Network HD video over powerlines

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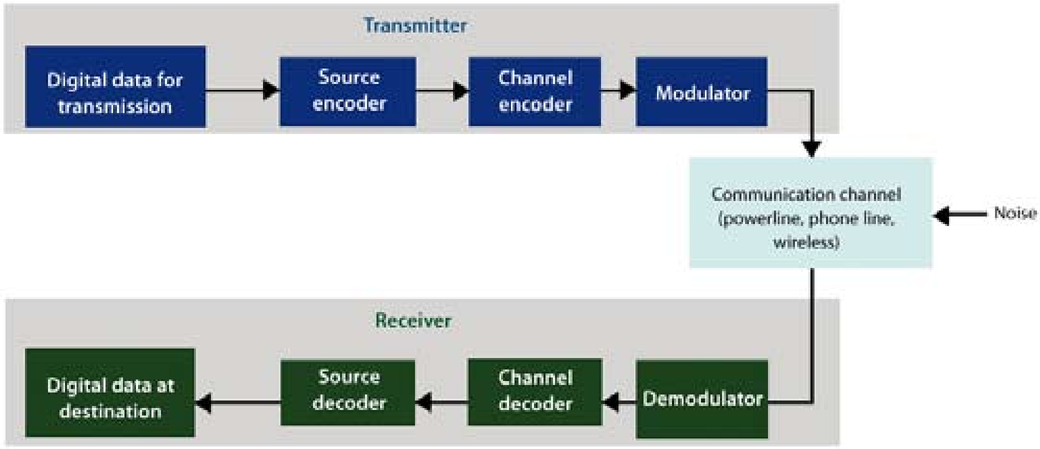

Figure 1: A generic digital communication system block diagram is shown.

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 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 QoS to provide an acceptable viewing experience. Only a wired medium can offer this.

Why EoP makes sense

A user has several options to choose from when setting up a wired home network, as shown in the table. 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.
- EoP products are plug-and-play devices, and involve no rewiring.
- Powerline products offer data rates of up to 200Mbit/s and multiple 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 into EoP.
- The Time Division Multiple Access technology on which EoP is based ensures guaranteed bandwidth for video transport.

How it works

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 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 inexpensive that these computationally-intensive algorithms can be implemented on a single chip that is cost-effective 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 analog line data, and then overlaps the ana-

Technology	Data rates	Strength	Weakness	Standards/ consortium
Ethernet-over-powerline	200Mbit/s (max) 120Mbit/s (realistic)	Ubiquitous, no new wires	Will it work or not perception	UPA, HD-PLC, HomePlug
Ethernet (over Cat 5 cable)	100Mbit/s (max) 50Mbit/s (realistic)	Simple installation	Wiring required	IEEE
Next-gen Wi-Fi IEEE 802.11n	100Mbit/s (max) 15-30Mbit/s (realistic)	No wires	Interference from neighborhood networks	IEEE
Ethernet-over-Coax	270Mbit/s (max) 135Mbit/s (realistic)	Low interference from neighboring networks	Wiring required for homes without coax	MoCa, TVnet
Ethernet over phone line	140Mbit/s (max) 80-100Mbit/s (realistic)	No interference from neighboring networks	Wiring required for homes without phone line installation	HomePNA
Source: Heavy Reading report, Multimedia Whole-Home Networking: Solving the IPTV Distribution Dilemma May 2006				

The table compares the specifications of wired home networking technologies. Source: Heavy Reading report, "Multimedia Whole-Home Networking: Solving the IPTV Distribution Dilemma" May 2006 log line data with the powerline. At the receiver end, it converts the analog line data inputted through the powerline to digital signals and transfers them to the appropriate device (**Figure 1**).

A version of EoP developed by the Universal Powerline Association (UPA), the Digital Home Standard (DHS), 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 (**Figure 2**).

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 2-32MHz 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: the UPA's technology uses 1,536-carrier OFDM modulation, with modulation densities from 2bits to 10bits 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: this refers to adapting modulation parameters for each pair of transmitters/receivers in real time depending on channel-quality parameters for each carrier. The SNR is measured for each carrier and the optimum modulation is chosen, with the objective of achieving the maximum transmission speed while maintaining the desired BER. This minimizes interference from other connected devices.
4. FEC 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 DHS specification uses dynamic Reed-Solomon codes to implement FEC.

