SPECTRUM POLICY PROGRAM

PROFILES OF
MUNICIPAL AND COMMUNITY BROADBAND NETWORKS[1]

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Introduction

Low-cost, high-speed, community operated wireless broadband networks are revolutionizing public communications, spurring economic development, and bridging the digital divide. If this new technology can be blended with good public policy, the next few years could witness a transformation in American telecommunications.

New wireless networks crop up across the country every day. Clouds of wireless connectivity now cover the business districts in our urban areas. They blanket entire towns and cities in rural America and serve as mobile communications systems for public safety officials in communities nationwide. Often, these networks are public/private partnerships operated jointly by local governments and technology firms. Still others are run by community groups or non-profit organizations. Taken together, these wireless networks offer the potential for broadband access to consumers, business, and government as a public utility—just like sewer, gas, electric, or the city streets.

What these networks all have in common is the unlicensed spectrum they use to transmit signals—tiny slivers of the public airwaves that have not been licensed to the federal government or commercial incumbents. It is a public commons on the public airwaves—a perfect free market open to technological entrepreneurs. Unlicensed spectrum has spurred billions in economic investment and opened up new opportunities for community development that were unthinkable a decade ago. Arguably, at no point in history has such a small amount of a public resource been leveraged to produce such an enormous social gain.

Policies to Tap the Potential of Wireless
The primary policy challenge for the expansion of this technology is the expansion of unlicensed spectrum access. The more unlicensed spectrum is available, the more available these technologies will become. Wireless broadband networks share the scarce unlicensed spectrum available in the public airwaves today with devices such as cordless phones, baby monitors, and microwave ovens. Interference can sometimes be a problem. Increasingly, wireless broadband systems will rely on "smart radios," devices that listen before they talk, adjust power levels dynamically for precise "volume" control, and automatically seek out empty spectrum in the shared sector of the airwaves.

But as these networks grow, inevitably they will require more – and better – spectrum. Not every frequency in the public airwaves is created equal. Some can pass through obstacles and travel long distances better than others. The bad news is that the bands that are currently unlicensed are not ideally situated. The good news is that there is a great deal of highly useful spectrum that sits unused the vast majority of the time. A combination of "smart radios" and government authorization to use these frequencies could turn a fallow resource into a public treasure trove. Not only would this be a multi-billion dollar marketplace, it would enable universal, affordable broadband access to all Americans within a decade.

How Does the Technology Work?
The most sophisticated wireless broadband networks are known as "mesh networks." This simply means that the antennas that transmit the broadband signal through the network are arrayed across a town or city like a web, or mesh. Each point of intersection on the web represents a small antenna with a data router, or a "node." Each "node" broadcasts a bubble of connectivity. The bubbles from each node then overlap with one another, forming a cloud of connectivity over the length and breadth of the network for PCs, laptops, PDAs, and any wireless device within range to use (even if they are in motion). It is similar to how a cellular phone

passes from one coverage zone to the next. However, unlike cell phones, wireless broadband uses the same "open architecture" as the wired Internet. The web of nodes, or mesh, distributes data, voice, video, and audio across the network.

A mesh network has no identifiable center—no large, expensive towers that serve as "hubs". The nodes in a mesh network are relatively small and inexpensive. They are placed on top of city street lights, on residential rooftops, buildings, or even grain silos in rural areas. Unlike centralized networks, each new node on the network does not use extra capacity from a central hub; nor must all the data traffic flow back to the center before it goes out again to the edges of the network. The mesh is versatile, sending data around obstacles and finding new pathways automatically to utilize all the available capacity in the network. Much like the Internet itself, the more nodes are in the network, the more robust the system becomes.

Municipal Wireless Broadband Case Studies

Profiles Include:

> 1. *Philadelphia, PA*
> 2. *Corpus Christi and Granbury, TX*
> 3. *Chaska, MN*
> 4. *Greene County, NC*
> 5. *Scottsburg, Indiana: Citizen's Communications Corporation*
> 6. *Unlicensed Public Safety Networks: Secure, Affordable and Fast*
> 7. *Rockwood Area School District: An Unlicensed Educational Network*

