Broadband over Power Lines a Foundation for the Utility of the Future

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Topics

- BPL Explored a Primer
- The Duke Experience
- BPL as an Enabler of the Utility of the Future

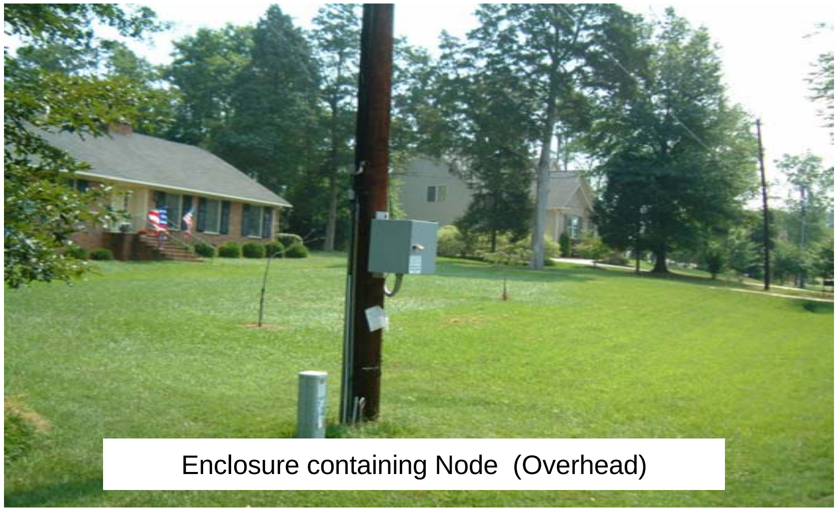
BPL Explored

A Primer

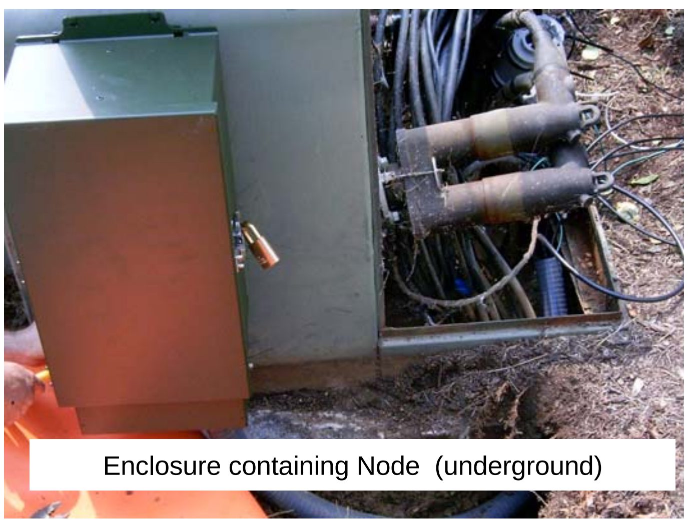
BPL Defined

- ***Access Broadband Over Power Line (Access BPL).*** A carrier current system installed and operated on an electric utility service as an unintentional radiator that sends radio frequency energy on frequencies between 1.705 MHz and 80 MHz over medium voltage lines or low voltage lines to provide broadband communications and is located on the supply side of the utility service's points of interconnection with customer premises. Access BPL does not include power line carrier systems as defined in Section 15.3(t) of this part or In-House BPL systems as defined in Section 15.3(gg) of this part. (FCC)
  - Electric utility companies can use Access BPL systems to monitor, and thereby more effectively manage, their electric power distribution operations.
  - Access BPL systems can also deliver high speed Internet and other broadband services to homes and businesses.
- ***In-House Broadband Over Power line (In-House BPL).*** A carrier current system, operating as an unintentional radiator, that sends radio frequency energy to provide broadband communications on frequencies between 1.705 MHz and 80 MHz over low-voltage electric power lines that are not owned, operated or controlled by an electric service provider. The electric power lines may be aerial (overhead), underground, or inside walls, floors or ceilings of user premises. In-House BPL devices may establish closed networks within a user's premises or provide connections to Access BPL (as defined in Section 15.3(ff) of this part) networks, or both. (FCC)

Equipment Installation



Enclosure containing Node (Overhead)



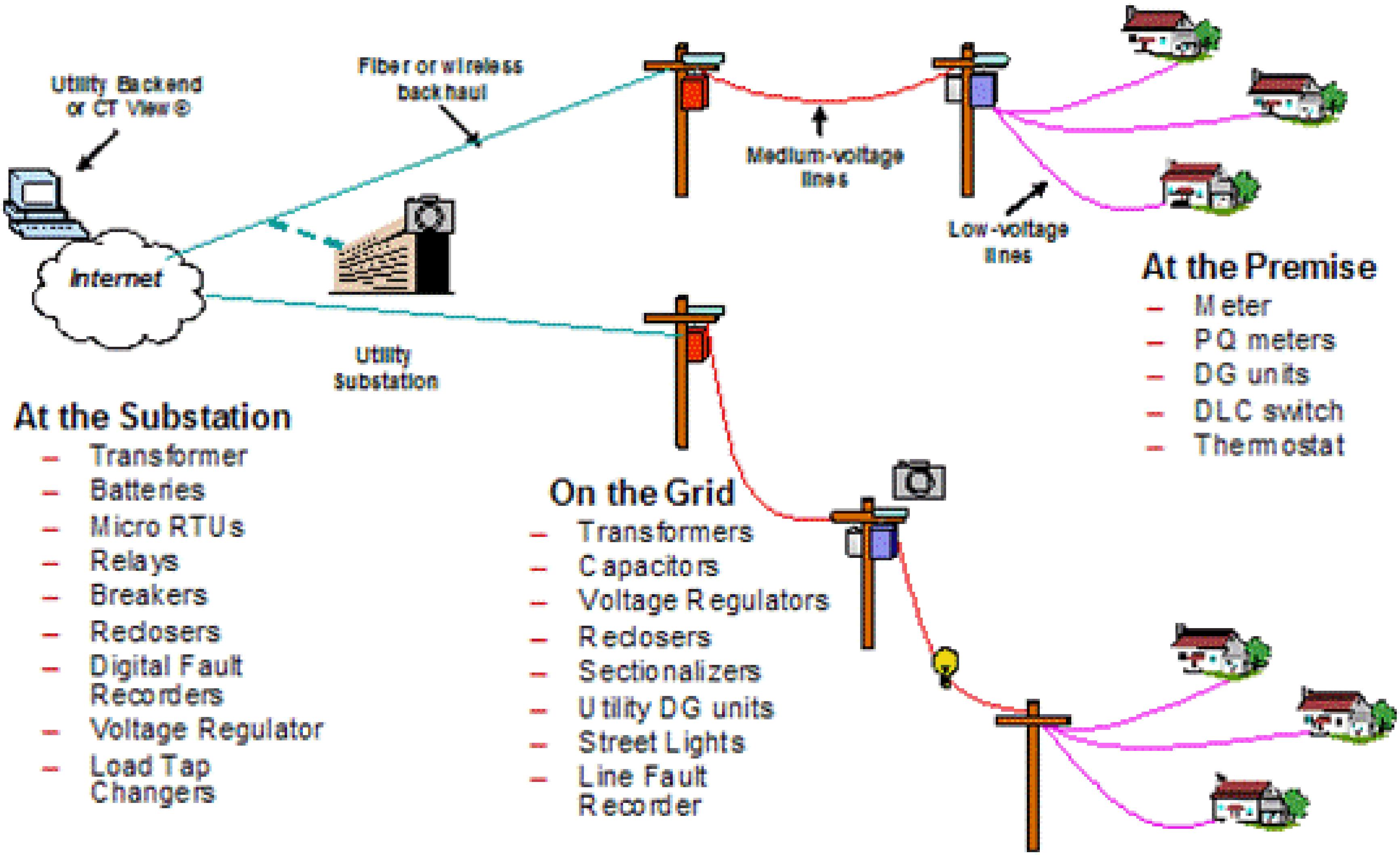
Enclosure containing Node (underground)

