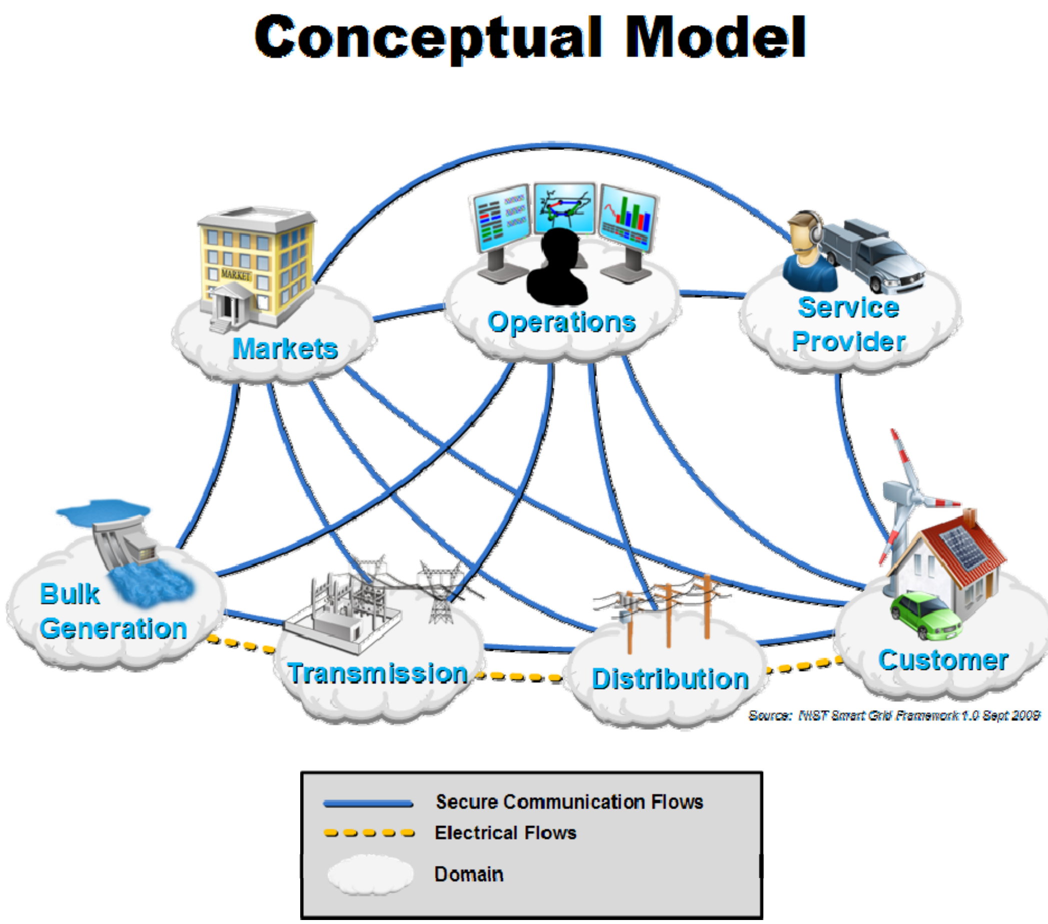
SMART GRID CONCEPTUAL MODEL

Version 1.0
April 20, 2010

Executive Summary

This document describes the Smart Grid Conceptual Model, a tool for discussing the structure and operation of the power system. It defines a set of domains, actors, applications, associations and interfaces that can be used in the process of defining smart grid information architectures. It includes diagrams that can be used for visualizing the use cases and components of the smart grid and its implementation.



Acknowledgements

This white paper is based on the NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0 and is based on the work of the Architecture Team assembled by EPRI.

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The Conceptual Model

The conceptual model presented in this white paper supports planning and organization of the diverse, expanding collection of interconnected networks that will compose the Smart Grid.

The Smart Grid Conceptual Model is a set of views (diagrams) and descriptions that are the basis for discussing the characteristics, uses, behavior, interfaces, requirements and standards of the Smart Grid.

The conceptual model described here provides a high-level, overarching perspective. It is not only a tool for identifying actors and possible communications paths in the Smart Grid, but also a useful way for identifying potential intra- and inter-domain interactions and potential applications and capabilities enabled by these interactions. The conceptual model is intended to aid in analysis; it is ***not*** a design diagram that defines a solution and its implementation. In other words, the conceptual model is descriptive and not prescriptive. It is meant to foster understanding of Smart Grid operational intricacies but not prescribe how the Smart Grid will be implemented.

This does not represent the final *architecture* of the Smart Grid; rather it is a tool for describing, discussing, and developing that architecture. The conceptual model provides a context for analysis of interoperation and standards, both for the rest of this document, and for the development of the architectures of the Smart Grid. The top level domains of the conceptual model are shown in Figure 1.

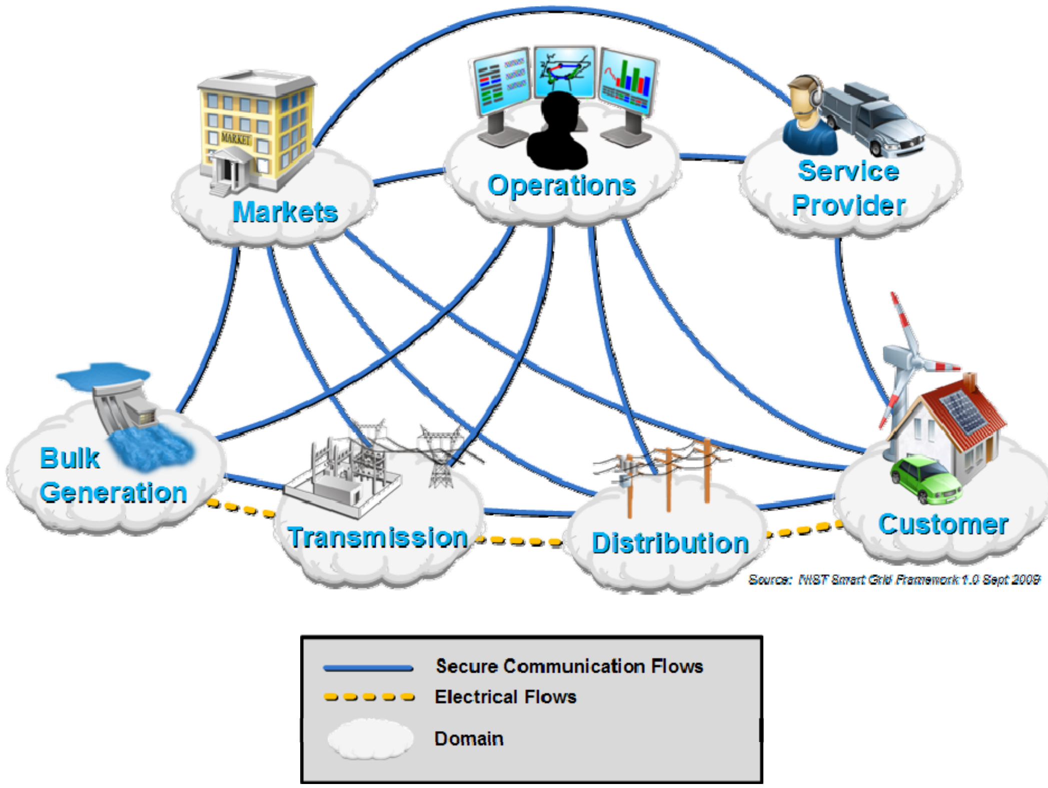

Figure 1 – Smart Grid Conceptual Model – Top Level Domains

The conceptual model consists of several *domains* – and its sub-domains – each of which contains many *actors* and *applications:*

- **Actors** may be devices, computer systems or software programs and/or the organizations that own them. Actors have the capability to make decisions and exchange information with other actors through interfaces.
- **Applications** are the tasks performed by the actors within the domains. Some applications are performed by a single actor, others by several actors working together.
- **Domains** group actors to discover the commonalities that will define the interfaces. In general, actors in the same domain have similar objectives. Communications within the same domain may have similar characteristics and requirements. Domains may contain other domains.
- **Flows** represent the flow of energy or information through the power grid (in the case of electrical flow) or the communication networks (in the case of information flow).
- **Interfaces** represent the point of access between a system or domain. There exist both electrical and communications interfaces (for the smart grid, the communications interfaces are of interest). Communications interfaces may be

bidirectional and represent the access point for information to enter and exit a system or domain (interfaces are logical). They represent logical connections rather than physical connections.

The domains of the Smart Grid are listed briefly in Table 1 and discussed in more detail in the sections that follow. In Figure 1, domains are shown as clouds.

Table 1 – Domains in the Smart Grid Conceptual Model

Domain	Actors in the Domain
Customers	The end users of electricity. May also generate, store, and manage the use of energy. Traditionally, three customer types are discussed, each with its own domain: home, commercial/building, and industrial.
Markets	The operators and participants in electricity markets
Service Providers	The organizations providing services to electrical customers and utilities
Operations	The managers of the movement of electricity
Bulk Generation	The generators of electricity in bulk quantities. May also store energy for later distribution.
Transmission	The carriers of bulk electricity over long distances. May also store and generate electricity.
Distribution	The distributors of electricity to and from customers. May also store and generate electricity.

