DR controller-to-HAN GW protocol, HAN technologies (SEP and other equivalents) can evolve with common AMI interface
  - Will allow DR application service control to evolve separate of HAN
  - Will allow stable head-end system investments to be made without impacting HAN choices

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Eka's Continuing IP Work

- Eka is about network communications and is working within the IETF to define the standards for IP over low power RF sensor networks
  - Author: Routing Over Low power Lossy Networks (ROLL-Urban)
  - Author: Security Framework for Low power Lossy Networks (L2N)
  - Monitoring of 6LowPAN (IPv6 including link-layer adaptation)
- Eka is a founding and technical advisory board member of the IPSO (IP for Smart Objects) industry alliance
  - Promoting IP education, marketing, and interoperability testing
- Eka's AMI system provides an open network platform that can transparently support utility applications
  - Work is on-going to implement and certify relevant RFC-specified IPv6 functionality while developing applicable IETF L2N network standards
- Eka has a developed modular, layered AMI architecture that directly allows IPv6 adoption at the network layer as standardized
  - Application interoperability will evolve to certified IP interoperability

EkaNet Standards-based Interoperability

- Eka's architecture currently supports application interoperability using standards-based IP interworking at the utility enterprise head-end
  - New service applications such as DR, HAN, DA etc. can be easily introduced without core AMI network impact
- Eka is working towards an AMI intra-system network platform on which utility service providers can eventually develop standard applications directly on meter nodes
  - Emulating a true internet model in which applications are developed independent of the network
- Eka's vision is based on an open networking model that will support full meter/end device IP connectivity
  - This will allow direct end-to-end IP connectivity to the utility end devices (meters, T&D device, HAN Gateways, etc.)

Summary/Conclusions

- There are very strong reasons/benefits to common IPv6 networking
  - Both intra-system and for eventual inter-system interoperability
- The is a clearly charted standards path specifying how to get to common IP interworking and for certifying when it is achieved
- The work of application protocol development and interoperability is important to meet Smart Grid operational and service objectives
  - This effort is important when inter-system network interoperability is eventually achieved as well as while getting there – particularly if applications are less tightly coupled to current networks
- Intra-system (AMI, HAN, DA systems, etc.) application development (incl. security support) should proceed actively while in parallel IPv6 should be set as the standard network target towards which all smart grid systems evolution should be aligned
  - This will extend the lifetime of current application development investments and enhance future ability for industry to develop and introduce new and innovative Smart Grid applications

Questions

Thank You!

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