Coupler installation (underground)

Coupler installation (overhead)

Repeater installed at meter base

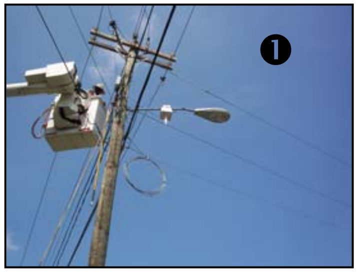
BPL has broad reach for the utility



Utility Applications Examples

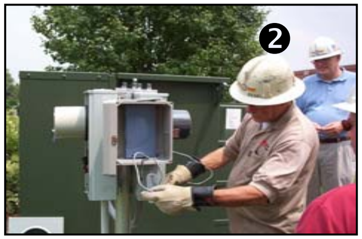
❶ RF meter collector

- Enables hybrid AMR solution leveraging existing MMR infrastructure
- Enables electric, gas and water meter reads



❷ Form 9 Polyphase transformer rated IP meter

- Replacement for exception route meter
- Enables remote reading and programming

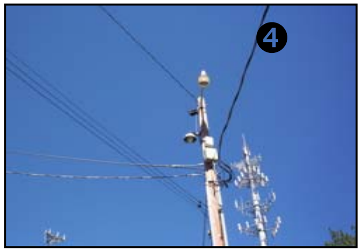


❸ Switched capacitor bank control model

- Existing utility equipment
- Enables remote reading and programming

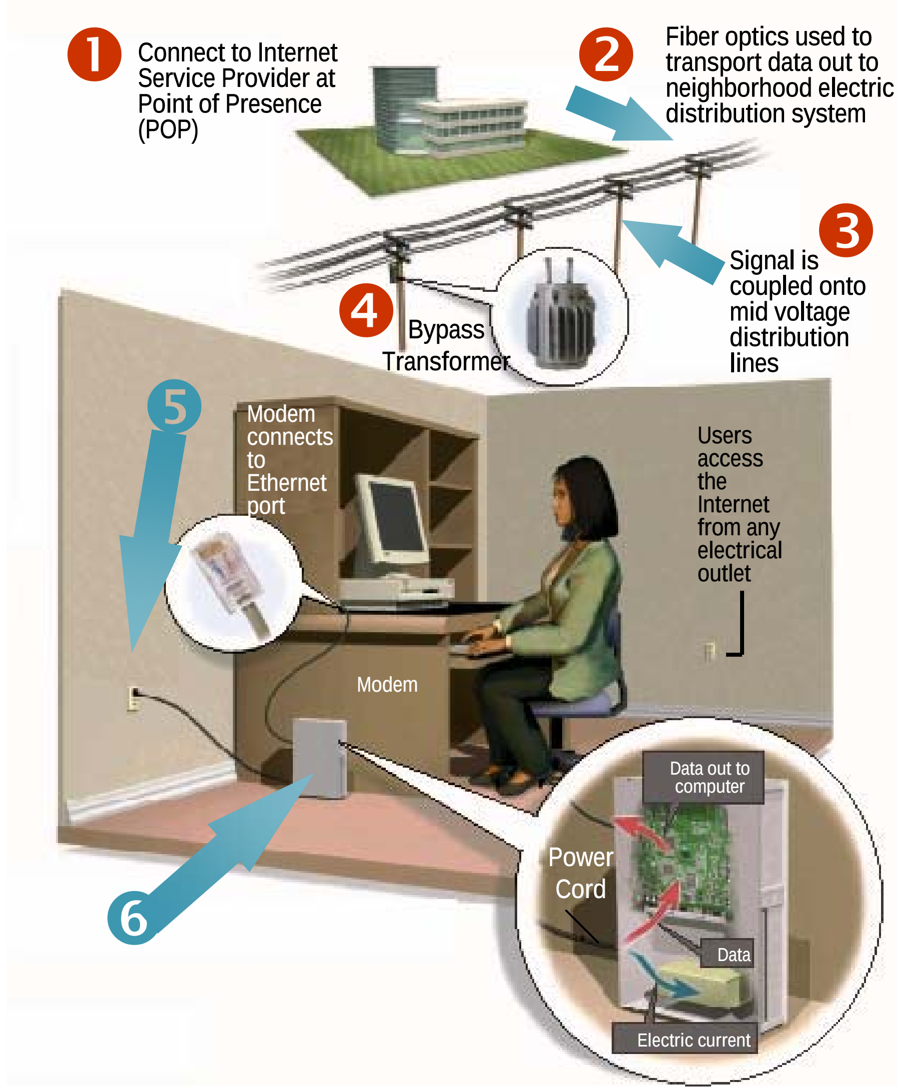
❹ Security camera at substation

- New utility application
- Remote monitoring of facilities



Utility Commercial BPL Service

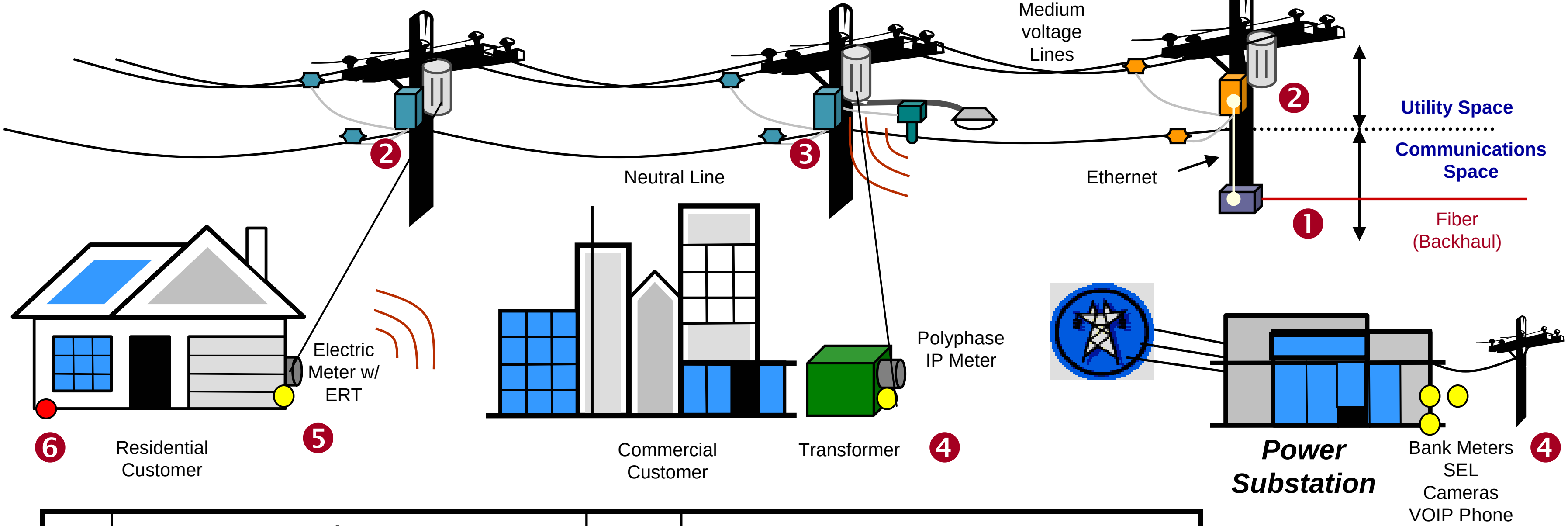
- Interconnection with service provider partners at existing utility facilities
- Use fiber optic network to transport out to neighborhood (FTTN)
- Coupler injects signal onto medium voltage distribution system. Signal is repeated as necessary.
- At customer premise, transformer is bypassed and signal is injected on low voltage line
- Customer receives signal through outlets in home
- Special modem extracts signal and communicates via Ethernet to computer