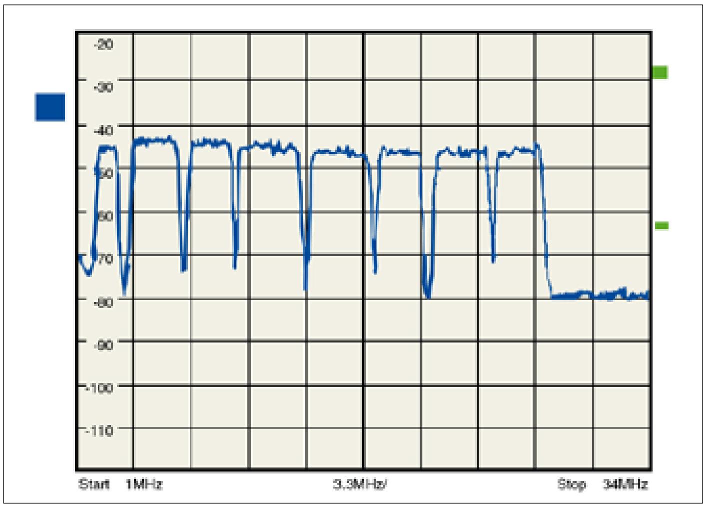

Figure 3: The DHS uses a technique called windowed-OFDM modulation that provides programmable notches with a negligible loss of performance outside the notched frequencies.

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 DHS uses a technique called windowed-OFDM modulation that provides programmable notches with a negligible loss of performance outside the notched frequencies (**Figure 3**).

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

The DHS uses traffic classification and centralized bandwidth management to achieve this. This technology, known as Advanced Dynamic Time Division MAC (ADTDM), is optimized for audio/video-distribution applications in which high performance, stringent bandwidth reservation, strict traffic prioritization and QoS are of paramount importance. All the nodes in the

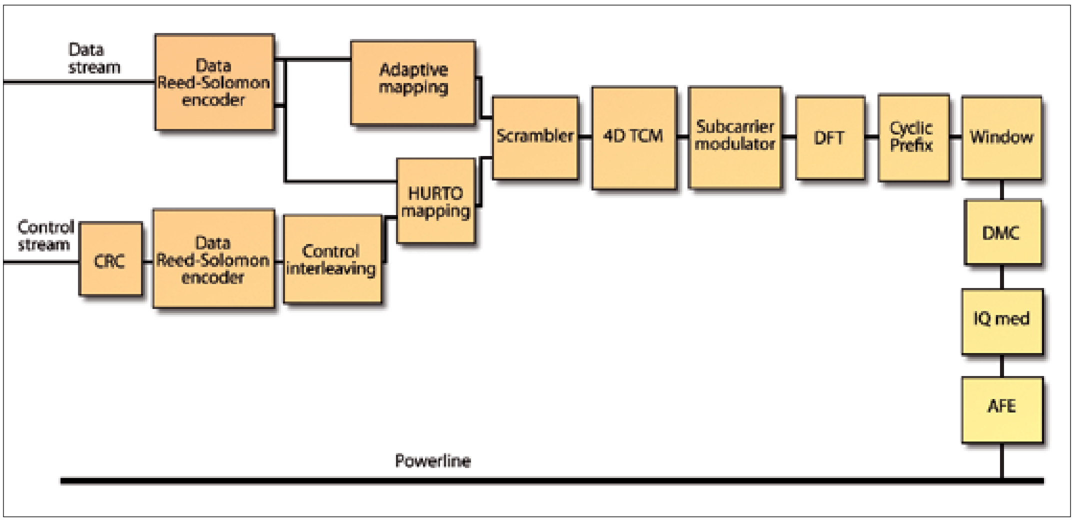

Figure 2: The DHS PHY is based on a master-slave control architecture and uses a peer-to-peer architecture for data transmission.

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 simplest and most effective way to ensure bandwidth allocation to different traffic types on the network.

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

Other options

EoP technology is available in multiple flavors. These include UPA, High Definition-Power Line Communication, 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 150Mbit/s is essential. UPA, HD-PLC and HomePlug AV offer 200Mbit/s throughput. Older powerline technologies such as HomePlug 1.0 and HomePlug 1.0 Turbo offer more modest data rates (14Mbit/s and 85Mbit/s respectively).
- Technology Maturity: the UPA's 200Mbit/s chipsets have shipped more than 1 million 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 200Mbit/s chipsets are now sampling, with consumer products being announced by vendors in early 2007.

No volume shipment data is available for HD-PLC (200Mbit/s) technology.

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 150Mbit/s bandwidth will win the race to market dominance.