Business & Technology Surveillance

Get Connected on the Right Level:
Finding Communications Options that Meet Your Needs

BY: Eric Wirth and Tom Asp, Power System Engineering

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NRECA
America's Electric Cooperatives

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ARTICLE SNAPSHOT

WHAT HAS CHANGED?

Electric cooperatives are experiencing a rapidly evolving communications landscape, driven by advances such as Private LTE, Low Earth Orbit (LEO) satellites, enhanced cellular reliability, broadband deployments, and FCC updates on frequency sharing. These developments have expanded the range of viable connectivity options for utilities, improving performance, security, and cost-effectiveness, while adding complexity to decision-making.

WHAT IS THE IMPACT ON ELECTRIC COOPERATIVES?

These changes allow co-ops to gather and utilize data more effectively from across their systems, from substations to consumer devices, enabling smarter grid management, improved automation, and quicker restoration efforts. However, the diversity of options creates challenges, as co-ops must carefully evaluate the trade-offs between performance, cost, and long-term viability to avoid adopting solutions that may quickly become obsolete or misaligned with their strategic goals.

WHAT DO CO-OPS NEED TO KNOW OR DO ABOUT IT?

Co-ops need to adopt a strategic, holistic approach to communications planning, considering their unique operational needs, geographic factors, and risk tolerance. This includes evaluating performance requirements at different system levels, assessing cost-effectiveness, and weighing the benefits of owning versus leasing infrastructure. By aligning communications decisions with broader objectives and leveraging appropriate technologies, co-ops can avoid creating fragmented, inefficient systems and instead build resilient, future-proof communications networks.

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Executive Summary

Electric cooperatives are quickly becoming data driven. Not just data from the substation, but from field devices throughout the distribution system and consumer premises as well. Co-ops are also adjusting to a rapidly changing communication alternatives landscape with an influx in availability and reliability of cellular for enhanced communications, the changing FCC landscape of frequency sharing, new wireless technology offerings such as Private LTE, advances in Low Earth Orbit (LEO) satellite, and increased deployments of broadband infrastructure. These options, along with providers evolving their ability to support security and service-level requirements, can make the selection of the best fit alternatives murky for decision makers.

This article provides guidance on the broad range of communications advances that are available to co-ops today. It offers an unbiased and independent view of technology and approaches for identifying the appropriate application based on a co-op's needs, member needs, and business strategies.

The article is based on a deep understanding of the systems co-ops deploy (AMI, substation, DA, protection, mobile work, renewables), lessons learned from those deployments, and a forward-thinking eye toward meeting your objectives. Communication alternatives and appropriateness are addressed from a variety of technical and strategy perspectives, including:

- What are the connectivity performance needs for the locations and applications supported?
- What are the appropriate communication alternatives needs for the locations and applications supported?
- What is the co-op's tolerance for risk of control? This influences the desire to own and operate the infrastructure versus exploration of lease alternatives.
- What is the co-op's tolerance for risk of technology early entry to obsolescence? This influences the desire to own and operate the infrastructure versus exploration of lease alternatives.
- What performance attributes are driven by the application (SCADA, DA, ADMS, AMI, and other)?
- What performance attributes are driven by the device location (substation, tie-point, feeder, consumer premises, and other)?
- What are the impacts to alternatives if the co-op is required to meet NERC security requirements?

The goal of this article is to provide clarity on alternatives and to provide a roadmap for choosing the best-fit strategies.

To Connect or Not to Connect

There are a variety of devices and applications which may drive needing communications. For critical facilities and infrastructure, the answer to connect is often *yes* – low-latency, high availability communications is needed.

But, different co-ops have different philosophies on their approach to communications. Some feel that the utility's goal should be to connect every downline device in the system for monitoring, control, automation, and improved restoration. Other co-ops take a hybrid approach where devices may be connected based on priority and application served. And yet others may connect devices based on the cost-effectiveness of connecting to a particular location.

None of these choices are wrong, and your final determination of best-fit strategy will be shaped by the specifics of your co-op, such as service territory size, number of meters, geography, and staffing. However, general industry consensus is that, as electrification and new technologies continue to evolve, it will be necessary to extend communications deeper into the electric grid.

Connectivity Options

Many connectivity options exist, including both utility owned and operated, and leased services, as summarized below.

Utility Owned and Operated

- **AMI Network**

  Advanced Metering Infrastructure (AMI) is a fixed two-way network system that enables communication between utilities and devices located at the consumer premises. AMI allows for utilities to track energy usage, analyze data, monitor electric system attributes, and control devices. Each AMI network is proprietary, and vendors use a range of communication technologies including licensed 450MHz, licensed 900MHz, unlicensed 900 MHz, Wi-Fi, and powerline carrier. Users will typically see low data rate with moderate to high latency.

- **Private LTE**

  The primary differences between public and private LTE and 5G networks is who holds the spectrum license, who has priority access, and who owns and operates the network's infrastructure. With private LTE, the electric utility has full control over the network and allows it to completely isolate its users from other public networks. A variation of private LTE is a Hybrid Private LTE and 5G, in which parts of the network are either owned, shared, or operated by a wireless carrier or another organization. In the U.S., the Citizens Broadband Radio Service (CBRS) in the 3.5 GHz band is the most common frequency for private LTE. There are, however, alternatives including a portion of 900MHz, and unlicensed 5 GHz. The private LTE operator can design the network for supporting high throughput, low latency, and high availability and dependability.

- **Utility Fiber**

  Fiber is constructed by the co-op to serve internal needs. The fiber and the network electronics are owned and operated by the co-op to meet connectivity performance needs. The co-op can design the network for supporting high throughput, low latency, and high availability and dependability.

- **Utility FTTP (GPON)**

  As part of a co-op's broadband offering with a fiber to the premises (FTTP) deployment, strands and capacity is reserved for utility use. The most common FTTP architecture is a Gigabit Passive Optical Network (GPON). The FTTP network is owned and operated by the co-op's broadband department and provides connectivity services to other departments. The co-op can design the network for supporting high throughput and low latency. GPON is subject to a single point of failure in some of the network segments.

- **Licensed (150-900 MHz)**

  Licensed 150MHz, 220MHz, 450 MHz, and 900 MHz radio is used for creating a Field Area Network (FAN) to connect distribution devices in the co-ops service area. Typically, a point-to-multi configuration is used. Low to moderate data rates are supported.

- **Unlicensed 900 MHz**

  Unlicensed 900 MHz (902 to 028 MHz) radio is used for creating a Field Area Network (FAN) to connect distribution devices in the co-ops service area. Typically, a point-to-multi configuration is used. Low to moderate data rates are supported.

- **Unlicensed Wi-Fi**

  Unlicensed 2.4 GHz and 5 GHz radio are used for creating a Field Area Network (FAN) to connect distribution devices in the co-ops service area. Typically, a point-to-multi configuration is used. Moderate to high data rates are supported.

- **Microwave (licensed)**

  Commonly called "fixed wireless backhaul," this is deployed as point-to-point connections. Licensed microwave links offer exclusivity to frequencies in the 6GHz to 40GHz bands, and such systems are engineered to provide predictable multi-gigabit speeds with high reliability and low latency.

- **Microwave (unlicensed)**

  Commonly called "fixed wireless backhaul," this is deployed as point-to-point connections. Unlicensed microwave links use shared spectrum in the 2.4 GH, 5 GHz, and 900 MHz bands, and such systems are engineered to provide predictable multi-gigabit speeds with high reliability and low latency.

Leased Services

- **Cellular (including LTE)**

  Cellular is providers-offered connectivity service with limited-service-level agreements. This service will have VPN options for security. It has high throughput and low latency; however, it is subject to other users having priority if network congestions exist.

- **Cellular Cat M**

  This service is designed to support Internet of Things (IoT) and other low-to-moderate data speeds. Providers offer long-term service contracts at relatively low monthly fees that align with AMI cost constraints.

- **Provider Cable Modem**

  Broadband operators that have a Hybrid Fiber-Coaxial (HFC) network often will provide a broadband connection service which incorporates a VPN. Service has high throughput and low latency; however, it is subject to a single point of failure in some of the network segments.

- **Leased Line (DSL, other)**

  These wire-line based connection services do not carry strong service level agreements (SLA). Service can have a high throughput and low latency: however, it is subject to a single point of failure in some of the network segments.

