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Stipes Hall 518
Western Illinois University
1 University Circle
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www.IIRA.org

Wireless Broadband Communications Systems in Rural Wisconsin

by Kenneth J. Schlager[1]

The low population density of rural areas makes them economically marginal for cost-effective deployment of broadband communications technology, and a serious need exists for system design optimization to provide an adequate return on the infrastructure investment. This report presents a systems engineering approach for the design of broadband wireless communications networks in rural areas.

Although the approach presented here draws on historical roots dating back to the early days of the Bell System and its associated Bell Telephone Laboratories, the methodology has been largely neglected in an era of unrestrained market competition. Recent experience in Wisconsin strongly supports the power of communications systems engineering in developing cost-effective rural broadband wireless communications networks.

Rural communities in the U.S. have long been on the wrong side of the so-called "digital divide" that separates areas with and areas without broadband communications. Rural America is limited not only compared to urban areas, but even more so with respect to advanced countries in East Asia and Europe—our global economic competitors. Despite America's leadership in technological innovation and pioneering efforts in almost every form of modern communications, the U.S. still lags far behind its world competitors in broadband communications (24th in global standings) (Websiteoptimization.com 2008). This low standing, even in metro areas, compounds the problems of rural broadband communications, placing it almost in the Third World, undeveloped subnation category.

The roots of the U.S. and rural America's dilemma lie not only in failed national communications policies but also in a lack of system planning of advanced communications networks. Prior to 1984, the year of the breakup of the Bell System, the U.S. had the premier telecommunications network. Now, 23 years later, after two unprecedented decades of U.S.-driven advances in communications technology, the U.S. has been overtaken and bypassed by nations better organized to deploy new technologies.

How has this situation come about? During the Bell System era, communications networks—especially those employing new technology—were planned in great detail by the Systems Engineering Division of the Bell Telephone Laboratories. The amount of effort devoted to the design of networks and systems often exceeded the work hours involved in developing the original technologies.

The end result was a systematic structuring of technologies to meet a defined set of user needs. Such a system design regimen is especially critical in economically marginal system applications such as broadband rural communications systems. An urban environment with high population density has a higher margin of error, but the margin between success and failure can be very small in rural applications.

This report describes a communications system engineering planning process that demonstrates an ability to design and deploy cost-effective broadband networks in low density rural areas. The emphasis is on innovative solutions and systems optimization because of the marginal nature of rural telecommunications infrastructure investments. Otherwise, rural America will continue to lag behind in an unforgiving global economy.

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[1]Author is Chief Telecommunications Engineer at the Southeastern Wisconsin Regional Planning Commission (SEWRPC). SEWRPC is a regional planning agency that provides land use and physical infrastructure planning services to seven counties in southeastern Wisconsin. He also founded a small engineering company that develops and manufactures wireless communications equipment.

Context

The free market approach to the telecommunications services market in the U.S. began with the consent decree that broke up the Bell System in 1984. Previously, AT&T and other carriers formed a regulated monopoly controlled by the Federal Communications Commission (FCC) and the various state public service commissions. The original breakup, while splitting up AT&T into seven "Baby Bells," still retained a semi-regulatory environment in the service sector with a combination of state and federal regulations. The telecommunications equipment market, however, was freed of all regulation, resulting in a tremendous surge of technological innovation. This surge was amplified by the growth and commercialization of the Internet and the rapid expansion of mobile wireless services.

Deregulation of the service sector was accelerated by the U.S. Telecommunications Act of 1996 ("Telecommunications Act" 2008) which attempted to introduce competition into all segments of the telecommunications market. Both the Internet and wireless services continued to grow at a rapid rate resulting in a frantic "rush to market" in all segments of telecommunications. This rush was only temporarily interrupted by the collapse of the Dot.Com boom in 2000. Despite heavy financial losses to some investors, the telecommunications services market continued to expand—particularly in the Internet and wireless segments.

Free market telecommunications growth, however, heavily emphasized private return on investment, which resulted in the neglect of marginal economic areas. Rural areas were unattractive for infrastructure investment. Their marginal economic disadvantages were compounded by the "rush to market" decision making patterns of service providers. Affluent markets were besieged by multiple providers of cellular wireless networks. Vast fiber optic networks were deployed throughout the U.S., leading to a glut of long line capacity that even today represents excess capacity in a growing market.

No longer was there a Bell Telephone Laboratories with its systems planning function to provide rationality to telecommunications growth and deployment. Nor was there a compact—a Federal/Bell compact—to provide universal service to all urban and rural areas. A rational approach to telecommunications infrastructure at all levels of government and geography—local, regional, state, and national—is needed. One example is taking place in seven southeastern Wisconsin counties.

