An introduction to Broadband Powerline (BPL) Technology

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DS2 – VP Technology & Strategic Partnerships

IEEE ComSoc Meeting
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Agenda

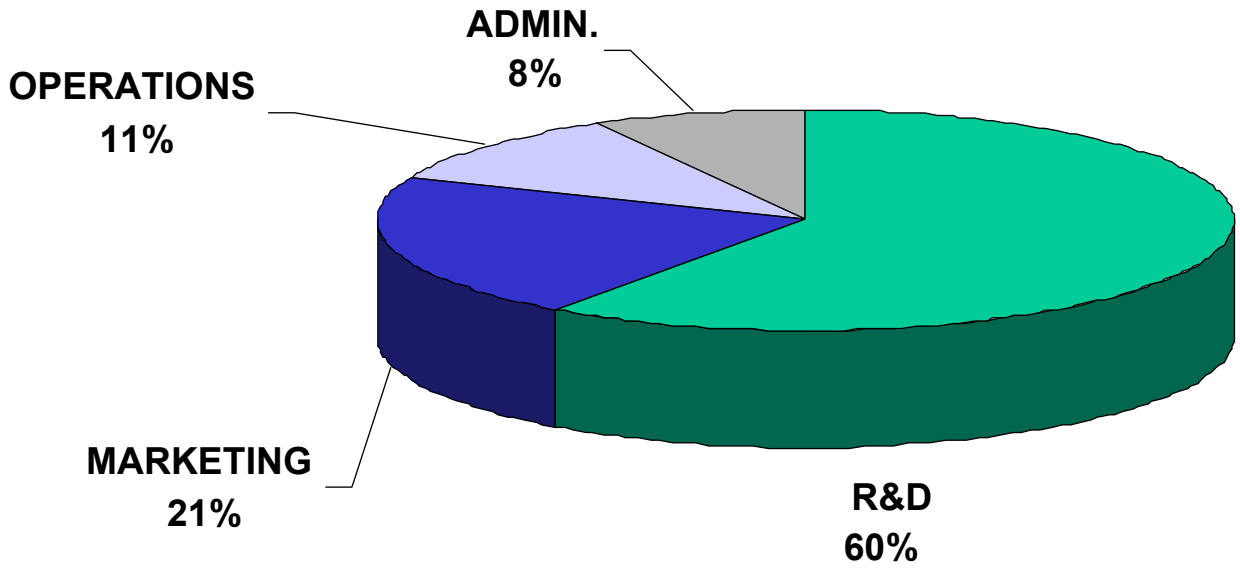
- About DS2
- Applications of BPL
  - (why is this technology useful?)
- Technical description of BPL
  - (how does this technology work?)
- Standardization of BPL

About DS2

- Founded in 1998/Feb/15th
- Fab-less silicon design house
- Mission:
  - To become the leading supplier of IPR (silicon and software) for high speed Broadband Powerline Technology (BPL).
- Shareholders
  - 78 % Local Private Investors
  - 15 % Endesa
  - 5 % Employees
  - 2 % Itochu Corp

DS2 Profile

- DS2 staff is 110 people, 60% focused on R&D tasks



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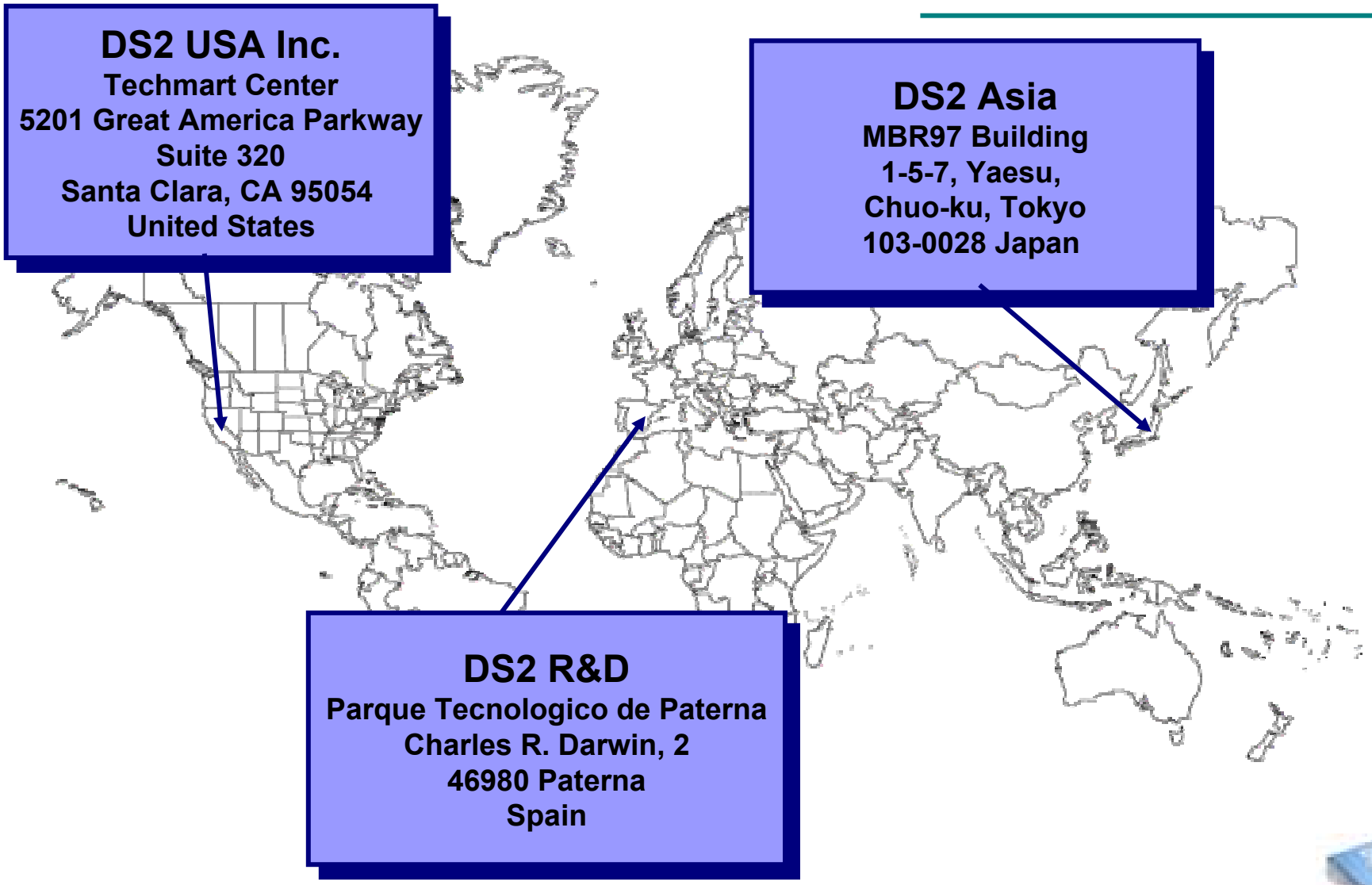
DS2 worldwide



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Using Powerlines as an Access Network (BPL)

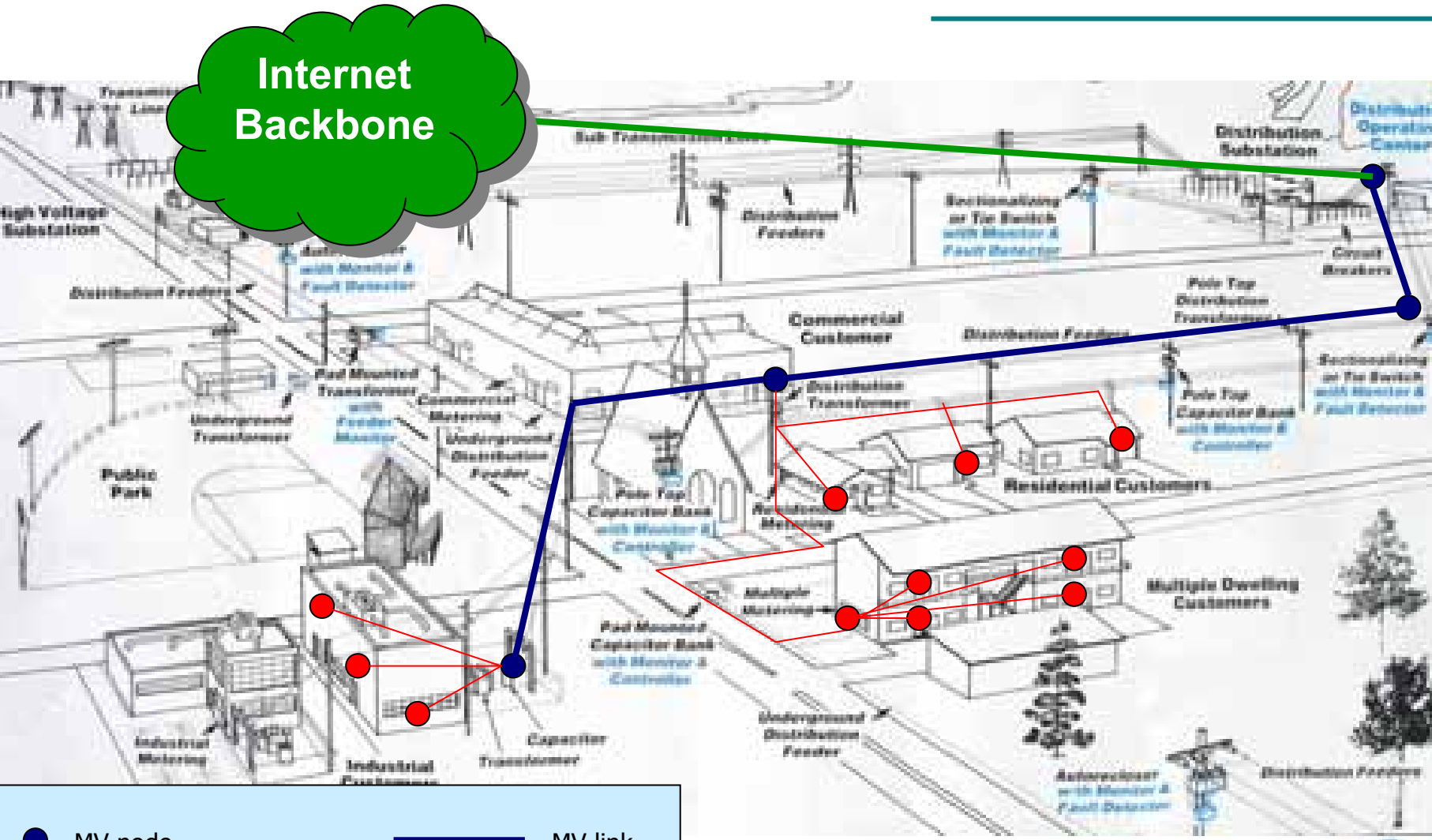
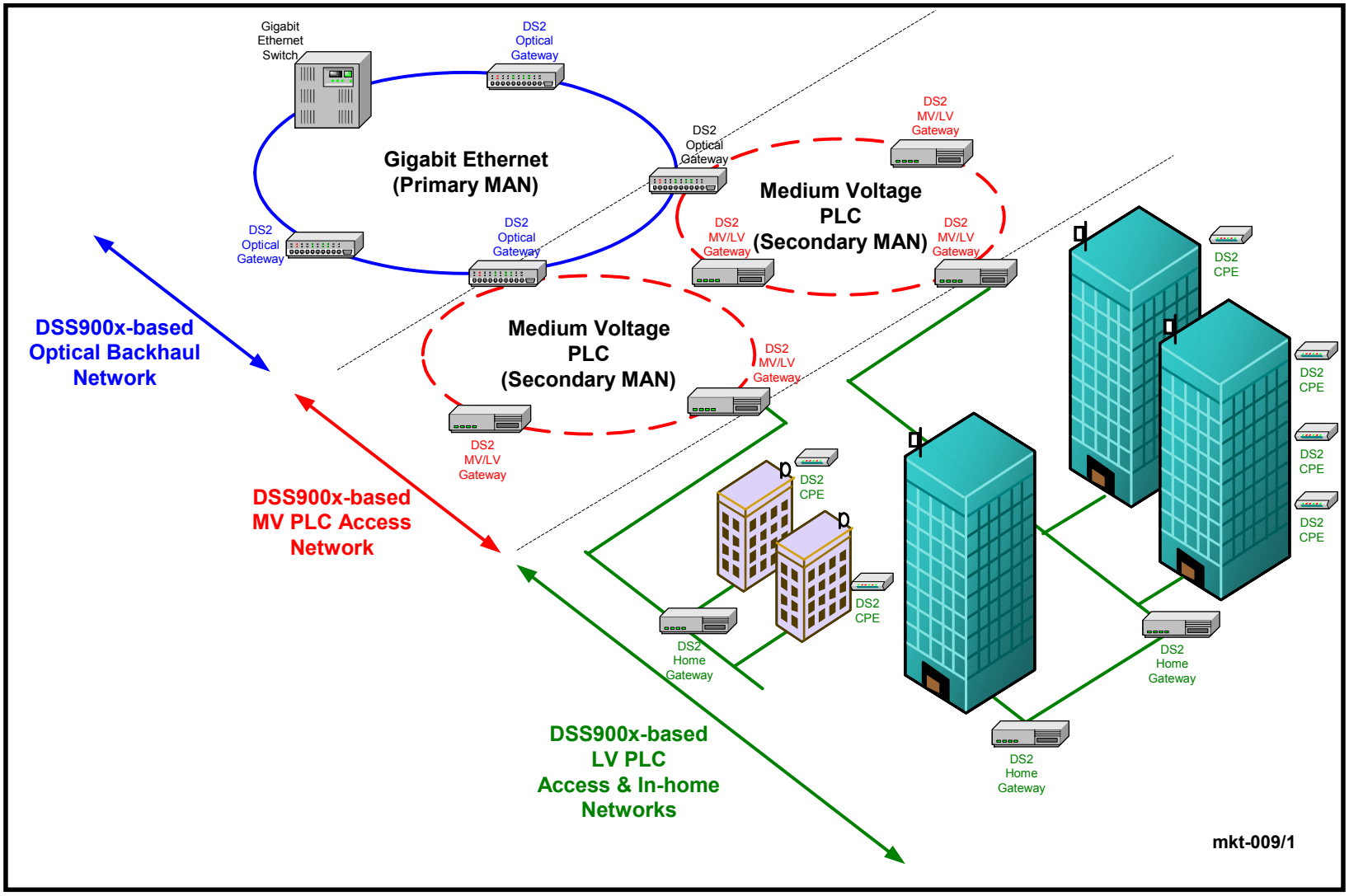


Image Source: Southern California Edison

3-level architecture



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Applications of BPL Access

- User-side applications:
  - Broadband Internet Access
  - Telephony
- Utility-side applications
  - Remote control of transformers/substations
  - Remote meter reading
  - Remote connection/disconnection of customers
  - Supply quality monitoring
  - Theft detection
  - Homeland security (Video surveillance, Sensor networks, etc)

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Target markets

- For user-side applications
  - Rural/underserved areas in developed countries
  - Developing countries (Mexico, China, India, etc)
    - Large percentage (99%) of users have access to electricity but a very small fraction of them (10%-20%) have access to telecom infrastructure (even plain telephone service)
- For utility-side applications
  - Every country where the Power company can benefit from automating the grid