- **Managed Service (Ethernet, other)**

  These wire-line based connection services carry service-level agreements (SLA). Service can have a high throughput and low latency, however depending upon provider can be subject to a single point of failure in some of the network segments.

- **Leased Fiber (IRU or Lease)**

  Lease of fiber strands are dedicated to the co-op. Lease is either a long-term (10 to 20 years) Indefeasible Right of Use (IRU) or a monthly lease Monthly Lease for 1-, 3-, or 5-year terms. The co-op owns and operates the network electronics to meet connectivity performance needs, and can design the network for supporting high throughput, low latency, and high availability and dependability.

- **Provider FTTP (GPON)**

  The most common FTTP architecture is a Gigabit Passive Optical Network (GPON). The FTTP network is owned and operated by a private operator and provides connectivity services to the co-op. The provider can design the network for supporting high throughput and low latency. GPON is subject to a single point of failure in some of the network segments.

- **LEO (StarLink, other)**

  This is leased service that leverages Low Earth Orbiting (LEO) satellite. The LEO provider can support a high throughput service with moderate to and low latency. Depending upon the provider, redundant paths are available, but performance can be impacted by weather conditions.

- **GEO (BGAN, VSAT, other)**

  This is leased service that leverages Geostationary Earth Orbit (GEO) satellite. The GEO provider can support a moderate to high throughput service with moderate to high latency. Performance can be impacted by weather conditions.

Cost Comparisons

With so many connectivity options available, it might be helpful to first understand the costs. Costs vary widely, and all communications options do not fit every application. On the high end of the spectrum are fixed wireline and wireless systems, including utility-owned or leased fiber, managed ethernet services point-to-point microwave, and Private LTE. These communications options are typically deployed for facilities and devices that are critical for the operation of the electrical network where cost sensitivity for communications is low with the exception being Private LTE, which has a large implementation cost but serves a wide array of devices and application.

Here is an overview from most to least expensive:

While **utility-owned fiber** is usually the most expensive option, when the routes are designed to pass downline devices, the cost for connecting those devices may end up being cost-beneficial. The capital and operating costs of Private LTE may also be cost-beneficial, if multiple distinct applications and systems can be migrated to a single Private LTE platform.

Medium-end communications cost options can include fixed wireless point-to-multipoint systems, managed ethernet service, and satellite service, provider FTTP service. Except for utility-owned fixed wireless, the other services require monthly service fees to the provider. These services for the most part provide higher bandwidths than the low-end communications cost options or provide coverage in areas where medium-end communications do not cover (e.g. satellite services). Medium-end communications options can be used for a wide variety of utility devices from the substation to downline devices and AMI collectors out in the field.

Fixed wireless point-to-multipoint systems have a wide range of costs depending on how many base stations are needed to connect to the remote locations and the number and density of those locations. A point-to-multipoint that only serves a small number of sites is more costly than a network that can connect a greater number of sites from a single base station.

Low-end communications cost services include wireline and wireless leased communications services, such as DSL, cable modem, and cellular services. These services have a relatively low monthly service fee and provide best effort service to a utility. These services can usually be established quickly and at low cost to field devices where the utility does not have other forms of existing communications. The relatively low cost also allows utilities to establish communications at a large number of facilities, such as AMI collectors or field devices like reclosers, regulators, and cap banks. Security is a concern over leased services, and it is recommended to use virtual private networks (VPNs) to securely pass traffic from the field device back to the utility’s core networks.

Decision-Making Framework

There is no mix or set of connectivity options that will work for every co-op electric. The selection will vary according to local conditions (terrain, consumer density, proximity to metro areas), co-op objectives, co-op preferences (ownership, licensing preferences), and provider options in the co-op's service area.

This section presents a framework for examining and selecting options that meet your overall objectives. It is important to view connectivity decisions as part of an overall strategy, not just a selection of options based on support of independent applications. Making narrowly-focused technology investment decisions results in an enterprise IT and communications infrastructure that is both complex and challenging to manage. Avoid ending up with this kind of accidental architecture by developing a communications strategy and architecture that is best for you based on the collective set of connectivity needs.

Performance Requirements

Key performance attributes of any connectivity option include:

- **Throughput:** Rate of data transmission typically measured in bits or bytes per second.
- **Latency**: Delay from when message sent to when it is received.
- **Jitter:** A measure of the variation in latency over a period of time.
- **Availability**: Percent of time link is up vs. down over given time.
- **Dependability**: Probability application/connection will operate correctly.
- **Packet Loss:** Loss of packets along the data path.

It is also important to consider the total number of devices, the per-location value (benefits versus cost), cost per location, and cost sensitivity.

Location Levels

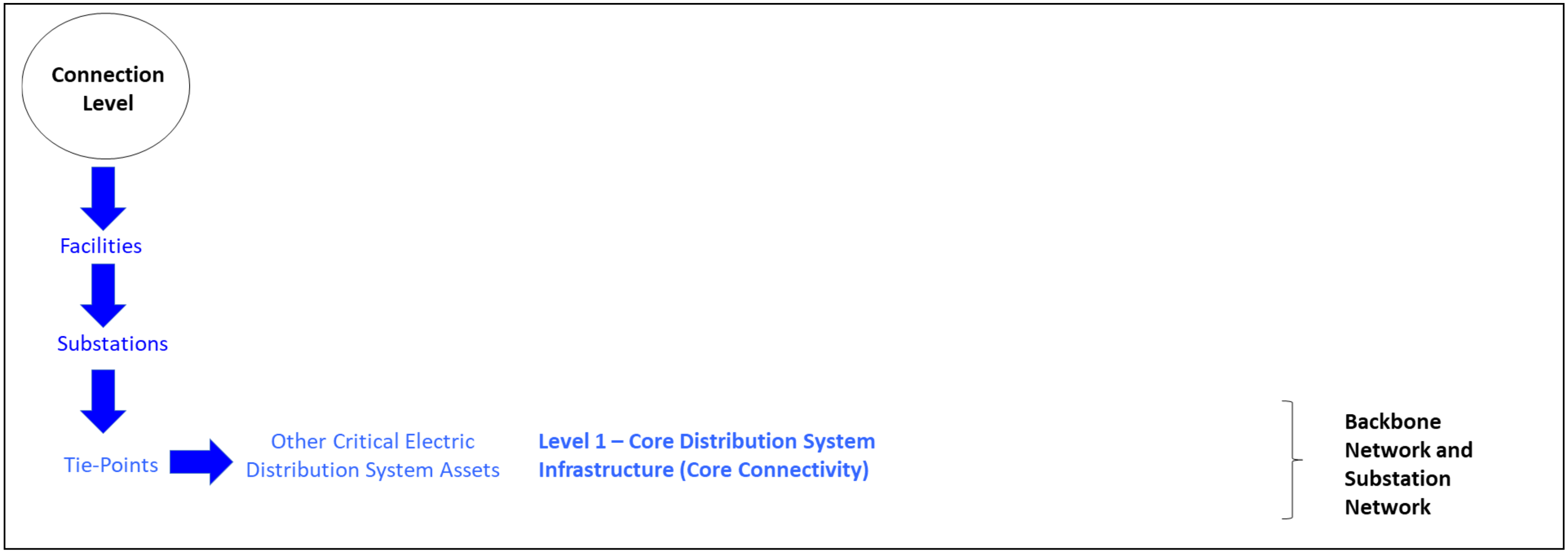
Different locations on the electric distribution system have a range of device types, device quantities, application needs, performance requirements, and cost objectives. We have segmented the distribution system into seven (7) levels.

Read through the descriptions of each of the seven levels below to determine which level(s) best represent the communications your co-op is striving to achieve. The corresponding figures below show the type of facilities or devices connected within each level.