Telecommunications Planning in Southeastern Wisconsin

Arthur Hall (1992) of the Bell Telephone Laboratories in his book, *A Methodology for Systems Engineering*, considered systems engineering a vital link in the chain of activities leading to deployment of advanced telecommunications networks. This sequence of activities included the functions of research, systems engineering, development, manufacture, and operation.

While the other functions have been retained, systems engineering, as previously noted, has mostly disappeared from telecommunications planning. Its reintroduction into the telecommunications planning process of the Southeastern Wisconsin Regional Planning Commission (SEWRPC) represents a small reincarnation of the original Bell Systems engineering discipline. Planning for infrastructure in a contiguous, multi-county region by a public agency, however, presents additional challenges not encountered in the original Bell System.

First, SEWRPC is only an advisory agency with no direct implementation powers. It has some indirect control over plan implementation in transportation infrastructure (i.e., highway and public transit) through a gatekeeper role for state and federal funding, but there is no equivalent in primarily privately funded telecommunications infrastructure. To develop public and business support for its plans, SEWRPC typically creates an advisory committee of representatives from both public and private sectors who are knowledgeable and concerned with the specific infrastructure plan and its subsequent implementation. The guidance and support of such advisory committees have proven their worth in the past and were considered necessary for the newly initiated telecommunications planning function (SEWRPC 2007).

Membership on the advisory committee included representatives from the wireless and wireline communications service industries such as AT&T, CenturyTel, and Verizon Wireless, plus personnel from local governmental agencies. This advisory committee reviewed and approved each stage of the communications planning process beginning in 2004 and until final plan approval in September 2007.

Although the goals and much of the methodology of the telecommunications planning process were similar to that of systems engineering at the Bell Telephone Laboratories, there were two significant differences that had to be recognized from the beginning (SEWRPC 2003):

1. *Regional Context* – Conducted under a regional planning commission, telecommunications planning was required to serve the needs of a geographic region—the seven counties of southeastern Wisconsin surrounding a major city, Milwaukee. Systems engineering within the Bell System typically was project-oriented for new technologies that would serve operating companies throughout the U.S. with little concern for other needs of the population. Regional telecommunications planning had to be integrated with the land-use pattern and the social and economic characteristics of the region, along with other infrastructure such as the transportation network.

2. *Development Context* – Telecommunications systems, however, differ significantly from other public works infrastructures, such as highway and public transit networks, in their rapidly changing technology and their tradition of private ownership. Communications technology was evolving so rapidly that five-year or at most ten-year planning time horizons were the limit, unlike the 20- to 30-year time horizons of most public works plans. Close attention to the state and direction of communications technology was an absolute necessity lest the plans become obsolete before they are published. Innovation itself became an implied characteristic of visionary, yet practical, telecommunications plans.

Regional Telecommunications Systems Planning Process

The end result was the newly created telecommunications planning process in southeastern Wisconsin that married traditional regional planning with telecommunications systems engineering (SEWRPC 2003). The regional aspect of the process makes it especially applicable to rural areas where regions with similar socioeconomic characteristics can be addressed as a unified entity. As practiced in Wisconsin, this planning process involves the following interrelated activities:

- Objectives and standards
- Service-level, performance, and network infrastructure inventories
- Telecommunications needs
- Forecasts
- Plan design
- Plan implementation

Objectives and Standards

Formulating a set of telecommunications system service objectives is an essential task to be accomplished before alternative plans can be prepared and a recommended plan selected. Objectives must be related in a demonstrable way to alternative regional telecommunications plans and related system development proposals through quantifiable standards. Only if the objectives clearly relate to telecommunications service quality and development through the standards, and are subject to objective tests, can a choice be made from among alternative plans to select a plan that best meets the agreed-upon objectives.

In scope, the telecommunications plan and system development objectives and standards may be expected to range from general objectives relating to the growth of the regional economy to detailed standards related to the types and quality of service to be provided in urban, suburban, and rural areas in the region.

Although specific objectives and standards may vary by region depending on the state of telecommunications and the general state of the social economy, the objectives used in southeastern Wisconsin are typical for many rural regions:

- *Performance*
  - Measured by network throughput expressed in megabits per second of average data transfer rate
  - Represents the very definition of broadband communications services

- *Universal Geographic Coverage*
  - Measured by the percentage of the regional area to be served with broadband telecommunications services

- *Capital and Operating Costs*
  - Measured by the combination of infrastructure costs and the present value of future operating costs

- *Redundancy*
  - Measured by the average number of alternative transmission paths between users in a network
  - Necessary to provide reliable communications, especially during major public emergencies

- *Provision for Public Safety Communications*
  - Measured by the multimedia (i.e., voice, data, and video) performance and reliability of the public safety communications network
  - Promotes infrastructure cost-sharing with commercial networks—a major factor in economic feasibility

- *Serve Most Demanding Application*
  - Measured by the throughput required to serve various forms of video from standard television broadcasting and videoconferencing to interactive television
  - Standards for the above can range from three megabits per second (for standard television) to 100 megabits per second (for interactive television)

The listed objectives and measurement standards are the criteria by which alternative plans are evaluated and selected.

