New America Foundation

Spectrum Policy Program

April 2004

Unlicensed Wireless Broadband Profiles

Community, Municipal & Commercial Success Stories

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Introduction

In recent years, the license-exempt bands have been the font of astounding economic growth in the telecom sector and expanded opportunities for broadband Internet access for hundreds of thousands of Americans. In 2003 alone, an estimated 22.7 million wireless access points and networking cards using unlicensed spectrum were shipped, generating over $2.5 billion in revenues.[1] The wide-scale adoption of WiFi technology (short for "Wireless Fidelity," but referring to the 802.11 engineering standard for wireless local area networking) largely explains the success of the unlicensed bands. But merely attributing the success of unlicensed spectrum to WiFi overlooks the diverse variety of applications that exist because of the shared spectrum protocol employed in the unlicensed bands.

Unlicensed wireless broadband is not only a technology of immense promise, it is also a demonstrated protocol for a more efficient and equitable allocation of the public airwaves. License-free access, characterized by low-power frequency sharing and the use of smart radio devices, represents a movement of both technological, political, and social importance, the likes of which the spectrum policy community is only now beginning to fully understand. This paper attempts to describe just a few of the more prominent success stories, as they exist on the community level and among municipal and commercial broadband access providers.

The following profiles focus on how and why community networks and commercial Wireless Internet Service Providers (WISPs) have taken advantage of open and shared access to the unlicensed bands to bring high-speed Internet access – and sometimes community Intranets – to rural and low income areas nationwide. The paper is intended to demonstrate the diversity of environments, organizations, and applications in which unlicensed wireless is deployed. It is by no means a comprehensive or complete compendium of case studies, but merely the tip of the unlicensed iceberg.

This document is organized in three sections: 1) Community Networks; 2) Municipal Networks; 3) Commercial Networks. Each section includes a summary of activity in that sector and a few representative profiles illustrating how these networks are built and their applications.

[1] *See* In-Stat/MDR, "Joe Schmo Has Wi-Fi: The Wireless Home Becomes a Reality," [report] December 2003. *Also see* Synergy Research Group, WLAN Market Eclipses $2.5 Billion Mark, Press Release for Report, February 11, 2004: Available at http://srgresearch.com/store/press/2-11-04.html.

Community Broadband Networks Using Unlicensed Spectrum

Profiles Include:

- Champaign-Urbana Community Wireless Network
- The Southern California Tribal Digital Village
- The Bay Area Research Wireless Network
- NYCwireless.net
- EastServe Metropolitan Area Wireless Network
- Rural India: FirstMile Solutions Mobile Access Points

In the past three years, the technology press has extensively covered the business of WiFi and the commercial successes brought about by the unlicensed bands. But lost within all of this economic success are the social and community benefits of unlicensed spectrum and pervasive connectivity. All across the country, educational leaders, community activists, and ordinary citizens are building free, open-access wireless networks in an effort to make their communities more livable. Recent research on wireless community networking suggests that there are over 50 recognized WiFi Cooperatives in the United States, Europe and Australia that are providing affordable, high-speed Internet access to users in the last mile.[2] The most renowned include the Champaign-Urbana Community Wireless Network, the Bay Area Research Wireless Network, NYCwireless.net, SeattleWireless.net, Austin Wireless City, and dozens of other well-organized, volunteer organizations that are actively spreading unlicensed access to urban, suburban and rural communities. Countless other less-publicized, ad hoc networks have also been started; and anyone with a WiFi sniffer on their laptop can attest that free networks are not difficult to find.

So is there something more to this emerging movement beyond free WiFi for laptop-endowed road warriors and Starbuck's denizens? The network profiles below suggest that we are still in the nascent stages of the community wireless movement, but the social benefits of ubiquitous, community broadband are becoming obvious:

- Improved access to education resources for students, parents and teachers *(see the Rockwood Area School District network profiled in the next section)*
- Equitable and efficient distribution of costly, wired high-speed Internet connections *(see the Mesh networking example of CU Wireless, below)*
- Expansion of community resources, such as library facilities and technical expertise *(see BAWRN and Southern California Tribal Digital Village, below)*
- Building the platform for future e-government initiatives; public health and social service knowledge building; civil society development and community and individual expression and freedom of speech.

But perhaps what comes through most clearly from the following profiles, and the dozens of other cases to be explored, is that unlicensed spectrum and affordable wireless

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[2] See Sandvig, C. (forthcoming), "An Initial Assessment of Cooperative Action in Wi-Fi Networking," *Telecommunications Policy. Available at* http://research.niftyc.org/Initial_Assessment_of_Coop.pdf

technologies have given each of these communities the ability to address a pressing need for bandwidth for themselves. For the following community networks, unlicensed spectrum has unleashed a spirit of community ingenuity and initiative that should be the basis for great local innovations to come.

Profile 1:
Champaign-Urbana Community Wireless Network
An Affordable Metropolitan Mesh Network

Across the country, a number of unlicensed wireless community networks have independently emerged to provide free wireless access to the public. Most of these networks are started by early WiFi adopters using inexpensive, off-the-shelf routers to provide access to anyone within distance of their access points. While some community networks have volunteer members who provide technical expertise to help new users install public access points (NYCwireless, Austin City Wireless, Seattle Wireless and others), few have developed their own technology to bridge the last mile. The Champaign-Urbana Community Wireless Network (CU Wireless), however, is trying to reinvent the community wireless model, by developing an open source mesh network built with recycled computers and 2.4 GHz antennas that can be implemented in underserved areas everywhere.

The project began in 2000, when members of the Urbana-Champaign Independent Media Center, a non-profit, community technology center in Champaign, Illinois, wanted to find inexpensive way to extend the reach of their technology center and provide broadband Internet access to a wider population. While WiFi routers and wireless cards were just entering the market, Independent Media center volunteers wanted a network technology that would connect users to each other and grow into underserved populations around the area. With funding assistance from the Open Society Institute, CU Wireless programmers designed and launched a mesh architecture network designed to be easily replicated at a low cost in developing economies.

The mesh technology used in the CU Wireless network employs a very different network than the access-point (hub and spoke) architecture used by most community networks. Typical WiFi networks provide shared bandwidth to a number of different users who connect directly to a centrally located access point. If multiple users are connected to the access point at the same time, those users that are closer or who have a clearer line-of-site to the access point receive access at higher data rates than more distant or non-line-of-site users. Furthermore, many community networks use WiFi routers that were originally designed for inside use in homes or businesses. While these radios work best within 300 feet, experimenting community networkers have learned that with a bit of tweaking, these radios can be mounted on towers with good line-or-site and reach users as far as 10 miles away. While this model has been successful for a number of communities (see the Bay Area Research Wireless Network profile below), the network capacity is limited by the number of users it can support and the distance it can reach.

Central access point networks have a hub and spoke design, with the access point hub sending signals to users located within reach of the signal. Mesh networks, however, resemble a spider web, with users connected to each other by short-distance wireless links made by directional antennas that ultimately lead back to a wired Internet connection through a number of relayed hops. The CU Wireless project is a metropolitan area mesh network in the City of Urbana, Illinois covering .

Project leaders of the CU Wireless network have posted ten antennas or network nodes, on the roofs of 9 area homes on the bell tower of the City Hall. These nodes use the 2.4 GHz unlicensed band to connect to each other in low-power transmissions that allow for numerous paths back to one of two separate DSL lines provided by the Independent Media Center and another non-profit organization. The multiple nodes create a mesh architecture that allows data to be routed in the most efficient route possible to the Internet. As more nodes are added to the network, the network adds more routing paths and actually grows in robustness and flexibility.

