MEMORANDUM REPORT NO. 168

SECTORAL CELLULAR WIRELESS NETWORK PLAN MILWAUKEE NORTH SHORE COMMUNITIES

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

Special acknowledgement is due Mr. Jason W. Zehrung, Senior Telecommunications Planner, for his contributions to this report.

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Prepared by the

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SECTORAL CELLULAR WIRELESS NETWORK PLAN
MILWAUKEE NORTH SHORE COMMUNITIES

INTRODUCTION

The Southeastern Wisconsin Regional Planning Commission is charged by law with the function and duty of "making and adopting a master plan for the physical development of the Region." The permissible scope and content of this plan, as outlined in the enabling legislation, extend to all phases of regional development, implicitly emphasizing, however, the preparation of spatial designs for the use of land and for supporting transportation and other utility facilities, including telecommunications facilities.

Because regional telecommunications planning comprises an integral part of a broader regional planning program, the Commission is developing a region-wide telecommunications plan. One major component of this plan is a regional wireless telecommunications plan. This plan will define a two-level hierarchical network comprised of a set of lower level community WiFi (IEEE 802.11g) networks and an upper level WiMAX (802.16d) regional backhaul network. The WiMAX backhaul network services multiple WiFi networks throughout the region providing high volume, low-cost Internet connections at special backhaul stations called