Level 1 includes facilities (buildings), substations, tie-points, and other critical distribution assets. General characteristics include:

- Considered core distribution system infrastructure
- Communication to meet core connectivity for co-op
- Considered part of a backbone & substation network
- Has low location cost sensitivity
- Requires real-time, low latency, dependability, and redundancy (some sites) performance

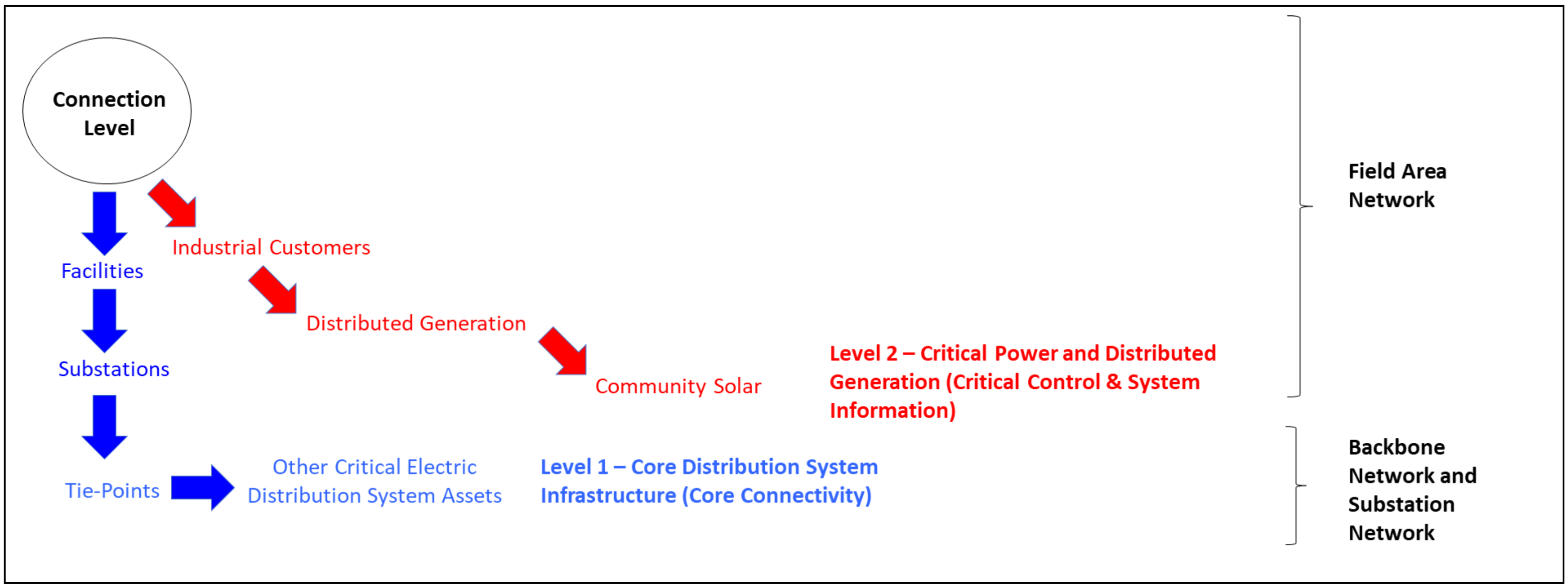
Figure 1: Level 1



Level 2 includes industrial consumers, distributed generation, and community solar. General characteristics include:

- Serves critical power and distributed generation
- Communication to meet critical control and system information for co-op
- Considered part of a field area network
- Has low to medium location cost sensitivity
- Requires real-time, low latency, redundancy, and resiliency performance
-

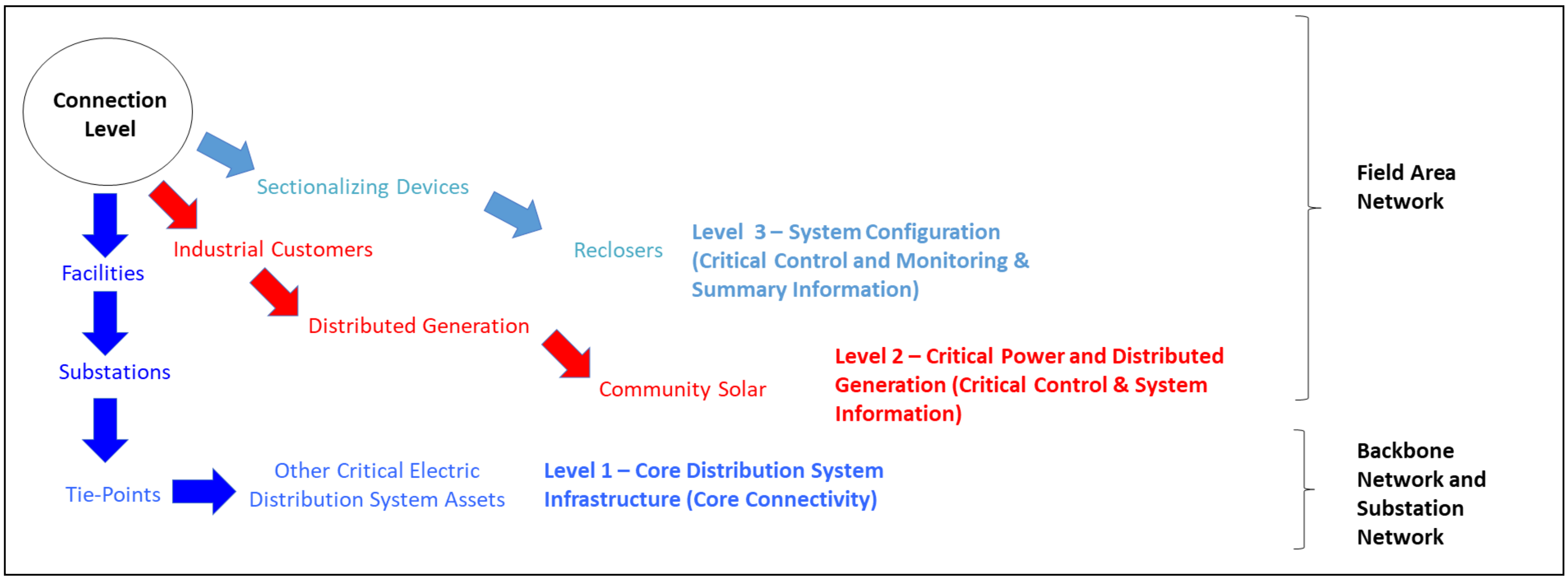
Figure 2: Level 2



Level 3 includes sectionalizing devices, and reclosers. General characteristics include:

- Supports system configuration activities.
- Communication to meet critical control, critical monitoring, and summary information for co-op.
- Considered part of a field area network.
- Has medium location cost sensitivity.
- Performance to support control, data transfers, and operation verification.
-

Figure 3: Level 3

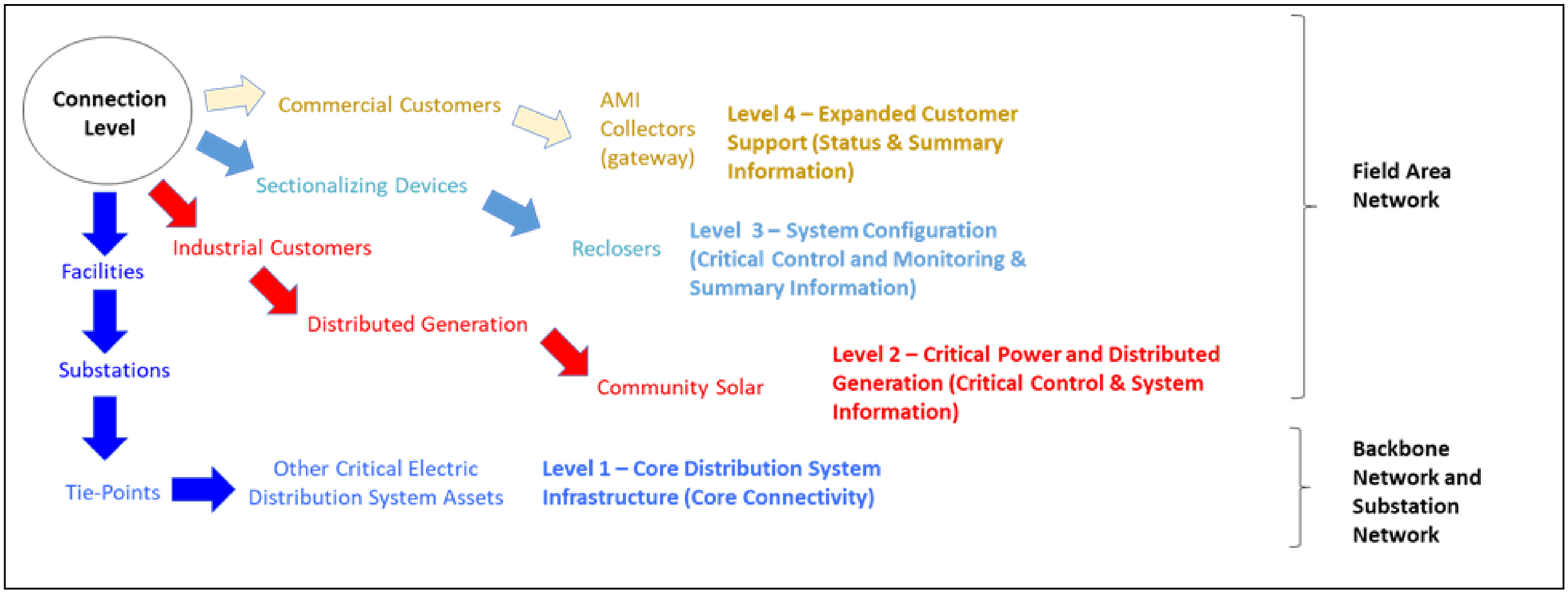


Level 4 includes commercial customers and AMI collectors. General characteristics include:

- Supports system configuration activities.
- Communication to support status and summary information.
- Considered part of a field area network.
- Has medium location cost sensitivity.