Joint-use BPL Network

Duke Energy

Powerline Communications Network



	PLC Network Components	Use	Comments
1	Backhaul component of PLC network	Joint	Provides connection back to POP (IP drain)
2	MV Collectors/Repeaters for PLC backbone	Joint	Transformers serving BPL customers would have repeaters with bypass coupler to transfer signal to LV line
3	MV repeaters w/ utility devices attached to Ethernet port	Utility	Example is MMR collector device to read ERT meters
4	LV repeater dedicated to utility application	Utility	Examples include IP meters, substation cameras, etc.
5	LV repeater at residential meter for BPL	BPL	Required at some residences to amplify signal into home
6	BPL Customer Premise Equipment (CPE)	BPL	Cost borne by service provider

PLC Collector/Injection Pint

Mid Volt Coupler/Repeater

Low Volt Repeater

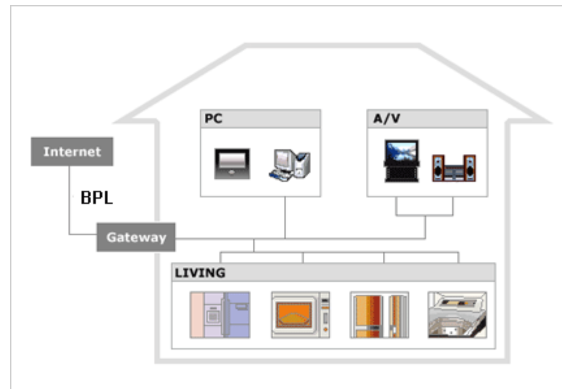
BPL Modem (CPE)

RF Collector for ERT Meters

Innovation for the Customer

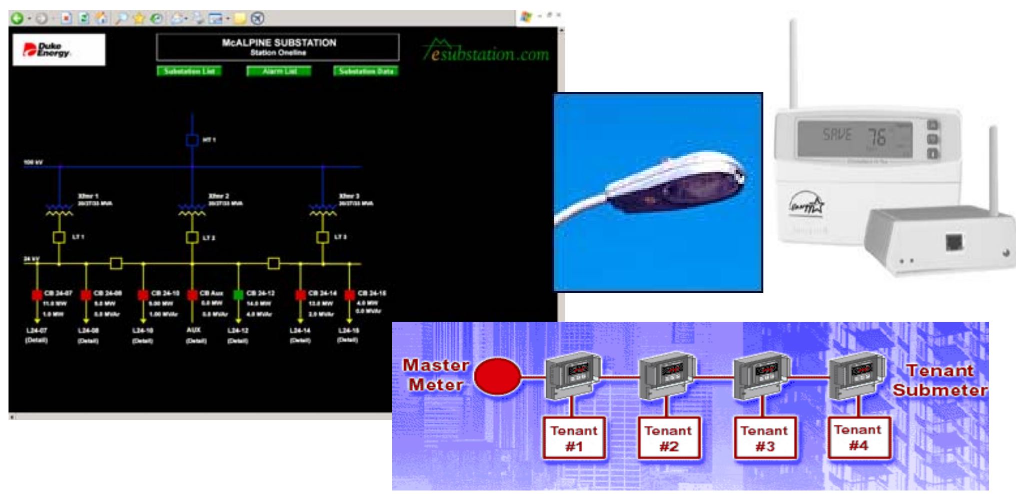
Residential/Small Business Applications

– Smart Appliances
– Security Systems
– Broadband Internet services
– Voice over Internet Protocol (VOIP)
– Video Conferencing
– Streaming Video
– IP Cameras

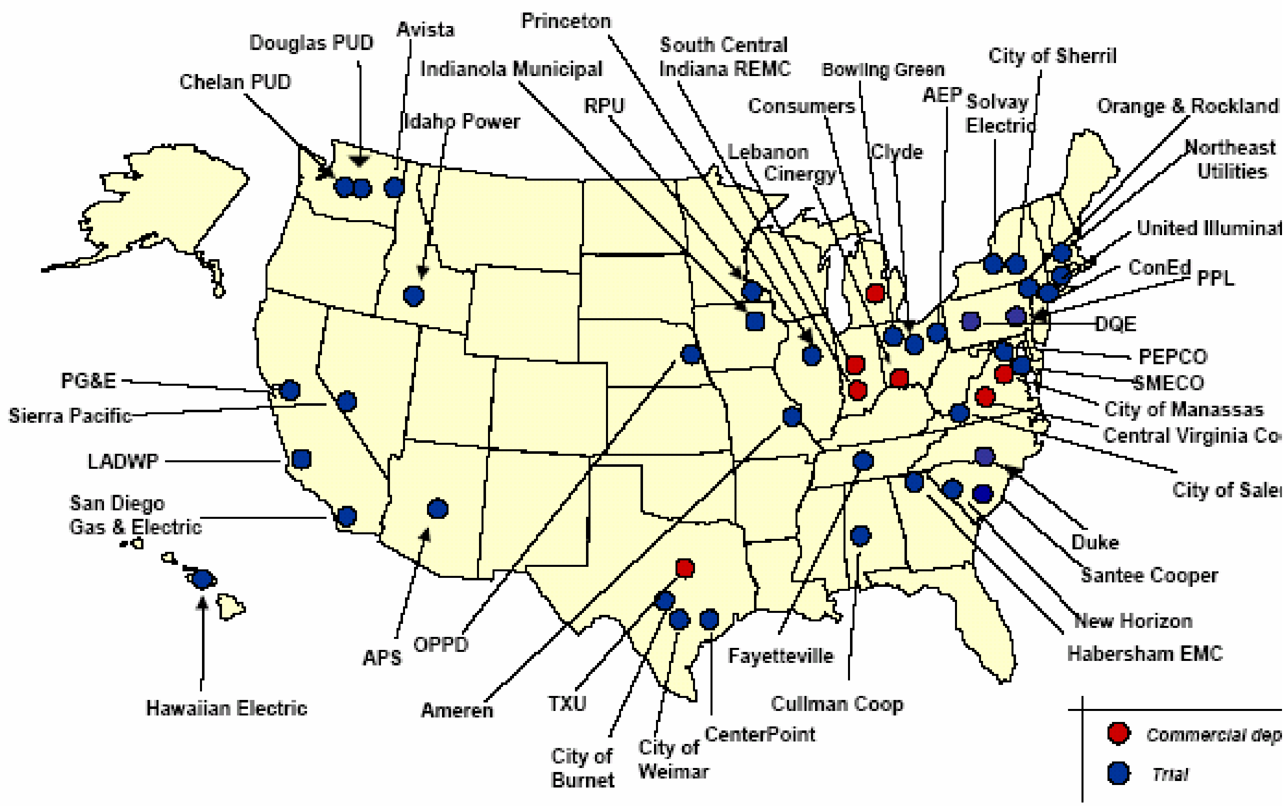


Commercial Applications

– Enhanced Metering Services
– Monitoring and Control
– Safety, Security and Lighting
– Power Quality / Load Management



BPL Deployment Map



Source - UPLC

The Duke Experience

Duke Energy Carolina's Approach to BPL

Duke has taken a phased and measured approach to the BPL opportunity in an attempt <u>to develop a multi-vendor source pool</u> for BPL equipment and service providers.