gateways. This regional WiMAX backhaul network is fully described in SEWRPC Planning Report No. 51 which will be published in July of 2006. This report will describe a community WiFi network plan for Milwaukee North Shore Communities in Milwaukee County. These North Shore Communities include the City of Glendale and the Villages of Shorewood, Bayside, Brown Deer, Fox Point, River Hills and Whitefish Bay. This plan is typical for a broadband wireless network in a suburban community in Southeastern Wisconsin.

This plan has been prepared in response to a letter requesting a broadband wireless plan from the Milwaukee North Shore communities dated March 20, 2006.

SECTORAL CELLULAR WIRELESS NETWORK PLAN – MILWAUKEE NORTH SHORE COMMUNITIES

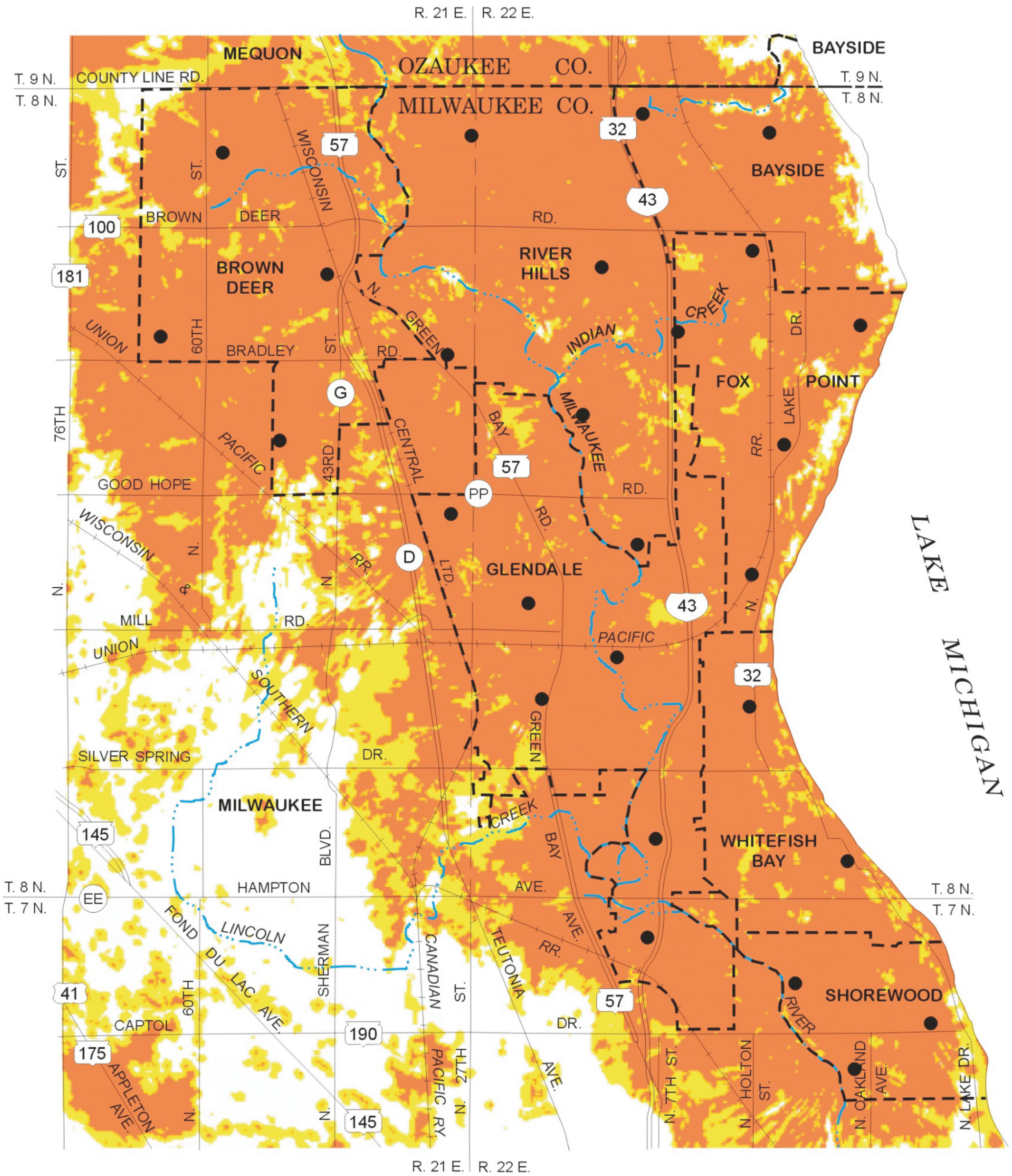
The sectoral cellular wireless telecommunication plan for the North Shore is shown in Maps 1, 2, 3, 4, and 5. On Map 1, the proposed 27 access points are shown in their preferred location for a fixed user system in which each user is equipped with a directional antenna having a gain of 13 dBi. The brown colored areas provide potential throughput performance of at least 24 megabits per second while the yellow areas have an estimated throughput performance of at least 6 megabits per second. The few white areas represent reduced signal levels that must be investigated through a field test study that will verify the signal level coverage in these areas. Although most of the white areas are believed to represent uninhabited low lying property, any inhabited area will be brought up to standards by access point adjustments in the final plan.