  Performance to support data transfers, availability, outage information, alarm support, and batch (load management).

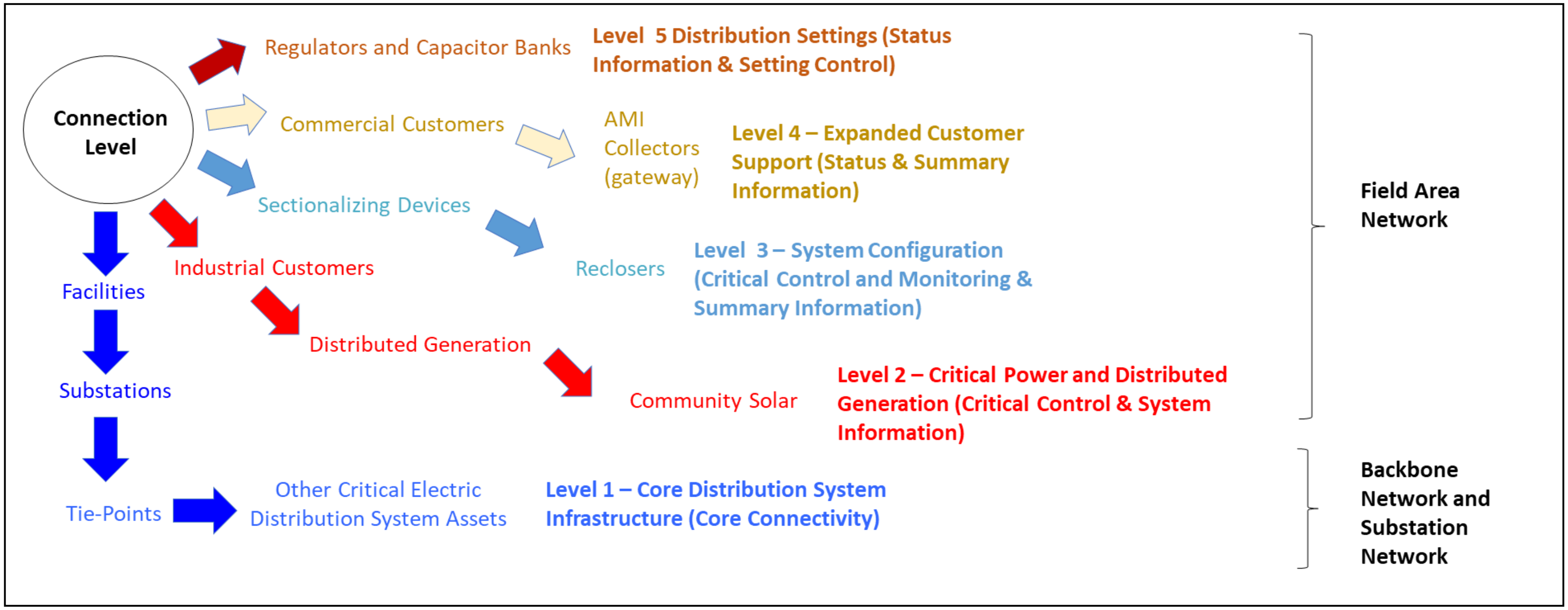
Figure 4: Level 4



Level 5 includes regulators, capacitor banks, recloser monitoring, and fault detectors. General characteristics include:

- Supports distribution setting applications,
- Communication to support status information and setting control,
- Considered part of a field area network,
- Has medium to high location cost sensitivity, and
- Performance to support batch (load management) control, site specific control, and data transfers.

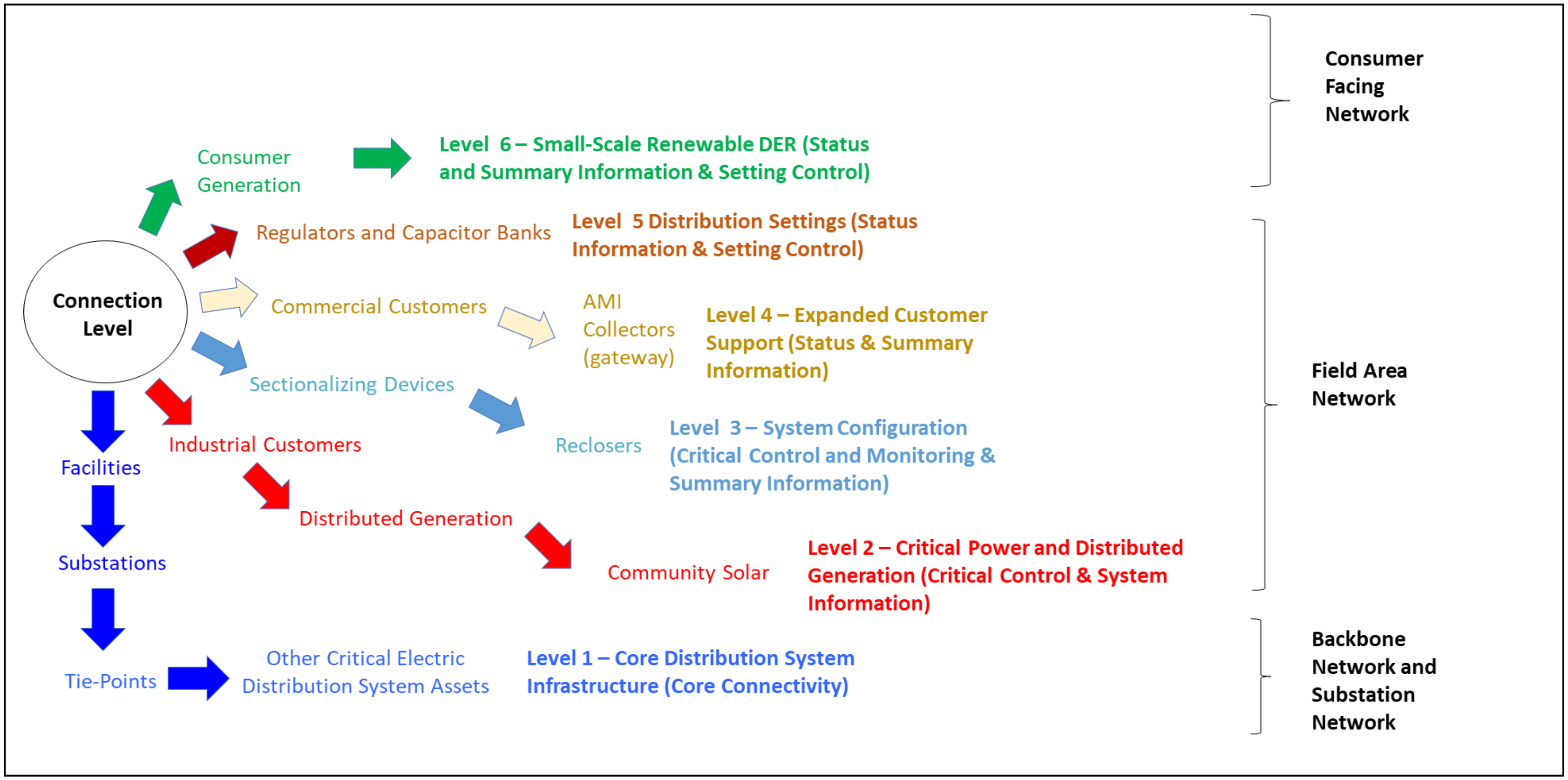
Figure 5: Level 5



Level 6 includes consumer generation (load forming). General characteristics include:

- Supports small-scale renewable DER.
- Communication to support status information, summary information, and setting control.
- Considered part of a consumer facing network.
- Has high end point cost sensitivity.
- Performance to support batch control, individual control, data transfers, and operation verification.

