Powerline communications - Electrifying the broadband

Powerline communications (PLC) is a rapidly evolving market that utilizes electricity power lines for the high-speed transmission of data and voice services. PLC works by transmitting high frequency data signals through the same power cable network used for carrying electricity power to household users. Such signal cannot pass through a transformer. This requires devices ("outdoor devices") that combine the voice and data signals with the low-voltage supply current in the local transformer stations to bridge the last mile. In the house, "indoor devices" (adapters) are used in order to filter out the voice and data signals and to feed them to the various applications (e.g.PC/Internet,telephone,etc.). In addition, BPL systems can be used by electric utilities to manage their electric power networks more efficiently.

PLC is simply data transfer via a combination of the power network within the home or office, the metropolitan power distribution grid. Of key important here, is that no new wires need to be installed in the "last mile", and PLC takes advantage of the largest network on earth by far, the global power grid. Using the existing power grid as a data transfer medium makes it possible to send and receive communications signals through standard power sockets.

The technology has roots going back to the 1950s. It has been used by power utilities for simple telemetering and control of electrical equipment in their networks. What is new is the integration of activities outside the building with those inside the building at a much higher bandwidth, 2.5 mbps or higher – this means voice and data transmission via the mains supply voltage network right through to every power socket in the building, as well as in the reverse direction at high speed.

The first technique to make use of power line for control messages was developed in the early 1950s. This method, “Ripple Control,” was characterized by the use of low frequencies (100-900 Hz), giving a low bit rate and a demand on very high transmitter power, often in the region of several 10 kWs. The system provided one-way communication, and was (and in some cases continues to be) used for the management of streetlights, load control, and switching tariffs. New systems were developed in the early 1980s, with a slightly higher bit rate.

By the mid-1980's, however, several utilities and equipment manufacturers investigated the characteristic properties of the electric grid as a medium for data transfer. Frequencies in the range of 5-500 kHz were often studied. The signal/noise-levels were important topics for measurements as well as the attenuation of the signal by the grid. Many utilities performed such studies both in Europe and in the U.S. The initial driving factor for those studies was the implementation of “SCADA” technology (“Supervisory Control And Data Acquisition”). After these initial efforts, bi-directional communication was finally developed in the late 1980s and early 1990s, and the present systems came on the market during this period. Through this development, two-way communications are now realistic. Today, advanced protocol techniques are now used and systems for proper data transfer are managed. The anticipated future development will use frequencies in the GHz-range, providing the much higher bandwidth and high data throughput, in the order of several Mbps.

In the local network station or aggregation points, communications signals and electricity are carried together on the grid and transported to the home. Once in the home, all existing power sockets can now symmetrically send and receive communications signals. PLC offers end-users a broad spectrum of applications and services including broadband Internet access, voice over IP, multimedia services, home automation and energy management. It offers the opportunity for the PC to be integrated into the household as never before. As part of the household power grid, PCs could easily be programmed to turn off lights and control security devices.

Advantages of PLC.

- Powerlines carry signals for long distances without requiring regeneration
- No Changes in Business or Household Wiring
- Broadband connection in every socket in every room
- Plug-and-play installation (instead of plug-and-pray with DSL & Cable Modems)
- Highest Bandwidth always on alternative
- Low Entry Barrier (for the Utility)
- Largest Existing Infrastructure in the World
- Value Adds: Surveillance, Alarming, Meter Reading, Power
- Management, Home Automation, Remote Maintenance, E-Services (Web Hosting, E-mail, ASP)
- Full control allows for higher quality of service
- Separate network from the incumbent allows for never before levels of independence and quality in last mile provisioning

• Their near light speed propagation makes them very powerful for fast delivery of video and audio data.

HomePlug drives powerline

Two separate efforts to create a standard for power line-based home networking could result in separate standards for the PC and consumer electronics worlds. Both HomePlug alliance and the R7.3 group of the consumer electronics association {CEA} are developing home-networking schemes that use existing power lines to send audio, video and data between devices within a home. ut the groups seem to be taking different paths, with the HomePlug Alliance possibly focused on PC data networking, while the R7.3 group looks at networking for a broader range of devices, including consumer electronics.