Map 2 represents a variation of the network design in Map 1 in which a preamplifier of 8 dB gain is added to the user's equipment configuration. Such an addition reduces the access point count to 14. This configuration, however, is not recommended as a staging network for a system servicing nomadic users because of potential interference problems caused by excessive receiver sensitivity at some fixed user locations. The network depicted in Map 1 with 27 access points provides a better foundation for a later network upgrade to service nomadic users.

Map 3 shows an 86 access point network that is designed to serve nomadic users with a laptop computer and a 802.11g network interface card. The major shortcoming of the nomadic user is reduced antenna gain. A typical laptop omnidirectional antenna gain is 5 dBi as opposed to 13 dBi for a fixed user with a directional antenna. The

Map 1

PLAN I FIXED USERS – NORTH SHORE WIRELESS BROADBAND SYSTEM
27 ACCESS POINTS



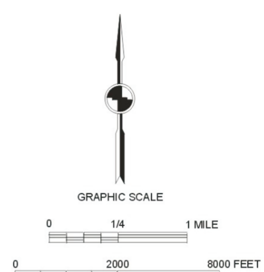
LEGEND

● ACCESS POINT-FIXED USER (27)

RECEIVED POWER AT REMOTE: GREATER THAN -89.0 dBmW, THROUGHPUT: 24 Mbps to 54 Mbps

RECEIVED POWER AT REMOTE: -97.0d BmW to -89.0 dBmW, THROUGHPUT: 6 Mbps to 24Mbps

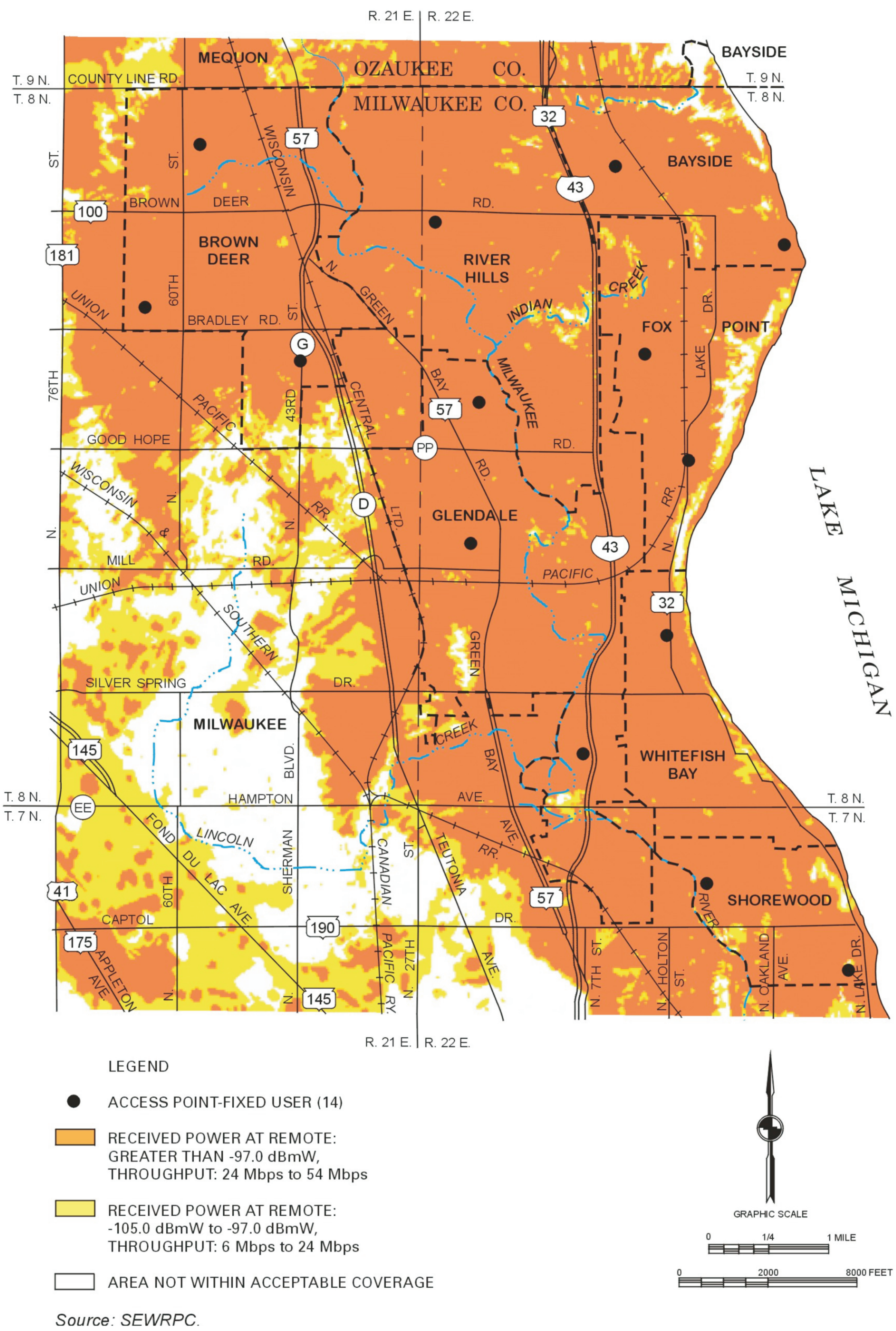
AREA NOT WITHIN ACCEPTABLE COVERAGE



Source: SEWRPC.