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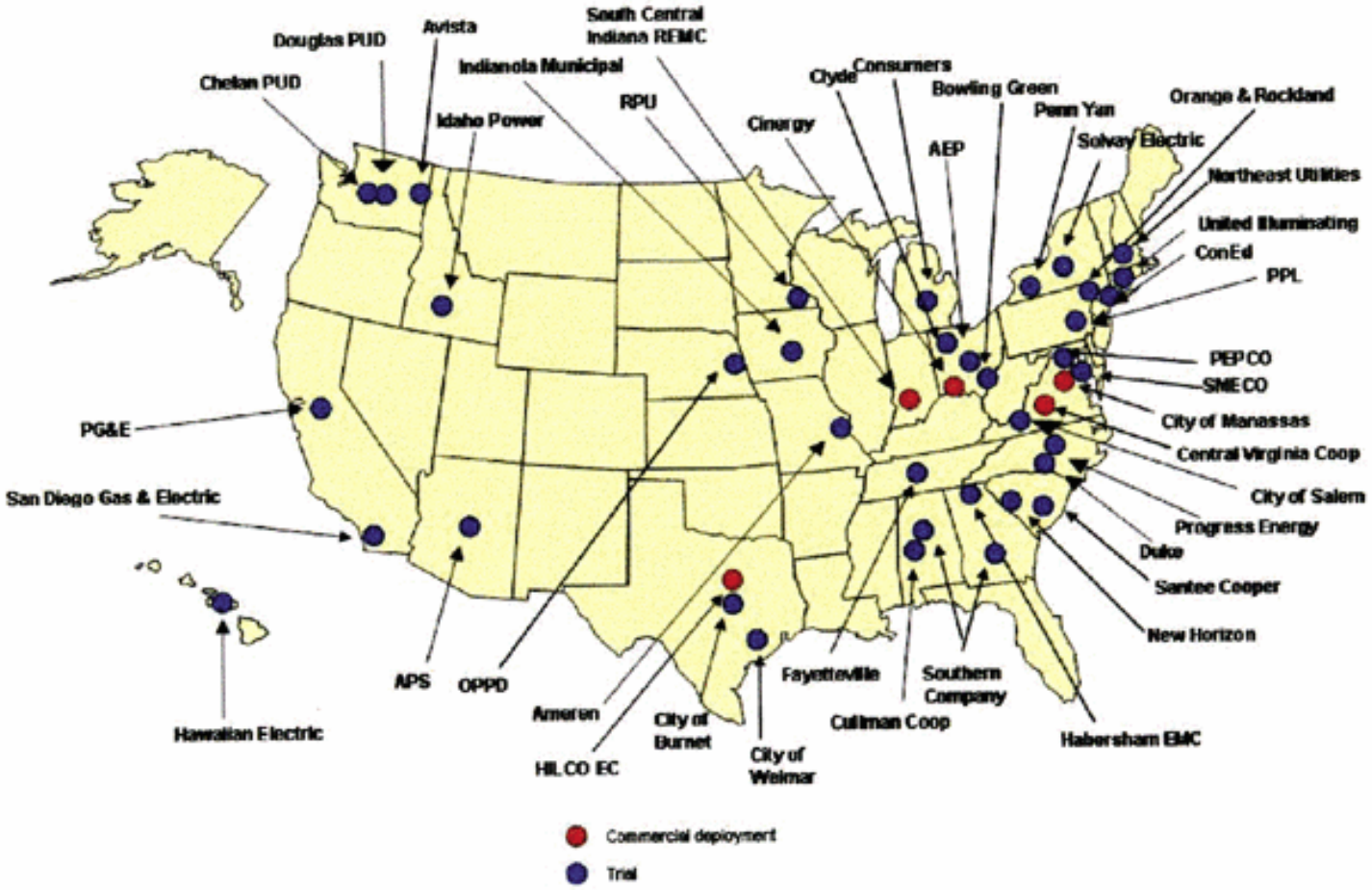
BPL deployments in North America



Source: Jerry Ramie, ARC Technical Resources, Inc, http://www.conformity.com/0508/0508review.html

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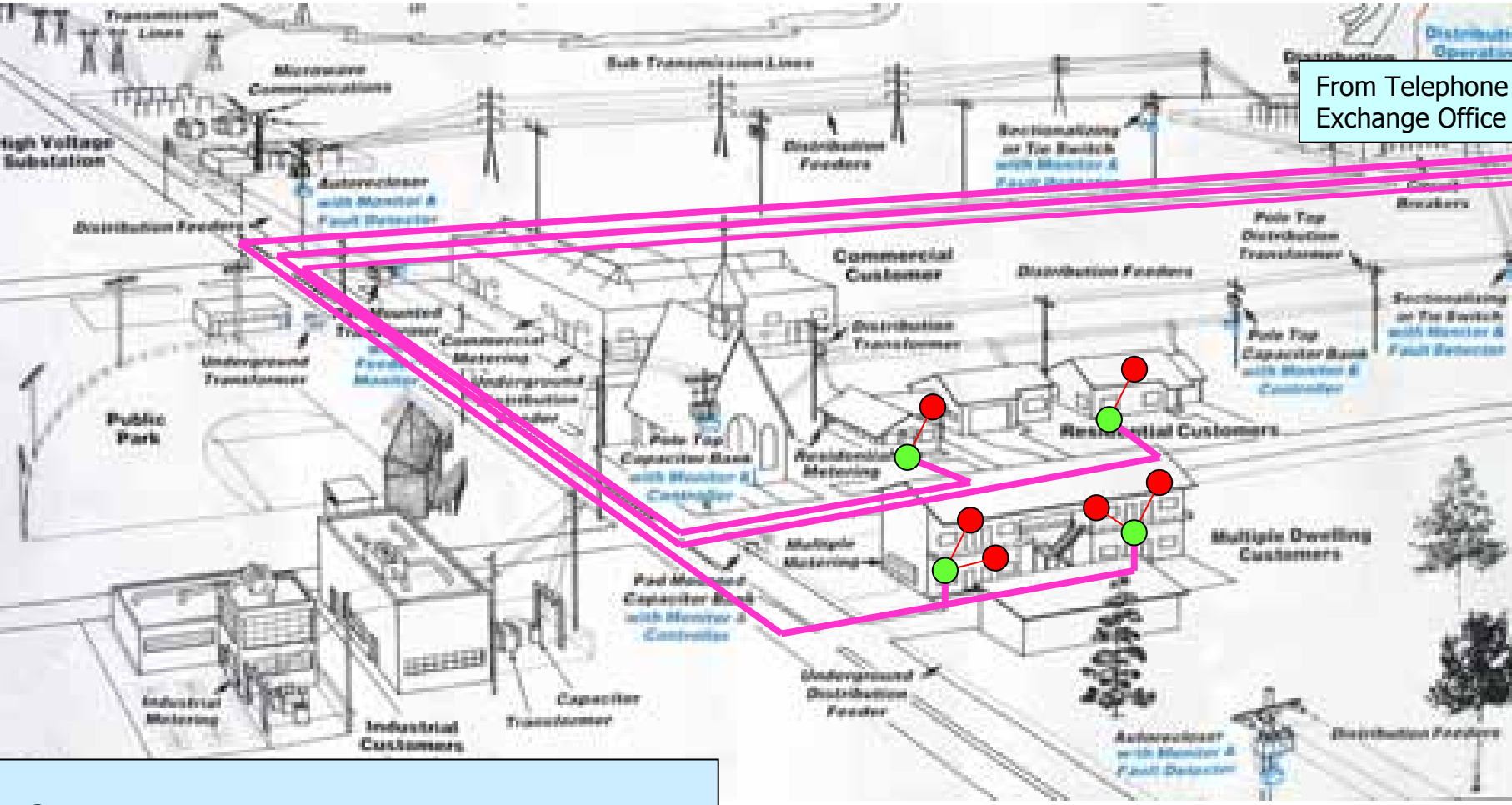
Using Powerlines for In-home Audio/Video (AV) distribution



xDSL-to-PLC gateway

PLC AV end-node

DSL line

PLC link

Image Source: Southern California Edison

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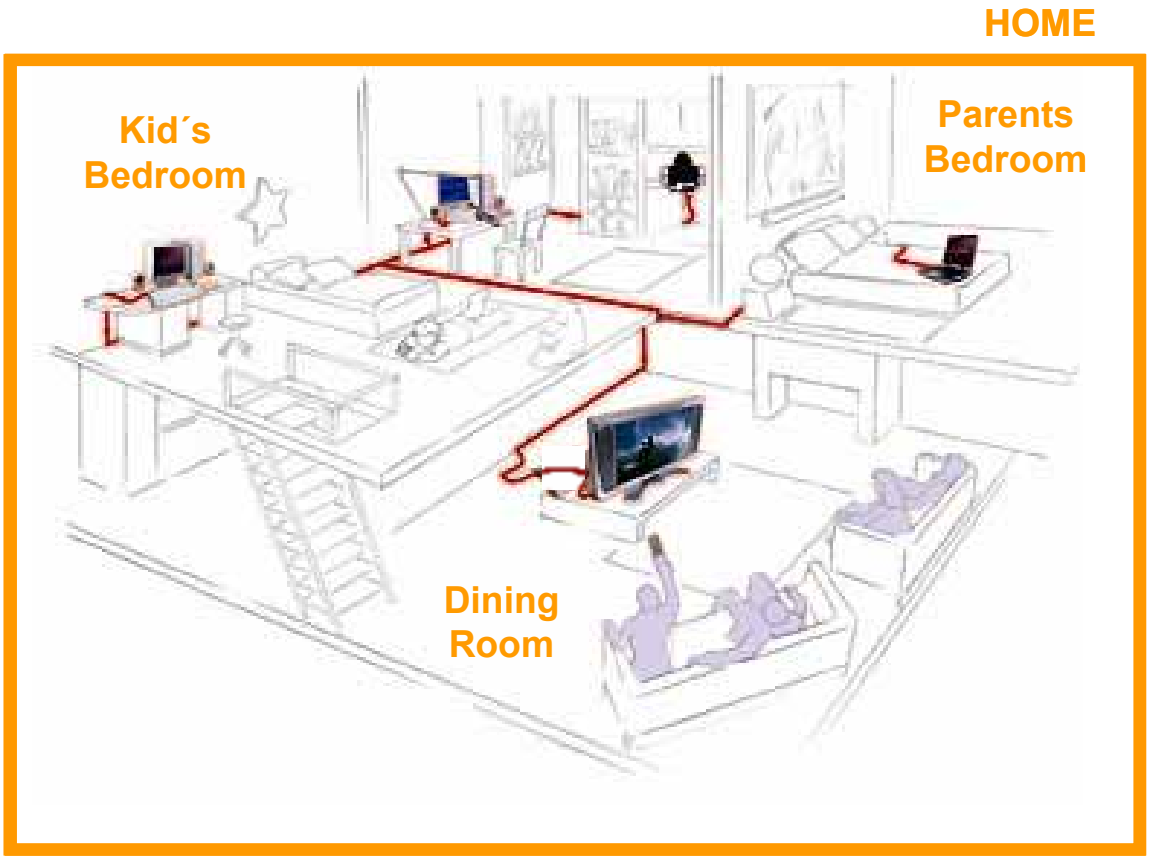
As broadband penetration increases…

- …more and more members of the family want to share the broadband connection, for different applications, from different parts of the home.



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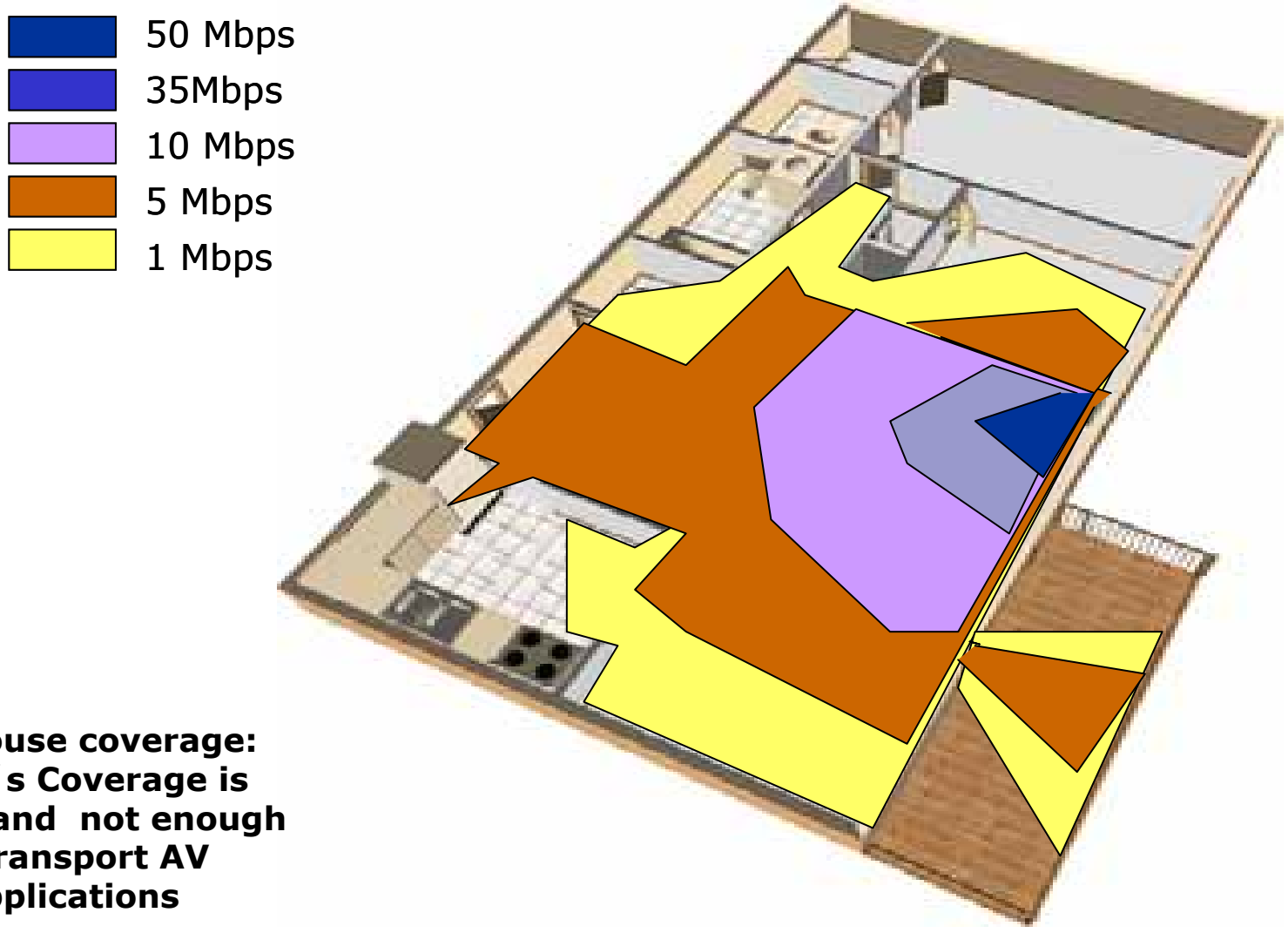
But WiFi is not suitable for some of the new Audio/Video applications



Full house coverage: WIFI´s Coverage is limited and not enough to transport AV applications

