IntelliGrid Architecture … a System with a view

Integrated Energy and Communications System Architecture

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Presented at the University of Illinois

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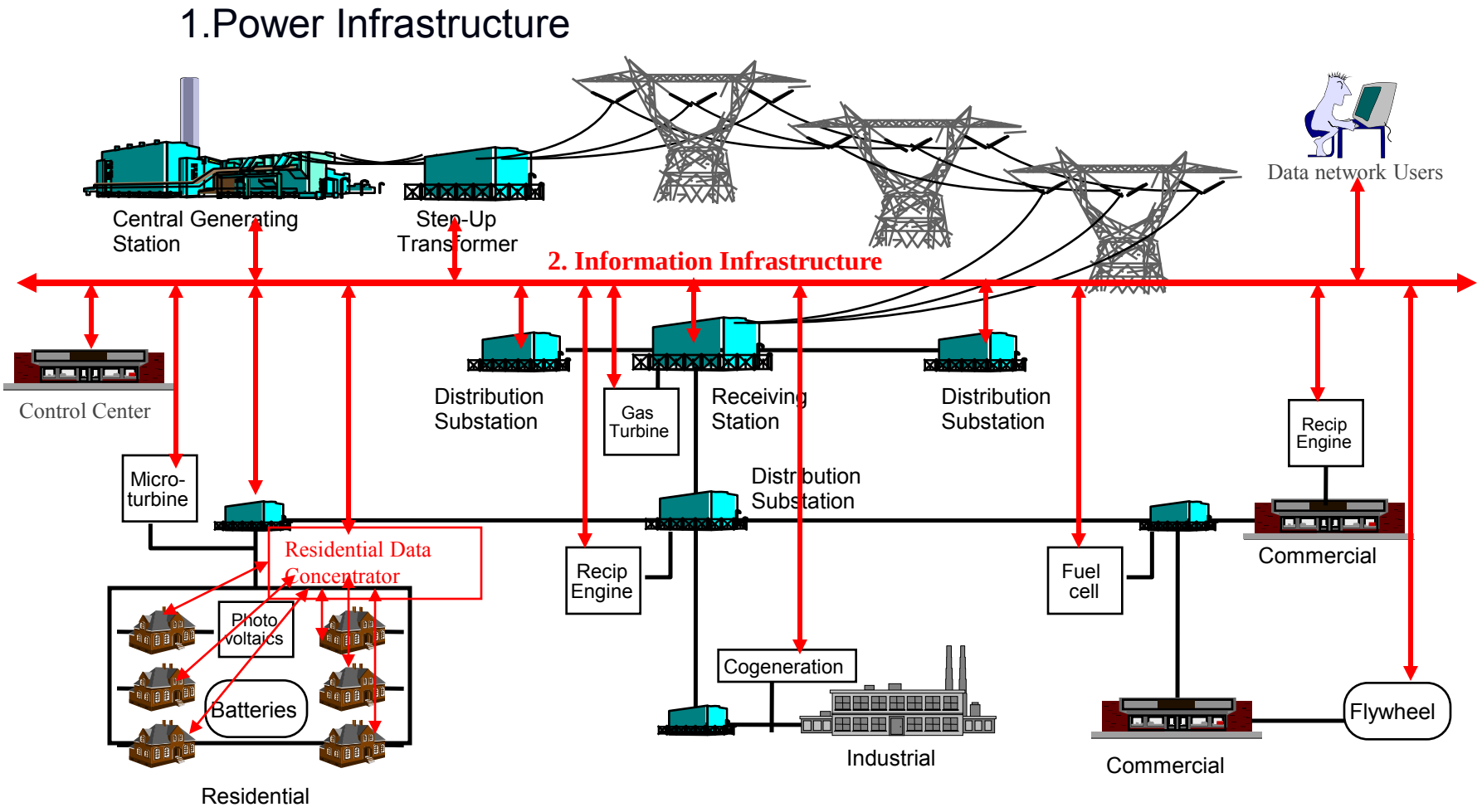
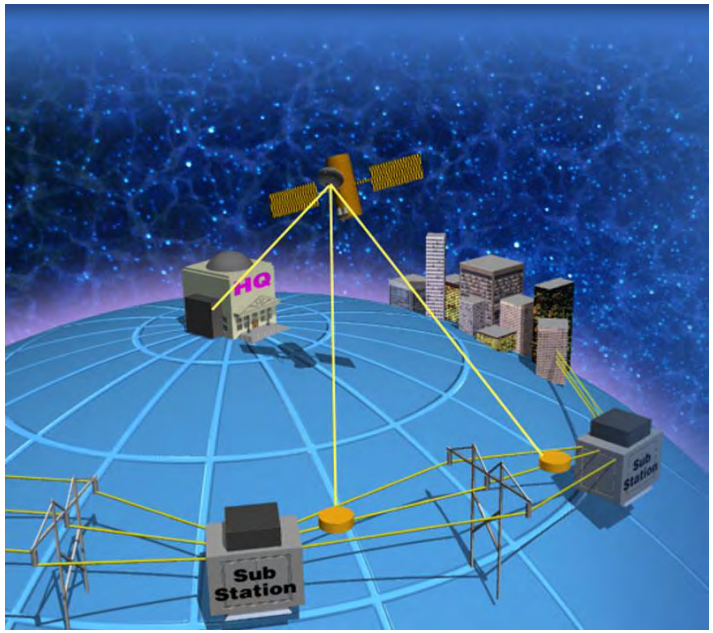
Merging Two Infrastructures

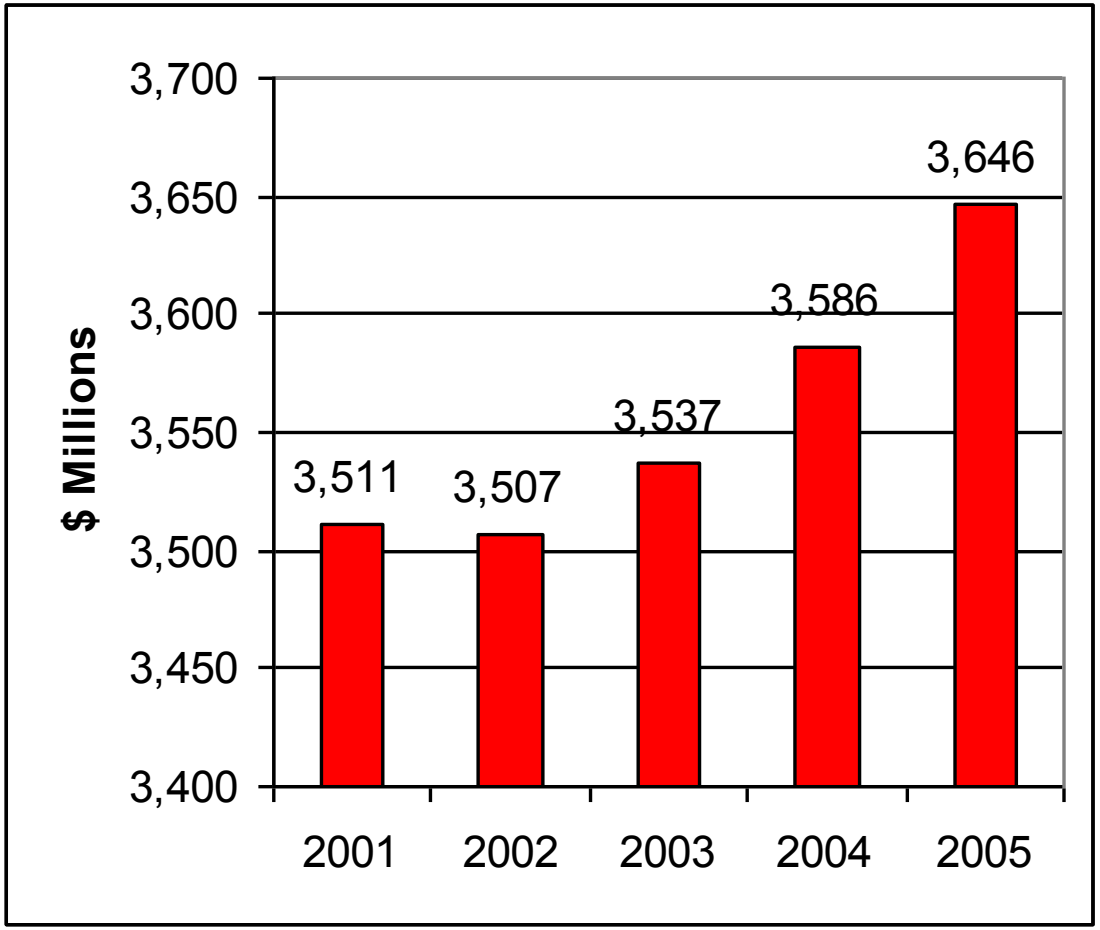


Vision of the Power System of the Future

- *Self-Healing* and *Adaptive* to correct problems before they become emergencies
- *Interactive* with consumers and markets
- *Optimized* to make best use of resources and equipment
- *Predictive* rather than reactive, to prevent emergencies ahead rather than solve after
- *Distributed assets and information* across geographical and organizational boundaries
- *Integrated* to merge all critical information
- *More Secure* from threats from all hazards



