The perfect home network you already have: using Powerlines to share HD video

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Networking the home is perhaps the next great consumer technology challenge. Home users of music, video and other multimedia content are now starting to want to share this content between devices (PCs, games consoles, hi-fi, media servers etc) over a high-bandwidth network that offers guaranteed Quality of Service (QoS).

Wireless home networks (normally using Wi-Fi technology) are not adequate to the task. Wi-Fi is suitable for sharing Internet connections between computers, where network traffic is light and bursty. But High-Definition (HD) video needs higher bandwidth and predictable Quality of Service (QoS) to provide an acceptable viewing experience. Only a wired medium can offer this.

Technology	Data Rates	Strength	Weakness	Standards/Consortium
Ethernet over Powerline	200 Mbps (max) 120 Mbps (realistic)*	Ubiquitous. No new wires	Will it work or not perception	UPA, HD-PLC, HomePlug
Ethernet (over Cat 5 cable)	100 Mbps (max) 50 Mbps (realistic)*	Simple installation	Wiring required	IEEE
Next-gen WiFi IEEE 802.11n	100 Mbps (max) 15-30 Mbps (realistic)*	No wires	Interference from neighborhood networks	IEEE
Ethernet over Coax	270 Mbps (max) 135 Mbps (realistic)*	Low interference from neighboring networks	Wiring required for homes without coax	MoCA, TVnet
Ethernet over Phone line	140 Mbps (max) 80-100 Mbps (realistic)*	No interference from neighborhood networks	Wiring required for homes without phone line installation	HomePNA

Fig. 1: comparison of options for wired home networking
** Source: Heavy Reading report, "Multimedia Whole-Home Networking: Solving the IPTV Distribution Dilemma" May 2006*

Why Ethernet-over-Powerline makes sense

A user has several options to choose from when setting up a wired home network (see Fig. 1). Ethernet-over-Powerline (EoP) is emerging as the most viable alternative to other home networking technologies, for several reasons:

- Powerlines are ubiquitous – powerline technology turns each electrical socket in a user's home into a potential network port
- Ethernet over Powerline products are plug-and-play devices, and involve no rewiring
- Powerline products today offer data rates of up to 200Mbps and multiple Quality of Service (QoS) levels. This makes them suitable for streaming HD and standard-definition video

- Powerline networks provide two levels of content security. A malicious user has to first break into your home and plug into the power sockets. Then they must overcome the encryption that is built in to EoP.
- The Time Division Multiple Access (TDMA) technology on which EoP is based ensures guaranteed bandwidth for video transport

The basics of EoP

In EoP systems, copper wires that are used to distribute power inside homes also act as the medium to transmit digital data. The system typically operates by superimposing a modulated carrier frequency on the AC signal carried on a powerline.

The concept of using powerlines as a data-communication medium has been around since the 1970s. But until the late 1990s, EoP technology only offered a low bit-rate that only provided enough bandwidth for the transmission of control signals.

Now, new algorithms to overcome noise on the powerline channel have made powerlines a viable high-speed digital content carrier. At the same time, silicon computing power is so cheap that these computationally-intensive algorithms can be implemented on a single chip that is cheap enough to be affordable to the mass market.

An EoP system starts with a transmitter that converts digital data from a PC or any network-connected device to analogue line data, and then overlaps the analogue line data with the powerline. At the receiver end, it converts the analogue line data inputted through the powerline to digital signals and transfers them to the appropriate device (see Fig. 2).