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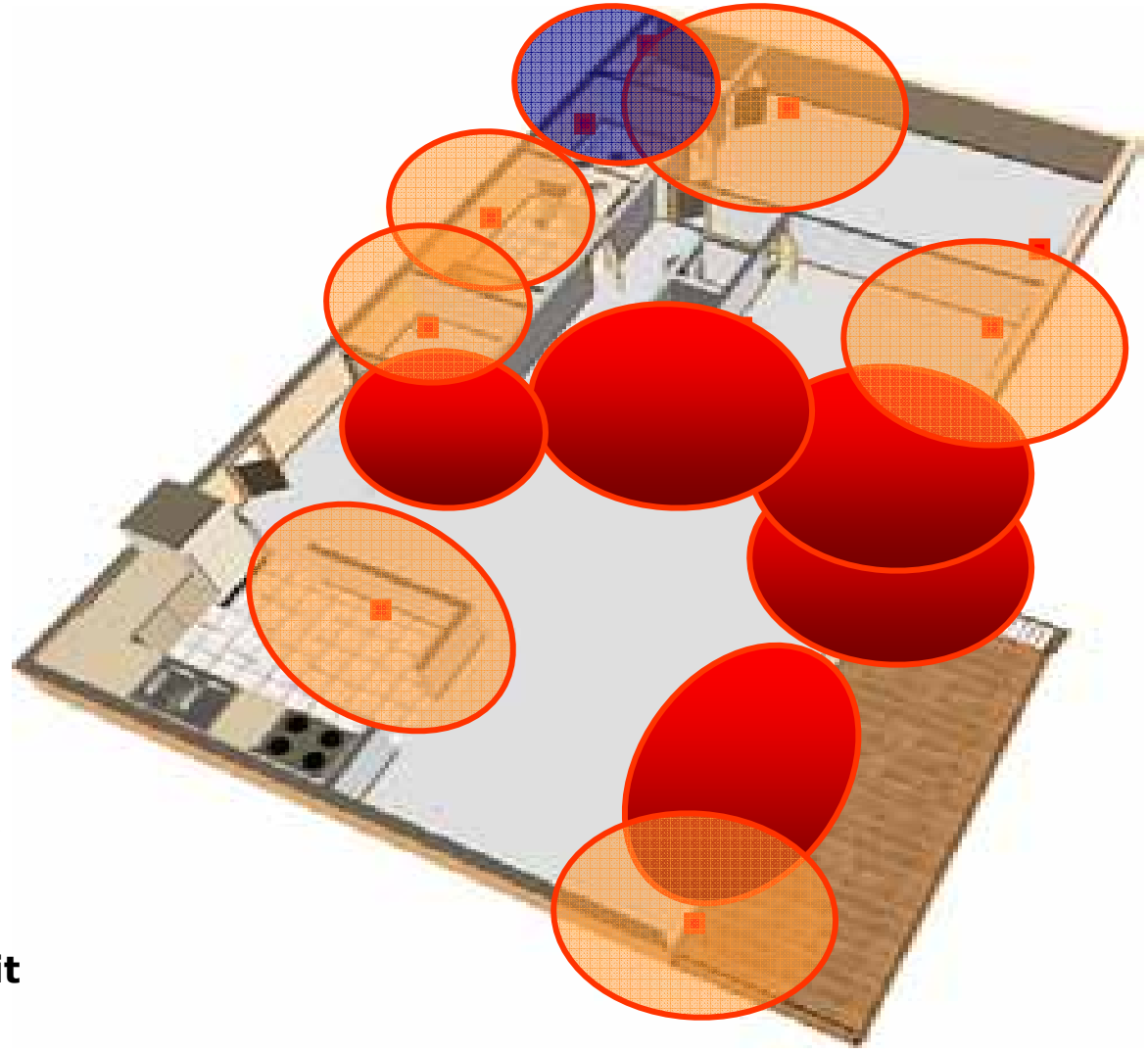
Using powerline technology for AV applications

200 Mbps
100 Mbps
50 Mbps
25 Mbps



Powerline technology provides speed in excess of 100 Mbps where you most need it

In-home AV distribution

- Sharing of DSL/cable connection
  - Higher speed, more secure and more stable than Wireless technology
- Home-networking
  - Sharing of peripherals: printers, scanners, network storage, etc.
- Advanced security applications
  - High-definition Video surveillance
- Distribution of IPTV service to every room
  - Powerline technology is currently the only available technology for this application

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Using powerline technology for MDUs

- Installing new wires in a large building is very costly, disturbing to tenants and sometimes plain impossible.
- Wireless technology is not an option (even if only basic Internet access is required) because of bad propagation through walls
- Powerline technology is a perfect solution for this market.
- Hotels, hospitals, etc can also benefit from this technology, avoiding costly installations and without annoying customers

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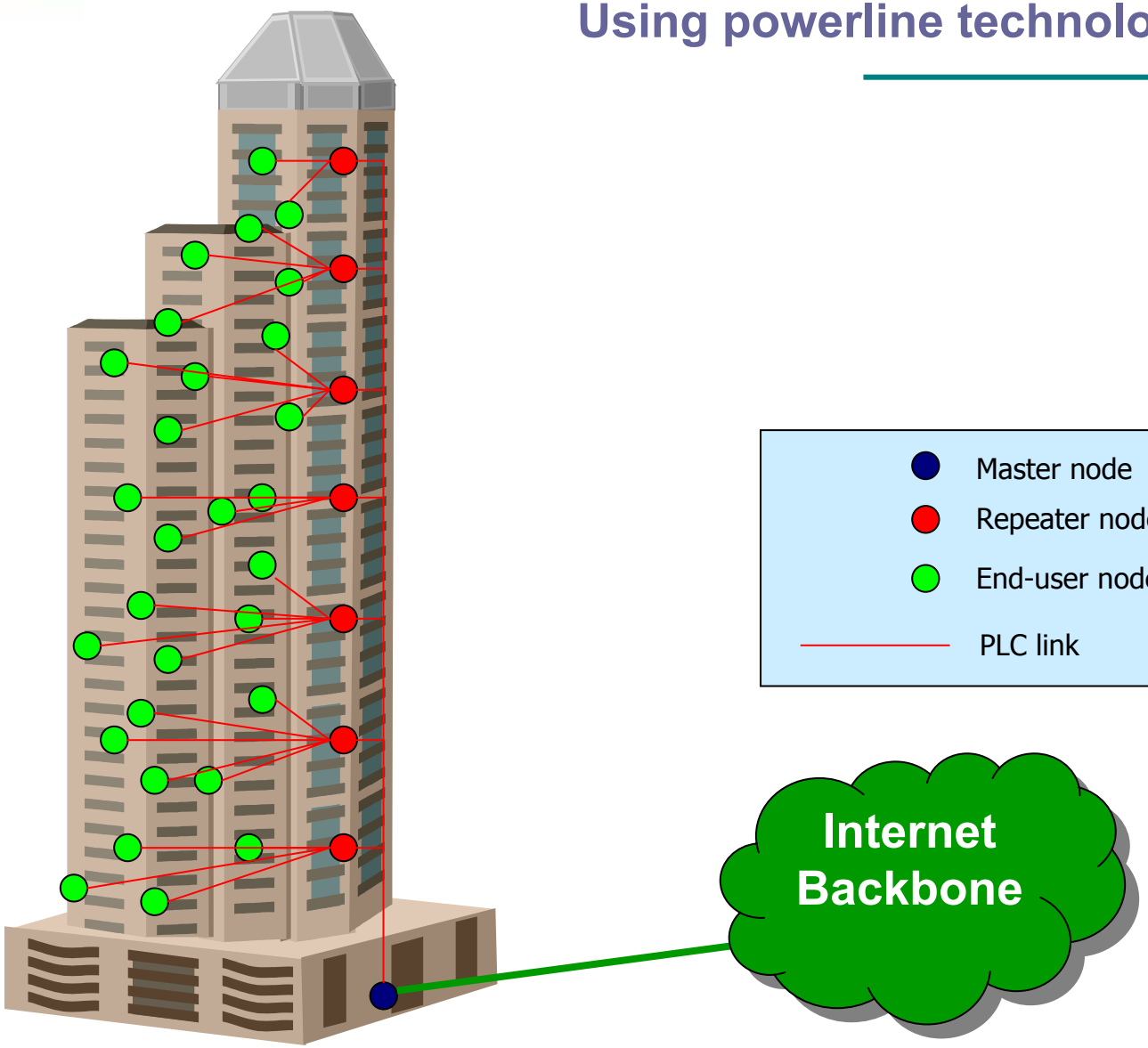
Using powerline technology in MDUs



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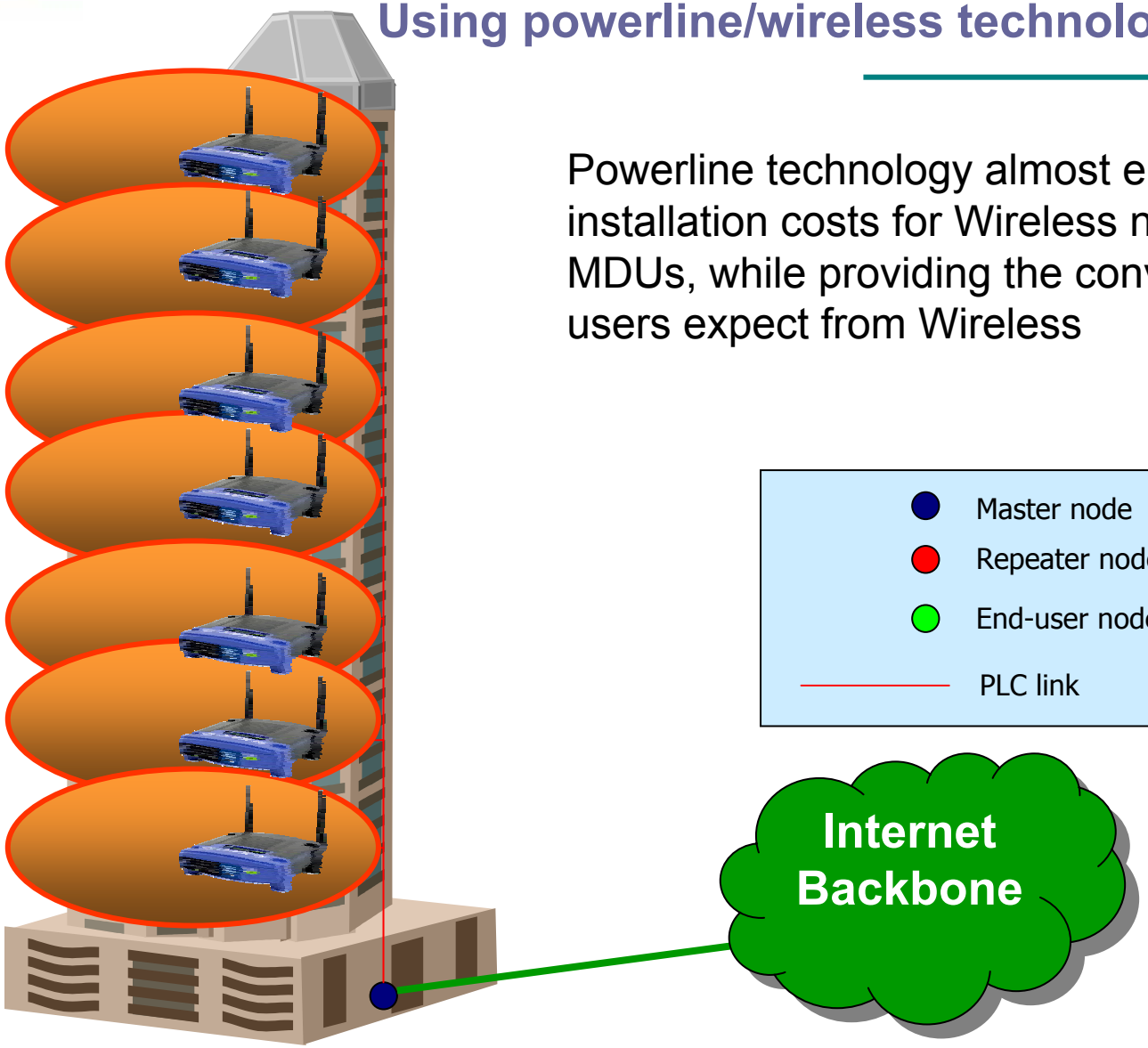
Using powerline/wireless technology in MDUs

Powerline technology almost eliminates the installation costs for Wireless networks in MDUs, while providing the convenience that users expect from Wireless



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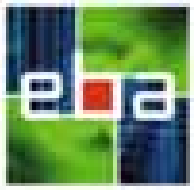
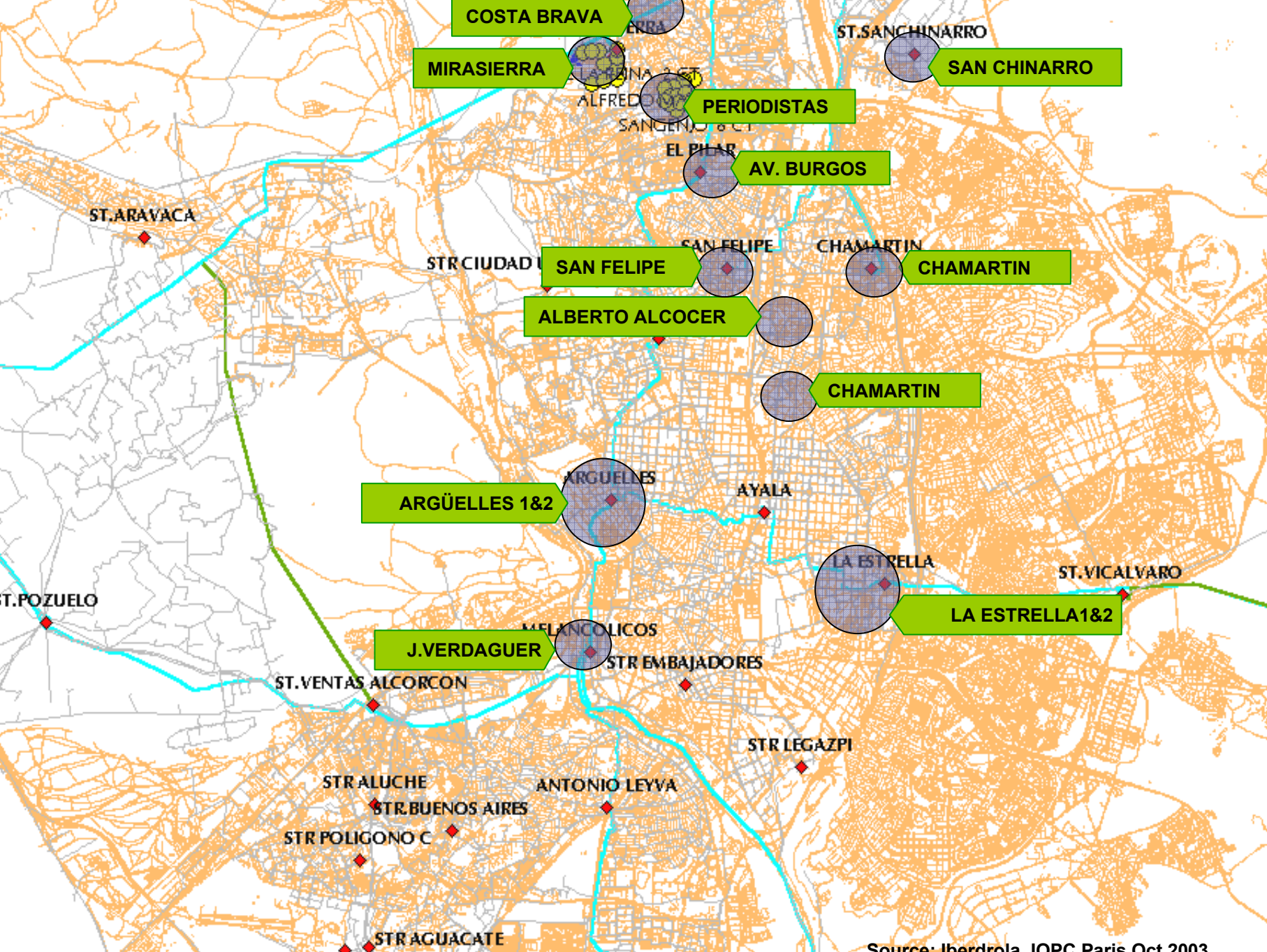
Equipment vendors



A successful case (Iberdrola)

- Iberdrola:
  - 17.4 M customers in Spain
  - 10314 M€ revenue during 2004
- During 2004, Iberdrola moved from a small trial (100 customers) to a full-scale commercial deployment (tens of thousands of paying customers) in two cities in Spain (Madrid and Valencia).

