



GOVERNOR'S NORTHERN WISCONSIN ECONOMIC DEVELOPMENT SUMMIT

LAC DU FLAMBEAU, WISCONSIN

NOVEMBER 17, 2008

***Closing The Digital Divide In Northern Wisconsin With
Advanced Wireless Communications Technology And
Public/private Partnerships***

KEN SCHLAGER, Ph.D., P.E.

Chief Telecommunications Engineer, Southeastern Wisconsin Regional Planning Commission

Waukesha, Wisconsin

and

President, HierComm, Inc.

Hartland, Wisconsin

and

BRUCE MCFADDEN

CFO, HierComm, Inc.

Agenda

- Rural Broadband Objective
 - Big Broadband not Little Broadband for Northern Wisconsin
 - U.S. now stands 24th globally in broadband coverage and performance
 - Copying Metro Little Broadband is not the answer
- Rural Broadband Issues
 - Low Population Density
 - Poor Return on Investment
- Changing the Capital Equation
 - Three Approaches
 - Regulatory
 - Subsidy
 - Advance Wireless Technology and
 - Public/Private Partnership
- The Other Approaches
 - Regulatory in Pennsylvania
 - Subsidy in Massachusetts
- Origin of Rural Broadband Wireless Project in Wisconsin
 - USDA SBIR Grant
 - SEWRPC Telecom Planning Program
- Advanced Wireless Technology
 - The Amplified Network
- Regional Telecom Planning
- Broadband Wireless for Public Safety
 - The Kenosha County Project
 - Long Range 4.9 GHZ Wireless Communications
- The Combined Public Safety/Commercial Wireless Network
 - Changing the Capital Equation
- A Combined Public/Private Broadband Telecom Network for Northern Wisconsin
 - The Rusk county Example
 - A Broadband Public Safety Initiative
- Rusk County Broadband Wireless Network
 - Full geographic coverage
 - Public safety network
 - Commercial network

The Rural Broadband Objective

- What is Little Broadband? What we have in the U.S.!
 - DSL – from telco providers
 - Cable modems – from coax cable providers
 - Fixed/mobile wireless providers
 - Generally less, mostly much less, than 5 megabits per sec. down and 1 megabits per sec. up
 - S.1492 and Connected Nation accept low goals
- What is Big Broadband?
 - What other advanced countries have, particularly East Asia!
 - Up to 100 megabits per second in Japan and South Korea
- U.S. in Global Broadband Telecommunications
 - First in technology
 - 24th in broadband participation, coverage and performance
- What is the problem?
 - Lack of a national telecommunications policy
 - Lack of telecommunications infrastructure planning

Rural Broadband Telecommunications Issues

- The Curse of Low Population Density
 - The 250 Per Sq. Mi. Threshold --> 50 Towns in SEW
 - Even in Suburban Brookfield
 - AT&T and U-Verse
 - The Low End
 - Town of Wayne in SE Wisconsin: 48 per Sq. Mi.
 - Rusk County: 17 per Sq. Mi.
- Low Return on Investment
- The Pennsylvania Solution
 - SEDA Council of Governments
 - 11 Rural Counties in Central Pennsylvania
 - Regulatory Coercion of Incumbent Service Providers
 - Primarily Verizon
 - Achievement (?)
 - Promise of “Universal Coverage” at 1.5 Megabits per sec.
 - By 2015



Rural Broadband Telecommunications Issues—continued

- The Massachusetts Solution
 - Subsidy of State - \$40 Million for Broadband and Infrastructure in Western Massachusetts
- The SE Wisconsin Solution
 - Broadband Wireless Public Safety Network (4.9 GHz)
 - Commercial Wireless Network (5.8 GHz)
 - Long Range Amplified Wireless Network Technology
 - Changing the Capital Equation

Origin Rural Broadband Wireless Project

USDA SBIR Grant

Broadband Telecommunications for
Rural America



USDA Objective:

Develop & demonstrate:
cost-effective broadband
telecommunications in a low population
density rural township



(SEWRPC)

Regional Telecommunications Plan for
Southeastern Wisconsin



SEWRPC Objective:

Universal geographic broadband
communications coverage of SEW

*50 townships in SE Wisconsin
(100-250 persons/sq. mile)
Wireless only real alternative*