Inventories

Inventories represent the current status of communications in the region and can range from cataloging current services for fixed, nomadic (i.e., laptop computers), and mobile (i.e., cell phones) users and their respective performance to detailed descriptions of existing wireless infrastructure in terms of all of the current antenna base station sites. The latter inventory is a regional resource that must be known in detail for the most cost-effective deployment of new broadband wireless networks.

Telecommunications service inventories are common in traditional survey-based studies of rural areas. These studies have typically emphasized geographic coverage or lack of coverage of various services such as telephone, television, and Internet access in areas throughout the region. Lacking have been inventories of the cost/performance of these services and how they compare with equivalent services in other rural and urban areas in both the U.S. and throughout the global economy.

In southeastern Wisconsin, extensive efforts were made to measure performance of current broadband telecommunications services and their related cost/performance indices, and how this performance compares with national and international standards. Only in this way can a base of inventory knowledge be established to determine the relative value of proposed new system designs. In some instances, such as mobile cellular communications services, local field measurements are required to determine network performance and reliability. For the bulk of performance measurements, existing Internet websites provide extensive information on throughput performance for both wireless and wireline networks at local, state, and national levels.

The most time-consuming and costly part of the inventory stage of the planning process is the data compilation of the current wireless and wireline infrastructure. Since new broadband telecommunications initiatives in most rural areas focus on wireless rather than wireline (i.e., optical fiber) networks, determining the current state of the location and characteristics of existing antenna tower sites is a primary priority. These sites represent a valuable resource for utilization in any proposed broadband wireless network. The term *antenna tower site* should be interpreted in a broad sense to include privately owned as well as publicly owned sites and other public structures, such as water towers or buildings, that could serve as structures for antenna base stations.

At the same time, it is important to realize that all wireless networks must eventually connect to an Internet gateway. For this reason, potential fiber network gateway locations must also be inventoried in order to provide potential Internet interconnect locations for new wireless networks. The final outcome of the inventory stage is an assessment of the state of communications in the selected region. Such an inventory provides the solid foundation necessary to design and implement broadband communication networks in the region.

Needs

A notably neglected area of regional planning, especially in telecommunications, is needs research. Too often, the assumption is made that need for advanced communications networks is self-evident. Deploy the networks and users will sign up in droves. Such an assumption often prevails in rural areas that have lagged behind urban areas in the availability and use of broadband Internet access.

While there is an element of truth in this assumption for rural broadband, it obscures the real challenge of creating applications that go beyond the transmission of e-mail messages and downloading Web pages. Given the isolation and travel time disadvantages of rural America, broadband communications can have a much greater impact in rural than in urban America if the same level of innovation applied to developing technology is devoted to its applications.

Returning to systems engineering in the Bell System and Bell Telephone Laboratory, needs research played a prominent role in the planning and deployment of new communications technology. The need for each new deployment was thoroughly reviewed prior to its full-scale deployment. Paper studies were often followed by experimental, small-scale deployments to test market acceptance prior to major investments. Although success was not universal, with the failure of the early “picture phone” as a primary example, the commitment to needs research as an integral part of the system engineering process was rarely questioned.

Telecommunications needs in rural areas may be classified into two categories: (1) current needs and (2) new applications. Current broadband telecommunications needs are fairly well-defined and understood and usually include the following:

- E-mail
- Web browsing
- Online education
- Online gaming

With the previous lack of broadband communications services in most rural areas, there is usually a pent-up demand for these traditional applications that have been severely restricted by the slow throughput rates of dialup services. Some of these traditional applications, such as Web browsing and online education, will find a new level of performance and practicality with the deployment of broadband communications.

The ultimate value of rural broadband communications, however, will be achieved with innovative new applications that improve the economic development and quality of life in a rural region. Extensive discussion of the possibilities for such new applications would take us too far afield here except to mention three categories of application that have stirred great interest and could each alone justify a new broadband telecommunications network:

1. As a network for a more independent and self-sustaining regional economy
2. As a network to upgrade health care in the rural region, particularly in areas such as home healthcare, mental healthcare, and emergency medicine
3. As a network for improved interactive education

Each of the above three applications could justify a separate *Rural Research Report*, but they are mentioned here to emphasize the potential of broadband communications in changing the nature of rural economics and rural life. As in previous new paradigm shifts, such as the railroads and highway transportation, the full value of broadband telecommunications will be realized only after it is fully integrated into the economy and social patterns of rural life.