PLC IBERDROLA
¿Qué es PLC Iberdrola?
Cómo funciona
Disponibilidad
Comparativa
Precio
Cómo contratar
INTERNET A LA VELOCIDAD DE LA LUZ
IBERDROLA
Queremos ser tu energía
© IBERDROLA, S.A. RESERVADOS TODOS LOS DERECHOS. INFORMACIÓN LEGAL / SEGURIDAD



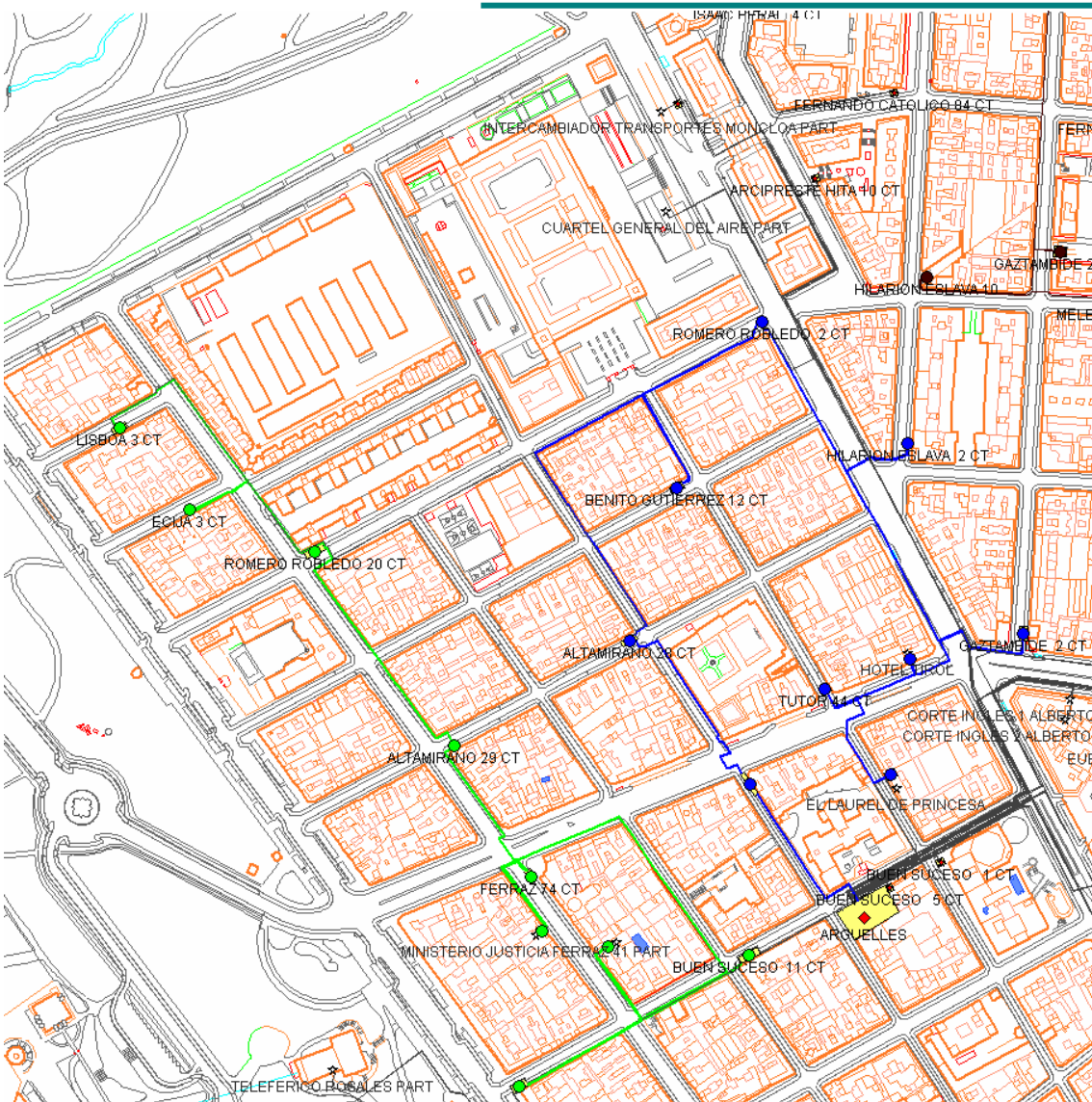
Source: Iberdrola, IOPC Paris Oct 2003

A detailed look to a BPL network (Medium Voltage)

- HV / MV Substation
- MV / LV Transformer
- Underground MV line

A large neighbourhood comprising thousands of “electricity” customers can be connected to the internet in a matter of days, just by installing BPL equipment in some key locations.

No civil works are required (no expensive digging of streets, no licenses needed, etc)



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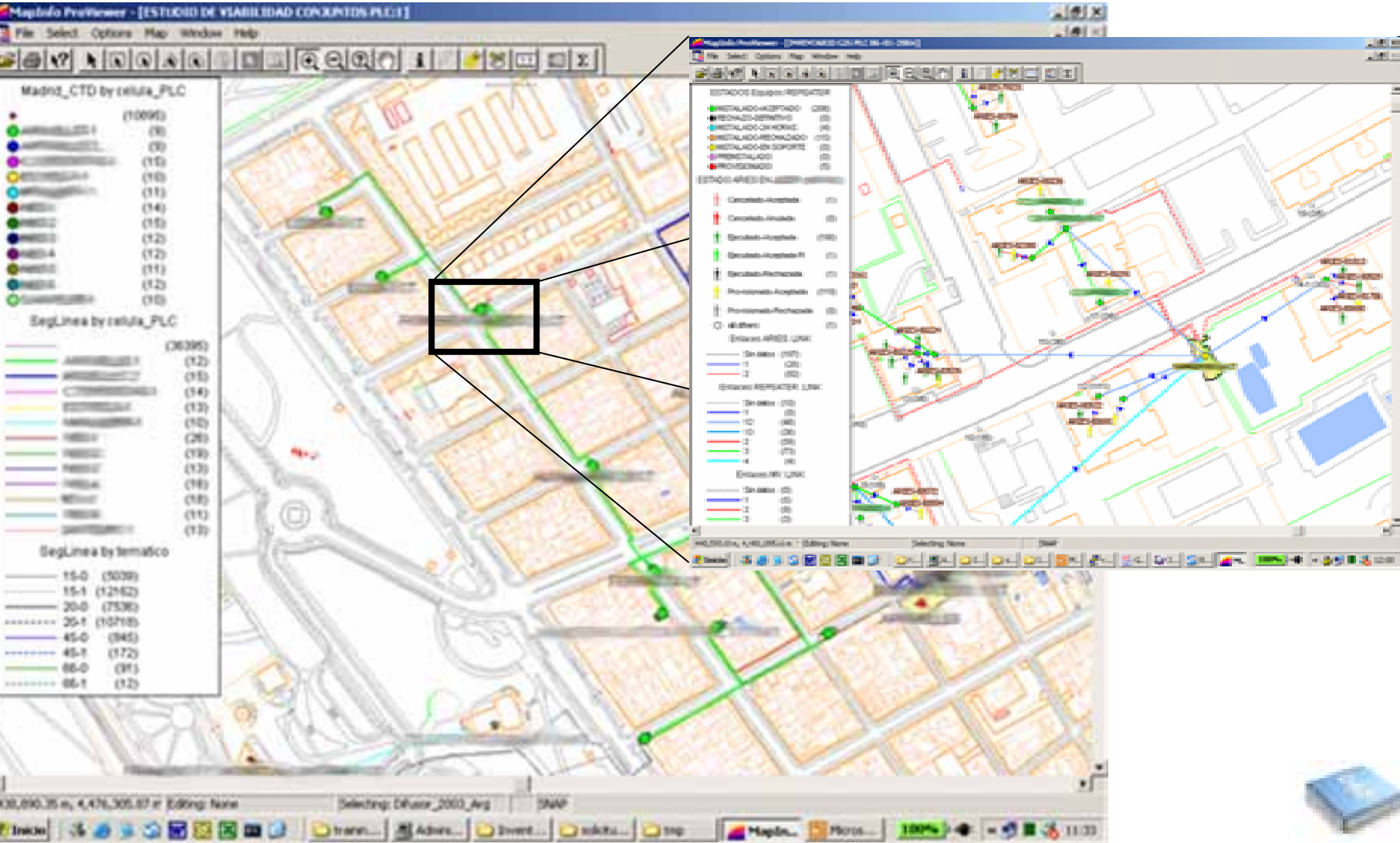
A detailed look to a BPL network (Low Voltage)



A successful case: Telefonica's IPTV deployment

- Telefonica:
  - Incumbent Telecom operator in Spain (and Brazil, Argentina, Chile & Peru)
  - 122 M customers worldwide
  - Telefonica decided to start offering IMAGENIO (IPTV services using ADSL2+ technology) as a way to increase the revenue per customer and to better compete with cable operators.

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A successful case: Telefonica's IPTV deployment

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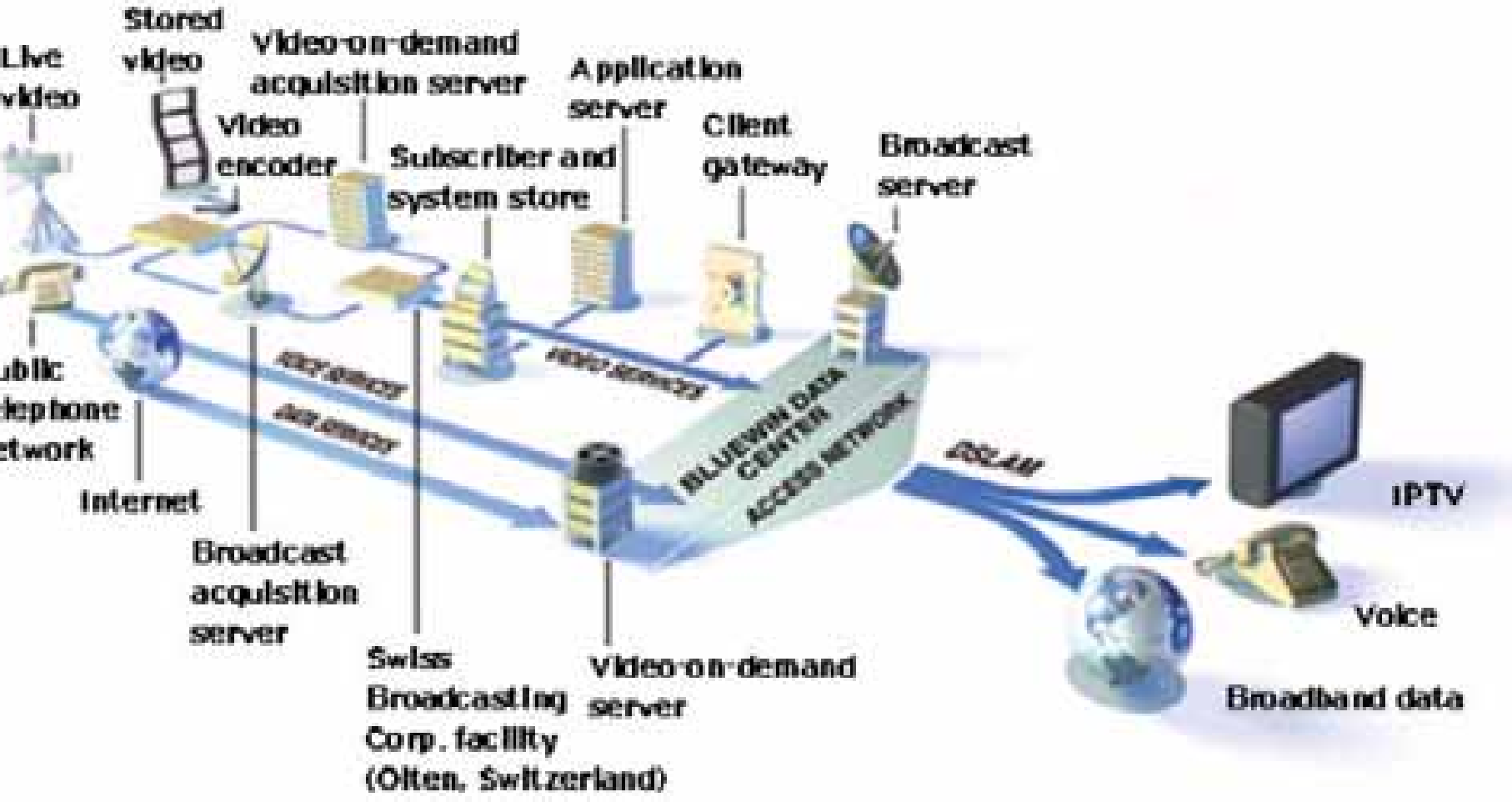
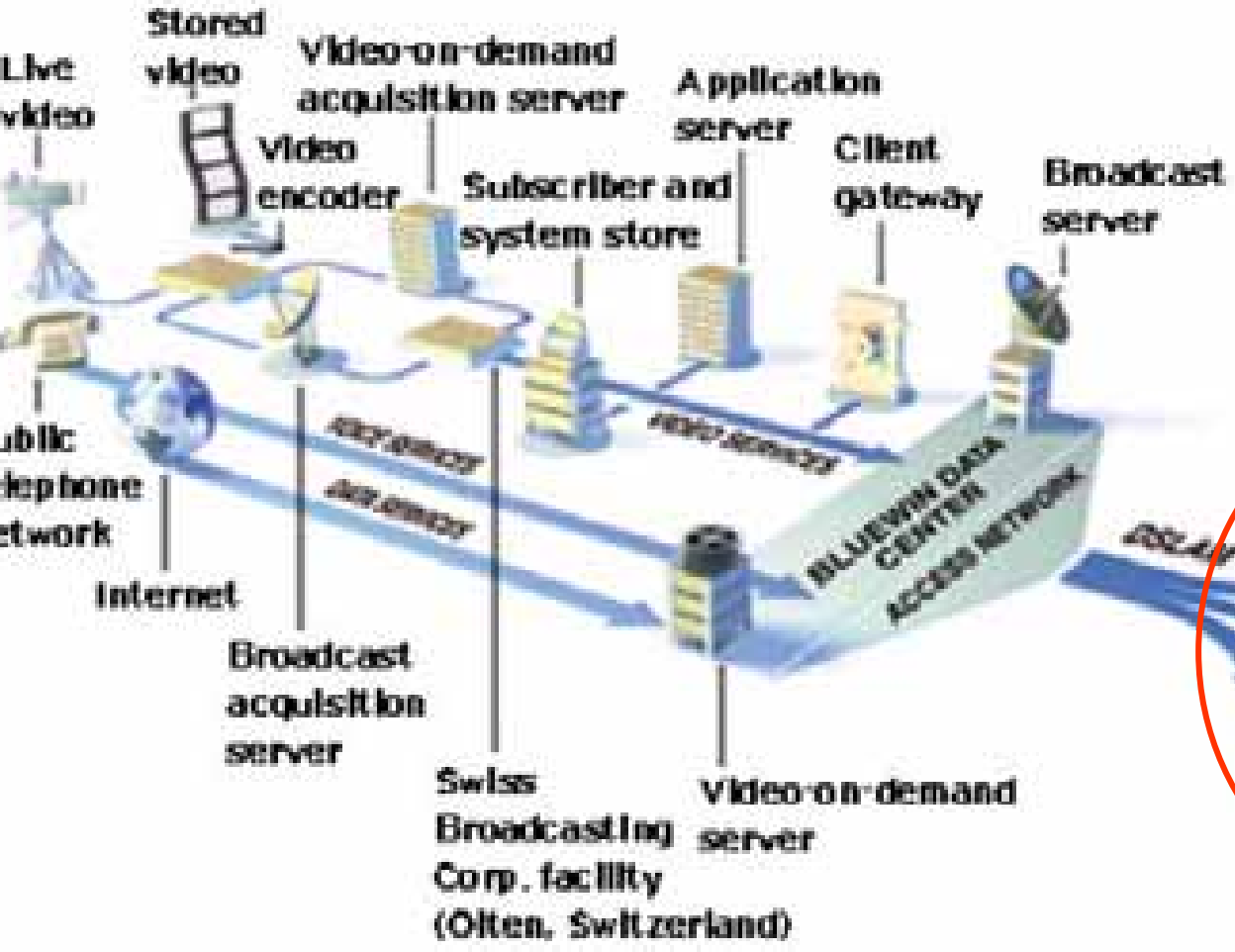
Generic Triple-Play services network