Map 2

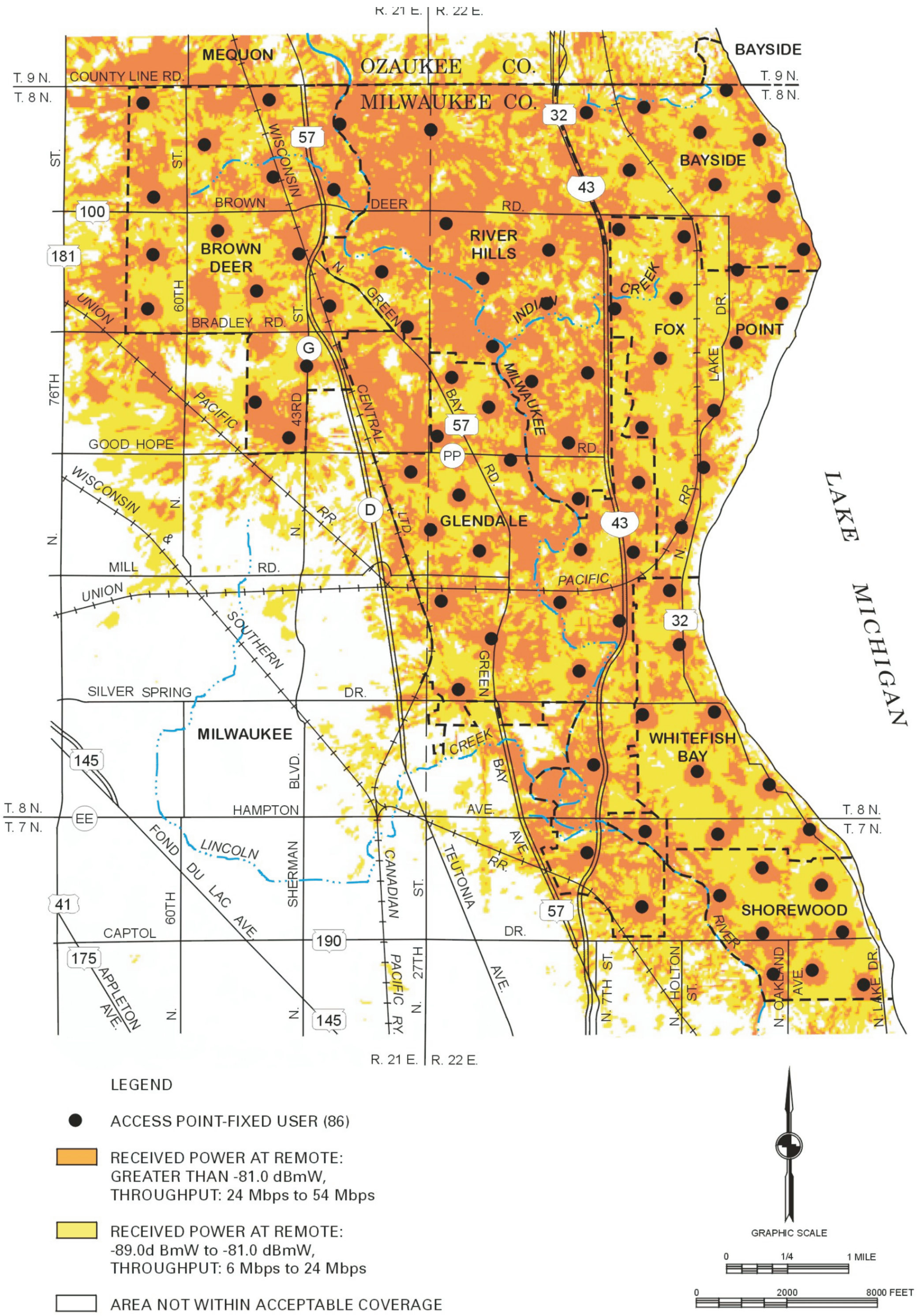
PLAN II FIXED USERS – NORTH SHORE WIRELESS BROADBAND SYSTEM
14 ACCESS POINTS



Source: SEWRPC.