In general, actors in the same domain have similar objectives. To enable Smart Grid functionality, the actors in a particular domain often interact with actors in other domains. However, communications within the same domain may not necessarily have similar characteristics and requirements. Moreover, particular domains also may contain components of other domains. For instance, the ten Independent System Operators and Regional Transmission Organizations (ISOs/RTOs) in North America have actors in both the Markets and Operations domains. Similarly, a distribution utility is not entirely contained within the Distribution domain—it is likely to contain actors in the Operations domain, such as a Distribution Management System (DMS), and in the Customer domain, such as meters.

Underlying the conceptual model is a legal and regulatory framework that includes policies and requirements that apply to various actors and applications and to their interactions. Regulations, adopted by the Federal Energy Regulatory Commission (FERC) at the federal level and by public utility commissions at the state and local levels, govern many aspects of the Smart Grid.

Such regulations are intended to ensure that electric rates are fair and reasonable and that security, reliability, safety, privacy, and other public policy requirements are met.[1] The transition to the Smart Grid introduces new regulatory considerations, which may transcend jurisdictional boundaries and require increased coordination among federal, state, and local lawmakers and regulators. The conceptual model must be consistent with the legal and regulatory framework and support its evolution over time. The standards and protocols identified in the framework also must align with existing and emerging regulatory objectives and responsibilities. The conceptual model is intended to be a useful tool for regulators at all levels to assess how best to achieve public policy goals that, along with business objectives, motivate investments in modernizing the nation's electric power infrastructure and building a clean energy economy.

The Smart Grid Conceptual Model is presented as successive diagrams of increasing levels of detail, as shown in Figure 2. Users of the model are encouraged to create additional levels or identify particular actors at a particular level in order to discuss the interaction between parts of the Smart Grid.

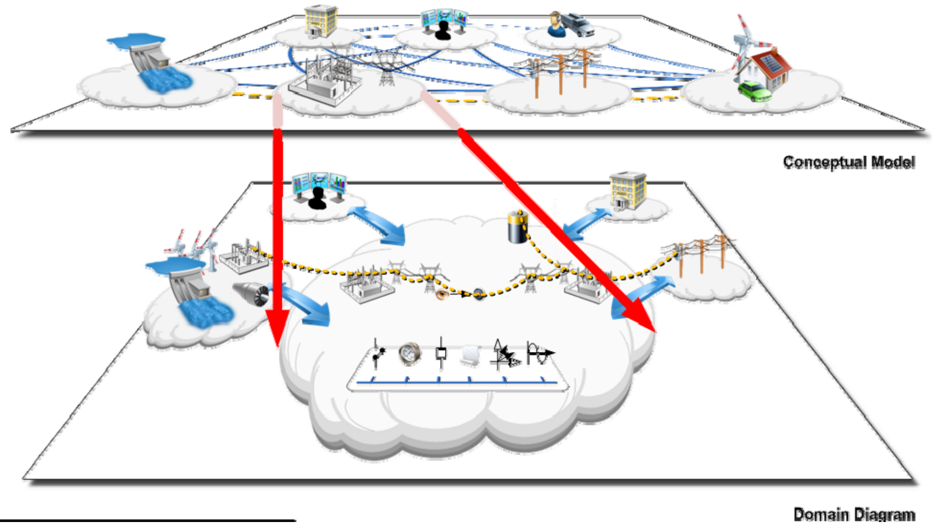

Figure 2 – Examining the Model in Detail

The conceptual model can be used to describe **use cases**. A use case is a story, told in structured and detailed steps, about how actors work together to reach a goal. A use case would be represented in the conceptual model by a path connecting several actors across multiple domains, as illustrated in Figure 3.

An example is the use case "Customers reduce demand in response to a price change". This type of demand response use case would involve actors in the Markets, Operations,

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[1] See, for example, the mission statements of National Association of Regulatory Utility Commissioners (NARUC) (http://www.naruc.org/about.cfm) and FERC (http://www.ferc.gov/about/about.asp).

Customer and possibly the Service Provider domains. Figure 3 depicts a hypothetical use case involving the Generation, Transmission and Distribution domains.

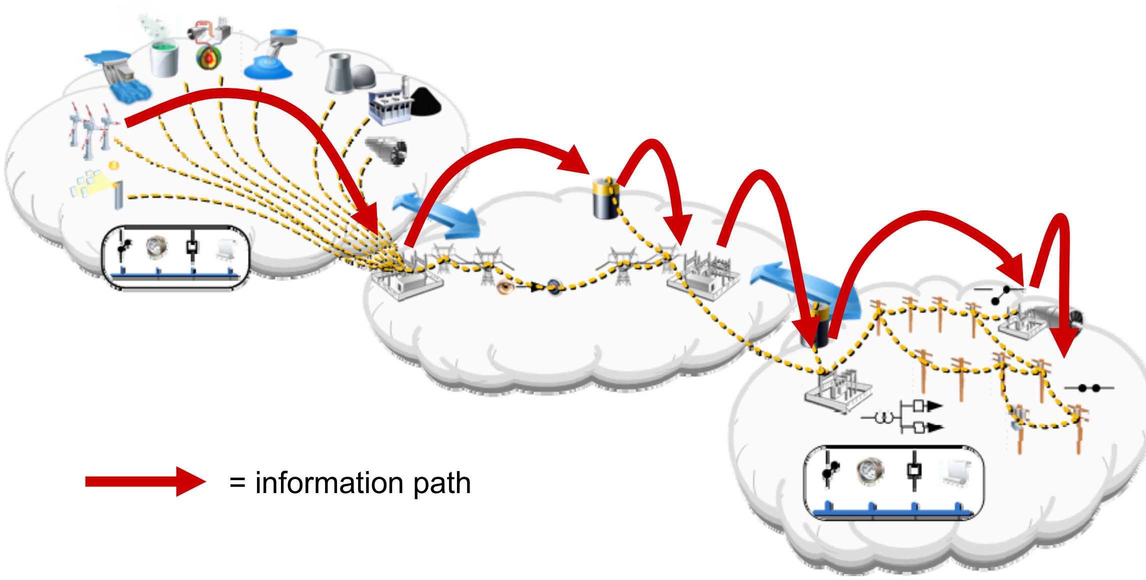

Figure 3 – Hypothetical Information Flow for a Smart Grid Use Case

The purpose of the conceptual model is to provide a framework for discussing both the existing power system and the evolving Smart Grid.

Note that the Conceptual Model, as presented, is not intended to be comprehensive in identifying all actors and all paths possible in the Smart Grid. This achievement will only be possible after additional elaboration and consolidation of use cases is achieved by stakeholder activities that are ongoing.

Scope of the Conceptual Model

It is important to note that the conceptual model of the Smart Grid is not limited to a single domain or a single application or use case. The use of the term "Smart Grid" has been applied in some circles to only distribution automation or in others to only advanced metering or demand response, for example. The conceptual model assumes that "Smart Grid" includes a wide variety of use cases and applications, especially (but not limited to) the four functional priorities identified by FERC.

The scope also includes cross cutting requirements including cyber security, network management, data management, and application integration, as described in the GridWise Architecture Council Interoperability Context-Setting Framework. As illustrated in Figure 4, the layers of this framework can be pictured as underlying the actors, domains, and interfaces pictured in the model.

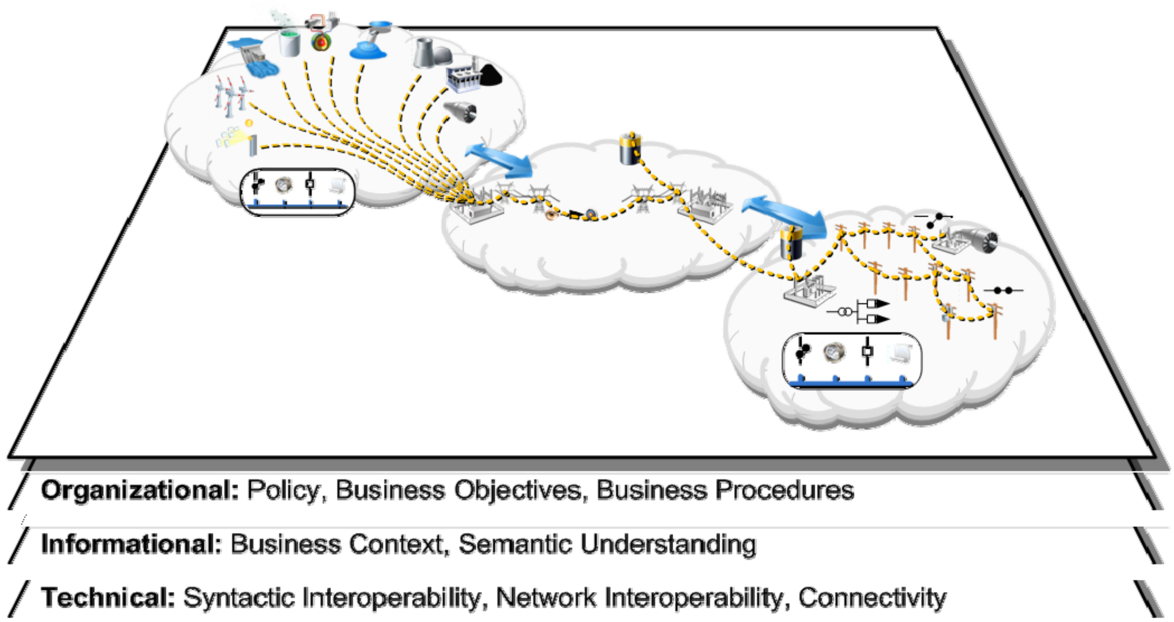

Figure 4 – The Conceptual Model and the GWAC Interoperability Framework

Customer Domain

The customer is ultimately the stakeholder that the entire grid was created to support. This is the domain where electricity is consumed (see Figure 5). Actors in the Customer domain enable customers to manage their energy usage and generation. Some actors also provide control and information flow between the customer and the other domains. The boundaries of the Customer domain are typically considered to be the utility meter and the Energy Services Interface (ESI). The ESI provides a secure interface for Utility-to-Consumer interactions. The ESI in turn can act as a bridge to facility-based systems such as a Building Automation System (BAS) or a customer's Energy Management System (EMS).