Our phases:

1. Safety and Standard review of equipment
2. Proof of Concept - 5-15 transformers
3. Technology Pilot - 500-700 home passed deployment
4. Pre-Commercialization Trial - 6000-15000 home passed deployment (15,000 is one substation)
5. Commercial large scale deployment – operational area, state, etc.

Performance is measured against phase gate requirements

There must be a path toward broader commercial deployment requirements

Phase Gate Requirements

<u>Phase Gate Requirements must be demonstrated at each phase to move to the next phase</u>

Equipment must pass safety and standards review to be installed

Minimum bandwidth specified must be available to each customer

Latency limits must be met

Packet loss limits must be met

Ping loss limits must be met to any point on the network

Data Security (Separation of customer's internal data on the network)

Element Management System (Comprehensive and self-aware)

Commercial Deployment Requirements

These requirements are our desired outcome. In an effort to move the industry along these were not required to move through each phase. Demonstrating a path to provide these was adequate.

However, <u>compliance is required to move beyond 15,000 homes passed</u>.

Ubiquitous coverage to all points on the distribution grid

Cost to deploy less than dollar target per home passed

New generation equipment must be backwards compatible

All devices need to have ethernet capable access

Overhead equipment must be of a size to be installed in the power space

BPL equipment must self recover on loop feed service

BPL equipment must be able to be installed without an outage

BPL equipment must be able to run on battery in key locations

FCC compliant and standards based

Today's Facts

- We have tested 4 vendors over the past 3 years and no vendors are ready for major deployments – trials continue
- Timeframe before any vendor will be ready for a large scale deployment is difficult to predict (each new product has a 9-12 month cycle)
- No standards exist today - 18 months to 3 years timeframe to impact
- Because of the nature of the electric grid, interference between nodes and from other sources is a major problem
- Development on major components still needs to be completed
- Network support for utility applications is within reach, for commercial Internet access it is still distant
- Cable and DSL have a much easier time increasing bandwidth on the network than BPL, making a competitive commercial broadband response easier
- Public policy concerns regarding reliability and efficiency of electric delivery and conservation have intensified

Strategic Focus

Utility Applications → **The Dual Purpose Network** ← **Broadband Business**

- **Strategic Fit**
  - Core business value-add
  - Regulatory Frame Needed
- **Operations Interest**
- **Unique Approach**

- **Ultimate Business Model**
- **Utility-Driven**
- **Regulatory Frame in Progress**

- **Initial Industry Focus**
  - Regulatory Issues deferred
  - Market Opportunity
- **Market Interest**
- **Unique Approach**

BPL becomes a core enabler for Utility of the Future

BPL as an Enabler of the Utility of the Future

Utility of the Future a Long Term Vision

- The Utility of the Future will
  - enable energy efficient behavior,
  - optimize the inputs required to generate electricity and
  - maximize the value of energy by creating an energy efficiency infrastructure across its distribution system

- The enabling technology, consisting of
  - IP enabled meters capable of two way communication,
  - a broadband communication system and
  - a data management system,
  - holds the potential to facilitate the required regulatory environment and change the mission of the utility