Wisconsin
Rural Broadband
Wireless Project



Wayne Project Progress



SEWRPC
Progress



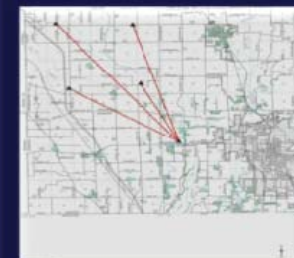
Developed
wireless plan
for Wayne



Field tested
wireless plan
for Wayne



Wayne
Access Point
Plan map



Wayne
Backhaul
map



HierComm
Progress:



Developed:
cost-effective long range,
high gain, high
throughput version of
IEEE Std. 802.11g

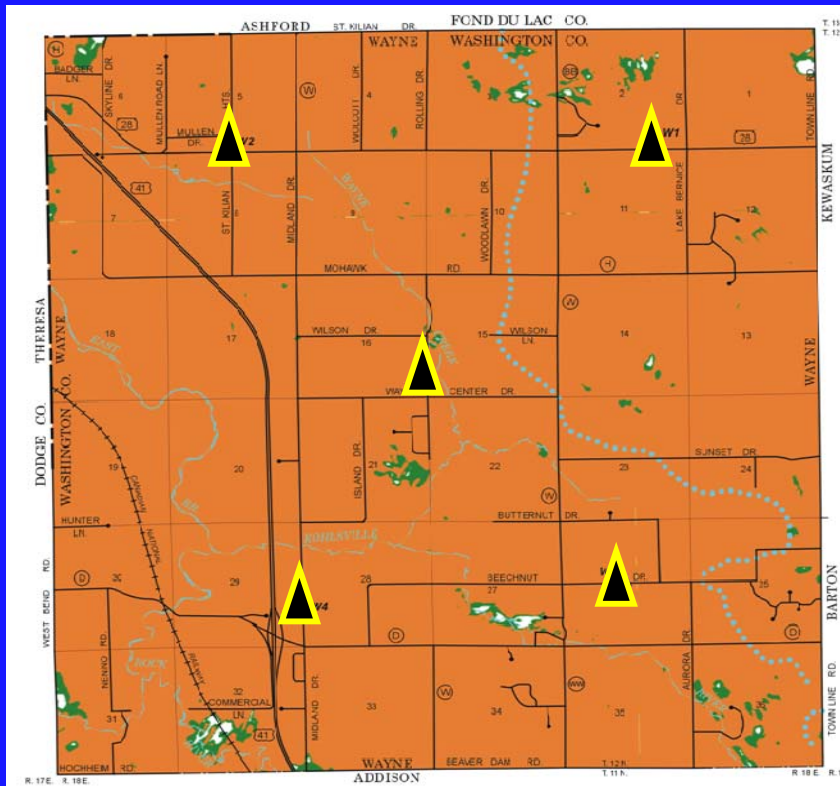


**Developed &
Demonstrated:**
SERT/WiFi technology in
Wayne (with 1 of 4 ASPs)

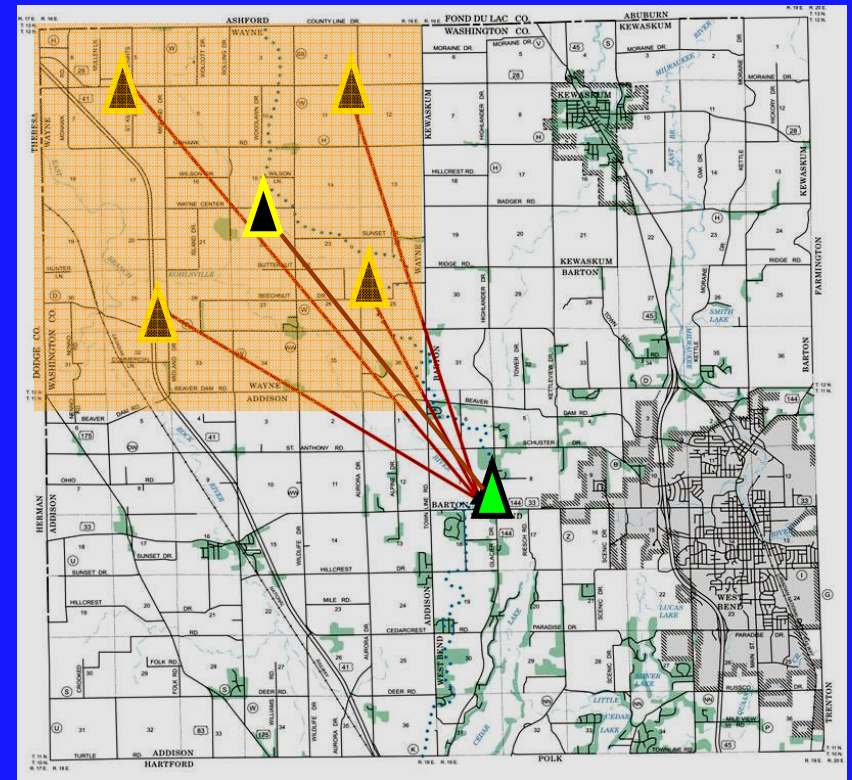


Demonstrated:
symmetric 20 Mbps
throughput

The Wayne Network



Network Map



Backhaul Map



ACCESS POINT LOCATIONS



RECEIVED POWER AT REMOTE
GREATER THAN -113.0 dBmW



RECEIVED POWER AT REMOTE
GREATER THAN -113.0 dBmW



AREA NOT WITHIN ACCEPTABLE COVERAGE



BACKHAUL ACCESS POINT



ACCESS POINT LOCATIONS



Transmission (Backhaul) Network

- Need for Backhaul Network
 - Internet connection
 - for commercial network
 - To County Public Safety Operations Center
 - for public safety networks
- Backhaul Alternatives
 - Closest Internet tower gateway
 - Wireless backhaul network
 - more dependable and competitive alternative



