

MINUTES OF THE THIRD MEETING
REGIONAL TELECOMMUNICATIONS PLANNING
ADVISORY COMMITTEE (Reconstituted)

DATE: October 26, 2004

TIME: 2:00 P.M.

PLACE: Commissioners' Conference Room
Regional Planning Commission Offices
W239 N1812 Rockwood Drive
Waukesha, Wisconsin

Members Present

Kurt W. Bauer Chairman	Executive Director Emeritus, SEWRPC
William R. Drew Vice Chairman	Vice-Chairman, SEWRPC; Executive Director, Milwaukee County Research Park
Roger Caron	President, Racine Area Manufacturers and Commerce
Bob Chernow	Chairman, Regional Telecommunications Commission
David L. DeAngelis	Village Manager, Village of Elm Grove
Michael Falaschi	President, Wisconsin Internet
Barry Gatz	Network Supervisor, CenturyTel
Michael E. Klasen	Director, Regulatory Affairs, SBC Wisconsin
J. Michael Long	Attorney-at-Law, Murn and Martin, SC
Jody McCann	Network Domain Manager, Wisconsin Department of Administration, BadgerNet
George E. Melcher	Director, Office of Planning and Development, Kenosha County
Paul E. Mueller	Administrator, Washington County Land Use and Park Department
Steven L. Ritt	Attorney at Law, Michael Best & Friedrich
James W. Romlein	Managing Director, MVLabs, LLC
Paul R. Schumacher	Program Manager, TriCounty Business Partnerships
Michael Ulicki	Vice President and Chief Technology Officer, Norlight Telecommunications
Gustav W. Wirth, Jr.	SEWRPC Commissioner

Members Absent

Kenneth Brown	RF Engineer, Nextel Communications, Inc.
Brahim Gaddour	Director of Network Operations, Time Warner Telecom of Wisconsin
Jeff Mantes	Commissioner of Public Works, City of Milwaukee
Bennett Schliesman	Director, Kenosha County Emergency Management /Homeland Security
Dale R. Shaver	Director, Waukesha County Department of Parks and Land Use
Darryl Winston	Director of Data Services, City of Milwaukee Police Department

Staff

Kenneth J. Schlager, PhD
Lynn G. Heis

Chief Telecommunications Engineer, SEWRPC
Staff Secretary, SEWRPC

CALL TO ORDER AND ROLL CALL

Chairman Bauer called the meeting to order at 2:00P.M. Roll call was taken by circulating an attendance signature sheet, and a quorum was declared present.

CONSIDERATION OF THE MINUTES OF THE MEETING OF SEPTEMBER 30, 2004

Chairman Bauer noted that copies of the minutes of the second meeting of the Reconstituted Regional Telecommunications Planning Advisory Committee held on September 30, 2004, had been distributed to all members of the Committee for review prior to the meeting, and asked that the Committee consider approval of those minutes.

Mr. Chernow called attention to the 6th full paragraph on page 10 and asked that his name be stricken from the paragraph in that he had not participated in the comment concerned.

Chairman Bauer called attention to Appendix 1 of the minutes consisting of a revised Technical Study Design Memorandum No. 3: Wireless Antenna Site and Related Infrastructure Design, particularly noting the extensive changes made in the memorandum on pages 4, 5, and 6 of the memorandum in response to Committee direction. He also called attention to Appendix 2 of the minutes consisting of a revised Technical Study Design Memorandum No. 4: Public Networks, again particularly noting the extensive changes made in the memorandum on pages 3, 4, 5, 6 and 7 of the memorandum in response to Committee direction.

There being no further questions, comments, or corrections, on a motion by Mr. Romlein, seconded by Mr. Drew and carried, with Mr. Ritt voting no, the minutes of the meeting of September 30, 2004, were approved as corrected.

Mr. Ritt indicated that he had voted no because of his continued concerns about Technical Study Design Memorandum No. 3 dealing with Wireless Antenna Site Location. He reiterated his opinion that the proposed antenna site plan would complicate and delay needed antenna siting within the Region.

Chairman Bauer noted that the action taken gives final Committee approval to Technical Study Design Memoranda Numbers 3 and 4 and, in effect, authorized the staff to proceed with the work as outlined in those memoranda.

CONSIDERATION OF APPENDIX A TO SEWRPC TECHNICAL STUDY DESIGN MEMORANDUM NO. 3: WIRELESS ANTENNA SITE AND RELATED INFRASTRUCTURE DESIGN

Chairman Bauer then asked Mr. Schlager to undertake a page by page review of Appendix A to SEWRPC Technical Study Design Memorandum No. 3: Wireless Antenna Site and Related Infrastructure Design. The following questions, comments, and proposals for change were raised during the Committee consideration of the Appendix.

In answer to a question by Mr. Chernow, Mr. Schlager indicated that the mathematical model described in the Appendix concerned was intended to assist in providing definitive data on wireless service coverage

within the Region. The model, he said, was concerned with geographic coverage; the type and quality of service within the coverage areas being defined by radio wave propagation modeling. The mathematical model concerned, he said, would be used to provide coverage data for at least four different transmission frequencies.

Mr. Caron observed that the radio propagation and antenna site location site optimization models would have significant value not only in the development of a recommended antenna site configuration, but in evaluating over time proposed changes in that configuration that may be necessary to accommodate changes in land use development within the Region.

In answer to a question by Mr. Chernow, Mr. Schlager indicated that the models -- once developed, calibrated and validated -- could be made available to both public and private agencies operating within the Region, including economic development agencies and interested service providers.

In answer to a question by Mr. Long, Mr. Schlager indicated that the model could be applied to develop an antenna site location configuration for each of at least the four frequency bands listed on the top of page 4 of the Appendix. In answer to a further question by Mr. Long, Mr. Schlager indicated that it was the "w" vector in the model equation that changes with transmission frequency. In answer to a further question by Mr. Long, Mr. Schlager indicated that optimization models of the type proposed have not been widely used within the telecommunications industry, although he was aware of some applications used to help design antenna configurations to serve universities and industrial campuses.

In answer to a question by Mr. Falaschi, Mr. Schlager indicated that transmission tower height would indeed be reflected in the radio propagation model, the model which provides the "w" vectors in the optimization model equation.

Mr. Ritt suggested that the Committee's review of Appendix not be focused on the mathematical equations presented on page 2, but rather on the proposed application of the model. He again expressed his concern that the presentation of an "optimized" site configuration for the Region could create conflicts between local regulatory agencies and service providers, when the regulatory agencies rely on such a plan that might well be flawed in reviewing applications for new antenna locations. Mr. Schlager indicated that it was clearly the intent of the planning effort to develop a minimum set of antenna site locations that would provide needed service coverage within the Region at desired levels of service. He noted that, at the specific request of Mr. Ritt, a collegial approach to the preparation of the antenna site plan involving the creation of a subcommittee of radio engineers employed by the various service providers to review the plan and a means for conflict resolution during plan implementation had been included in Technical Study Design Memorandum No. 3, as that memorandum was just approved by the Committee.

Mr. Caron observed that an antenna site location plan, together with an orderly means for reevaluating and amending that plan over time, was very much needed with the Region and would be particularly valuable to the various economic development organizations operating with the Region. The availability of a plan and a means for reevaluating the plan as land use and service development proposals are advanced within the Region would be most helpful in furthering the needed economic development. Mr. Caron noted that there was precedent for such planning in other areas of the United States.

Mr. Ritt expressed disagreement with Mr. Caron, indicating that the wireless service providers within the Region could readily provide the information which Mr. Caron indicates to be needed. He expressed concern that the proposed models and therefore plans may be flawed and therefore cause needless confusion, conflict, and delay in antenna site location within the Region.

Chairman Bauer noted that the concern expressed by Mr. Ritt had been discussed at some length at the September 30, 2004, meeting of the Committee, and that the Committee agreed upon changes had been made to Memorandum No. 3 in an effort to respond to Mr. Ritt's expressed concerns. He noted that although Mr. Ritt's concerns were appreciated, there is a contrary viewpoint that an adopted public antenna siting plan will provide an invaluable point of departure for local regulatory agencies in considering proposed new or revised antenna siting. Such a plan, he said, would provide the public agencies concerned with information to which they are entitled and which they do not now have at their disposal. He indicated that long experience within the Region with the preparation and implementation of areawide development plans of various kinds had shown that such plans not only assist in reaching development decisions that are in the public interest, but serve to facilitate the public decision making process.

Mr. Chernow agreed, indicating that the plan proposed was in effect an overlay to base maps indicating antenna locations and attendant service coverage and identifying gaps in such coverage. The plan, he said, should be as useful to the service providers as to the public regulatory agencies concerned; noting that concerned citizens are often suspicious of proposals advanced by service providers. In such an environment of suspicion a sound plan prepared by an unbiased agency should indeed be useful to the service providers.

Mr. Wirth also agreed, indicating that there was a need to examine antenna site locations required not only to provide existing levels of service, but to provide the advanced levels of broadband wireless service required to make this region economically competitive with other regions of the United States and of the world.

Mr. Melcher also agreed, indicating that it was highly desirable to have as much information as possible available when his agency was asked to make antenna location and related development decisions. The need, he said, was for unbiased information that could be used to evaluate proposed antenna locations. He indicated further that in his opinion, the availability of a sound plan would expedite the review process.