Revenue from Telecom Equipment and Services Sold to Utilities

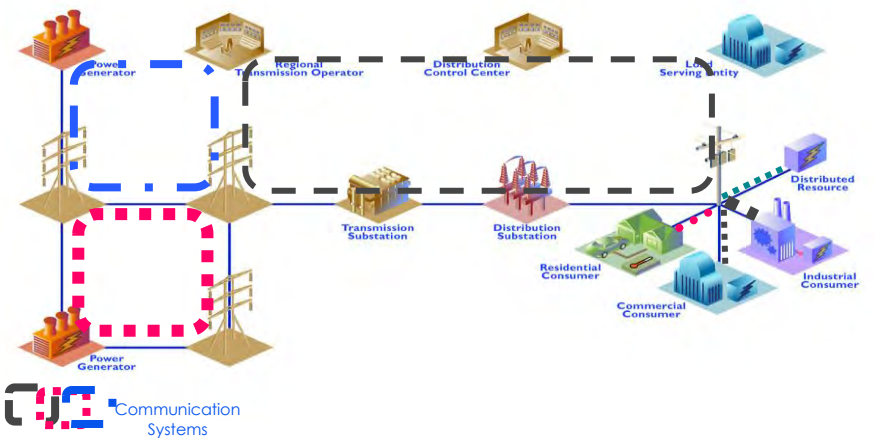


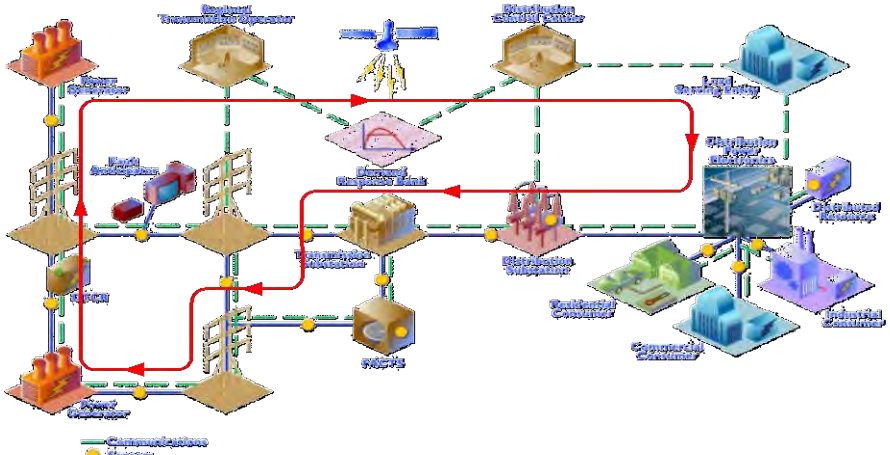
Source: UTC Research WWW.RESEARCH.UTC.ORG/STATS&DATA

What is Impeding the Industry?

- Lack of interoperability
- Limited methods or tools for designing complex communications systems
- Incomplete, overlapping and conflicting standards
- Lack of a common “vision”
- Regulatory and financial uncertainty
- Perceived investment needed

The Goal:





Turn “Islands of Automation”

into

Interoperating Networks

Future power system will support higher levels of integration and federated systems services to meet the needs of a “digital” society

Key Points of Interoperability

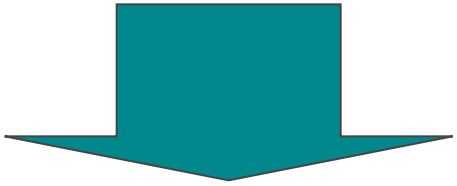
- **Standardized object models including:**
  - formats for exchanging data among different applications and systems.
- **Metadata representation**–data that describes data
- **Self describing** – available data is discoverable
- **Internet and industry standards**–Using the Internet and other industry standards
- **Time synchronization over a widespread geographic areas**
- **Identification of new technologies and subsequent adoption**
  - Meta-data repositories

How Do We Overcome These Barriers?

Other industries have faced similar problems

- Integration of disparate systems
- Large complex systems
- Need for interoperability, scalability, upgradeability and security

Aerospace, Software industry, Telecom



- **Enterprise architecture encompassing:**
  - **Systems Engineering methods**
  - **Modeling - UML**
  - **Open Standards**

What is an Architecture?

The structure of components, their interrelationships, and the principles and guidelines governing their design and evolution over time.*

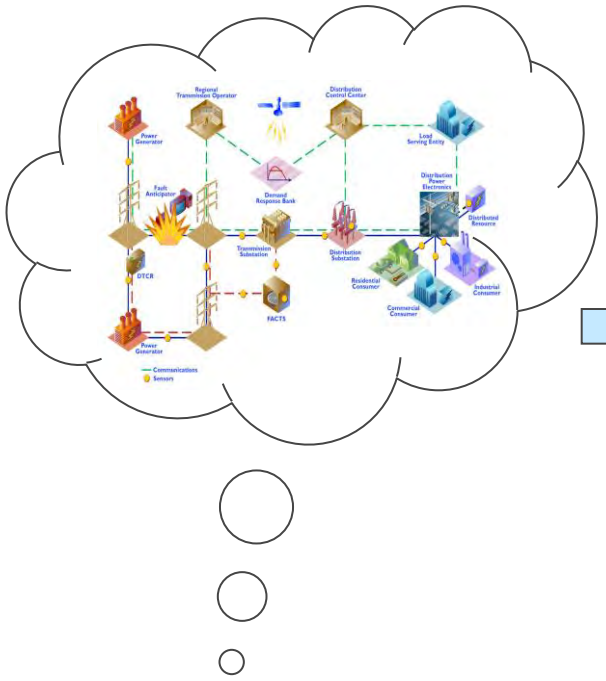
"The purpose of Federal Enterprise Architecture is to identify opportunities to simplify processes and unify work across the agencies and within the lines of business of the Federal Government. The outcome of this effort will be a more citizen-centered, customer-focused government that maximizes technology investments to better achieve mission outcomes."