Transmission (Backhaul) Network— continued

- Regional Wireless Backhaul Network
 - 54 backhaul base stations
 - 7 are Internet gateways
 - County backhaul base stations
 - Kenosha – 5
 - Milwaukee – 7
 - Washington – 10
 - Waukesha - 14
- Regional Wireless Economics
 - Infrastructure cost = \$2.0 million
 - Annual savings = \$1.5 million/year

LEGEND

BACKHAUL BASE STATION (47)

GATEWAY BASE STATION (7)

BACKHAUL RADIO COVERAGE AREA

AREA OF LOW SIGNAL COVERAGE



HierComm Technology

$$\text{Channel Capacity} = \text{Bandwidth} \times \log_2(1 + \text{Signal/Noise})$$

(bits/sec) (Hz) (mW) (mW)



Channel Capacity (Throughput) Depends on:

1. Bandwidth of the Medium	Fixed by the FCC (3 - 20Mhz channels in the 2.4 GHz band)
2. Transmit Power	Limited by the FCC (for un-licensed spectrum)
3. Signal Power at the Receiver	HierComm: Increase Signal Level Through Amplification
4. Noise Power at the Receiver	HierComm: Reduce Noise levels – Future implementation

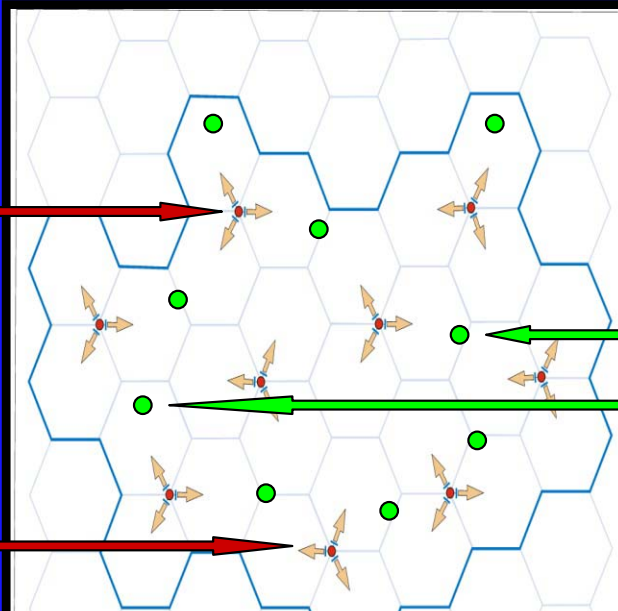
HierComm's *SERT™* Technology

Shannon Enhanced Radio Technology

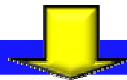


Access Points (AP)

High gain directional antennas
Higher signal intensity
Longer range – Fewer Required



