Presentation to Cincinnati IEEE Meeting

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Current Technologies

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Agenda

- Overview of BPL
- Power Line as Communications Channel
- OFDM basics
- System Architecture
- Transformer Bypass
- Compatibility with Licensed Spectral Uses
- Review of Commercial Offering in Cincinnati
- Industry Status and Next Steps

What is BPL? What is PLC?

- Broadband over Power Lines generally refers to high speed (multi-megabit) systems that transmit data over power lines
  - In-House – For use in home networking
  - Access - For delivering bandwidth to home or business

- BPL systems have been long promised but only recently coming to commercial practice
  - 2 Major Advances Have Made BPL Possible
    - Low cost, effective power line modems
    - Safe and effective means to bypass transformers

- PLC Systems are different – Low speed systems used for automation and control (ex: X-10, LonWorks)

Current's BPL solution provides end-to-end broadband data and voice services using the existing power grid

The *Current* Platform

Broadband Data
2-4 Mbps net symmetrical available today—50+ Mbps in next generation

Voice
Voice over IP (VoIP)

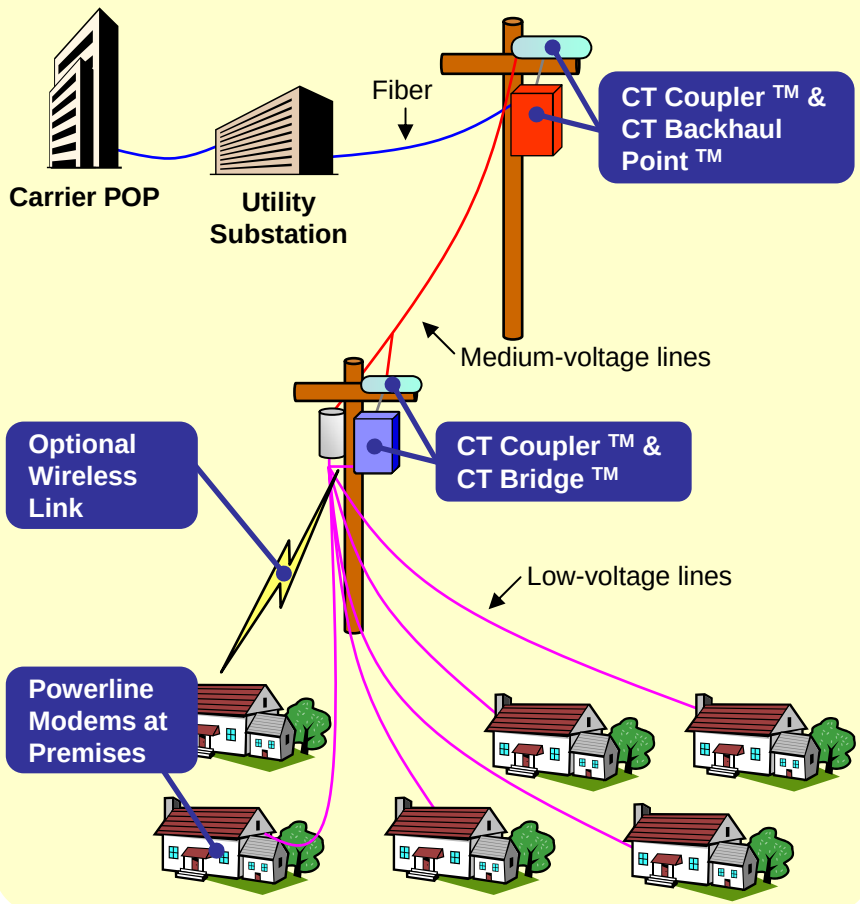
Truly Plug-and-play
No truck roll to the customer premises

Network Manageability
All active network elements managed

Low-latency and Symmetrical
QoS applications

In-home/-office Networking
All electrical outlets are ports for broadband access and local-area networking

The *Current* Overlay Architecture



Why Is BPL Attractive?

- Power lines are most ubiquitous infrastructure
- Broadband competition
  - Potential 3rd provider into home
  - Existing wires – lower cost of deployment
- Enhanced Utility Services
  - Adds advanced capabilities to electricity distribution infrastructure

Electricity Distribution Basics

Generation	*Transmission*	**Distribution**

Distribution

From the transmission lines, the voltage is stepped down at a substation and distributed to end-users over the local power grid