Forecasts

Traditional regional planning for public works infrastructure develops forecasts of infrastructure demand based on population and economic activity projections. Such forecasts in areas such as transportation, water supply, and wastewater treatment typically extend 20 to 30 years into the future. Such long-term forecasting is not appropriate because telecommunications is characterized by rapidly changing technology and usage patterns.

Rather, most wireless telecommunications networks are designed to meet current demand as determined by the previously cited inventory and with some excess capacity that is limited by the need, particularly in rural areas, to maintain an adequate return on investment. Since wireless communications networks are easily reconfigured and expanded, detailed forecasts of future demand are really not required. At the same time, new technology typically provides more performance at lower cost, allowing for expansion in network capacity with only minor changes in network structure.

Wireless Communications System Design in Rural Regions

The previous planning activities relating to setting objectives/standards and inventorying existing communications infrastructure, services, performance, and user needs all set the stage for the most important phase of the planning process—system design. Communications system design as part of a regional planning process differs from more traditional planning functions, such as transportation, in the rapidly changing nature of communications technology (SEWRPC 2007). Such rapid changes offer opportunities but also some pitfalls. Opportunities result from the myriad of system configurations possible with ever-improving hardware and software options. Such options are critically needed to overcome the economic challenges of deploying advanced communications systems in low population density rural areas.

To be more specific, a direct application of the known and emerging wireless communications will not necessarily prove cost-effective in rural America. Such deficiencies manifest themselves in wireless network solutions having such a poor return on investment that neither private nor public organizational entities can justify the investment.

Examples of broadband wireless network deployments in a rural town and a partially rural county in southeastern Wisconsin presented later in this report will illustrate both the need for system design innovation and the efficacy of particular solutions. For this reason, the communications design sequence described here must often be interrupted by searches for new alternatives in order to achieve the cost-effectiveness necessary for rural regions.

Wireless network system design typically involves the following three-step sequence:

1. *Radio Propagation Modeling-Based Network Layout*
   - Estimates network coverage and performance for a trial set of antenna sites through a computer-based simulation model
   - Uses a database containing information on geographic terrain, forestation, and building structures
   - Provides an initial network layout and infrastructure cost estimate
2. *Network Field Testing* (SEWRPC 2006)
   - Verifies and/or modifies the modeled plan based on radio signal measurements in the field.
   - Employs portable truck-mounted antennas and radio transceivers
   - Records network coverage and performance for some or all of the proposed antenna site locations
3. *Revised Network Layout*
   - Is based on field test experience
   - Provides a final system design ready for network deployment and plan implementation

If the revised wireless system design satisfies all of the objectives and standards previously specified at a cost compatible with an adequate return on investment, the project moves to network deployment and plan implementation.

Experiences in Wisconsin and many other areas of rural America have often produced wireless network designs that are lacking in economic viability. The return on investment is too low to attract either private or public investment. The process stalls, and the rural digital divide continues.

The innovations required to break this chain of failure in the Wisconsin experience took two forms of innovation: (1) technical and (2) institutional. In the area of technical innovation, the primary challenge of rural wireless communications is the high cost of infrastructure deployment relative to the expected return in revenue from communications services. This excessive cost is manifested in the number of access points required to serve a low population density rural area. An extension of the range coverage of each antenna site is needed so that the access point density is reduced to an acceptable level.

Technical innovation took the form of greatly improved receiver performance that significantly expanded the range of each antenna site so that the costs of network infrastructure provided a more than adequate return on investment. While previously it required 15 to 20 antenna sites to service a 36 square mile rural town, the high-performing new wireless receivers reduced the number of antenna sites to only four. FCC regulations severely limit the transmit power on unlicensed WiFi bands, but they do not limit the sensitivity of the receiver—the improvement of which transformed the application from a problem into an opportunity.

Even with a cost-effective system design, however, the funds for wireless communications are often not available in many rural communities. Frequently, there are better opportunities for investment capital than wireless communications. Although the long-term benefits of rural broadband communications may be extraordinary for rural

America, these benefits are sometimes overshadowed by the demands of more traditional community needs.

Once again, innovation of a different kind was needed to stimulate investment in a broadband communications infrastructure. This innovation took the form of a public/private partnership to spread the costs of infrastructure deployment over a wider range of public and private communications services. Wireless communications play a vital role in the public safety function at all levels of government.

Law enforcement, fire fighting, and pre-hospital emergency medicine all depend on wireless communication to carry out their work tasks, especially in times of emergency situations. If the needs of public safety communications could be joined with the needs of personal and commercial communications in a rural area, then the economies of broadband wireless could be transformed and the rationale for capital investment completely changed.