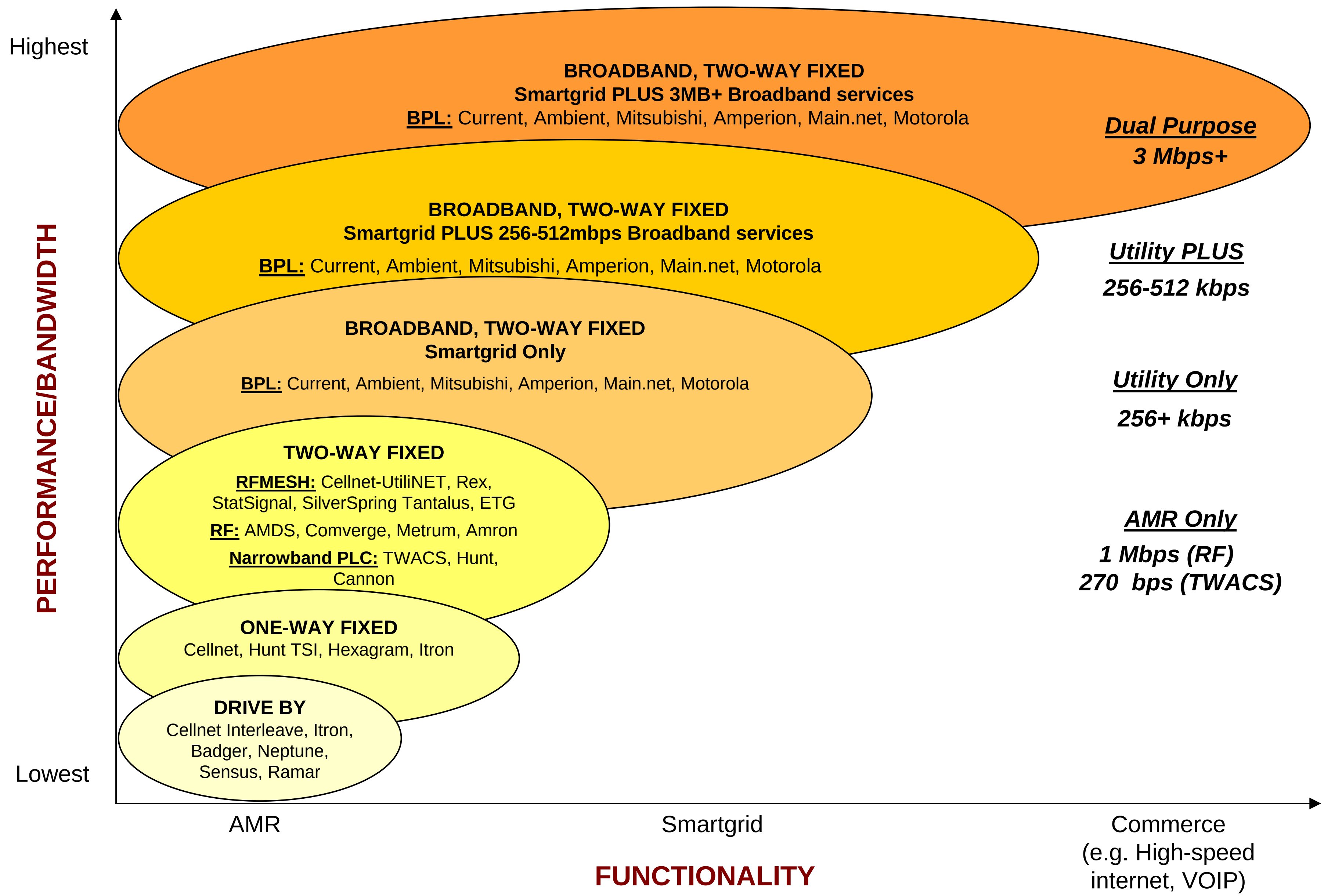
Facilitating Utility of the Future

- Two-way communication is essential to realizing benefits

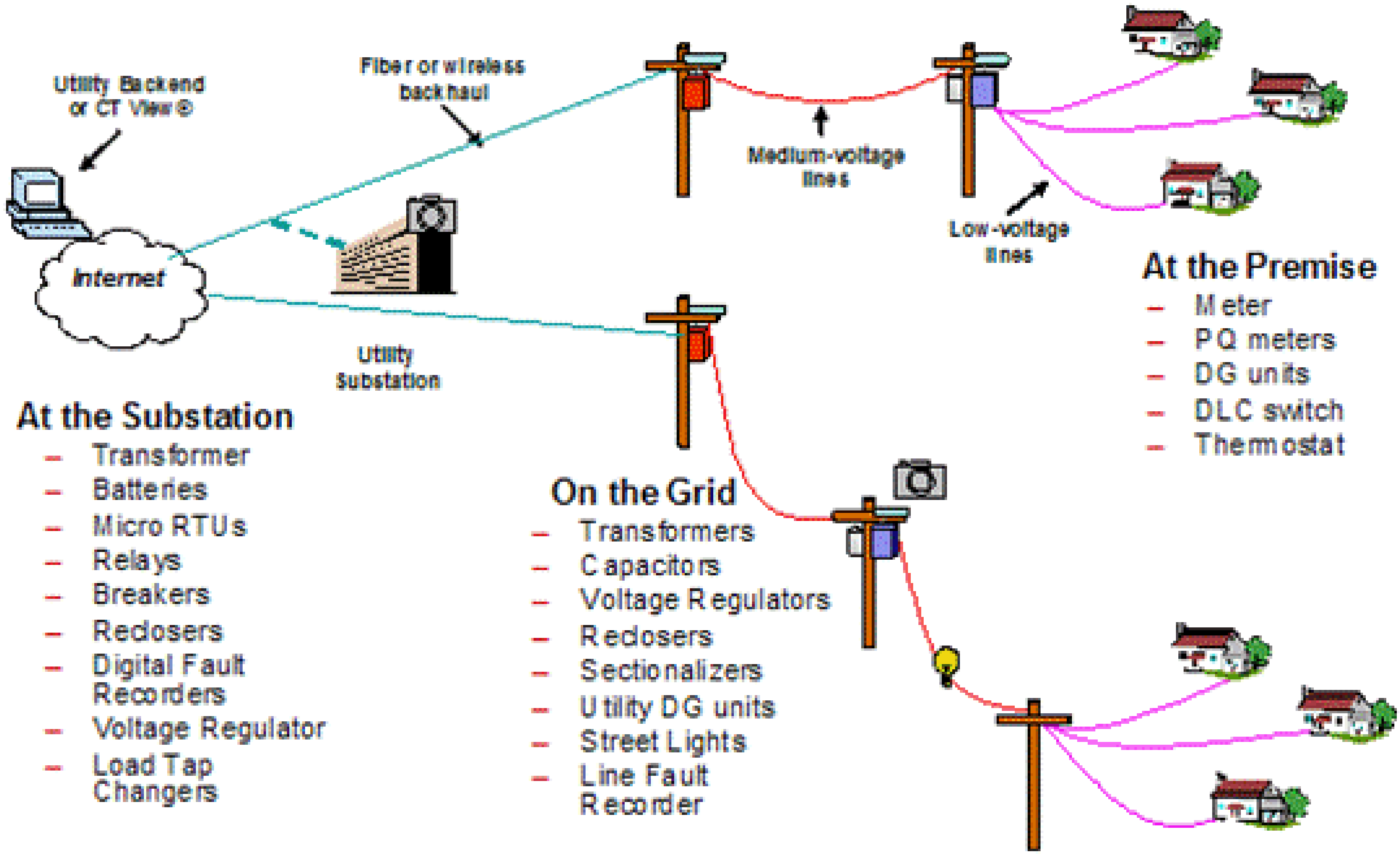
- High bandwidth communication provides optionality across the system
  - Constant communication and asset optimization
  - Real time load management and verification of operations
  - Commercial communication based service offerings

- Low bandwidth communications are proven but less flexible
  - Less costly solutions using existing assets
  - Technology risk has been socialized across the industry
  - Communication with the system is self-initiated