Example Companies

NSTAR

Duke Power. A Duke Energy Company

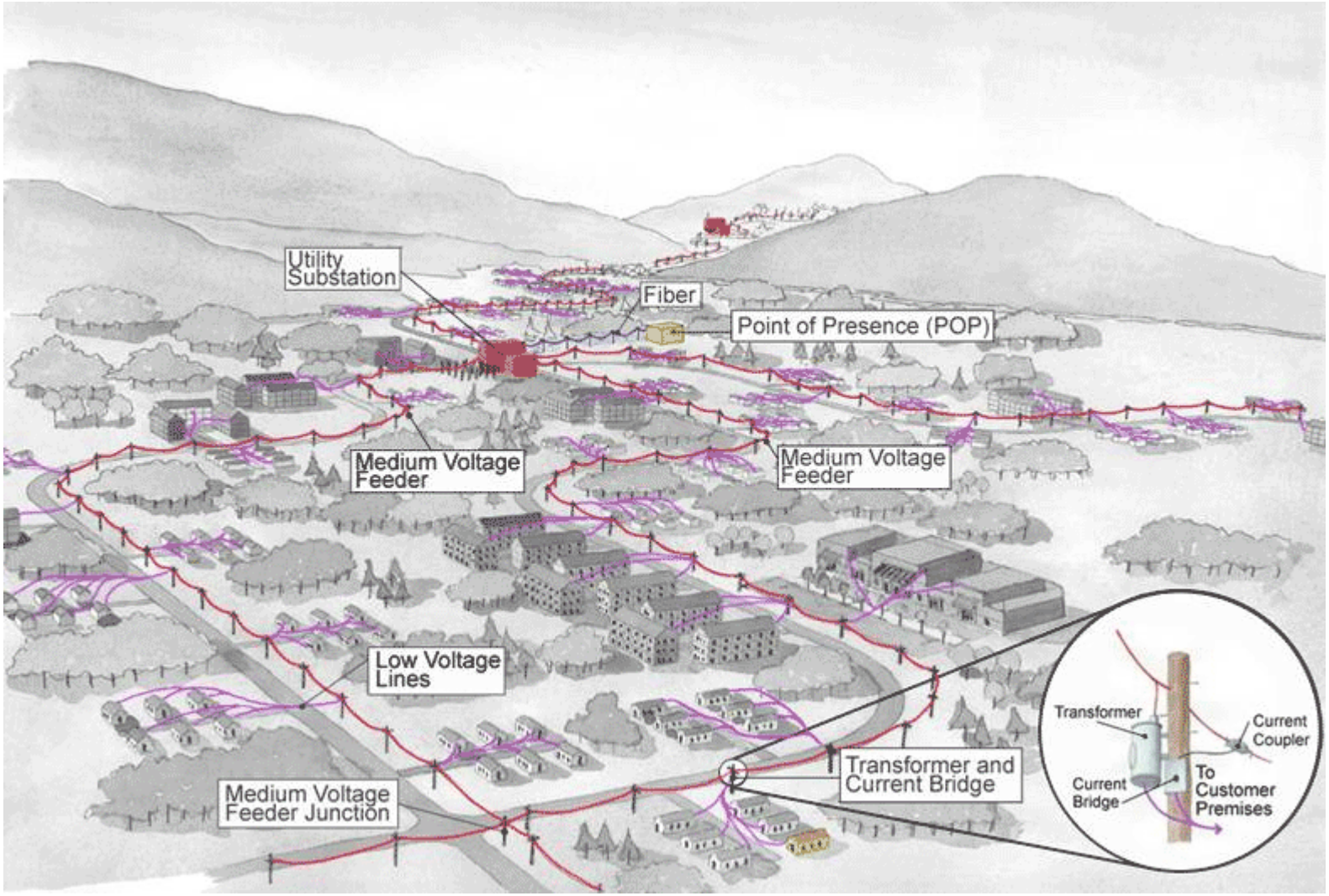
CINERGY. the power of change

PG&E Pacific Gas and Electric Company

Nevada Power.

pepco Energy Services

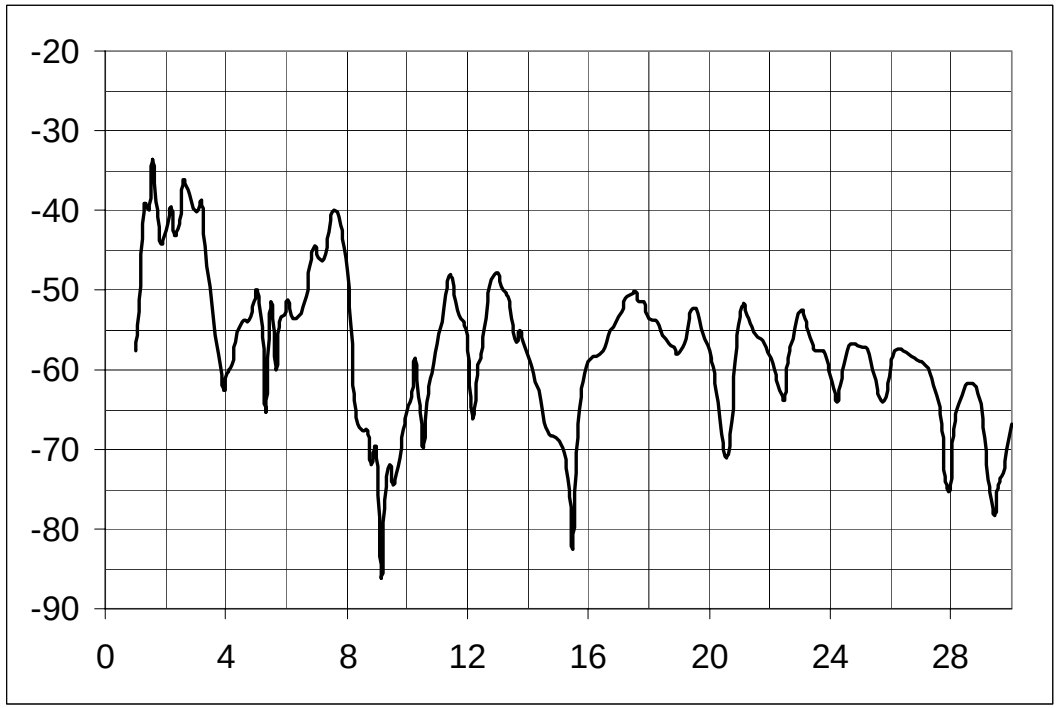
Municipality Layout



Power Line Is A Hostile Channel for Communications

- Power lines full of channel impairments
  - Impedance Mismatch
  - Unterminated Stubs
  - Conducted Noise
  - Ingress Noise
  - Attenuation
  - Frequency Selective Characteristics

All of this time varying!!



Channel Spectral Characteristics Post Ferrite Choke Insertion
Horizontal scale = Frequency (MHz)
Vertical Scale = Through Response (dB)

How to Deal with Impairments – Possible Solutions

- **Condition power line network -** minimize mismatches, terminate stubs, filter noise, etc.