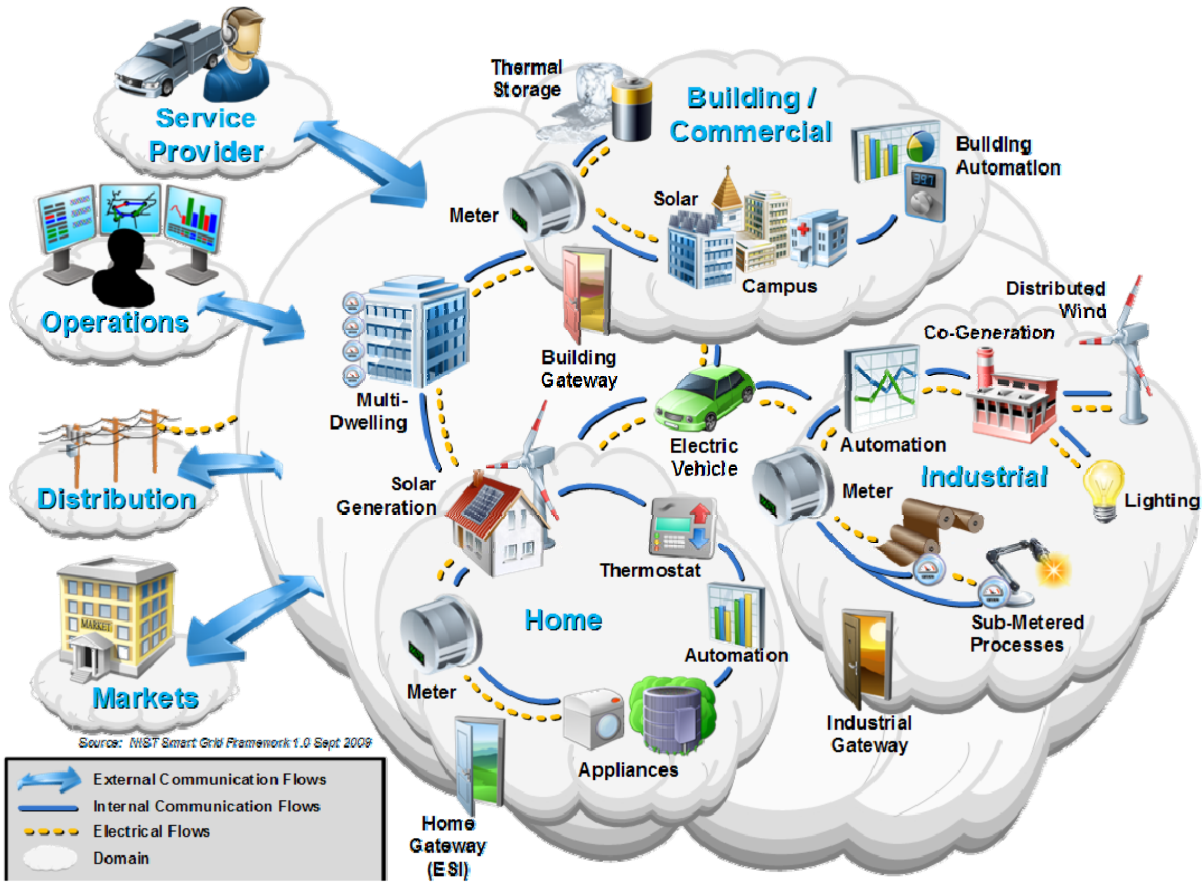

Figure 5 – Overview of the Customer Domain

The Customer domain is usually segmented into sub-domains for home, commercial/building, and industrial. The energy needs of these sub-domains are typically set at less than 20 kW of demand for Home, 20-200 kW for Commercial/Building, and over 200 kW for Industrial. Each sub-domain has multiple actors and applications, which may also be present in the other sub-domains. Each sub-domain has a meter actor and an ESI that may reside in the meter or on the EMS or in an independent gateway.

The ESI is the primary service interface to the Customer domains. The ESI may communicate with other domains via the AMI infrastructure or via another means, such as the Internet. The ESI communicates to devices and systems within the customer premises across a Home Area Network or other Local Area Network.

There may be more than one EMS— and therefore more than one communications path—per customer. The EMS is the entry point for such applications as remote load control, monitoring and control of distributed generation, in-home display of customer usage, reading of non-energy meters, and integration with building management systems and the enterprise. The EMS may provide auditing/logging for cyber security purposes. The Customer domain is electrically connected to the Distribution domain. It communicates with the Distribution, Operations, Market, and Service Provider domains.

Table 2 – Typical Applications within the Customer Domain

Application	Description
Building / Home Automation	A system that is capable of controlling various functions within a building such as lighting and temperature control.
Industrial Automation	A system that controls industrial processes such as manufacturing or warehousing.
Micro-generation	Includes all types of distributed generation including; Solar, Wind, and Hydro generators. Generation harnesses energy for electricity at a customer location. May be monitored, dispatched, or controlled via communications.

Markets Domain

The markets are where grid assets are bought and sold. Actors in the Markets domain exchange price and balance supply and demand within the power system (see Figure 6). The boundaries of the Market domain include the edge of the Operations domain where control happens, the domains supplying assets (e.g. generation, transmission, etc), and the Customer domain.

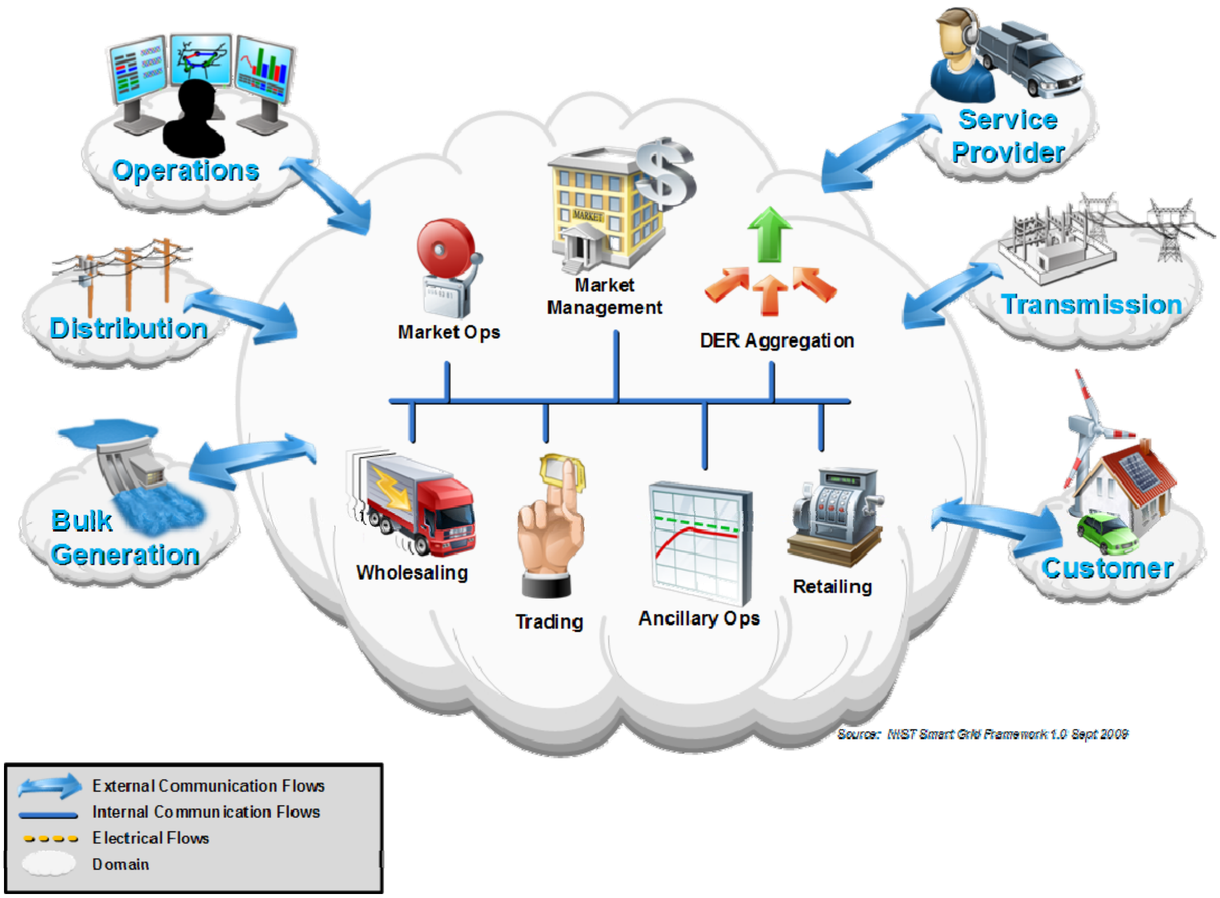

Figure 6 – Overview of the Markets Domain

Communication between the Markets domain and the domains supplying energy are critical because efficient matching of production with consumption is dependent on markets. Energy supply domains include the Bulk Generation domain and Distributed Energy Resources (DER). DER resides in the Transmission, Distribution, and Customer domains. NERC CIPs consider suppliers of more than 300 megawatts to be Bulk Generation; most DER is smaller and is typically served through aggregators. DERs participate in markets to some extent today, and will participate to a greater extent as the Smart Grid becomes more interactive.