The mesh design has the advantage of allowing users without line-of-site to the Internet connection point to be added to the network, as network paths can be routed around tall buildings and other obstacles. Also, because typical Internet usage is "bursty," meaning that bandwidth is used in sporadic or intermittent pulses when files are being downloaded or uploaded, the mesh design allows a greater number of users to efficiently access one wired Internet connection than typical WiFi networks. As such, community networks can save money by having more users and more nodes sharing and extending a single wired connection.

The CU Wireless network is designed to be an incubator project for future wireless mesh networks, and project engineers developed an affordable and easily installed network nodes that can operate on retired CPUs. CU Wireless programmers have created open-source software that is loaded onto a CD-ROM and powered by a bare-bones computer placed in the attic of the home or building hosting the network node. An antenna is mounted on the roof and positioned to communicate with other roof-mounted antennas in the neighborhood. It is then connected to the computer node in the attic. When the antenna receives a signal, the node "reads" the network and chooses the most appropriate path leading back to the Internet.

The system also includes a "bandwidth shaping" protocol to monitor how the network is being used and regulate traffic to ensure that all users have adequate access to the network, and to prevent bandwidth hogging.

Currently, the network supports approximately 25 regular users, most of whom access the system via the Independent Media Center or from the homes hosting network nodes. The group has also placed a node on the City Hall overlooking Lincoln Park to give visitors and vendors of the park's weekly farmers' market free access. This summer the network will expand with 50 new nodes by 2005 in two adjacent neighborhoods.

Ultimately, project coordinator Sascha Meinrath and technical lead David Young would like the mesh network to connect to the City of Urbana's government use municipal fiber network, which is largely dormant during the evening hours when most residential users use the Internet. Only a handful of municipalities across the country have leveraged their government-use fiber networks with unlicensed wireless, but some interesting cases have emerged (see Allconet and Scottsburg, IN below) that suggest that such arrangements are on the horizon.

Profile 2:
The Southern California Tribal Digital Village
A Wide Area Unlicensed Network Serving 18 Tribal Nations

Perhaps nowhere in the United States is the challenge of bridging the last mile as great as it is on Native American lands. With some tribal nations still struggling to bring universal phone service to their communities, high-speed Internet access would seem beyond the reach of most Reservation leaders. Fortunately, a few successful experiments with unlicensed wireless broadband are proving that even if the telecom companies can't or will not build networks in remote areas, affordable wireless solutions are possible.

With the help of a $5 Million grant from Hewlett-Packard, the Southern California Tribal Chairman's Association has constructed a 12,000 square-mile unlicensed wireless network connecting 18 tribal nations in rural San Diego County. The Southern California Tribal Digital Village (SCTDV) relies on the 5 GHz unlicensed band for point-to-point, long-distance connections between reservations, and uses the 2.4 GHz bands for last-mile access within reservations to tribal government users.

The network currently reaches more than 500 workstations, including fire departments and school computer labs on each reservation. The network also provides high-speed access to community technology centers on the reservations, where residents can access the network for free and even checkout wireless laptops to connect to the network from their homes.

The SCTDV network uses a 45 Mbps Internet connection purchased through the Universal Service Administrative Company (USAC) which provides E-rate subsidies to the Tribal Nations' library system. The unlicensed wireless network uses and distributes the excess bandwidth across the 18 reservations with base station antennas and relays installed by SCTDV youth volunteers and Interns. These 5 GHz backhaul transceivers are placed on mountain ridges with long line-of-site views of the next reservation. Point-to-point connections span a total distance of over 200 miles across the arid terrain, and point-to-multipoint transmitters within the communities connect to individual users or access points via the 2.4 GHz band using WiFi technology.

The next challenge for the project is to find an affordable solution for Reservation residents to access the network from their homes more readily. Currently, customer premise equipment (CPE) costs are costly for residential users, with commercial-grade rooftop antennas and bridges available in the $300 - $500 range. Less expensive options, such as those being developed at the Bay Area Research Wireless Network (below), are available for $100 - $150, but are not currently mass produced. One possible solution being explored by the SCTDV is to sell access from the tribal unlicensed network to higher-income, non-Native households in the area who are also too rural to receive DSL connections, and use that revenue to fund a bulk CPE purchase for Reservation dwellers.

Regardless of what path the Nations choose, their network provides a robust platform for growth and future education and community development applications for the local population.

Profile 3:
The Bay Area Research Wireless Network
Community Access for the Urban Last Mile

While the success of commercial WISPs has generated much attention, grassroots Community Access Networks or CANs are equally influential in building the unlicensed movement. Most CANs are groups of like-minded individuals sharing a similar philosophy—that citizens should and can have open, inexpensive, and ubiquitous access to the Internet. Using affordable and easily installed WiFi technology, community members in Seattle, New York, Austin, San Francisco, Portland, Oregon, and Athens, Georgia have built expanding networks of independently maintained wireless access points that are shared among many.

Most CANs provide access to people in public spaces, however some groups have made forays into residential space, by connecting neighborhoods with centrally placed access points. One such organization is the Bay Area Wireless Users Group (BAWUG), an informal group of wireless early adopters who began mounting WiFi transmitters on the roofs of their homes to give neighbors free or shared-cost Internet connections via their DSL and cable lines. While the cable and phone companies didn't approve of the practice, consumers did and access points began popping up all over the city. There are more than 25 BAWUG assisted access points in the area.

But BAWUG has not stopped there. Under the leadership of Tim Pozar, a telecommunications engineer and one of BAWUG's founders, the group has launched the Bay Area Research Wireless Network (BARWN). BARWN is an active wireless network with a mission to discover the best technical solutions to bring wireless broadband to remote and economically disadvantaged communities.

BARWN has set up two centrally located access points atop the San Bruno Mountain and Potrero Hill in south San Francisco, allowing anyone within an 8-mile radius to point a 2.4 GHz antenna at the BARWN towers to share the 11Mbps of bandwidth they provide. Pozar says that a third public access point is soon to be installed on Yerba Buena Island in the San Francisco Bay, which will link to the East Bay and light-up an underserved area called Treasure Island.

All of these access points are constructed with non-proprietary equipment and open protocols to keep costs down and to learn what technologies can be most easily adopted by lower income communities.

As evidence of the network's stability and flexibility, BARWN is working with the City of San Francisco to use this network for public safety communications—such as earthquake or disaster response. Pozar says one application for the unlicensed service would be to provide streaming video of a disaster site to command centers to evaluate response tactics.

Profile 4:
NYCwireless.net
Evolution of a Wireless User Group

To followers of the unlicensed wireless broadband revolution, New York has been a hotspot of activity among U.S. cities, and the NYCwireless user group has been leading the movement. The group began as an informal network of early WiFi adopters who placed access points on their apartment widows to share their broadband access with the public parks below their buildings. As the trend gained acceptance, the users organized to form NYCwireless, a non-profit, volunteer organization, to encourage others to share their broadband and foster an ethic of free public Internet access across the city.

“New Yorkers live in cramped quarters, and our goal has been to get people out of their apartments and into the public parks,” says NYCwireless volunteer Dustin Goodwin. The group considers ubiquitous broadband access to be a public amenity equivalent to streetlights or water fountains. However, it’s difficult, if not impossible, to provide public parks with wired broadband access because of construction impediments on historic or public land. Cheap, and easily installed WiFi technology allowed apartment dwellers with good line-of-site to their parks to install the 802.11b transmitters and address the problem for themselves.

Volunteers from NYCwireless have built networks in Bryant Park, Bowling Green Park, and Tompkins Square Park, among others. This past year, founding members of the group formed a consulting firm, Emenity, to deploy six more public hot spots in lower Manhattan for the NYC Downtown Alliance. The new company was started to provide service to commercial clients, but their mission of building public access networks remains intact.

Emenity has recently built a public network in Union Square Park. This project is unique in that it relies on a wireless backhaul to connect to the Internet provided by the commercial wireless broadband provider TowerStream. Most public access points in the city ultimately access the Internet via a DSL Internet connection.