  Eliminates advantages of electricity network!!!

- **Choose modulation schemes robust enough to work in hostile channels**
  - Direct Sequence Spread Spectrum (DSSS)
  - Orthogonal Frequency Division Multiplexing (OFDM)
  - Single Carrier

OFDM Offers Superior Performance for BPL Applications

	OFDM	Spread Spectrum Techniques (FH and DS)	Single Carrier
Spectral Efficiency	**Good**	Poor	Moderate
Robustness Against Channel Distortions	**Excellent**	Not Good	Good
Robustness Against Impulsive Noise	**Fair**	Fair	Good
Ability to adapt to channel changes	**Excellent**	Fair	Good
EMC Aspects	**Good**	Good-Excellent	Poor
Implementation Costs (Equalizers, etc.)	**Fair**	Poor	Poor (Equalizers required)

OFDM System Block Diagram

- OFDM uses multiple narrowband carriers instead of one broad carrier as in a single carrier system.

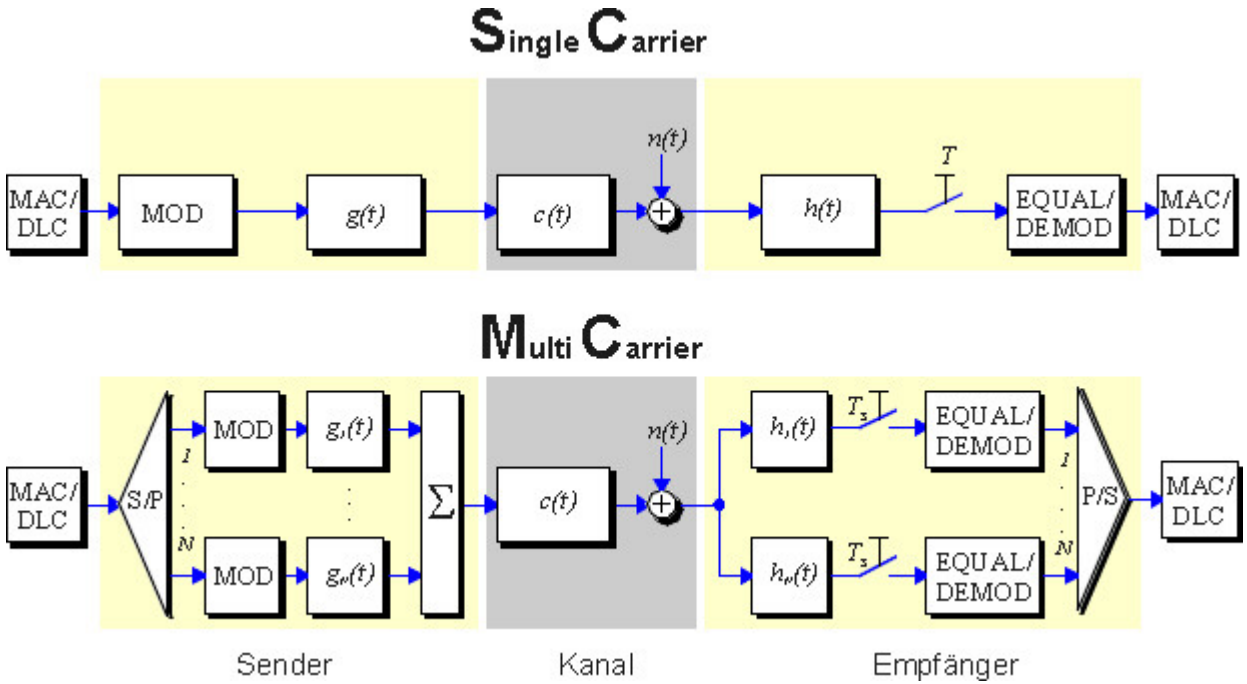


Image: http://www.ant.uni-bremen.de/research/wlan/ofdm.html

OFDM Signal Generation

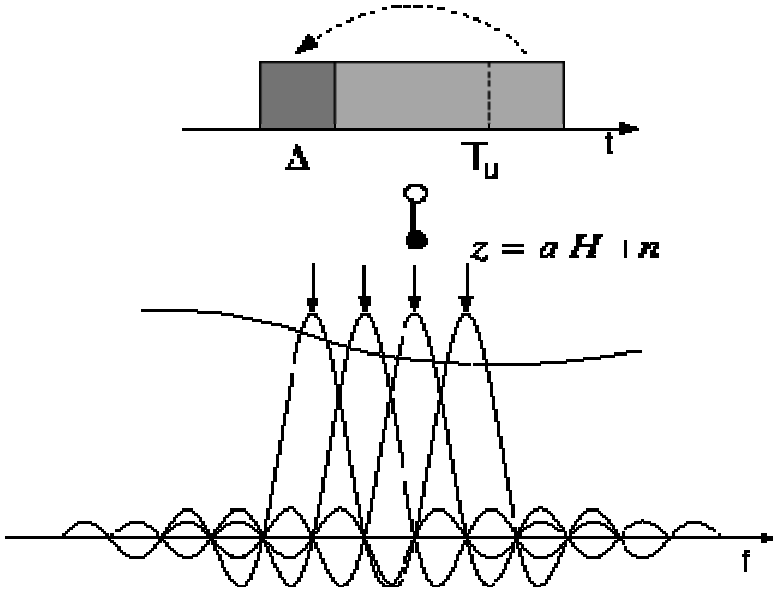


Image: http://www.ert.rwth-aachen.de/Projekte/Theo/OFDM/node6.html

- OFDM carriers are closely spaced
  - Note each carrier is placed at the nulls of other carriers