HomePlug Alliance group, which includes Intel, Advanced Micro Devices, Motorola, 3Com, Cisco and Texas Instruments, it intends to get power line-based home-networking products to market. Formed at the end of 1999, CEA's R7.3 group is also working to specify a data networking standard based on power lines. Its original members included Enikia, I-Tran Communications, Inari, Adaptive Networks and others.

Promoted and certified by the HomePlug Powerline Alliance, powerline devices plug into an electrical outlet and use Ethernet to connect to other computers and IP devices. A simple powerline network may consist of a cable modem or DSL router in a home office connected to a powerline Ethernet bridge plugged into an electric outlet. A computer connected into another Ethernet bridge plugged into an outlet in a faraway bedroom, for example, completes the network. Similarly, an 802.11b-enabled powerline device can receive a broadband signal from a cable modem/DSL router through a home's power grid and pass it wirelessly to an 802.11b-capable PC.

Other favorable aspects of HomePlug include its ease and simplicity in setting up a network due to its reliance on Ethernet, and its industrial strength, always-on 56-bit DES encryption. Wi-Fi, in comparison, offers an optional, albeit hackable, 10-bit WEP (Wired Equivalent Privacy) encryption scheme, but devices that support the more fortified Wi-Fi Protected Access (WPA) platform are on the way.

For modulation and transmission, the HomePlug 1.0 specification relies on Orthogonal Frequency Division Multiplexing (OFDM), selects the tones with the best signal-to-noise ratio, filters out noisy parts of the spectrum, and transmits on the “clean” portion of the spectrum. HomePlug 1.0 uses 76 tones within the 4 MHz to 21 MHz spectrum. The HomePlug 1.0 specification provides for a basic throughput at the Physical Layer of 14 megabits per second, although actual throughputs range from 5 Mbps to 8 Mbps.

PLC methods

1. Intellon's PowerPacket technology - Intellon's PowerPacket technology, which serves as the basis for the HomePlug Powerline Alliance standard, uses an enhanced form of orthogonal frequency-division multiplexing (OFDM) with forward error-correction, similar to the technology found in DSL MODEMS. OFDM is a variation of the frequency-division multiplexing (FDM) used inphone line networking. FDM puts computer data on separate frequencies from the voice signals being carried by the phone line, separating the extra signal space on a typical phone line into distinct data channels by splitting it into uniform chunks of bandwidth.

In the case of OFDM, the available range of frequencies on the electrical subsystem (4.3 MHz to 20.9 MHz) is split into 84 separate carriers. OFDM sends packets of data simultaneously along several of the carrier frequencies, allowing for increased speed and reliability. If noise or a surge in power usage disrupts one of the frequencies, the PowerPacket chip will sense it and switch that data to another carrier. This rate-adaptive design allows PowerPacket to maintain an Ethernet-class connection throughout the power-line network without losing any data. PowerPacket employs a spectrum efficient modulation technique that enables powerline transmission of very high data rates. Data rates up to 100 Million bits per second (Mbps) are possible.

The latest generation of Power Packet technology is rated at 14 Mbps, which is faster than existing phone-line and wireless solutions. However, as broadband access and Internet-based content like streaming audio and video and voice-over-IP become more commonplace, speed requirements will continue to increase. Along these lines, Intellon's OFDM approach to power-line networking is highly scalable, eventually allowing the technology to surpass 100 Mbps. This new technology lends itself to functioning reliably in the harsh environments of the AC powerline.

2. Intelogis power-line technology - The older power-line technology used by Intelogis relies on frequency-shift keying (FSK) to send data back and

forth over the electrical wires in your home. FSK uses two frequencies, one for 1s and the other for 0s, to send digital information between the computers on the network. The frequencies used are in a narrow band just above the level where most line noise occurs. Although this method works, it is somewhat fragile. Anything that impinges on either frequency can disrupt the data flow, causing the transmitting computer to have to resend the data. This can affect the performance of the network. Intelogis includes line-conditioning power strips with its network kit and encourages you to insert them between the wall outlet and your computer equipment to help reduce the amount of electrical-line noise. Because the current crop of power-line networks are designed to work on 110-volt electrical systems, the technology is not very useful to countries outside of North America that use different standards.