According to an April 2004 report from the White House on American innovation: "The President has called for universal, affordable access for broadband technology by the year 2007 and wants to make sure we give Americans plenty of technology choices when it comes to purchasing broadband." This is a clarion call for public policy that encourages technological innovation, fosters local ingenuity, and sparks new competition in every marketplace—especially those underserved in rural and low-income communities. The report continues: "Broadband technology will enhance our Nation's economic competitiveness and will help improve education and health care for all Americans. Broadband provides Americans with high-speed Internet access connections that improve the Nation's economic productivity and offer life-enhancing applications, such as distance learning, remote medical diagnostics, and the ability to work from home more effectively."[2]

Unfortunately, many Americans find themselves on the wrong side of the digital divide. Without dramatic changes in broadband policy, many Americans will struggle to find the advantages the President acclaims. Many more will not be online at all. The commercial broadband market has not only failed to produce universal access in 2005, it is nowhere close. According to NTIA's latest report, only 20% of American households currently have "high speed" access, defined generously as 200 kbps. Around 35% use dial-up, and over 40% do not have Internet access at home. Over 35% do not have computers.[3] We are not among the top 10 countries worldwide for broadband penetration, and our rates are much higher than those of other developed nations.[4] This is largely because a handful of cable and telephone companies enjoy almost total control of the marketplace. They use that power to secure monopoly profits, pressure localities into leasing public rights-of-way well below market value, lobby state legislatures to pass laws that restrict municipal entry into the market, and fight against policies that would open networks and airwaves for public service.

In the past few years, hundreds of municipal governments have begun exploring how to directly provide high-speed broadband through local, municipal networks. Whether building a wireless system, installing fiber directly to homes, or exploring broadband over power lines – or some combination of these options – local communities are finding they can get better service for less money if they do it themselves. In response, major telecom firms have pushed legislation in more than a dozen states that prohibits public entities from entering into the broadband market. At least

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[2] http://www.whitehouse.gov/infocus/technology/economic_policy200404/innovation.pdf
[3] http://www.ntia.doc.gov/reports/anol/ [Data was compiled through October 2003.]
[4] http://www.itu.int/osg/spu/newslog/2004/09/15.html#a720 [The US is ranked 13th in this study.]

eight additional state legislatures – with more expected soon – are considering similar anti-municipal broadband bills in 2005.[5]

The most high-profile of these fights occurred in Pennsylvania, where Verizon pushed through a bill in late November – in the face of widespread public outrage – to prevent local communities from offering competitive broadband services. This political contest is now playing out across the country, notably in the heartland of rural America, Nebraska, Iowa, Illinois, and Indiana. The legislative outcomes will contribute in no small part to deciding whether the market can meet the President's goals. Without municipal broadband, the gaps in the market will persist. Without municipal broadband, low-income and rural communities will be left behind.

Profile 1:
Philadelphia, PA: Wireless Philadelphia[6]
City Intends to Set Standard by which Wireless Accessibility is Measured

Wireless Philadelphia is an initiative of the City of Philadelphia to establish a digital infrastructure for open-air internet access. The city has partnered with interested public and private parties to provide wireless access for the entire city, in an effort to create a truly digital city that supports economic development, social development and helps close the digital divide.

The City of Philadelphia has invested in the creation of a new wireless mesh network serving the entire city based upon the current Wi-Fi 802.11b standards. By deploying individual Wi-Fi cells on street lights and other traffic control devises, the city has covered large areas quickly, and can serve these areas at a low cost. When the Wi-Fi units have been installed, they will create a self-organizing and self-healing wireless mesh. While some of the units will require a high capacity connection to the Internet, most units will only require access to a power source that can be readily obtained from the existing street or traffic light. Anywhere from 8 to 16 units will be needed per square mile depending upon topography and the built environment.

It is estimated that this type of wireless mesh network can be deployed for approximately $60,000 per square mile. For the City of Philadelphia, with approximately 135 square miles of land area, wireless access could be provided to the entire city for $7.0 to $10.0 million. An example of a model that could be used to finance the initiative is a public/private partnership that could be funded through public grants, industry donations/sponsorships, strategic partnerships and collaborations and foundations.

In April 2003, Dianah Neff, the Chief Information Officer of the City of Philadelphia, presented a briefing paper to the Mayor on citywide broadband wireless access. The Mayor then authorized a pilot using a wireless LAN mesh network that was completed successfully in Love Park in June 2004.[7] In August 2004, Mayor John F. Street announced the appointment of the Wireless Philadelphia Executive Committee, which was established to work with the city's Chief Information Officer to create a business plan for the initiative.