The efforts of NYCwireless have not gone unnoticed by broadband service providers. Some providers have slapped “acceptable use” clauses on their subscriber contracts in an effort to discourage wireless bandwidth sharing. One large cable operator has been accused of sending out a WiFi “sniffer” to scour the city in search of access points leading back to their customers’ connections to close down the transmitters.

However, as WiFi use has reached a critical mass, more broadband providers are trying to enter the public space arena. Speakeasy, Inc., a national DSL reseller, now offers “WiFi Netshare,” a service that allows users to resell their broadband connections to neighbors, with Speakeasy handling the billing. And Verizon DSL has built a number of hotspots in New York that are free to their DSL home subscribers.

NYCwireless volunteer Dustin Goodwin sees the commercial attention to public WiFi in the city as a direct response to NYCwireless' success. While some see the entrance of commercial players into the public space as a threat to free access, others see the development as an important step to recognizing WiFi as a free public amenity that companies and organizations should provide as a value-added service to their constituents.

Now that wireless broadband has gained a foothold in New York City parks, Goodwin says that NYCwireless is expanding its mission to resemble a volunteer "Geek Corps" for communities without affordable broadband Internet. Currently, NYCwireless volunteers are helping a non-profit housing organization, Community Access, bring broadband to clients living in their community homes. The group has trained the housing residents to build and maintain a wireless network, which will provide more than 50 residents with private, high-speed connections.

Profile 5:
EastServe Metropolitan Area Wireless Network
Unlicensed Spectrum for Underserved Urban Areas

While policy makers in the U.S. debate over how to bridge the last mile, unlicensed technology is giving disadvantage communities the ability to confront and solve access issues for themselves. One shining example is the case of the EastServe network in East Manchester, England, where community members have installed a wireless broadband network connecting 350 households, 17 area schools, and nine community technology centers.

The EastServe network was created by residents from the towns of Beswick, Clayton and Openshaw through the British government's "Wired Up Communities" initiative, which pulls public and private entities to bring broadband Internet to disadvantaged areas. There are seven pilot communities across England in the Wired Up Communities initiative -- each of which is using a slightly different technology to learn the best strategy to reach the UK last mile.

For East Manchester, wireless was the only viable solution. Ninety percent of the population have no high-speed cable access, and 25% have no fixed-line phone service since many households only use mobile phones. With 80% of the population living in houses, almost half of which are publicly funded, the expense of laying cable or a DSL loop to each residence is especially prohibitive. But a wireless solution, with its flexible and facile installation, allows community stakeholders to set-up, manage and trouble-shoot technical problems themselves.

A local company, Gaia Technologies, has trained resident volunteers to install and maintain the 10 community access points currently in place. Volunteers from the neighborhoods will add an additional 15 access points in the next phases of the project. Over 700 households within a 6-mile area have signed up for the service, and project leaders estimate that with the ease of rooftop installation they can bring 100 new users per week onto the network.

Gaia Technologies Managing Director, Anas Mawla says the network is a ring formation of six backbone towers, which are located among the 17 schools and nine on-line centers on the network. These six towers provide a total of 45 Mbps of data transmitted in narrow beam, point-to-point connections on the 5.8 GHz band. The backbone relies on a partial mesh design for redundancy. Proxim makes the 5.8 GHz transceivers.

Within this ring of towers, twenty-five 802.11b access points transmit in wedge-shaped sectors to reach households with up to 11 Mbps of data to be shared among users. EastServe uses Cisco Systems' Aironet customer premise antennas for the last-mile link to houses. Flat dwellers share a wireless link that connects directly to the backbone.

Since activating the network, the local telephone carrier has launched limited ADSL access to parts of East Manchester, however this service offers a much slower, asymmetrical service at higher prices than the EastServe wireless network. EastServe users also have access to a community Intranet; customer service provided by community members; and the ability to purchase new or recycled computers through the program. They also have the added comfort that they will soon own and maintain their network—no longer at the mercy of a third-party provider to bring them the service.

Profile 6:
Making the Last Mile First in Developing Economies
Unlicensed Networks Reaching the Poorest of the Poor

A general rule in introducing new technologies to developing economies is that one size does not fit all. Often, for a new technology to be economically viable in developing countries, substantial changes in the model must be made. Now that unlicensed wireless technologies are bridging the last-mile service gap for hundred's of thousands of homes in America, efforts have begun to make the wireless model work in developing economies.

The Dandin Group, an unlicensed wireless engineering firm, has built successful networks on the island of Tonga and in the capital of Mongolia, Ulaan Bataar. China Unicom has begun unlicensed fixed wireless deployments in the Guangzhou and Shenyang provinces, and China Netcom has built over 2,000 Wi-Fi hotspots in four of China's largest cities. But most deployments only reach relatively high-income users.

The biggest barrier to reaching the poorest of the poor is the high cost of equipment compared to the scant resources of individual users. Wireless Internet service providers need new ways to aggregate users and get the most out of each piece of technology. FirstMile Solutions, a consultancy of MIT Media Lab engineers, has taken a novel approach to this problem, effectually turning the mobility model on its head. Instead of building stationary transmitter towers to reach mobile users, as cellular phones work, FirstMile engineers in India have been experimenting with Mobile Access Points (MAPs) to bring high-speed connectivity to rural villages. By mounting wireless access points onto buses with daily routes to rural villages, one access point is able to serve many villages with periodic service.

The bus-mounted MAPs connect to Wi-Fi enabled computer centers located near the bus routes. Users are able to write email messages or record digital video messages, as in a typical Internet café. Then, when the bus drives by, the access point connects with the computer center and uploads all the stored files from the previous 24-hours, and delivers new messages to user in-boxes. When the bus drives back to its point of origin in a larger town, it connects with a fixed-base Internet connection and uploads all the data collected in its rounds, and downloads new data to be delivered the next day on its route.

The project is designed to fit the needs of rural villages lacking the resources or the demand for full-time connectivity. The periodic, "store-and-forward" connection provides an email application previously unavailable to rural villagers, which can be purchased as needed from a local Internet café.

In July of 2003, the World Radio Conference moved toward harmonized standards on the 5 GHz licensed-exempt band, making spectrum available at 5.15 – 5.25 GHz, 5.25 – 5.35 GHz, and 5.47 – 5.725 GHz frequencies. This move toward standardized unlicensed bands should provide equipment manufacturers with an incentive to reach global markets with an economy of scale for mass-produced transmitters and receivers. As unlicensed wireless equipment becomes more of a commodity, the developing world should benefit from more novel wireless applications.

Municipal Unlicensed Wireless Broadband Case Studies

Profiles Include:

- Scottsburg, Indiana: Citizen's Communications Corporation
- Allconet: A Rural Municipal Deployment Expands
- Unlicensed Public Safety Networks: Secure, Affordable and Fast
- Rockwood Area School District: An Unlicensed Educational Network

Just as community organizations and entrepreneurs have been empowered by affordable unlicensed broadband technology, so too have dozens of US municipalities that have deployed wide area wireless networks for their citizenry. Municipal Electrical Utilities (MEUs) and city or county governments themselves have become the most recent providers of unlicensed wireless broadband. Alvarion, the largest manufacturer of unlicensed wireless equipment, claims that municipal organizations represented 10% of the overall market for commercial grade equipment.[3] Dozens of MEUs from across the country have built unlicensed wireless networks in the past two years with rapid returns on their investment, including Owensboro, Kentucky; Buffalo, Minnesota; Dickenson County, Virginia; Sun Prairie and Waupaca, Wisconsin; Franklin County, Washington, and others.[4]

The municipal attraction to unlicensed wireless networking lays in the amount of taxpayer money local governments can save by building these networks rather than laying expensive fiber rings or even more costly last-mile wired service to residents and businesses. Also, for municipalities that own their own water towers, streetlights, and other infrastructure, the wireless solution is an ideal way to leverage local assets and provide additional services to citizens while generating reoccurring revenue without great investment. But perhaps the greatest incentive to municipalities is not one of choice, but rather of necessity. Most of the governments who have built these networks are smaller, more rural towns and populations that have long-been ignored by the large telecoms.