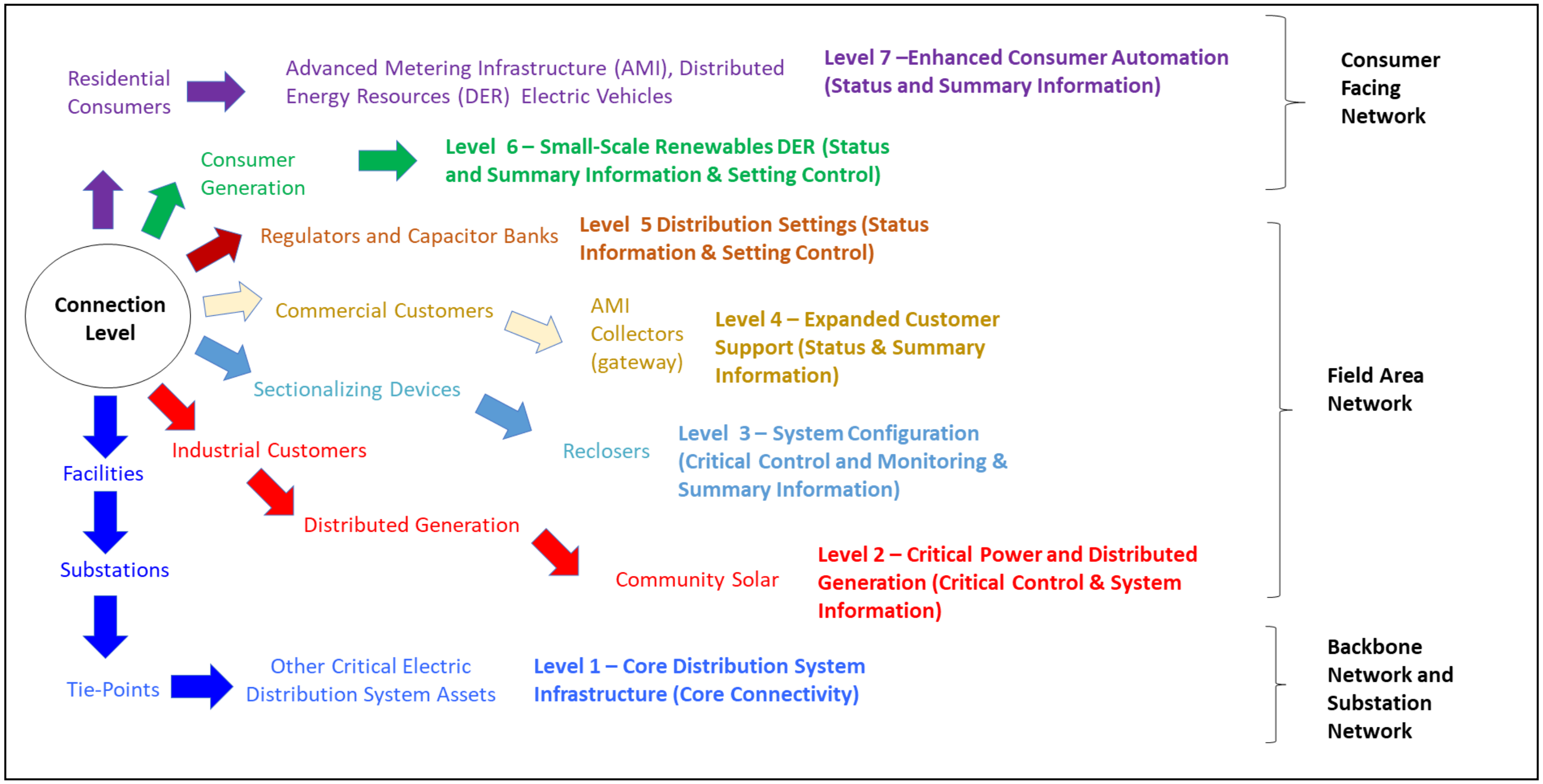
Figure 6: Level 6



Level 7 includes residential consumers, residential meters, and small commercial meters. General characteristics include:

- Supports enhanced consumer automation.
- Communication to support status and summary information.
- Considered part of a consumer facing network.
- Has very high-end point cost sensitivity.
- Performance to support traffic management, alarm reporting, service disconnect, service connect, batch control, and data transfers.

Figure 7: Level 7



Requirements Summary by Level

Now that you've identified which level(s) represent the communications your co-op is striving to achieve, refer to the tables below to determine the specific performance requirements, general locations characteristics, and cost sensitivities by location for that level of desired communications.

For example, if deploying an AMI network, which is Level 4, the communications performance requirements are a network with moderate throughput, latency, jitter, availability and dependability. The network also requires low to moderate packet loss.

Table 1: Performance Requirements by Level

Location Characteristics			Connection Level						
			Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
			Core Distribution System Infrastructure	Critical Power and Distributed Generation	System Configuration	Expanded Customer Support	Distribution Settings	Small-Scale Renewable DER	Enhanced Consumer Automation
			Example Locations and Devices						
			Facilities, Substations, Tie Points	Industrial Consumers, Distributed Generation, Community Solar	Sectionalizing Devices, Reclosers	Commercial Consumers, AMI Collectors	Regulators, Capacitor Banks, Recloser Monitoring, Fault Detectors	Consumer Generation (Grid Forming)	Residential Consumers, Residential Meters, Small Commercial Meters
Performance Requirements	Throughput	Rate of data transmission typically measured in bits or bytes per second.	High	Moderate	Moderate	Moderate	Moderate to Low	Low	Low
	Latency	Delay from when message sent to when it is received	Low	Low	Low	Moderate	Moderate to High	Moderate to High	High
	Jitter	A measure of the variation in latency over a period of time.	Low	Low	Low	Moderate	Moderate to High	Moderate to High	High
	Availability	Percent of time link is up vs. down over given time.	High	High	High	Moderate	Moderate	Moderate	Moderate
	Dependability	Probability application/connection will operate correctly.	High	High	High	Moderate	Moderate	Moderate	Moderate
	Packet Loss	Lose of packets along the data path	Low	Low	Low	Low to Moderate	Moderate	Moderate	Moderate

Table 2: General Location Characteristics by Level

Location Characteristics		Connection Level						
		Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
		Core Distribution System Infrastructure	Critical Power and Distributed Generation	System Configuration	Expanded Customer Support	Distribution Settings	Small-Scale Renewable DER	Enhanced Consumer Automation
		Example Locations and Devices						
		Facilities, Substations, Tie Points	Industrial Consumers, Distributed Generation, Community Solar	Sectionalizing Devices, Reclosers	Commercial Consumers, AMI Collectors	Regulators, Capacitor Banks, Recloser Monitoring, Fault Detectors	Consumer Generation (Grid Forming)	Residential Consumers, Residential Meters, Small Commercial Meters
General Location Features	Focus	Core Connectivity	Critical Control and System Information	Critical Control, Critical Monitoring, and Summary Information	Status and Summary Information	Status Information and Setting Control	Status Information, Summary Information, and Setting Control	Status and Summary Information
	Network	Backbone & Substation Network	Field Area Network	Field Area Network	Field Area Network	Field Area Network	Consumer Facing Network	Consumer Facing Network
	Number of Locations (relative)	Low	Low	Low to Moderate	Moderate	Moderate	Moderate	High
	Operation Features	Real-time, low latency, dependability, and redundancy (some sites)	Real-time, low latency, redundancy, and resiliency	Control, data transfers, and operation verification	Data transfers, availability, outage information, alarm support, and batch (load management) control	Batch (load management) control, site specific control, and data transfers	Batch control, individual control, data transfers, and operation verification	Traffic management, alarm reporting, service disconnect, service connect, batch control, and data transfers