Sectoral-Cellular Topology



Customer Premises (CPE)

Patented active high gain antenna +
high gain amplifier
200X (23dB) the signal sensitivity
Higher throughput & longer range



Enhanced Signal Level thru Amplification Delivers:

Longer range per access point

Up to 2 miles

Higher throughput

Up to 20 Mbps

Reduced access point (AP) density

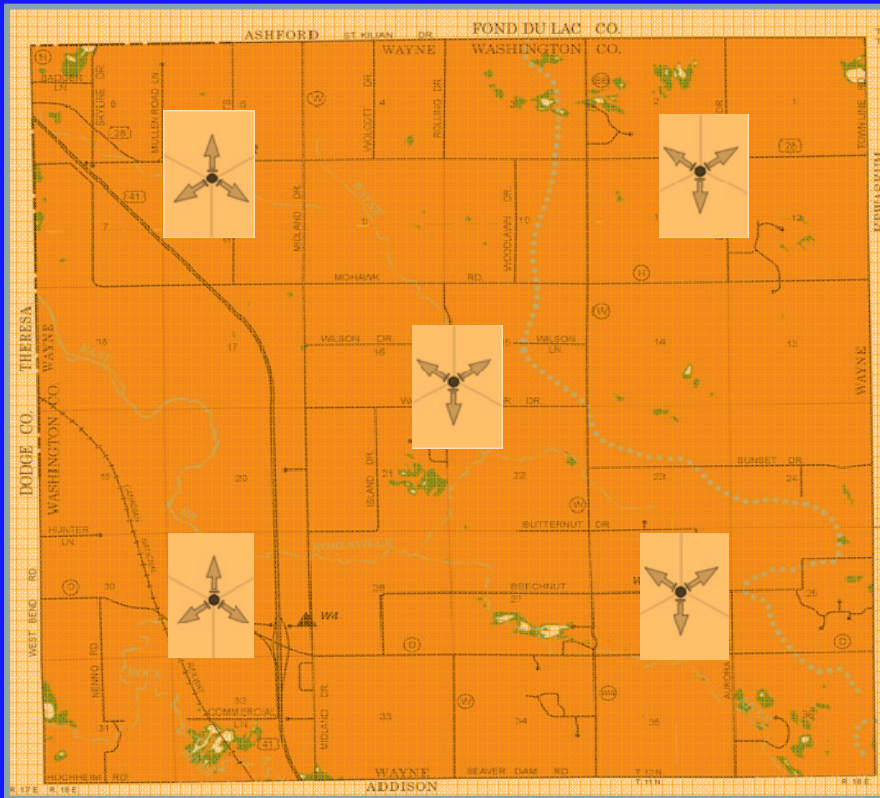
1/10th the density of WiFi-WiMAX

Dramatically reduced capital costs

Fastest return on investment

Sectoral Cellular vs. Mesh Network

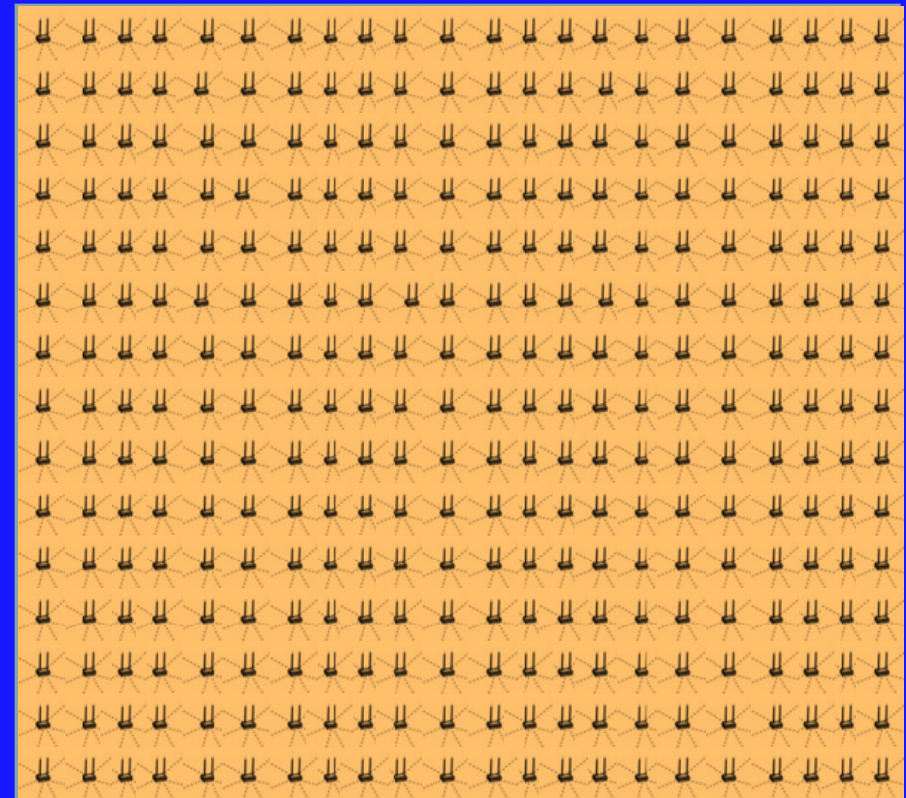
Wayne, Wisconsin
Area = 36 sq. miles
Pop: 600 households