Communications for Markets domain interactions must be reliable. They must be traceable and auditable. They must support e-commerce standards for integrity and non-repudiation. As the percentage of energy supplied by small DER increases, the allowed latency in communications with these resources must be reduced.

The high-priority challenges in the Markets domain are: extension of price and DER signals to each of the Customer sub-domains; simplification of market rules; expanding the capabilities of aggregators; interoperability across all providers and consumers of market information; managing the growth (and regulation) of retail and wholesale energy sales, and evolving communication mechanisms for prices and energy characteristics between and throughout the Markets and Customer domains.

Table 3 – Typical Applications in the Markets Domain

Example	Description
Market Management	Market managers include ISOs for wholesale markets or NYMEX for forward markets in many ISO/RTO regions. There are transmission and services and demand response markets as well. Some DER Curtailment resources are treated today as dispatchable generation.
Retailing	Retailers sell power to end customers and may in the future aggregate or broker DER between customers or into the market. Most are connected to a trading organization to allow participation in the wholesale market.
DER Aggregation	Aggregators combine smaller participants (as providers or customers or curtailment) to enable distributed resources to play in the larger markets.
Trading	Traders are participants in markets, which include aggregators for provision and consumption and curtailment, and other qualified entities. There are a number of companies whose primary business is the buying and selling of energy.
Market Operations	Make a particular market function smoothly. Functions include financial and goods sold clearing, price quotation streams, audit, balancing, and more.
Ancillary Operations	Provide a market to provide frequency support, voltage support, spinning reserve and other ancillary services as defined by FERC, NERC and the various ISO. These markets function on a regional or ISO basis normally.

Service Provider Domain

Actors in the Service Provider domain perform services to support the business processes of power system producers, distributors and customers. These business processes range from traditional utility services such as billing and customer account management to enhanced customer services such as management of energy use and home energy generation.

The service provider must not compromise the cyber security, reliability, stability, integrity and safety of the electrical power network when delivering existing or emerging services.

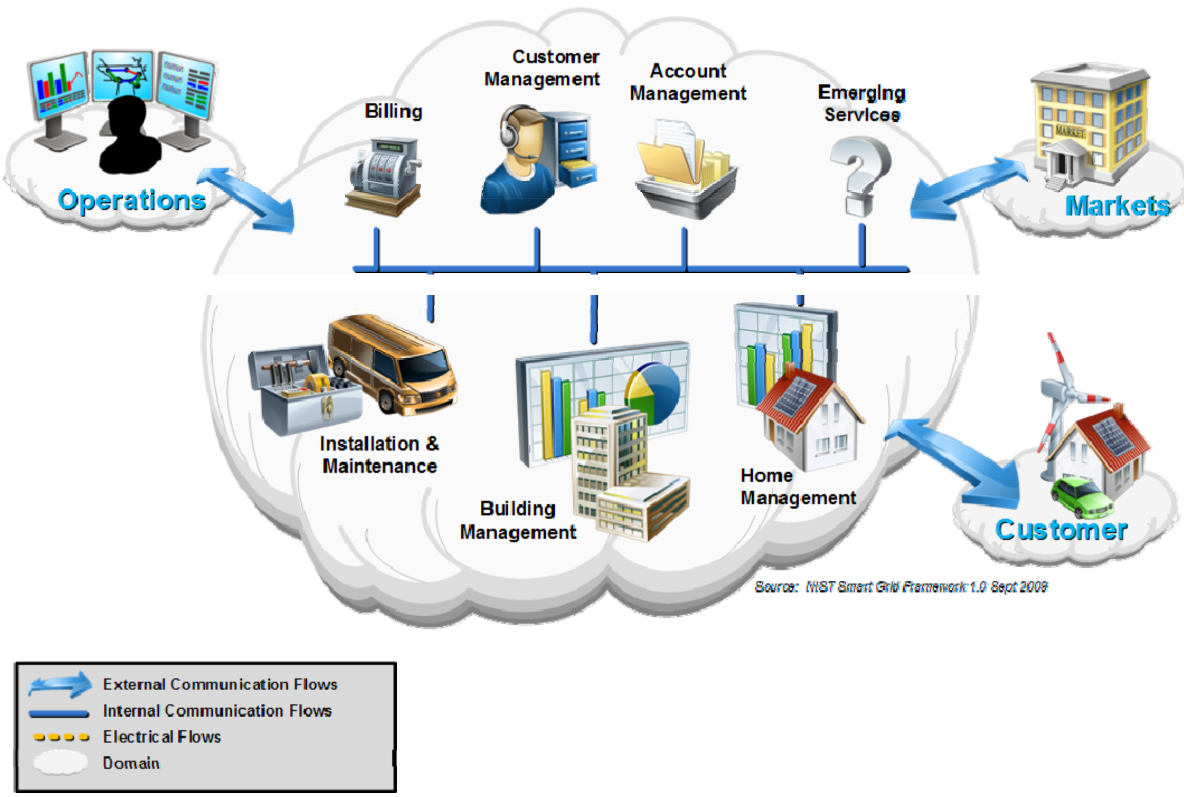

Figure 7 – Overview of the Service Provider Domain

The Service Provider domain shares interfaces with the Markets, Operations, and Customer domains. Communications with the Operations domain are critical for system control and situational awareness; communications with the Markets and Customer domains are critical for enabling economic growth through the development of "smart" services. For example, the Service Provider domain may provide the interface enabling the customer to interact with the market(s).

Service providers will create new and innovative services and products to meet the new requirements and opportunities presented by the evolving Smart Grid. Services may be performed by the electric service provider, by existing third parties, or by new participants drawn by the new business models. Emerging services represent an area of significant new economic growth.

The priority challenge in the Service Provider domain is to develop the key interfaces and standards that will enable a dynamic market-driven ecosystem while protecting the critical power infrastructure. These interfaces must be able to operate over a variety of networking technologies while maintaining consistent messaging semantics. Some benefits to the Service Provider domain from the deployment of the Smart Grid include:

1) The development of a growing market for third parties to provide value-added services and products to customers, utilities and other stakeholders at competitive costs.
2) The decrease in cost of business services for other Smart Grid domains.
3) A decrease in power consumption and an increase in power generation as customers become active participants in the power supply chain.

Table 4 – Typical Applications in the Service Provider Domain

Example	Description
Customer Management	Managing customer relationships by providing point-of-contact and resolution for customer issues and problems.
Installation & Maintenance	Installing and maintaining premises equipment that interacts with the Smart Grid.
Building Management	Monitoring and controlling building energy and responding to Smart Grid signals while minimizing impact on building occupants.
Home Management	Monitoring and controlling home energy and responding to Smart Grid signals while minimizing impact on home occupants.
Billing	Managing customer billing information, sending billing statements and processing received payments.
Account Management	Managing the supplier and customer business accounts.
Emerging Services	All of the services and innovations that have yet to be created. These will be instrumental in defining the Smart Grid of the future.

Operations Domain

Actors in the Operations domain are responsible for the smooth operation of the power system. Today, the majority of these functions are the responsibility of a regulated utility. The smart grid will enable more of them to be outsourced to service providers; others may evolve over time. No matter how the Service Provider and Markets domains evolve, there will still be basic functions needed for planning and operating the service delivery points of a "wires" company.

In transmission operations, Energy Management Systems (EMS) are used to analyze and operate the transmission power system reliably and efficiently, while in distribution operations, similar Distribution Management Systems (DMS) are used for analyzing and operating the distribution system.

Representative applications within the Operations domain are described in Table 5. These applications are derived from the IEC 61968-1 Interface Reference Model (IRM) for this domain[2].