*A Practical Guide to Federal Enterprise Architecture, Chief Information Officer Council, Feb 2001

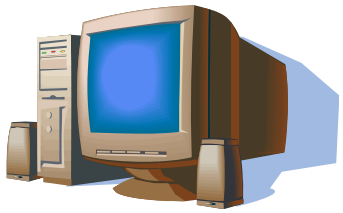
Project Team

- General Electric
  - Global Research
  - Network Solutions
  - Multilin
  - SAS
  - PSE
- Lucent Technologies
- Utility Consulting International
- SISCO
- EnerNex Corporation

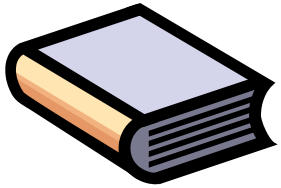
The Intelligrid Architecture Project Processes



Initial Results



Methods and Tools



Recommendations

Establish the Vision of the Future Energy System

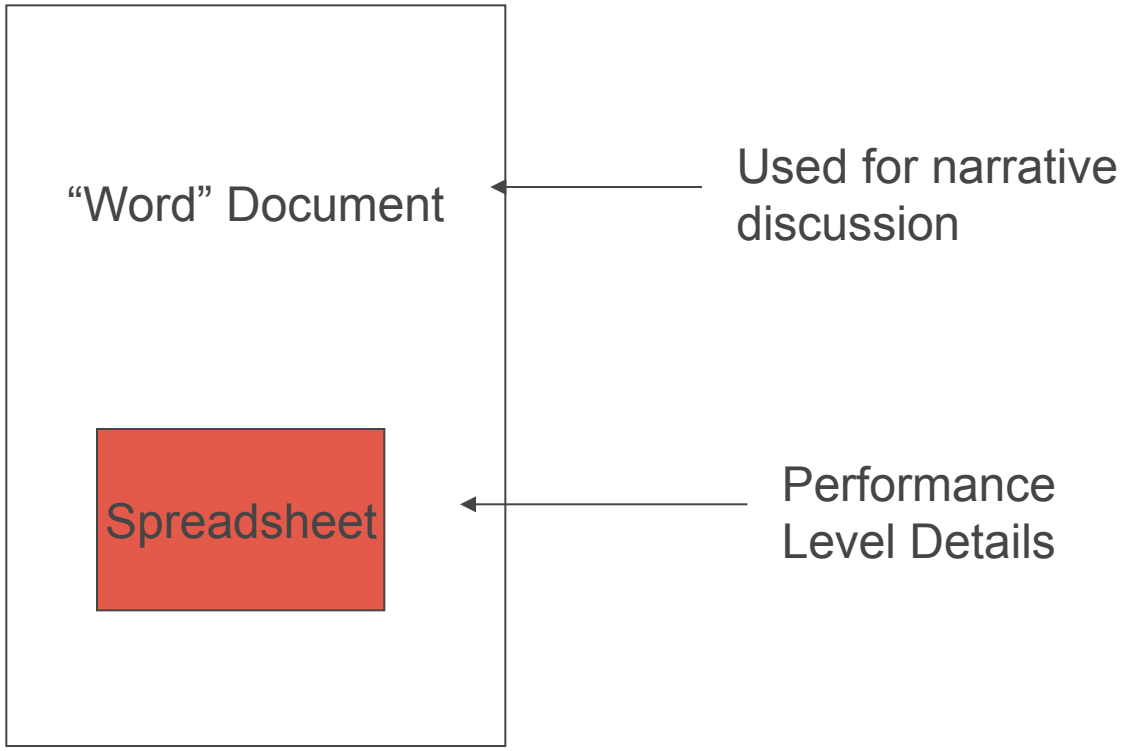
Work with Stakeholders to Refine Vision, Define Requirements and Analyze

Available for Download and Public Use:

www.epri-intelligrid.com

www.intelligrid.info

IntelliGrid Requirements Development Template



Develop Requirements for the Three Major Communication Categories:

- Applications:
  - System must support the requirements coming from power engineering needs
- Systems and Network Management:
  - Installed Communications Networks and Intelligent Equipment Must be able to be maintained
- Security:
  - System must include adherence to security policies and include system “hardening” as well as managing residual risk

Example Use Case: One Way AMR - New Meter
1. Narrative

- An expert describes in text form how a given future power engineering function is performed including the high level business and technical context.
- Narrative focuses on the necessary distributed computing needs/requirements of the function
- Includes diagrams that can be understood by the stakeholder communities..power engineers, rate administrators etc.

The purpose of the One-Way Fixed Network AMR Function is to collect meter information from customer sites, including monthly meter readings, on-demand meter readings, tamper detection, soft connects and disconnects (on-demand meter readings), and outage detection. These systems can be used for all types of customers.

The one-way fixed network AMR system must first be installed. These AMR systems are "in-bound" vendor-proprietary networks using different media, such as telephone, power line carrier, satellite pager systems, wireless cellular systems, and possibly the Internet. Different vendors provide different functionalities, which are constantly changing as technologies and equipment prices change. Some fixed network AMR systems are basically one-way, but can provide limited two-way functionality, possibly through low bandwidth signals or Internet Web pages providing information back to the customer. *(For IntelliGrid Architecture project, the internal functioning of these vendor-proprietary systems is out of scope: interested readers are directed to the Web Sites of the various AMR vendors.)*

Example Use Case: New Meter Installation
2. Identify the Actors

- From the narrative, determine the key players, or ***Actors (devices, people, systems).***
- Name the actor and describe what it does in tabular form

Actor (Stakeholder) Roles

Grouping (Community)		***Group Description***
Customer Site		***Those entities that are located at customer's premises***
Actor Name	***Actor Type (person, device, system etc.)***	***Actor Description***
Customer	Person	One requesting the sign up for the Demand Reduction Program.
Customer Communication Portal	System	System handling communications function at customer's premises
DLC Switch Controller	Device	Device performing cycling of the air conditioning unit
Meter Device	Device	Device capturing energy usage data for use in Measurement & Verification purposes.
Remote Meter Device	System	System for transmitting interval meter data on demand to the utility [in this case, using a satellite communications link provided by a third party contracted by the utility].

Example Use Case: New Meter Installation
3. Identify the Information

- What information do the actors exchange?
- Focus on exchanges that may cause communications problems.

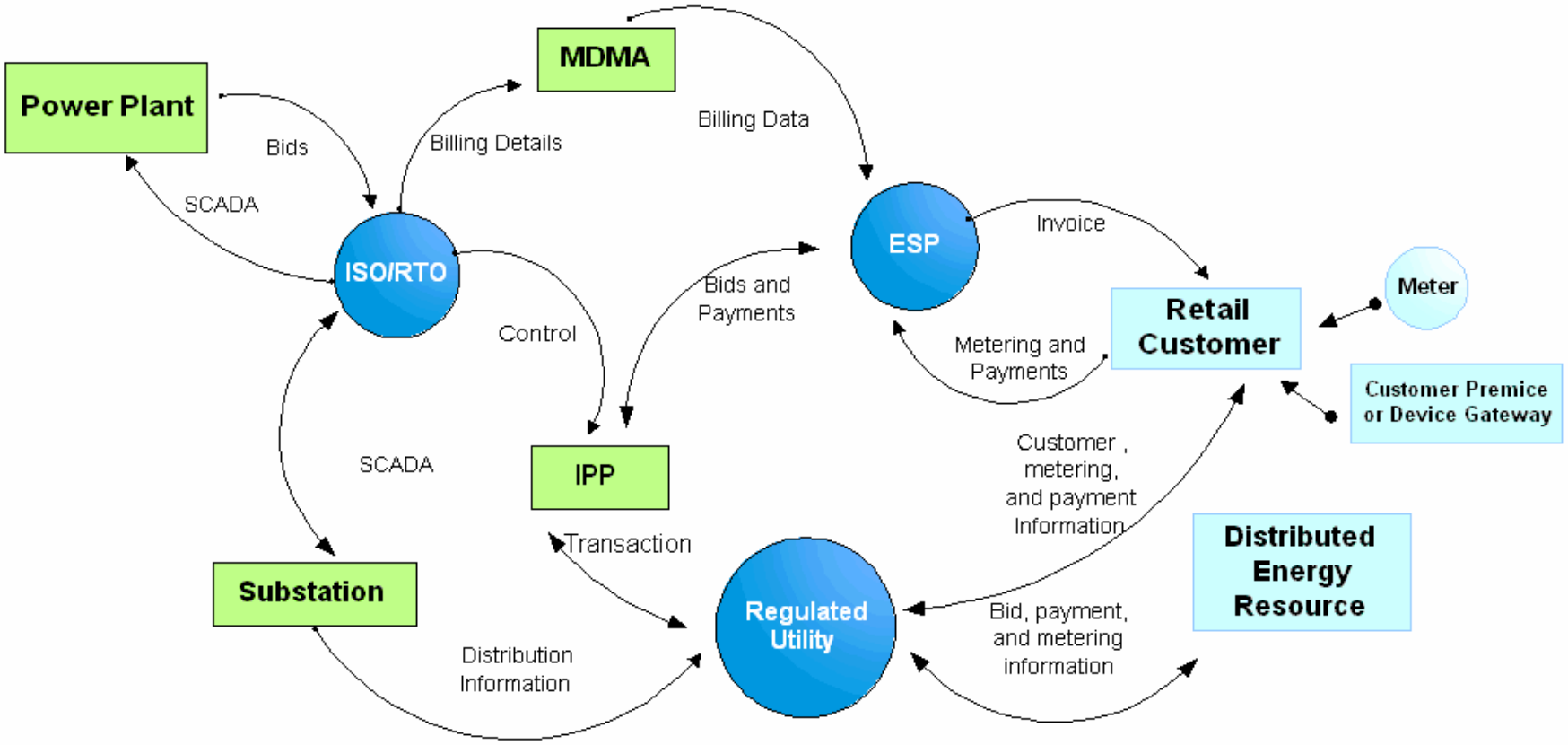
Information Object Name	*Information Object Description*
Customer Demand Reduction Program Signup Request	Information from the customer call for signing up to participate in the utility's Demand Reduction Program
Customer System Installation Order	Information on scheduling the installation at customer's site, equipment to be installed [interval meter, remote meter reading module and DLC], programming information on cycling regime, details to be passed on to the billing program on initiating incentive reward, intimation to Demand Response Program Manager and triggers to start tracking energy usage for program performance verification, and interval data for utility's M & V functions
M & V Information Request	Information trigger generated by the utility's customer information database to initiate recording of interval energy usage data
M & V Information Delivery	Delivery of M & V information collected from customer's site to utility's Power Purchase and Transmission Service Provider departments and to the Public Utility Commission for program results verification