The services that PLC will support fall into two categories.

Internet Access/Home & Business Networking

Broadband Power Line Communications or PLC is simply data transfer via a combination of the power network within the home or office, the metropolitan power distribution grid. Of key importance here is that no new wires need to be installed in the "last mile," and PLC takes advantage of the largest network on earth by far, the global power grid.

Utility Related Services

Although the PLC Network is based on the power distribution network, it will be able to provide and will enable services to utility the power network operators to improve the safety and efficiency of the power network. These services include: Network Switching, Network Monitoring Fault Diagnosis, Demand side management of power distribution network, Remote load control, Tariff Switching, Meter reading telemetry.

OFDM Modulation

High bandwidth digital devices communicating on power line devices need to use powerful error correction coding along with appropriate modulation techniques.

OFDM Modulation scheme for use on power line have the following desirable properties

1. Ability to over come non-linear channel characteristics.
2. Ability to over come multipath spread.
3. Ability to adjust dynamically
4. Ability to mask certain frequencies

OFDM is generally view as a collection of transmission techniques. When applied in wireless environment it is called OFDM. However in a wired environment the term Discrete Multi Tone (DMT) is more commonly used. OFDM is currently used in the European Digital Audio Broadcast (DAB) standards. Several DAB systems proposed{IBOC} for North America are also based on OFDM. OFDM under the name DMT has also attracted a great deal of attention as an efficient technology for high-speed transmission on the existing telephone networks.

The basic idea of OFDM is to divide the available spectrum into many narrowband, low data rate carriers (or subcarriers). To obtain high spectral efficiency the frequency response of the subcarriers are overlapping and orthogonal, hence the name OFDM. Each narrowband subcarrier can be modulated using various modulation formats where BPSK, QPSK and QAM are commonly used. In PLC, the available range of frequencies on the electrical subsystem (4.3 MHz to 20.9 MHz) is split into 84 separate carriers. OFDM sends packets of data simultaneously along several of the carrier frequencies, allowing for increased speed and reliability.

OFDM divides available spectrum into small paths that are overlapped and spaced perpendicular to each other. The greater the overlapping, the more paths can be handled. While each path has a low data rate, together they offer a higher rate and a more efficient use of the spectrum. The method of using small data packets means that inside the home-where distribution might have been interrupted by electrical devices being turned on and off-only a little bit of data might be lost, rather than the whole signal.

Challenges ahead

Communication on the AC powerline is difficult because of unpredictable noise and interference from sources such as vacuum cleaners, blenders, hair dryers, etc. Additionally, compared to Ethernet cabling, which has consistent characteristics, Powerline is not controlled or constant over time. The constant plugging and unplugging, turning on and off, of these appliances throughout the day and evening causes the powerline characteristics to constantly change. Trying to send data over this inconsistent medium is what has stumped powerline technology companies for years.

Security is always a concern in a typical neighborhood; multiple homes share the same electrical power transformer-and the same physical wire. In some cases, depending on how close the homes are physically located, data communication within one home can travel across to your neighbor as well.

PLC technology already has been deployed in some European countries, and amateurs there have complained about interference. Japan--responding in part to concerns expressed by its amateur community--decided last year not to adopt the technology because of its interference potential.

Interference Problem

The system uses frequencies that will radiate into the air and cause interference to licensed services including Amateur Radio. The frequencies PLC uses in general is 1 to 80 MHz (megahertz). This particular band of frequencies are known as HF (which is actually 1 – 30 MHz). This part of the radio spectrum has very special properties not found elsewhere. With this band, one can communicate around the world with very minute power levels. This is due to the fact that radio waves in this band can bounce off the ionosphere multiple times to get to the destination. Other portions of the radio spectrum are essentially line-of-sight. This means that the signals cannot bend or bounce off the ionosphere, but they can only propagate like light – in a straight line.