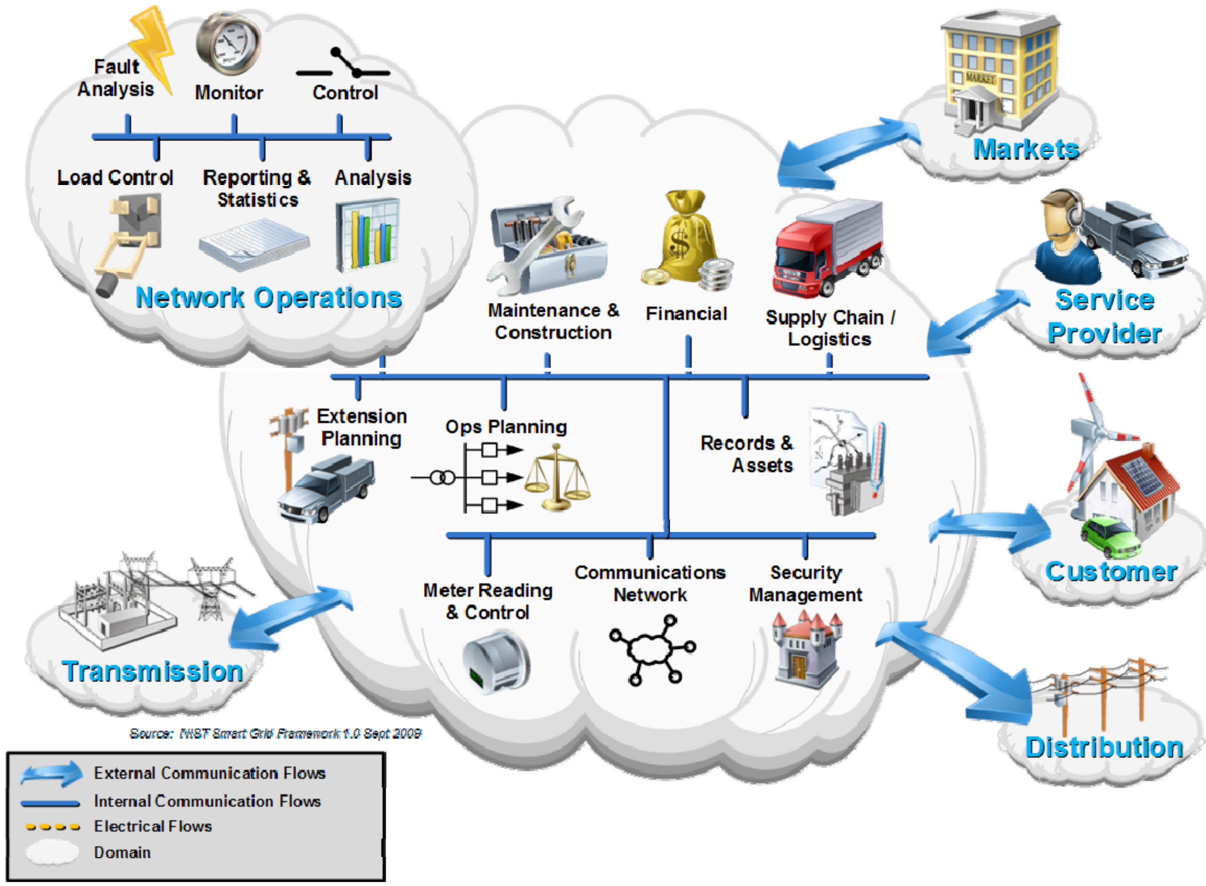

Figure 8 – Overview of the Operations Domain

Table 5 – Typical Applications in the Operations Domain

Application	**Description**
Network Operations	The Network Operations domain (actually a sub-domain) within Operations includes the applications:

[2] To review and comment on a more detailed breakdown of the IRM, please refer to the IEC 61968-1 document available under the Shared Documents directory at http://osgug.ucaiug.org/utilityami/AMIENT

Application	**Description**
• Monitoring	Network Operation Monitoring actors supervise network topology, connectivity and loading conditions, including breaker and switch states, and control equipment status. They locate customer telephone complaints and field crews.
• Control	Network control is coordinated by actors in this domain, although they may only supervise wide area, substation, and local automatic or manual control.
• Fault Management	Fault Management actors enhance the speed at which faults can be located, identified, and sectionalized and service can be restored. They provide information for customers, coordinate with workforce dispatch and compile information for statistics.
• Analysis	Operation Feedback Analysis actors compare records taken from real-time operation related with information on network incidents, connectivity and loading to optimize periodic maintenance.
• Reporting and Statistics	Operational Statistics and Reporting actors archive on-line data and to perform feedback analysis about system efficiency and reliability.
• Calculations	Real-time Network Calculations actors (not shown) provide system operators with the ability to assess the reliability and security of the power system.
• Training	Dispatcher Training actors provide facilities for dispatchers that simulate the actual system they will be using. (not shown on diagram)
Records and Assets	The Records and Asset Management actors track and report on the substation and network equipment inventory, provide geospatial data and geographic displays, maintain records on non-electrical assets, and perform asset investment planning.
Operational Planning	Operational Planning and Optimization actors perform simulation of network operations, schedule switching actions, dispatch repair crews, inform affected customers, and schedule the importing of power. They keep the cost of imported power low through peak generation, switching, load shedding or demand response.

Application	Description
Maintenance and Construction	Maintenance and Construction actors coordinate inspection, cleaning and adjustment of equipment, organize construction and design, dispatch and schedule maintenance and construction work, capture records gathered by field personnel and permit them to view necessary information to perform their tasks.
Extension Planning	Network Extension planning actors develop long term plans for power system reliability, monitor the cost, performance and schedule of construction, and define projects to extend the network such as new lines, feeders or switchgear.
Customer Support	Customer Support actors help customers to purchase, provision, install and troubleshoot power system services, and relay and record customer trouble reports.
Meter Reading and Control	Meter Reading and Control actors perform a variety of functions on the metering system including data collection, disconnect/reconnect, outage management, prepayment point of sale, power quality and reliability monitoring, meter maintenance and asset management, meter data management including validation, estimation and editing (VEE), customer billing, and load management, including load analysis and control, demand response, and risk management.
Supply Chain and Logistics	Supply Chain and Logistics actors manage the processes for acquiring necessary supplies; tracking acquired and ordered supplies; and allocating them.
Financial	Financial actors measure performance across the whole organization, including the evaluation of investments in capital projects, maintenance, or operations. They track risk, benefits, costs and impact on levels of service.
Communications Network	The planning, operations and maintenance of all communications network asset that are required to support Operations.
Security Management	The management of security policies, distribution and maintenance of security credentials, and centralized authentication and authorization as appropriate.
Premises	Information regarding the location of a service. This set of functions includes: Address management; Right of ways, easements, grants; and Real estate management.

Application	Description
Human Resources	Human Resources actors manage personnel information and activities including safety, training, benefits, performance, review, compensation, recruiting and expenses.
Business Planning and Reporting	These actors perform strategic business modeling, manpower planning, reporting, account management, and both assess and report on risk, performance and business impact.
Stakeholder Planning and Management	These actors perform track and manage the needs and concerns of various utility stakeholders by monitoring customer input, regulators, service standards, and legal proceedings.

Bulk Generation Domain

Applications in the Bulk Generation domain are the first processes in the delivery of electricity to customers. Electricity generation is the process of creating electricity from other forms of energy, which may vary from chemical combustion to nuclear fission, flowing water, wind, solar radiation and geothermal heat. The boundary of the Generation domain is typically the Transmission domain.

The Bulk Generation domain is electrically connected to the Transmission domains and shares interfaces with the Operations, Markets and Transmission domains.

Communications with the Transmission domain are the most critical because without transmission, customers cannot be served. The Bulk Generation domain must communicate key performance and quality of service issues such as scarcity (especially for wind and sun) and generator failure. These communications may cause the routing of electricity onto the transmission system from other sources. A lack of sufficient supply may be addressed directly (via Operations) or indirectly (via Markets).

New requirements for the Bulk Generation domain include green house gas emissions controls, increases in renewable energy sources, provision of storage to manage the variability of renewable generation.

Actors in the Bulk Generation domain may include various devices such as protection relays, remote terminal units, equipment monitors, fault recorders, user interfaces and programmable logic controllers. They typically perform the applications shown in Figure 9 and discussed in the table below.

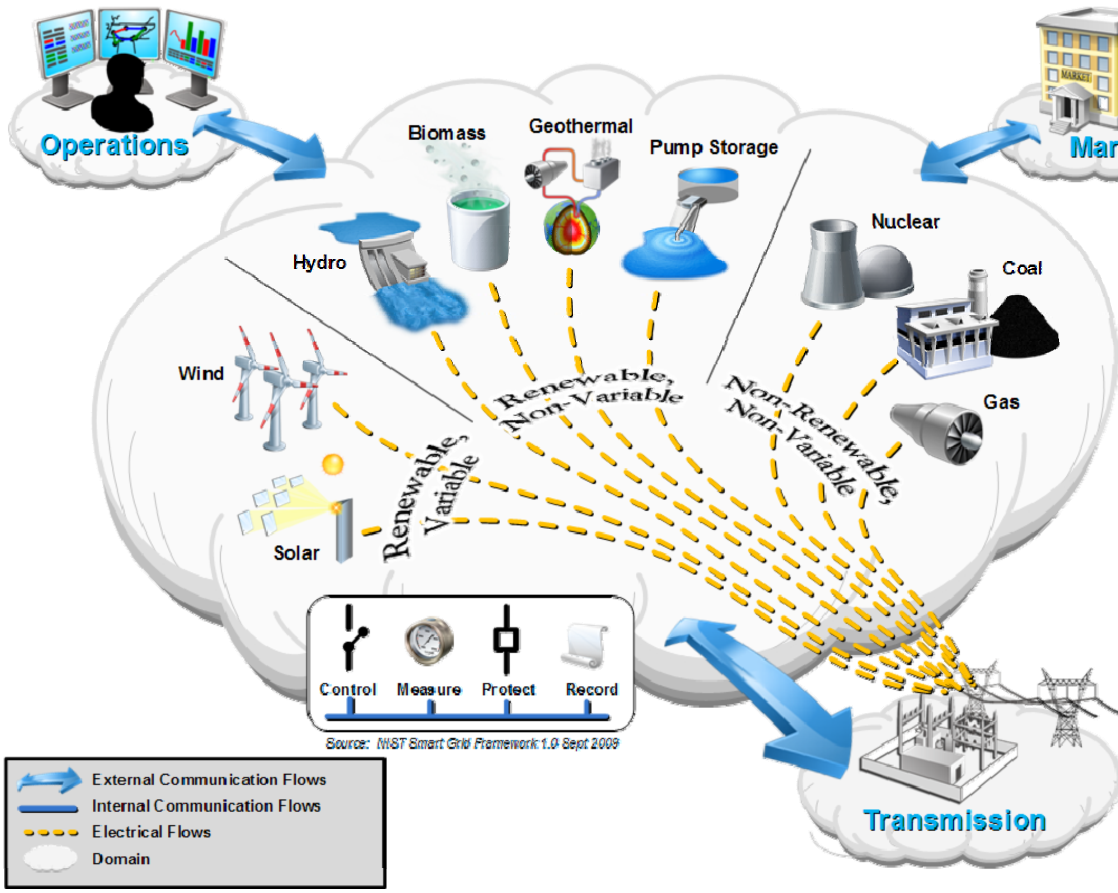

Figure 9 – Overview of the Bulk Generation Domain

Table 6 – Bulk Generation Categories

Category	**Description**
Variable	Generation from wind, sun, wave power, etc. that can vary with time.
Non-Variable	Generation from continuous process, coal, uranium, water, biomass, etc
Renewable	Generation from a source that can be replenished, e.g. wind, water, biomass
Non-Renewable	Generation from a source that cannot be replenished, e.g. coal, oil, uranium

Note that similarity exists in the common applications for Bulk Generation, Transmission, and the Distribution Domains. These common kinds of applications are summarized in Table 7 which follows. These applications, therefore, apply to each of the three power conduction path Domains.