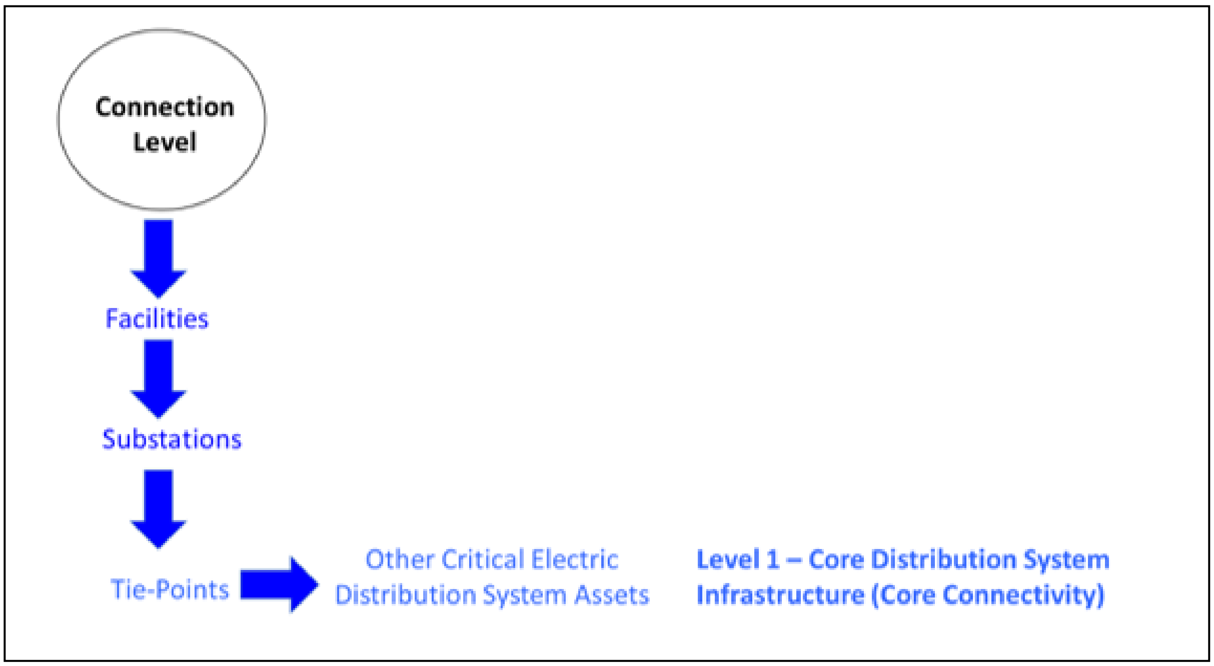
Table 3: Cost Sensitivities by Location by Level

Location Characteristics		Connection Level						
		Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
		Core Distribution System Infrastructure	Critical Power and Distributed Generation	System Configuration	Expanded Customer Support	Distribution Settings	Small-Scale Renewable DER	Enhanced Consumer Automation
		Example Locations and Devices						
		Facilities, Substations, Tie Points	Industrial Consumers, Distributed Generation, Community Solar	Sectionalizing Devices, Reclosers	Commercial Consumers, AMI Collectors	Regulators, Capacitor Banks, Recloser Monitoring, Fault Detectors	Consumer Generation (Grid Forming)	Residential Consumers, Residential Meters, Small Commercial Meters
Value Features	Value (per location) - benefits vs cost	High	Moderate to High	Moderate	Moderate	Moderate to Low	Low	Low
	Cost (per location)	High	Moderate to High	Moderate	Moderate	Moderate to Low	Moderate to Low	Low
	Cost Sensitivity	Low location cost sensitivity	Low to medium location cost sensitivity	Medium end-point cost sensitivity	Medium end point cost sensitivity	Medium to high end point cost sensitivity	High end point cost sensitivity	Very high end point cost sensitivity

Connectivity Options Fit by Level

The seven figures below highlight the potential fit of the identified utility owned and leased network options for each level. As seen, the available options that align with each level's need decline as you move from Level 1 to Level 7. In addition, there is overlap between each level. For example, if deploying an AMI network, Level 4, there are seven potential utility-owned and eight leased services that could potentially provide communications suitable to your coo-op's needs

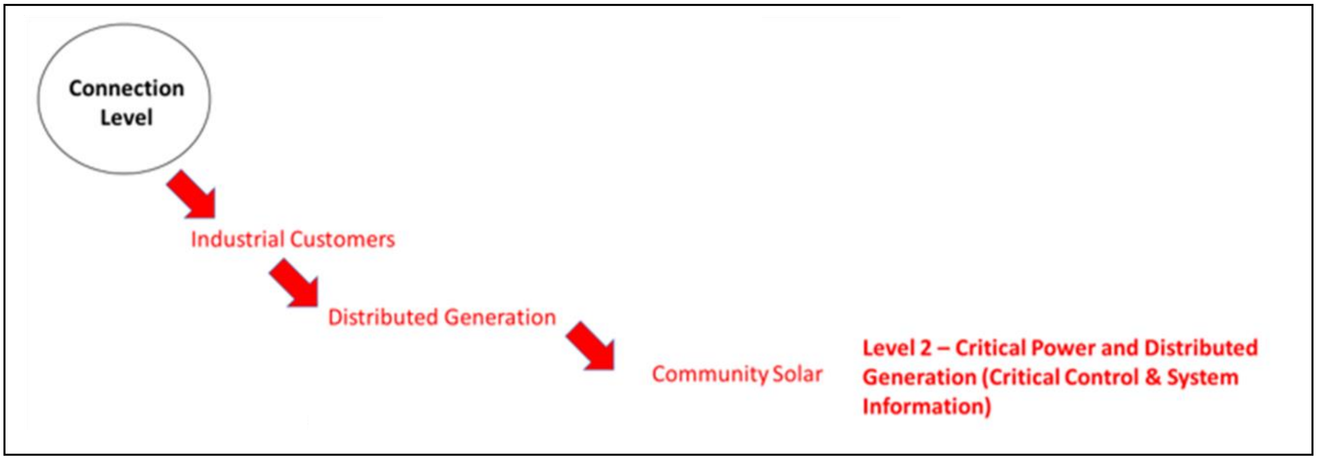
Figure 8: Potential Connectivity Solutions (Level 1)



- Utility Owned and Operated
  - Private LTE (1)
  - Utility Fiber
  - Utility FTTP (GPON) (1)
  - Licensed (150-900 MHz) (1)
  - Unlicensed 900 MHz(1)
  - Unlicensed Wi-Fi (1)
  - Microwave (licensed)
  - Microwave (unlicensed)
- Leased
  - Cellular (including LTE) (1)
  - Provider Cable Modem (1)
  - Managed Service (Ethernet, other)
  - Leased Fiber (IRU or Lease)
  - Provider FTTP (GPON) (1)
  - LEO (Starlink, other) (1)
  - GEO (BGAN, VSAT, other) (1)

Notes
(1) For some substations
(2) Monitor focus, limited switching
(3) Cost is potential issue
(4) For meter reports and alarms
(5) For meters, not collectors
(6) Deployment cost is a potential iss
(7) Connection cost maybe an issue

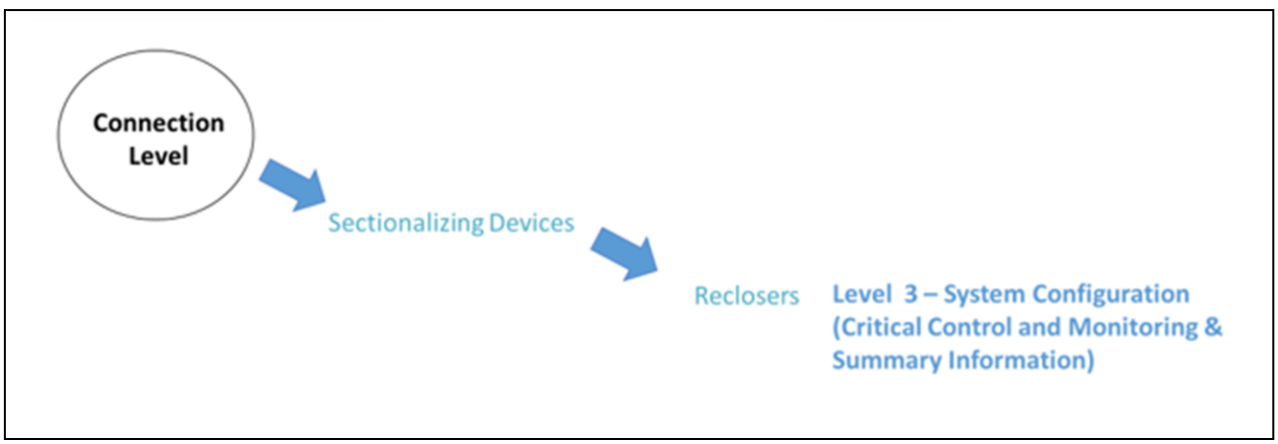
Figure 9: Potential Connectivity Solutions (Level 2)