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[5] http://www.freepress.net/communityinternet/=munibroad
[6] Source unless otherwise noted: Wireless Philadelphia Executive Committee, "Frequently Asked Questions," available at: http://www.phila.gov/wireless/faqs.html
[7] John Cox, "Full Speed Ahead for Philly's Wi-Fi Plan," *Network World Fusion*, January 17, 2005

Profile 2:

Corpus Christi and Granbury, TX[8,9]

Two Texas Municipalities Leverage Citywide Wi-Fi Networks for Public Safety and Affordable Business and Residential Internet Access

Corpus Christi, Texas, originally deployed a citywide Wi-Fi network for use by the city-owned water and gas utilities, public works departments, and public safety agencies. The city first used its Wi-Fi network for a municipal application when it implemented an automated gas and water meter reading system. Currently, each meter in the coverage area relays usage information twice a day to strategically placed receivers throughout the city. In turn, each of these receivers transmits information from its region to the central office over the citywide Wi-Fi network, utilizing an unlicensed band. Eliminating the need for utility personnel to visit each meter and manually record customer consumption, the city can more quickly and accurately provide up-to-date billing information to their service recipients. Additionally, utility customers have immediate, real-time usage data available to them through a Web-based billing and information system run by the city and, which is automatically updated with the latest meter readings. With this application alone, Corpus Christi's wireless broadband network is resulting in significant cost savings and increased productivity for the city.

In addition to the utility applications, the network has now become available for use by the Corpus Christi Police and Fire Departments. The public safety agencies, with more than 315 police, fire, and EMS vehicles in their collective fleet, will use VPN authenticated access to all of the applications currently available only in their offices. Previously, the city would have had to implement an expensive trunked data network for secure police applications. Wi-Fi enabled access to the police VPN has eliminated the need for this expensive system. Now, members of the Corpus Christi police force are able to access full-color photos of crime scenes and suspects from their squad cars. Soon, they will be able to view streaming video of disaster sites and crime scenes (this application is currently in the proof-of-concept phase). The city also plans to operate GPS-based asset and vehicle tracking applications over the Wi-Fi network, increasing both officer and community safety.

Corpus Christi is one of the few but growing number of municipalities with a truly mixed-use wireless broadband network. All citizens have free access to the City of Corpus Christi's network (with all government-related sites), and the city has also partnered with several ISPs to offer full Internet access for a reasonable price.

Granbury, Texas (pop. 6,000) is deploying a Wi-Fi network that covers 26 square kilometers. The city will use the network for public safety (police, fire and emergency services), building inspection, meter reading and public access. Granbury, like Corpus Christi, is one of the first communities to launch a mixed use citywide Wi-Fi network.

The city did not put out a tender to build the network. They have an ongoing partnership with a local ISP, Frontier Broadband, for wireless local area network (WLAN) infrastructure management. The city gives Frontier permission to use city property to mount mesh nodes and antennas; it also allows Frontier to use city employees to install them.

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[8] Adapted from "Corpus Christi, Texas Gets Citywide Wi-Fi," July 29, 2004 and "Granbury, Texas Unwired," October 19, 2004, www.muniwireless.com.

[9] Additional information provided by Leonard Scott, Project Director, City of Corpus Christi Wireless Network, and Mike Timmins, Vice President, Frontier Broadband

The city has already implemented wireless broadband access for the offices of the city government. As in Corpus Christi, improving public safety is a major strategic goal of the Granbury wireless network. All police squad cars in Granbury now have access to the Internet using the wireless network, giving officers the ability to conduct research and retrieve information on secure Internet sites, something they previously had to go back to the office to do. The city's Wi-Fi network has helped improve public safety by giving the police force faster access to information and by keeping officers out on the streets longer. In addition, Granbury's network also results in a sizeable return on investment for the police department, which the city estimates to be $80,000 in the first year. Wireless access is not limited to the police department alone. The fire department has recently also been equipped with access to the network, and ambulatory services and wildlife rangers in the region will be equipped soon.

For public access (residential and business subscriptions), Frontier Broadband has a multi-tiered pricing plan, with basic 384 Kbps service costing $19.95 per month, and higher speeds tiered up to $30. This pricing makes it very competitive with dialup services in the region.