Example Use Case: One Way AMR
4. Define Steps

- What happens, and in what order? Steps are numbered.
- References the actors and the information
- Formal, rigorous, ***machine-readable*** description of the narrative

#	Event	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Type of Info Exchanged	IntelliGrid Architecture Environment
2.1	Daily or other periodicity	Read meter	Read the meter over the network, capturing either meter readings or energy usage over multiple time periods, e.g. on a daily basis, read 5-minute energy usage data. If available in the meter, read the demand measurements for specific time periods, e.g. demand for each 15-minute period.	Meter	Metering database	Energy usage for multiple time periods. Demand measurements for multiple time periods	Customer to ESP Environment
2.2	Upon special request	Read meter	Read the meter upon request, capturing either meter readings or energy usage, and demand measurements if available. These meter readings can be used for customer inquiries, soft disconnect/connect requests, or reading validations	Meter	Metering database	Energy usage for multiple time periods. Demand measurements for multiple time periods	Customer to ESP Environment
2.3.1	Upon outage detection	Outage detection	An outage at one or more meters is detected	Meter	Metering system	Outage data	Customer to ESP Environment
2.3.2		Outage detection	Metering system issues an alarm of an outage detected at one or more meters	Metering system	Outage Management System	Outage alarm and supporting data	Intra-corporation Environment

Resultant: Well Defined Information Flows



Example Use Case: One Way AMR
5. Identify Architectural Issues

- For each step, mark multiple-choice X's regarding configuration, quality of service, security and data management
- A ***machine-readable*** rating of qualitative values.

File Edit View Insert Format Tools Data Window Help

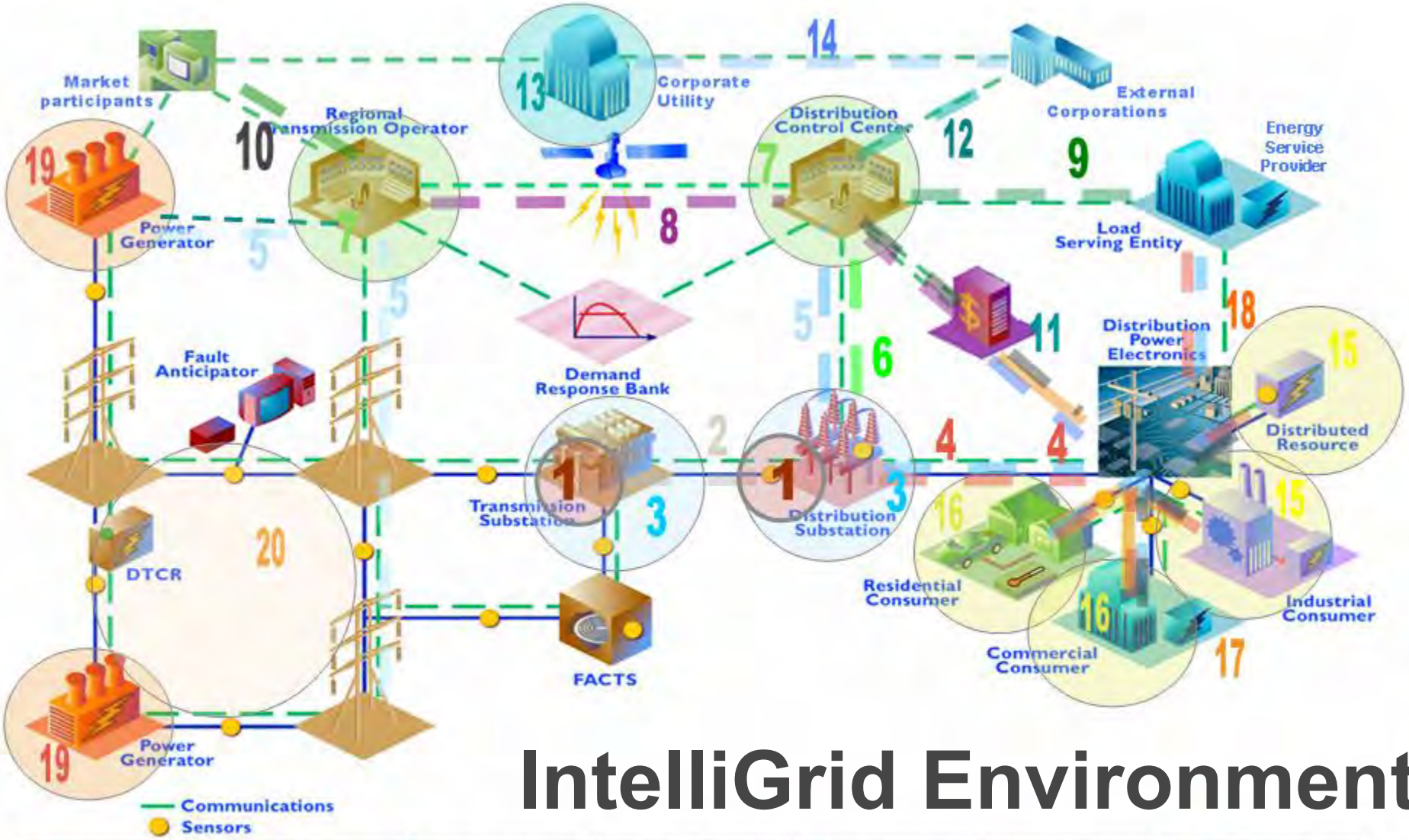
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1			**Quality of Service Requirements**	**Advanced Auto-Restoration**												
2			***Quality of Service Requirements, as well as Concerns and Problems***					**Use Case Steps**								
3			Please describe typical, probable, or envisioned communication configurations that are relevant to the Use Case Step. In some cases, only one of the possible choices is reasonable, while for other situations, more than one choice is reasonable. Feel free to add comments or even new choices	Pre-conditions	Report Fault	Report Loss of Service	Initial Trip	First Reclose Attempt	Report Fault	2nd Trip	Auto-sectionalize	Report Upstream Power Restored	Request Isolation	Confirm Isolation	Isolate Fault	Report Isolation Complete
4				Pre	1A	1B	2.1	2.2	2.3	2.4	2.5	2.6	3.1	3.2	3.3	3.4
5			***Typical, Probable, or Envisioned Quality of Service Requirements***													
6		a.	Elapsed time response requirements for exchanging data:													
7			– 1-4 milliseconds													
8			– 4-10 milliseconds													
9			– Less than 1 second		X	X	X	X	X	X						
10			– 1-2 seconds	X								X			X	X
11			– 10 seconds										X	X		
12			– More than 10 seconds													
13			– No specific response requirements													
14			– **Other _Must occur between trip and reclose**								X					
15		b.	Contractual timeliness for exchanging data is required:													
16			– Within 1 second													
17			– Within 1 minute													
18			– Within 5 minute													
19			– Within some longer time:													
20			– No specific contractual timeliness is required	X	X	X	X	X	X	X	X	X	X	X	X	X
21			– Other _____													
22		c.	Availability of information flows:													
23			– 99.9999% + availability ~ 1/2 second per year													
24			– 99.999% + availability ~ 5 minutes per year													
25			– 99.99% + availability ~ 1 hour per year													
26			– 99.9% + availability ~ 9 hours per year	X	X	X	X	X	X	X	X	X	X	X	X	X
27			– 99% + availability ~ 3.5 days per year													
28			– 90% + availability ~ 1 month per year													

