Chapter 4. Broadband Technologies

Similar to the diversity found in the number and type of broadband providers, California is home to a number of different technology platforms that are used to deliver broadband to consumers.

4.1 Digital Subscriber Line (DSL)

Figure 4.1
DSL Characteristics

What is it?	Benefits	Limitations	Price[53]
Broadband service that uses the same phone line used for voice service	Widely available and relatively affordable; the leading platform used for broadband service in California	Limited bandwidth potential and transmission range (<18,000 ft.)	$14.95 | $79.95 per month

DSL runs on the traditional wireline network, utilizing the higher frequency spectrum available in a pair of copper telephone wires which is unused by analog telephone services. Upgrading copper loops for DSL services essentially involves installing a piece of new equipment[54] in the telephone company central office, and removing interference generating devices from the local loop.

Depending on a consumer's distance from the central office, DSL can achieve download speeds of up to 8 Mbps, although DSL service providers usually cap the maximum download speed at about 1.5 Mbps and only guarantee a minimum download speed of 384 Kbps.[55] DSL speeds are sufficient to bring streaming video into customer homes and for customers to send out basic information such as video selections.[56] DSL works well as a basic Internet connection, since most residential Internet consumers place greater emphasis on the download speeds needed for surfing the web, downloading files, and sending email messages. Since being introduced in the 1990s, DSL has become the leading broadband

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[53] Prices are for consumer, not wholesale, customers. Broadband pricing can vary greatly depending on a variety of factors: length of contract, speed, equipment (rent or buy), promotional period pricing, existence of market competitors, and bundling with other services (See the discussion of convergence in section 8.2.1 of the report). Generally, costs and prices of all broadband technologies decline as efficiencies due to economies of scale and equipment standardization are realized.

[54] This equipment is called a Digital Subscriber Line Access Multiplexer. The DSLAM allows for the simultaneous transmission of high-speed data and voice services over traditional copper phone lines.

[55] Broadbandreports.com; http://www.dslreports.com/faq/356.

[56] There are other variations of DSL including ADSL, SDSL and VDSL. ADSL, or Asymmetric DSL offers different bandwidth speeds depending upon the direction of the information flow. Data coming from the Internet to the customer's modem will be sent at a higher speed while data coming from the subscriber and going to the Internet is sent at a relatively lower speed or bandwidth. SDSL stands for Symmetric DSL, which offers the same upload and download speed, but would require a pair of dedicated copper loop. VDSL stands for very high data-rate DSL that offer a much higher speed than DSL (52 Mbps) but has a very limited range of less than 4,000 feet.

technology in California and the second leading broadband technology in the national market.

DSL has certain technical limitations. The most significant limitation is the transmission range. As a digital signal is transmitted through the copper loop, the signal suffers from greater distortion the farther it must travel from a provider's central office to the customer. Debilitating signal degradation generally occurs when the local loop length between customer premises and the central office is between 16,000 and 18,000 feet.

DSL had traditionally suffered from other technical limitations, that are now being addressed through technological advances. For example, DSL had previously been limited in its deployment due to the requirement that it operate only in a pure copper environment. However, telecommunications companies have overcome this technical limitation by installing DSLAMs inside remote terminals.[57]

Also, DSL's bandwidth capacity has traditionally limited the ability of DSL providers to offer the same type of "triple play" package, including video, data and voice services, that can be delivered over cable or fiber facilities. However, new compression technologies are being developed that will allow high definition TV to be delivered over existing copper phone lines.[58] In addition, in order to compete effectively with companies offering bundled services, ILECs such as Verizon, SBC and BellSouth have partnered with satellite companies to add video to their bundled services.[59] For a more detailed discussion of the role of Convergence and Service Bundling, please see section 8.2.1 of the report.