Profile 3:
Chaska, MN
Community Values Drive Push for Affordable Community Broadband Access

Located 20 miles southwest of Minneapolis, the small town of Chaska (pop. 17,449) has built one of the first city-wide wireless mesh networks—Chaska.net. According to the city's Information Systems Manager Bradley Mayer, Chaska, Minnesota went into the broadband business because the town cares about community. "Chaska has always had this real tie to traditional small-town community values," Mayer explains. "Everything thing we do here from the parks to the Internet access is driven by that sense of community."[10] City managers talk about public service as their number one priority, bringing broadband to their citizens where they work, study, and live.

Deployed over the course of a few months in 2004 for about $800,000, the system now has over 2,000 subscribers and is expected to grow by another 1,000 to 1,500 over the course of the next year. With this level of participation, the network will pay for itself and turn a profit. Furthermore, because the project was financed by a $1 million private loan, it was created at no cost to taxpayers working with wireless mesh vendor, Tropos.[11] The backbone of the Chaska network is formed by 250 Tropos 5110 outdoor antennas which cover most of the city's 15 square miles.[12] These form a wireless mesh network, which uses a series of interconnected antennas that rout traffic through each other, rather than an expensive fiber-optic backbone. After some initial kinks were worked out during the installation process, the network is running smoothly and claims a 99.9% uptime and speeds of 1.5 to 3 Megabits per second.

On top of all this, the service costs only $16 per month, far less than can be claimed by local incumbents Time Warner and Sprint. Perhaps surprisingly, Chaska has yet to be confronted by these companies, which Mayer attributes to being a small enough town to get "under the radar."[13] In addition to residential uses, access to the network is also available to businesses, and it is used by the police force to communicate with officers on the move.[14] Ultimately, though, the service was created for the community its founders speak so glowingly of: "We firmly believe that the Internet is going to be just as much a part of everybody's future as the telephone or electricity is

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[10] http://www.wi-fiplanet.com/columns/article.php/3369331
[11] http://www.freepress.net/news/6741
[12] http://www.tropos.com/products/5110outdoor.shtml
[13] http://www.freepress.net/news/6741
[14] http://www.wi-fiplanet.com/columns/article.php/3369331

and we want to make sure that everybody has equal access to it," says Mayer. "We wanted to ensure there was some sort of broadband activity that could be affordable by our residents."[15]

Profile 4:
Greene County, NC: Beyond Tobacco
Economically Depressed County Looks to Unlicensed Wireless Broadband to Help Citizens Help Themselves

In 2003, the Greene County School Board decided to start a digital revolution in rural North Carolina. For an agricultural county of under 20,000 people ranked the second most tobacco-dependent in the nation, the past few years have been devastating. Almost 15% of Greene County's workforce lost their jobs between 1998 and 2000 alone. Faced with an uncertain future for its 3,000 schoolchildren, Superintendent Steve Mazingo and the school board asked themselves: "What will it take to provide a level playing field?"

Their answer was "iTech," a $3.5 million dollar program that put Apple laptops in the hands of every student from sixth through twelfth grade: over 1,500 in all. Wireless internet access was provided on school grounds and the laptops were incorporated into everyday lesson plans. Mazingo praised the results: "The principals told me that as soon as the kids had the iBook laptops in their hands, the school environment just became different. It got quieter everywhere, the students became less rowdy, and there were documented reductions in disciplinary problems. Because those schools are entirely wireless, students are taking advantage of that capability during break times and in between classes. In fact, we actually see students out in the athletic stadium or in their cars with their iBook laptops open, working." Using technology, Greene County students have taken charge of their digital future.

Now, the county wants to take it to the next level and offer low-cost wireless across the county. Currently, DSL service and T-l lines are currently available to less than 8% of the population. "I don't know of anyone else who has an interest in providing broadband in our market," Mazingo said.[16] It is the classic case of market failure. Commercial broadband providers simply have not provided adequate service. Local governments have found a solution in wireless broadband, and they intend to move quickly to help their citizens help themselves.

The plan is called Beyond Tobacco, and it was approved by the school board in February 2004.[17] In order to move internet access beyond the schools and into people's homes, businesses and communities, it uses a wireless network both for last-mile connections and also for hot-spots in public places where people congregate. Specifically, they plan to use Motorola's Canopy Technology which uses a 900Mhz framework capable of transmitting long distances through obstacles. Although this product is not yet commercially available, the county will be part of Motorola's beta test. Another component of the plan is to create online content for use by their customers, both agriculture-specific such as "an eBay for farm equipment," and more general purpose features, from community events to information and advice on how to start a new business.