Full Screen
Close Full Screen

Less than one second end-to-end, but not less than 10 ms

No contractual requirements

99.9% availability required

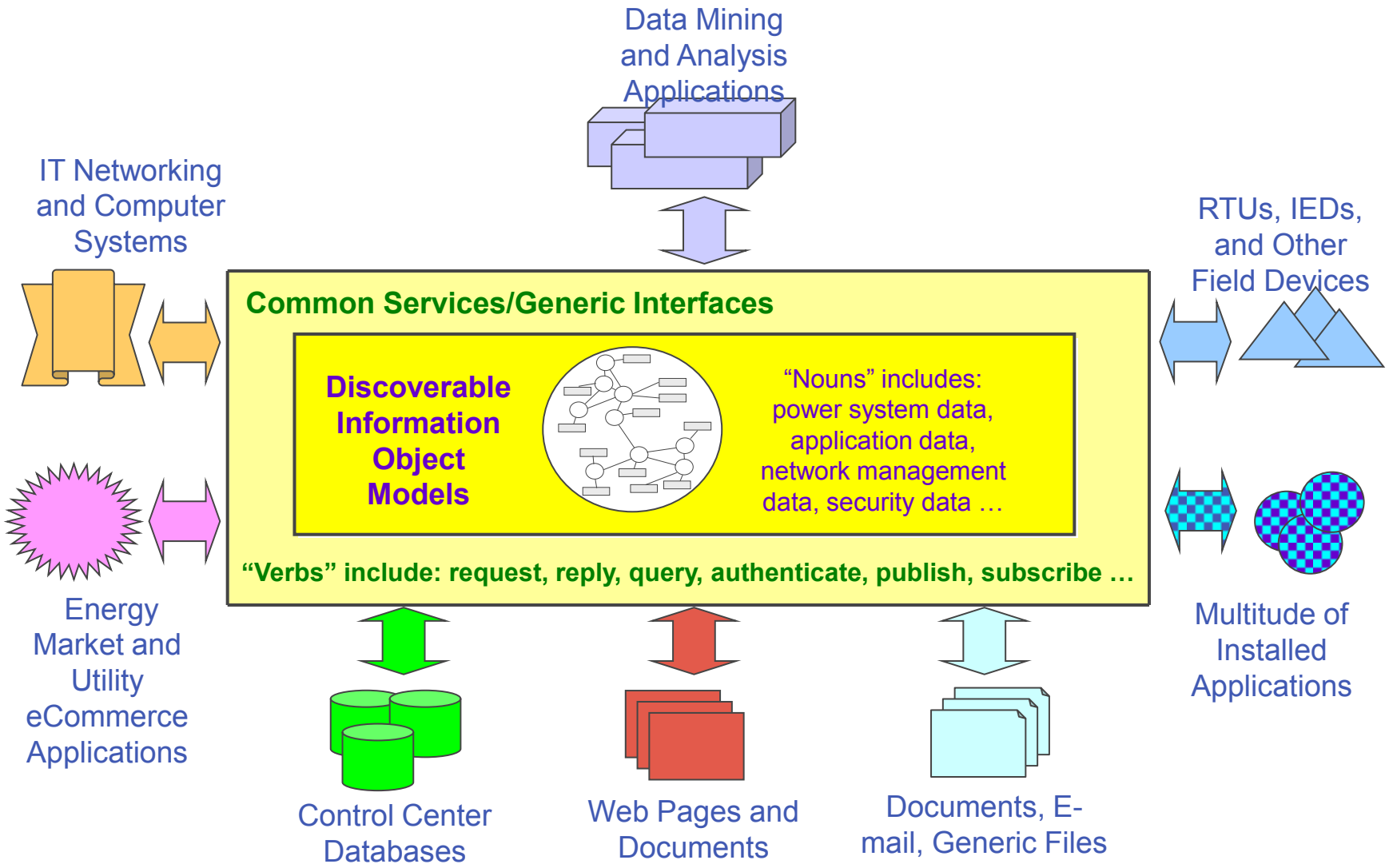


IntelliGrid Environment

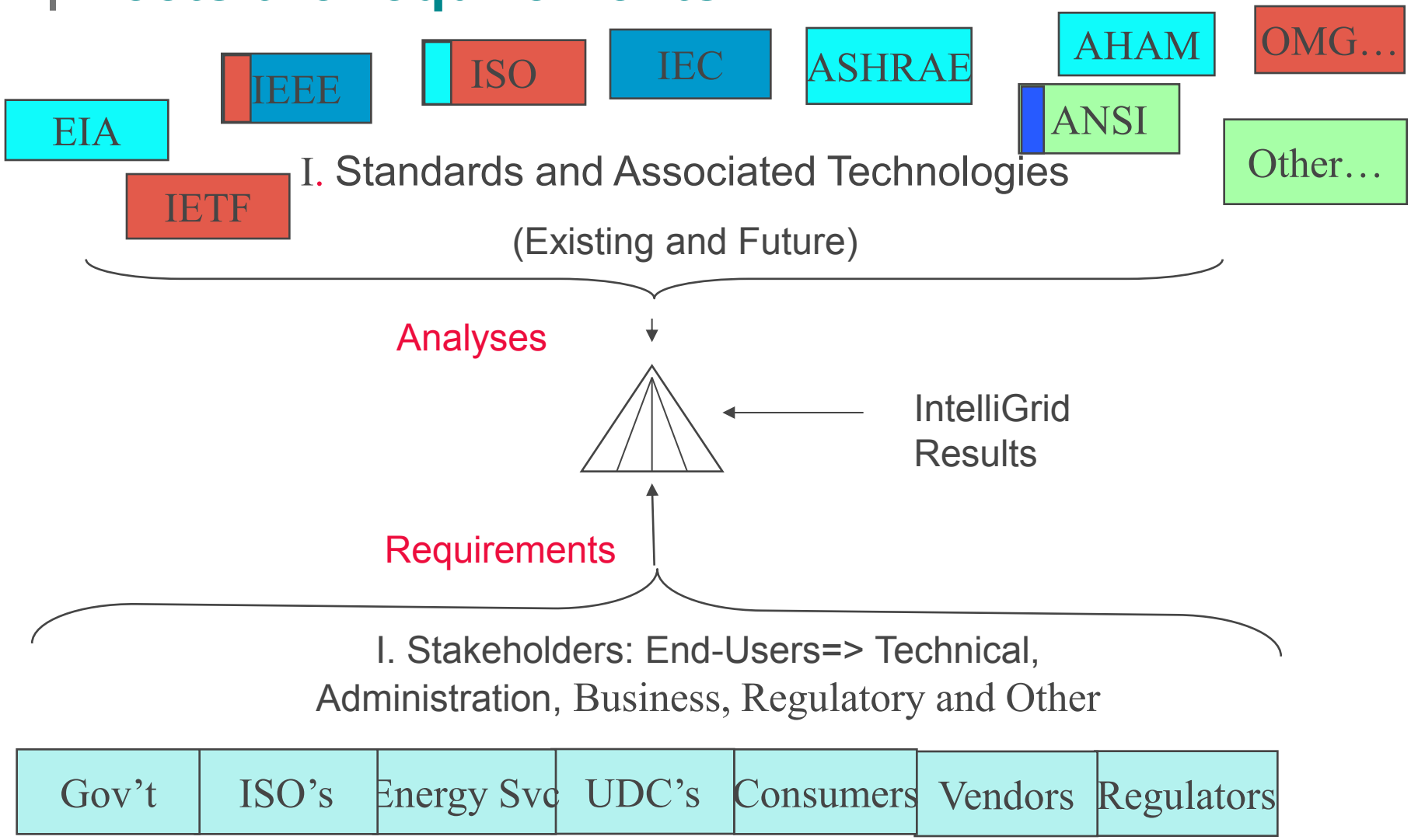
1 Deterministic Rapid Response Intra-Substation	4 Inter-Field Equipment	7 Intra-Control Center	10 RTOs / Market Participants	13 Intra-Corporation	16 Intra-Customer Site	19 HV Generation Plant
2 Deterministic Rapid Response Inter-Site	5 Critical Operations DAC	8 Inter-Control Center	11 Control Center / Customer Equip	14 Inter-Corporation	17 Inter-Customer Sites	20 Field Equipment Maintenance
3 Critical Operations Intra-Substation	6 Non-Critical Operations DAC:	9 Control Centers / ESPs	12 Control Center / Corporations	15 DER Monitoring and Control	18 Customer / ESP	21 Special