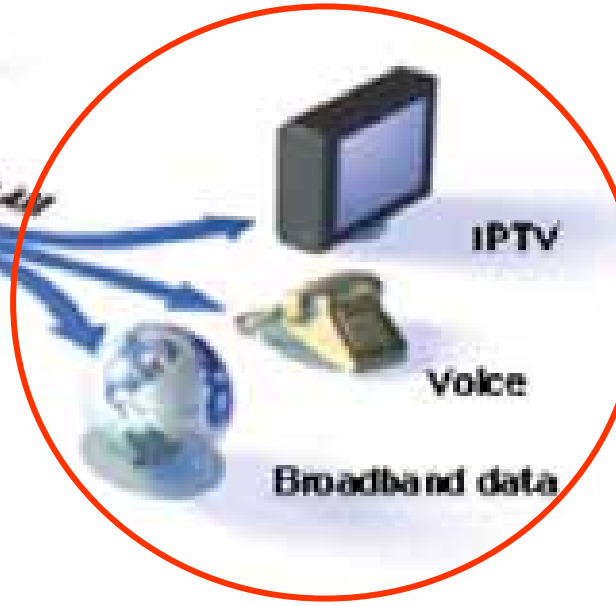
A successful case: Telefonica's IPTV deployment

- Problems:
  - What happens when your DSL router is in one room and your IPTV STB is in a different room?
  - A connection between both devices is required, but **customers "hate" installation of new wires** in their home.
  - After several trials with several alternative technologies, Telefonica realized that Wireless technology (IEEE 802.11) was not a feasible solution (lack of QoS, bad coverage in houses with brick walls)

Generic Triple-Play services network



How do we bring these services to the exact place in the home **where the customer wants them**, without costly installations



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A successful case: Telefonica's IPTV deployment

Solution: Telefonica decided to provide their customers with a **200 Mbps** powerline solution:

-High bandwidth
-Whole house coverage
-Reliability
-Predictability
-Security
-Plug'n'play installation

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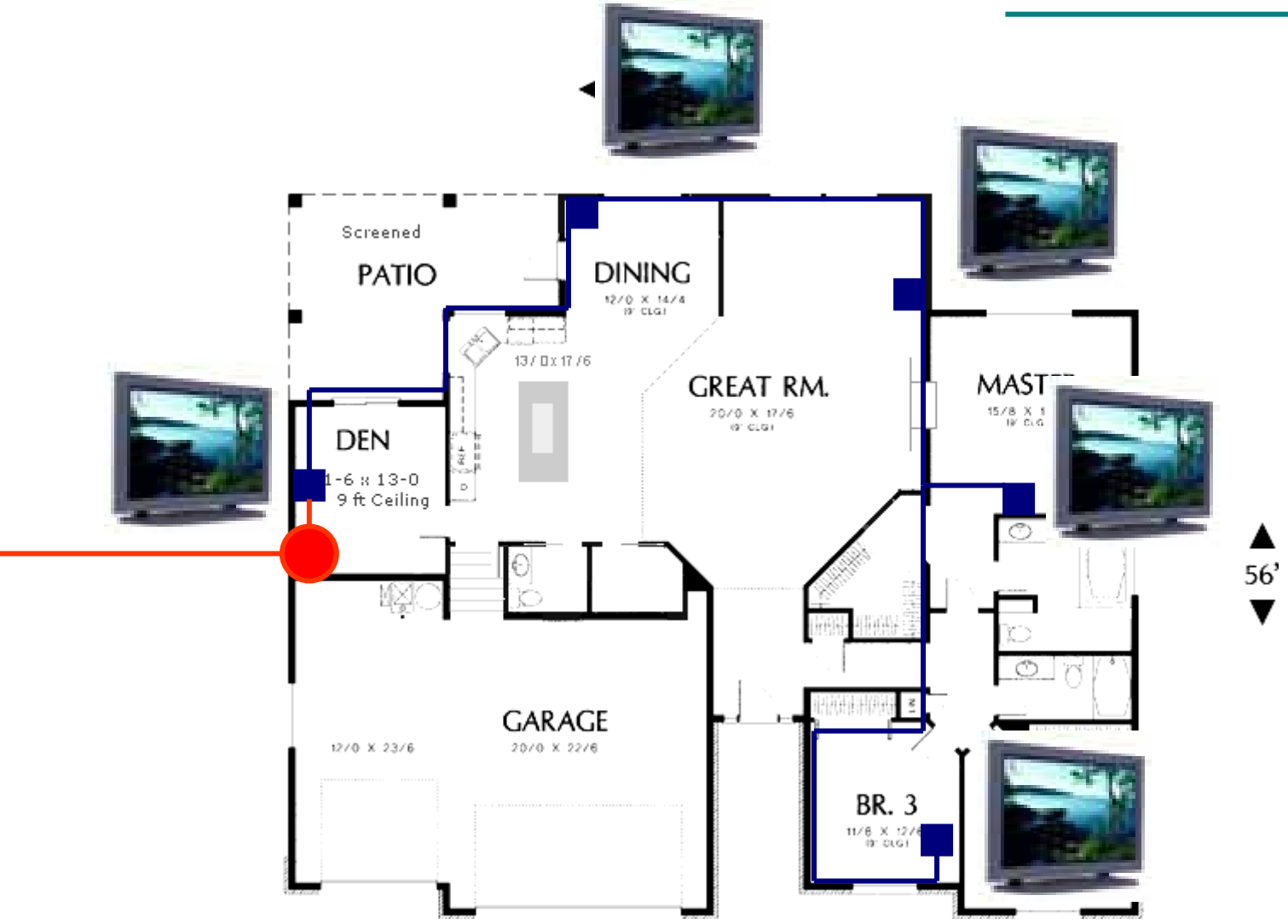
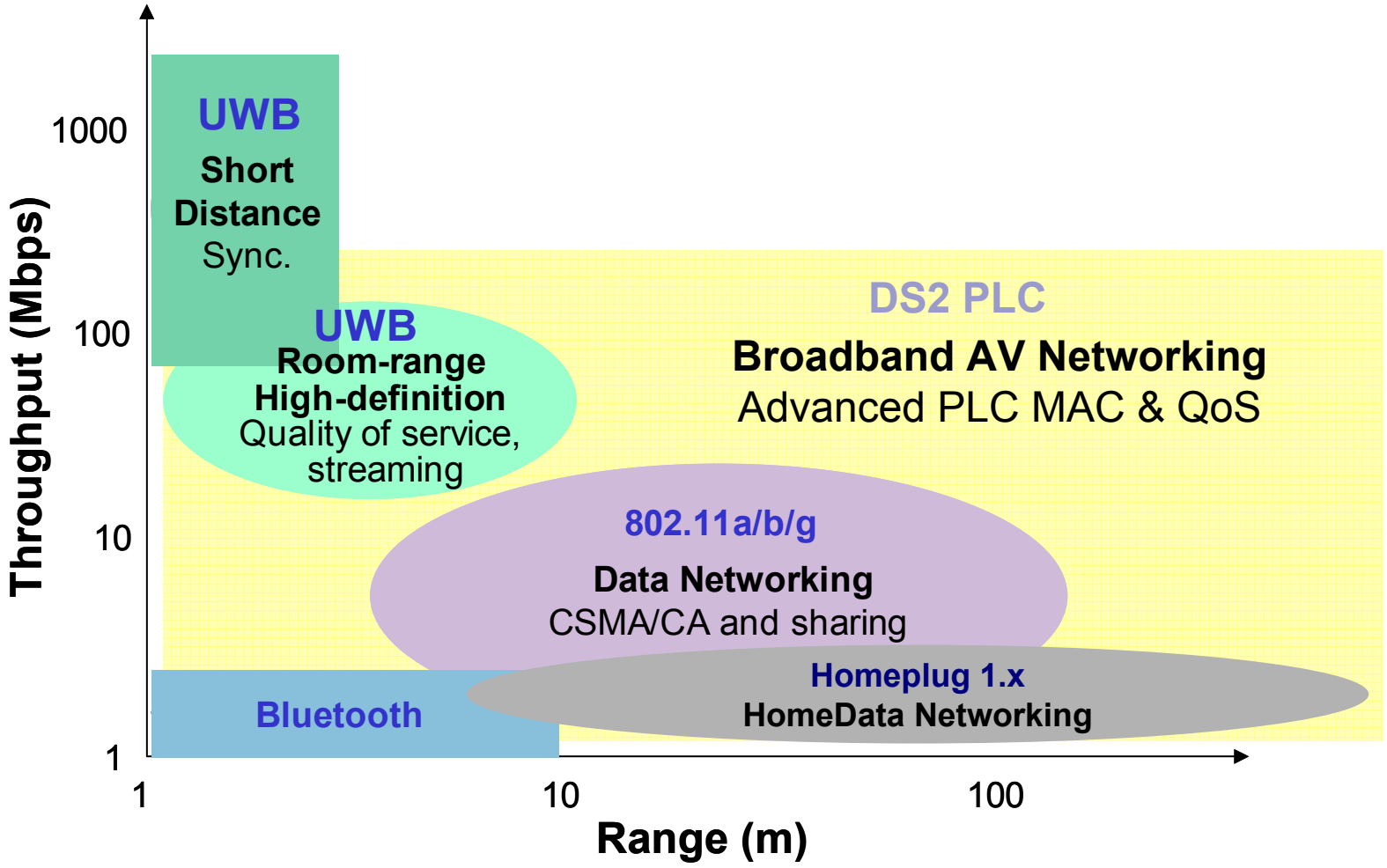
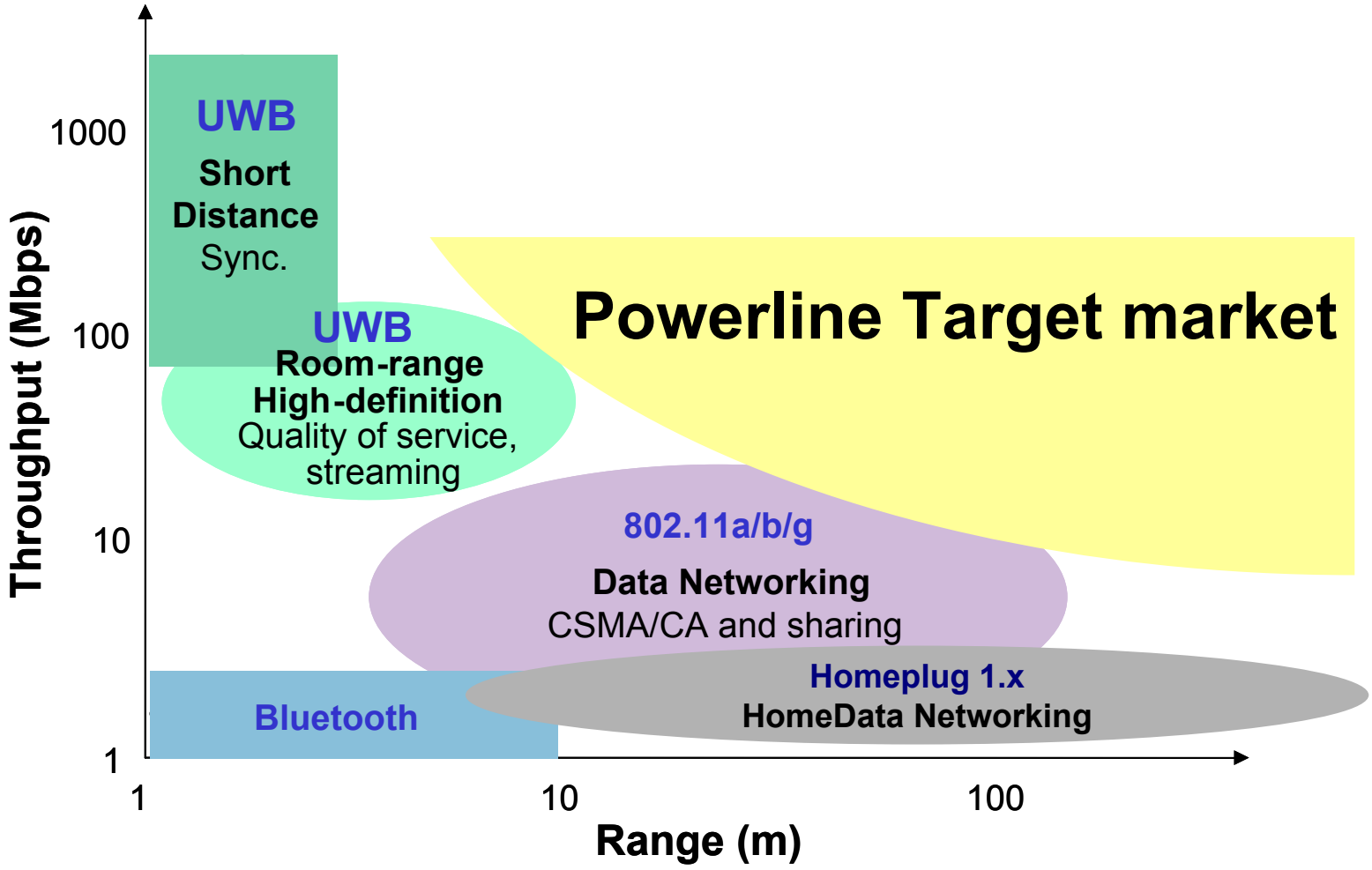

Screened
PATIO
DINING
12/0 X 14/4
9' CLG
13/0 x 17/6
GREAT RM.
20/0 X 17/6
9' CLG
MAST
15/8 X
9' CLG
DEN
1-6 x 13-0
9 ft Ceiling
GARAGE
12/0 X 23/6
20/0 X 22/6
BR. 3
11/8 X 12/
9' CLG
56'