Mr. Ritt observed that he was clearly concerned that the information and plans produced under the study may be flawed; and he was also concerned that the Chairman and Commission staff appear unwilling to concede that Commission information and Commission plans might indeed be flawed. He noted that he had never held that the information or plans absolutely would be flawed, nor that information provided to public officials would not be valuable. For the record, however, he said he was still concerned that the planning effort may produce problematic information that would complicate and delay antenna site location decisions.

In answer to a question by Mr. Long, Mr. Schlager indicated that the model could indeed reflect constraints other than those imposed by technology and topography, specifically including such as the one raised by Mr. Long, namely local land use zoning. He indicated that it would be possible to block out areas of the Region in which the location of antenna towers might be constrained or even prohibited by local zoning ordinances. In answer to a further question by Mr. Long, Mr. Schlager indicated that the model would indeed provide a "yes" or "no" answer with respect to the need for a specific type of antenna location within any particular U.S. Public Land Survey section within the planning region.

In answer to a question to Mr. Ulicki, Mr. Schlager indicated that variables such as antenna heights, patterns, orientation, and type could all be reflected in the radio propagation model. Mr. Ulicki expressed concern about the ability of the staff to compile and utilize information that would accurately reflect the complexities of antenna characteristics and performance.

Mr. Schlager indicated that radio propagation modeling was a highly developed science and art which does take into account such factors as antenna heights, type, and propagation patterns. The models used, he said, must be verified by field measurements and such measurements will be a part of the antenna site planning program. In the end, he said, the area coverage data developed under the study will -- to the extent possible -- be compared and reconciled with data provided by cooperating service providers.

There being no further questions or comments, a motion by Mr. Caron, seconded by Mr. Melcher, and carried, with Mr. Ritt voting "no", Appendix A to SEWRPC Technical Study Design Memorandum No. 3 was approved as presented. (Copy of Appendix A to SEWRPC Technical Study Design Memorandum No. 3 attached as Appendix 1 to these minutes.)

CONSIDERATION OF TECHNICAL STUDY DESIGN MEMORANDUM NO. 5:

Chairman Bauer then asked the Committee to consider the preliminary draft of Technical Study Design Memorandum No. 5: Telecommunication Services Forecasting. He noted that all Committee members had received a copy of the draft memorandum dated July 7, 2004, for review prior to the meeting.

Chairman Bauer then asked Dr. Schlager to undertake a page by page review of the memorandum. The following questions, comments, and proposals for change were raised during the Committee consideration of the memorandum.

Mr. Klasen indicated that SBC could not support the work products proposed in Memorandum Nos. 5 and 6, and he recalled that was the position of the firm at the time the study Prospectus was being developed. He indicated that the primary concern of SBC was that some public agency may use a plan developed by the Commission in denying service providers access to public rights-of-way for infrastructure location. He indicated that his firm believed that service providers needed to have freedom to identify the types of service to be provided to the customer base concerned and to be free to construct the required infrastructure as may be needed in public rights-of-way. Accordingly, he asked that text be added to Memorandum No. 6 to clearly state that any plans developed by the Commission were not intended to be used to foreclose, or impede, approval of service provider access to public rights-of-way for facility location because a provider proposal did not conform to the plans developed by the Commission.

Mr. Chernow did not see any reason for the Committee not to accommodate Mr. Klasen's request for the addition of text that essentially assured the continued access of providers such as SBC to public rights-of-way for infrastructure development.

Mr. Ritt observed that Mr. Klasen's concerns were precisely the same as his own expressed concerns.

Chairman Bauer observed that the concerns expressed by Mr. Ritt and Mr. Klasen were similar, but not truly identical. He noted that Mr. Ritt's concerns involved antenna siting issues which more often involved privately owned lands, or publicly owned lands such as water storage tower sites, and which involve antenna siting directly in complex land use planning and zoning issues. Mr. Klasen's concerns, he said, involved public rights-of-way where the service provider is faced with a much simpler problem of obtaining a street opening permit, generally from a local Director of Public Works or City Engineer. Mr. Chernow noted that public right-of-way location decisions could also involve conflicts, such as those created when a service provider wishes to locate cables under a newly reconstructed or repaved roadway. Chairman Bauer agreed with Mr. Chernow, but noted that the problems inherent in coordinating major street improvement projects with utility construction or reconstruction are normally addressed through preconstruction conferences which all concerned parties are invited to attend in order to achieve the needed coordination of underground and above ground utility location or relocation and the roadway improvement projects.

After some further discussion, it was the consensus of the Committee that the staff should make a preliminary draft of a paragraph which would be added to Memorandum No. 6 indicating that any plan produced by the Commission would not be intended to preclude a telecommunications service provider's free access to public rights-of-way for infrastructure location. Chairman Bauer noted that the Committee would be able to review the proposed paragraph when it considers the minutes of this meeting.

Mr. Chernow expressed concern about the use of Federal Communications Commission (FCC) information in the proposed forecasting procedure. He noted that the FCC tended to frequently revise its data base and that it would be important for the Commission staff to clearly identify the date of any FCC data used and to provide independent checks on the FCC data from other available sources. He noted that changes in the FCC data base are sometimes politically rather than technically motivated.

Mr. McCann indicated that while use of the FCC data would be necessary it would be important to also use other sources of data in order to provide needed cross verification.

Mr. Klasen indicated that the use of the term "coaxial copper cable" under the first numbered item on page 5 was confusing and he suggested, and the Committee agreed, that the word "copper" be eliminated from the phrase. He also suggested, and the Committee agreed, that the phrase "has become" under the third item on page be changed to "is becoming". Finally, he suggested and the Committee agreed that the word "monopoly" in the last sentence of the last full paragraph on page 5 be changed to "regulation". In answer to a question by Mr. Long, Mr. Schlager indicated that a service such as "Roadrunner" which does not use wireless facilities nor the Internet but does use fiber optic transmission cables would fit under the first numbered category on page 5. Mr. Klasen suggested, and the Committee concurred, that the last sentence on page 7 be eliminated.

In answer to a question by Mr. Long, Mr. Schlager indicated that the types of data being sought for use in the forecasting process consists primarily of voice, data, and multi-media traffic carried by wireless and land line facilities.

Mr. Klasen indicated, and the Committee concurred, that the term "access network" under item No. 4 of the first set of numbered items on page 9 be clarified by changing the term to "last mile" access networks. Mr. Klasen, referring to the second numbered item in the second set of numbered items on page 9, questioned the emphasis being placed on voice over Internet in that the modal split being considered was simply telephone and cable networks versus the Internet. After some brief discussion, it was agreed to strike the phrase "but with emphasis on VoIP" from the second numbered item concerned. Mr. Klasen also suggested, and the Committee agreed, that U.S. Cellular be added to the list of service providers in the last full paragraph on page 9 and that the sentence of that paragraph be changed to read as follows: "The second modal split, however, has implications that are potentially even more disruptive because of the nature of the Internet and its lack of regulatory oversight".

Mr. Klasen suggested, and the Committee concurred, that the word "public" be stricken from the last line of the first full paragraph on page 9.

Mr. Klasen observed that a reference was made in the first line of the Summary section of the memorandum on page 12 to a Table One and that no such Table was attached to the memorandum. Mr. Schlager indicated that the referenced Table had been inadvertently omitted from the memorandum.

Chairman Bauer indicated that the Table would be attached to the revised copy of the memorandum to be attached to the minutes and would be subject to Committee review as the Committee considers the minutes of this meeting at the next meeting.

There being no further questions or comments, on a motion by Mr. Chernow, seconded by Mr. McCann, and carried with Mr. Klasen voting no, Technical Study Design Memorandum No. 5: Telecommunication Services Forecasting, dated July 7, 2004, was approved as amended. (Copy of revised memorandum, including Table 1, attached as Appendix 2.)

CONSIDERATION OF TECHNICAL STUDY DESIGN MEMORANDUM NO. 6:

Chairman Bauer noted that all members of the Committee had received a copy of the preliminary draft of Technical Study Design Memorandum No. 6: Regional Telecommunications Network Design, dated August 3, 2004, for review prior to the meeting.

Chairman Bauer then asked Mr. Schlager to undertake a page by page review of the memorandum. The following questions, comments, and proposals for change were raised during the Committee consideration of the memorandum.

Mr. Klasen suggested, and the Committee concurred, that a good place to add the paragraph on access to public rights-of-way which he requested in the Committee's consideration of Study Design Memorandum No. 5, would be after the first full paragraph on page 2 of Memorandum No. 6.

[Secretary's Note: A preliminary draft of the text required is set forth on page 2 of the revised Memorandum No. 6 attached to these minutes.]

In answer to a question by Mr. Chernow, Mr. Schlager indicated that the literature was replete with both capital and operating cost data for telecommunication facilities and services. The use of such data, in the planning work, he said, would be subject to Committee review and approval. Messrs. Klasen, McCann, and Ulicki all indicated the need to discipline the terminology used in the text beginning with the last paragraph on page 10 and the terminology used in the diagrams presented in Figure 1 with particular attention to the terms used in the legend and the identification of the various acronyms used in the text such as DSL.

[Secretary's Note: The last paragraph which began on page 10 of the preliminary draft of the memorandum and the related Figure 1, have been revised in response to the Committee's direction.

