Bridging the Last Mile
California's Wireless Internet Providers

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While high speed Internet is available in almost every major community within California, there are still 1.4 million homes and businesses, mostly in rural communities, that are unable to receive a broadband connection.[1] One of the solutions available to connect these residents is wireless Internet service. While the recently released report by the California Broadband Taskforce examined both wired and mobile wireless broadband services across the state, this paper will focus on the status of fixed wireless Internet service providers (WISPs) in California.

Network Architecture and Terminology

Californians can access the Internet through either wired or wireless technologies. Regardless of the technology employed there are usually three steps that information must take to reach the "Internet" from the end user. [1] The first is the "backbone." This is a high speed connection that connects the local Internet service provider servers to the rest of the Internet. The second step is the "backhaul." This connects the local ISP servers with distribution nodes throughout the ISP's network. The final step is the "last mile." This is the link between the distribution node and the end user. When an end user contracts with a service provider for broadband access it is the technology used for the last mile connection that primarily differentiates the network carriers.

This report is intended to provide policymakers and other interested parties with information about the WISP community in California. The paper explains the basic technical elements of WISP infrastructure and architecture, but focuses on explaining what WISPs offer, where they provide service, and the challenges the providers have identified in

developing a viable business model. This research does not contain any policy recommendations and should be viewed as background material that can further the broadband availability discussion.

Fixed wireless Internet service providers (WISPs) contribute to California's broadband market either by acting as the sole local broadband provider or by increasing competition among providers in a community. In a survey that was conducted for this report, almost half of the WISPs that responded indicated that consumers in rural communities are their primary subscribers, and 70% (9) report that they compete with wireline broadband services in some portion of their service territory.

Wireless Internet Services

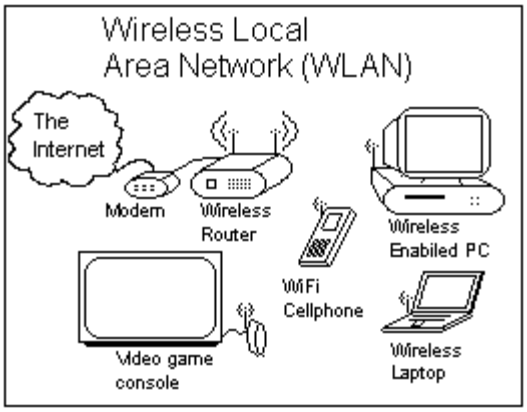
There are two types of wireless Internet services available to consumers, mobile wireless and fixed wireless; consumers need to select a service that best suits their needs.

Mobile wireless is the more prevalent of the two services.[2] This market is dominated by national carriers such as AT&T, Verizon Wireless, T-Mobile and Sprint. Mobile broadband technologies enable users to access the Internet via a mobile handset, a smart phone, or a wireless modem card connected to a laptop computer or PDA.[3] Mobile wireless can allow a user to access the network while indoors or while traveling in a car. These mobile wireless networks are made up of thousands of antennas whose large overlapping coverage areas are networked together. This allows for the connection to a mobile device to be passed from one antenna to another as the user moves throughout the coverage area.

Fixed wireless is a much smaller segment of the market. Most fixed wireless operators are smaller, locally owned businesses. Fixed wireless broadband connections enable users to connect to the Internet through a Wireless Local Area Network (WLAN) using the wireless network adapter in their computer or a Wireless Wide Area Network (WWAN) using a modem and antenna on their rooftop. Unlike the mobile wireless networks, fixed wireless places mobility limits on users. WLAN broadcasts in a much smaller coverage area while WWAN requires a stationary line-of-sight or near line of sight to the network antenna. In exchange for these limitations fixed wireless offers a faster, perpetual connection. With some exceptions WISP business models are predominantly built on WWAN connections with WLAN being more of a consumer or end user application.

Wireless Local Area Networks (WLAN)

Wireless Local Area Networks (WLANs) are short range wireless networks that are used both commercially and residentially. WLANs commonly use a network router that has been attached to a radio transceiver and a small antenna called a whip. This is the networking technology typically used in environments such as school campuses, homes, hotels, airports and coffee shops. Networks of this type that are available for public use are called "hotspots."[4] Many devices throughout the home and office such as wireless printers, video game systems, and even some new wireless phones operate on a WLAN.