OFDM systems are practical with DSP techniques

Single chip engines available

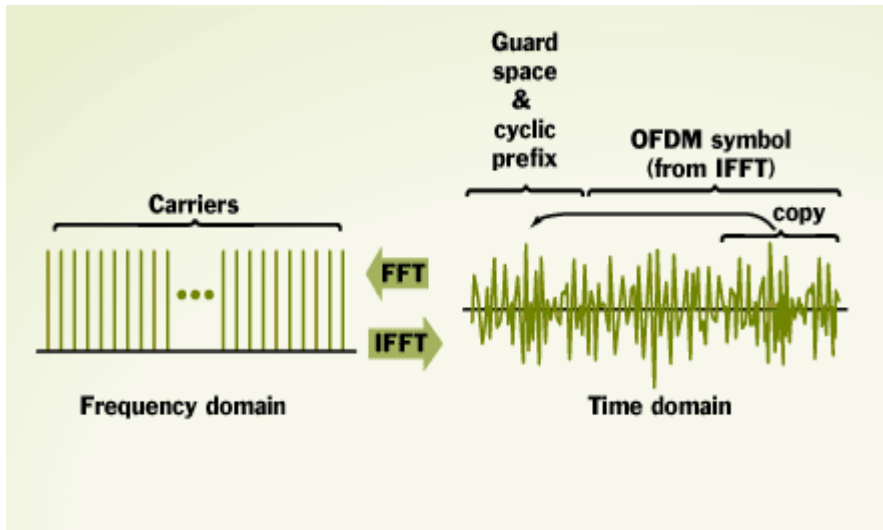
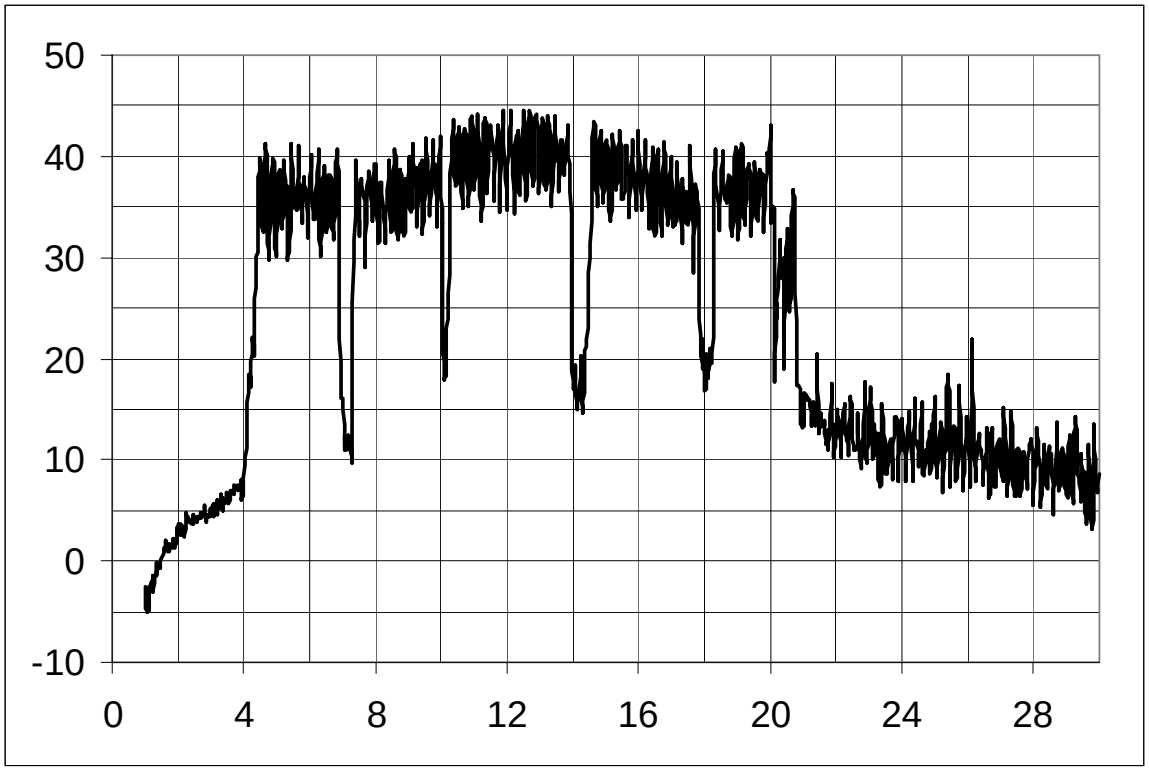


FIGURE 2: *Transform from the frequency to the time domain and adding the cyclic prefix.*