Map 3

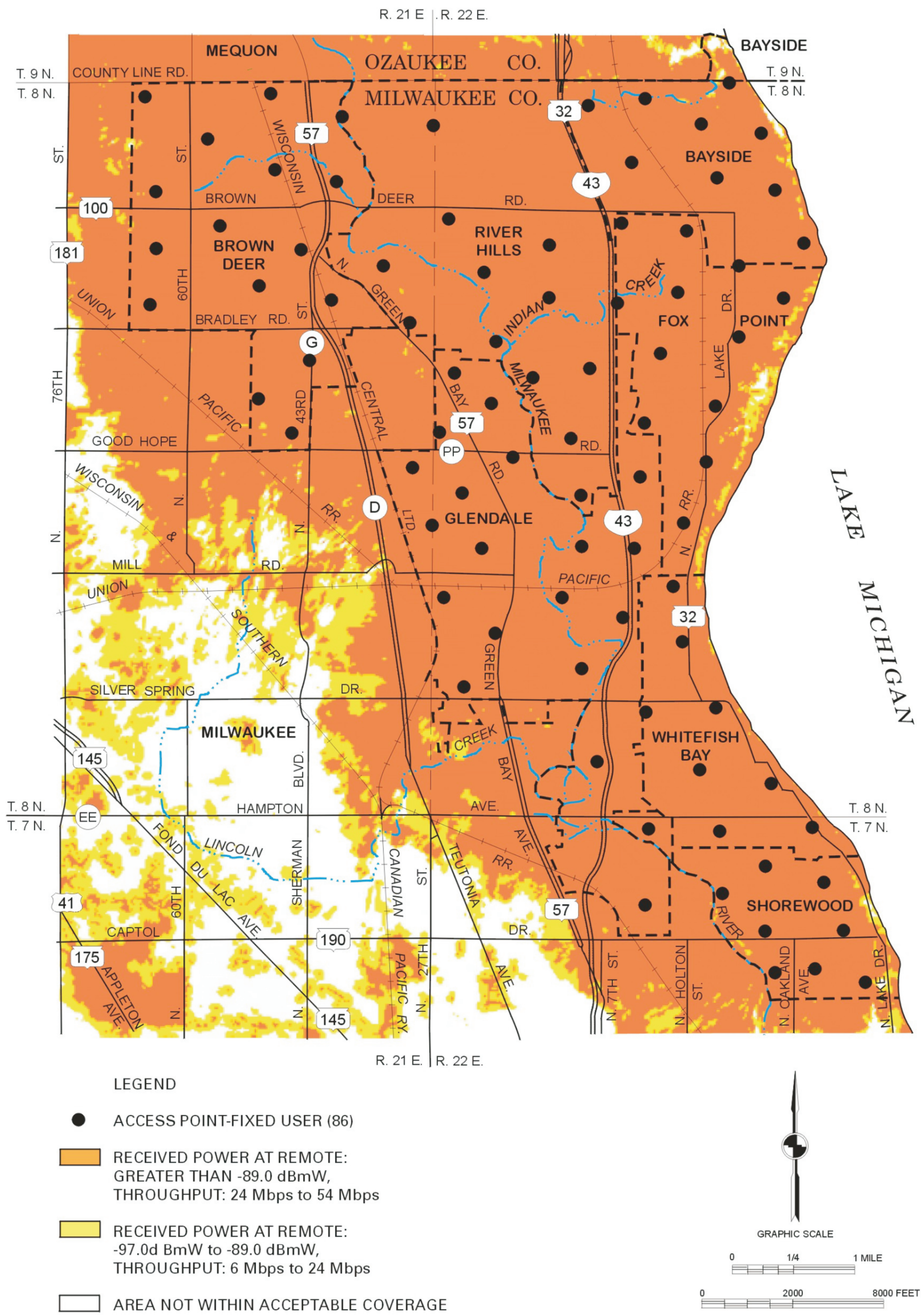
PLAN III NOMADIC USERS – NORTH SHORE WIRELESS BROADBAND SYSTEM
86 ACCESS POINTS



Source: SEWRPC.