Unlicensed wireless is often the technology of last resort for small, cash-strapped municipalities looking to build infrastructure to save and encourage local jobs—but, interestingly, unlicensed wireless is also the fist choice among other wireless options, including licensed spectrum. Because of the great innovations and economies-of-scale in the license-exempt bands in recent years, unlicensed wireless technology is considered the most robust, most economical, and most easily deployed technology available.

For these reasons, the communities profiled below have selected an unlicensed wireless option to connect residents, businesses, schools, and non-profits. Recent research by MIT Economists suggests that this trend will only continue and accelerate as more and

[3] *See* Patrick Leary, "Unlicensed Wireless Broadband: Statistics and Snapshots from the Trenches," Presentation, New America Foundation's "Pervasive Connectivity" Conference, April 16th, 2004. *Available at* http://www.newamerica.net/index.cfm?pg=event&EveID=351.
[4] *See* Appendix A, which gives more detailed information on some of these efforts.

more MEUs leverage their assets to make unlicensed wireless broadband the great public utility of the 21st Century.[5]

Profile 1:
Scottsburg, Indiana's Citizen's Communications Corporation
City Builds Unlicensed Network to Secure Local Jobs

Judging by the Democratic primary campaign speeches in the Midwest and from President Bush's series of town hall meetings on the economy, the touchstone issue across the region is jobs. Yet beyond the rhetoric of the campaign, there have been few tangible solutions offered to local governments looking to stimulate their economies. A need for such a solution emerged in Scottsburg Indiana, when two local employers contacted Mayor Bill Graham to inform him they were considering relocating to an area with a better communications infrastructure. Graham knew the city would either have to act or suffer job losses.

The city quickly formed a committee to explore possible solutions, such as building a municipal fiber network or requesting the telecom providers to upgrade their lines. By December of 2002, the city decided that the fastest and most cost-effective solution was to build a municipal wireless network using unlicensed spectrum.

The City of Scottsburg (pop. 6,000), which also serves as Scott County's municipal electric utility, formed the Citizen's Communication Corp. (C3) to build and manage the network. Working with unlicensed equipment manufacturer Alvarion, C3 used the municipal utility's water and electric towers to create a wireless coverage footprint extending throughout Scott County and reaching more than 90% of the County's 23,000 residents.

The network was built over a four-month period during which 45 wireless transmitters were mounted on 15 towers. In the first year of operation, more than 350 households and, more importantly, 50 local businesses have subscribed to the city's broadband service.

The C3 network design is similar to those of most commercial WISPs, and uses a mix of 5 GHz, 2.4 GHz and 900 MHz radio transmitters. The higher frequency (5 GHz) transmitters are used for long-distance, backhaul services, and these point-to-point transmissions can reach as far as 30 miles. The last-mile links to subscribers use the 2.4 GHz transmitters, which operate on the same frequency as off-the-shelf Wi-Fi access points. But proprietary equipment, manufactured by Alvarion and a number of other companies, provides a higher level of service and security than commodity grade 802.11 routers, and last-mile connections are typically 2 to 3 miles, but links as far as 10 miles are possible by using phased array or directional antennas mounted on subscriber roofs.

The 900 MHz radios operate on the lowest frequency unlicensed band, and are often used by municipalities to reach residential customers in foliated areas without a line-of-site

[5] *See* Gillett, Sharon E., William H. Lehr, and Carlos Osorio, "Local Government Broadband Initiatives," MIT Program on Internet and Telecoms Convergence, December 3, 2003.

view of the transmitter towers. One of the leading manufacturers of 900 MHz equipment is WaveRider, which markets their Direct Sequence Spread Spectrum (DSSS) transmitters to municipalities, offering packages that include installation trainings, bases stations, and customer premise units sold in bulk quantities.

Unlicensed fixed-wireless equipment manufacturers, such as Alvarion, WaveRider, Navini, Aperto and others, rely on a variety of spread spectrum technologies, like DSSS, to efficiently use the license-exempt bands. The technology for these unlicensed networks is often more advanced than solutions created for the licensed bands, as unlicensed networks must be rigorous enough to withstand interference from the thousands of consumer devices, such as baby monitors, cordless phones, and garage door openers, that operate in the unlicensed bands.

The enabling principal behind spread-spectrum radios is that they divide data streams into packets and send them separately over numerous frequency channels. Advanced receivers reorganize and translate the packet data using a variety of different protocols. DSSS radios, such as WaveRider's 900 MHz radios, attach "chipping codes" to divided packets that tell the receiver how to reassemble the stream across multiple frequencies. Other non-line-of-site (NLOS) technologies include Frequency Hopping Spread Spectrum (FHSS), used by Alvarion 900 MHz transmitters, which rapidly switches the carrier frequency during transmission to avoid signal interference. Another NLOS technology is Orthogonal Frequency Division Modulation (OFDM), which aligns a modulation signal to data packets, creating a composite signal which modulates the receiver to the main carrier frequency.

While the physics of these radio technologies may be slippery to grasp, the installation of the technology is easy enough for cities to handle themselves without adding a team of RF engineers. In Scottsburg, the municipal utility staff learned to mount transmitters on water towers, and point the directional antennas at subscriber antennas or at the next tower-mounted transmitter. Each of the 15 towers host approximately three transmitters, and more can be added if subscriber numbers swell. The city powers the low-power transmitters using the existing electrical connections at the base of the towers.

Installation at the subscriber site is easier, as most customer premise antennas are suction-cupped inside a window facing the directional transmitters on the towers. For subscribers located in valleys or without a line-of-site view of the tower, the city mounts a small, weatherproof directional antenna on the roof, which relays to an 802.11 bridge inside the subscriber's home or business.

Profile 2:
Allconet: A Rural Municipal Deployment Expands
A Municipal Unlicensed Network that Reaches the Business and Residential Last Mile

While the trend of local governments using unlicensed spectrum for wireless data networks is still a fairly recent phenomenon, there are a few early examples of municipal networks that have a long-enough history to demonstrate how these newer municipal networks may progress. The most often cited early example comes from Allegheny County in the rural Appalachian mountains of Western Maryland.

In 1994, the Allegheny County government abandoned their hopes that the regional telecom provider would upgrade their copper service lines and build a high-speed network for the sparsely populated area. Instead of lamenting the issue, network administrators from the Allegheny County Government, the Board of Education, the Public Library System and the City of Cumberland pursued the only option available to them and looked for funding to build a wireless network to serve the local government.

In 1996, using a mere $60,000 in initial funding from the Appalachian Regional Commission, the county built the first links of the wide area local government network. The project, dubbed Allconet 1, provides broadband services to 90 municipal buildings, including 27 schools, 6 libraries, and dozens of public safety and non-profit organizations, reaching over 4,000 workstations across the county. The second phase of this project, Allconet 2 will be launched on June 1, 2004 and will provide high-speed access to 95% of the County's businesses and 85% of the County's 70,000 residents.

Allconet 1: A Municipal Wireless Platform

The county built the Allconet 1 network with the intention if it supporting the future telecommunications needs of the entire county. Allegheny County's largest city, Cumberland, is a two-and-a-half-hour drive from Washington DC, and a viable location for back-office federal government operations. The County hoped that the state-of-the-art communications network would attract both private industry and federal government jobs to the area. As such, Allconet is designed to be a common carrier for a number of bandwidth intensive applications, including PBX (Private Branch/Business eXchange) applications such as those supporting call centers or large corporate networks.