Image: Communications Systems Design, Dec 2000

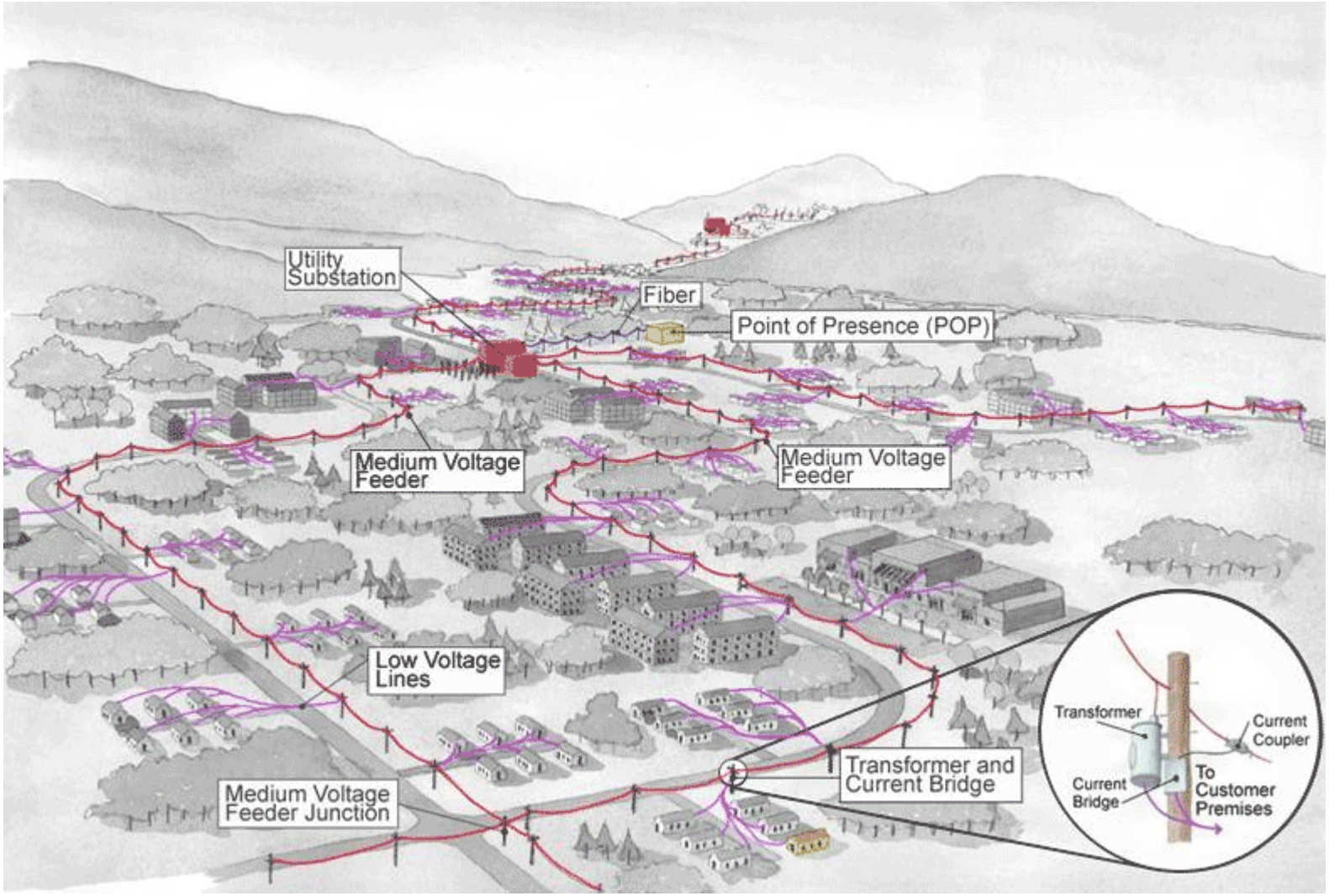
OFDM System Example: Homeplug

- Homeplug is a standard for power line networking
  - Used as the LV modem in Current's solution
- 84 carriers from 4.5-21 MHz – notches for amateur radio bands



- Raw Throughout 14 Mbps
- Effective throughput 6-7 Mbps
- DES encryption
- Products Widely Available and Low Cost

Electricity System Layout



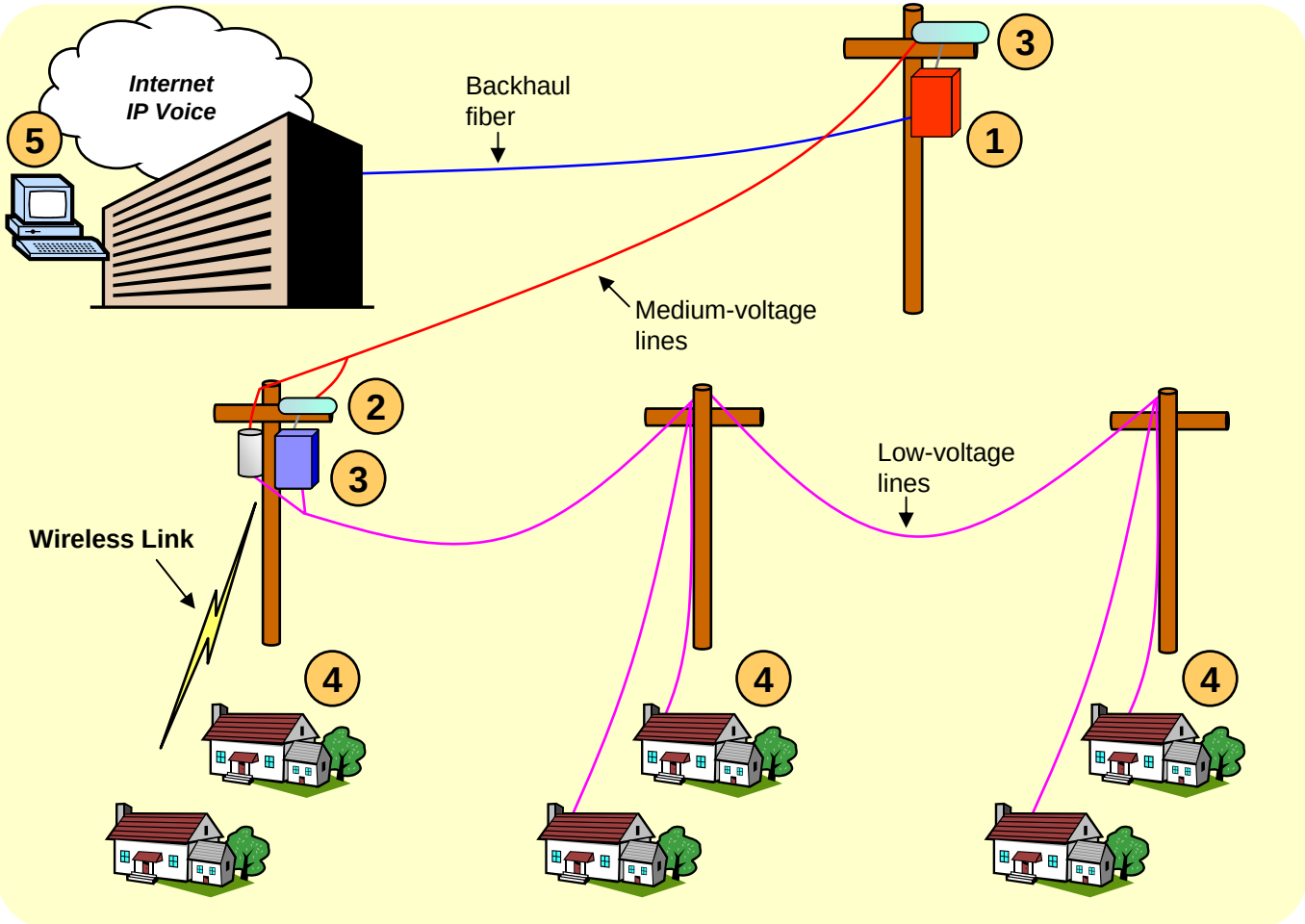
Key Architectural Choices For BPL System