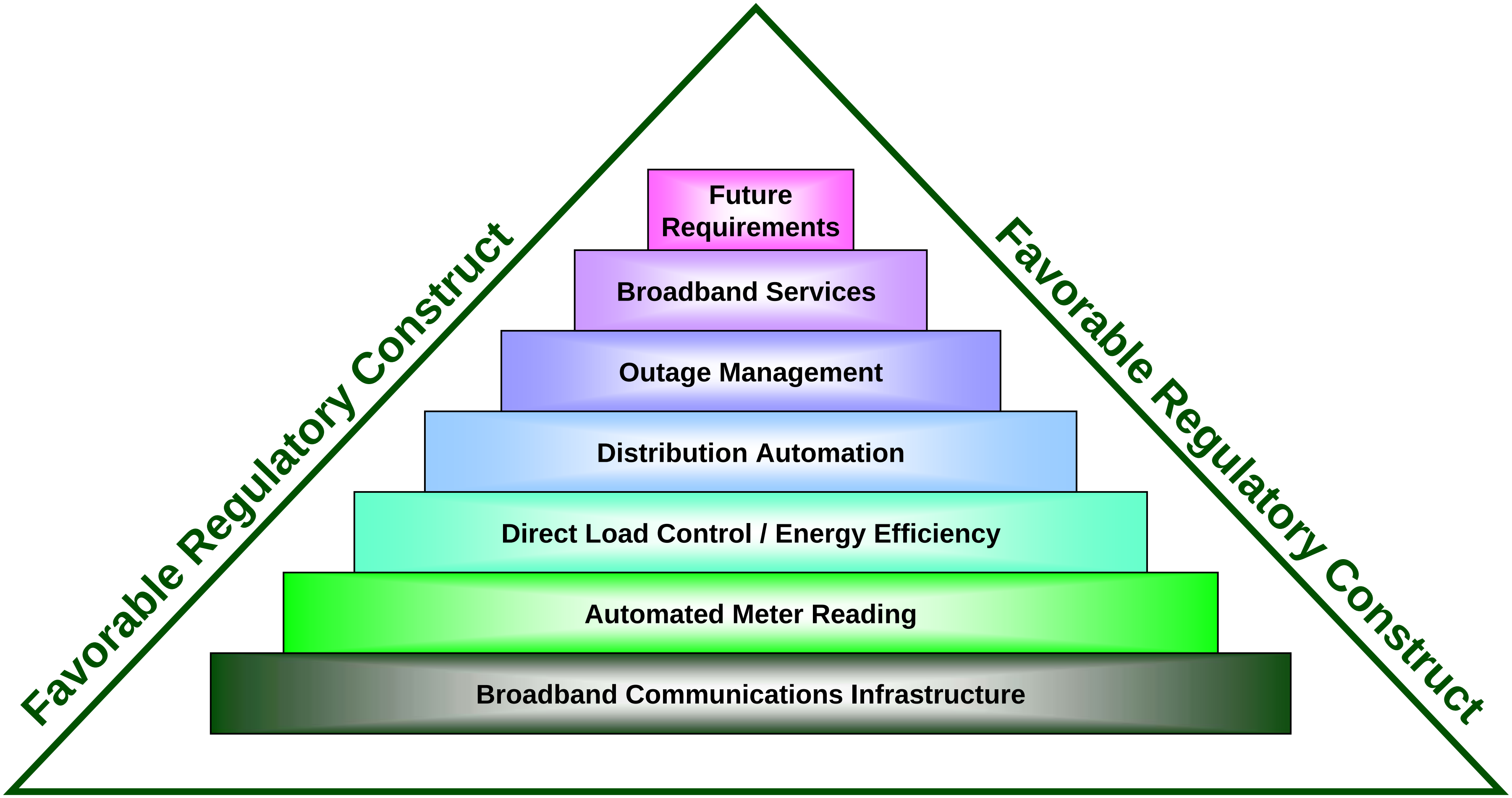
Performance Differentiation



BPL has broad reach for the utility

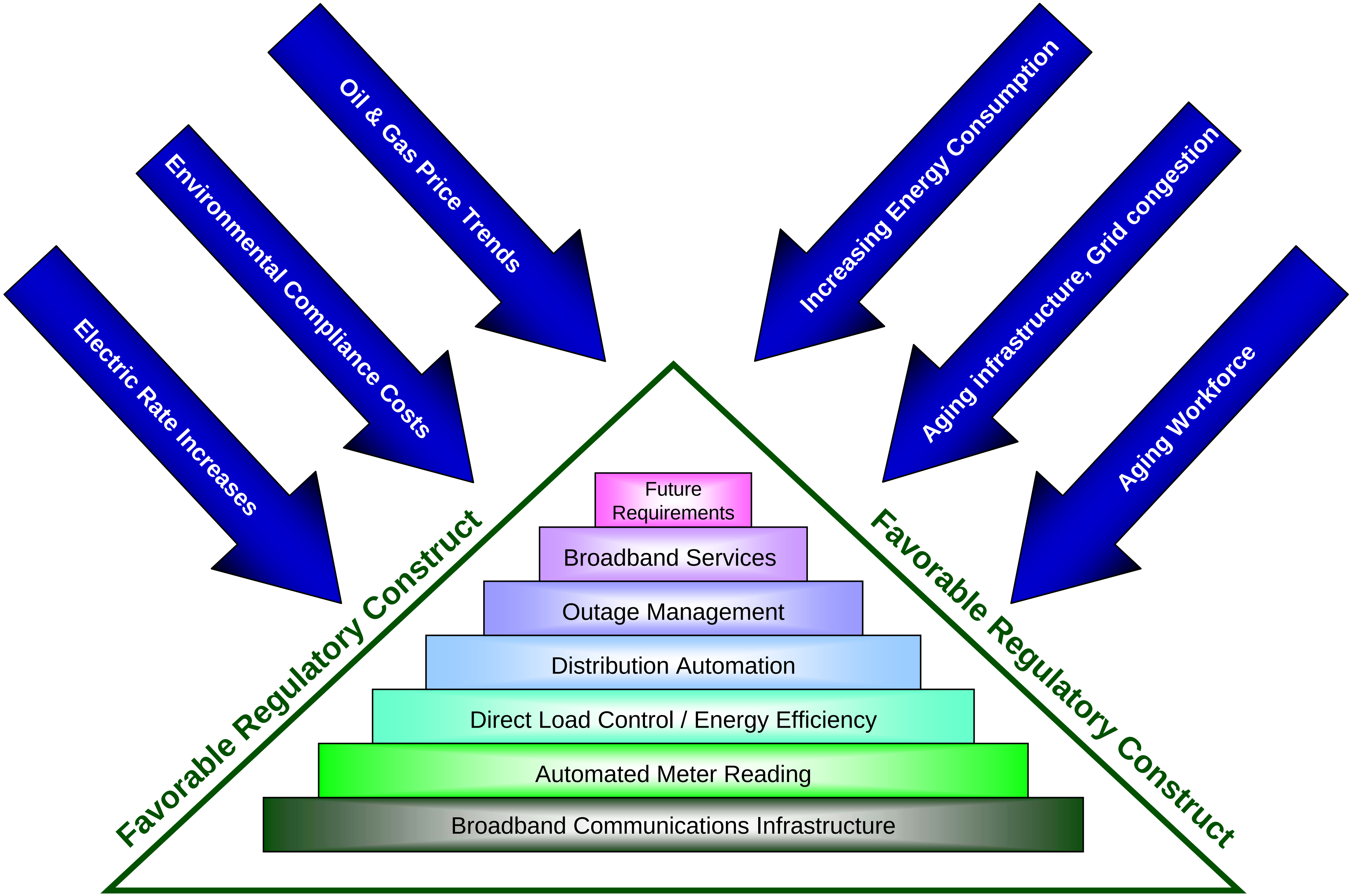


Smart Grid Foundation



Ubiquitous coverage is essential to capture Smartgrid benefits.
BPL will be a core technology, but not exclusive.
Other platforms will include fiber, wireless, microwave, narrowband PLC.

Utility of the Future Business Drivers



UotF Value Proposition

- The UotF value proposition can be categorized in three main areas:
  - Utility operation benefits
  - Market based benefits
  - Corporate citizenship and sustainability

- The combined value can range from mere millions of dollars a year to hundreds of millions depending on the operating structure and utility utilization of the technology

UotF Value Proposition - Utility

- Utility operations model
  - Expenses are reduced
    - Meter readers eliminated along with equipment used to manually read meters
    - Billing becomes more efficient
    - O&M is more targeted and capital efficiency can be improved
  - Revenue increases
    - Accurate metering and billing improves the top line
    - New rate products can be tailored to usage patterns

UotF Value Proposition - Market

- Market based opportunities emerge using load as a resource
  - Load can be used as a planning and operating tool – where today load is purely a requirement
    - Load used as operating reserves
    - Economic dispatch of load
    - Optimization of generation and transmission products using load as a lever
  - Value of load will vary depending on market prices, operating characteristics of the system and corporate strategy

UotF Value Proposition - Sustainability

- A utility’s investment in an energy efficiency infrastructure will position it as a market leader in efficiency investment
- Future environmental benefits flow to the company by optimizing the system
  - Additional benefits are difficult to quantify due to unknown, but highly likely carbon taxes
- The utility will be positioned to radically change work practices, through much more granular and specific consumption data, for planning and operations

Customers' Value Proposition

- Customers will be able to see the impact of their energy use behavior on their costs
  - Technology will enable matching energy use with desired cost
  - The utility will be able to provide enhanced direct load control, demand side management and energy efficiency programs
  - Verifiable load shedding facilitates a customer participating in the economic upside the utility enjoys by selling power in the wholesale market
  - Load management in the planning process may lower overall system infrastructure cost increases
- Benefits to customers become directly proportional to their energy use choices and behaviors