The Allconet backbone is a wireless SONET (Synchronous Optical Network), which uses licensed frequencies on the 11, 18, and 23 GHz bands for point-to-point transmissions and unlicensed frequencies on 900 MHz, 2.4 GHz, and 5 GHz for last-mile connections to the schools, libraries and municipal buildings. Instead of purchasing tower space, the transmitters are mounted on existing municipal structures. Two water towers, the roof of the Fort Hill High School, a local bell tower, and three freestanding airport towers host both licensed and unlicensed radio transmitters. The network uses eight towers in stretching across a 525-mile area.

To manage traffic, the system uses an Asynchronous Transfer Mode (ATM) protocol, which divides and sends data into packets, in a manner similar to how the Internet works.

Allconet can support 622 Mbps of bandwidth, or four OC-3 connections to the Internet—the equivalent of 12 DS3 lines, or well over 400 individual T1 lines.

Currently, the SONET uses only on a fraction of that capacity, and is served by three DS3 lines leased by the County Board Of Education. Through the Universal Service Fund's E-rate program, the county leases each DS3 line for $3,500 a month, which provides ample bandwidth for the network at a very affordable cost. T1 lines provided by the State of Maryland's SAILOR network, which provides high-speed access to state libraries, also feed the network.

Allconet 2: Extending the Network for Business and Residential Users

The next phase of this project, Allconet 2, will leverage the municipal backbone with unlicensed spectrum and provide affordable broadband to business and residential subscribers. The county is installing a network of complementary unlicensed transmitters to navigate the rugged forest terrain of the region. The engineering plans call for approximately 32, 2.4 GHz access points; 48 access points for advanced service connections on the 5.7 GHz band; and 16 lower-frequency (900 MHz) transmitters for last-mile access to users who may not have perfect line-of-site to the towers.

To avoid the administrative demands of servicing commercial and residential network subscribers, the county is allowing local ISPs to access the network for a nominal fee and market the broadband service directly to customers. Between three and five local ISPs will compete for customers on price and quality of customer service, but all will share the same network infrastructure, managed by the County. Currently, 50 businesses have lined-up to become the first customers, which bodes well for local ISPs.

This market structure resembles those used in other open-access municipal networks. Benton County, Oregon has built and maintained an unlicensed network that connects to the Public Utility District's (PUD) fiber network. They also allow local ISPs to service customers through the network. The City of Ashland Oregon, which has an extensive fiber network, encourages shop owners, bed and breakfast operators, and cafes to install wireless hotspots to attract tourists and commercial activity into the downtown area.

Simply opening the network to ISPs won't ensure the success of the Allconet 2 build-out. For ISPs to invest in attracting wireless broadband customers, they will need to trust that the network will be stable and reliable. Service calls, or truck rolls, can drain an ISPs resources and inhibit investment. For the last-mile to be reached, the County must prove that the wireless network will provide a high quality of service.

Fortunately, Allconet can rely on its eight-year history as a stable municipal network, and the County will invest $600,000 in local government funds to ensure the residential and business networks are well engineered.

Allegheny County leaders are hoping that this advanced municipal network will have the capacity and reach to alter the economic landscape for the entire region. Other rural areas are watching closely, and similar projects – such as western North Carolina's Mountain Area Information Network (MAIN) and central Pennsylvania's Broadband Rural Access

Information Network (BRAIN, see below) – have also had strong starts to connect remote areas long-ignored by traditional broadband providers.

Profile 3:
Unlicensed Public Safety Networks: Secure, Affordable and Fast
More and More Law Enforcement Agencies Choose Unlicensed Wireless

In the wake of 9/11, public safety agencies across the country began looking closely at the mobile and fixed data networks serving their community's first responders. Many of them found that their networks were too slow for high-speed Internet applications, such as streaming disaster video for first-responders, or providing police officers with fast downloads of criminal records and suspect mug shots. They also found that the different agency networks used different technologies and were inoperable with each other, complicating collaborative investigations and response. To remedy this systemic problem, many public safety agencies are deploying unlicensed wireless networks because they are the most affordable and adaptable high-quality option available.

Patrick Leary, Assistant Vice President of Alvarion, a leading manufacturer of unlicensed wireless equipment, estimates that the market for unlicensed public safety networks is only a year old. But in that time an estimated 60 municipalities across the country have installed unlicensed networks.

One of Alvarion's networks include the San Diego County Sheriff's Department, which has installed between 40 – 50 base stations and access points on buildings and facilities across the County. More than 600 of the County's patrol vehicles are equipped with Alvarion receivers, allowing officers access to data at rates up to 3 Mbps while stationary, and at slower data rates while driving.

The San Diego County deployment is illustrative of how larger municipal agencies are using unlicensed wireless. But Leary suggests that the smaller, more rural law enforcement agencies are the most active public safety market because unlicensed wireless is the most cost-effective solution for their limited budgets. Rural agencies such as the cities of Price and Helper Utah; Yakima County, Washington; Midland, Texas; and Pratt, Kansas have recently installed networks.

The City of Pratt's Police Department went through a typical decision making process in selecting an unlicensed network, according to Leary. The Pratt force of 10 officers were using narrowband radios which were capable of transmitting only 9.6 kbps, and which were unsuitable for anything but simple two-way voice communication. They looked into the traditional law enforcement solution of installing a Cellular Digital Packet Data (CDPD) system, but these networks only provide 19.2 kbps—more than twice as slow as the typical 56 kbps dial-up connections used in most homes. Also, because there's a limited market for CDPD services for law enforcement agencies, the technology and the service fees from a licensed provider make this solution too expensive for Pratt's small force.

The Pratt officers also considered purchasing a license to operate radios on the 2.5 GHz frequency bands licensed for Multipoint Microwave Distribution Systems (MMDS). But the high administrative and economic costs of bidding for a license and purchasing expensive technology for licensed bands put the MMDS solution beyond their means. In a typical process of elimination, Pratt selected unlicensed wireless because of the wide range of affordable equipment available for the unlicensed bands, and for the cost savings of not having to bid for a spectrum license.

Mesh Networks Enter the Public Safety Space

Recently, a number of municipalities have installed unlicensed mesh networks to provide wide-area connectivity to mobile officers and first responders in the field. Mesh networking, as described in the Champaign-Urbana Community Wireless network profiled above, uses dynamically routing radio transmitters that communicate with each other and with vehicle-mounted antennas or hand-held user devices to create flexible, ad-hoc wireless environments highly suitable for first responders. The technology was originally developed for military applications, for flexible, temporary, local-area communication networks used on the battlefield.

Recently, companies like Tropos Networks and MeshNetworks have developed unlicensed wireless products that can be mounted on city streetlights and electrical infrastructure to cover wide-area metropolitan landscapes. The first such public safety network was built in San Mateo, California using Tropos equipment and the 2.4 GHz unlicensed bands. The San Mateo network is being undertaken in phases, with the City installing approximately 30 meshed WiFi nodes covering the city's 16 square-mile area, and accessing municipal fiber connections at the city hall and the San Mateo Police and Fire Departments. The network is easily deployed, with city workers installing and servicing the transmitters.

Other mesh public safety mesh networks are being built in Garland, Texas; Medford, Oregon and LaFayette, Louisiana. A similar network has been built in Cerritos, California, where a combination of Tropos, Trangos, and Motorola transmitters have been deployed by Aiirmesh, a company that builds municipal wireless networks.

Profile 4:
The Rockwood Area School District Unlicensed Educational Network
A Wireless Model to Connect Rural School Communities

While U.S. school districts have been issued the command to "leave no child behind," many rural schools are without the resources to bring broadband Internet access into their classrooms. This is especially true for rural communities beyond the reach of DSL or cable lines. This last-mile problem presents hardships not only for schools, but also for local households and businesses unable to fully participate in the information economy. A public/private partnership has been formed in western Pennsylvania to use unlicensed spectrum and the social capital of local school districts to address the last mile on their own. Thus far, the efforts of the Broadband Rural Access Information Network (BRAIN) have yielded great results connecting rural areas, and their example could provide a template for other rural school communities across the country.