Map 4

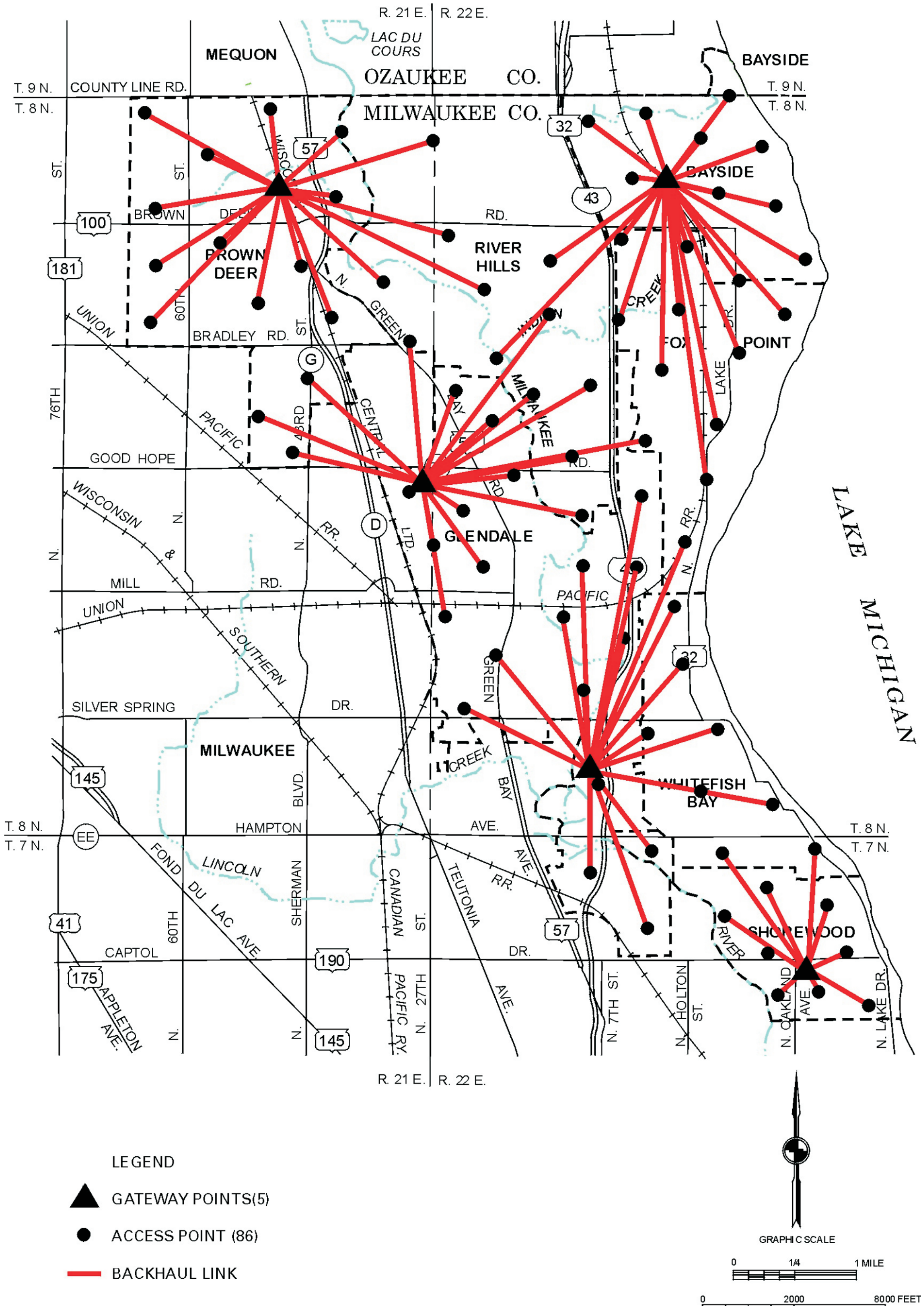
PLAN III FIXED USERS – NORTH SHORE WIRELESS BROADBAND SYSTEM
86 ACCESS POINTS



Source: SEWRPC.

Map 5

**BACKHAUL NETWORK NORTH SHORE WIRELESS BROADBAND SYSTEM
5 GATEWAYS**



Source: SEWRPC.

brown coloring represents 24 megabits per second service areas and the yellow coloring 6 megabits per second service areas. As the future quality of laptop computer antennas improve, performance for the nomadic user will approach that of the fixed user. Nomadic users, unlike fixed users, require omnidirectional antennas since they are not aware of the direction of the nearest access point location.

Map 4 indicates the throughput performance of fixed users for the 86 access point network. The predominant brown coloring indicates nearly universal 24 megabits per second performance. Yellow areas representing 600 megabits per second throughput performance are limited to lower shore areas.

Map 5 represents the 802.11a, 5.8 GHz backhaul, network in which the 86 access points report to one of the five gateways for Internet connection. Each of the backhaul links are shown to the appropriate gateway point of presence (POP) facility. All access points operate in the same contention environment in the backhaul as the 802.11g end users. All access points served by a particular 4-sector gateway sector share a common channel which is managed using Ethernet-like control rules. As traffic grows on the network, additional gateways will be added to the backhaul network structure to maintain system performance. It is important to understand that an access point as defined in this network plan is not a 100-200 foot tower base station, but only an antenna and associated transceiver equipment mounted on a utility pole at a height of about 20 feet. In communities lacking such utility poles in some neighborhoods, a non-obtrusive pole installation would be required with household grade 110 volt ac power availability.

Network Monitoring System

An important feature of any wireless communications system is a network monitoring system that would continuously monitor network performance to insure quality of service and to allow for rapid response to network problems. Such a monitoring system with a cost of about $10,000 will be included in the final system plan.