Power lines, copper twisted pair, and coaxial cable all act like natural low pass filters, meaning higher frequencies are attenuated more than lower frequencies when attempting to transmit them through the medium. The exact slope of the graph of attenuation depends on the specific construction of the material, but in general, twisted pair is suitable up to 100 MHz and coaxial cable can go up to about 3 GHz. Again, these are very general figures and determining the suitability for any application depends on other factors. Power lines would be suitable for up to perhaps 20 KHz, maybe 350 kHz at a stretch, with caveats, but note that this is kilohertz, not megahertz or gigahertz. These are essentially audio frequencies, and equate to a data rate in the neighborhood of ISDN.

Again, unlike all other broadband mediums, power lines are excellent radiators of the frequencies PLC uses. Copper twisted pair, coaxial cable, and fiber are all inherently non-radiating mediums. It should be noted that twisted pair and coaxial cable do actually radiate to some extent, but in proportion to the amplitude of the signal they are carrying, it is minuscule.

According to radio amateurs and some broadcasters, PLC is said to be a polluter of the radio spectrum, causing a large rise in the `noise floor' in urban areas akin to "radio smog". The American Radio relay league - ARRL has demonstrated the interference effects of PLC on Amateur Radio communications, and also demonstrated strong interference from quite low power HF transmitters into the PLC network, using PLC test sites running in the U.S. Some radio amateurs, according to media reports, complained, and saying streetlights functioned as enormous antenna. Most PLC suppliers use devices called repeaters to amplify and clean up the data signal carried on power lines, and those devices, as well as PLC modems, emit frequencies in the same range as radios used by ham radio operators and some emergency responders, according to the ARRL. Some PLC suppliers are experimenting with devices that use microwave signals, and the ARRL says those devices would not interfere with ham radios.

Broadcasters themselves also have exhibited increased concern about the potential of PLC to prevent their signals from reaching listeners. The Research and Development branch of the British Broadcasting Corporation (BBC) has released a report on a brief trial in Scotland. The two competing PLC systems in operation in the town of Crieff both interfered with HF reception. Tests were conducted at four locations. At the first location, a residence, interference from a Main.Net modem was audible even on very strong broadcast signals. Reception was also significantly impaired at a neighbor's house as well as at various locations in the street between the residence and the substation serving it. This was despite the fact that the main distributor cable was underground.

The BBC engineers described the interference as varying between "'annoying' and a level sufficient to make the broadcast completely unintelligible."

Interference free PLC G-line technology

It now appears there is a technology that will provide faster data rates (demonstrated up to 216 Mbps) than the high frequency systems operating in the 1.7 to 80 MHz range and also eliminate interference to HF operations. The system, developed by Corridor systems-USA, uses microwave spectrum instead of HF frequencies. This new technology can leverage existing low-cost 802.11 chipsets, achieving lower cost than competing PLC solutions. Corridor Systems' technology uses the spectrum between 2 GHz and 20 GHz, avoiding the HF and VHF frequencies entirely.

How can microwaves be transmitted over a wire? Ham radio operators may remember a UHF/microwave transmission line system that used a single wire. This technology, referred to as G-line, used cone shaped launchers at each end of a single wire.

Recently, Corridor Systems has tested and demonstrated simultaneous operation of its PLC technology and amateur radio HF communications. Utilizing a 100 watt, 7 MHz, 21 MHz and 28 MHz amateur SSB/CW transmitter connected to a dipole antenna located within 20 feet of an operating PLC system, there was not any evidence whatsoever of the operation of one system in the other. Amateur UHF communications at 446 MHz and at a 25-watt power level were similarly unaffected and in turn were not detected by the PLC system. Examination of the .1-30 MHz HF spectrum with a quality communications receiver also revealed no evidence of the PLC system