Such an opportunity arose with the FCC announcement in 2002 of a new frequency band at 4.9 GHz for broadband wireless communications for public safety functions. Using this frequency band, the previous restrictions on high-speed data and video communications in public safety could be overcome. Fortunately, there is also a nearby unlicensed frequency band at 5.8 GHz that would allow for a common antenna site infrastructure able to serve both public safety and commercial needs.

This joint public/private partnership approach was incorporated in the recommended broadband telecommunications plan for southeastern Wisconsin. One of the seven counties, Kenosha County, has already begun the implementation of this joint public/private partnership approach in a joint project with the regional planning commission. The point here is that an institutional innovation was able to change the economics of broadband wireless and allow for the deployment of a network to serve the otherwise unserved rural areas in the western part of the county.

Plan Implementation

Implementation of broadband wireless network deployment in the U.S. has proven to be a difficult task even in urban areas where higher population densities provide a larger potential market. Wireless mesh networks in larger cities such as Philadelphia, San Francisco, Milwaukee, and Chicago have encountered serious setbacks in achieving an economically sustainable operation.

The key to success lies in the business model for communications services operations. The market situation in metro areas differs significantly from that in rural areas. In metro areas, broadband communications services in the form of telephone company digital subscriber line (DSL) or cable company modems are widely available. While these technologies do not rise to the performance level of the broadband wireless networks discussed here, they do seem to satisfy the Internet access needs of most residential and small business subscribers.

Most rural areas in the U.S., in contrast, have very limited Internet access alternatives. The two primary alternatives are a slow telephone dial-up service or a very expensive but almost equally slow satellite service. A survey of one rural town in southeastern Wisconsin indicated a large, pent-up demand for broadband wireless communications services. In the Town of Wayne, Wisconsin, more than 20 percent of the households were ready to subscribe to such a service as soon as it became available (SEWRPC 2006). The SEWRPC region has 50 rural towns like Wayne largely without broadband communications services and ready to cross the digital divide for survival and growth in a global economy.

Lacking the competitive market conditions of urban areas, implementation of broadband wireless networks in rural America reduces to two major tasks: (1) financing, installing, and maintaining the network; and (2) operating the network as a business. These two separate, but related, functions may or may not be performed by the same organizations. The business operations function requires the background and talents of an Internet Service Provider (ISP). Since many ISPs lack both the capital and the expertise to finance, install, and operate advanced wireless communications, these functions usually fall to either a unit of government or a private organization skilled in wireless communications.

The previously discussed public/private partnership embracing both public safety and commercial WiFi that lies at the heart of the regional telecommunications plan in southeastern Wisconsin is a primary example of government leadership in plan implementation. Whatever the organizational structure, it must meet the needs of the two primary tasks previously cited.

Wayne is a rural town in Washington County, Wisconsin. Like most mid-western townships, it has a total area of approximately 36 square miles. Although officially listed as part of the Milwaukee-Racine-Waukesha Metropolitan area, it is very rural in nature with an average population density of only 17 persons/square mile. With a 2000 census population of 1,727 people and 582 households, it is one of the most rural of communities in the southeastern Wisconsin region. Its present and continuing rural character is further indicated by its 2020 Land Use Plan prepared in 1999 by the southeastern Wisconsin Regional Planning Commission (SEWRPC 1999). This plan provides for the preservation of natural resource areas and primary agricultural lands into the distant future. New residential development will be maintained at rural densities, and nonresidential developments will be confined to three small defined areas in the town.

As a rural community in one of the seven counties of the southeastern Wisconsin region, Wayne was selected jointly by SEWRPC and HierComm, Inc. as a demonstration site to determine the feasibility of a broadband wireless communications system in a rural town. SEWRPC would support communication systems planning services for the project, and HierComm, Inc. would provide engineering design services and deploy and operate the new network. The project was financially supported by a three-year grant from the U.S. Department of Agriculture. It is important to point out that there are 23 other low population density townships (less than 100 persons per square mile) in the southeastern Wisconsin region. For this reason, the Wayne demonstration project was a key part of the regional telecommunications plan for the seven counties of the region. The SEWRPC developed a broadband wireless communications plan for the rural areas (approximately 67% of the seven-county land area) of the region. The U.S. Department of Agriculture awarded an Small Business Innovation Research (SIBR) grant to HierComm, Inc. to develop and demonstrate a cost-effective, broadband wireless system in a rural community. SEWRPC developed and field-tested the wireless network plan, with four access points and one backhaul link serving the entire 36 square mile area as shown in Figure 1 and Figure 2 (SEWRPC 2006).