IntelliGrid Platform Independent Model

- Common information models, services, and interfaces



Analysis Challenges: Which technology best meets the requirements?



IntelliGrid Technologies

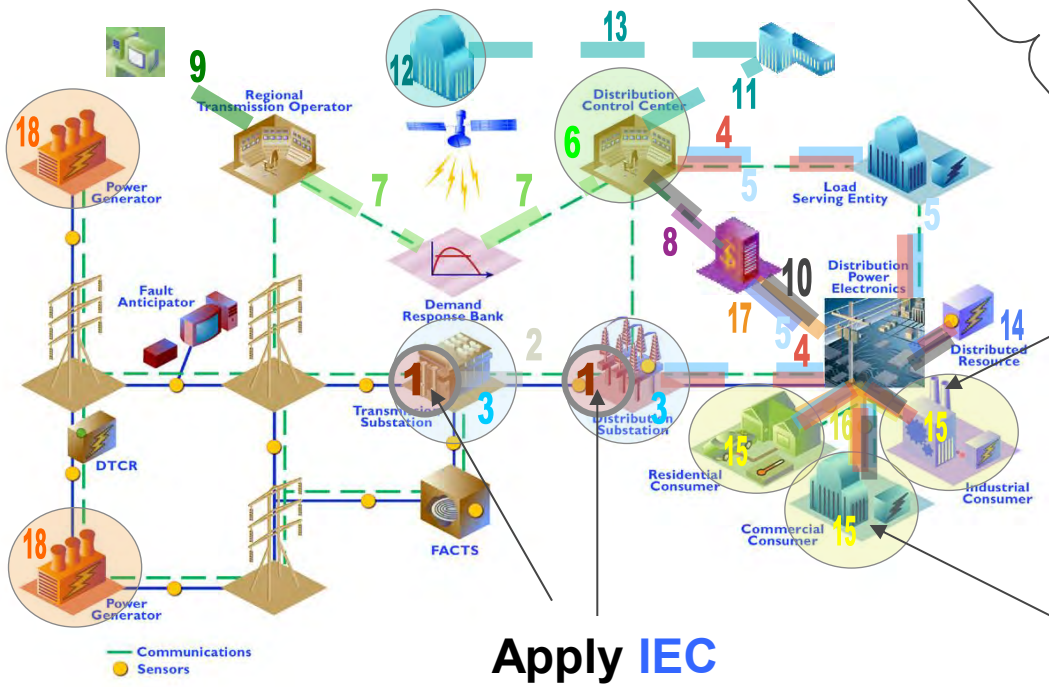
- IntelliGrid is all about requirements first, analysis second, technology selection last. When it comes to the technologies though, we do have a short list.
  - IEC 61850, 61400 – field device communications and general device object modeling
  - IEC 61968, 61970 – Common Information Model (CIM) and Generic Interface Definition (GID) – enterprise information management and integration
  - IEC 62351 – IED Communications Security
  - ANSI C12 – revenue metering communications
  - ASHRAE BACnet – building communications
  - Internet Technologies - TCP/IP, SONET, Satellite IP, DSL, BPL, Web Services, XML, SOAP, NTP/SNTP
  - IEEE 1588 (time), IEEE 802 series (Ethernet, WiFi, WiMAX)