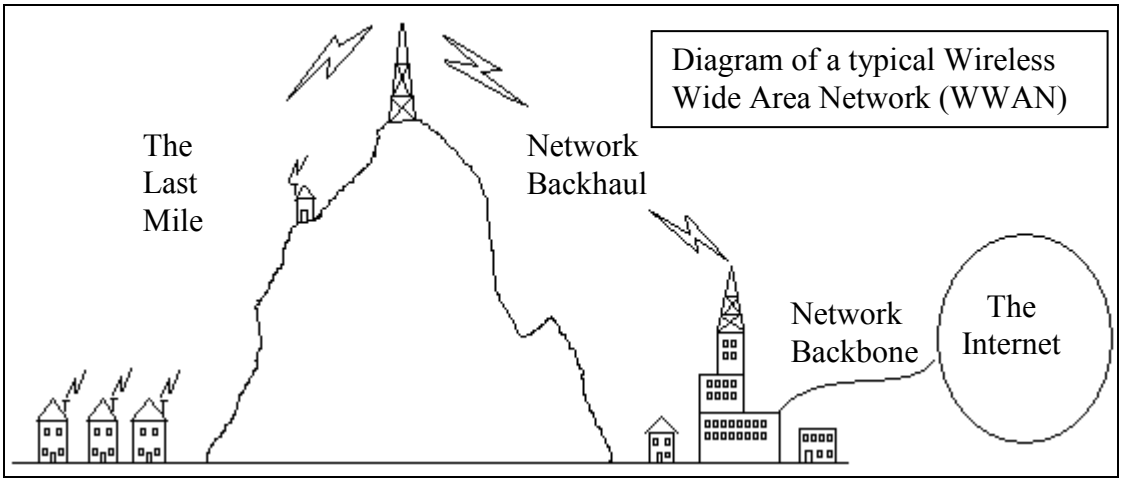


The most prevalent WLAN equipment is manufactured in accordance with the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard, commonly known as "Wi-Fi," short for wireless fidelity.[5] WLAN's predominantly operate in the unlicensed spectrum of 2.5 GHz and 5 GHz. WWAN standard communication speed is 54 Mps. Typical residential wireless routers can transmit approximately 150ft (46m) indoors and 300ft (92) outdoors. Some high power wireless routers are available on the market. Federal law limits the maximum transmission power of these wireless routers (or any unlicensed device) to 1 watt.[6] At this maximum power, using standard whip antennas and without physical or electronic interference, a commercial Wi-Fi network router can create a cloud of connectivity with a range of approximately ¼ mile.[7]

WLAN can be used in many situations. When a business, like a coffee shop, wants to offer a pay-per-use hotspot connection at their location, some Internet service providers will lease equipment and bandwidth to the business at a discounted rate in exchange for advertising. Wi-Fi is also the architecture predominantly used by municipal wireless Internet service providers. Because of the prevalence of IEEE 802.11 compatible networking devices in consumer products, few users need any additional equipment to connect to these networks.

Wireless Wide Area Networks (WWAN)

The other type of fixed wireless Internet service is Wireless Wide Area Networking (WWAN). WWAN uses directional antennas to transmit a broadband signal that can range up to five miles in unlicensed frequencies and 30 miles if licensed.[8] The wireless Internet service provider uses a network distribution node and an array of antennas to connect to users using rooftop directional antennas. The node and antenna array are usually located on a high point such as hilltop, tower or large building. Once the customer has made the link to the WWAN they can further subdivide this connection into several wired or wireless local area networks.



The transmissions that connect a distribution array to the user can be in the 900 MHz, 2.5 GHz or 5 GHz bands or, with additional registration by the FCC, in the 3.65 GHz band.[9] Each of these frequencies has different characteristics. Some of the differences between these frequencies are: lower frequencies can travel farther at the same power level and they are slightly less susceptible to interference; as opposed to higher frequencies which can better penetrate walls and bounce around corners. [10] From the antenna array the signal is then sent through the network backhaul, either as another wireless transmission or as a fiber optic signal back to the ISP's central server. The recently developed IEEE 802.16 WiMax standard is the protocol that is being adopted by many operators for these wireless transmissions. Other operators use proprietary protocols developed in-house or acquired from third party developers.