4.2 Cable Modem

Figure 4.2
Cable Modem Characteristics

What is it?	Benefits	Limitations	Price
Broadband service that uses the same coaxial cable used for cable television service	Widely available and relatively affordable; the leading platform used for broadband service in the U.S.	Limited future bandwidth potential; not widely deployed to business customers	$19.95 | $49.95 per month

Internet service via coaxial cable became available with the cable television industry's migration from analog to digital TV.[60] In the early 1990s, most of the cable television infrastructure in the United States was incapable of carrying digital TV signals. Upgrades were needed to make coaxial networks capable of delivering digital TV, including a high capacity fiber-optic backbone to carry the increase in data, as well as the capability for two-

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57 CPUC Staff interview with SBC representatives, February 1, 2005.
58 See, e.g., Carol Wilson, "Qbit unveils new compression approach," Telephony Online, January 7, 2005.
59 "SBC, EchoStar Announce Strategic Marketing Alliance," April 17, 2002. www.sbc.com
60 Digital TV programming is digitized and compressed before being transmitted over the coaxial cable, enabling much more programming to be carried over a single coaxial cable.

way data transmission. The cable industry spent more than $65 billion dollars between 1996 and 2002 to upgrade its infrastructure.[61] This new cable TV network architecture, called a hybrid fiber-coaxial (HFC) network, allows high-capacity, digitized, two-way data transmission that is used for broadband Internet services today.

Because of the industry's head start in upgrading its network,[62] cable modem has been the dominant national broadband technology since 2000.[63] At the end of 2002, there were more than 65 million cable television customers in the United States, with more than 10 million of those customers subscribing to cable modem service. By September 2004, the number of cable modem subscribers had grown to more than 19.4 million.[64]

The HFC network architecture consists of a fiber backbone linking the cable company headend to a local distribution node.[65] The local distribution node is where cable TV and cable modem data are converted from optical signals to radio frequency (RF) signals to be retransmitted through coaxial cable to a nearby customer's premise. While the fiber backbone has a capacity of 5 Gbps, only 6 Mhz bandwidth is allocated for cable modem service from the node to the customer. A theoretical 40 Mbps bandwidth is possible over the 6 Mhz bandwidth for each individual cable modem user.[66] This 40 Mbps is shared by all of the cable modem customers serviced by the distribution node, with the possible maximum of 30 Mbps of the 40 Mbps available to each cable modem user under the new cable modem standard.[67] A single node may serve hundreds of customers, so service degradation can occur if many users are connected to the internet simultaneously.[68] Today, most cable modem services promise customers a download speeds of between 1.5 Mbps and 3 Mbps.

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[61] National Cable & Telecommunications Association (NCTA), http://www.ncta.com/Docs/pagecontent.cfm?pageID=96.
[62] MediaOne, since acquired by AT&T and then Comcast, began to offer cable modem service in 1994 in West Los Angeles.
[63] This is not the case for California. DSL service is currently the dominant technology in California.
[64] National Cable & Telecommunications Association (NCTA); http://www.ncta.com/Docs/pagecontent.cfm?pageID=96
[65] A "headend" is a master facility for receiving TV signals for processing and distribution over a cable TV system; http://en.wikipedia.org/wiki/Cable_TV_headend. Headend is also where cable modem data is received and retransmitted to the Internet or the customer's computer. A headend serves a region that can be one city, several cities or part(s) of a city depending on the number of households subscribing to the cable data service.
[66] Working through an industry association CableLab, the cable industry agreed on a common cable modem technical standard DOCSIS 2.0 (Data Over Cable Service Interface Specification), which allocated a cable channel of spectrum for cable modem with 40 Mbps of bandwidth.
[67] Under the previous cable modem standard DOCSIS 1.1, each cable modem customer can achieve maximum download speed of 10 Mbps, DOCSIS 2.0. increases the maximum download speed to 30 Mbps.
[68] Institute of Electrical and Electronics Engineers (IEEE); http://www.spectrum.ieee.org/WEBONLY/publicfeature/jun01/cmode.html. DSL Reports; http://www.dslreports.com/faq/7135.

4.3 Satellite

Figure 4.3 Satellite Broadband Characteristics			
What is it?	**Benefits**	**Limitations**	**Price**
Broadband service delivered through geostationary satellites	Covers all areas with a direct view of the southern sky	Limited bandwidth; providers often limit amount of data downloaded per month; difficult and expensive to add capacity	$49.59 | $99.99 per month

Satellite broadband services utilize geo-synchronized satellites that stay in a fixed point in the southern sky to receive and transmit data to and from satellite broadband customers who must install a satellite dish. The primary advantage of satellite broadband technology is that it is available to customers located anywhere in the U.S. with a direct view of the southern sky. The availability of satellite broadband services makes it technically possible, albeit generally at higher cost ($60 - $80 per month) and lower speed (400 Kbps),[69] for virtually anyone living in the United States to obtain broadband service.