Examples of Intelligrid Architecture Recommendations

Develop and implement consistent systems management and security policies

Apply IEC 61970 and 61968 for Enterprise Data Sharing

R&D: Harmonize IEC 61850 and 61970 Standards



Apply ANSI C12 for Revenue Metering

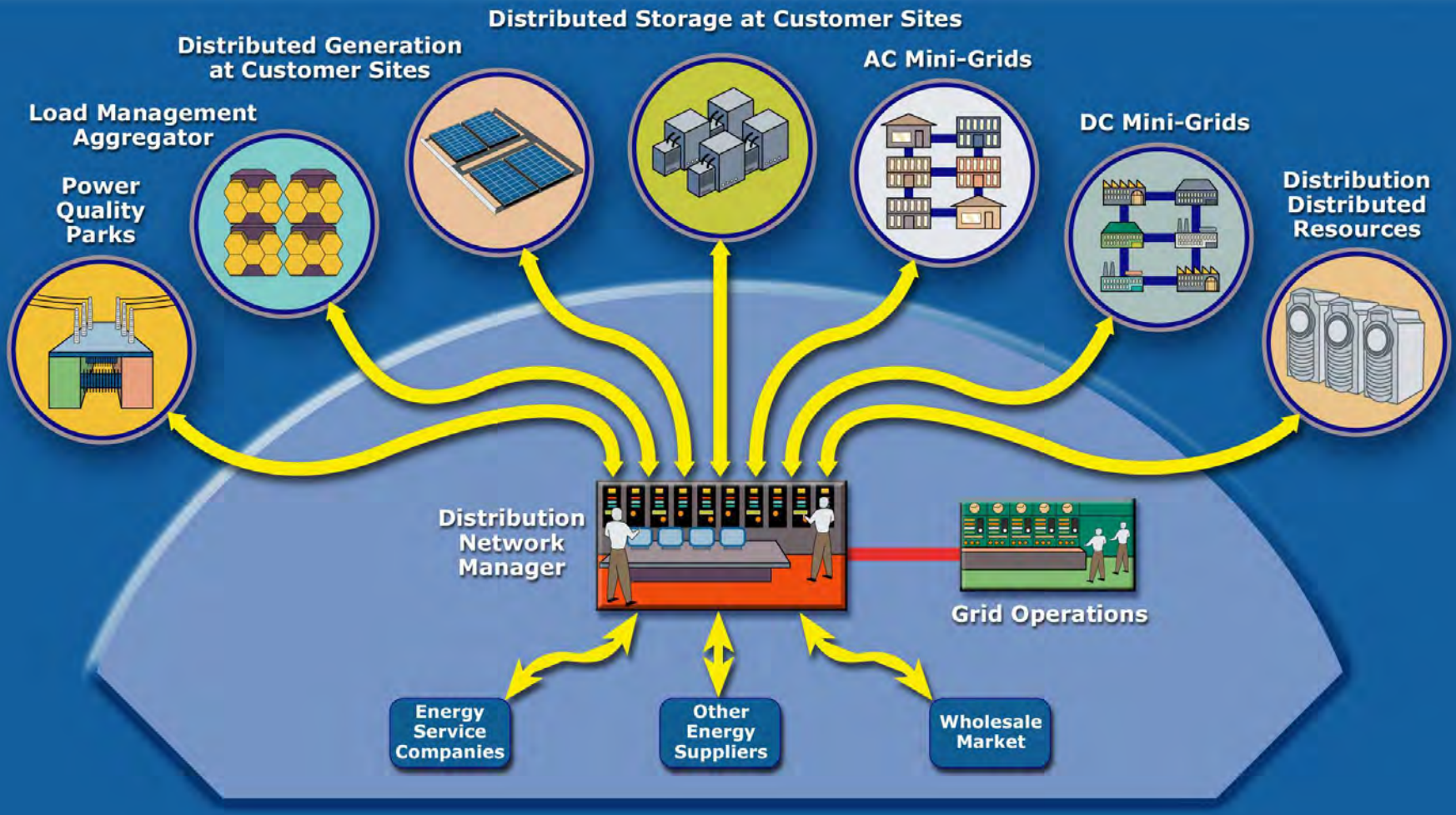
Apply IEC 61850 for Real-Time Controls

Apply ASHRAE BACnet™ for Building Automation

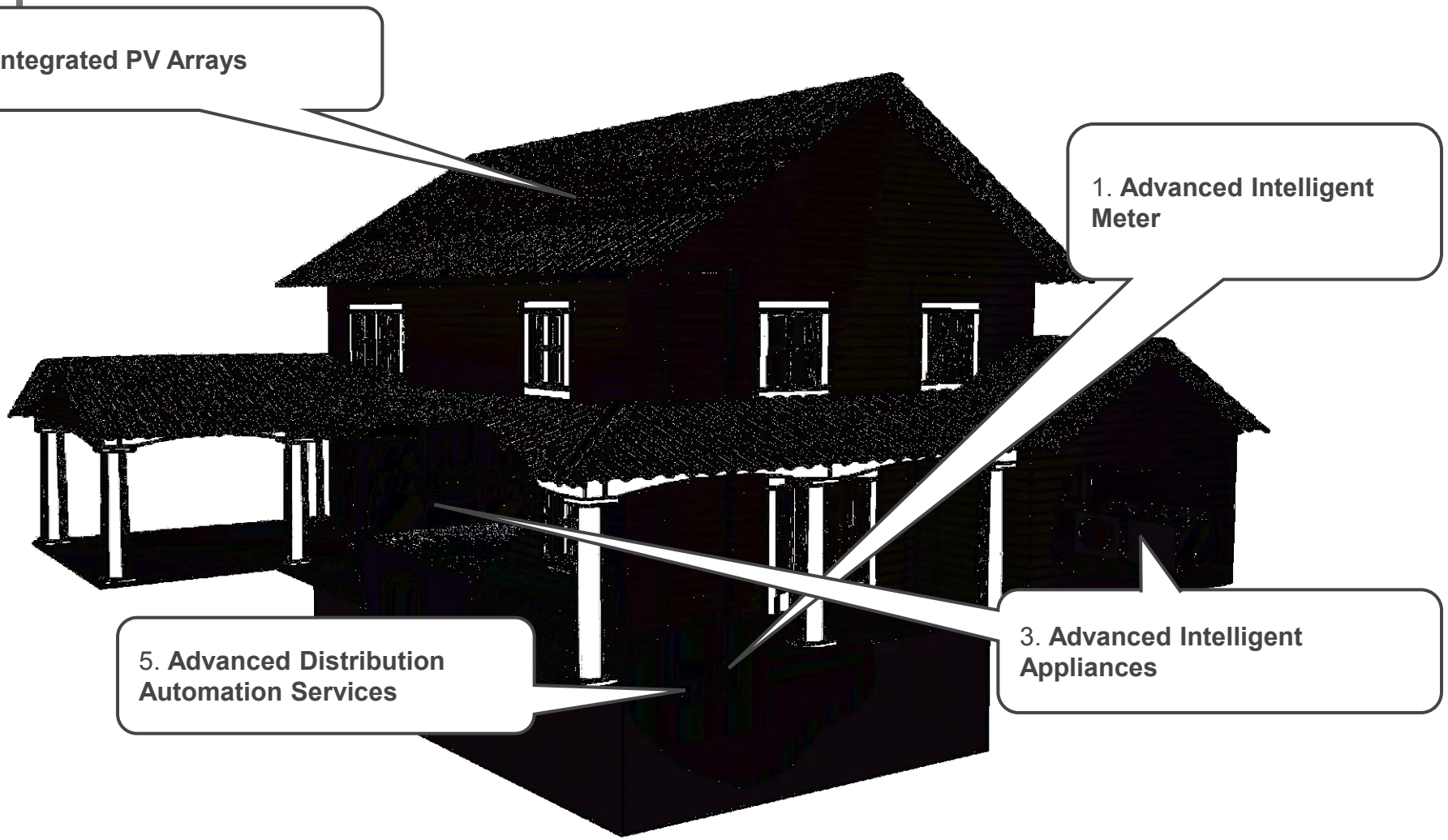
Early Application of IntelliGrid

- **California Energy Commission** - California Demand Response/Innovative Pricing Implementations
  - California is expected to implement a widespread, dynamic pricing tariff in the near future
  - The CEC has commissioned a project to develop a “reference design” to address these concerns
  - The CEC would like to use as much of the Architecture’s principles and process as possible in developing this reference design

Distribution Automation Scope



Extended Distribution Automation



The Scope of DA is Expanding….

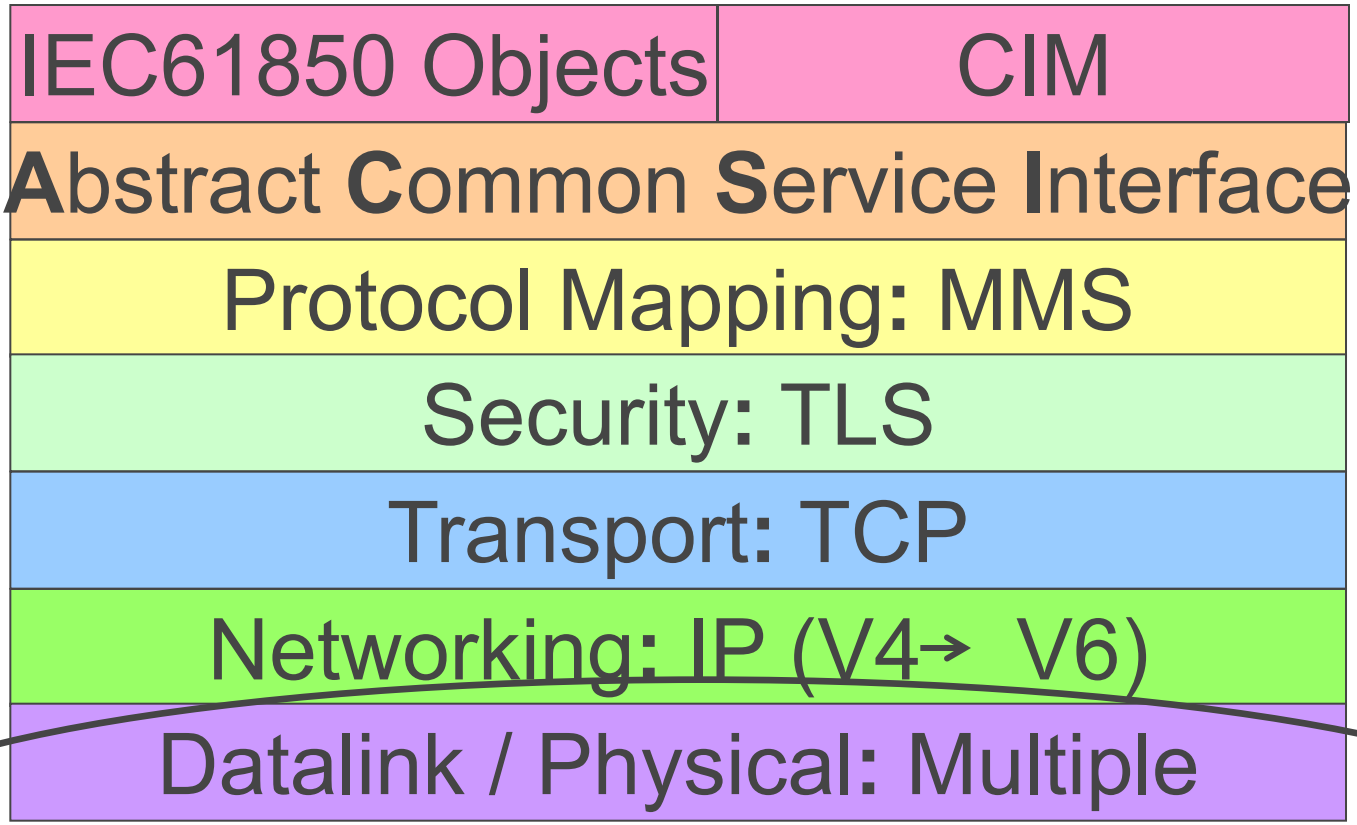
Communication Requirements

- Configuration
  - 2-way Communication
  - Large number of devices
  - Large number of data objects
  - Asset Management
- Quality of Service
  - High availability
  - Varying degrees of performance
- Security
  - Authentication
  - Confidentiality
- Data Management
- Constraints/concerns
  - Legacy device interface