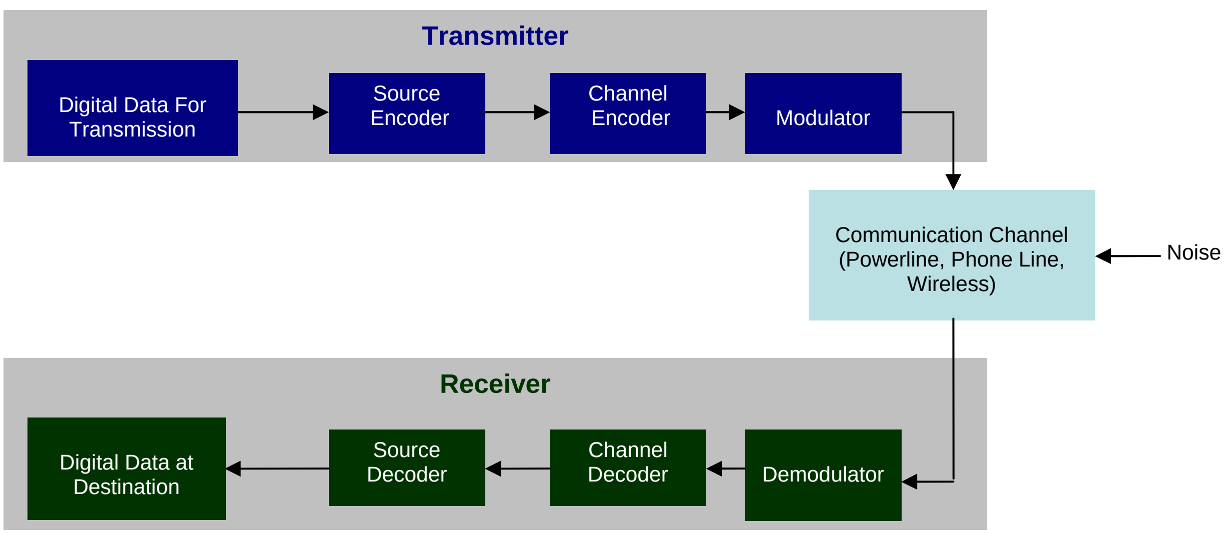

Fig. 2: generic digital communication system block diagram

A version of EoP developed by the Universal Powerline Association (UPA), its so-called Digital Home Standard (DHS) specification, is designed for managed and unmanaged in-home powerline networks. It is based on a Master-Slave control architecture and uses a peer-to-peer architecture for data transmission (see Fig. 3).

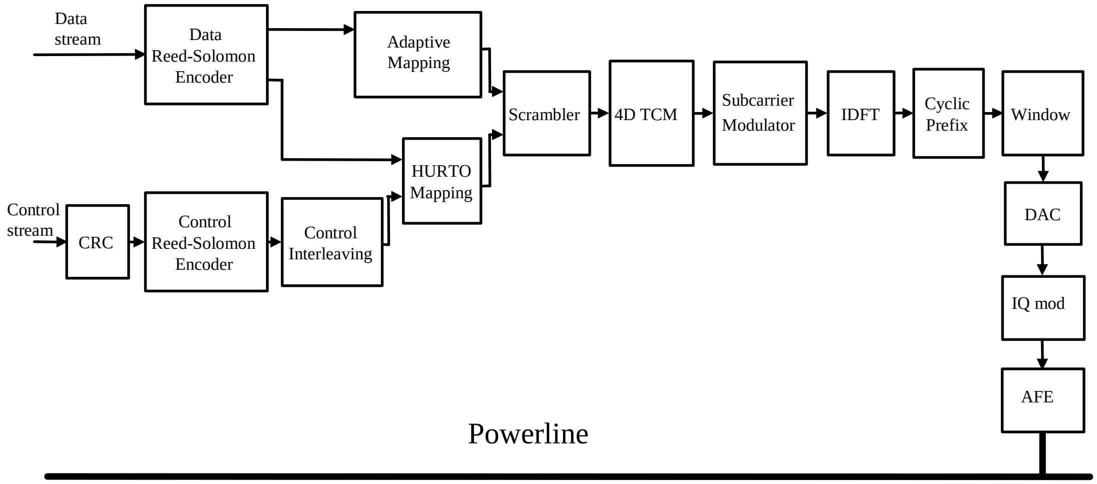

Fig. 3: DHS physical layer (PHY) block diagram

Common powerline communication challenges

Like any high-speed powerline communication technology, DHS has to solve some big and obvious design challenges. These include the following.

Voltage spikes: The biggest misconception about EoP technology is that because this technology uses the powerline as a communication method, its performance is related to the quality of electrical power on the powerline. The DHS PHY, however, operates in the 2MHz-32MHz frequency range of the powerline channel. AC power in homes is usually distributed either at 50Hz or 60Hz. Using the 2-32MHz spectrum ensures that digital data signals are less susceptible to voltage spikes or fluctuations at the 50Hz/60Hz frequency bands.

Noise on the Powerline: Noise is the biggest obstacle to using powerlines as a data-communication medium. An EoP product must deliver high-quality HD video even if the user plugs in a blender or hair-dryer into the power sockets in their home.

The DHS uses four methods to solve the noise problem:

1. Robust modulation
2. Frequent channel estimation
3. Adaptive bit loading
4. Forward error correction.

1. Robust modulation: the UPA’s technology uses 1,536-carrier OFDM (Orthogonal Frequency Division Multiplexing) modulation, with modulation densities from 2 bits to 10 bits per subcarrier applied independently to each subcarrier.

2. Frequent channel estimation: the noise that the powerline channel is subject to is often bursty, since it largely comes from home appliances such as food blenders and microwave ovens that are used infrequently. The UPA’s version of EoP performs frequent channel estimation, exchanging training data between the transmitters and the receivers. Channel estimation provides the EoP devices with information about the parts of the powerline channel that are the biggest contributors of noise. Once noise has been detected, the transmitters perform adaptive bit loading to ensure optimal usage of the powerline spectrum.