The BRAIN effort began with the vision of a small school district superintendent, Andy Demidont, and the help of a large regional WISP, Sting Communications. Demidont wanted to provide high-speed access to the Rockwood High School and the Kingwood Elementary School in mountainous Somerset County. The schools' existing dial-up accounts were expensive, and rendered connection speeds barely surpassing 14 kbps.

Relying on the technical guidance from Sting Communications, and using grant money awarded from the Individuals with Disabilities Act and E-Rate discounts, the school district installed wireless access points on the roofs of both schools, turning each school into state-of-the-art wireless hotspots.

In total, Sting Communications installed three towers, creating a pie-shaped hot-zone using the 5.8 GHz and 2.4 GHz license-exempt bands. The Rockwood High School gymnasium hosts a 100-foot tower that transmits to a 150-foot tower located at Kingwood Elementary school. The two towers share a narrow beam, point-to-point connection with a third tower owned by the local Seven Springs Ski Resort.

Simply bringing the technology to the area wasn't the end goal – using the network to connect the school with the community is the ultimate design of the project. Both the Rockwood and Kingwood schools have put many classroom and administrative operations on-line. Teachers use Palm Pilots and laptops to track student progress, design lessons, and record grades – which are available to parents online. Students can use the high-speed connection in each classroom, with each school "unwired" for access.

The project was designed to also give community residents a chance to purchase access from the school's network, with the school district serving as a WISP for the area. Between the three towers, Sting has installed access points in neighborhoods to provide coverage for much of the community. Sting has also provided an incentive for community members to join the network, by offering subscription rates between $11 and $20 per month, depending on the number of subscribers the school can attract. Thus far, 65 families have joined the network.

From the project's onset, Sting hoped their approach could be replicated in other rural school communities. Building on what they have learned in Somerset County, Sting has built a much larger network in Cambria and Clearfield Counties to connect four more regional school districts. Sting Vice President Bob Roland says that this new network spans an 1100 square mile area, reaching residents of the Glendale, Philipsburgh, Osceola, and Moshannon Valley school districts. This network (see Figure 13 below) uses both 5 GHz frequency-hopping spread spectrum and 802.11 connections for the last mile.

BRAIN is seeking to expand the model into more communities. The group has applied for a $7.4 million grant from the USDA's Rural Utilities Service to "light-up" a wide corridor between central Pennsylvania and Maryland. This larger effort could provide a valuable last-mile case study for rural school communities around the country.

Commercial Unlicensed Wireless Broadband Case Studies

Profiles Include:

- Think Globally, Act Locally: AMA*TechTel & Prairie iNet
- Loudoun County, Virginia: Roadstar Internet Services
- Michigan Broadband Development Authority Invests in Unlicensed

In technology and business circles, 2003 may be known as the year that the radio revolution happening in the unlicensed bands went mainstream. With WiFi clouds mushrooming across commercial districts in large and small towns alike and WiFi chips being built into high-end laptops, PDAs, and even mobile phones rolling off the lines, the hype of the wireless world has become a reality for businesses and consumers alike. In 2003 an estimated 22.7 million access points and networking cards were shipped and WiFi hardware revenue market grew to $1.7 Billion and WLAN equipment sales reached $2.5 Billion.[6]

But while WiFi is making the waves in the business world, few understand that all of this economic success is happening in the tiny, unlicensed slivers of the grossly-underused (and grossly-over-licensed) electromagnetic spectrum. For skeptics who don't believe that an open spectrum paradigm meshes well with capitalist innovation, the success of over 2,400 Wireless Internet Service Providers (WISPs) serving over 6,000 U.S. markets offers a healthy dose of reality.[7] Parks Associates, a research firm, estimates that over 200,000 households in the U.S. currently receive broadband access via unlicensed wireless. In 2003, these rurally located, small business WISPs generated an estimated $250 Million dollars in recurring revenue. By 2008, recurring WISP revenues should exceed $2 Billion per year.[8] Furthermore, the numbers of consumers receiving access via licensed spectrum pale in comparison.[9]

Undoubtedly, unlicensed wireless has had a great economic impact on the telecom landscape, but the most tangible benefits are those felt by end-users: the scores of rural businesses and households who finally have broadband access, and the thousands of underserved communities who finally have second or third choice in broadband platforms over the legacy cable and DSL duopoly.

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[6] *See* In-Stat/MDR, "Joe Schmo Has Wi-Fi: The Wireless Home Becomes a Reality," [report] December 2003. For other estimates of economic growth*, see* Synergy Research Group, Press Release from February 11, 2004: WLAN Market Eclipses $2.5 Billion Mark, Available at http://srgresearch.com/store/press/2-11-04.html.
[7] For information on the growth of unlicensed WISPs, *See* ISP-Market LLC, Broadband Wireless Access 2002: Service Provider Profiles, Market Drivers and Spending Projections, [report] 2002. Also see
[8] *See* Parks Associates, "Unlicensed Broadband Wireless: Solutions and Applications," [report] December 2003.
[9] Parks Associates estimates that unlicensed wireless residential subscribers outnumber licensed fixed wireless subscribers by three to one, as an estimated 40,000 – 70,000 households across the U.S. use licensed fixed wireless for high-speed Internet service.

Profile 1:
Think Globally, Act Locally – AMA*TechTel & Prairie iNet
WISPs Evolve from Hot Spots, to Hot Zones, to Regional Broadband Providers

At the onset of the unlicensed movement, Wireless Internet Service Providers (WISPs) were typically small-scale efforts to bring broadband access to local areas using adapted WiFi equipment. Many of these efforts were scaled-up versions of the WiFi hotspots, now ubiquitous in urban coffee shops, hotel lobbies, and even some public parks. In recent years, however, unlicensed equipment has advanced well beyond WiFi to include more sophisticated technologies -- such as frequency-hopping, non-line-of-sight transmitters, mesh networks, and high-gain directional antennas that can make point-to-point connections over 20 miles. These days, providers construct networks into scalable cell sectors with varying levels of redundancy and security based on customer need, and they carefully engineer their deployments to accept more subscribers without compromising service as the network expands. In fact, the most successful WISPs have long-since outgrown the hotspot model and are now building contiguous wide-area networks that have raised the standard for unlicensed service.

One company that is redefining the notion of a WISP is AMA*TechTel Communications of Amarillo, Texas. With more than 4,000 users on their license-exempt network, AMA*TechTel is one of the country's largest regional carriers of wireless broadband. The company has built a 20,000 square mile, organic network comprised of 63 transmitting towers stretching across the North Texas plains.

According to Patrick Leary, Assistant Vice President of Marketing for Alvarion, one of the largest manufacturers of broadband wireless technology, the AMA deployment is a sophisticated, contiguous network that provides secure service to residential, corporate and educational campuses. Using Alvarion transmitters and multiple unlicensed bands (to include 900 MHz, 2.4 GHz, and 5 GHz) AMA has created private virtual environments for three college campuses, multiple school systems, law enforcement and public safety agencies, hospitals, and numerous banks within their expanding footprint.

The company is now building a wireless backbone for Texas Tech University that will connect Amarillo to Hobbs, New Mexico and provide broadband access to communities along its route. This wide area network will support K-12 and adult education and business development programs.

The expansiveness of the AMA network is due to the company's partnership with Attebury Grain, a large grain storage company that contracted AMA to connect their grain elevators to the commodities market. After the project, the two companies combined forces to widen the network using Attebury's numerous grain elevators to reach towns and businesses within line-of-sight of the elevator towers.

The wireless service is becomingly increasingly popular with residents in North Texas towns who may or may not have DSL access. According to AMA*TechTel Vice President of Business Development, Douglas Campbell, the company has been growing by 150 new subscribers a month with very little marketing.