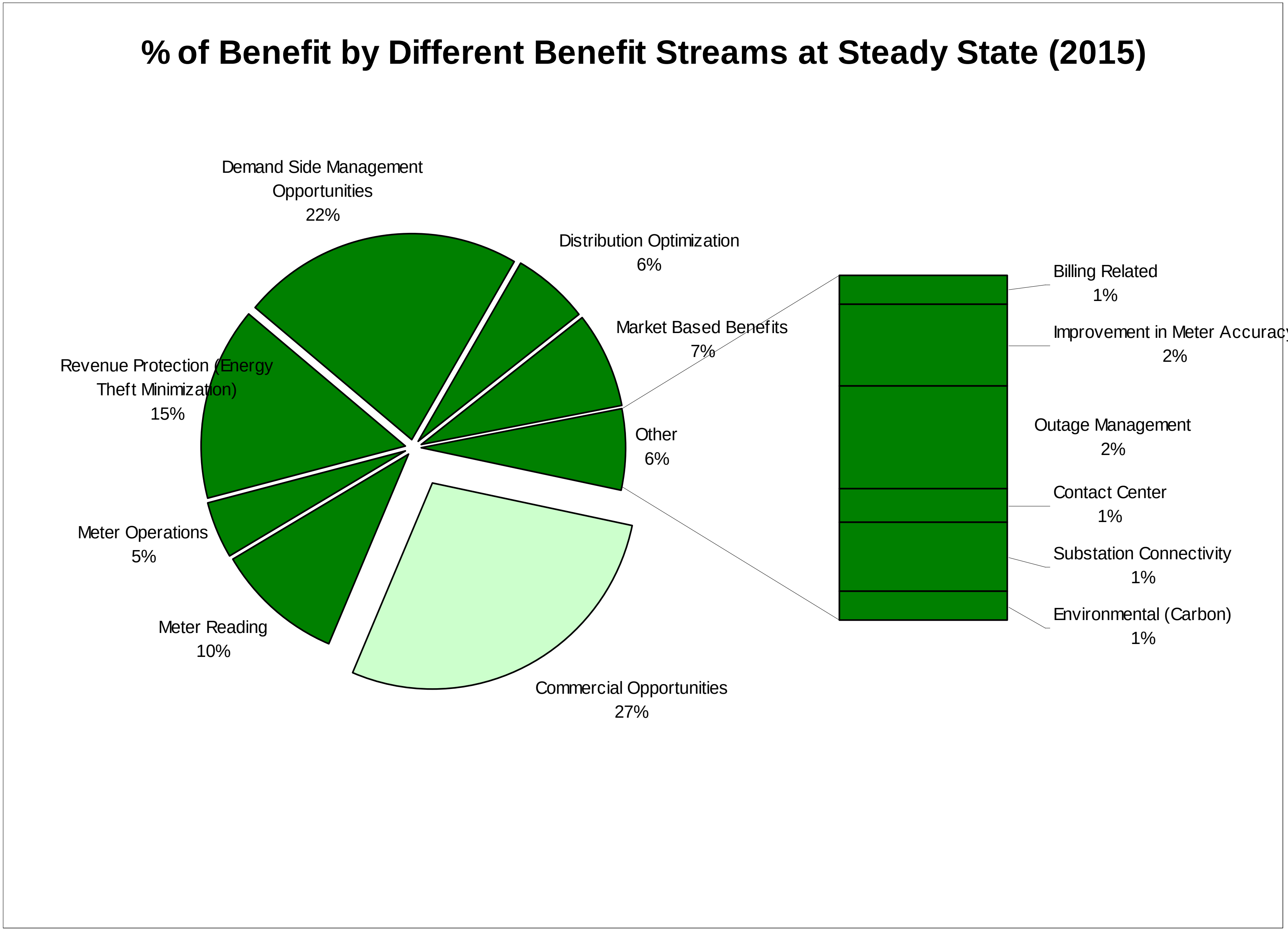
Regulators' Value Proposition

- Regulators are positioned to empower consumers
  - Utility's success in implementing an energy efficiency infrastructure provides greater consumer choice at the same or less cost
  - Improvements made to the distribution system increase overall reliability and stability of the grid
- Additionally, regulators can leverage ancillary benefits of the project, including:
  - Economic development
  - Environmental benefits
  - Greater customer choices in energy usage without deregulation

Regulatory Environment

- Regulation enabling the deployment of energy efficiency infrastructure with the appropriate cost recovery mechanisms
- Utility will have the ability to dispatch economically using load as a resource
- Efficiency efforts will be broadly deployed, allowing the customer to reap benefits of efficiency without incentive payments
- Regulation will facilitate the correct business model and activities
  - Utility owned and operated assets
  - Utility owned assets with a JV or outsourced operator
  - Regulated and commercial use of the BPL system

Example Benefits Forecast

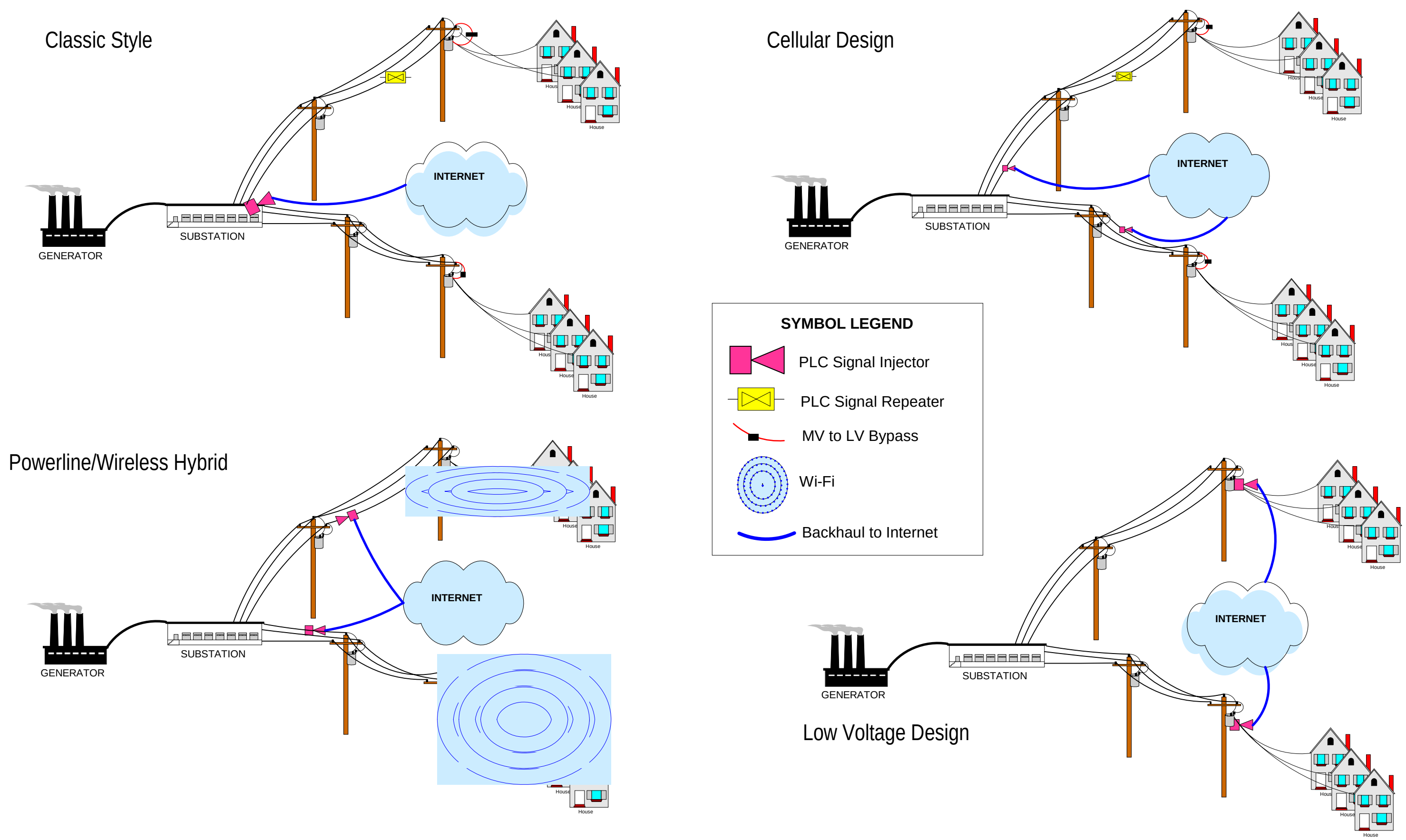


In Conclusion

- The Utility of the Future can, will, and must be significantly different
- BPL is an exciting technology with the potential to enable the Utility of the Future to
  - Improve reliability, efficiency and productivity
  - Reduce capital investment requirements
  - Increase consumer benefits
- The Utility of the Future and BPL are dependent upon
  - Additional research and development
  - Continued regulatory restraint and innovation

Backup Slides

BPL Architectures



Potential Business Models

- *Landlord*
- Under this model, the utility would allow a prospective network operator to build on the power grid in return for access fees. The landlord model features less long-term potential, virtually no cash outflows and the smallest risk to shareholders. The greatest challenge in this model is that the utility has no control over network build-out and therefore little hope of obtaining significant operational benefits from the network.
- *Developer*
- Under this model, the utility builds the power line communications network and subsequently hands off to a service provider for end-user provisioning. Revenue would be in the form of a combination of access fees or revenue sharing. Benefits of this model are control of the deployment (enabling utility application benefits), fewer execution issues and shifting the majority of market acquisition costs to the third-party service provider.
- *Service Provider*
- Under this model, the utility has decided to develop the power line communications network and own the customer relationship throughout. This positions the utility for the largest potential overall return, but also requires the largest funding requirements. In addition, key activities like marketing and network management will be called for; it is imperative that these are in line with utility experience and capability.