3. Adaptive bit loading: adaptive bit loading refers to adapting modulation parameters for each pair of transmitters/receivers in real time depending on channel-quality parameters for each carrier. The signal-to-noise ratio is measured for each carrier and the optimum modulation is chosen, with the objective of achieving the maximum transmission speed while maintaining the desired Bit Error Rate (BER). This minimises interference from other connected devices.

4. Forward error correction methods transmit enough information from the transmitter so that in case of data-loss due to noise, the original transmitted data can be recovered at the receiver without re-transmission of the original data. The UPA's DHS specification uses dynamic Reed-Solomon codes to implement forward error correction.

Interference with radio communication: broadband powerline communication uses the 2-32MHz frequencies of the powerline spectrum. These frequencies may be licensed to radio services, including amateur radio. The UPA EoP technology provides programmable 'spectral notching' that can be used to avoid frequencies not licensed for use by government regulations. The UPA's DHS uses a technique called windowed-OFDM modulation that provides programmable notches with a negligible loss of performance outside the notched frequencies.

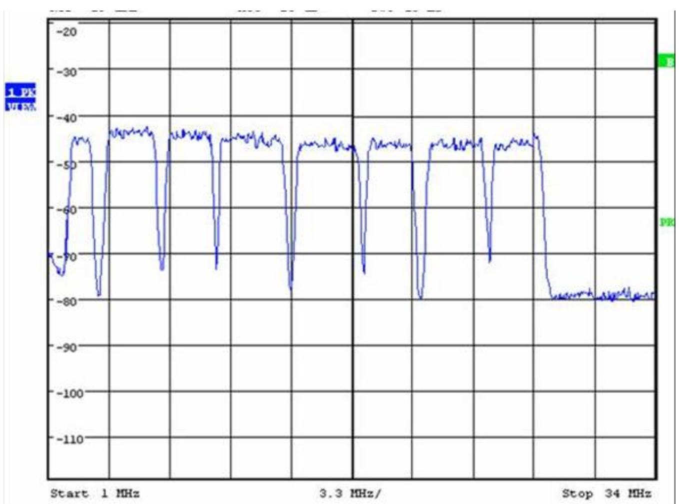

Fig. 6: spectral notching prevents interference with radios

Bandwidth allocation for QoS requirements: HD television requires huge amounts of bandwidth. The system must provide smooth video delivery even under difficult conditions, such as intermittent noise, interference from neighbouring powerline networks, or a network saturated with low-priority data.

The DHS uses traffic classification and centralised bandwidth management to achieve this. This technology, known as Advanced Dynamic Time Division MAC (ADTDM), is optimised for audio/video-distribution applications in which high performance, stringent bandwidth reservation, strict traffic prioritisation and QoS are of paramount importance. All the nodes in the powerline network are given collision-free access to the channel according to different service priorities. These priorities can be adjusted to suit different applications, including data, VoIP and video-on-demand.

The UPA's EoP system also uses a master/slave architecture, in which one EoP device on the network is chosen as the master while all other devices are designated as slaves. The master device allocates channel access time to other EoP devices on the network. This is the most effective (and simplest) way to ensure bandwidth allocation to different traffic types on the network.

Content security: the UPA's specification employs 168-bit AES encryption to provide secure content distribution.

Other options for implementing EoP

EoP technology is available in multiple flavours. These include UPA, HD-PLC, HomePlug 1.0, HomePlug 1.0 Turbo and HomePlug AV. Important factors to consider when choosing a powerline specification are:

Performance: for distributing HD video content in the home, a data rate of at least 150Mbps is essential. UPA, HD-PLC and HomePlug AV offer 200Mbps throughput. Older powerline technologies such as HomePlug 1.0 and HomePlug 1.0 Turbo offer more modest data rates (14Mbps and 85Mbps respectively).

Technology Maturity: the UPA's 200Mbps chipsets have shipped more than 1million units since the technology was introduced in 2004. The technology has been deployed by telecommunications service providers in Europe, helping to prove the viability of the technology.

HomePlug AV was launched three years after the UPA's DHS. HomePlug AV 200Mbps chipsets are now sampling, with consumer products being announced by vendors in early 2007.

No volume shipment data is available for HD-PLC (200Mbps) technology.

Conclusion

The viability of EoP technology has been proved by the successful mass deployment of consumer products in Europe and elsewhere. For consumers, the powerline is by far the cheapest and most convenient medium in the home for providing high bandwidth to any device, in any room. All that remains is to see which of the competing technologies that offer at least 150Mbps bandwidth will win the race to market dominance.