The estimated infrastructure deployment costs for each of the system configurations are tabulated below:

27 AP Fixed User Only Sectoral Cellular Network Wireless Infrastructure Costs

1.	Access Point Base Stations 27 at $6,196 each =	$167,292
2.	Gateway POP Stations Fiber Internet Connection 2 at $17,300 =	34,600
3.	Project Management and Engineering =	75,000
	Total	$276,892

14 AP Fixed User Only Sectoral Cellular Network Wireless Infrastructure Costs

1.	Access Point Base Stations 86 at $6,196 each =	$532,856
2.	Gateway POP Stations 5 at $17,300 =	86,500
3.	Project Management and Engineering =	100,000
	Total	$719,356

86 AP Fixed and Nomadic User Sectoral Cellular Network Wireless Infrastructure Costs

1.	Access Point Base Stations 14 at $6,196 each =	$ 86,744
2.	Gateway POP Stations 2 at $17,300 =	34,600
3.	Project Management and Engineering =	75,000
	Total	$196,344

Mesh Network Evaluation of a North Shore Deployment

Sufficient experience with WiFi-based mesh networks has been reported to allow for comparative cost and performance estimates of a potential wireless mesh network deployment in the North Shore area. The Tropos Networks report on a mesh network deployment in Chaska, Minnesota is particularly helpful in this respect. Tropos is the reported leader in the number of wireless mesh networks deployed in American communities. Tropos is also purported to be the supplier for the forthcoming Milwaukee wireless network. In Chaska, Tropos required an access point density of 16 per square mile at a cost of approximately $3,100 per access point. Applying these cost rates and point densities to the North Shore area of 24.7 square miles, a total access point deployment cost of $1,224,500 is indicated. Adding the costs of a network monitoring system and project management and engineering would place the total cost at about $1,450,000. Other mesh network manufacturers such as Nortel Networks and Motorola specify higher access point densities for their networks. Nortel specified 30 access points per square mile for suburban areas which would increase the mesh network deployment cost for the North Shore area to over $2.5 million.

Even with these increased costs, mesh network throughput performance does not rise to the standards specified for a 4G network. Based on the Tropos Chaska experience, data throughput in the 0.5 to 3.0 megabits per second range was achieved. This performance is below the low threshold of 6.0 megabits per second in the cellular network alternative and well below the 24 to 54 megabits per second provided the fixed location user in the recommended cellular plan.

Sectoral Cellular System Characteristics

On a cost-performance basis, the sectoral cellular wireless plan is decidedly superior. Two primary characteristics are believed to account for the difference in cellular versus mesh network performance:

1. Omnidirectional Antennas
   The nature of a mesh network requires the use of omnidirectional antennas which have significantly lower gain than the directional antennas used in the sectoral cellular system. These lower gain antennas result in reduced signal levels and correspondingly lower data transmission rates.

2. High packet loss rates
   The lower signal levels in turn cause high packet loss rates which further reduce throughput performance. Such reduction is compounded by the procedures followed by the Internet TCP/IP protocol in handling packet losses.

A final comment concerning WiFi-based mesh networks is relevant here. Because these networks employ proprietary routing protocols and other vendor specific features, they no longer qualify as IEEE standards technologies with the lower costs and other benefits of standards-based technologies. A WiFi mesh network standard (802.11s) is in preparation, but it is not expected to be certified until 2008.

The estimated cost of cellular infrastructure deployment for the North Shore area was based upon equipment cost quotations from a WiFi/WiMAX equipment manufacturer. Total cost of the infrastructure was determined based upon the cost of each access point plus the cost of Internet access – whether the access is provided through a WiMAX backhaul network or through a direct POP connection to an optical fiber network. In this estimate, a direct optical fiber network connection was assumed.

Part of the project engineering cost would support field testing to verify the performance of the plan access point locations in providing specified signal levels throughout their individual coverage areas. The cost estimate encompasses only the network infrastructure and does not include the cost of user equipment which would be purchased by individual users.

The North Shore area broadband wireless telecommunications system is designed to serve the residential, business or other fixed location user as well as nomadic users with laptop computers. Fixed user transceiver equipment, particularly the antenna, must be upgraded to process the reduced wireless signal levels. Such an upgrade would take the form of a directional antenna. Such a directional antenna mounted on the side of a dwelling or other building in a manner similar to a satellite TV antenna will increase the gain of the fixed user's receiver allowing for higher data transmission rates. The user's receiver gain may be further enhanced using an active antenna. An active antenna includes electronic circuitry to boost the signal level and to provide a proper impedance match for the cable that connects the antenna to the user's transceiver network interface card. To support this enhanced receiving capability, the fixed user will require two equipment items: (1) an active antenna with appropriate cabling connections; and (2) a network interface card available at many retail outlets.