There are one-way and two-way satellite broadband services. One-way satellite broadband service requires a telephone line to send data upstream, while data is downloaded directly from the satellite. Initially, for satellite broadband service, only one-way service was available because satellites at that time were not designed to receive data from customers. Those satellites were designed to transmit TV signals back to earth rather than provide two-way communications required for broadband service. Two-way satellite broadband became possible when a new generation of satellites, designed with broadband service in mind, was placed into orbit in the mid-1990s.

The limitation of satellite broadband services is that its capacity, both in terms of total bandwidth and number of customers, cannot be readily or easily upgraded since it involves launching new satellites into orbit. The architecture of satellite broadband is similar to the architecture of the cable modem HFC network, except satellite uses radio waves instead of fiber and coaxial cable to connect to the node. As a result, satellite broadband service providers limit the amount of data their customers can download and upload each month, and charge additional fees to customers exceeding the monthly cap. Another limitation for satellite broadband service is that it is more susceptible to service interruptions from severe weather conditions.[70]

[69] As compared to typical DSL and cable modem price ($29.95 to $49.95) and bandwidth (1.5 Mbps to 3 Mbps).
[70] Lonestar Broadband, http://www.lonestarbroadband.org/technology/satellite.htm.

4.4 Wireless

Figure 4.4 Wireless Broadband Characteristics				
	What is it?	**Benefits**	**Limitations**	**Price**
WirelessLAN (Wi-Fi / UWB) Wireless MAN (WiMax) 2.5/3G Cellular	Broadband technology using licensed and/or unlicensed radio frequency spectrum for transmission	Low deployment costs and widespread access	Availability of spectrum; technical standards for higher bandwidth and longer range technologies still being developed; licensed spectrum for dedicated services is expensive	Free | $99.99 per month

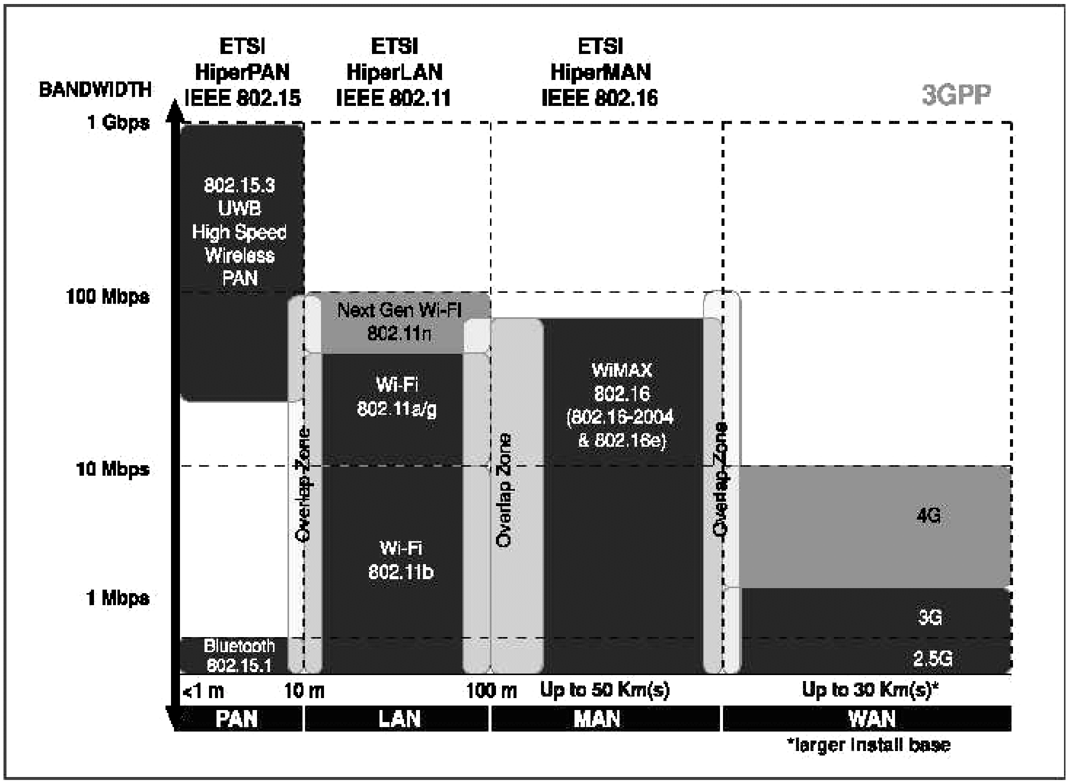
Wireless communications are revolutionizing peoples' lives, enabling consumers to access a high-speed connection to the Internet using virtually any device, at any time, from any location. Wireless technologies being deployed today are as diverse as the ideas for how to use them, from Bluetooth, to hot spots, to wireless Internet backbones stretching hundreds of miles over mountain ranges.