Powerline Technology Positioning



Source: Texas Instruments - May 2004

Powerline Technology Positioning



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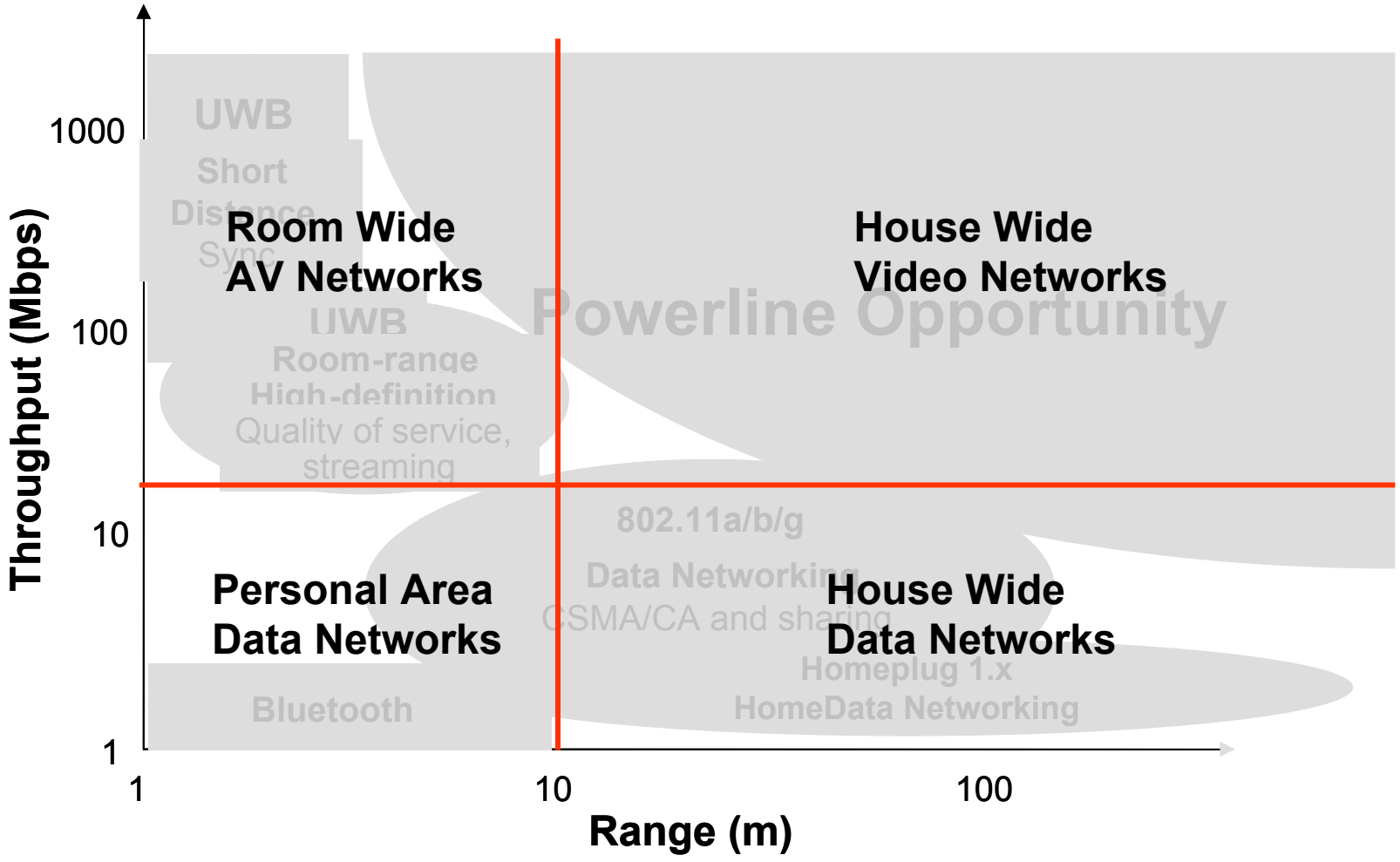
Powerline Technology Positioning



Source: Texas Instruments - May 2004

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How does BPL technology work?

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Main Technical Specification of 2nd Generation (200 Mbps) Powerline Technology

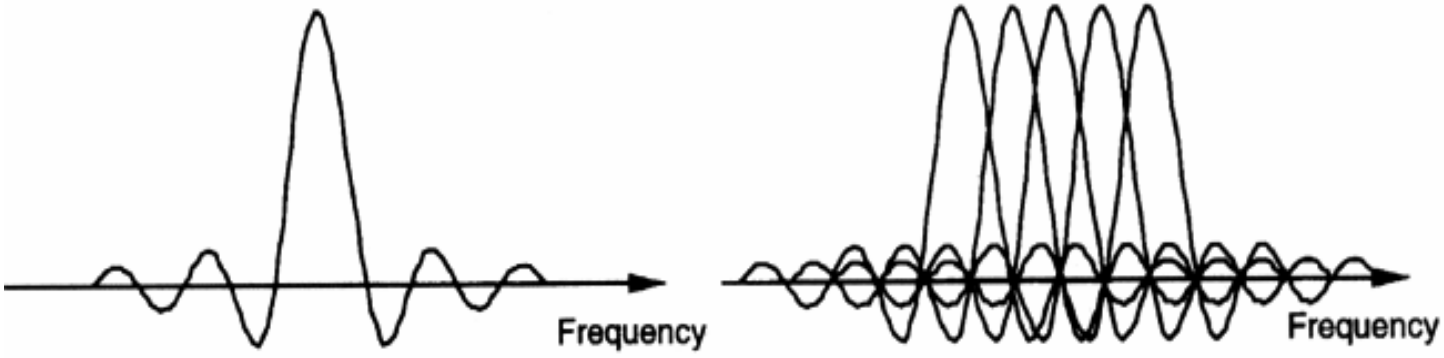
- 200 Mbps PHY maximum data rate
- >1000-carriers OFDM
- Adaptive bit-loading
- TDMA MAC
- 50%-66% protocol efficiency
- Master/Slave architecture
- Strong encryption (3DES)
- 80 to 90 dB of dynamic range (end-to-end-attenuation)
- Reed-Solomon + Trellis Code error correction
- Layer-2 ACK + retransmission
- Programmable power mask for EMI compliance
- Advanced QoS support

Adaptive Bit-loading (I)

- Wiring was originally designed for transmitting electricity (50 Hz), not wideband signals (MHz)
- It is a “hostile” channel for communications
  - Strong interference from electrical appliances or radio services
  - Energy loses and “multipath effect” due to impedance mismatch
  - Medium characteristics change with time, when electrical appliances are plugged/unplugged

About OFDM

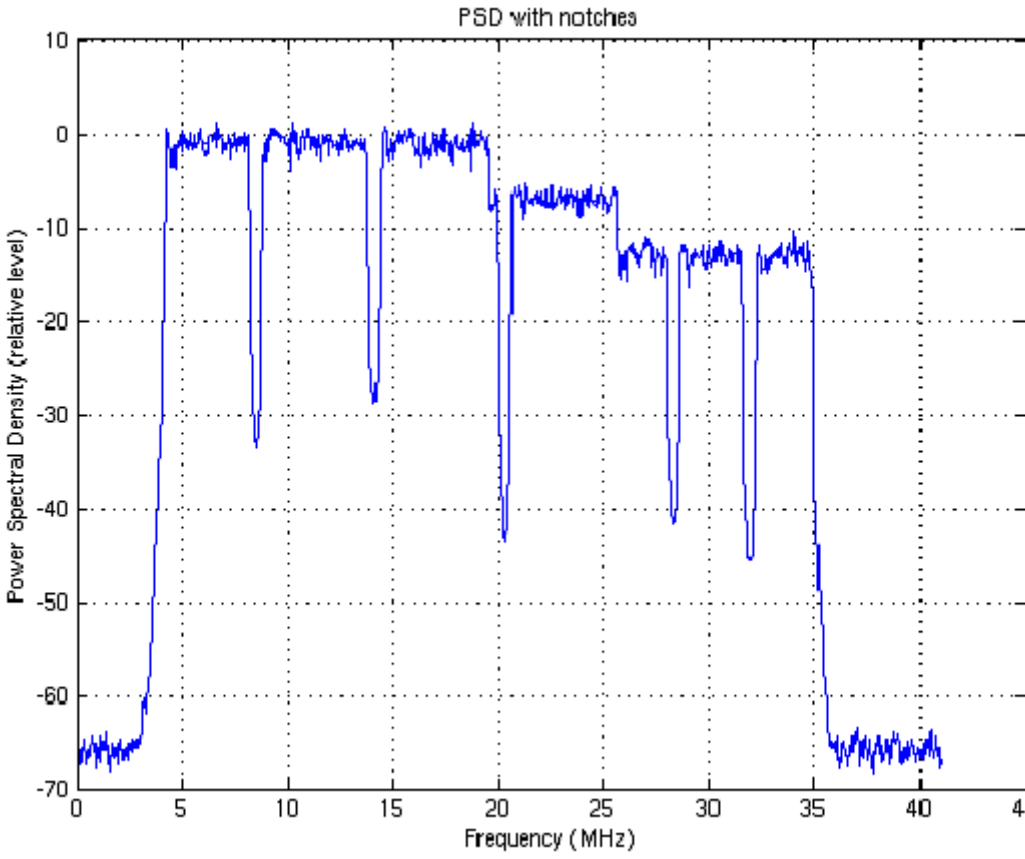
- OFDM (Orthogonal Frequency Division Multiplexing) is a type of multi-carrier modulation
- OFDM divides the spectrum in several sub-carriers, optimizing the modulation in each one independently
- Sub-carriers are partially overlapping, maximizing transmission capacity
- OFDM is used both in Wireline (DSL, powerline), Wireless (802.11a, 802.16) and Broadcast (DVB, DAB) communication systems



About DS2 200Mbps OFDM

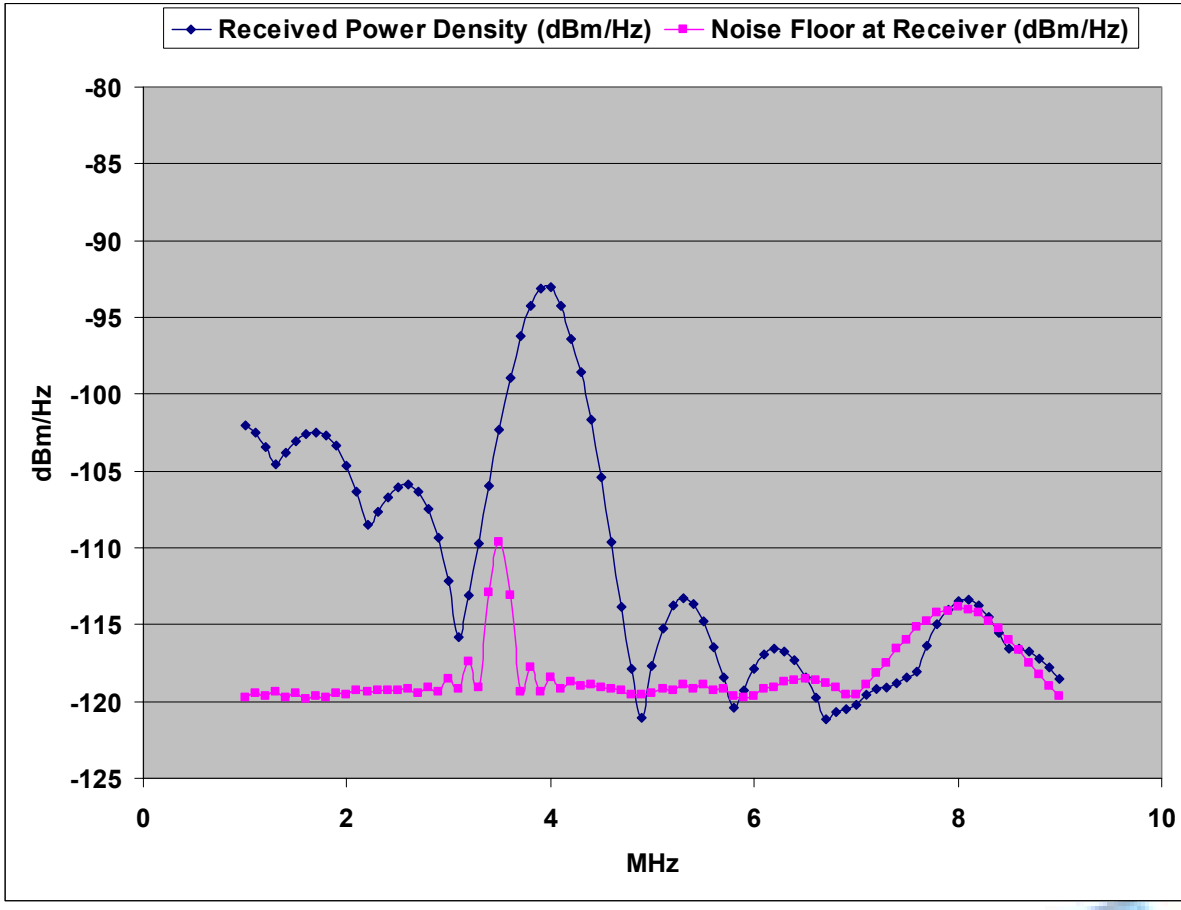
- Can operate with a bandwidth of 10, 20 or 30 MHz, transmitted between 2-34 MHz
- 1536 carriers
- Programmable notches (each carriers can be independently attenuated or turned off for EMI compliance worldwide)
- Notching can be performed on-the-fly, while the network is operating

Sample power mask showing notches



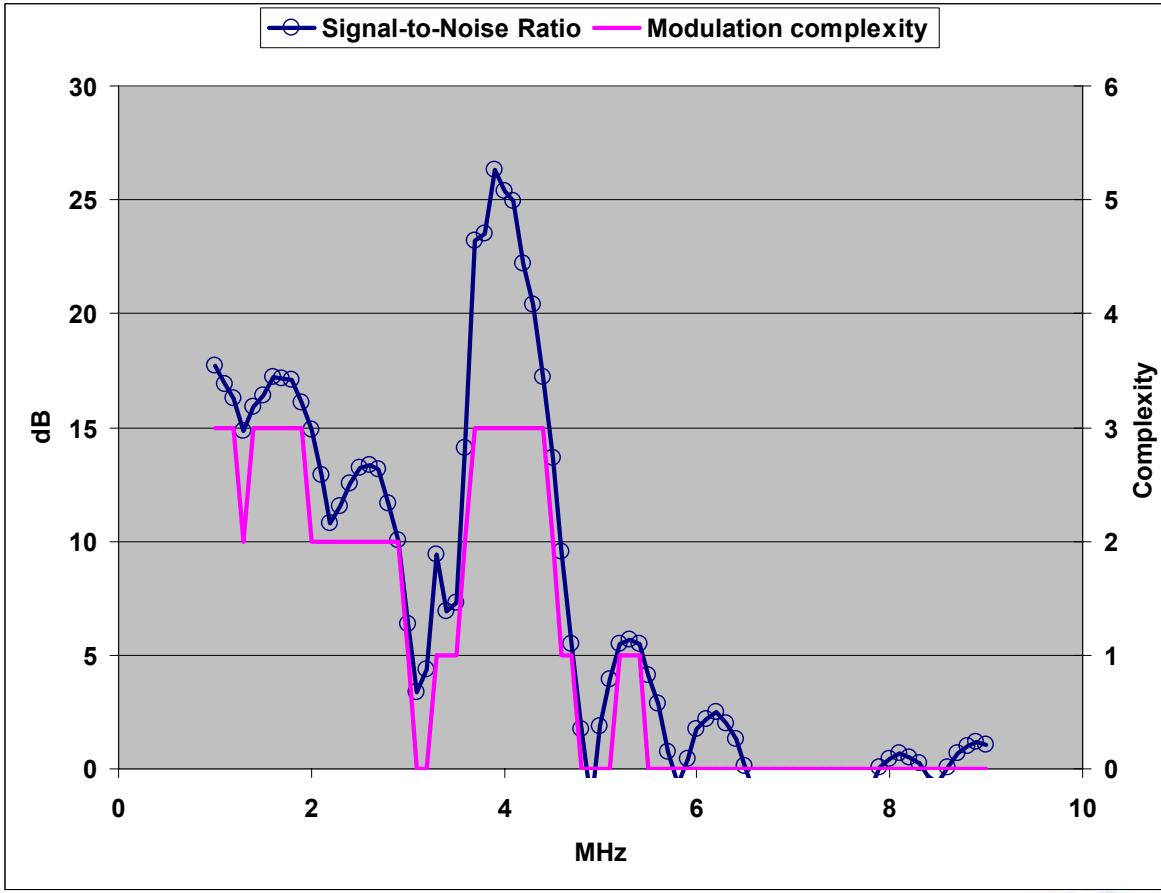
Adaptive Bit-loading (II)

- Received signal power (blue) and interfering noise level (magenta) is different for each frequency and changes with time



Adaptive Bit-loading (III)