Mr. Klasen suggested, and the Committee concurred, that the word "public" in the first line of the last full paragraph on page 13 be changed to "open".

There being no further questions or comments, on a motion by Mr. Chernow, seconded by Mr. Caron, and carried with Messrs. Klasen and Ritt voting no, Technical Study Design Memorandum No. 6: Telecommunications Network Design, dated August 3, 2004, was approved as amended. (Copy of revised memorandum attached as Appendix 3.)

DATE AND TIME OF NEXT MEETING

Chairman Bauer then asked the Committee to consider the date and time for the next Committee meeting. After some brief discussion it was determined that the next meeting of the Committee should be scheduled to be held on December 14, 2004, beginning at 2:00P.M. in the Commission offices.

ADJOURNMENT

There being no further business to come before the Committee, on a motion by Mr. Wirth, seconded by Mr. McCann, and carried unanimously, the meeting was adjourned at 4:15 P.M.

Respectfully Submitted,

Lynn G. Heis
Staff Secretary

KWB/lgh
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Appendix 1

**TO SEWRPC TECHNICAL STUDY DESIGN
MEMORANDUM NO. 3: WIRELESS ANTENNA
SITE AND RELATED INFRASTRUCTURE DESIGN**

Appendix A

**TO SEWRPC TECHNICAL STUDY DESIGN
MEMORANDUM NO. 3: WIRELESS ANTENNA
SITE AND RELATED INFRASTRUCTURE DESIGN**

APPENDIX A
TO SEWRPC TECHNICAL STUDY DESIGN MEMORANDUM NO. 3:
WIRELESS ANTENNA SITE AND RELATED INFRASTRUCTURE DESIGN

DESCRIPTION OF MATHEMATICAL PROGRAMMING MODEL FOR
REGIONAL ANTENNA SITE LOCATION OPTIMIZATION

This Appendix has been prepared in support of SEWRPC Technical Study Design Memorandum No. 3 on Wireless Antenna Site and Related Infrastructure Design. It describes the mathematical reasoning underlying the mathematical programming model being developed and proposed to be used to optimize antenna site locations in the seven county planning area.

All mathematical programming models maximize or minimize some objective function subject to a set of constraints. In the antenna site location problem, the objective is to minimize the number of antenna sites required as constrained by the need to provide quality coverage to all parts of the planning area. Other constraints including; technical, economic or political constraints, may be added to the model. The costs attendant to these constraints in the development and operation of an areawide telecommunications system, will be estimated by a detailed analysis of model results.

Mathematical programming models have been developed for a wide range of applications with the most popular linear programming (LP) model featuring linear objective functions and continuous variables. Another version, integer programming (IP), involves discrete binary variables (ones or zeroes) also with a linear objective function. The IP version is very suitable for the antenna site optimization problem.

The basic antenna site location problem may be expressed mathematically as follows:

$$\begin{array}{ll} \text{minimize} & \sum_{i=1}^m \sum_{j=1}^n p_{ij} x_{ij} \\ \\ \text{subject to} & \sum_{j=1}^n w_{ij} x_{ij} = c_i \quad i = 1, \dots, m, \\ & \sum_{i=1}^m x_{ij} = d_j \quad j = 1, \dots, n, \\ & x_{ij} = 0 \text{ or } 1, \quad i = 1, \dots, m, j = 1, \dots, n, \end{array}$$

Where

x_{ij}	=	antenna site j covering areal unit i
p_{ij}	=	cost of antenna j covering areal unit i
p_{ij}	=	1 for the basic case
w_{ij}	=	coverage vector for antenna site j and areal unit i
c_i	=	coverage, value for areal unit i
w_{ij}	=	1- covers site i
(or)	=	0 – does not cover site i
c_i	=	1 – covered by one antenna
		2 – covered by two antennas
d_j	=	areal site number limit for each antenna

The first listed function is the objective function which accumulates the minimum number of sites necessary to satisfy the expressed constraints. The second listed function constrains the solution to provide coverage to all areal units. The third function limits the number of areal sites covered by each antenna. The last function states that x_{ij} values are either 1 or 0, (activated to cover areal site i with antenna site j or not).

The IP model could be modified to maximize some other objective function, such as expected revenue for an individual provider with other technical, economic or political constraints.

To apply the IP model to the antenna site optimization problem, the areal unit must be defined and data collected consistent with that definition. The U.S. Public Land Survey system section, with an area of approximately one square mile has been selected as the areal unit i . The w_{ij} vector for each of the estimated 560 antenna sites in the Region, will be a set of ones or zeroes indicating coverage or no coverage of a particular section. If the c variable is set at one (=1), then one antenna site must provide coverage for each areal unit. If set at two (=2), two antenna sites must cover each areal unit.

IP Model Solution Algorithms

A number of IP model algorithms are available for solving the antenna site location problem. Integer programming models differ from linear programming models in that there is no one algorithm, such as the simplex algorithm in LP, that fits all applications. Rather, there are a variety of IP algorithms that fit particular problem structures. Examples are cutting plane methods such as the Gomory Algorithm. Another class of branch and bound methods have been used for appropriate problem structures. The antenna sites optimization problem falls into a category called the generalized assignment problem. Expressed in antenna site terms, what minimum set of antenna sites will provide coverage of all of the planning area. This problem can be considered as a generalized assignment problem.

Data Acquisition

Data inputs for the IP model will include:

1. Antenna site coverage – (w) vectors
2. Areal sites requiring coverage – (c) matrix

Collecting the required input data will involve radio propagation modeling for each antenna site. The output of the radio propagation modeling process will be a “w” vector indicating which areal units are covered by each antenna site for a particular frequency, antenna height, transmitter power, and receiver sensitivity. These “w” vectors along with the designated areal sites will constitute the input to the model along with the “p” vector which will initially be a unit vector of all ones.

The IP matrix will be comprised of r rows and c columns with number of x rows varying with the number of whole or partial sections in each county of the planning area. The number of sections will vary from a maximum of 576 in Walworth and Waukesha Counties to a minimum of 246 in Ozaukee County. The number of columns will vary with the number of antenna sites. The value of c will depend on the number of existing and potential antenna sites in each county. An initial estimate for Walworth County tabulated 52 existing antenna sites within that County: Initial plans call for testing the IP model in Walworth County and then expanding it to the rest of the planning area. The initial model output for Walworth County would be a list of the minimal number and names of the antenna sites required to provide areal coverage.

Plans call for running the IP model for at least four frequency bands:

1. 800-900 MHz
2. 1900 Mhz
3. 2.4 GHz
4. 5.2 – 5.9 GHz

The first two bands would relate to mobile cellular/PCS wireless and the last two to fixed wireless systems. The latter two frequency bands will probably require many new sites since the coverage areas are smaller for each antenna, and Regional coverage is sparse, particularly in rural areas.

IP Model Enhancements and Challenges

IP model optimization is only as good as the quality of the input data. It will be possible to challenge the w vectors produced by initial radio propagation modeling. More accurate radio propagation modeling verified by field measurements will undoubtedly improve model quality. Wireless service providers could provide their own alternative w vectors for each antenna site to determine their effect on the optimal solution.

Addition of other constraint equations to the model is also possible to reflect other technical, economic or political restraints. Allowing for double coverage for each areal unit would significantly change the optimal solution. The model can also be run for each service provider to allow for service provider optimization. The objective function could also be changed to a maximization function based on potential call revenue which in turn could be based on land use and other factors.

Overall, the IP model has great potential for wireless system design for the mutual benefit of all concerned – service providers, subscribers and the public at large.

Appendix 2

**TECHNICAL STUDY DESIGN
MEMORANDUM No. 5
TELECOMMUNICATION SERVICES
FORECASTING**

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

REGIONAL TELECOMMUNICATIONS PLANNING PROGRAM

TECHNICAL STUDY DESIGN MEMORANDUM No. 5 TELECOMMUNICATION SERVICES FORECASTING

July 7, 2004

INTRODUCTION

The Southeastern Wisconsin Regional Planning Commission is the official areawide planning agency for the seven-county Southeastern Wisconsin region comprised of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha. The Commission is charged with the responsibility for the collection, analysis, and dissemination of basic planning and engineering data on a uniform, areawide basis, for the preparation of a framework of long range plans for the physical development of the Region, and for the promotion of intergovernmental cooperation and coordination in the adoption and implementation of such long range plans.

The Commission recognized that following the breakup of the Bell System and the American Telephone and Telegraph Company, and with the subsequent rapid advances in communications technology, telecommunications, while becoming increasingly important in the local, national, and global economy, also was becoming increasingly chaotic. The Federal Telecommunications Act of 1996, intended to further encourage local competition, has led to the development of a "network of networks" largely beyond the regulatory purview of any level of government.

Recognizing that telecommunications networks form a critical part of the regional infrastructure, the Commission, in December 2002, created an Advisory Committee to assist the Commission in addressing telecommunication issues within the Region. The Committee recommended that the Commission undertake a regional telecommunications planning program, and set forth the need for, and the scope and content of, such a planning program in a Prospectus published in December 2003.