There are four major categories of wireless technologies today that enable high speed connections to the Internet:

- Personal Area Networks (PANs) including Ultra-Wide Band (UWB);
- Local Area Networks (LANs) including Wireless Fidelity (WiFi);
- Metropolitan Area Networks (WANs) including the Worldwide Interoperability for Microwave Access standard known as "WiMAX;" and
- Next-generation cellular technologies also known as "3G" and "4G" such as Verizon Wireless's EvDO and Cingular Wireless's OFDM services.

Each provides a solution to access broadband Internet that varies based on distance, bandwidth and quality of service that can be tailored to meet the specific needs of consumers based on the price, quality and type of usage they need. Each technology is discussed below.

Figure 4.5
Types of Wireless Broadband Technologies



Source: Intel, Understanding Wi-Fi and Wi-MAX as Metro-Access Solutions

4.4.1 Wireless Personal Area Networks (WPAN) and Ultra-Wide Band

Wireless Personal Area Networks (WPANs) use two types of standards: 802.15.1 (also known as Bluetooth) and 802.15.3 (Ultra-Wide Band). Both are designed for very small networks within a confined space, such as a home office, desk, or car. Bluetooth is used primarily for communications and computing peripherals, such as computer to printer or handset to headset. Ultra-wide band provides higher bandwidth (over 400 Mbps) for small networks, which allow multimedia services such as DVD-quality video to be shared wirelessly throughout a home.

4.4.2 Wireless Local Area Networks (WLAN) and WiFi / Mesh-Networks

Wireless Local Area Networks (WLANs) have a broader range than WPANs (up to 100 meters) and are typically found in "hot spots," such as cafes, hotels, airports, offices and home networks. The wireless standard associated with WLANs is IEEE[71] 802.11. Three

[71] Institute of Electrical and Electronics Engineers, www.ieee.org.

versions of the 802.11 standard are commonly used and built into most laptops and mobile devices today:

- 802.11a supports bandwidth speeds up to 54 Mbps
- 802.11b supports bandwidth speeds up to 11 Mbps
- 802.11g supports bandwidth speeds up to 54 Mbps[72]

Wireless Internet Service Providers (WISPs) using directional antennas or implementing "mesh" network technologies have been able to increase WLAN performance beyond 54 Mbps and to cover wider areas (over 10 km) using the 802.11 standard. To extend wireless access nodes, providers still mostly rely on wires or fiber for long distance backhaul to the provider, and from the provider to the core network.

Directional Antennas

WiFi LANs (such as those at Starbuck's "hotspots") use omni-directional antennas that transmit radio frequency (RF) signals in all directions equally. Alternatively, high gain directional antennas can concentrate RF signals primarily in one direction like the beam of a spotlight. By extending the signal across longer distances, these directional antennas can serve as point-to-point links between buildings and access points. These line-of-sight links using directional antennas can be used to bridge last mile gaps, but are sensitive to interference from buildings, mountains and other obstacles.