Table 7 – Common Applications in Bulk Generation, Transmission, and Distribution Domains

Application	Description
Control	Performed by actors that permit the Operations domain to manage the flow of power and reliability of the system. An example would be the use of phase angle regulators within a substation to control power flow between two adjacent power systems
Measure	Performed by actors that provide visibility into the flow of power and the condition of the systems in the field. In the future measurement might be found in built into meters, transformers, feeders, switches and other devices in the grid. An example would be the digital and analog measurements collected through the SCADA system from a remote terminal unit (RTU) and provide to a grid control center in the Operations domain.
Protect	Performed by Actors that react rapidly to faults and other events in the system that might cause power outages, brownouts, or the destruction of equipment. Performed to maintain high levels of reliability and power quality. May work locally or on a wide scale.
Record	Performed by actors that permit other domains to review what has happened on the grid for financial, engineering, operational, and forecasting purposes.
Asset Management	Performed by actors that work together to determine when equipment should have maintenance, calculate the life expectancy of the device, and record its history of operations and maintenance so it can be reviewed in the future for operational and engineering decisions.
Stabilize and Optimize	Performed by actors that ensure the network is operating with the appropriate tolerances across the system. They may gather information to make control decisions that ensure reliable and proper operations (stability) or more efficient operations (optimization). Measurement and control form a feedback loop that allows grid operators to stabilize the flow of energy across the electric network or safely increase the load on a transmission path.

Transmission Domain

Transmission is the bulk transfer of electrical power from generation sources to distribution through multiple substations. A transmission network is typically operated by a Regional Transmission Operator or Independent System Operator (RTO/ISO) whose primary responsibility is to maintain stability on the electric grid by balancing generation (supply) with load (demand) across the transmission network.

Examples of actors in the transmission domain include remote terminal units, substation meters, protection relays, power quality monitors, phasor measurement units, sag monitors, fault recorders, and substation user interfaces. They typically perform the applications shown in the diagram (Figure 12) and described in Table 7 above.

The transmission domain may contain Distributed Energy Resources (DER) such as electrical storage or peaking generation units. Energy and supporting ancillary services (capacity that can be dispatched when needed to stabilize the grid) are procured through the Markets domain and scheduled and operated from the Operations domain, and finally delivered through the Transmission domain to the distribution system and finally to the Customer Domain.

Most activity in the Transmission domain is in a substation. An electrical substation uses transformers to change voltage from high to low or the reverse across the electric supply chain. Substations also contain switching, protection and control equipment. The figure depicts both step-up and step down sub-stations connecting generation (including peaking units) and storage with distribution. Substations may also connect two or more transmission lines. Transmission towers, power lines and field telemetry such as the line sag detector shown make up the balance of the transmission network infrastructure.

The transmission network is typically monitored and controlled through a Supervisory Control and Data Acquisition (SCADA) system composed of a communication network, monitoring devices and control devices.

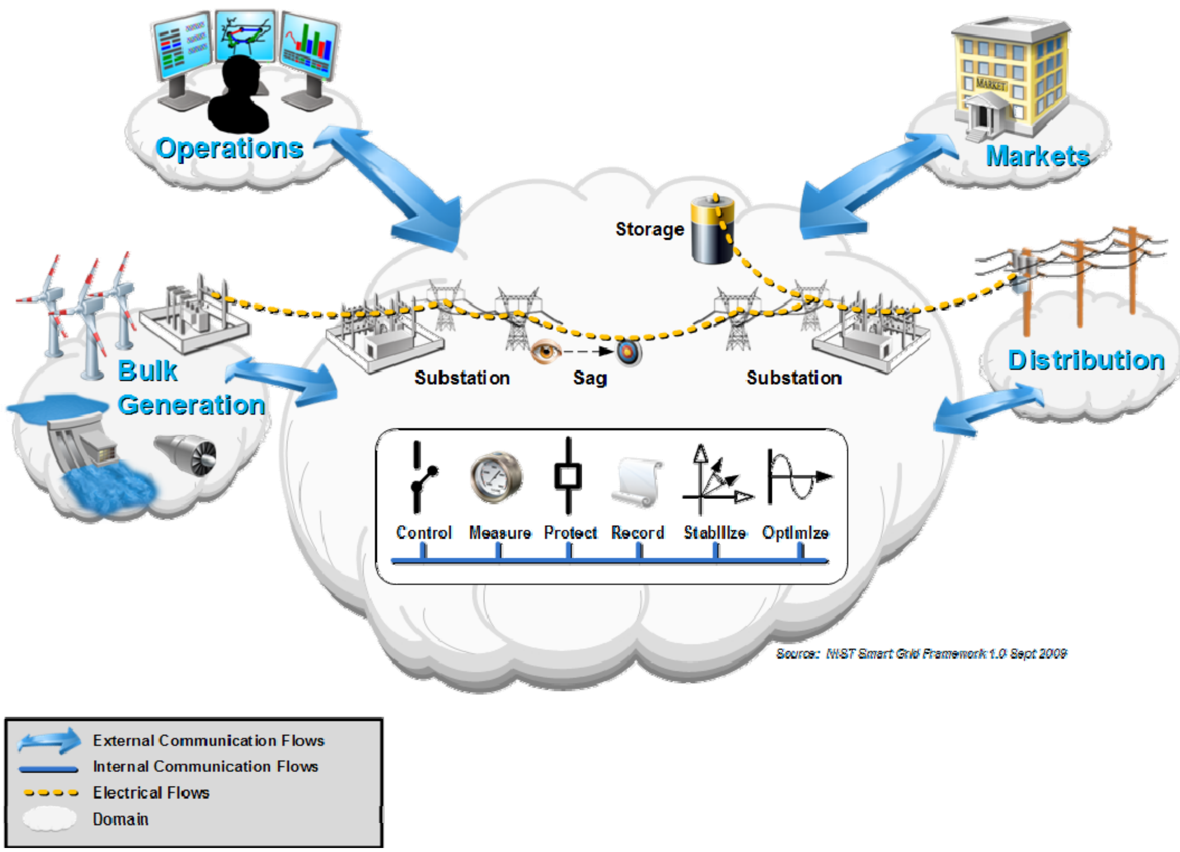

Figure 10 – Overview of the Transmission Domain

Distribution Domain

The Distribution domain is the electrical interconnection between the Transmission domain, the Customer domain and the metering points for consumption, distributed storage, and distributed generation. The electrical distribution system may be arranged in a variety of structures, including radial, looped or meshed.

The reliability of the distribution system varies depending on its structure, the types of actors that are deployed, and the degree to which they communicate with each other and with the actors in other domains. Historically distribution systems have been radial configurations, with little telemetry, and almost all communications within the domain was performed by humans. The primary installed sensor base in this domain is the customer with a telephone, whose call initiates the dispatch of a field crew to restore power.

Historically, many communications interfaces within this domain were hierarchical and unidirectional, although they now generally can be considered to work in both directions, even as the electrical connections are beginning to do. Distribution actors may have local inter-device (peer-to-peer) communication or a more centralized communication methodology.

In the smart grid, the Distribution domain will communicate more closely with the Operations domain in real-time to manage the power flows associated with a more dynamic Markets domain and other environmental and security-based factors. The Markets domain will communicate with Distribution in ways that will effect localized consumption and generation. In turn, these behavioral changes due to market forces may have electrical and structural impacts on the Distribution domain and the larger grid. Under some models, third party Customer Service Providers may communicate with the Customer domain using the infrastructure of the Distribution domain; such a change would change the communications infrastructure selected for use within the Domain.