The Prospectus recognized that the conduct of the recommended planning program must be preceded by the preparation of a study design. That study design was to include the preparation of a series of detailed staff memoranda setting forth the methods and procedures to be followed in accomplishing

certain critical elements of the planning program. One of these technical study design memoranda was to address forecasting the needs for future telecommunications services in the Region.

TELECOMMUNICATIONS SERVICES FORECASTING - CHALLENGES AND SOLUTIONS

Any forecast of needs for future Regional telecommunications services must contend with the dynamics of both communication user preferences and rapidly changing telecommunications technologies. Prior to the breakup of the Bell System in 1984, the need for future telecommunication services could be safely extrapolated from current subscriber trends and a slowly evolving set of technologies. Two major developments in the 1980 and 1990 decades, however, have significantly influenced the growth and diversity of modern telecommunications: the birth and phenomenal growth of the Internet; and the rapid expansion of wireless communications.

These major developments have been reinforced and amplified by technological breakthroughs in areas such as fiber optic transmission, electronics miniaturization, and telecommunications protocols such as the Ethernet. These rapid and revolutionary changes in the growth of modern telecommunications should inject a cautionary note relating to the potential accuracy of any telecommunications services forecasts.

Nonetheless, forecasts of future communications needs are required for sound telecommunications planning. An understanding of future needs, and the technologies that could service these needs, provide an important basis for the preparation of a Regional telecommunications plan.

While uncertainties are produced by rapidly changing technologies and the receptions received by these technologies in the marketplace, there are mitigating factors that reduce these uncertainties and enhance the usefulness of any telecommunications services forecasting effort. These mitigating factors include:

1. Availability of quality demographic, economic and land use data for the Region.

The Regional Planning Commission requires such data and forecasts for all of its public infrastructure planning programs and has established a reputation for high quality socio-economic and land use forecasting.

2. Well established techniques and procedures for preparation of spatial services forecasts.

The methodology to be employed for spatial allocation of telecommunications services needs parallels that used in transportation system planning. This methodology has proven its effectiveness over the years, and it should prove equally effective in telecommunications application.

3. Insensitivity to small/scale forecasting inaccuracies.

Regional network plans are designed to allow for uncertainties in both forecast aggregate and spatial service demands. The cost-effectiveness of each plan design can thus be retained over an extensive range of telecommunications service needs.

AGGREGATE TELECOMMUNICATIONS SERVICES FORECASTING

Five types of forecasts will be utilized to determine the probable aggregate regional demand for telecommunications services: demographic, economic, land use, technological, and regulatory. These forecasts will provide independent variables for use in forecasting the following three principal categories of telecommunication services: voice, data, and multimedia.

Voice and data are currently the primary media used in most telecommunication activity, but with the spread of broadband capabilities, all forms of media - voice, data, text, graphics and video – may be expected to merge into a single multimedia category. This merger may be expected to take place over a number of years. For this reason, aggregate regional forecasts will be prepared only for the three principal categories of telecommunication services: voice, data and multimedia. Multimedia growth may be expected to be closely related to adaptation of voice over the Internet (VoIP). As the transition to VoIP takes place, multimedia may be expected to become the dominant form of telecommunications.

Basic Procedure

Aggregate telecommunication services forecasts will be based primarily on available Federal Communications Commission (FCC) data banks which provide historical information on voice, data and other media use in telecommunications at a national level. A statistical forecasting method known as exponential smoothing will be used to extrapolate existing trends. The exponential smoothing method allows for use of linear, exponential or higher order models with adaptive smoothing techniques for ready production and updates of forecasts on a periodic basis. Exponential smoothing technology also allows for ready testing of various models based on past data to aid in selecting for use a particular model that has worked well in the past.

National aggregate forecasts of telecommunication needs for each principal category will be converted to regional aggregate forecasts by application of regional allocations of national demographic and economic data and forecasts and measured trends. Southeastern Wisconsin currently represents a reasonably stable portion of the national population and national economic output. Various forms of linear and nonlinear regression analyses will be used to quantify these regional allocations of the national forecasts.

The accuracy and reliability of these allocations can be verified using other data sources that independently quantify voice, data or multimedia traffic at the State or local level. Such data sources may include the Public Service Commission of Wisconsin and telecommunications trade associations. Statistical comparisons between allocated estimates and other data sources can serve to establish the accuracy of the national to regional allocation approach to telecommunications forecasting.

Quantitative aggregate telecommunication forecasts will be supplemented by qualitative appraisals of technological and regulatory status and trends and how these may influence national and regional aggregate forecasts. Forecasting the need for telecommunications services is, because of the rapidly changing technologies concerned, inherently difficult. Careful observation of recent trends indicate, however, that the aggregate demands for voice, data and communications services have followed rapidly growing but still predictable trends. The primary difficulty in telecommunications forecasting lies, not so much at the aggregate level, but in the impact of new, disruptive technologies on the supply of telecommunication services. Such disruption, while having some impact at the aggregate need level, can have major impact at the service provider level.

The telecommunications service industry has been impacted in the past 25 years by three major new technologies:

1. Fiber optic transmission

Fiber optic cable has replaced coaxial ~~copper~~ cable as the primary channel for wireline transmission, and has greatly expanded the capacity of wide area networks.

2. Wireless communications

Cellular wireless communication has experienced very rapid growth over the last decade, and is rapidly displacing wireline as the primary supplier of voice communication services. An emerging set of fixed wireless technologies may further disrupt the telecommunications marketplace.

3. The Internet

Packet-switching and its primary manifestation, the Internet, ~~has become~~ *is becoming* the primary global network for all forms of telecommunications, displacing proprietary telephone company networks as the transmission channel of choice.

The influence of these and other emerging trends will be presented at the global and national levels but with a view that their primary impact will take place at lower levels of the forecasting process.

Regulatory trends determined primarily by the Federal Communications Commission (FCC), but also by state and local units of government, will also be considered at the national level for potential effects on regional telecommunication needs. The primary governing force in this respect is the Federal Telecommunications Act of 1996, as amplified and modified by a number of FCC rulings over the past few years. The 1996 Act has accelerated the introduction of new technology in the industry and has generally increased the level of market competition, but its primary future impact may be related to the maintenance of open markets to fuel expanding demand for telecom services. A return to even a modified form of earlier telephone utility ~~monopoly~~ *regulation* would undoubtedly serve as a brake on demand for future telecommunication services.

Data Sources

The Federal Communications Commission (FCC) primary data source has been previously mentioned. The available FCC data should fulfill the needs for national-level data and forecasts for

aggregate voice, data and multimedia forecasting. The demographic and economic databases of Regional Planning Commission will furnish the means to convert the national aggregate forecasts into regional aggregate forecasts. The key variables here derive from relationships between the demand for telecommunication services (voice, data and multimedia) and demographic and economic change. If these relationships can be regressively established on the national level, they can be transferred to the Southeastern Wisconsin regional level using the available regional demographic and economic data and forecasts available from the Regional Planning Commission, including forecasts of demographic and economic variables for the target years of the Regional Telecommunications Network Plan.

The FCC and Regional Planning Commission databases, while the primary basis for regional aggregate telecommunications forecasting, will be supplemented by databases residing at the Public Service Commission of Wisconsin and various trade associations in the industry. Information available from these sources also serve as reality checks for the regional economic forecasts. The output of the regional aggregate forecasting process will be estimates of the probable future demand - or need -- for voice, data and multimedia services to the plan design year of 2035. Although 2035 is the plan design year, both forecasts and regional network plans will be staged in 5 year increments beginning in the year 2010. The dynamic nature of telecommunication technology and market forces require such a staged approach.

Methodology

As already noted, the forecasting methodology will emphasize statistical methods such as experimental smoothing and linear/nonlinear regression analysis. Exponential smoothing-based technology, when furnished with data of quality, has a notable reputation in both private industry and government for producing accurate forecasts. Regression analysis is a standard statistical method for establishing quantitative relationships between variables. Powerful mathematical techniques also are available to test the validity of any regression function and to estimate the uncertainty of its forecasts.

All forecasts are characterized by uncertainty. An advantage of using statistical forecasting methods is that uncertainty itself can be quantified so that each forecast consists of an estimated future mean value along with an associated measure of uncertainty such as the variance, standard deviation, or root mean square error of the estimated mean. Such uncertainty measures are particularly important in telecommunications network planning since they express the range of input values that each network plan must not only function, but also operate in a cost effective manner. Generally, measures

of uncertainty of whatever kind are converted to confidence intervals so that each forecasted variable is expressed as both an estimated mean value with a confidence interval usually at the 95 percent level. Such a forecast implies that forecasted variable may be expected to fall within the confidence limits 95 percent of the time. All of the statistical methods previously referenced such as regression analysis or exponential smoothing provide the required uncertainty parameters as part of their normal application. The end result is that all of the forecast methodologies here will provide confidence intervals as a regular feature of their output whether the forecast relates to aggregate, spatial or model split application.

SPATIAL TELECOMMUNICATIONS SERVICES FORECASTING

Spatial telecommunication services forecasting will provide:

1. Estimates of probable future telecommunication media call generation (voice, data and multimedia) by regional areas by U.S. Public Land Survey System township, and if necessary, section and quarter-section based on land use patterns.
2. A regional source/destination traffic matrix, which will distribute intra-regional and extra-regional telecommunication traffic based on land use patterns by the three prepared categories - voice, data and multimedia.