Like most other rural townships in southeastern Wisconsin, Wayne lacked broadband telecommunications services. Neither telephone DSL nor cable broadband services were available in the area. Most residents and businesses were restricted to very slow dial-up Internet services. A few residents were subscribers to a fixed wireless service provider in the area, but even these services did not meet SEWRPC broadband communications standards. Verizon North, a subsidiary of Verizon Communications of New York, provided traditional telephone services to the town. Charter Communications provided cable-based Internet services in the nearby city of West Bend. Neither service provider had any known plans to deploy broadband communications services in Wayne because Wayne did not satisfy the population density criterion of either service provider for cost-effective deployment.

Design of the network infrastructure in terms of antenna site (access point) locations and backhaul links was carried out in a four-step sequence as follows:

1. *Technology Selection Development* – Specifying the technical characteristics of access point and user equipment

2. *Preliminary Network Layout Design* – Using a radio propagation modeling tool that mapped theoretical signal strengths from each access point

3. *Design Evaluation* – Evaluating the preliminary network design based on previous objectives and standards

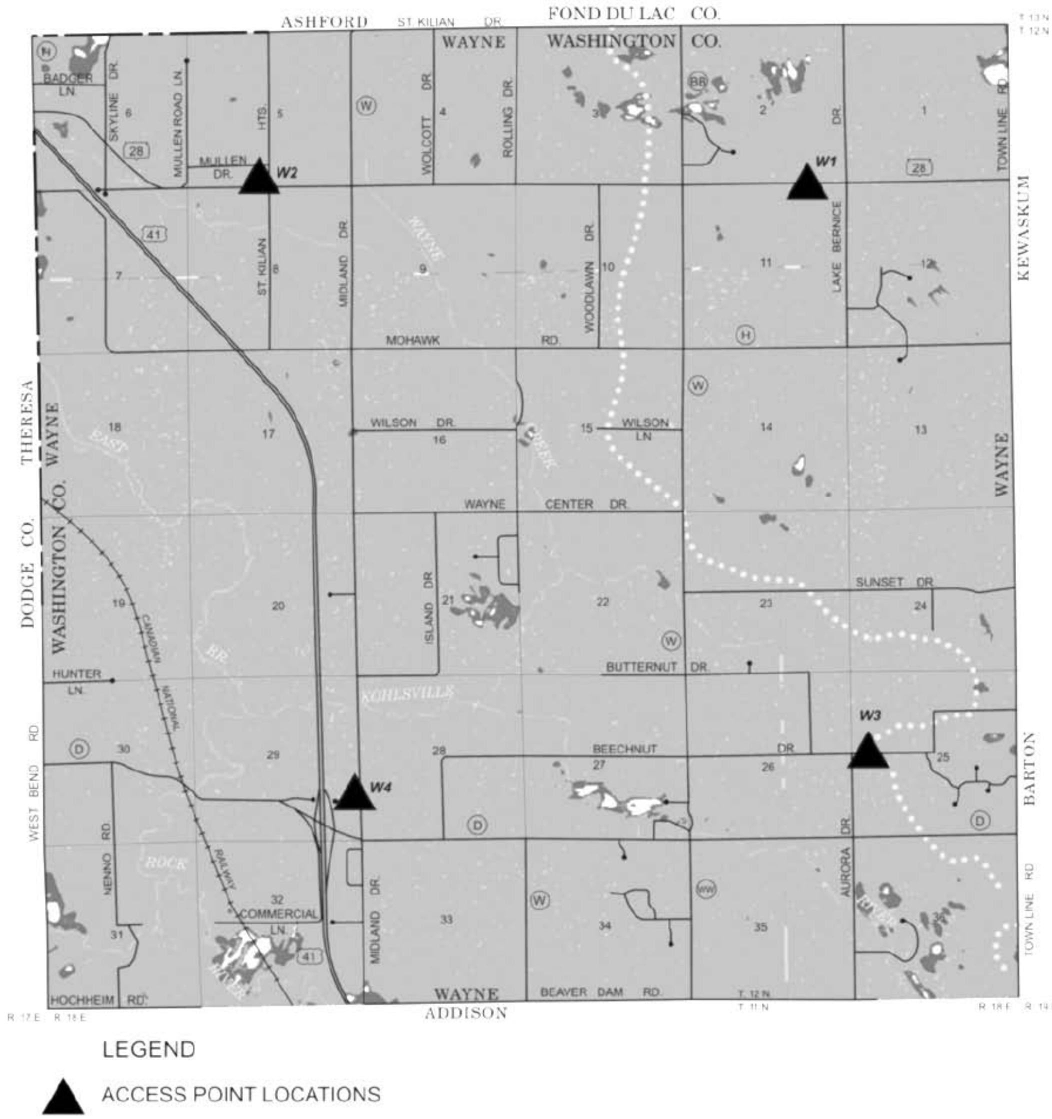
4. *Field Test* – Performing test measurements that confirm, modify, or negate model-based network design

In the first design, an attempt was made to utilize commercial off-the-shelf hardware and software based on WiFi (IEEE Standard 802.11g) technology. The low cost and wide availability of WiFi made it particularly attractive for rural application. A sectoral cellular network structure was employed to allow for the use of high gain directional antennas, which extended access point range and reduced the number of required access points. This initial design still required 30 access points, however, indicating an initial infrastructure investment of about $300,000, allowing $8,000 for each access point and $60,000 for engineering and installation costs. This cost still exceeded the target cost of $125,000 required for an adequate return on investment, however.