The combined cost of the fixed user's equipment, including installation, should approximate $300. Part of the cost can be recovered from the user as part of the initial installation, and the rest could be amortized over the life of a one year or two year subscription contract. Allocation decisions on these startup costs will be influenced by the Internet Service Provider (ISP) who would be engaged to build and/or manage the system.

Business Models

Two alternative business models are proposed for community consideration. The first would involve an outside investor-operator who would install and operate the system with one or more Internet Service Providers (ISPs). The second would involve local government ownership of the infrastructure with a contracted ISP. Both models bring broadband wireless services to the entire community. The first model involves no financial commitment by the local unit of government, but does involve surrender of control of an important service and economic development tool to a private owner.

There are investor-operator firms interested in proposing on this broadband wireless system for the North Shore area. Careful consideration should be given to the advantages and disadvantages of private versus pubic ownership of the network.

Wireless Voice Communications

The initial deployment of the network will focus on data communications and Internet access. Voice communications services, however, could be incorporated into the system at an early date. Such voice communications services would utilize the Voice-over-Internet Protocol (VoIP) capabilities of the broadband wireless network. VoIP services may be incorporated into the network in one of three ways:

1. ISP Operator Upgrade
   In this scenario, the ISP would purchase and install the necessary server equipment to provide VoIP services.

2. User Provider Selections
   Here, the user would select his own VoIP service from a national or regional provider independent of the ISP's data services.

3. ISP Contract with Major VoIP service provider
   In this alternative, the ISP would contract with a national VoIP service provider to furnish the service on a wholesale basis.

The third alternative is probably preferable since the best quality of service is obtained with a minimal investment and with competitive service to the user.

Wireless Network Development Process
The currently prevailing wireless telecommunication system development process within the United States places the responsibility for system development largely within the private sector. Therefore, the system development process is driven by decisions made within national corporate structures in response to competitive market forces. Public telecommunication service planning efforts, such as that conducted by the Southeastern Wisconsin Regional Planning Commission, are intended not to replace, but rather to influence this competitive, market driven process in the public interest. To be effective, the introduction of public planning requires some changes in the current entirely private development process. The modified system development process, then, consists of the following sequence of steps:

1. Public preparation of a broadband wireless system plan for a designated service area;
2. Preliminary review and approval of system plan by the municipalities comprising each service area concerned;
3. Field studies to verify or modify the preliminary plan as may be found necessary;
4. Final review and approval of system plan by the municipalities comprising each service area concerned;
5. Issuance of a request for proposals to deploy infrastructure in accordance with approved plan;
6. Selection of infrastructure development vendor;
7. Issuance of a request for proposals to operate system;
8. Selection of an internet service provider to operate the system; and
9. System operation

Step 1 of the above sequence has been accomplished in conjunction with the first phase of the system planning process. The plan is now being presented for approval by the municipalities concerned. Plan approval will be followed by a field study. This field study will test each access point by temporarily stationing a vehicle equipped with a three-sector antenna set and related transceiver equipment. A second vehicle then travels around the service area recording and mapping signal levels and other pertinent performance parameters. After each of the proposed access point areas has been recorded, a comprehensive areawide signal level coverage map is prepared and compared with the original radio propagation model coverage maps to identify areas of weak signal coverage in any of the communities. If poor coverage areas are revealed in the field study mapping, then changes in access point locations will be made to provide uniform high quality radio coverage.

The remaining steps of the development sequence relate to the bidding and selection process for the infrastructure installation and network operation. These steps are more properly covered as part of the plan implementation which will be detailed in the final report following the field study.

SUMMARY

A broadband WiFi wireless communications system plan has been prepared for the Milwaukee North Shore area. Two primary broadband wireless plan alternatives have been described; one for fixed users only and the other for nomadic (laptop computer) users as well as fixed users. Fixed users in all plan versions are provided fourth generation (4G) quality throughput service of 20 megabits per second or faster. Nomadic users are serviced with a throughput rate of 6 megabits per second or better in all areas.

The infrastructure costs for a fixed users only broadband wireless system for the entire North Shore area is $251,350 for a network with active antennas at all fixed users. These same infrastructure costs for a network designed to serve nomadic laptop computer users as well as fixed users totaled $638,000.

A nine step plan design, test and system implementation process was outlined in which Commission staff would assist the North Shore communities in broadband wireless system deployment from the initial network plan confirmed by field test verification through the procurement and service provider selection process to systems startup and operation. The initial system development supports only data communications and high speed Internet connection, but voice communications using VoIP technology can be added at a later date.