HierComm WiFi SERT Network

AP Density	0.14 per sq. mile
Total AP Required	5

Wayne, Wisconsin
Area = 36 sq. miles
Pop: 600 households



Tropos WiFi Mesh Network

AP Density	25 per sq. mile
Total AP Required	Approx. 900



SEWRPC and Regional Telecommunications Planning

- History of Telecom Planning
 - Bell Telephone Labs and The Bell System
 - From the early days of AT &T
 - Non-rural urban nature of Bell System
 - 1984 breakup
 - Decline of telecom planning after 1984 breakup and 1996 Telecom Act
- Telecom Planning at SEWRPC
 - Community Wireless Plan
 - Its rural-exurban emphasis
 - Regional Wireless Plan
 - Its combination public safety/commercial emphasis



SEWRPC and Regional Telecommunications Planning—continued

- Telecom Planning for Wisconsin
 - Northern Wisconsin – a regional plan
 - Northern Wisconsin – a county-by-county plan
- Telecom Planning
 - Infrastructure planning
 - Business model planning
 - Need for revival of telecom planning
- Field Testing for a Ready-to-Build Plan
 - Limitations of radio propagation modeling
 - Database shortcomings
 - Field test procedure
 - Modified, field tested infrastructure plan
 - Ready to deploy



The Kenosha County 4.9/5.8 GHz Public Safety Wireless Communications Project I

- Primary Objective
 - Implementation of SEW Regional Wireless Plan
 - Real broadband performance with universal geographic coverage
- Operational Objective
 - Full geographic coverage with 10 existing base station sites
 - 20 megabits per second throughput performance
- Ad Hoc peer-to-peer network communications alternative
 - For universal geographic coverage
 - For major public safety emergencies



The Kenosha County 4.9/5.8 GHz Public Safety Wireless Communications Project II

- Network Architecture
 - Sectoral Cellular
 - Peer-to-Peer Dynamic Mesh
- System Equipment
 - The Amplified Network
 - Centralized Access Control
 - Versatile Mobile Omni-Directional Antenna
 - Innovation and New Critical Components



Development and Demonstration Program Kenosha County Broadband Public Safety Communications Network

1. Radio Propagation Modeling
2. The County-Wide 4.9/5.8 GHz Network Plan
3. Equipment Development, Assembly and Checkout
4. Stage I Field Test – Vehicular AP
5. Stage II Field Test – Tower AP – 4.9 GHz and 5.8 GHz



Stage I Field Test

Vehicular Access Point

Goals:

1. Equipment operation verification in a field environment
 - Laboratory checkout alone is not sufficient.
2. Experimental simulation of 4.9 GHz
 - Testing with lower height (20 ft.) antenna
3. Adjustments for optimal operation in high tower environment

Operation:

1. Park vehicular AP truck at test location.
2. Roam surrounding area with test truck recording signal and interference/noise levels.

Test Results:

1. Coverage of SNR=10 or greater
2. Out to 1.5 miles
3. Radio prop-modeling at AP-150 feet
4. 3 miles and beyond

Stage II Field Test

160 foot high Antenna Base Station

Goals:

1. Verify 4.9/5.8 GHz geographic coverage in county field environment with single base station.
2. Verify 4.9/5.8 GHz throughput performance in coverage area.

