

# Network Architecture in the Smart Grid



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**Architectural Requirements in  
the NIST Framework and how to  
meet them**





# Architectural designs

## *Internet Architecture*

<b>Application</b>	<b>Application Protocol, encoding, AAA, identity, encryption</b>
Transport	End to end reliability
Internet	End to end routing, VPN, Network AAA, identity, encryption
Data Link	Link encoding on physical layer
Physical	Physical Interconnect

## *“1-2-7” Architecture*

<b>Application</b>	<b>Application Protocol, encoding, AAA, identity, encryption, End to end reliability, end to end routing</b>
Data Link	Link encoding on the physical layer
Physical	Physical Interconnect

# Examples

## *Internet Architecture*

- The Internet
  - IPv4 or IPv6
- The ISO OSI Reference Model
  - breaking the application into several layers
- Novell Netware
- AppleTalk
- DECNet
- XNS Internet Transport
- etc

*Designed to work in  
Enterprise and general  
networks*

## *“1-2-7” Architectures*

- IEC 14908
  - Implements 7 layers, but in the application protocol
- Zigbee 1.0
- Many others in the Grid

*Wire replacement, designed  
to work in local networks*



# Zones of Smart Grid Communications

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- **Enterprise bus:**
  - **Connects control center applications to markets, generators, and each other**
- **Field Area Networks:**
  - **Devices that control circuit breakers and transformers**
- **Substation Networks**
  - **Premise networks in substations: special requirements**
- **Premises Networks:**
  - **Connections within customer and utility premises**
- **AMI Networks:**
  - **Connecting utilities to premises**



# Functional Requirements for communication

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- **“...the Network should enable an application in a particular domain to communicate with an application in any other domain in the information network, with proper management control over who and where applications can be interconnected.”**



# Implication of functional requirements: *Link layer independence*

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- **Many different link layer networks are used in the Smart Grid**
  - Ethernet, IEEE 802.11, IEEE 802.15.4g, Homeplug, ...
- **Therefore, either**
  - *Each link layer must be directly translatable to any other via a gateway, and addressable end to end, or*
  - *Network addressing and routing must be independent of the link layers in the Smart Grid*
- ***Link layers are not designed to be translatable and application-independent gateway technology is not defined***
  - **No “1-2-7” architectures**



# Implication of functional requirements: *End to End Security*

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- **Link layer network standards are not designed for application identity/authentication/authorization/confidentiality management**
  - **IEEE has defined many of these within local area networks, but not end-to-end**
  - **They are also used at the network layer via IETF specifications**
- **Therefore,**
  - ***Applications and network elements must implement interoperable AAA and encryption standards***



# Implication of functional requirements: *Divisibility into manageable domains*

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- **Design intent of specifications**
  - **Link layer standards, including link layer networks, are designed as wire replacements – they connect every system to every other within their domain**
  - **Network layer standards are designed to organize networks into separable and separately manageable domains**
- ***Use each for the purpose for which it was designed***





# Implication of functional requirements: *End-to-end interoperability*

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- **Multi-link-layer and Multi-network *interoperability* is proven in the Internet Architecture**
- **There is no other architecture in current use that has demonstrated world-wide, multilingual, general purpose *interoperability***



# Internet Community to Smart Grid: adopt our working technologies; *make new mistakes*

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- **Focus on security**
  - We have defined and partially implemented security solutions, but many don't use them
  - *Use them*
- **Addressing**
  - We have largely used up the IPv4 address space;  
*use the larger address space in IPv6*
- **Focus on interoperable manageability**
  - We have solutions for this, but little market requirements; *use proven encodings like XML and application architectures like BEEP, ATOM, and XMPP*

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