A wireless Internet service provider can create large coverage areas with relatively low infrastructure costs by linking multiple antenna arrays. Using a network of antenna arrays, a WISP can serve several valleys from a few mountain tops or an entire residential subdivision from a water or broadcast tower. Each antenna array is commonly comprised of several directional antennas positioned so that their coverage areas slightly overlap. Any user who has a line of sight, or near line of sight, from their location to the antenna array and the appropriate equipment is capable of receiving a signal. The customer will need a modem and directional antenna supplied by the WISP. There may be additional fees included with the use or purchase of equipment.

WISP Survey

Between March 28th and April 30th the author conducted an Internet survey to ascertain the status of WISPs within California. The survey focused on the costs, data rates, and network architecture of the WISPs. A copy of the survey is included in Appendix 1. 48 wireless providers were invited to participate in the survey; 13 (27%) responded. Some respondents did not answer all of the questions. Although this limited sampling is statistically insignificant it does offer some insight into market conditions and network topology.

Customers

The survey asked the WISPs to provide a general range of the number of clients they serve. Their responses were divided between business and residential customers. While 8 of the respondents (72%) serve between fifty and five hundred residential customers, 1 WISP (9%) reports to serve more than one thousand homes and 2 WISPs (18%) claim to serve less than ten. On the business side, the responses were slightly more diverse. 4 WISPs (40%) report that they have less then one hundred business clients, 3 (30%) of those with less than fifty and 1 (10%) with less than ten. 6 WISPs (60%) also report serving more than one hundred business customers; of those, 3 (30%) serve more than five hundred and 2 (20%) serve more than one thousand. This wide range of customers served by WISPs show that several different business models are capable of supporting WISP operations. Additionally, the data shows that that having a high number of customers may not be necessary in order for a WISP to be profitable.

Number of business customers	Number of WISPs	Number of residential customers	Number of WISPs
<10	2	<10	1
10 – 50	0	10 – 50	2
50 – 100	3	50 – 100	1
100 – 500	5	100 – 500	3
500 – 1000	0	500 – 1000	1
1000 – 5000	1	1000 – 5000	2

Connection speeds

Data rates available through fixed wireless Internet connections are impacted by a multitude of variables such as interference, signal degradation, and network congestion. Thus, the connection speeds achieved by different customers can vary significantly. Most respondents report speeds that exceed their advertised data rates and in some cases exceed their wireline competitors.[11]

Data transfer speeds can be measured in several ways. One of these methods is a "ping;" this measures the amount of time it takes for a single packet of information to be sent out to another computer, a website server for example, and then for a response to return. Other methods measure the one-way transfer of large amounts of information such as downloading a movie or uploading an email with a large attachment. These upload and download speeds can be measured separately or combined into a single throughput speed. Historically, Internet service providers place the majority of their bandwidth into download transfers. This is because the typical end user is more likely to be downloading content rather than uploading. Additionally, moving information toward the user was technologically more feasible when serving multiple users on a single multiplexed connection. Recently this trend has started to shift to more equal upload and download speeds. This is a result of changing usage by the customer and new technological developments, specifically in fiber optics.

For the purposes of the survey the WISPs were asked to provide separate upload and download speeds for both business and residential customers. As the graphs show, WISPs operate in a wide range of

data transmission speeds. For their residential customers, the WISPs surveyed report upload and download speeds between 256Kbps (Kilobytes per second) to more than 5Mbps (Megabytes per second). Of the 13 respondents; 2 (15%) have download speeds between 256Kbps and 512Kbps, 4 (30%) download from 512Kbps to 1Mbps, 3 (23%) download between 1Mbps and 3Mbps, 3 (23%) more download between 3Mbps and 5Mbps, leaving 1 (7%) WISP to offer download speeds in excess of 5Mbps. Upload speeds are generally slower with 7 (53%) WISPs offering between 256Kbps to 512Kbps, 2 (15%) WISPs uploading between 512Kbps and 1Mbps, 1 (7%) between 1Mbps and 3Mbps, 2 (15%) upload between 3Mbps and 5Mbps and only 1 (7%) WISP offering residential upload speeds in excess of 5Mbps.