- Utility Owned and Operated
  - Private LTE
  - Utility Fiber
  - Utility FTTP (GPON)
  - Licensed (150-900 MHz)
  - Unlicensed 900 MHz
  - Unlicensed Wi-Fi
  - Microwave (licensed)
  - Microwave (unlicensed)
- Leased
  - Cellular (including LTE)
  - Provider Cable Modem
  - Leased Line (DSL, other)
  - Managed Service (Ethernet, other)
  - Leased Fiber (IRU or Lease)
  - Provider FTTP (GPON)
  - LEO (Starlink, other)
  - GEO (BGAN, VSAT, other)

Notes
(1) For some substations
(2) Monitor focus, limited switching
(3) Cost is potential issue
(4) For meter reports and alarms
(5) For meters, not collectors
(6) Deployment cost is a potential issue
(7) Connection cost maybe an issue

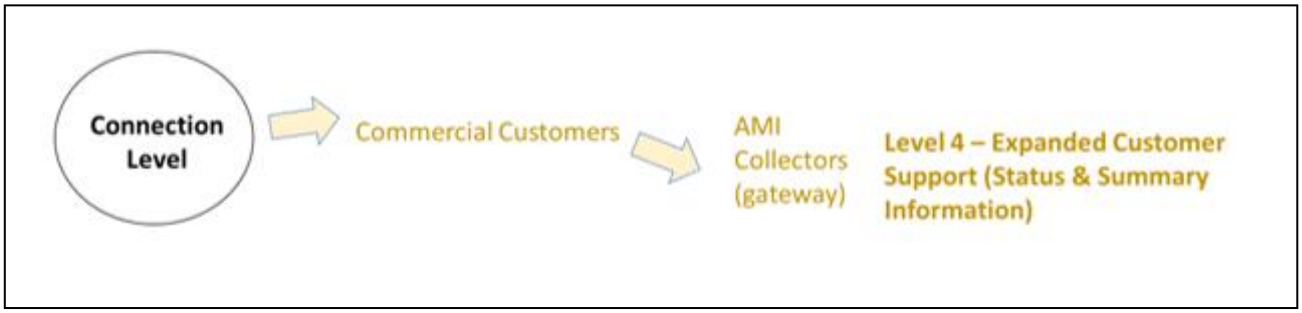
Figure 10: Potential Connectivity Solutions (Level 3)



- Utility Owned and Operated
  - AMI Network (2)
  - Private LTE
  - Utility Fiber
  - Utility FTTP (GPON)
  - Licensed (150-900 MHz)
  - Unlicensed 900 MHz
  - Unlicensed Wi-Fi
- Leased
  - Cellular (including LTE) (3)
  - Cellular Cat M
  - Provider Cable Modem (3)
  - Leased Line (DSL, other) (3)
  - Managed Service (Ethernet, other) (3)
  - Leased Fiber (IRU or Lease) (3)
  - Provider FTTP (GPON) (3)
  - LEO (Starlink, other) (3)
  - GEO (BGAN, VSAT, other) (3)

Notes
(1) For some substations
(2) Monitor focus, limited switching
(3) Cost is potential issue
(4) For meter reports and alarms
(5) For meters, not collectors
(6) Deployment cost is a potential issue
(7) Connection cost maybe an issue

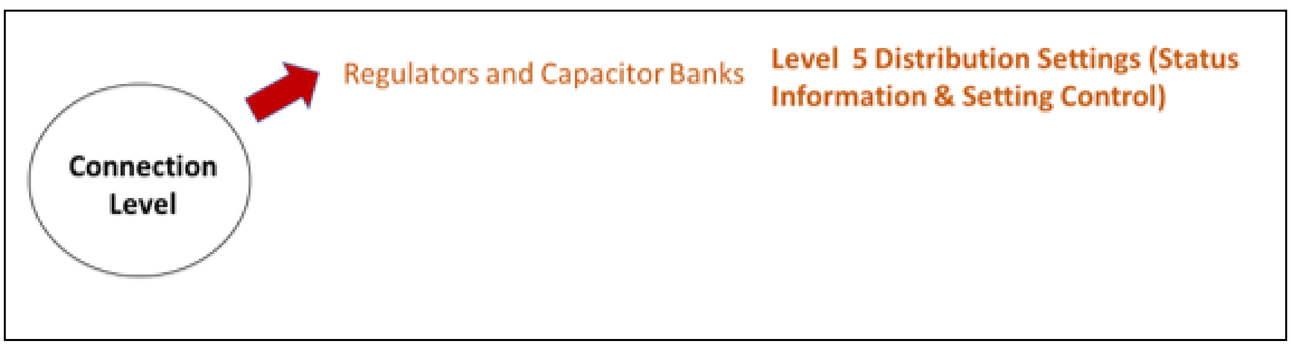
Figure 11: Potential Connectivity Solutions (Level 4)



- Utility Owned and Operated
  - AMI Network (4)
  - Private LTE
  - Utility Fiber
  - Utility FTTP (GPON)
  - Licensed (150-900 MHz)
  - Unlicensed 900 MHz
  - Unlicensed Wi-Fi
- Leased
  - Cellular (including LTE)
  - Cellular Cat M (5)
  - Provider Cable Modem
  - Leased Line (DSL, other) (6)
  - Managed Service (Ethernet, other) (6)
  - Provider FTTP (GPON) (6)
  - LEO (Starlink, other) (3)
  - GEO (BGAN, VSAT, other) (3)

Notes
(1) For some substations
(2) Monitor focus, limited switching
(3) Cost is potential issue
(4) For meter reports and alarms
(5) For meters, not collectors
(6) Deployment cost is a potential issue
(7) Connection cost maybe an issue

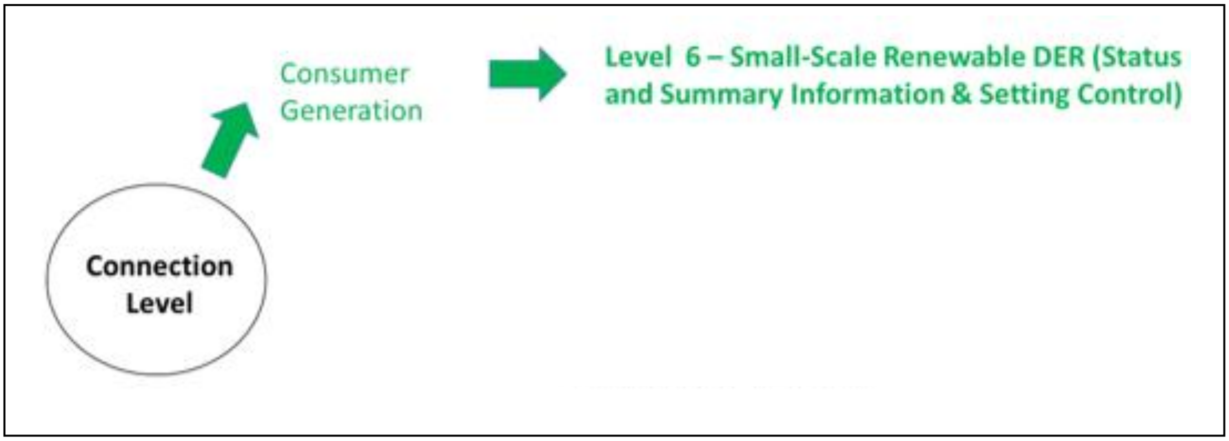
Figure 12: Potential Connectivity Solutions (Level 5)