The success of AMA*TechTel may be daunting to entrepreneurs wanting to enter the WISP arena, however this ambitious network may not be the only successful model available. Numerous smaller-scale providers have relied on skillful engineering and integrated technology packages to build smaller networks for remote communities (see previous sidebars). These localized efforts usually focus on rural communities that have no other option for broadband, where WISPs can safely access unlicensed spectrum without fear of harmful interference. One company that has implemented this localized approach on a large scale is Prairie iNet, of Des Moines, Iowa.

With a total network reach of approximately 20,000 miles, Prairie iNet builds localized wireless oases in communities long ignored by telecommunications and cable companies. By focusing on towns such as Broadland, Illinois (population 350) and 120 other communities in Illinois and Iowa, Prairie iNet has the flexibility to concentrate their efforts on specific markets with a broadband demand.

Like AMA*TechTel, Prairie iNet relies on the existing infrastructure of the high plains, with local silos, barns, and rooftops serving as towers for the company's point-to-point and point-to-multipoint transmitters. The company uses the 5 GHz frequencies for tower-to-tower and backhaul transmissions, while the last-mile connections to users are typically over a mile, and on the 2.4 GHz unlicensed band. The wireless networks eventually connect to the Internet via a DS3 fiber line. As of the summer of 2003, more than 4,000 users were receiving high-speed connections on Prairie iNet networks.

Both the wide-area "hot pathway" model and the localized network design present varying benefits. Regional utility companies with existing towers and customer base can learn quite a bit from AMA*TechTel and leverage their infrastructure and clientele to create scalable, secure virtual private networks (VPN) for larger organizations and residential service for customers. Utility companies around the country are rapidly following suit: East Bay Municipal Utility District in Oakland, California has recently installed the Motorola Canopy system; Owensboro Municipal Utilities in Kentucky and Wheatland Electric Cooperative, Inc. in Kansas have both installed Alvarion networks; and rural cellular providers like Midwest Wireless have also built a broadband business using unlicensed spectrum.

Localized networks, like the ones used by Prairie iNet offer a level of deployment flexibility not usually available with an existing fixed tower infrastructure. Localized networks can concentrate their infrastructure into the best available opportunity space and reach new markets quickly. This model has inspired small local providers to pop-up in many rural and suburban communities across the country. ISP-Market, a technology research firm, estimates that there are an estimated 2,400 WISPs in operation; and a 2003 Parks Associates study estimates that more than 200,000 U.S. households currently rely on unlicensed wireless for their broadband Internet connections. Low start-up costs, numerous equipment options, and high consumer demand are part of this growth.

Profile 2:
Revolution in the Rural Last Mile – Roadstar Internet Services
Unlicensed Spectrum Closing the Technology Divide in Northern Virginia

Despite their proximity to northern Virginia's Internet backbone, many towns in Loudoun County have no broadband access. The mountainous western regions of the county are far from the technology infrastructure of Northern Virginia where companies like AOL and VeriSign reside. However, because of license-exempt wireless activity, the technology divide across the county is starting to close.

The Northern Virginia area profited from the technology boom of the late 90s. But, when the technology bubble burst, as many as 30,000 jobs in the region were lost. Many laid-off professionals accustomed to broadband connections at their work started their own businesses or began working from their homes, creating a large demand for high-speed home services. One local company, Roadstar Internet, is meeting that demand by building a rapidly growing wireless network in rural Loudoun County.

Started in the autumn of 2002, the Roadstar Internet network connects more than 150 rural households and small businesses using 100% unlicensed spectrum. Most wireless subscribers do not know exactly how their service operates; since what matters most to users is that their connections are fast and reliable, and not necessarily the technology behind the service. But, the Roadstar unlicensed network is similar in design to many other WISP efforts, and uses a combination of point-to-point connections for the long-distance transmissions, and point-to-multipoint transmissions to connect neighborhood access points to subscribers.

The first leg of the network travels 18 miles from a mountaintop transceiver using 5 GHz license-exempt bands. Roadstar uses OFDM (Orthogonal Frequency Division Multiplexing) technology that allows for point-to-point connections without perfect line-of-sight. OFDM transmissions make efficient, and secure, use of spread spectrum by dividing data into packets and encoding it over multiple frequencies.

Long distance point-to-point transmissions are the standard for rural WISPs seeking to extend their markets and reach larger population pockets. Under Part 15 rules for unlicensed usage, the FCC allows operators to make point-to-point connections without reducing Transmitter Power Output (TPO) for the 5.725 GHz and 5.825 GHz band. Because of this regulatory latitude for narrow beam transmissions, providers are able to reach long line-of-site distances with relatively low power.

The Roadstar network makes final, last-mile connections within neighborhoods by using modified WiFi wireless access points mounted on customer silos, barns and rooftops. Roadstar and other WISPs are able to transmit distances greater than the 300-foot standards for WiFi, 802.11b technology by creating sectorized cells with high-gain, directional antennas. These last-mile connections on the 2.4 GHz band are the result of good planning and engineering, and typically reach two to three miles.

Profile 3:
Michigan Puts its Money in Unlicensed Spectrum
The Michigan Broadband Development Authority's Inaugural Loan Builds Unlicensed Network

As state and local government policy makers look for solutions to their own last-mile issues, wireless broadband is getting more attention as a viable alternative to cable or DSL. The great test of wireless broadband as an accepted solution to the last-mile problem is the use of state funds to help build wireless networks. An example is the State of Michigan's Broadband Development Authority, which gave its vote of confidence to unlicensed wireless by awarding its inaugural loan to a local WISP. ISP Wireless was awarded a $350,000 loan in April 2003 to expand its service to seven cities in northern Michigan.

The Michigan Broadband Development Authority (MBDA) was created by the state legislature in 2002 to attract private sector investment in high-speed Internet deployment across the state. The MBDA offers low-cost loans to companies with proven business plans and a successful record of broadband deployments.

ISP Wireless, which has 200 wireless subscribers in addition to its established customer base of dial-up and DSL subscribers, is using the loan to purchase wireless transmitters and customer antennas to extend their network.

The WISP has selected the equipment manufacturer WaveRider's non-line-of-sight, 900 MHz point-to-multipoint transmitters and customer receivers for the last-mile connections. The company uses Trango Broadband's 5.8 GHz microwave transmitters for their point-to-point connections.

ISP Wireless President Chris Carey says the loan will establish seven new transmitter towers and bring 500 new subscribers online in the coming months. Carey says most of the point-to-point transmitters will be attached to grain elevators, which then connect to point-to-multipoint cell sectors in neighborhoods and communities.

Building the infrastructure to support the new network is much easier and less expensive than extending DSL loops or laying new cable lines. Depending on a customer's proximity and line-of-sight to the local access point, the WaveRider customer antennas can either be mounted on the customer's roof, or posted on the users' window sill or interior wall. The company is currently connecting between two and 10 new customers a day.

The unlicensed wireless service is less expensive and faster than DSL. ISP Wireless charges $49.95 per month for a symmetrical wireless connection of 384 Kbps, while a comparable DSL connection with same speed is $72.50 per month.

Carey says recent innovations in the unlicensed band technology have made a huge impact in his business. Before offering the wireless connection, dial-up and DSL installations were flat and it was becoming increasingly difficult to attract enterprise customers. However, since building the unlicensed network, the company's largest growth is in the small, medium and large enterprise market. ISP Wireless has connected municipal offices for the City of Alma; a private K through12 school; an auto supply manufacturer and numerous small, and home-based businesses.

Attracting and building business growth is the goal of the Michigan Broadband Development Authority. According to a recent report by TechNet, a bipartisan organization of company CEO's, the state of Michigan is the national leader in promoting broadband deployment; and unlicensed spectrum is playing an increasing role in energizing business investment and bridging Michigan's last mile.