Mesh Networking

Mesh-network technology extends the range of traditional WLANs by allowing a collection of 802.11 standard "nodes" (an individual laptop or fixed access point such as a hot spot) to interconnect and move data between nodes acting as one "shared" network. In a mesh network (sometimes referred to as "multi-hop" network) small nodes are installed throughout a large area, such as a neighborhood or school, and each acts as a router, transmitting data from one node to the next. One advantage of mesh networks is the use of dynamic path configuration that allows RF signals to navigate around large obstacles, such as mountains or buildings. If one path to the base station is blocked, a transmission using a mesh network will automatically find another path through another node. Another advantage is reliability. In a "single-hop" network, if one node goes down, the entire WiFi LAN network goes down. In a mesh-network architecture, if one node goes down, the network continues to operate by routing data through other nodes.

4.4.3 WMANs, WiMAX and WWANs

Wireless Metropolitan Area Networks (WMANs), also known as WiMAX, use the 802.16 standard and cover a much greater distance than WLANs - up to 50 km. This standard is also referred to as "fixed wireless" because it uses a mounted antenna at the subscriber's site to transmit the RF signal from point to point (or point to multi-point) over long distances. WiMAX uses more sophisticated transmission protocols than the 802.11 standards, which

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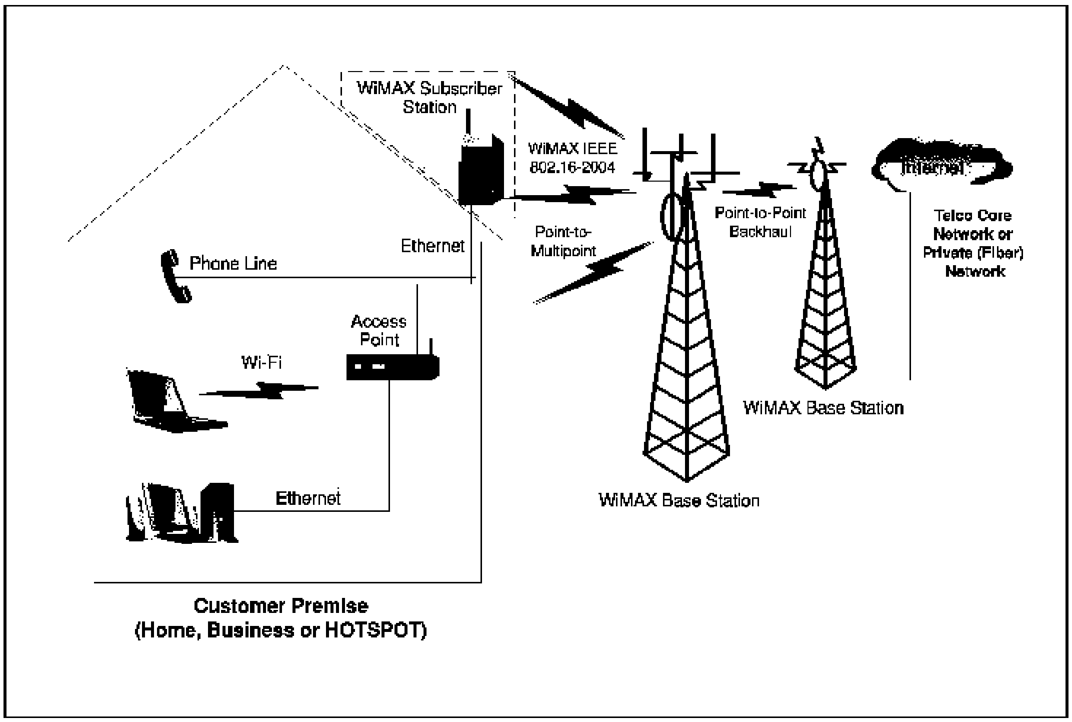
[72] Both 802.11a and 802.11g standards offer up to 54 Mbps in bandwidth but use different radio spectrums and technologies.

result in improved connectivity, network reliability and quality of service. WiMAX therefore serves as a carrier-class solution for the last mile problem - a wireless alternative to cable, DSL or fiber optics. For example, the 802.16 standard enables wireless Internet service providers to guarantee high bandwidth to business customers, and low latency for voice and video applications.

Figure 4.6
WiMAX Network Topology



Source: Intel, Understanding Wi-Fi and Wi-MAX as Metro-Access Solutions

WiMAX can also be used to aggregate WiFi networks (such as mesh-networks and hot spots) and provide long distance backhaul to a core network.