- Utility Owned and Operated
  - AMI Network
  - Private LTE
  - Utility Fiber (7)
  - Utility FTTP (GPON)
  - Licensed (150-900 MHz)
  - Unlicensed 900 MHz
  - Unlicensed Wi-Fi
- Leased
  - Cellular (including LTE)
  - Cellular Cat M
  - Provider Cable Modem (7)
  - Leased Line (DSL, other) (3)
  - Managed Service (Ethernet, other) (3)
  - Leased Fiber (IRU or Lease)
  - Provider FTTP (GPON) (7)

Notes
(1) For some substations
(2) Monitor focus, limited switching
(3) Cost is potential issue
(4) For meter reports and alarms
(5) For meters, not collectors
(6) Deployment cost is a potential issue
(7) Connection cost maybe an issue

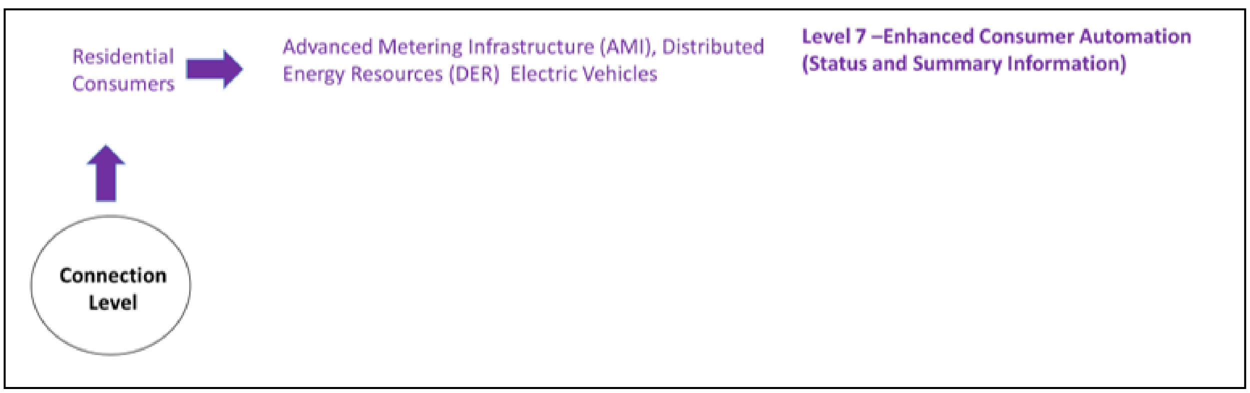
Figure 13: Potential Connectivity Solutions (Level 6)



- Utility Owned and Operated
  - AMI Network
  - Private LTE
  - Utility FTTP (GPON)
  - Licensed (150-900 MHz)
  - Unlicensed 900 MHz
  - Unlicensed Wi-Fi
- Leased
  - Cellular (including LTE)
  - Cellular Cat M
  - Provider Cable Modem (3)
  - Leased Line (DSL, other)(3)
  - Managed Service (Ethernet, other) (3)
  - Leased Fiber (IRU or Lease) (3)
  - Provider FTTP (GPON) (3)
  - LEO (Starlink, other) (3)

Notes
(1) For some substations
(2) Monitor focus, limited switching
(3) Cost is potential issue
(4) For meter reports and alarms
(5) For meters, not collectors
(6) Deployment cost is a potential issue
(7) Connection cost maybe an issue

Figure 14: Potential Connectivity Solutions (Level 7)



- Utility Owned and Operated
  - AMI Network
- Leased
  - Cellular Cat M

Notes
(1) For some substations
(2) Monitor focus, limited switching
(3) Cost is potential issue
(4) For meter reports and alarms
(5) For meters, not collectors
(6) Deployment cost is a potential issue
(7) Connection cost maybe an issue

The tables below summarize what technology types best fit the connection levels a co-op is trying to achieve.

Table 4: Fit of Utility Owned and Operated Networks

Connectivity Options			Connection Level						
			Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
			Core Distribution System Infrastructure	Critical Power and Distributed Generation	System Configuration	Expanded Customer Support	Distribution Settings	Small-Scale Renewable DER	Enhanced Consumer Automation
Utility Owned and Operated	Specialty Networks	AMI Network			X (monitor focused - limited switching)	X (for meter reports and alarms)	X	X	X
		Private LTE	X (for some substations)	X	X	X	X	X	
	Fiber	Utility Fiber	X	X	X	X	X (connection cost maybe a concern)		
		Utility FTTP (GPON)	X (for some substations)	X	X	X	X	X	
	Radio (Multiple Configurations (point-point, point-multipoint, other)	Licensed (150-900 MHz)	X (for some substations)	X	X	X	X	X	
		Unlicensed 900 MHz	X (for some substations)	X	X	X	X	X	
		Unlicensed Wi-Fi	X (for some substations)	X	X	X	X	X	
	Radio (Point-to-Point)	Microwave (licensed)	X	X					
		Microwave (unlicensed)	X	X					

Table 5: Fit of Leased Services

Connectivity Options			Connection Level						
			Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
			Core Distribution System Infrastructure	Critical Power and Distributed Generation	System Configuration	Expanded Customer Support	Distribution Settings	Small-Scale Renewable DER	Enhanced Consumer Automation
Leased	Carrier Wireless	Cellular (including LTE)	X (for some substations)	X	X (cost is potential issue)	X	X	X	
		Cellular Cat M			X	X (for meters, not for collector)	X	X	X
	Leased Wireline	Provider Cable Modem	X (for some substations)	X	X (cost is potential issue)	X	X (connection cost maybe a concern)	X (cost is potential issue)	
		Leased Line (DSL, other)		X	X (cost is potential issue)	X (deployment cost is a potential issue)	X (cost is potential issue)	X (cost is potential issue)	
		Managed Service (Ethernet, other)	X	X	X (cost is potential issue)	X (deployment cost is a potential issue)	X (cost is potential issue)	X (cost is potential issue)	
		Leased Fiber (IRU or Lease)	X	X	X (cost is potential issue)			X (cost is potential issue)	
		Provider FTTP (GPON)	X (for some substations)	X	X (cost is potential issue)	X (deployment cost is a potential issue)	X (connection cost maybe a concern)	X (cost is potential issue)	
	Satellite	LEO (Starlink, other)	X (for some substations)	X	X (cost is potential issue)	X (cost is potential issue)		X (cost is potential issue)	
		GEO (BGAN, VSAT, other)	X (for some substations, latency questions)	X	X (cost is potential issue)	X (cost is potential issue)			

Conclusion

As seen in the framework discussed in this report, a range of options can meet overall location requirements. It is important to view connectivity decisions as part of an overall strategy, and not just select options to support independent applications. Otherwise, an "accidental architecture" can result based on narrowly focused technology investments, and an enterprise IT and communications infrastructure that is both complex and challenging to manage. The starting point in avoiding an accidental architecture is developing a comprehensive communications strategy and architecture that is best for the co-op's unique circumstances, based on the collective set of connectivity needs.

About the Author

Eric Wirth, Principal Communications Systems Engineer at PSE, earned a BS degree in Electrical Engineering from the University of Virginia at Charlottesville, Virginia. He has over 20 years of communication engineering experience in evaluating broadband telecommunications technologies and designing communications networks for utility and industrial uses. He develops fiber network designs and cost estimates as well as wireless networks using a variety of licensed and unlicensed radio frequency (RF) spectrums to meet clients' needs for capacity, coverage, and reliability.

Tom Asp, Senior Communications & Automation Consultant at PSE, earned a BS degree in Electrical Engineering from North Dakota State University and an MBA from the University of St. Thomas - St. Paul, MN. He has more than 35 years of experience in communication planning and business development for electric co-op and public power systems. He is recognized as a nationwide expert in evaluating and offering recommendations regarding electric utility communications systems.

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To find more resources on business and technology issues for cooperatives, visit our **website**.

Analytics, Resiliency and Reliability Work Group

The **Analytics, Resiliency and Reliability (ARR) Work Group**, part of NRECA's Business and Technology Strategies department, is focused on on current and future data and research required to provide prompt technical and economic support to the NRECA membership. Specifically focused toward the electric co-op community, ARR products and services include: development and maintenance of a portfolio of energy analytics products and services; collection and analysis of data; and provision of additional products and services in the areas of the data collection, IT architecture, sensors, and energy markets. For more information, please visit **www.cooperative.com**, and for the current work by the Business and Technology Strategies department of NRECA, please see our **Portfolio**.

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