Relevant IntelliGrid Environments for Distribution Automation

- Control Center to Customers Environment - #11
- Control Centers to Corporate Environment - #12
- Intra-Corporation Environment - #13
- Inter-Corporation Environment - #14
- DER Monitoring and Control Environment - #15
- Intra-Customer Site Environment - #16
- Inter-Customer Sites Environment - #17
- Customer to ESP Environment - #18
- Field Equipment Maintenance Environment - #20
- Inter-Field Equipment Environment - #4

IntelliGrid Recommended Solutions



Industry will optimize this choice…

“Cabled” Communication Solutions

- Fiber
- Leased line / Pilot Wire
- Power Line Carrier (60 Hz and others)
- Existing ISP
  - Cable Modem
  - DSL
  - Dial-up

Wireless Solutions - 1

Wi-Fi: Wireless Fidelity

- IEEE 802.11 based
- Operates in the unlicensed 2.4 (vers. b & g) and 5.6 GHz (ver. a) frequency bands
- Uses Direct Sequence Spread Spectrum
- Operates in Infrastructure or Ad-Hoc modes
- Distances from 10m to 100m
- Speeds up to 54Mbps
- Highly Interoperable

Wireless Solutions - 2

WiMAX

- Worldwide interoperability Microwave Access
- IEEE 802.16 based
- 2.4/3.5/5.8 GHz Operation
- 3-5 mile typical operating range
  - — Up to 30 mile operation possible
- Provides metropolitan area network connectivity
- Speeds of up to 75 Mb/sec
- Stand alone/Chip set solutions available

Wireless Solutions - 3

"Other" Wireless Technologies:

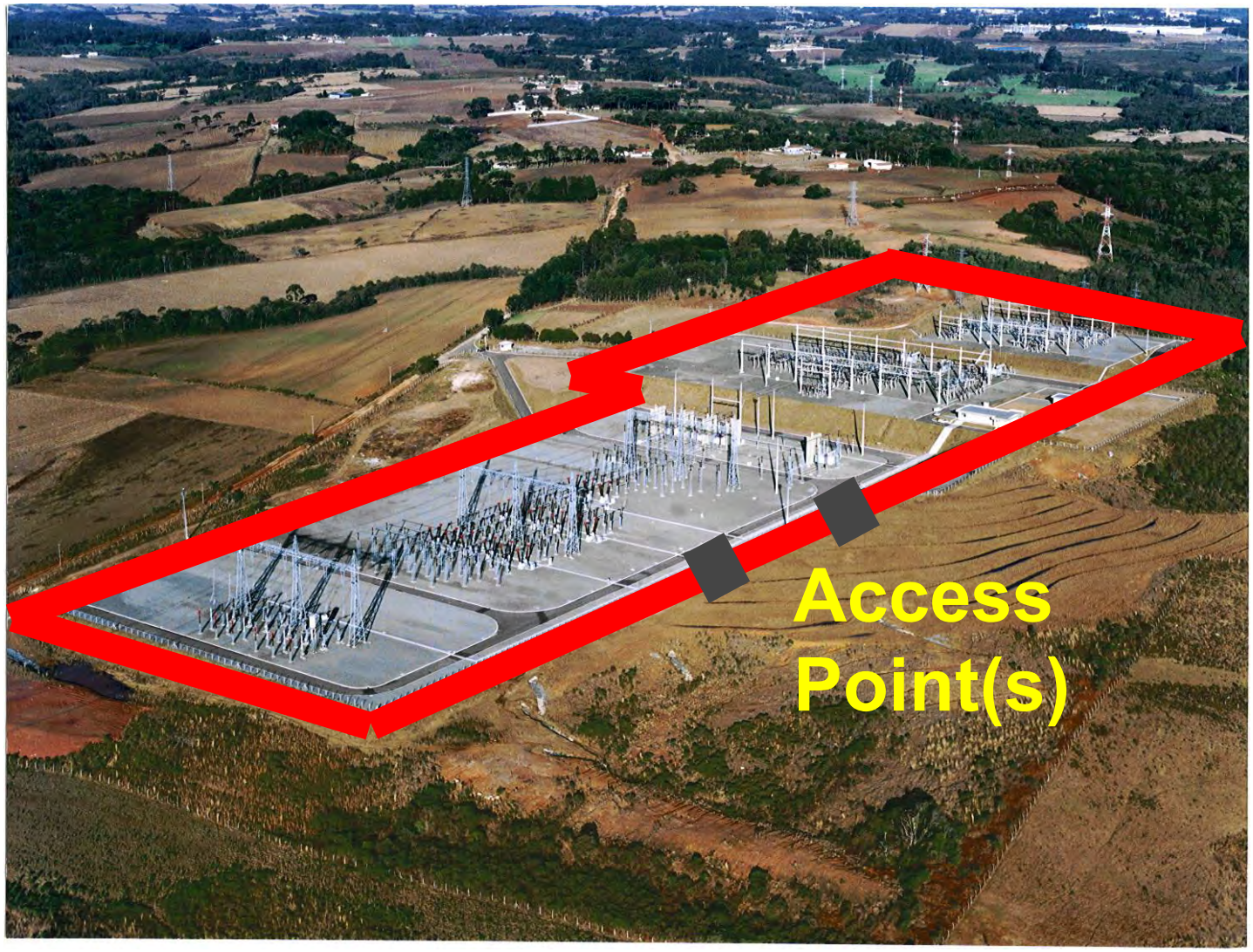
- GPRS - General Packet Radio Service
- Enhanced Data rates for Global Evolution (EDGE)
- CDMA Data Service
- "Home Grown" 900MHz solutions[1]
- Licensed radio
- MAS radio

[1]900MHz signals have significant improvement in transmission performance over 2.4GHz and higher frequencies

Areas addressed by NERC CIP – Critical Infrastructure Protection

- Identification of Critical Cyber Asset (CIP-002)
  - Any device w/ network interface
  - Any device w/ dial-up access
- Security Management Controls (CIP-003)
- Personnel and Training (CIP-004)
- Electronic Security (CIP-005)
- Physical Security (CIP-006)
- Systems Security Management (CIP-007)
- Incident Response Planning (CIP-008)
- Recovery Plans (CIP-009)

Electronic Security Perimeter



Cyber Perimeter Security Monitoring

- Access Control to cyber assets
  - Disabling of un-used ports
  - Restricting access
    - 2 factor authentication
    - Digital Certificates
- Monitoring of Cyber Asset Access Controls
  - Authorized/un-authorized access
  - Attempts at un-authorized access (UR alarm)
- Management of security policy

Key Observations

- Power engineers must now know enough about information technology to get beyond the dangerous stage – they must know enough to be effective
- Power engineering is already a relatively small subset of electrical engineering
- Power engineers who are interested in, let alone like, understand, or are enthralled by information technology are much harder to come buy
- This issue could be a major impediment to moving the electric power industry into the 21st century

Summary - IntelliGrid Architecture Concepts

- The IntelliGrid is a **set of "building codes"** that address:
  - **Requirements for future power system operational functions**
  - The use of **system and data modeling**
  - The definition of utility-specific **environments**
  - The use of **layered technologies**
  - The use of **common services, information models,** and **technology-independent interfaces**
  - The recommendation of **specific standards, associated technologies and best practices**
  - The identification of **missing or overlapping technologies**