PLC developments around the world

The Homeplug Powerline Alliance (HPA), a U.S. consortium of 90 members, including such high-tech giants as Cisco, Intel, Motorola, and Hwelett-Packard is working on technology to link appliances such as TVs, computers and cookers via the home electrical system.
Last December Intellon announced its PowerPacket powerline networking chipset, the first product certified as compliant with the HPA's 1.0 Specification introduced earlier that year. The chipset allows users to access the Internet and connect computers and other devices at speeds up to 14 mbps by simply plugging into power outlets throughout a home or small office.
Appliance makers like Samsung Electronics Co. have been solidifying cooperation with their technology partners to enable them to market Internet-controllable home appliances year 2004. Samsung plans to set up a “Dream LG” site on its homepage to advertise its Internet-enabled products to potential customers.
However, PLC is in the very early stages of adoption. Systems are installed throughout Europe, USA, Asia, Africa, and New Zealand. Most of these systems are small trials, however commercial roll-out is happening now in Europe and the U.S. More than 150,000 homes have PLC available in the U.S., and Australia is about to adopt PLC technology in October with the help of Development Bank funding ahead of a proposed rollout throughout the nations of the South Pacific. Hong Kong, Malaysia, Singapore, and Indonesia are also adopting the technology. PLC is projected to have 9% of the broadband traffic in Europe by 2008. The news is not all supportive of PLC technology, and Japan has rejected the technology due to interference problems and pending further investigation.

Conclusion
Trends in both the electric and telecommunications industry have lead to a climate where PLC should be a big player. These trends include customer demand for affordable and high speed Internet access, deregulation of electrical utilities, and the repercussions of a variety of telecommunications legislation. Digital PowerLine technology is an exciting alternative to connecting to the Internet via phone and modem. Though this technology is not commercially available yet, it should be available before other broadband technologies due to the relatively low cost of its local loop.
So perhaps it will not be long before the power socket on your wall doubles as a broadband communications gateway. The future will see power-line technology in business data communication applications and particularly in home automation applications.

Side bar items
1. Historical developments in PLC
1950s
The first technique to use power lines to control messages called the "Ripple Control," was developed. This technology used low frequencies (100-00 Hz) giving a low bit rate and a demand on very high transmitter power, often in the region of several 10kW. The system provided one-way communication and was used in the management of street lights, load control and switching tariffs.
Mid 1980s
Investigation of the use of the electricity grid as a medium for data transfer began. Frequencies of 5 to 500 kHz were studies, with the focus on signal/noise levels and attenuation of the signal by the grid.
Late 1980s
Bi-directional communication was developed.
Late 1990s
The transmission of data signals over powerline at reasonable speeds has made advances and has been tested worldwide.
2000s
high speed Internet access via the power line trial is underway in several countries like USA,UK,china,germany etc.
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2 . Advantages of OFDM in PLC
1. Very good at mitigating the effects of time-dispersion,
2. Very good at mitigating the effect of in-band narrowband interference,
3. High bandwidth efficiency,
4. Scalable to high data rates,
5. Flexible and can be made adaptive; different modulation schemes for subcarriers, bit loading, adaptable bandwidth/data rates possible,
6. Does not require channel equalization,

3 . Possible applications of PLC

• Telephony Services: Local and long-distance voice services, including real-time videoconferencing.

• Ease of use: Pre-configured “plug & play” household appliances, preloaded content, “always on” Internet, no need for a PC and technical support/network administration.

• Next Generation Services: E-commerce, home healthcare, distance learning, and more.

• Residential Services: Local and remote configuration of home security, remote automation, HVAC control, and more.

• Bundling of Multiple Services: Single brand and single bill for communications, Internet, information, and entertainment.

4 . Technical Specifications of intellon powerpacket technology

• Integrated Physical Layer (PHY) and Media Access Controller (MAC)

• Data rate: up to 14 Mbps

• Frequency band 4.3 MHz - 20.9 MHz

• OFDM symbol modulation

• 84 carriers

• Automatic channel adaptation

• Forward Error Correction

• Carrier modulation methods supported:

• DQPSK, DBPSK, ROBO

• Access methods supported:

• CSMA/CA

• Meets FCC Part 15 emission standards

• Secure communications

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