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[15] http://www.cnn.com/2004/TECH/internet/10/18/wireless.city/index.html
[16] http://www.kinston.com/SiteProcessor.cfm?Template=/GlobalTemplates/Details.cfm&StoryID=18120&Section=Local; http://ntiaotiant2.ntia.doc.gov/top/details.cfm?oeam=376004004
[17] http://www.kinston.com/SiteProcessor.cfm?Template=/GlobalTemplates/Details.cfm&StoryID=18120&Section=Local

Actual installation and administration of the network will be handled by Greenville-based ISP Wavelength, Inc. Wavelength currently lists its prices starting at $34.95 per month. Because 2,000 laptops have already been given to students and their families in Greene County – together reaching over 25% of the population – the network has a built-in customer base, but Beyond Tobacco aims to extend the opportunity to every resident.

The plan to phase the network in over the next three years got a major leg up when the School Board was awarded a $524,000 grant from the National Telecommunications and Information Administration's Technology Opportunities Program in 2004. This is enough to cover over half the cost of the initial set-up. Strategic government investment in technology by federal and local officials offers to yield enormous dividends in the quality of life in rural America. The NTIA deserves credit for recognizing such a promising initiative that has the real potential to improve the quality of life in this county – and to help it finally kick its tobacco habit.[18]

Profile 5:
Scottsburg, Indiana: 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

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[18] http://ntiaotiant2.ntia.doc.gov/top/details.cfm?oeam=376004004;
http://ntiaotiant2.ntia.doc.gov/top/docs/nar/pdf/376004004n.pdf

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 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 6:
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 7:
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.

Simply bringing the technology to the area wasn't the end goal – using the network to connect the school with the community was 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.

Community Broadband Networks Using Unlicensed Spectrum

Profiles Include:

> 1. ***Champaign-Urbana Community Wireless Network***
> 2. ***The Southern California Tribal Digital Village***

Community wireless networks aimed at serving social needs will eventually provide not only universal, low-cost access for public government, civic organizations, churches, and educators, but also the impetus for a new tier of commercial applications and attendant economic development. Much like the Internet has done, community wireless will provide an enormous return on investments — maintaining low costs with accelerating benefits.

Central to this technology is public access. Wireless networks increase the number of speakers in the public sphere by decreasing the cost and lowering barriers to access. The mesh network offers not only connection to the Internet, but it also provides a local network for sharing a variety of public services. Using wireless broadband networks, local communities can offer citizens streaming audio and video for:

- Secure communications between public safety officials
- Enhanced services for small businesses
- Internet radio stations
- Forums for local political debate
- Galleries for local artists
- Telemedicine
- Interactive distance education
- City council
- PTA meetings
- Music festivals
- Church services
- High school football games

Rural communities cut off from urban economic centers have leaped ahead of metropolitan wired technologies using wireless networking. Entire regions of isolated towns in Texas, Washington, Maryland, and California (just to name a few) are now connected to next generation wireless networks. In an amazingly short time period, wireless technology has created state-of-the-art, public media systems delivered by businesses, governments, and not-for-profits in the communities they serve. These systems have proven a boon for economic development and an asset for improving quality of life.

This is a technology whose time has come. The success of wireless broadband in rural America has inspired international aid workers to explore how community wireless networks can be implemented in developing countries to bring them rapidly into the modern economy. This is an idealistic technology with realistic goals in practical applications. The following examples demonstrate.

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. 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 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

Access to unlicensed airwaves can create economic and education opportunities in rural communities. This is especially important to sovereign Native American tribes who are in some of the most remote locations in North America. 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 created the Southern California Tribal Digital Village (TDV) which has constructed a 7500 square-mile unlicensed bandwidth, wireless network connecting 18 federally-recognized tribes in rural San Diego County.

The network currently reaches more than 500 workstations, including Tribal Libraries, Tribal administration buildings, E.P.A., Sheriff, fire departments and Tribal 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.

The Southern California Tribal Digital Village (SCTDV) network connects the Tribal libraries through a Universal Service Administrative Company (USAC) subsidy.

The network uses and distributes the excess bandwidth across the 18 reservations with base station antennas and relays installed by SCTDV staff, student/youth volunteers and trainees. These 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 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. 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 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.