Business services tend to be slightly faster than residential with the majority of the respondents reporting higher speed ranges as well as higher maximum speeds. Only 1 (7%) WISP reported business rate download speeds between 256Mbps and 512Mbps. 4 (30%) are downloading between 512Kbps and 1Mbps, 3 (23%) between 1Mbps and 3 Mbps, 1 (7%) downloads between 3Mbps and 5Mbps, 3 (23%) more offer between 5Mbps and 10Mbps and 1 (7%) maxing out in excess of 10Mbps. Upload speeds are also faster for business services. 2 (15%) of the WISPs offer upload speeds in the 256Kbps to 512Kbps range, 3 (23%) between 512Kbps and 1Mbps, 4 (30%) are in the 1Mbps to 3 Mbps upload range, 1 (7%) between 3Mbps and 5Mbps, 2 (15%) more are uploading between 5Mbps and 10Mbps and 1 (7%) capping the group with upload speeds in excess of 10Mbps.

Residential data rates offered by WISPs	**Number of WISPs, download**	**Number of WISPs, upload**
256 - 512 Kbps	2	7
512 – 1 Mbps	4	2
1 - 3 Mbps	3	1
3 - 5 Mbps	3	2
5 - 10 Mbps	1	1
More than 10 Mbps	0	0

Business data rates offered by WISPs	**Number of WISPs, download**	**Number of WISPs, upload**
256 - 512 Kbps	1	2
512 - 1 Mbps	4	3
1 - 3 Mbps	3	4
3 - 5 Mbps	1	1
5 - 10 Mbps	3	2
More than 10 Mbps	1	1

Monthly Price and Start-Up Costs

The survey continued dividing the research regarding WISP prices between residential and business customers. The questions further subdivided the costs between one time startup costs and recurring monthly charges. Many of the WISPs offer tiered service plans for higher data rates. The survey only requested information regarding the lowest cost to receive a connection. For their residential customers the majority of WISPs, 6 (54%), charge between $200 and $300 to install and activate service. 1 WISP (9%) reports a startup price between $150 and $200 while another 1 (9%) charges more than $300 for service activation. Conversely, 3 (24%) of the WISPs charge less than $60 to start the service and of those 2 (16%) charge less than $20.

Residential service rates	Number of WISPs who reported startup costs	Number of WISPs who reported monthly costs
< $20	2	2
$20 - $40		4
$40 - $60	1	3
$60 - $80		2
$80 - $100		1
$100 - $125		
$125 - $150		
$150 - $200	1	
$200 - $300	6	
> $300	1	

Business service rates	Number of WISPs who reported startup costs	Number of WISPs who reported monthly costs
< $20	3	
$20 - $40		1
$40 - $60		4
$60 - $80		4
$80 - $100		1
$100 - $125		
$125 - $150		
$150 - $200	2	2
$200 - $300	4	
> $300	4	

WISPs in California offer a range of monthly residential price points. 2 (16%) of the providers reported offering service at $20/month or less, 4 (33%) of the providers charge between $20-$40/month. 3 (25%) offer service between $40-60/month, and 3 (25%) charge between $60-100/month.

Activation and recurring fees for business customers are slightly higher and correspond with the increased data transfer speeds that business clients receive. Of the 13 total respondents 3 (23%) charge business customers less than $20 to activate service. Of the other 10 respondents all charge above $150 for their startup costs. 8 (61%) of them charge more than $200 and 4 (31%) charge more than $300 to begin providing service.

Monthly service prices for business customers are generally between $40 and $80 a month. 1 (8%) WISP charges between $20 and $40 a month. 4 (33%) provide service in the $40 to $60 range, while 4 more (33%) are between $60 and $80 a month. 1 (8%) offers service in the $80 to $100 range and the last 2 (16%) charge between $150 and $200 for monthly business service.

The survey respondents report service activation costs that tend to be somewhat higher for WISP customers than many wireline providers.[12] This is likely due to equipment costs and mandatory professional installation. Monthly usage costs are much more comparable to wireline competitors. Additionally, 3 (23%) respondents also offer some form of free access to their network hotspots.

Competition

9 (69%) respondents reported that wired Internet services such as Cable Internet, Digital Subscriber Line (DSL) or Fiber To The Premises (FTTP) are available somewhere within the same market as the WISP. Cable Internet leads the group with 9 (69%) respondents; DSL follows with 8 (61 %) and finally FTTP with 2 (15 %) respondents. Although WISPs can have network service areas that overlap wireline service areas, there are many customers served by WISPs who are unable to receive a wireline connection. Outlying addresses, construction sites and remote emergency services are examples of locations that need high speed Internet access but may not be connected to a broadband network. This capability to serve rural consumers as well as those who would not have a connection otherwise make it possible for local WISP operators to compete with larger Internet service providers.