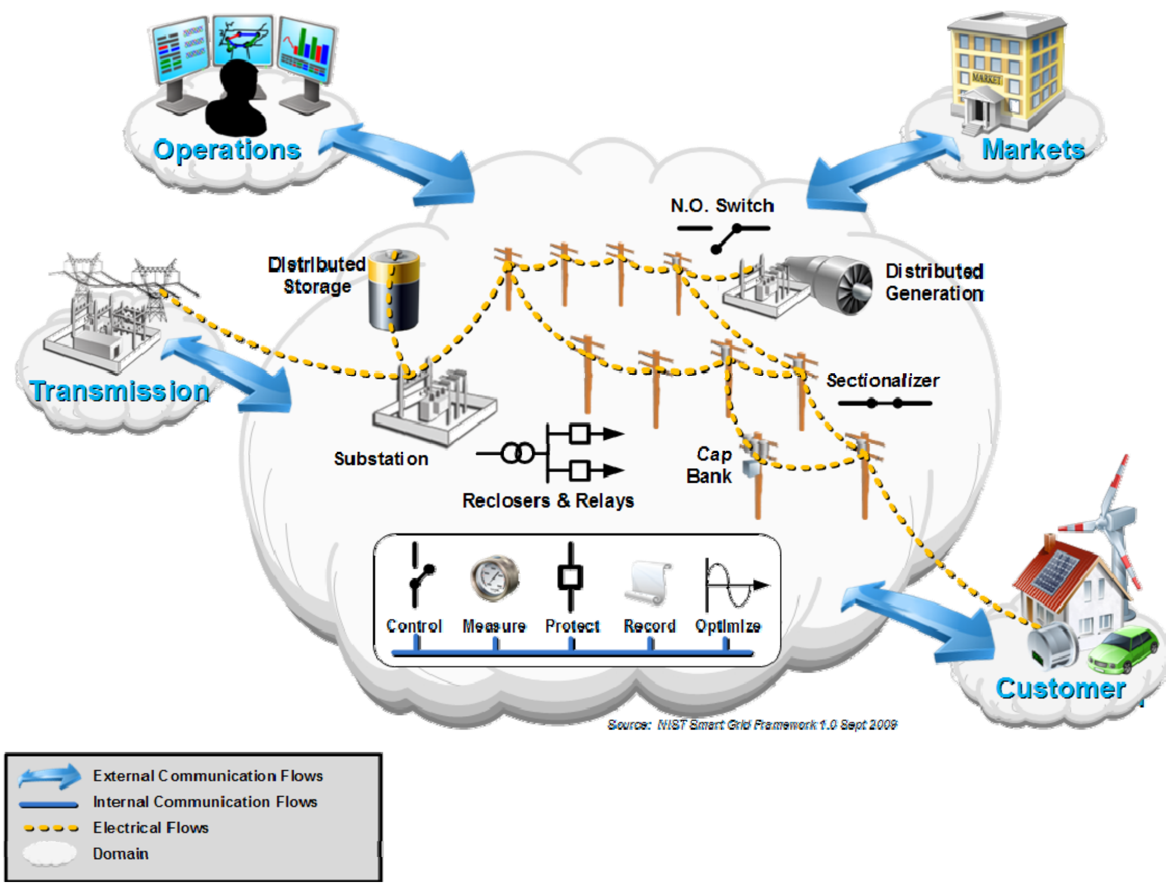

Figure 11 – Distribution Domain Diagram

Actors in the Distribution domain include capacitor banks, sectionalizers, reclosers, protection relays, storage devices, and distributed generators. They typically perform the applications shown in the diagram (Figure 13) and described in Table 7 above.

Conceptual Model Actors

The following table contains a list of all Actors and Applications (specialized Actors) from the Conceptual Model.

Table 8: Conceptual Model Actors

Actor	Type	Domain	Description
Thermal Storage	Device	Customer	
Campus	Geographic	Customer	
Solar	Device	Customer	
Meter	Device	Customer	
Building Automation	Subsystem	Customer	
Building Gateway	Subsystem	Customer	
Multi-Dwelling	Geographic	Customer	
Thermostat	Device	Customer	
Home Automation	Device	Customer	
Appliances	Device	Customer	
ESI	Device	Customer	
Electric Vehicle	Device	Customer	
Distributed Wind	Device	Customer	
Co-Generation	Device	Customer	
Industrial Automation	Subsystem	Customer	
Lighting	Subsystem	Customer	

Sub-Metered Processes	Subsystem	Customer	
Industrial Gateway	Device	Customer	
Market Ops	Application	Markets	Make a particular market function smoothly. Functions include financial and goods sold clearing, price quotation streams, audit, balancing, and more.
Market Management	Application	Markets	Market managers include ISOs for wholesale markets or NYMEX for forward markets in many ISO/RTO regions. There are transmission and services and demand response markets as well. Some DER Curtailment resources are treated today as dispatchable generation.
DER Aggregation	Application	Markets	Aggregators combine smaller participants (as providers or customers or curtailment) to enable distributed resources to play in the larger markets.
Retailing	Application	Markets	Retailers sell power to end customers and may in the future aggregate or broker DER between customers or into the market. Most are connected to a trading organization to allow participation in the wholesale market.
Ancillary Ops	Application	Markets	Provide a market to provide frequency support, voltage support, spinning reserve and other ancillary services as defined by FERC, NERC and the various ISO. These markets function on a regional or ISO basis normally.
Trading	Application	Markets	Traders are participants in markets, which include aggregators for provision and consumption and curtailment, and other qualified entities. There are a number of companies whose primary business is the buying and selling of energy.
Wholesaling	Application	Markets	
Customer Management	Application	Service Provider	Managing customer relationships by providing point-of-contact and resolution for customer issues and problems.

Account Management	Application	Service Provider	Managing the supplier and customer business accounts.
Billing	Application	Service Provider	Managing customer billing information, sending billing statements and processing received payments.
Emerging Services	Application	Service Provider	All of the services and innovations that have yet to be created. These will be instrumental in defining the Smart Grid of the future.
Installation and Maintenance	Application	Service Provider	Installing and maintaining premises equipment that interacts with the Smart Grid.
Building Management	Application	Service Provider	Monitoring and controlling building energy and responding to Smart Grid signals while minimizing impact on building occupants.
Home Management	Application	Service Provider	Monitoring and controlling home energy and responding to Smart Grid signals while minimizing impact on home occupants.
Maintenance and Construction	Application	Operations	Maintenance and Construction actors coordinate inspection, cleaning and adjustment of equipment, organize construction and design, dispatch and schedule maintenance and construction work, capture records gathered by field personnel and permit them to view necessary information to perform their tasks.
Financial	Application	Operations	Financial actors measure performance across the whole organization, including the evaluation of investments in capital projects, maintenance, or operations. They track risk, benefits, costs and impact on levels of service.
Supply Chain Logistics	Application	Operations	Supply Chain and Logistics actors manage the processes for acquiring necessary supplies; tracking acquired and ordered supplies; and allocating them.

Extension Planning	Application	Operations	Network Extension planning actors develop long term plans for power system reliability, monitor the cost, performance and schedule of construction, and define projects to extend the network such as new lines, feeders or switchgear.
Ops Planning	Application	Operations	Operational Planning and Optimization actors perform simulation of network operations, schedule switching actions, dispatch repair crews, inform affected customers, and schedule the importing of power. They keep the cost of imported power low through peak generation, switching, load shedding or demand response.
Records and Assets	Application	Operations	The Records and Asset Management actors track and report on the substation and network equipment inventory, provide geospatial data and geographic displays, maintain records on non-electrical assets, and perform asset investment planning.
Meter Reading and Control	Application	Operations	Meter Reading and Control actors perform a variety of functions on the metering system including data collection, disconnect/reconnect, outage management, prepayment point of sale, power quality and reliability monitoring, meter maintenance and asset management, meter data management including validation, estimation and editing (VEE), customer billing, and load management, including load analysis and control, demand response, and risk management.
Communications Network	Application	Operations	The planning, operations and maintenance of all communications network asset that are required to support Operations.

Security Management	Application	Operations	The management of security policies, distribution and maintenance of security credentials, and centralized authentication and authorization as appropriate.
Customer Support	Application	Operations	Customer Support actors help customers to purchase, provision, install and troubleshoot power system services, and relay and record customer trouble reports.
Premises	Application	Operations	Information regarding the location of a service. This set of functions includes: Address management; Right of ways, easements, grants; and Real estate management.
Human Resources	Application	Operations	Human Resources actors manage personnel information and activities including safety, training, benefits, performance, review, compensation, recruiting and expenses.
Business Planning and Reporting	Application	Operations	These actors perform strategic business modeling, manpower planning, reporting, account management, and both assess and report on risk, performance and business impact.
Stakeholder Planning and Reporting	Application	Operations	These actors perform track and manage the needs and concerns of various utility stakeholders by monitoring customer input, regulators, service standards, and legal proceedings.
Network Operations	Application	Operations	The Network Operations domain (actually a sub-domain) within Operations includes the applications:
Network Operations - Fault Analysis	Application	Operations	Fault Management actors enhance the speed at which faults can be located, identified, and sectionalized and service can be restored. They provide information for customers, coordinate with workforce dispatch and compile information for statistics.

Network Operations - Monitor	Application	Operations	Network Operation Monitoring actors supervise network topology, connectivity and loading conditions, including breaker and switch states, and control equipment status. They locate customer telephone complaints and field crews.
Network Operations - Control	Application	Operations	Network control is coordinated by actors in this domain, although they may only supervise wide area, substation, and local automatic or manual control.
Network Operations - Reporting and Statistics	Application	Operations	Operational Statistics and Reporting actors archive on-line data and to perform feedback analysis about system efficiency and reliability.
Network Operations - Analysis	Application	Operations	Operation Feedback Analysis actors compare records taken from real-time operation related with information on network incidents, connectivity and loading to optimize periodic maintenance.
Network Operations - Calculations	Application	Operations	Real-time Network Calculations actors (not shown) provide system operators with the ability to assess the reliability and security of the power system.
Wind	Device	Bulk Generation	
Hydro	Device	Bulk Generation	
Biomass	Device	Bulk Generation	
Geothermal	Device	Bulk Generation	
Pump Storage	Device	Bulk Generation	
Solar	Device	Bulk Generation	
Nuclear	Device	Bulk Generation	
Coal	Device	Bulk Generation	
Gas	Device	Bulk Generation	

Generation - Control	Application	Bulk Generation	Performed by actors that permit the Operations domain to manage the flow of power and reliability of the system. An example would be the use of phase angle regulators within a substation to control power flow between two adjacent power systems
Generation - Measure	Application	Bulk Generation	Performed by actors that provide visibility into the flow of power and the condition of the systems in the field. In the future measurement might be found in built into meters, transformers, feeders, switches and other devices in the grid. An example would be the digital and analog measurements collected through the SCADA system from a remote terminal unit (RTU) and provide to a grid control center in the Operations domain.
Generation - Protect	Application	Bulk Generation	Performed by Actors that react rapidly to faults and other events in the system that might cause power outages, brownouts, or the destruction of equipment. Performed to maintain high levels of reliability and power quality. May work locally or on a wide scale.
Generation - Record	Application	Bulk Generation	Performed by actors that permit other domains to review what has happened on the grid for financial, engineering, operational, and forecasting purposes.
Generation - Asset Management	Application	Bulk Generation	Performed by actors that work together to determine when equipment should have maintenance, calculate the life expectancy of the device, and record its history of operations and maintenance so it can be reviewed in the future for operational and engineering decisions.