- Bypass Transformer or Pierce Transformer? (MV to LV Conversion)
  - Bypassing transformer allows lower and more predictable signal loss, piercing requires no equipment
- Signal Repetition
  - Regenerating data packets at various points allows greater reach at the expense of lower bandwidth and greater latency
- Frequency Plan
  - Selection of operating frequencies for backbone and service links
  - FDD vs. TDD
  - Coexistence with licensed services
- Bandwidth and latency
  - Desired service offerings
  - Latency sensitive applications – voice and gaming

Current leverages the existing powerline infrastructure to provide a "third pipe" for broadband access

Components	Solutions

1. CT Backhaul Point ™
2. CT Coupler ™
3. CT Bridge ™
4. Third-party CPE
5. *Current* Management Software

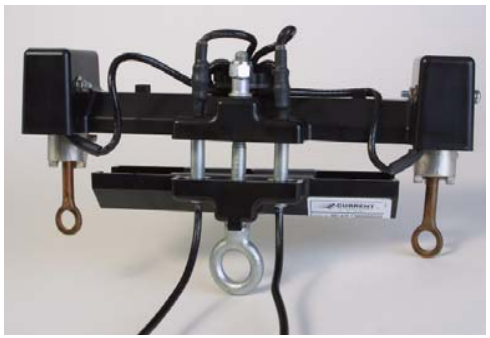


CT Coupler ®: Provides communication between medium-voltage and low-voltage lines

Overhead Coupler Assembly

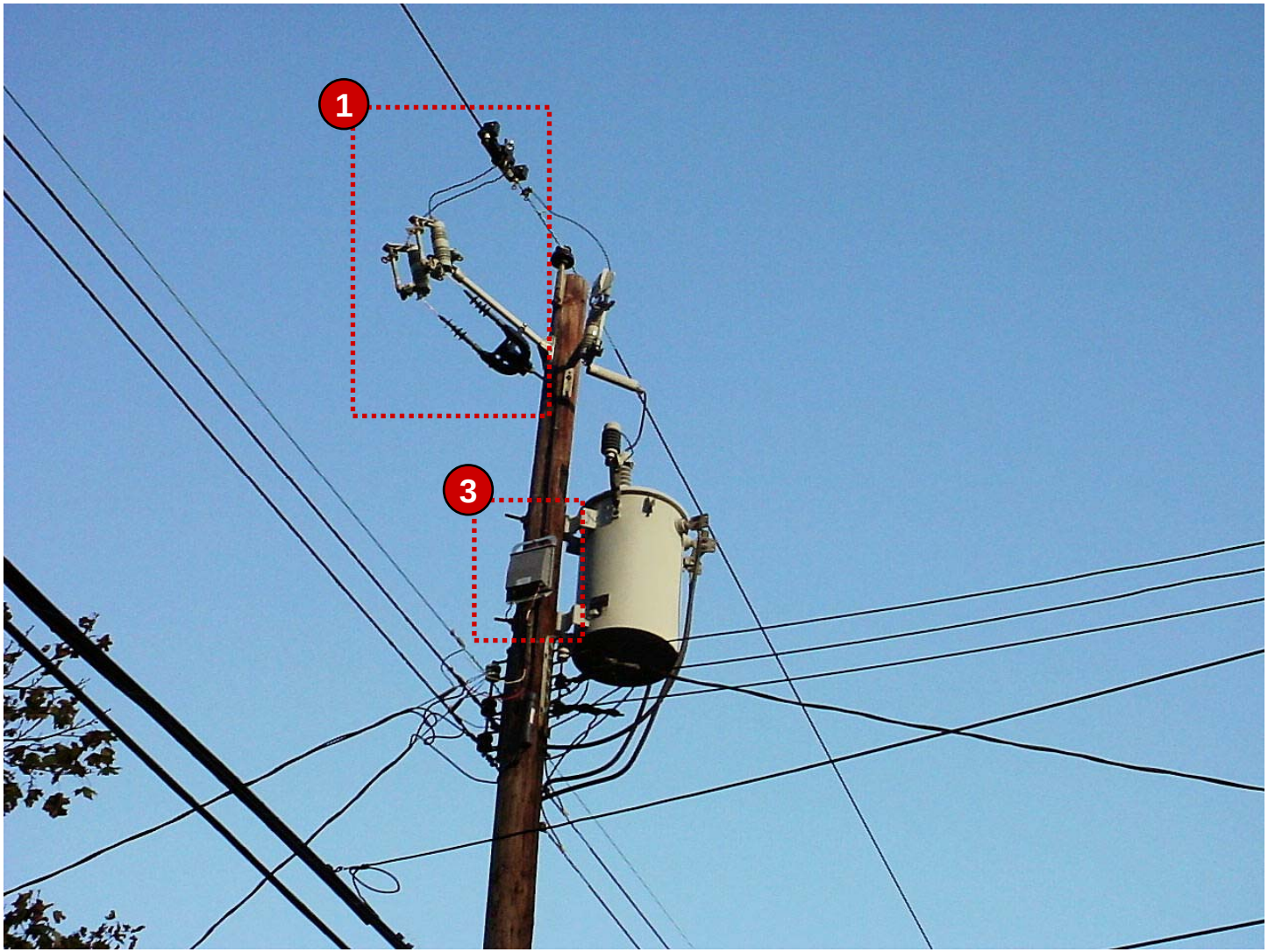
- Allows data signals to travel to CT Bridge ® and CT Backhaul Point ™, but blocks medium voltage from passing
- Separated from medium-voltage signals by utility-approved cutout fuses and URD
- Bypasses transformer to ensure optimal signal strength