WISPs also compete with another industry when targeting underserved rural customers, satellite Internet service providers. Companies such as WildBlue and HughesNet offer a broadband connection to virtually any subscriber in North America with a view of the Southern sky. Connections through satellite networks typically run between 512K and 1Mbps for residential services and up to 1.5Mbps for business class.[13] This connection is more than sufficient for typical Internet usage such as web browsing, online shopping, and email; however, it is not appropriate for higher speed demands of website hosting or FTP file serving. Satellite connections do have an inherent latency do to the distance that the signal must travel. This delay can cause disruption in applications that are very time

sensitive such as Voice over IP (VoIP) communication, real-time stock trading or some multiplayer online gaming.[14]

Government partnerships

Almost all of the WISPs who responded to the survey reported that they have contracts with government agencies; 89% (8) of WISPs have local government clients, 55% (5) have state government clients and 11% (1) reported contracting with the federal government. WISPs reported that they provide Internet access to emergency responders such as police, fire, and forestry agencies as well as local schools and government administrative facilities. One respondent reported having a contract to provide comprehensive network service bridging multiple law enforcement agencies and jurisdictions in a major California city. Some WISPs have traditional contracts with government while others provide network service in exchange for tower access or decreased taxes.

Challenges faced by WISPs

Respondents to the survey, 83% (10), reported technological and regulatory challenges they are currently facing. The first is a lack of high speed backbone connectivity. Several WISPs in remote parts of the state report limited or no access to high-speed backbone connections; which are required to move traffic back and forth from the WISP to the Internet at large. The demand for backbone connectivity in rural areas is often so high that even when access is available, rural WISP operators often pay much higher lease rates than urban providers. Respondents report that this lack of connectivity and high overhead cost limits their ability to expand despite a growing client base and increasing bandwidth demands on their networks.

Compounding the problems of high cost and limited access to backbone connectivity, rural WISPs also lack an existing large subscriber base that, unlike their urban counterparts, prevents them from diffusing the costs of backbone investment among many users. Thus rural WISP operators have a higher overhead than urban operators and less opportunity to invest in upgrading their backbone connection. This impacts the company's profitability and limits a WISP's resources and capability to face future challenges.

Another obstacle reported by the providers is that communities often require local WISP operators to meet the same standards for their towers and antenna arrays as digital voice (cell phone) network providers. The technology used in a cell phone tower is significantly more complex and transmits in high power, regulated frequencies. One of the survey respondents report that building their Wi-Fi instillation to matching standards as the cell phone tower increases its infrastructure overhead by as much as 300%.

Many WISP operators report problems gaining access to hill and mountain tops that are necessary to provide service to the surrounding communities. Such locations can be regulated by a multitude of different state and federal agencies, each with its own access and Rights-of-Way standards. Navigating these regulations can be especially burdensome for small businesses who have limited personnel and resources.

One of the largest problems WISP operators face is signal interference. The portion of the spectrum that is unlicensed is used by many different types of technologies. Transmissions from devices such as cordless phones, garage door openers, microwave ovens and wireless microphones can corrupt the data within a packet on the same frequency. This means that layers of redundancy must be built into the network to ensure that any corrupted data is identified and replaced. While these steps increase a networks quality of service, they also increase latency or cause delays in data delivery.

Conclusion

There are more than 50 independent WISPs operating in California. They provide a valuable service to residential and business clients and sometimes serve as the sole provider in California's rural communities. As the survey found, some WISP startup costs can be high compared to the larger wireline broadband providers. Given the high poverty rates often found in rural areas, more research should be done to understand the impact of cost on broadband adoption in these communities.

Additionally, it would be beneficial to research differing business models for WISPs and the extent to which they could profitably expand into even more hard-to-reach regions. This analysis should include WISP profit margins, potential for infrastructure investment and probable adoption rates of likely customers. Finally, implications from the recent FCC auction of the 700 MHz spectrum blocks will also need to be analyzed as next generation wireless networks are deployed.

Map of California WISPs:

Using information available online, the Broadband Initiative has developed a draft map of WISPs operating in California. Stakeholders are welcome to add or edit information. The map can be reached here: http://tinyurl.com/5cznku. Note: Because this map may be edited by any stakeholder, the State of California cannot guarantee the accuracy of the information contained herein.

Antenna photo courtesy of The National Science Foundation and the University of California, San Diego

http://www.nsf.gov/od/lpa/news/press/images/hproute2_big.jpg

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