Generation - Stabilize and Optimize	Application	Bulk Generation	Performed by actors that ensure the network is operating with the appropriate tolerances across the system. They may gather information to make control decisions that ensure reliable and proper operations (stability) or more efficient operations (optimization). Measurement and control form a feedback loop that allows grid operators to stabilize the flow of energy across the electric network or safely increase the load on a transmission path.
Storage	Device	Transmission	
Substation	Geographic	Transmission	
Transmission - Control	Application	Transmission	Performed by actors that permit the Operations domain to manage the flow of power and reliability of the system. An example would be the use of phase angle regulators within a substation to control power flow between two adjacent power systems
Transmission - Measure	Application	Transmission	Performed by actors that provide visibility into the flow of power and the condition of the systems in the field. In the future measurement might be found in built into meters, transformers, feeders, switches and other devices in the grid. An example would be the digital and analog measurements collected through the SCADA system from a remote terminal unit (RTU) and provide to a grid control center in the Operations domain.
Transmission - Protect	Application	Transmission	Performed by Actors that react rapidly to faults and other events in the system that might cause power outages, brownouts, or the destruction of equipment. Performed to maintain high levels of reliability and power quality. May work locally or on a wide scale.

Transmission - Record	Application	Transmission	Performed by actors that permit other domains to review what has happened on the grid for financial, engineering, operational, and forecasting purposes.
Transmission - Asset Management	Application	Transmission	Performed by actors that work together to determine when equipment should have maintenance, calculate the life expectancy of the device, and record its history of operations and maintenance so it can be reviewed in the future for operational and engineering decisions.
Transmission - Stabilize and Optimize	Application	Transmission	Performed by actors that ensure the network is operating with the appropriate tolerances across the system. They may gather information to make control decisions that ensure reliable and proper operations (stability) or more efficient operations (optimization). Measurement and control form a feedback loop that allows grid operators to stabilize the flow of energy across the electric network or safely increase the load on a transmission path.
NO Switch	Device	Distribution	
Distributed Generation	Device	Distribution	
Sectionalizer	Device	Distribution	
Cap Bank	Device	Distribution	
Recloser	Device	Distribution	
Relay	Device	Distribution	
Distributed Storage	Device	Distribution	
Distribution - Control	Application	Distribution	Performed by actors that permit the Operations domain to manage the flow of power and reliability of the system. An example would be the use of phase angle regulators within a substation to control power flow between two adjacent power systems

Distribution - Measure	Application	Distribution	Performed by actors that provide visibility into the flow of power and the condition of the systems in the field. In the future measurement might be found in built into meters, transformers, feeders, switches and other devices in the grid. An example would be the digital and analog measurements collected through the SCADA system from a remote terminal unit (RTU) and provide to a grid control center in the Operations domain.
Distribution - Protect	Application	Distribution	Performed by Actors that react rapidly to faults and other events in the system that might cause power outages, brownouts, or the destruction of equipment. Performed to maintain high levels of reliability and power quality. May work locally or on a wide scale.
Distribution - Record	Application	Distribution	Performed by actors that permit other domains to review what has happened on the grid for financial, engineering, operational, and forecasting purposes.
Distribution - Asset Management	Application	Distribution	Performed by actors that work together to determine when equipment should have maintenance, calculate the life expectancy of the device, and record its history of operations and maintenance so it can be reviewed in the future for operational and engineering decisions.
Distribution - Stabilize and Optimize	Application	Distribution	Performed by actors that ensure the network is operating with the appropriate tolerances across the system. They may gather information to make control decisions that ensure reliable and proper operations (stability) or more efficient operations (optimization). Measurement and control form a feedback loop that allows grid operators to stabilize

		the flow of energy across the electric network or safely increase the load on a transmission path.

The Combined Conceptual Reference Diagram

The diagram in this section is a refinement of the conceptual model to combine the domain views into one diagram and includes example actor names, organizational structure, communications networks and some information about security concerns.

It is intended to be high-level. It is a tool for identifying actors and possible communications paths in the Smart Grid. It is useful for identifying potential intra- and inter-domain interactions and potential applications and capabilities enabled by these interactions. The diagram shown in Figure 12 is intended to aid in analysis; it is ***not*** a design diagram that defines a solution and its implementation. In other words, the conceptual model and the combined conceptual reference diagram are descriptive and not prescriptive. They are meant to foster understanding of Smart Grid operational intricacies; they do not prescribe how the Smart Grid will be implemented.

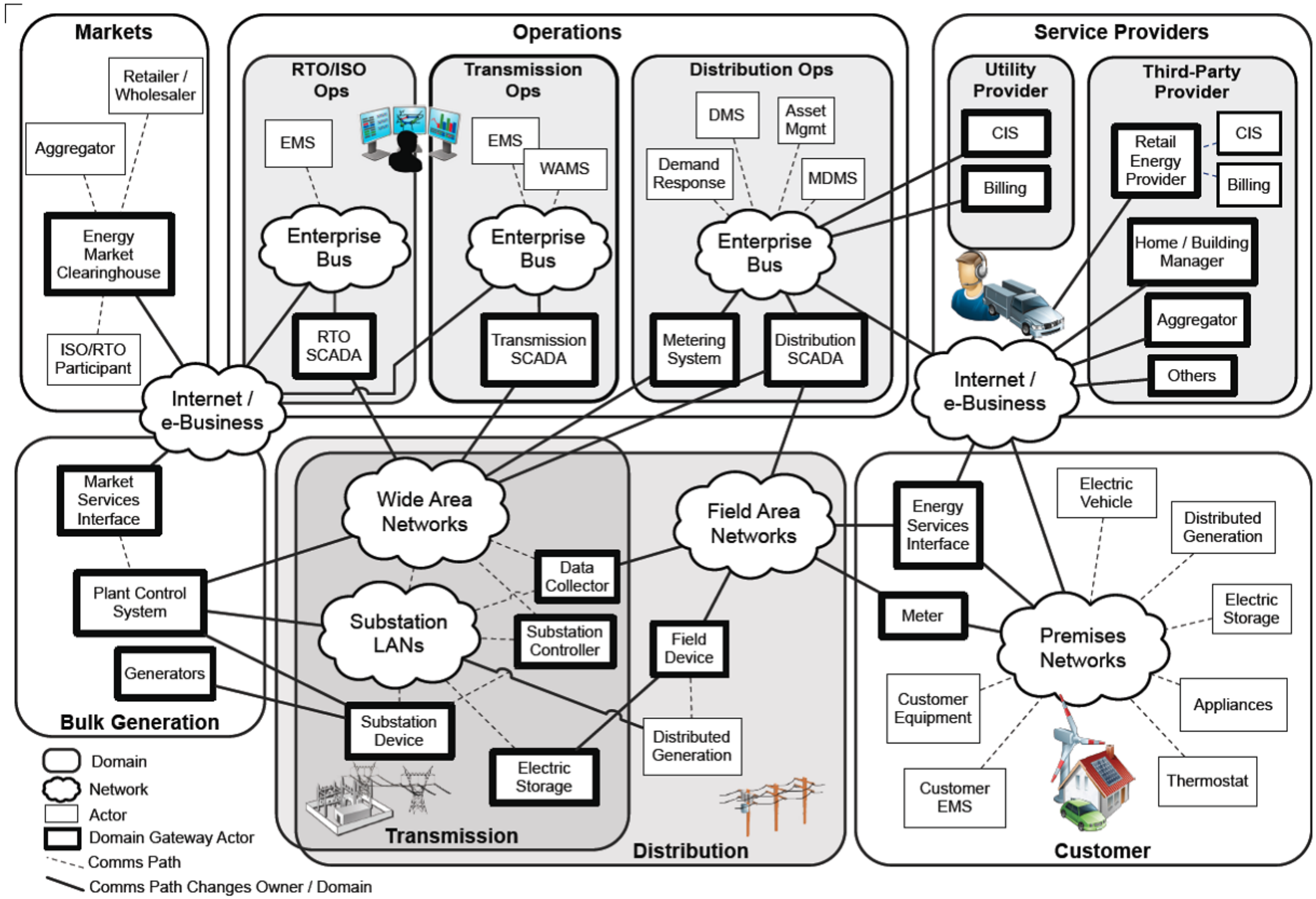

Figure 12 – Smart Grid Conceptual Reference Diagram (Source: NIST Interoperability Framework 1.0)

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