Overhead Coupler Choke



- Only component that physically touches the medium-voltage line
- Designed to be installed quickly and simply by utility linemen
- Both the coupler choke and the assembly have a useful product life of 10+ years

Overhead Installation / MV and LV lines



What About Interference?

- Some parties have expressed concern over potential interference to licensed radio users
  - Amateur radio operators most vocal opponents

- BPL power limits set by FCC Part 15 limits
  - Limits same as millions of other devices
  - Verification must be done *in situ*
  - Limits extremely low – nanowatts of radiated power
  - Any resultant interference must be resolved by BPL operator

- Current's Approach to Interference
  - Avoidance is most effective mitigation technique
  - Only one device on a link transmits at a time
  - No overlap with amateur, broadcast, satellite frequencies
  - Largest BPL deployment in North America
  - No interference complaints

Cincinnati Commercial Offering

- Joint venture between Current Communications and Cinergy

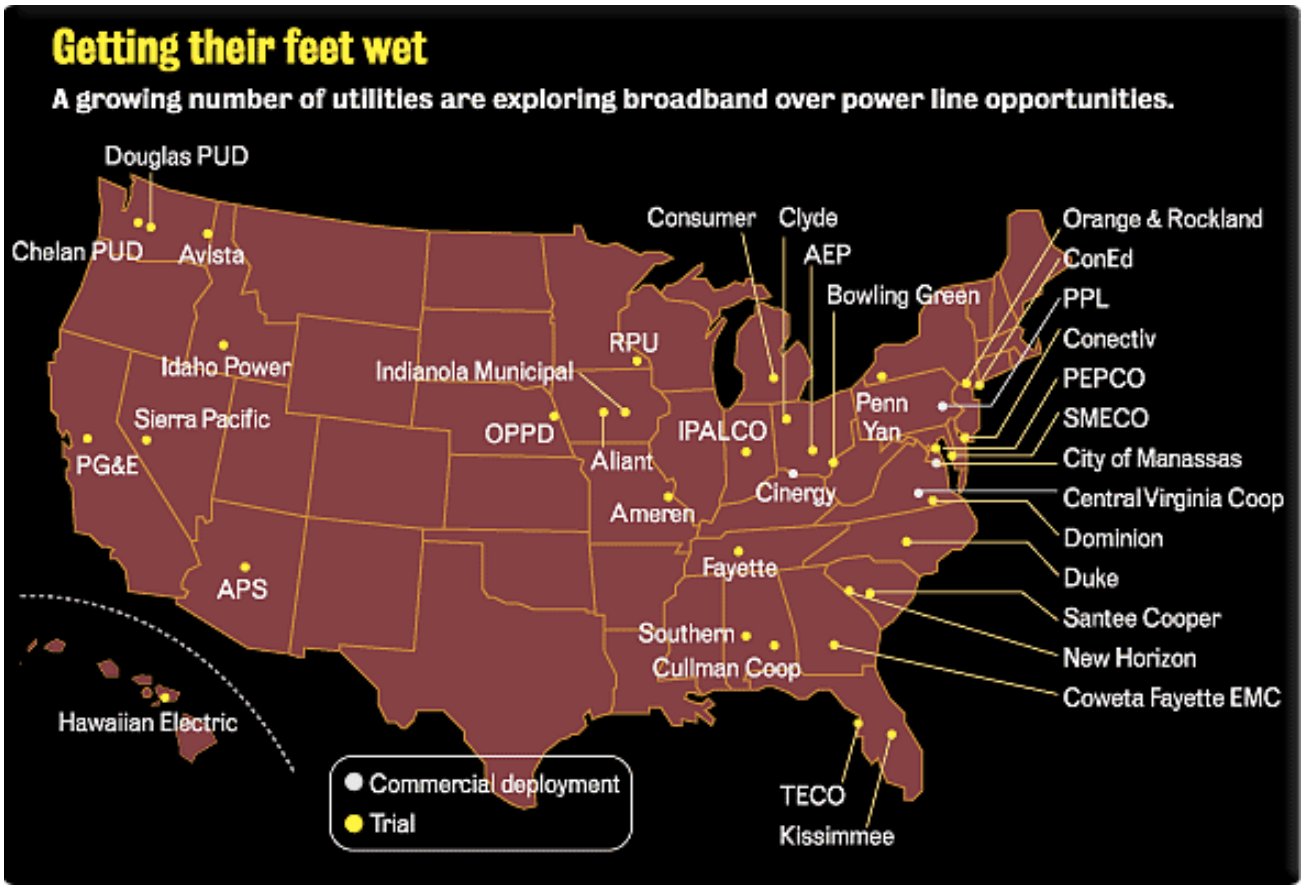
- Offer includes 5 e-mail addresses, personal web site, etc.
- More information at www.current.net