A second design iteration incorporated the new high gain radio receivers previously discussed, which greatly extended access point range, reducing the number of access points to only four and the infrastructure investment to $100,000, well within the target cost range. This network design shown in the network and backhaul link layouts in Figures 1 and 2 has been subsequently deployed, demonstrating throughput performance in the ten to 17 megabits per second for trial subscribers. Ownership of the Wayne network is currently being transferred to a local ISP for the start of full-scale commercial operation.

Kenosha County is a mixed urban/rural county in the southeastern corner of Wisconsin, bordering Illinois to the

Figure 1. Wayne Network



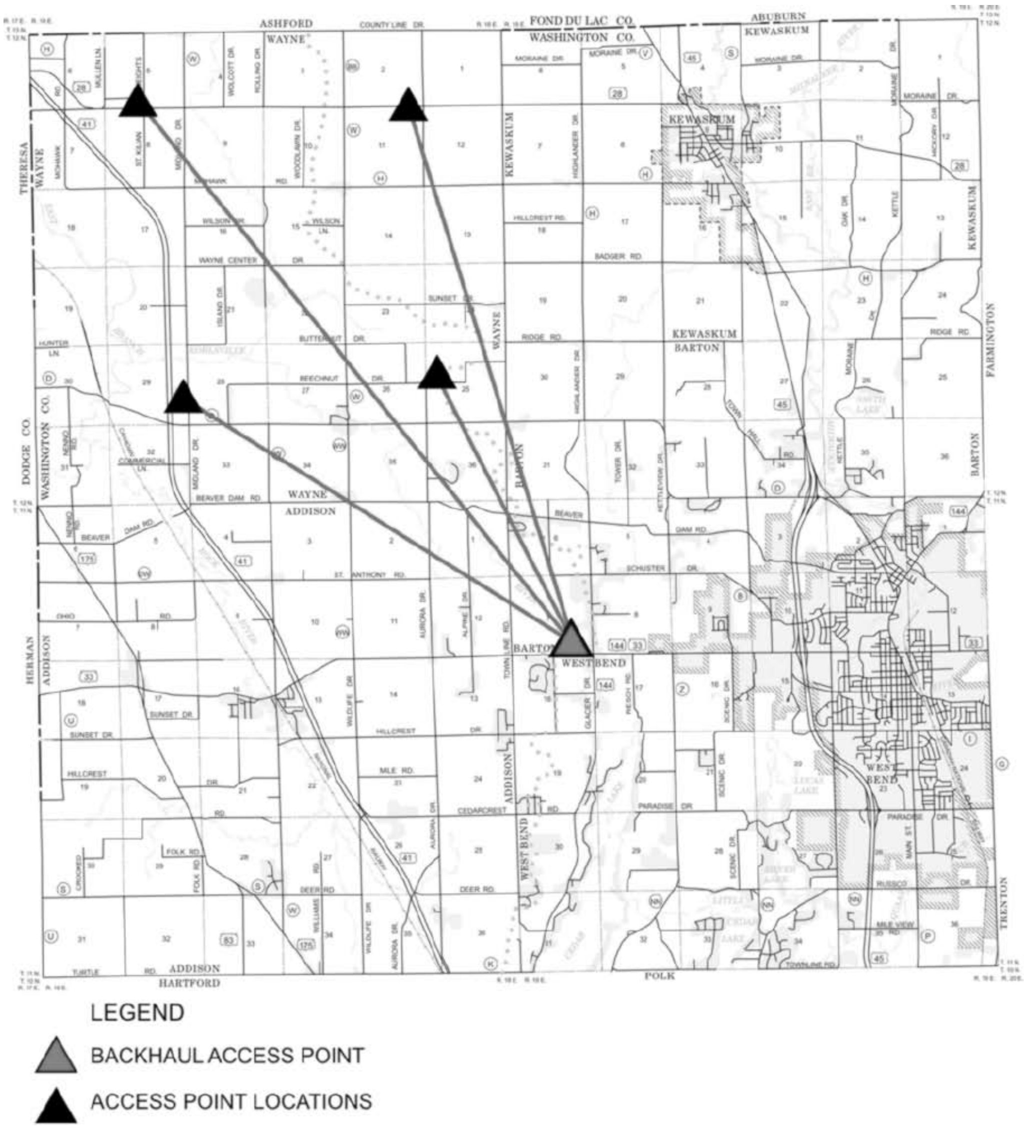
Source: SEWRPC 2006

south. The county is divided into rural and urban segments by interstate highway I-94 with 70 percent of the land area west of I-94 rural and 30 percent east of I-94 urban and suburban. The eastern urban/suburban portion of the county that includes the city of Kenosha and numerous suburbs is currently provided broadband wireline communications services by both telephone company DSL and cable company broadband. The western rural area, however, with population densities similar to Wayne, is generally unserved by any broadband communications service provider other than satellite.

In September 2007, Kenosha County became the first of the seven counties of southeastern Wisconsin to approve SEWRPC (SEWRPC 2007). Coinciding with the official publication of the plan that same month, Kenosha entered into a development/demonstration contract with SEWRPC to first demonstrate and, if successful, to fully deploy a combination public/commercial broadband communications system covering the entire geographical area of the county.

Central features of this planned network were the following: (1) long-range radio transmission in both the 4.9 GHz public safety band and the 5.8 GHz commercial band, which resulted in a low-cost, low antenna site density network; and (2) emergency backup communications capability for when the antenna site infrastructure suffers major damage (as in 9/11 and Katrina).

Figure 2. Wayne Backhaul Links



Source: SEWRPC 2006

This technical infrastructure allows for a public/private partnership to deploy a hybrid, public/commercial network that achieves a level of economic viability and synergy not possible as separate public safety and commercial wireless networks. The project that began last September is now proceeding toward a demonstration of the technology based on two initial antenna site base stations. The economic viability of the new technology depends on extending the range of radio transceivers based on highly sensitive radio reception at both ends of the mobile communications link. For this reason, project focus emphasizes the verification of this range capability by field demonstration. Suitably equipped vehicles will cruise the coverage area of the two base station sites verifying radio contact and throughput performance. Radio coverage demonstration will then be followed by a field test of the peer-to-peer communications software, which provides emergency mode communications in major public emergencies. Public safety communications have failed in every recent major national public emergency from Oklahoma City to 9/11 and