Data Sources

Incumbent local exchange carriers (ILECs) could be rich sources of data for these spatial forecasts. The extent of local ILEC cooperation, however, is still uncertain. For this reason, a backup national approach to such data acquisition should be available. FCC reports and databases will be searched to find data that can be used to estimate residential, commercial, governmental and institutional calling rates that can be related to land use. Other governmental and trade association databases will also be searched to amplify or confirm the FCC information. These same sources will be used to determine the destination of calls in order to construct a source/destination traffic matrix. ~~Some other jurisdictions such as the State of North Carolina, have overcome this problem by enacting legislation requiring service providers to supply data to appropriate state and local governmental agencies.~~

Methodology

Having the requisite data, the statistical methodology requirements are readily satisfied. Land use-based call generation functions can be developed using basic regression analysis techniques. Source-destination matrices are easily calculated given data availability. In both areas, significant efforts will also be made to establish the uncertainty of the call generation rates and the source/destination matrices as part of the analysis process. Again, standard statistical methods can be used to establish such confidence intervals.

Outputs and Applications

The output of spatial telecommunication services forecasting will be:

1. A set of land use-based call generation rates by principal land use category for voice, data and multimedia service.
2. A set of source-destination traffic matrices for voice, data and multimedia.

These parameters will then be employed as coefficients in a regional telecommunications simulation model to evaluate the adequacy of various regional network infrastructures as described later in this memorandum.

MODAL SPLITS

Aggregate and spatial telecommunication forecasts are important in forecasting the probable future demand for regional and areal telecommunication services. These demand estimates establish the need for infrastructure to support these services. The required nature of this infrastructure, however, will be determined by the modal split phase of the forecasting process. The dynamics of telecommunications technology are manifested primarily in modal split allocations rather than in aggregate and spatial forecasts. The term modal split is a carryover from transportation system planning where the term modal refers to the means of transportation, and the split is between automobile and transit use. While the general concept is similar in telecommunications, the dynamics are vastly different. Transportation technologies are also changing but at a modest rate. Telecommunication technology, by contrast, is changing very rapidly. Despite this rapid rate of change, the functional impact of current technological trends are fairly clear. They include:

1. A steady transition from wireline to wireless communications, particularly for voice traffic and for mobile access networks;
2. An accelerating transition from circuit-switched to packet-switched networks;
3. A parallel transition away from proprietary telephone and cable networks, packet as well as circuit switched, to the Internet;
4. A continuing growth in the capacity of fiber optic core networks which are out of balance with the capacity of “*last mile*” access networks; and
5. The recognition of the “last mile” access as the primary bottleneck in the growth of broadband telecommunications.

Based upon consideration of these trends, two modal split categories emerge:

1. Wireless vs. wireline for mobile and fixed wireless communications and voice, data and multimedia; *and*
2. Telephone *and* cable networks versus the Internet for all three classes of media, ~~but with emphasis on VoIP~~

Both of these modal splits may be expected to have potentially significant impact on the telecommunication services industry and the nature of future telecommunication networks. Anticipating trends in the first modal split, the major service providers have already responded through acquiring ownership of wireless service providers such as Verizon Wireless, ~~and~~ Cingular, *and U.S. Cellular*. The second modal split, however, has implications that are potentially even more disruptive because of the ~~public~~ nature of the Internet and its ~~absence of proprietary private ownership~~ *lack of regulatory oversight*.

Data Sources

Multiple sources of data exist at the national level for modal split analysis. The FCC has jurisdiction over both wireless and wireline communications and has extensive data bases relative to both

domains. Federal data can be supplemented by additional data from wireless service providers and from their trade associations. Data on the growth of the Internet for various forms of traffic including VoIP are also available from a number of sources, and data on the decline of traditional POTS subscribers are available from the FCC. Data availability should not constitute a limitation on modal split analyses.

Methodology

With wide availability of data, the problem in modal split analyses will be determining the proper mix of statistical trending versus estimates of technical or regulatory disruptions that could severely modify these trends.

Statistical trending of either modal split is readily accomplished with one or more of the exponential smoothing models. Forecasts of wireline and wireless media forecasts can be combined to produce the wireline/wireless modal split for any number of target years. In like manner, the telenet/Internet modal split can be determined from similar forecasts of voice and data traffic on each respective network. Technical disruptions to statistical trending of the two modal splits are less likely since these splits are reflecting technological change. The shift from wireline to wireless communications is a reflection of both the increasing mobility of our society as well as the improving quality of wireless communications. A similar situation exists in the telenet/Internet modal split. The steadily improving quality of VoIP, as well as the increasing flexibility and economy of the Internet in general, has made this ~~public~~ network very attractive for all forms of telecommunications.

Regulatory changes could slow, but probably not stop both of these modal split trends. Federal regulation of the Internet is unlikely since this network is global in scope, and such regulation would be damaging to the American economy. Mobile wireless and its frequency spectra are tightly controlled by the FCC, but fixed wireless as represented by WiFi (IEEE 802.11) and the emerging WiMax (IEEE 802.16) operate in unlicensed frequency bands and are essentially unregulated.

It may be concluded that statistical trending of both modal splits should produce meaningful results barring drastic change in the regulatory climate.

NETWORK SIMULATION MODELING

The end objective of telecommunications forecasting is to produce a set of inputs for simulation modeling of current and prospective regional networks. Such modeling is intended to test the adequacy of current or proposed network designs.

Network simulation models have been employed in systems planning and engineering for over 40 years. Such models allow for the evaluation of alternative roadway and transit facility network plans as part of transportation system design, test, and evaluation process. These transportation models were developed with Federal and State support over a number of years, often by planning agencies, including the Southeastern Wisconsin Regional Planning Commission. Prior to the breakup of the Bell System, the Systems Engineering Department of the Bell Telephone Laboratories utilized simulation modeling in the design of telecommunications networks. Unfortunately, these Bell Telephone Laboratories models were oriented toward circuit-switched networks, which form an important, but declining, portion of current-day telecommunications networks.

A number of general purpose simulation modeling software packages applicable to telecommunication system planning are available in the commercial marketplace. One of these software packages, Visual Slam, is particularly well suited to telecommunication network simulation modeling. Developed over a 20 year period by Professor Alan Pritsker of Purdue University, the product is now supported by Frontstep Corporation in West Lafayette, Indiana. The modeling program allows for both discrete and continuous simulation and allows for user program inputs using Visual Basic or C languages to reflect network management algorithms. Employing the Visual Slam Simulation model, it will be possible to evaluate Regional telecommunications networks at various levels of detail. Simulation modeling may be used to investigate both incremental changes in current networks and to evaluate future network designs.

The imbalance between excess core network capacity and the limitations of last mile access networks is well acknowledged in the telecommunications services industry. Core networks in most metro areas are capable of carrying traffic far in excess of current loads. For this reason, the network simulation modeling will emphasize access networks in an attempt to determine the most effective approach to removing this acknowledged bottleneck in modern communication networks. Emphasis in the initial application of simulation modeling in the forecasting element of the planning process will be on the adequacy or inadequacy of the current Regional network. This same simulation model, however, will have more extensive use in the evaluation of alternative future networks in the plan design phase of the program.

DOCUMENTATION

The regional aggregate, spatial and modal split forecasts, together with the results of the initial network simulation studies will be documented in a SEWRPC ~~Technical~~ Report in Month 3 of Year 2 of the program in accordance with the project schedule in the Prospectus.

SUMMARY

The entire telecommunications services forecasting work element is depicted in Table 1: The table lists the types of forecasts to be made, the data sources concerned, the analytical techniques used, and the outputs of the forecasts. These outputs include:

1. Call generation – providing the total number of calls generated within the planning area on an average weekday.
2. Call generation by land use – providing the number of calls generated within the planning area by each major land use category on an average weekday.
3. Source/Destination Traffic Matrix - providing the percentage of calls from each geographic subarea of the region to every other subarea on an average weekday.
4. Modal Split Wireless - providing the percentage of wireless calls to the total of wireless plus wireline calls on an average weekday.
5. Modal Split – Internet - providing the percentage of Internet calls to the total of Internet plus Telenet calls on an average weekday.

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#97654 v1 - T/C Technical Study Design Memo No. 5

10/6/04

Table 1

TELECOMMUNICATIONS SERVICES FORECASTING

Type/Inputs	Methods			Outputs
	Exponential Smoothing	Regression Analysis	Matrix Analysis	
Aggregate FCC SEWRPC Population Economic	X	X		National call generation Regional call generation
Spatial Call Generation FCC SEWRPC Land Use Population Economic Traffic Matrix FCC SEWRPC Land Use Population Economic		X	X	Call generation by land use Source/destination traffic matrix
Modal Split Wireline/Wireless FCC Internet/Telenet FCC	X X			Wireless— Total ratio Internet— Total ratio

Source: SEWRPC.