Major Categories of Regulatory Issues

- Service Protection
- Provider Access
- Affiliate Transactions
- Cost Allocation
- Easements, Right of Way, Franchise and Jurisdiction

Operational Principles for BPL

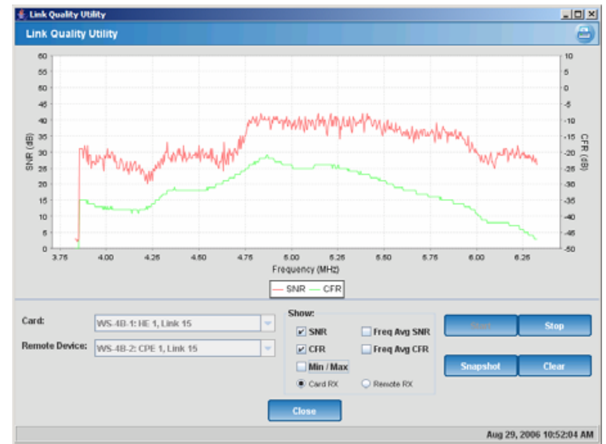
- Fiber optics and optical electronic equipment is installed to connect from the utility POP (point of presence) to the power company's electrical distribution network
- Electronic equipment is installed to convert to a signal that is compatible with the power line
- An RF signal from 2Mhz to 80Mhz is coupled onto the existing power line either through inductive or capacitive coupling
- The RF signal is repeated as necessary on the medium voltage lines by installing additional electronics
- At each transformer electronics are installed to by-pass the transformer and couple the signal to the low-voltage lines feeding the customers meters.
- Additional electronics may be required at the customers meters to obtain signal in the residence
- Electronics will need to be placed in the residence to convert the signal from the RF utilized on the power line to an ethernet signal that can be recognized by the ethernet devices (computers, smart appliances, etc.)

The BPL Operating Environment

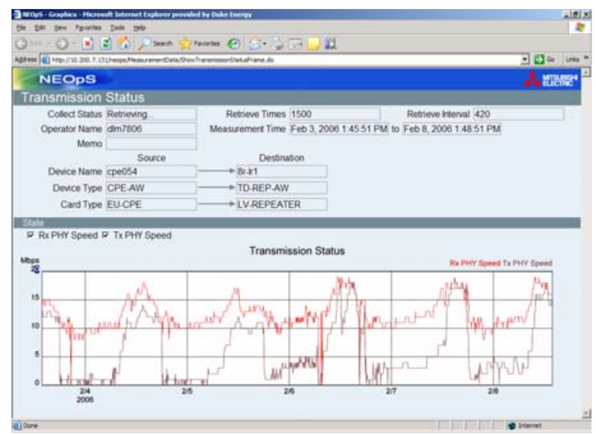
- The amount of signal coupled to the power lines is governed by the FCC Part 15 requirements. (extremely low power).
- The RF spectrum allowed for use in access BPL is from 2 Mhz to 80 Mhz.
- The RF signal that is coupled on to the power line is adversely impacted by the following non-inclusive list of factors
  - capacitor banks
  - motor noise, air conditioners, refrigerators, fluorescent lights
  - line size
  - loose insulators and loose connections
  - temperature
  - sun spots
  - RF interference from outside sources such as AM radio
  - the number of branches on the circuit.
  - Impedance changes on the distribution grid
- Most vendors are using OFDM (Orthogonal Frequency Division Multiplexing) to mitigate adverse impacts to the BPL signal

OFDM

- OFDM stands for Orthogonal Frequency Division Multiplexing and is a modulation technique for transmitting large amounts of digital data over a radio wave.
- OFDM is conceptually simple, but the devil is in the details! The implementation relies on very high speed digital signal processing that has only in the last several years become available at a price that makes OFDM a competitive technology in the marketplace.
- A given radio spectrum is broken into a lot of small carriers that each carry a few bits of data
- This is the same modulation technique used in WiFi, DSL and some cable systems



Signal to Noise vs Bits Per Channel



Transmit and Receive Data Rates over time

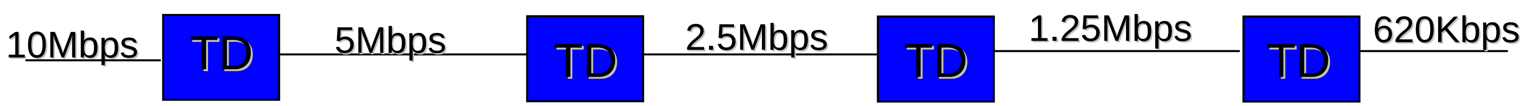
Repeating the signal on the line

- The output power of the BPL devices must be kept low to insure that no harmful interference to licensed operators is caused by the BPL signal.
- The output power of the BPL devices installed on the overhead lines is lower than the BPL devices installed on the underground because the overhead lines act as an antenna increasing the radiation of the RF and thus the likelihood of interference.
- Due to the attenuation of the lines and noise, the usable BPL signal does not travel a long distance over power lines (typical 600 to 1400 feet). The distance is dependent on a lot of factors such as number of feeders on the circuit, size of the wire, number of parallel conductors etc…
- Repeaters installed at various points on the line are required due to the factors above as well as at each transformer.
- Repeaters that are installed at each transformer serve two purposes: to repeat the signal down the mid voltage as well as bypass the transformer and inject on the low voltage.

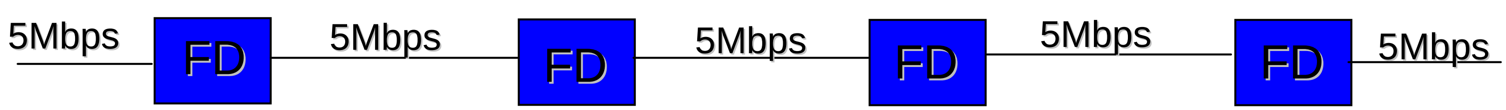
Time Division /Frequency Division

- Two basic forms of repeating the BPL signal on the electric grid are utilized.

  – Time Division (TD) – In a time division domain the same modulated frequency 2-80Mhz that is applied to the power line is utilized between adjacent nodes. Every time the signal is repeated the bandwidth is cut in half



  – Frequency Division (FD) – In a frequency division domain the 2-80Mhz spectrum will be broken up into smaller bands and a different frequency will be utilized at each repeater. Every time the signal is repeated the bandwidth is the maximum usable within the band



Latency, Bandwidth and BPL

- A common misunderstanding of communications is that having more throughput means a “faster” (lower-latency) connection. But, in many cases, the reverse is true, depending on the context and needs.
- Throughput – The amount of information that can be transferred over a connection in a given period of time. It is usually measured in bits per second.
- Latency – The amount of time it takes for a response to return from a request. Usually this is measured in a simple time value, typically in milliseconds on the internet.
- Latency has a more noticeable affect when trying to run VoIP (Voice over Internet Protocol)
- Un-like DSL, BPL is a shared medium the amount of data being run down the same pipe will affect the latency and thus the quality of service for VoIP.
- A latency of less than 100ms is required to provide voice grade service utilizing VoIP.