Katrina. Power outages, flooding, and network saturation have all contributed to the loss of communications at a time when they are urgently needed. Originally developed for military operations under the auspices of the Department of Defense, this software technology embedded in the network will allow users to continue to communicate through other users (peers) in the event of partial or total destruction of the network infrastructure. Both of these technologies have previously been successfully tested in related applications so that expectations are high for a successful conclusion of the Kenosha County Broadband Wireless Communications project by summer 2008. Radio receiver sensitivity as a vehicle for long-range WiFi networks has previously been demonstrated in the town of Wayne. Peer-to-peer wireless communications, in addition to military applications, have recently been demonstrated in forest fire fighting for the U.S. Forest Service.

In combination, Wayne, at the rural town level, and Kenosha, at the county level, provide models for broadband wireless communication in rural America. Low-cost wireless infrastructure provides a cost-effective technology, and the public safety/commercial partnership chosen by Kenosha County provides the institutional framework for action to close the digital divide throughout all rural regions of the U.S.

Any rural county in the U.S. can initiate a broadband wireless communications project in its area by utilizing the following methods:

- Developing a broadband wireless communications plan based on the public safety/commercial partnership model of Kenosha County, Wisconsin
- Developing an implementation strategy to deploy the planned network, including the public/private financial resources for network infrastructure construction and startup
- Selecting an ISP to operate the broadband wireless network
- Forming a county-based broadband communications task force to establish and direct network applications beyond the traditional e-mail and Web searching functions, with an emphasis on regional economies, health care, and education

A rural broadband wireless program at the state level could assist rural counties in carrying out the above county-level project. Regional grouping of counties could also improve the potential economic return of rural wireless networks. Such a statewide initiative is being planned by Illinois.

Conclusion

Telecommunications systems engineering provides an effective methodology to plan and design broadband wireless communications systems in rural areas. The marginal economic nature of broadband communications networks in rural areas requires an optimal approach to system design to achieve an adequate level of economic viability. Even an optimal system design with existing technology and institutional frameworks may not be sufficient to justify broadband wireless networks in rural America.

Two innovations, one technical and the other organizational, bridged the gap for broadband wireless in rural Wisconsin. Major improvements in radio receiver sensitivity reduced the cost of the network infrastructure to a level of economic efficacy. Public/private partnerships in wireless communications networks provided the financial capital and political incentive to make broadband rural wireless communications a reality in rural Wisconsin.

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