Appendix A: Municipal Unlicensed Wireless Networks

Location	Municipal Internal Use (For Local Government Use)	Municipal Commercial (Broadband as Public Utility)	Community Network (Non-Profit Open Access Net)	Commerce Network (Wi-Fi Amenity)	Populations Served	Technology Used	Frequencies Used	Network Infrastructure or Coverage	Details
Medford, Oregon	Municipal Internal				Law Enforcement	MeshNetworks	2.4 GHz	Meshed nodes posted on utility poles, traffic lights, buildings	Initial deployment covers 24-square-mile city area, costing $700,000. $500,000 came from Federal Homeland Security grants. Network allows law officers to connect at DSL speeds while driving at high speeds. Plan to extend network to 2,800 square mile area across Jackson County;
Garland, Texas	Municipal Internal				Law Enforcement	MeshNetworks	2.4 GHz	Meshed nodes posted on utility poles, traffic lights, buildings	Relies on MeshNetwork technology, originally designed for ad hoq networks in mobile miltary applications. End-user devices add to the network, serving as mobile relays.
Spokane, WA	Municipal Internal			Commerce Network	local government, law enforcement, fire dept., mobile municipal employees, public hotspots	Vivato Wi-Fi Outdoor Switch	2.4 GHz		100-block downtown hotzone
Central Oregon: Hermiston, Stanfield, Boardman, Irrigon, Echo, Umatilla	Municipal Internal				Oregon Chemical Stockpile Emergency Preparedness Program (CSEPP): First responders.	Proprietary 802.11	2.4 GHz	66 towers over a 50 mile by 15 mile area	CSEPP needed a secure wireless network to help protect the Army's Umatilla Chemical Depot from terrorist attack. The network will eventually be opened for resident and business access.

Sources:
Data was collected from newspaper articles collected from Nexis searches and private web sites who report on wireless networks, including: http://www.MuniWireless.com, http://gigaom.com/, http://wifinetnews.com/, and others.

Allegheny County, Maryland	Municipal Internal	Municipal Commercial			buildings (County gov't; City of Cumberland gov't; K-12 schools; police; fire;) 95% County	Alvarion, 5 GHz; 2.4 GHz; 900 MHz	5.8 GHz; 2.4 GHz; 900 MHz	8 Towers hosting approximately 116 Access Points across all unlicensed frequencies.	This extensive network in rural, mountainous Western Maryland connects to a a robust licensed wireless SONET that uses unlicensed freuencies for last-mile connections.
San Mateo, California	Municipal Internal				Law Enforcement	Tropos Mesh Network, 802.11	2.4 GHz	40 meshed nodes deployed over 2-square-mile downtown area, officers use wireless notebooks to connect to network	Tropos network end-users do not relay signals to each other, but connect directly through a wider network of access points.
University Circle, Cleveland (Part of the OneCleveland Metropolitan Area Network)			Community Network		Public Users	Cisco Aironet 1200	2.4 GHz	1,230 Access Points across the Case Western Reserve University campus, providing free Wi-Fi to public parks to anyone with a wireless card.	The initial wireless project in the OneCleveland metropolitan area fiber & wireless network.
Long Beach, California				Commerce Network	Public Users	Proprietary 802.11	2.4 GHz	Network covers 4 blocks and access points in 30 businesses	
Lower Manhattan New York City (Dntwn Alliance)				Commerce Network	Public Users	802.11	2.4 GHz	7 Access Points covering public areas, including City Hall Park and Bowling Green Park.	A project completed with help from Emenity and NYCWireless.

Sources:
Data was collected from newspaper articles collected from Nexis searches and private web sites who report on wireless networks, including:
http://www.MuniWireless.com, http://gigaom.com/, http://wifinetnews.com/, and others.

Stevenson, WA	Municipal Internal			Commerce Network	Public Users	LocustWorld Mesh Network	2.4 GHz	32 square blocks. One node is posted on County Courthouse providing access to downtown area, another providing access	Funded by Stevenson city council and led by Stevenson Business Association.
Portsmth, VA(Wstbry Public Housing Project)			Community Network		Residential (278 residences)	Alvarion proprietary 802.11	2.4 GHz	Access Point on roof of model home.	Funded initially with $32,000 in HUD money to cover Internet connection costs.
Lafeyette, Loisianna	Municipal Internal		Community Network		Public Safety, Public Users	Tropos Mesh Network, 802.11	2.4 GHz	Access points cover a 13-square mile area across the city	
Cerritos, California	Municipal Internal	Municipal Commercial			City Government, Businesses, Residential	Aiirmesh Wireless, 802.11 mesh	2.4 GHz	One of the first municipal wireless, mesh networks	
York County, PA	Municipal Internal				County Government, Nine school districts (40 schools)	Alvarion, OFDM, NLOS (WiMax grade)	5 GHz	Provides point to point connections between schools to distribute bandwidth from one T-3 connection.	Expected to save County over $200,000 per year over cost for leased T-1 lines for each school.
Ellaville, Georgia	Municipal Internal	Municipal Commercial			Residential, Business	Alvarion and WaveRider	2.4 GHz, 900 MHz, 5.8 GHz	Access points located on one central tower in small town	

Sources:
Data was collected from newspaper articles collected from Nexis searches and private web sites who report on wireless networks, including: http://www.MuniWireless.com, http://gigaom.com/, http://wifinetnews.com/, and others.

Buffalo, Minnesota	Municipal Internal	Municipal Commercial			Residential, Businesses, (700 customers)	WaveRider	900 MHz & 2.4 GHz	7 towers employed (5 are water towers); subscribers install antennas themselves w/ window mounted receivers. 14 x 12 mile coverage area.	Project run by the city electrical utility. Break even point for subscribers was 500.
Gladstone, Michigan		Municipal Commercial			Residential, Business			One tower covering a 10 square mile area in a town of 5,000	
Yakima County, WA	Municipal Internal				Law Enforcement (police forces in six districts; county INS and DEA offices)	Cisco Aironet 340	2.4 GHz (encrypted)	80 mile network extending from the city of Yakima, down the lower Yakima valley. Police vehicles contain wireless bridges and wireless laptops.	Officers can connect to network while driving at 70 MPH, have access to crime databases, mug shots at traffic stops for improved safety and arrests.
Dickenson County, Virginia		Municipal Commercial			Municipal, Business, Residential	Proprietary Solutions	2.4 GHz, 900 MHz, 5.8 GHz		
Sun Prairie, WI		Municipal Commercial			Business, Residential (450 subscribers), Schools, Municpal buildings			Antennas mounted on three water towers, connecting to municipal fiber for backhaul.	
Waupaca, WI		Municipal Commercial			Residential, Business (200 subscribers)			One large tower with multiple repeaters. Service area covers 17,000 residents over a 30 mile area.	

Sources:
Data was collected from newspaper articles collected from Nexis searches and private web sites who report on wireless networks, including: http://www.MuniWireless.com, http://gigaom.com/, http://wifinetnews.com/, and others.

Benton County, WA		Municipal Commercial			Residential, Business	Proprietary 802.11	2.4 GHz	Access Points posted on lamp posts and city buildings every 5 blocks in the City of Kenniwick, WA.	The Benton County PUD has built the wireless network, connecting it to the utility's fiber backbone, and local ISPs buy wholesale access to the network and sell service to customers.
Franklin County, WA		Municipal Commercial			Residential, Business	Proprietary Solutions	2.4 GHz; 5.7 GHz	Located across the river from Benton, robust sectorized network	The Franklin County PUD network is similar to Benton County, except with an improved infrastructure, according to a local WISP.

Sources:
Data was collected from newspaper articles collected from Nexis searches and private web sites who report on wireless networks, including: http://www.MuniWireless.com, http://gigaom.com/, http://wifinetnews.com/, and others.