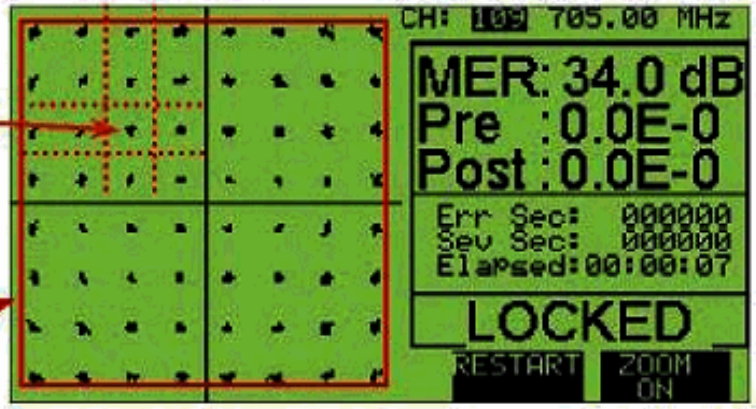
- SNR (Signal-to-Noise Ratio, in blue) is the ratio between desired signal and noise level.
- In any communications system, the SNR limits transmission capacity (Mbps).
- Adaptive-bitloading systems select the most appropriate modulation (magenta) for each frequency in real time, optimizing transmission capacity
- This is only possible using multi-carrier modulations like OFDM



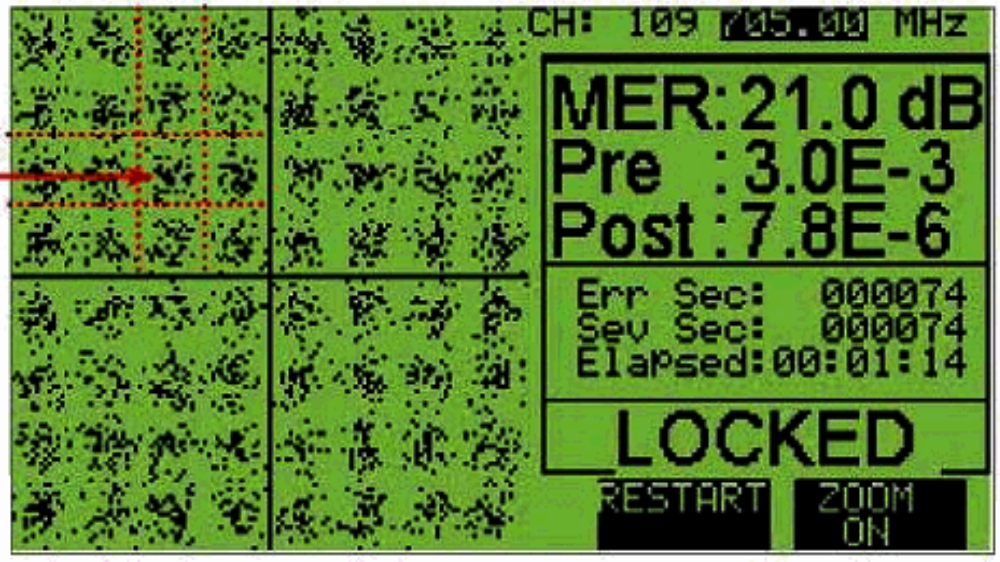
Noise and Jitter

Well Defined and away from the decision boundaries

Well Positioned Dots in a Square

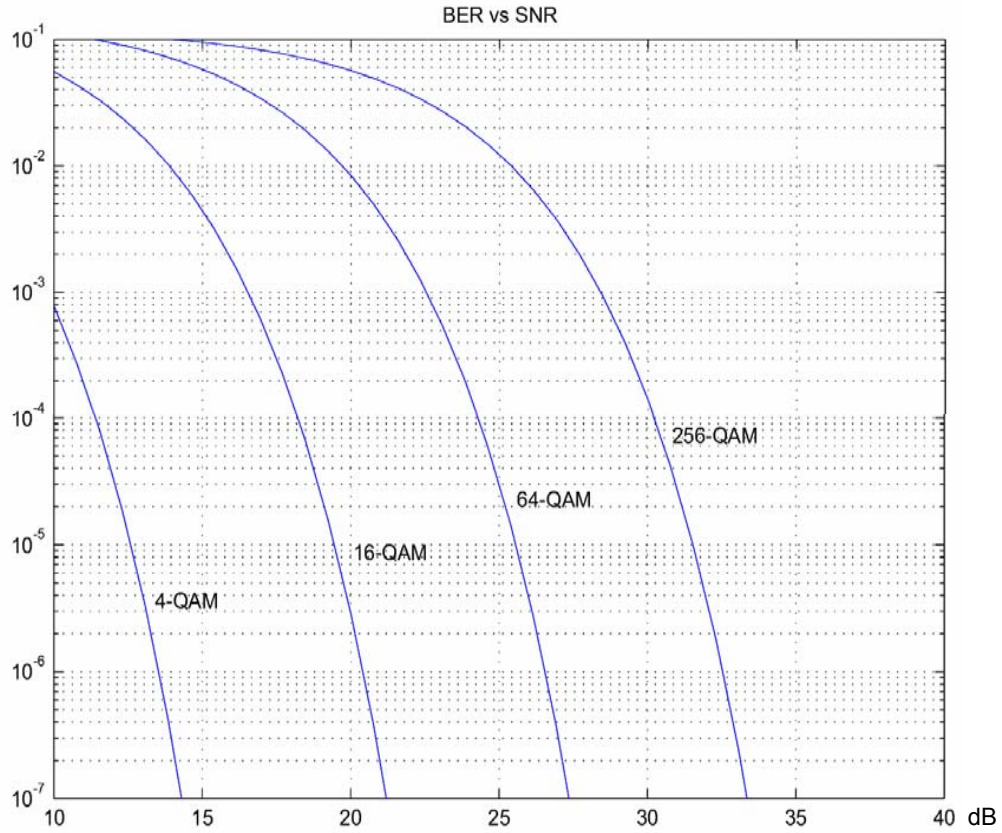


Dots are spread out causing errors to occur

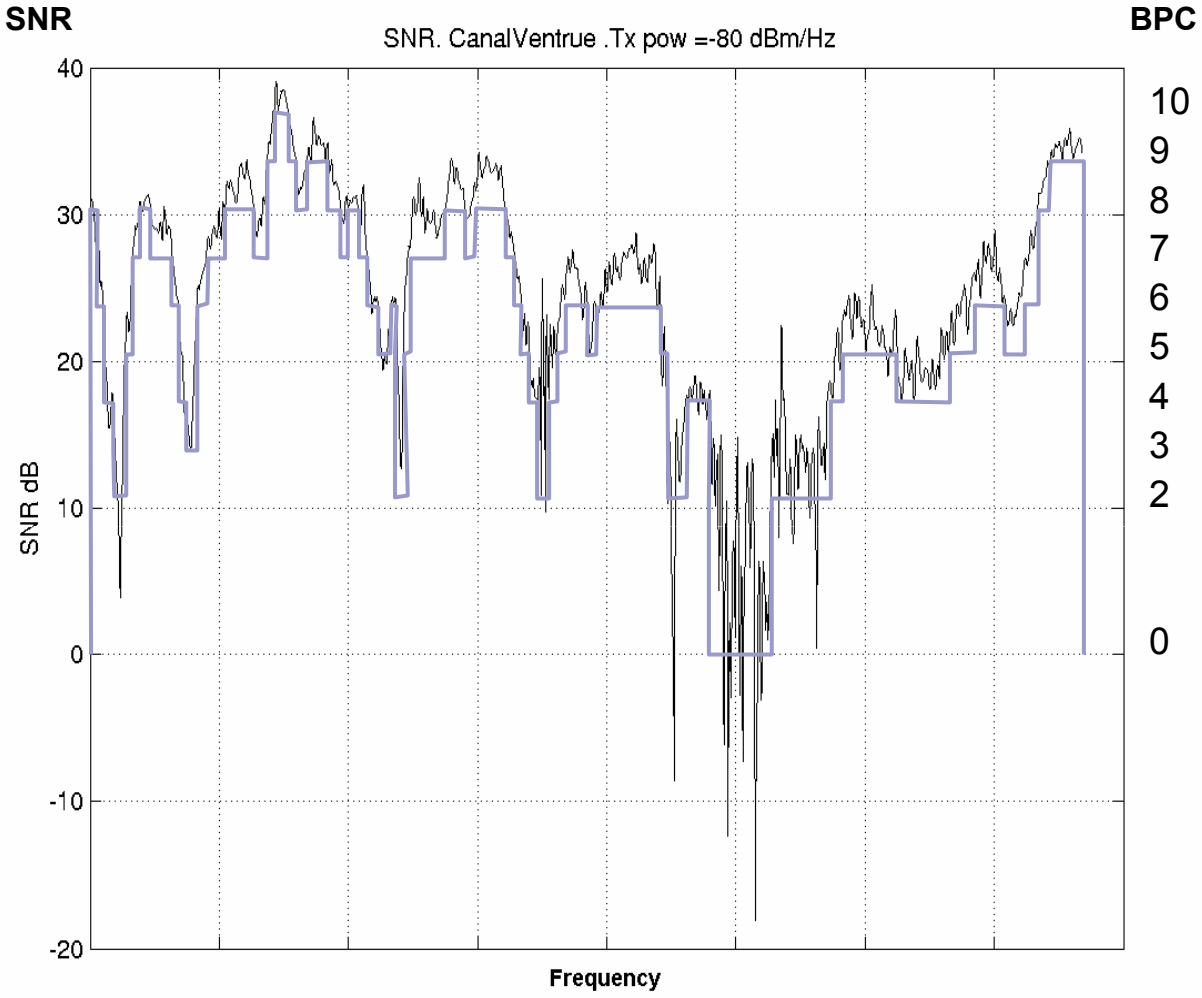


Bit Error Rate

- For a given modulation noise causes a certain number of errors per second
- Typical values are 10^{-3}, 10^{-6} and 10^{-9}
- For a given BER, there is a curve showing the SNR required to modulate n bits

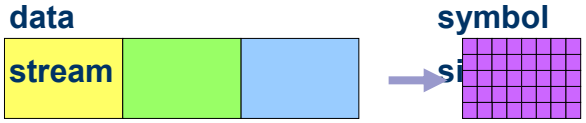


Adaptive Bit Loading

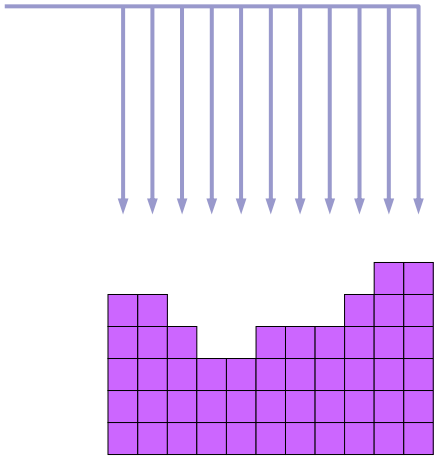


OFDM Symbol

$$\text{Symbol Size} = \sum BPC_i$$



Take data in chunks the size of a symbol



Distribute symbol data among carriers

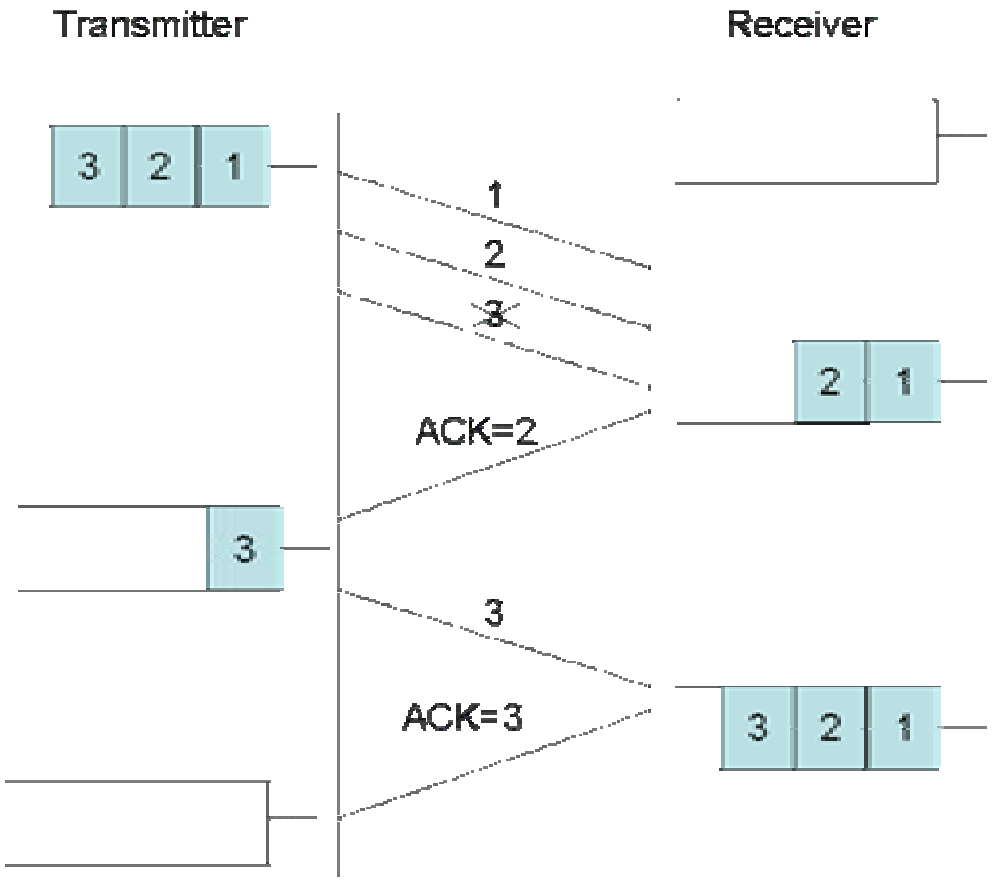
Medium Access Control

- Although there are some CSMA-based powerline products in the market, they are suited for data applications, not for audio/video applications that require strict QoS guarantees.
- CSMA systems are simple to implement, but suffer from network collisions, unbounded latency, decreasing efficiency as networks get large, and other well-know problems.
- The industry is moving to TDMA-based architectures, which provide collision-free operation and much better QoS control.

DS2 MAC

- Dynamic TDMA MAC (no fixed time-slots, so bandwidth is used efficiently)
- Master/Slave architecture: Channel access is allocated by a master device
- Any device can be a master: dynamically selected if no master is found in the network

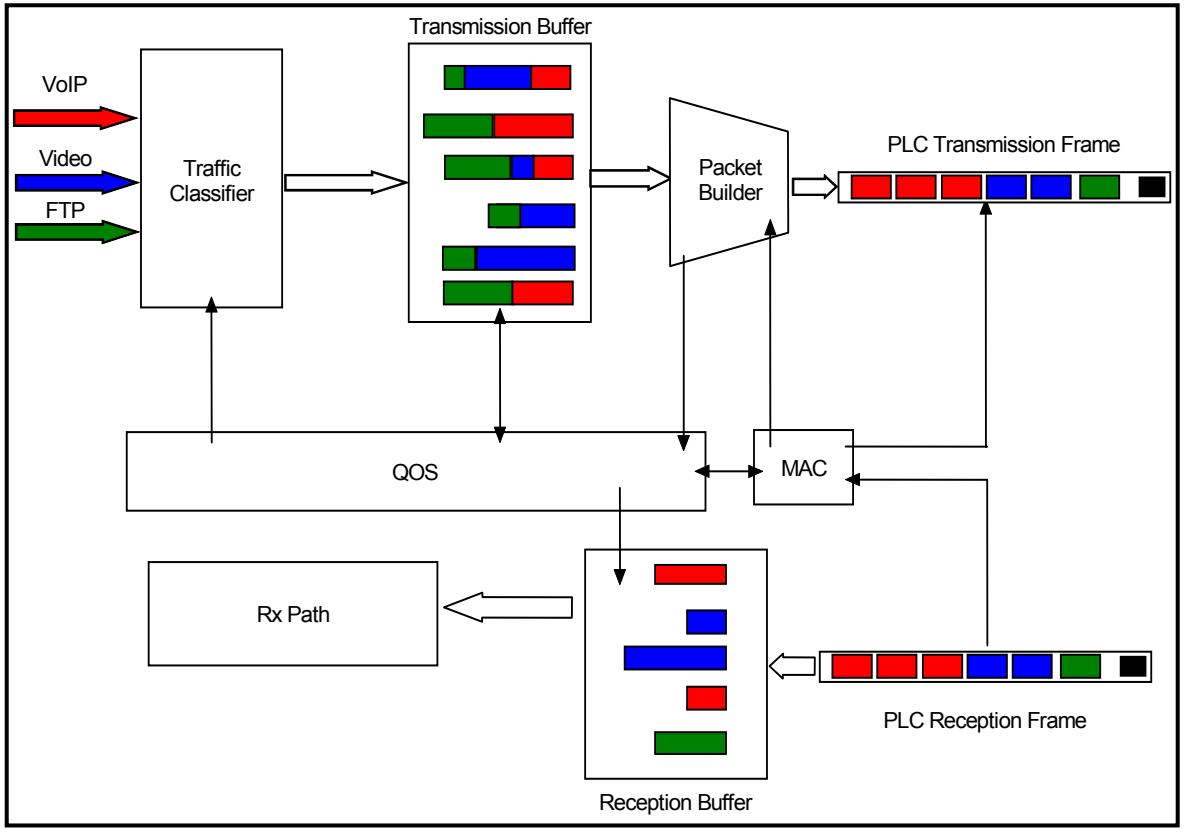
Data Link Layer – L2 ACK



QoS

- Any technology designed to transport a mix of data/audio/video must provide mechanisms to prioritize Ethernet frames from different devices & services depending on their QoS requirements.