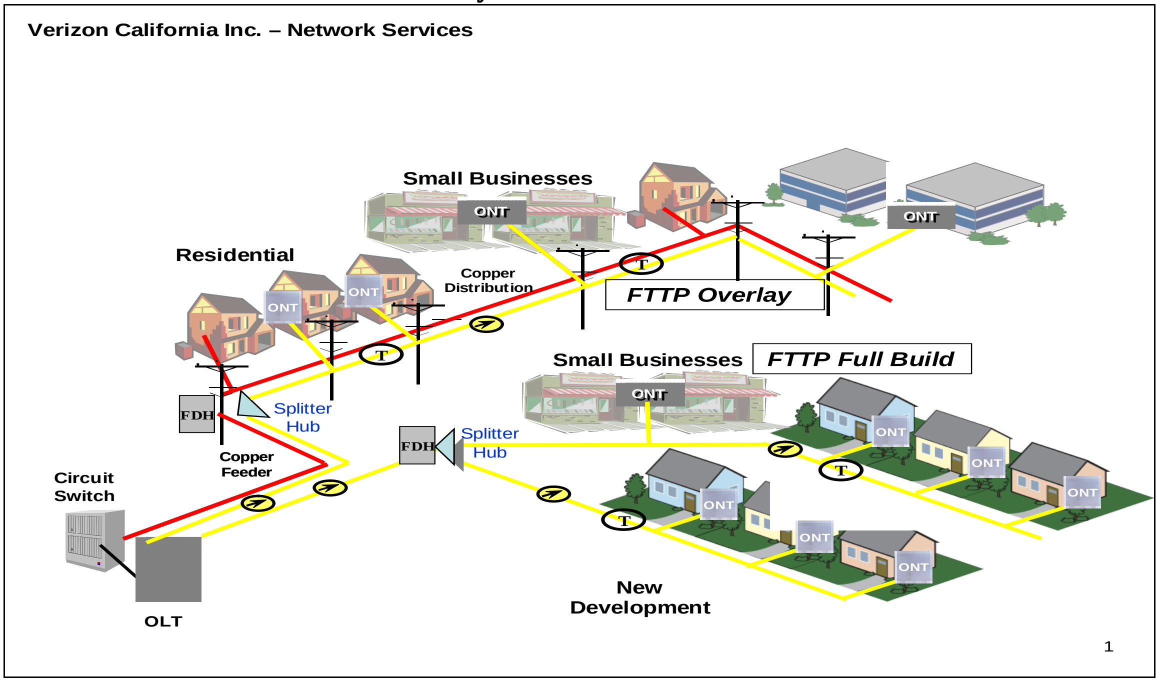
Wireless Wide-Area Networks (WWANs) aggregate WMANs over a large geographic area (over 50 km) using fiber optic or other wired links to connect to the core network, either using WiMAX point-to-point transmission for long distance backhaul or connecting directly to a fiber node.

4.5 Fiber-to-the-Premises

Figure 4.7 FTTP Characteristics			
What is it?	**Benefits**	**Limitations**	**Price**
Broadband service delivered through fiber optic cable	Great bandwidth potential	Expensive to deploy, especially for laying underground lines	$34.95 | $49.95

Fiber-to-the-Premises (FTTP) is a telecommunications network architecture currently being developed by the ILECs and others (including Broadband Overbuilders), to be the next generation of broadband technology. FTTP takes advantage of the extensive fiber backbone network that ILECs have built out over the years and further extends it into customers' homes and businesses. Under the current FTTP architecture, B-PON (Broadband Passive Optical Network), up to 32 customers can be served by a single optical node with a minimum bandwidth of 19.4 Mbps per customer. However, depending on the number of others online at the time, each subscriber could access the entire fiber node's bandwidth of 622 Mbps.[73]

Figure 4.8
FTTP Overlay & Greenfield Architectures



73 Renee Estes, SBC Laboratories Inc., "Fiber-to-the-Premise – Broadband Optical Passive Network," presented at CENIC conference on March 17, 2004.