Appendix 3

**TECHNICAL STUDY DESIGN
MEMORANDUM No. 6
TELECOMMUNICATION NETWORK DESIGN**

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

REGIONAL TELECOMMUNICATIONS PLANNING PROGRAM

**TECHNICAL STUDY DESIGN MEMORANDUM No. 6
REGIONAL TELECOMMUNICATIONS NETWORK DESIGN**

August 3, 2004

INTRODUCTION

The Southeastern Wisconsin Regional Planning Commission is the official areawide planning agency for the seven-county Southeastern Wisconsin region comprised of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha. The Commission is charged with the responsibility for the collection, analysis, and dissemination of basic planning and engineering data on a uniform, area-wide basis, for the preparation of a framework of long range plans for the physical development of the Region, and for the promotion of intergovernmental cooperation and coordination in the adoption and implementation of such long range plans.

The Commission recognized that following the breakup of the Bell System and the American Telephone and Telegraph Company, and with the subsequent rapid advances in communications technology, telecommunications, while becoming increasingly important in the local, national, and global economy, also was becoming increasingly chaotic. The Federal Telecommunications Act of 1996, intended to further encourage local competition, has led to the development of a "network of networks" largely beyond the regulatory purview of any level of government.

Recognizing that telecommunications networks form a critical part of the regional infrastructure, the Commission, in December 2002, created an Advisory Committee to assist the Commission in addressing telecommunication issues within the Region. The Committee recommended that the Commission undertake a regional telecommunications planning program, and set forth the need for, and the scope and content of, such a planning program in a Prospectus published in December 2003.

The Prospectus recognized that the conduct of the recommended planning program must be preceded by the preparation of a study design. That study design was to include the preparation of a series of detailed staff memoranda setting forth the methods and procedures to be followed in

accomplishing certain critical elements of the planning program. One of these technical study design memoranda was to address regional telecommunications network design.

THE REGIONAL NETWORK DESIGN PROCESS

One of the primary functions of the regional telecommunications planning process relates to the generation of future alternative regional network designs. These alternative network plans are then evaluated for consideration as the preferred network plan for the socioeconomic development of the Region. Since there are currently a number of available network structures and technologies, a major benefit of this process is simply the presentation of these alternatives to the citizens of the Region. Graphical presentation of these network alternatives along with the costs, benefits and implications for economic development of each provides a basis for an informed choice for the future telecommunications infrastructure in the Region. Such a plan selection process is in opposition to the common view that the future may only represent a continuation of current trends. Such a view point is particularly inappropriate in telecommunications with its dynamic changing technologies. There is no established precedent for a governmental telecommunications planning process in which the operators of the future network will primarily be private carriers. Although a component of the future regional system will be public networks serving special public needs, the predominant share of the system of networks will be those portions owned and operated by privately owned carriers.

None of the Commission's telecommunications plans would be intended to preclude any telecommunications service providers from free access to public rights-of-way for infrastructure location.

Although the pioneering nature of the telecommunications program in Southeastern Wisconsin lacks a preexisting prototype, there are two historical antecedents that suggest a network design process:

1. Regional Transportation Networks

There are similarities as well as important differences between transportation and telecommunications networks.

2. Enterprise Telecommunications Networks

There are also strong parallels between the design of a telecommunications network in a large corporate enterprise and the design of a regional telecommunications network. In both, the network and its infrastructure are the means to a higher end objective; the development and on-going operation of an organizational entity, the corporation or a socio-economic entity encompassing a geographic Region.

The regional telecommunication network design process herein described represents an integration of the two above precedents.

The process description herein provided will necessarily allude to other components of the planning process, previously presented in other study design memoranda, but the context here is the role of each component in a network design process, and not as an item of interest for other purposes.

Formulation of Objectives and Standards

As stated in the planning program Prospectus, plan objectives, to be meaningful, must be reflected through standards that are measurable in at least a qualitative sense in order that these objectives can be used in the development of a preferred network plan. Although the term standard has a different meaning in telecommunication technology as an equipment or protocol specification, it is herein used as a measurable indicator of the quality of telecommunications services. An important example is the bandwidth parameter as a measure of transmission speed in megabits per second. Bandwidth in combination with other parameters, such as quality of service and reliability, together define the performance of a network design plan.

A more detailed potential set of standards can be developed using data provided by the regional network monitoring system. These standards should define such elements of service quality as: availability, response time, throughput, and accuracy. Each of these standards may be further broken down into a set of sub-standards that taken together completely define network performance.

Coupled with network performance are potential network costs – initial capital investment and continuing operating costs. Future operating costs can be converted to their present values using standard techniques of engineering economics. The combination of network performance and

cost will allow for an objective evaluation of alternative network designs. Coupled with other qualitative benefits and constraints, an informed selection of a future network can be made.

Existing Infrastructure

From a design viewpoint, the important components of the current telecommunications infrastructure are the points of presence (POPs) in the regional core networks. With the current excess of capacity in both regional (core) networks and national long-line networks, design emphasis should focus on access networks. Such access networks must link with core-long-line networks at designated POP access points.

The design of wireless access networks will, in addition to POP designations, also require antenna site locations, existing and prospective. These will be provided by the antenna site and related infrastructure plan. The regional network plan will incorporate wireless networks -- both mobile and fixed -- from the antenna site plan and also the special public network plan to be developed under a separate work element.

Existing Traffic and Future Forecasts

The existing traffic inventories, as an inputs to the design process, are important as indicators of under-served telecommunications needs by area within the Region and by class of user. The on-going network monitoring system will be especially valuable in this regard since it will provide network performance data from a user perspective for a wide variety of network load conditions.

Future forecasts will provide estimates of the traffic demand to be satisfied in the alternative network plan designs. Particularly important will be spatial traffic forecasts and modal splits. In a packet-switched Internet world, the traffic matrix will be less important because of the multiple transmission paths available in TCP/IP (Transmission Control Protocol/Internet Protocol) networks. This situation is in sharp contrast to the traditional circuit switched networks, where the number of trunk lines between central offices would be influenced by traffic matrix patterns.

For the plan design years 2010 and beyond multimedia traffic is expected to predominate. Since video traffic will constitute a major portion of multimedia traffic, the accuracy of the forecast of such traffic will have a major influence on the accuracy of the aggregate forecasts, and the ability of network plan design to satisfy these traffic demands.

Alternative Network Plans Preparation

Network plans will be prepared in a two-stage sequence:

1. Logical Network Design including:
 - Network topology
 - Protocols
 - Network security
 - Network management

2. Physical Network Design
 - Core Network technology
 - Existing technologies
 - Alternative technologies
 - Proposed technologies

 - Access Network Technologies
 - Alternative technologies
 - Existing technologies
 - Proposed technologies

Alternative Network Plan Test and Evaluation

Network simulation models, as described in the planning program Prospectus, are valuable tools in the experimental evaluation of telecommunications networks. Such evaluation is not new to telecommunications. In traditional circuit-switched networks, a number of analytic as well as simulation models were developed as part of a discipline called telecommunications traffic engineering. Erlang and Poisson traffic formulas were used to “dimension” networks particularly in terms of the number of trunk lines needed to interconnect telephone exchange central offices. These models were based on circuit switched networks in which a subscriber is connected through a series of dedicated circuits until the call is completed.

With the growing predominance of packet-switched communications, previous traffic engineering models are no longer applicable. While circuit-switched networks were modeled as multiple layer waiting line systems, packet switched networks more closely resemble highway traffic networks. Such network modeling is also influenced by the routing rules used, as well as the

capacity of, the links comprising the networks. Special network features such as MPLS (multi-protocol label switching) also can significantly influence the efficiency of the network. With the current excess of core network capacity, primary interest will lie in the evaluation of alternative access networks, such as fiber-to-the-home or various fixed wireless network topologies. For these reasons, it is recommended that a general purpose simulation modeling software package, such as Visual SLAM as described in the Prospectus, be employed in evaluating alternative network plans. A number of such general purpose simulation modeling packages will be reviewed prior to selecting one for implementation.

The capital and operating costs of the alternative and recommended network plan will be estimated utilizing data available in the technical literature. These data include, among others, data on the costs of the installation and operation of broadband, fixed wireless facilities; installation of optical fiber cable; and capital and operation costs of advanced versions of mobile wireless systems.

The end output of network plan test and evaluation regardless of the methodology or tools employed must be measurable benefits and costs referencing the objectives and standards that are the basis for network plan evaluation. These benefits and costs, broadly defined, because the bases for the selection of a recommended plan. Such a plan may be a combination of two or more of the alternative plans considered.

TELECOMMUNICATIONS INFORMATION INFRASTRUCTURE TECHNOLOGIES

This section is intended to provide a summary of current and emerging telecommunications technologies that may play a role in the development of the alternative regional network plans. These technologies range from traditional legacy technologies, such as twisted wire pair, to emerging technologies such as wireless mesh networks and free space optics. These technologies are further classified by their employment in either core networks or access networks.

Core Network Technologies

Core networks are communications transport systems that handle large volumes of traffic that originate in access networks and are collected in multiplexed distribution networks. Core networks have passed through three generations since the 1960s. The first generation was the T/DS (Transport/Digital Signal) network based on copper coaxial cable. The capacity of these

networks was measured in megabits per second, with a maximum DS4 rate of 274 megabits per second. The term T1 was devised by the AT&T system before the divestiture in 1984 to describe a specific type of carrier technology. Post-divestiture, the DS terminologies replaced the T terminology, although many still refer to T lines for T1, T2, which represent different transmission speeds (digital bit rates).