Product	Maximum Speed	Monthly Price
Current™ Quick Access	1 Mbps	$29.95
Current™ Power Access	2 Mbps	$34.95
Current™ Premier Access	3 Mbps	$39.95
Current™ Home Office	3 Mbps	$49.95

Current Communications.htm

Status of BPL Industry

- 2 Commercial US Deployments
  - Cincinnati – Cinergy & Current Communications – Current Technologies
  - Manassas, VA – Municipal utility – Equipment from Main-Net

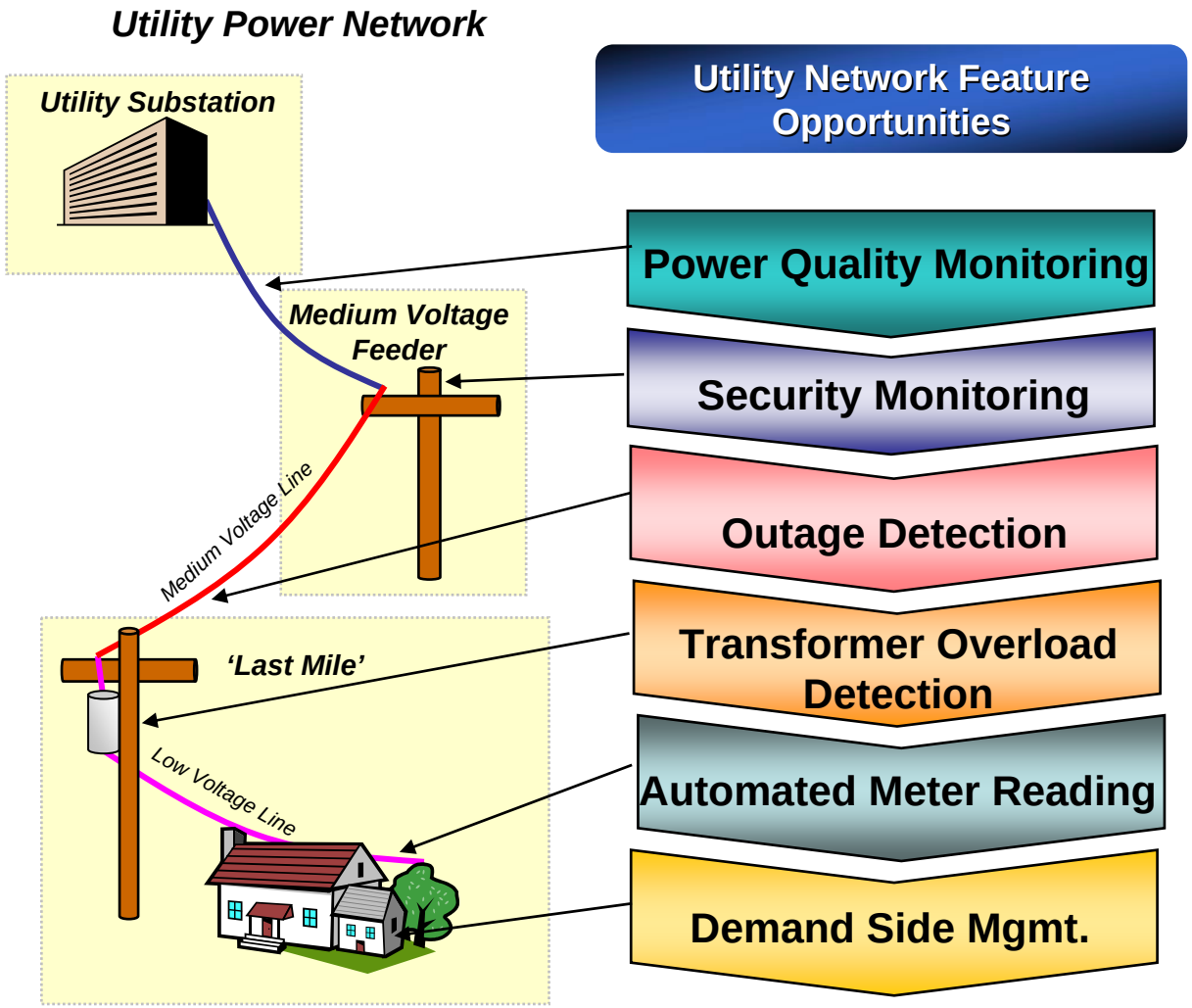


30+ trial deployments in US

Commercial deployments in Germany, Spain, Korea, Chile, Brazil,

Image: Network World, 23 Aug 2004

Current's Edge Software within the BPL network can also serve as platform to provide differentiated services for service provider or utility company



Big Questions for BPL Industry

- **Technical**
  - Verify scale - Technology works effectively, it now needs to demonstrate large scale operation
- **Non-technical**
  - Business Models - Industry business models need to be verified and shown to work in actual commercial deployment
  - Regulatory – BPL industry needs to show that regulatory issues can be handled similar to other industries (cross-subsidization, etc.)

Q&A

Questions?