The present FTTP standard can be upgraded to 1.2 Gbps, and a new standard offering speeds 2.4 Gbps, called GPON (Gigabyte-Capable Passive Optical Network) is near adoption by the industry. One of the great advantages of fiber is that bandwidth upgrades are achieved simply by installing new equipment at the ends of the fiber facilities.

The primary barrier to deploying FTTP is cost. The per-unit cost of deploying FTTP has dropped from $7,500 per home in the mid-1990s to $1,600 in 2002, and to $1,350 in 2004. This is the main reason that SBC, Verizon, and BellSouth chose a set of common FTTP technical standards, hoping equipment standardization and the combined economy of scales would drive the deployment cost down even further. Verizon estimates that deploying FTTP to its customers in all of its 29-state territory will cost between $20 and $40 billion.[74] There is a significant cost difference between overhead and underground fiber deployment because of the additional costs associated with trenching and digging up streets to bury fiber underground.

Despite the costs, fiber deployments are being made throughout the country. A recent survey indicated a significant increase in FTTP deployments in the United States, almost doubling in number in a six month period - from 78,000 homes in March 2004 to 146,500 homes in September 2004.[75] In California, Verizon has already begun FTTP deployment in the cities of Huntington Beach and Murrieta.[76] SBC developed one of the nation's first FTTP deployments in 2001 for the San Francisco Mission Bay community.[77] SureWest, recognized as one of the nation's leading independent providers of fiber, is deploying FTTP service in Sacramento in direct competition with SBC and the local cable company, and is estimated to be terminating fiber at approximately 30,000 homes.[78]

4.6 Broadband Over Powerline

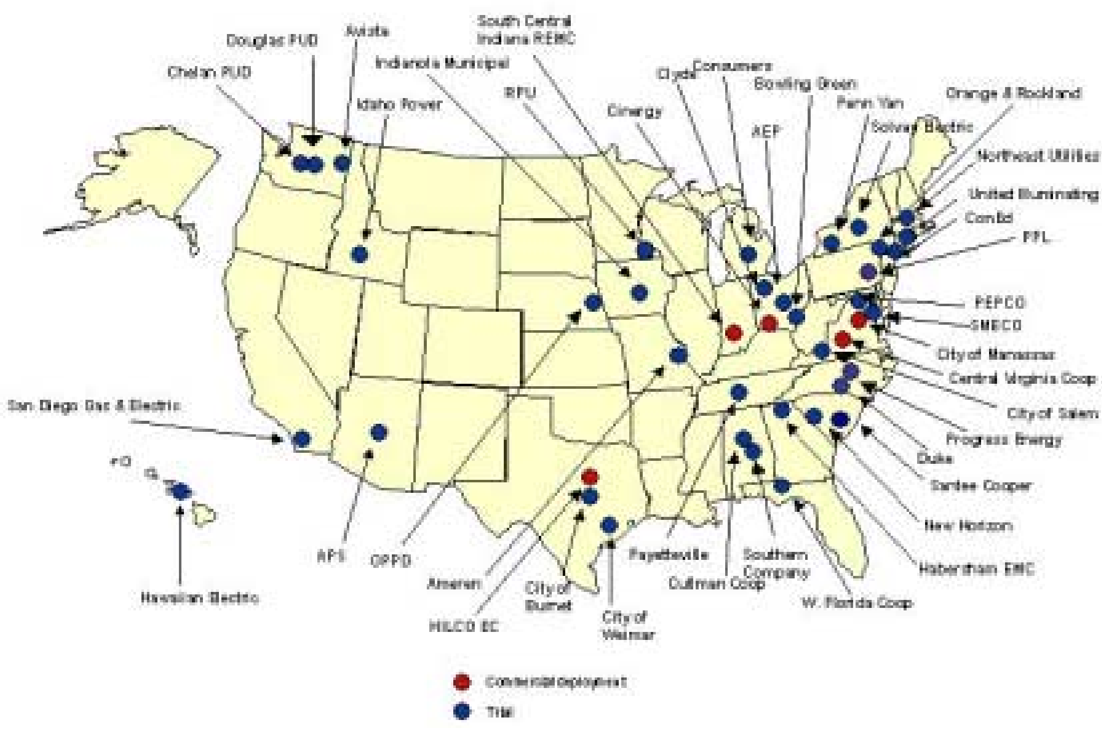
Figure 4.9
BPL Characteristics

What is it?	Benefits	Limitations	Price
Broadband service delivered through the electric distribution system.	Should have relatively low deployment cost and time since BPL utilizes the existing electric grid	Still in development/trial stage. Interferences to and generated from BPL is a potential hurdle	$27.00 | $49.95