The second generation introduced fiber optic cabling in the mid-1980s as the SONET/SDH (Synchronous Optical Network/Synchronous Digital Hierarchy) technology with transmission rates measured in gigabits per second on OC (Optical Carrier) designated lines. The maximum rate, for an OC-192 line is about 10 gigabits per second. Both the T/DS and the SONET/DH technologies utilize time division multiplexing (TDM).

The third and most advanced generation is the optical transport network technology (OTN) that employs wave division multiplexing (WDM) with transmission rates as high as 4 terabits per second. An important aspect of third generation communications transport is the shift from time division multiplexing to wave-division multiplexing. In TDM multiple subscriber packets are placed in sequential time slots based on extremely short-term pulses that allow for high rates of data transmission. TDM has been used in electronic, copper cable based communications for many years. Optical communications, by reason of its extremely short time pulses, provides much faster transmission rates than coaxial cables. There is a limit, however, to pulse width reduction even in optical fibers. For this reason, the third generation OTN transport systems have shifted to wave division multiplexing which involves using superimposed wavebands -- or core colors -- of light in a single fiber strand. These are not colors in the visible sense since they are typically in the 1500 to 1600 nanometer near infrared light range. Wave division multiplexing is similar to frequency division multiplexing in the radio range of frequencies. All broadcast and television broadcasting is based on sharing a frequency spectrum. In optical communications, because of the large numbers involved, it is more convenient to think in terms of wavelengths rather than frequencies. In any event, it is easier to pack more information into a fiber sharing waveband (WDM) than it is sharing time slots (TDM).

Fiber optic strands bundled into cables provide the transport medium for modern communications, but electronic equipment in the form of routers and switches provide the intelligence to move data and other media in a network. Above the physical layers of fiber optic strands, laser transmitters, and optical detector receivers, electronic control of packet transmission

depends on protocols such as the Internet protocol (TCP/IP), ATM (Asynchronous Transfer Mode) and Frame Relay -- the predominant telephone company protocols -- and Ethernet, the predominant local area network protocol. These protocols are not necessarily in competition, however, since ATM generally operates at Layer 2 -- access control and data integrity, while TCP/IP operates at Layers 4 -- message control, and 3 -- routing, respectively. Ethernet, as a Layer 2 technology, however, is definitely in competition with ATM and Frame Relay as a core network alternative. ATM and Frame Relay are now completely predominant in core networks, but Ethernet offers advantages in simplicity and lower investment costs. Technical limitations of Ethernet technology, for metropolitan area networks (MANs) are being overcome through supplemental additions, such as multiple protocol label switching (MPLS), so that it may become a formidable core network alternative in the near future. MPLS is an important auxiliary technology that can be added to a protocol such as Ethernet to make it more efficient. Label switching replaces the destination address usually used for routing purposes with a label that allows for more efficient routing decisions. MPLS is finding extensive use in third generation optical core transport networks.

The key questions in the core portion of a future regional network plan will relate to the protocols used to direct core networks. The physical optical link transport carrier is fairly pre-determined and currently in the ground as dark or lighted fiber. Still to be decided is that extent to which second layer Ethernet protocols and their associated electronics or their equivalents replace existing, ATM/Frame Relay technologies in which investment has historically been heavy. In future network plans, the benefits and costs of various core network technologies should be determined and publicized.

Access Network Technologies

Current broadband access technologies are limited in most areas to the digital subscriber line ADSL from the telephone companies and hybrid-fiber-coax from the Cable - TV companies. Emerging technologies include alone or in combination, active or passive, fiber to end users and various approaches to fixed terrestrial wireless. Added to these two primary approaches are secondary alternatives such as satellite wireless and power line-based communications.

The primary current and emerging broadband access technologies are illustrated in Figure 1. The leading current broadband access technology is the hybrid-fiber-coaxial cable configuration offered by the Cable TV companies (*Figure 1C*). In this technology, a fiber based channel with a

capacity of 30 megabits per second services between 50 and 500 subscribers *connected through coaxial cables in a treetoplogy*. Theoretical bandwidth based on cable modem capability is 3 megabits per second, but the actually experienced upload and download speeds are much lower than the theoretical maximum. Channel capacity for short burst messages may actually be higher than 3 megabits per second depending on the average channel usage rate. Some recently experienced cable modem service performances include: download rate 2518 megabits per second, and upload rate 405 kilobits per second.

Digital Subscriber Lines (DSL)

Digital subscriber line (DSL) is a modem technology that converts existing twisted pair telephone lines into access paths for multimedia and high speed data communications. DSL depends upon advanced digital signal processing techniques to channel high rates of data transmission through twisted pair telephone lines which have limited bandwidth. There are many categories of DSL technologies, with the most popular being asymmetric digital subscribe line (ADSL) (*Figure 1A*). This technology is asymmetric in that download speeds greatly exceed upload speeds by a factor of at least 6 to 1. The term line in digital subscriber line is a misnomer in that DSL is actually not a line -- which already exists in twisted pair form -- but a pair of modems -- one at a subscriber location and the other at a central office. Currently, ADSL subscribers must be located within ~~18,000~~ 12,000 feet -- approximately ~~3.4~~ 2.3 miles -- of a central office or a remote terminal. In Southeastern Wisconsin, approximately 85 percent of the Region is serviced by ADSL. Typical performance rates for ADSL regionally are: download rate 1217 megabits per second, upload rate 302 kilobits per second.

Other versions of DSL exist, but only VDSL (*Figure 1B*) can be considered as a serious alternative for most subscribers. The V stands for very high data rate offering theoretical rates as high as 12 to 96 megabits per second, but subscribers must be as close as 4,500 feet of a central office or a remote terminal. VDSL is currently not available in the Region, and has not yet to find broad acceptance in the United States.

Fiber Optic Based Access Technologies

The most heralded future technology for universal broadband access networks is fiber optical transmission. Optical fiber offers the highest potential bandwidth of any current technology. Most other technologies support data rates in the megabits per second range, while a single mode fiber link has a potential data rate of 40 gigabits per second or a thousand times that of most other

technologies. This potential data rate is considerably reduced, however, in the actual development of an access network.

Some of the possible access configurations are shown in Figure 1. The most direct, highest performance, and highest cost alternative is the ~~single star~~ *active optical network (AON)* (*Figure 1B*) in which an individual fiber serves each subscriber. When fiber runs are long, the provision of a high speed electronic multiplexer, at a remote site, is more economical than multiple fiber runs. A still lower cost alternative employs only passive optics for access saving the cost of field terminals.

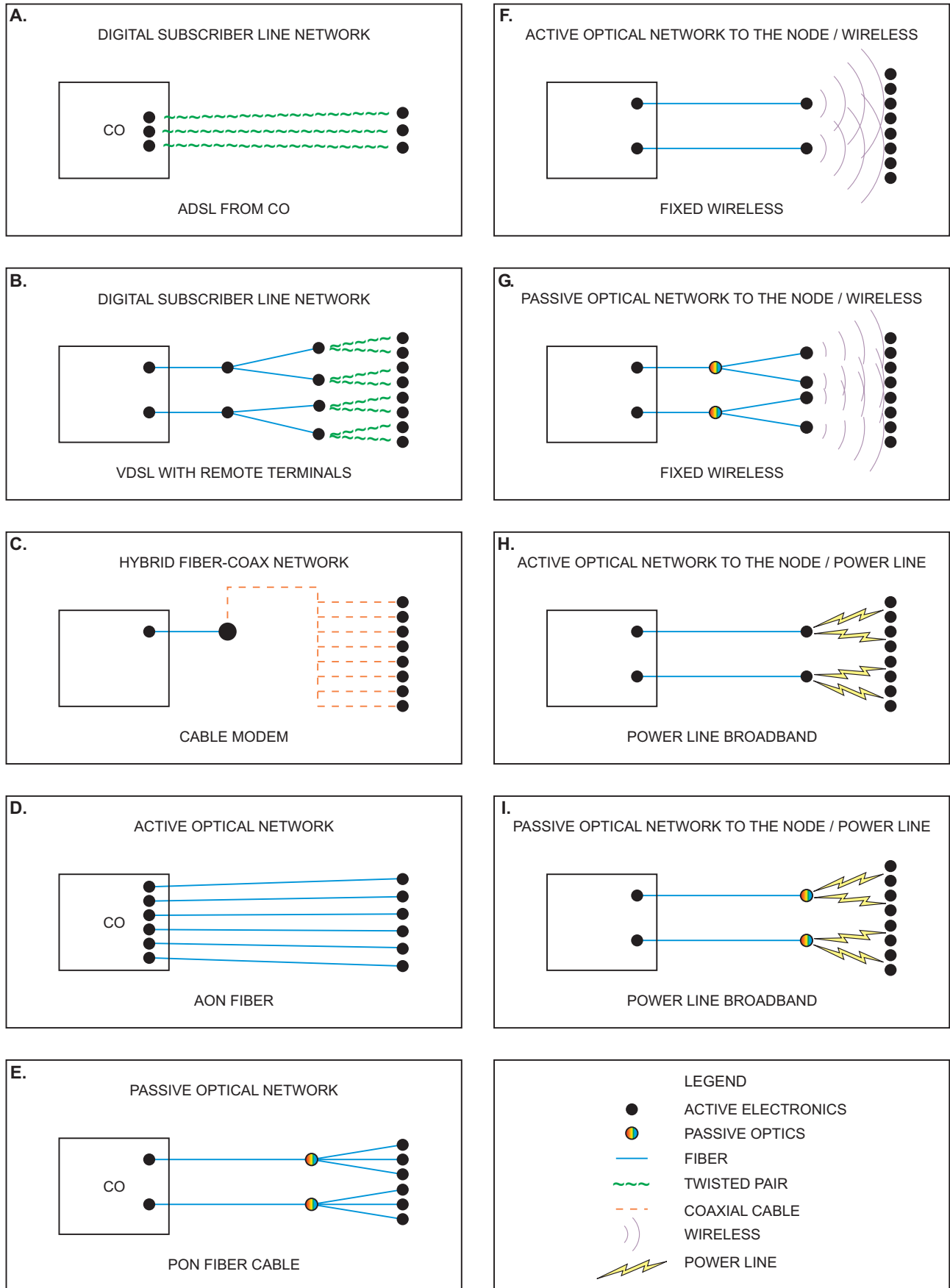
The passive optical network (PON) (*Figure 1E*), because of its lower cost, is the current choice for optical fiber access deployment. This network topology presents some problems, particularly in the upstream mode. In the downstream mode, a broadcast approach is used with each subscriber receiving only messages addressed to its address. In the upstream direction, there is inherent competition between subscribers which can be resolved basically in one of two ways: time slot assignments or contention. Contention is the Ethernet approach and variations of Ethernet are being studied as the primary access protocol for optical fiber PON access. PON optical fiber is in competition with remote extensions of VDSL as a high speed data transmission alternative.