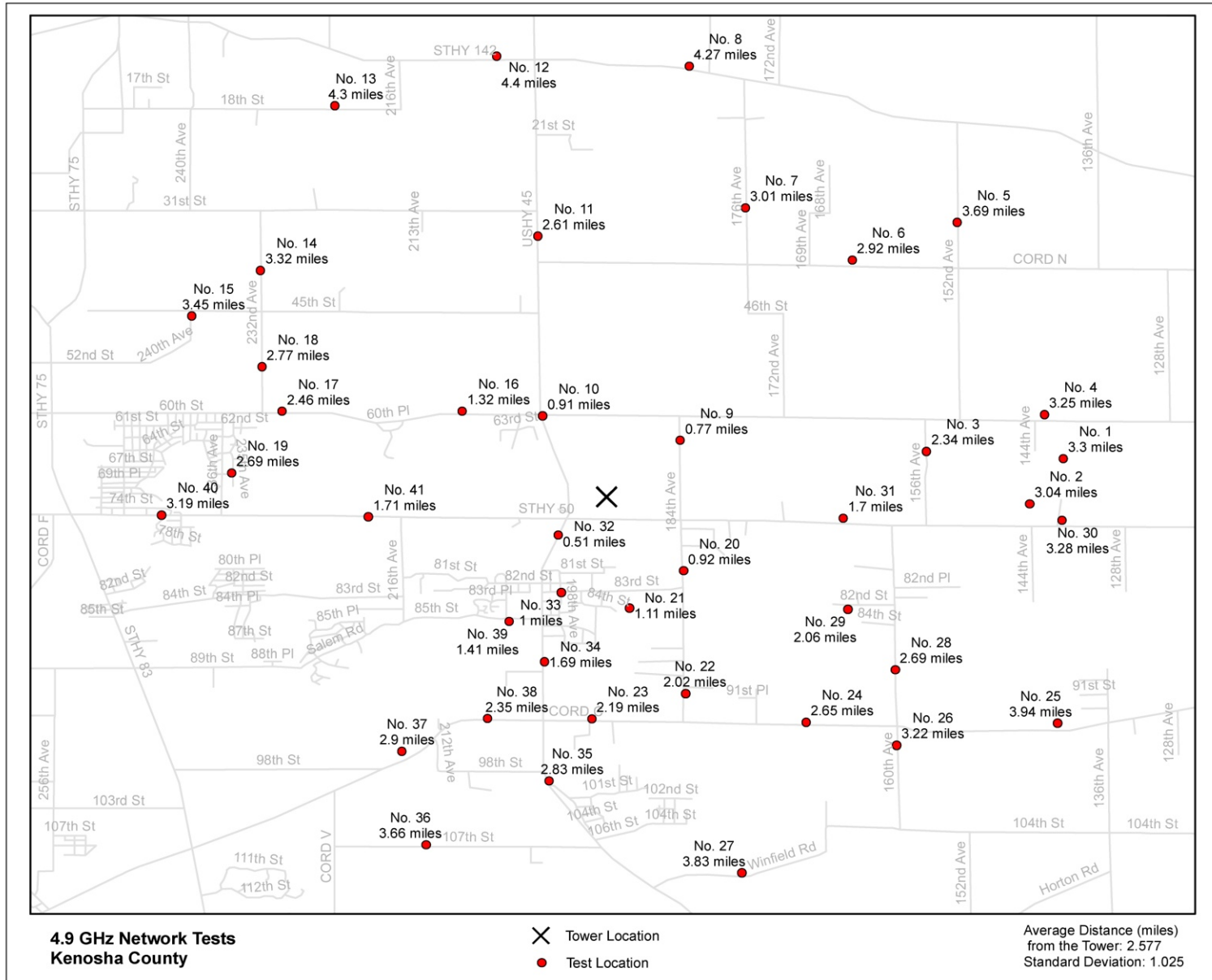
Operation:

1. Mount AP equipment on BST2 Tower.
2. Simulate 4.9 GHz public safety vehicle.
3. Simulate 5.8 GHz fixed user.
4. Measure Base Station range and throughput performance.