[74] Steve Rosenbush, "Verizon's Gutsy Bet," BusinessWeek, August 4, 2003.
[75] Vince Vittore, "IOCs," Telephony, February 28, 2005.
[76] Verizon News Release, July 19, 2004. http://newscenter.verizon.com/proactive/newsroom/release.vtml?id=86053
[77] SBC News Release, June 22, 2004; http://www.sbc.com/gen/press-room?pid=4800&cdvn=news&newsarticleid=21207.
[78] Vince Vittore, supra.

Broadband over Powerline (BPL) is the provision of broadband service over existing electricity distribution wires using the higher frequency bandwidth of those wires. The BPL signal is separated from the electric transmission before it reaches the transformer located on the pole outside the customer premise. It is then sent directly through the customer's wall sockets to equipment located at the premise, allowing a customer to access the Internet by plugging a computer into any electrical socket. Alternatively, BPL can be used to transmit broadband through the power distribution poles, with a wireless connection between a transmitter on the pole and the customer's computer used to achieve the final connection. This is feasible since electric poles are usually no more than 100 feet from people's homes, which is suitable for present Wi-Fi technologies. BPL offers similar bandwidth as DSL and at comparable prices, based on information from the few communities where BPL is in operation. The full bandwidth potential of BPL is not known, however, since it is still early in its development and deployment when compared to other broadband platforms. It is reported that new technologies will permit BPL to provide broadband at bandwidths of up to 200 Mbps by the summer of 2005.[79]

Figure 4.10[80]
BPL Projects and Trials in the United States



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[79] Ed Gubbins, "New Reports Suggest 2005 As Critical to Growth of BPL," Telephony, February 28, 2005, p. 9.
[80] United Telecom Council, www.utc.org.

The country's first city-wide commercial BPL deployment will be finished in April 2005 in the city of Manassas, Virginia. ComTek, the company offering the service received a license from the city and is providing BPL over power lines owned by the city Utilities Department.[81] ComTek has stated that more than 10% of the homes passed by its network have decided to take the 500 kpbs symmetrical service, which ComTek is offering for $29 per month. ComTek expects to achieve 20% to 30% pentration among the city's 12,500 homes and 2,500 businesses in the very near future.[82] Cincinnati, Ohio is another city with an active BPL deployment. That project is a joint venture between Cinergy, the local electric utility, and Current Communications, a BPL service provider.[83] Current Communications is also actively looking to commence a BPL project in California in the near future, although no specific plans have been announced.

About 100 residents of Menlo Park, California were to get 3Mbps BPL broadband and VoIP service as part of a trial co-sponsored by Pacific Gas and Electric Company (PG&E) and AT&T. AT&T dissolved the project in October 2004, four months after it was announced in July 2004.[84] PG&E has advised CPUC staff that it is still interested in exploring deployment of BPL technology but currently has no partner or active BPL project. At the Commission's Full Panel Hearing on this Report on February 8, 2005, San Diego Gas & Electric Company (SDG&E) publicly stated that it was moving forward with a BPL pilot project in its service territory in the near future.[85] The exact scope and nature of this pilot project is still being considered by SDG&E, but the service could potentially reach all 1.3 million customers in its service territory.[86]

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[81] http://www.powerline-plc.com/newsreleases/City_Of_Manassas_Utility_Connection_11_03.pdf
[82] Gubbins, supra.
[83] http://www.cinergy.com/News/default_corporate_news.asp?news_id=420.
[84] http://www.dslreports.com/shownews/48889;
http://www.arrl.org/news/stories/2004/10/21/100/?nc=1.
[85] Transcript of California Public Utilities Commission Full Panel Hearing on Broadband Deployment, February 8, 2005.
[86] Craig Rose, "SDG&E Explores Offering Web Access," San Diego Union-Tribune, February 10, 2005.