Prioritization in 200Mbps technology



The service classifier is designed to differentiate between 8 types of traffic.

Incoming packets are stored in th PL output buffers according to their priority.

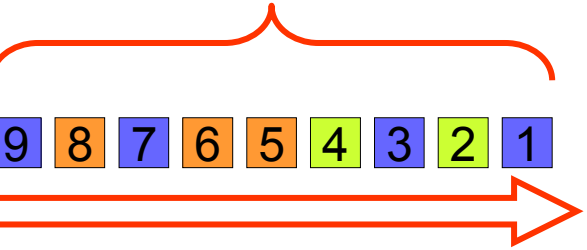
Depending on the port configuration and the QoS rules assigned to each traffic flow, the packet builder constructs the PLC bursts.

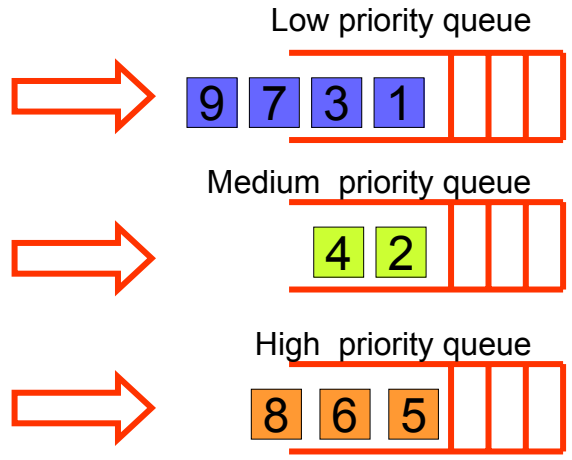
Upon reception of the PLC transmission frame, PLC bursts are disassembled.

Packet classifying is done in two steps: triggering and the classification itself

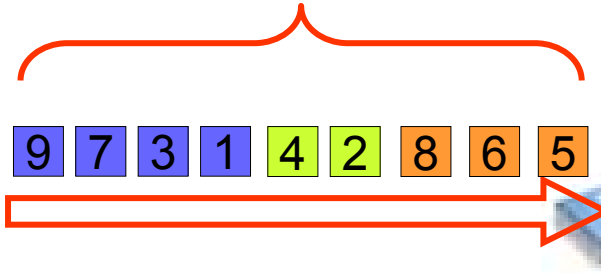
Service Classifier

Incoming data





Outgoing data



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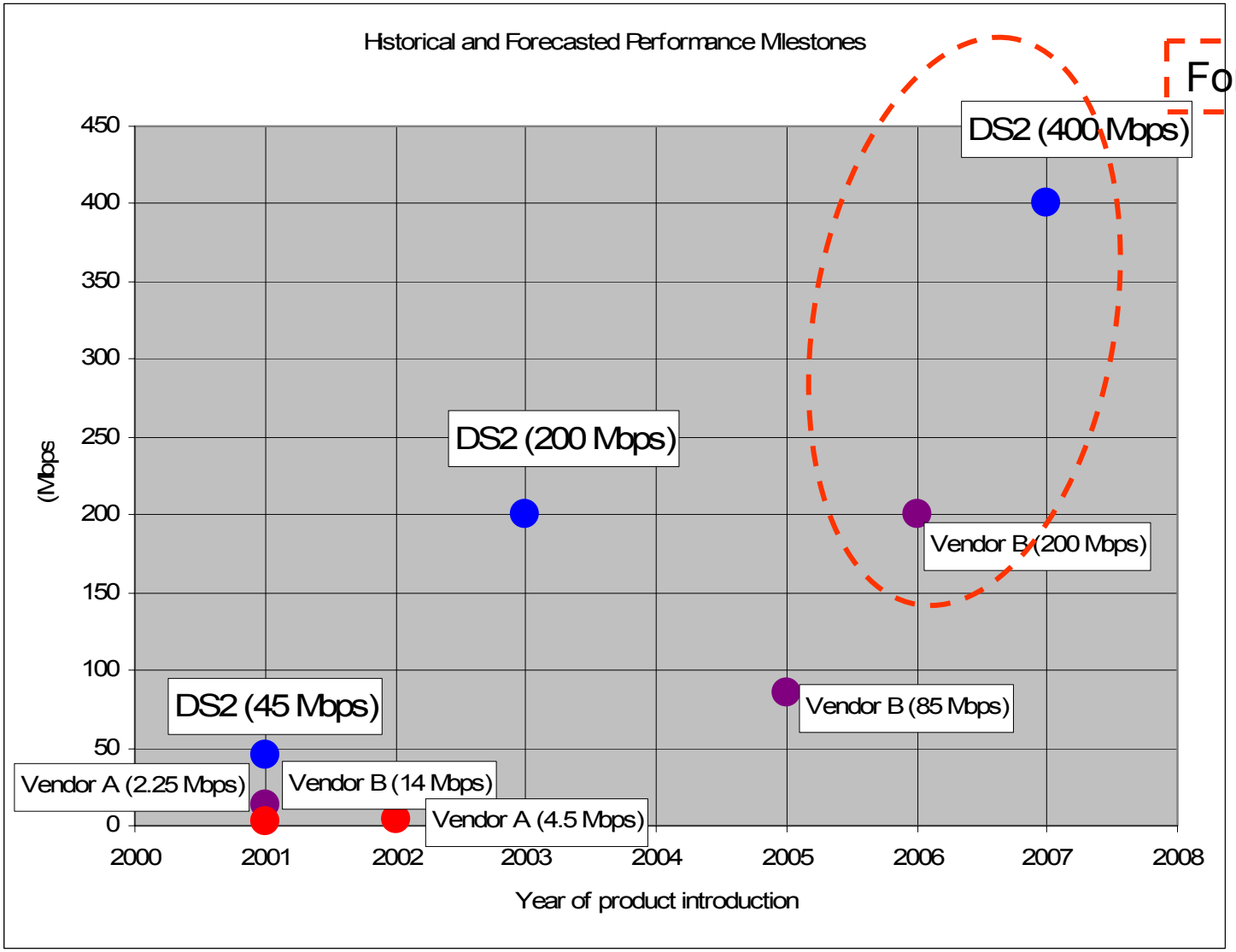
Industry milestones (2000-2007)



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Standardization of powerline communications

- Once the technology is ready, two non-technical key factors are required before mass adoption happens:
  - Political support (flexible regulation)
  - Standards (interoperable products)
- Political support
  - From European Commision
  - From FCC and US Government
- Standardization process
  - OPERA & UPA
  - IEEE & ETSI

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USA POLITICAL SUPPORT

- Michael Powell, former FCC Chairman
  - “The arrival of BPL is a monumental breakthrough in technology”
  - “Broadband over power lines can offer consumers freedom to access broadband services from any room in their home without need to pay for additional wiring, by simply plugging an adaptor into an existing electrical outlet”
  - “Broadband-over-power line systems have the potential of providing the consumer with another economic broadband access alternative. The competition fostered by additional broadband options should lead to lower prices and new and innovative services for the American public”
  - “Our goals of universal service will be substantially advanced if this service [BPL] is deployed”

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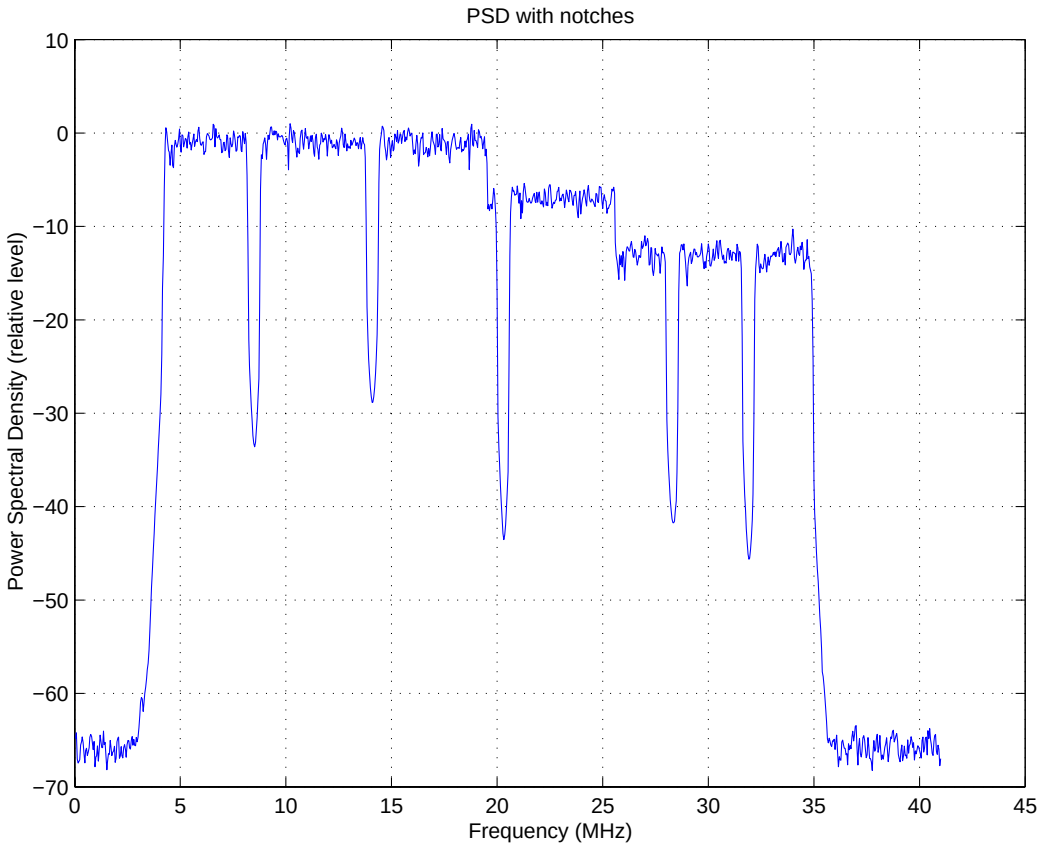
USA POLITICAL SUPPORT

- Ed Thomas, Chief Engineer, FCC OET
  - “Broadband-over-power line systems have the potential of providing the consumer with another economic broadband access alternative. The competition fostered by additional broadband options should lead to lower prices and new and innovative services for the American public”
- George Bush, President
  - “We need to get broadband to more Americans and so, therefore, I want to talk about two other ways to get broadband to the consumer. We need to use our power lines better. They go everywhere. It seems to make sense, doesn't it, if what you're looking for is avenues into the home. Well, electricity goes into the home. And so one great opportunity is to spread broadband throughout America via our power lines.”

FCC requirements regarding protection to radio services

- Having political support does not mean that BPL operators can deploy their networks without any limitations.
- Latest FCC regulation requires BPL devices to have the capability to avoid using any specific frequency and to remotely adjust or shut down any unit.
- Equipment based on DS2 technology can be configured to have any arbitrary “power mask”, avoiding specific bands or attenuating the signal any desired level.
- This flexibility provides total assurance against possible changes in regulation or any potential interference claim



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EUROPEAN POLITICAL SUPPORT

Letter from the European Commission to ETSI and CENELEC (January 2004):

- "After having consulted the Member States […], the Commission is of the opinion that […] roll-out of powerline communications infrastructure […] should be encouraged"
- "In order to achieve this goal, the Commission intends to issue a recommendation on broadband communications through powerlines"
- "This recommendation needs to be based on a sound technical specification reflecting the current state of the art of telecommunication networks, and in particular, powerline communications networks"

Standardization – Industry initiatives

- OPERA (Open PLC European Research Alliance)
  - 37 companies (silicon vendors, equipment vendors, power companies, telecom operators, universities) from 10 countries
  - €20M budget, funded by EU
  - Focus on broadband access applications
  - DS2 selected as baseline technology on Feb 2005 after field trials
  - Specification will be published on Dec 2005
- UPA (Universal Powerline Alliance)
  - 10 members (silicon vendors, equipment vendors, power companies, telecom operators) from USA, Canada, Europe and Japan.
  - Focus on broadband in-home applications
  - Compatible with OPERA
  - DS2 selected as baseline technology after field trials
  - Specification will be published shortly after OPERA spec

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IEEE To Standardize Broadband Over Powerlines

The IEEE has begun work on a standard for the delivery of broadband over powerlines (BPL), with a target of 2007 to complete a set of standards that will cover everything from first- and last-mile delivery to in-home networking over home electrical wiring. The standardization effort stems following nearly a year of study of BPL issues by IEEE committees.

The IEEE says the planned standard, to be called *Standard For Broadband Over Power Line Networks: Medium Access Control and Physical Layer Specifications (IEEE P1901)*, will "seek to create a balanced and efficient BPL channel that has the bandwidth and quality of service needed by all users."

"The ability to transmit digital data over power lines from substations to homes and offices is attracting attention because it can transform wall outlets into Internet portals," says Jim Mollenkopf, co-chair of the IEEE BPL PHY/MAC Working Group. "This approach resolves the tough task of linking long-distance fiber-optic cables to individual computers and should make use of the Internet even more universal than it now is. If BPL is to become widespread, there is a need for a robust standard that supports the use of many types of BPL devices. Our intent is for IEEE P1901 to be that standard."

"The physical and medium access layers to be defined in the new standard will ensure that BPL devices operating on the same network will be able to coexist without conflict. It also will allow for interoperability among BPL devices from different vendors so that end users can create viable systems according to their needs," added Jean-Philippe Faure, the other working group co-chair.

It's still not clear whether the standards that emerge from the IEEE will conflict with specifications already set by other groups, including the **HomePlug Power Alliance**. Companies prominently involved in the Alliance are represented on the IEEE committee looking at BPL. That typically means the standard that emerges will be heavily influenced by what's actually already deployed in the market.

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Conclusion

- Broadband Powerline is an exciting technology that is opening up several new applications and added-value services for Telecom Operators and Power utilities.
- Mass service deployments are starting in Europe and Asia and will very soon start in North America.
- DS2's 200 Mbps technology is leading the broadband powerline industry worldwide.
- DS2 technology has been selected as baseline technology by two different industry consortiums
- The ratification of global standards by ETSI and IEEE will drive mass adoption, enabling millions of users to take advantage of this technology.

Thank you for your attention

Chano Gomez
VP Technology and Strategic Partnerships

DS2

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