In *Figure 1B*, the VDSL is shown as fiber to the node. A better term would be fiber to the neighborhood since a single VDSL remote terminal is capable of serving as many as 1200 subscribers. The trade off relates to the greater transmission capacity of fiber to the subscriber versus the cost of optical fiber subscriber installation. Remote terminals for ADSL are already being used to extend the coverage of ADSL technology. Since the copper wire range of VDSL is approximately one third that of ADSL, nine times as many remote terminals are required to service the same area. The gain in theoretical data rate may not be worth the expenditure. By comparison, optical fiber PON appears to be more attractive, but the initial investment is high, and the average cost /subscriber is very sensitive to the take rate. A recent Institute of Electrical and Electronic Engineers (IEEE) study reached some pessimistic conclusions on the economic viability of fiber to the home economics.¹ While the broadband high data rates of optical fiber of at least 10 megabits per second are unquestioned, the ability of a typical subscriber to distinguish such a change from a shared lighted fiber coax channel is doubtful. The “bursty” nature of most

¹ See: Frigo, N.J. et al, “A View of Fiber to the Home”, IEEE Optical Communications, August, 2004.

Figure 1

ACCESS NETWORK ALTERNATIVES



Source: IEEE Optical Communications and SEWRPC.

current Internet applications, particularly in the upstream direction, make a high speed -- 10 megabits per second -- data channel indistinguishable from a 500 subscriber shared 30 megabits per second hybrid fiber/coaxial cable channel. Exceptions include large file transfers in both directions and video streams, which also require symmetric data transfers. These technical and economic issues will be addressed through the network design process.

Wireless Network Access

The popular perception of wireless communications derives from cellular wireless networks and the cell phone. Access networks, however, relate to a different set of technologies under the general heading of fixed wireless networks. *In Figure 1, fixed wireless networks are shown in inserts 1F (active fiber and 1G (passive fiber).* As their name implies, fixed wireless refers to networks on which one or both ends of a transmission are fixed. While fixed wireless technology is not new -- microwave transmission links have been in service for over 50 years -- two fairly recent versions of the technology may revolutionize the use of wireless for network access:

1. The development of two new IEEE standards:
 - a. 802.11 – WiFi (wireless fidelity)
 - b. 802.16 – WiMAX (maximum wireless)

2. The evolution of mesh network topology

The WiFi and WiMAX standards in their various lettered versions, as developed by a consortiums of engineering representatives from private industry, permit the provision of standard quality, well-tested, low cost, communications equipment by multiple manufacturers. This situation is in sharp contrast to that followed in the United States in cellular wireless communications where there are variety of proprietary technologies offered by various manufacturers and service providers.

First applications of WiFi related to short distance -- 300 feet maximum -- wireless access to the Internet. WiMAX extended this maximum range from hundreds of feet to miles – 20 miles is typical, but there are a wide variety of system approaches possible with these two technologies that make fixed wireless access a potentially very cost effective alternative for the last mile connection. WiFi (802.11) technology operates primarily in the 2.4 gigahertz unlicensed spectral band with various forms of spread spectrum communications technologies. WiMAX (802.16)

technology operate initially in the unlicensed 5.2-5.9 gigahertz band with advanced modulation/encoding and antenna designs. WiFi is predominantly a short range technology, but distances up to 1 mile or more have been achieved with advanced antenna designs. WiMAX is a longer range technology with distances up to 45 miles aimed at metropolitan area network infrastructures.

Powerline Access Networks

Power line communications (PLC) technologies *shown in Figures 1H and II* have been known since the 1930s, but they have not been traditionally considered as a medium for communications due to their low speed, low functionality and high cost. New modulation technologies, particularly orthogonal frequency division multiplexing (OFDM) have enabled PLC to become a viable alternative for access networks. Broadband PLC applications can be classified into three types:

1. In-home networks
2. Low voltage (LV) access networks
3. Medium voltage (MV) access networks

In-home networks use internal house wiring to provide communications between outlets. This technology can service local area networks as an alternative to conventional wiring or WiFi wireless interconnections (IEEE 802.11b). The user employs home networking devices such as Ethernet-to-PLC or USB-to-PLC USB (universal serial bus) for interconnecting several computers, sharing printers or DSL or cable modem connections. In-home PLC networking is a well established technology with devices commercially available from a number of manufacturers. It is not of primary concern here since it does not provide access to wide area networks.

Low voltage PLC networks can provide access to ~~public~~ *open* networks such as the Internet. With this approach, users gain access through a head-end modem installed in an MV-to-LV transformer providing connections to all subscribers in a neighborhood. The high end modem has a medium voltage link to a high speed core network. Cost reduction is achieved if the MV connection is used for communication since this link minimizes the number of remote modems required.

The primary advantage of PLC as an access technology is the presence of power line circuits in virtually every home and building in the nation. PLC access networks would utilize this existing power net. Problems encountered in PLC networks include time - varying channel attenuation, fading, and background noise. Another class of problems relates to electromagnetic interference with other forms of communications. Although multiple technical and regulatory problems exist with PLC as an access technology, it will be considered as an alternative access technology in the regional network design.

Technologies in Competition

In summary, a competitive race is now on to provide advanced broadband services in the United States. Among the Regional Bell Operating Companies (RBOCs), the alternatives seem to be optical fiber to the home (FTTH) (or premises) or fiber-to-the-node with enhanced VDSL (very high data rate digital subscriber line) using existing twisted pair copper wire beyond the remote terminals of each node. Cable service providers can be expected to provide continuous upgrades to their hybrid fiber-coax networks to remain competitive. The large investments required in providing FTTH will limit the participation to only large, well-financed service providers. Satellite communications is currently too slow in upstream transmission to provide effective competition except in low density rural areas. Fixed wireless, with its present point-to-multipoint infrastructure and its marginal business model, seems limited to niche markets. The only realistic potential broadband communications alternative to FTTH would appear to lie with a new generation of wireless communication such as fourth generation (4 G) cellular or mesh topologies. Power line communications may be the “sleeping giant” of broadband network alternatives because of its existing infrastructure and the capital resources of electric utilities.

NETWORK SIMULATION MODELING

A general approach to network simulation modeling was outlined in the planning program Prospectus. A versatile general purpose modeling software, Visual Slam, was suggested as a vehicle for simulation. This alternative will still be pursued, but the nature of current and emerging telecommunications technologies, particularly in access networks, would suggest the need for a series of special purpose simulation models reinforced by simplified analytical models to confirm their validity. An example exists in fiber-to-the-home (FTTH) broadband access networks. In the passive optical network (PON) version of optical fiber access networks, there are two basic approaches to upstream multiplexing; contention and time slot assignments. These same two alternatives apply to ADSL, VDSL and hybrid-fiber-coax (cable), so that alternative

plans for these existing and potential access networks could be evaluated with these simulation technologies. The time slot assignment as opposed to the contention organized approach in its various Ethernet forms has been extensively modeled using both analytical and simulation formulations. The time slot assignment approach, or more broadly the controlled access approach, has been modeled as a token passing access control method for local area networks. All of these analytic and simulation models have been described in a text by Sadiku.²

The point here is that evaluation of alternative regional network plans will require a combination of both general purpose and special purpose models to allow for comprehensive analysis of plan alternatives. The general purpose simulations model proposed to be used is the Visual SLAM model. In addition, it is proposed to use two special purpose models: Ethernet and ATM models.

DOCUMENTATION

The regional network plan alternatives in network map form, together with the results of the analytic/simulation studies of these alternatives will be documented in a SEWRPC [Technical Report](#) in Month 5 of year 2 of the program in accordance with the project schedule in the Prospectus.

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² See: Sadiku, M.N.O. et al, Simulation of Local Area Networks, CRC Press, 1995