Test Results:

- | | |
|---|--|
| 1. Coverage (Range)
Minimum – 0.51 miles
Maximum – 4.41 miles
Average – 2.58 miles | 3. Throughput (upload)
Minimum – 3.7 megabits/second
Maximum – 12.8 megabits/second
Average – 10.44 megabits/second |
| 2. Throughput (download)
Minimum – 4.40 megabits/second
Maximum – 22.9 megabits/second
Average – 12.45 megabits/second | 4. Signal-to-Noise Ration (SNR)
Minimum – 4.0 dB
Maximum – 33.0 dB
Average – 16.2 dB |

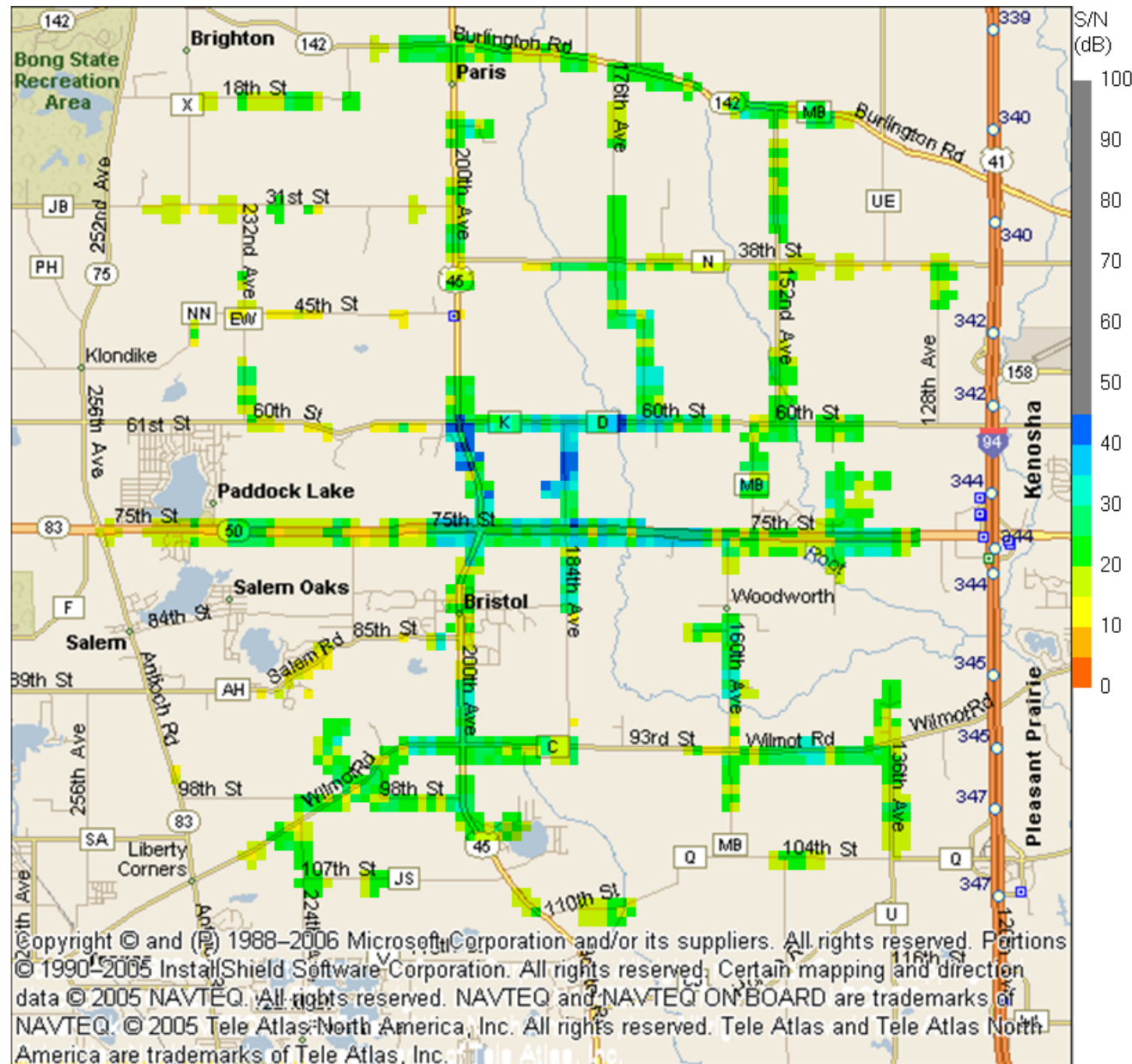
4.9 GHz Geographic Coverage Map



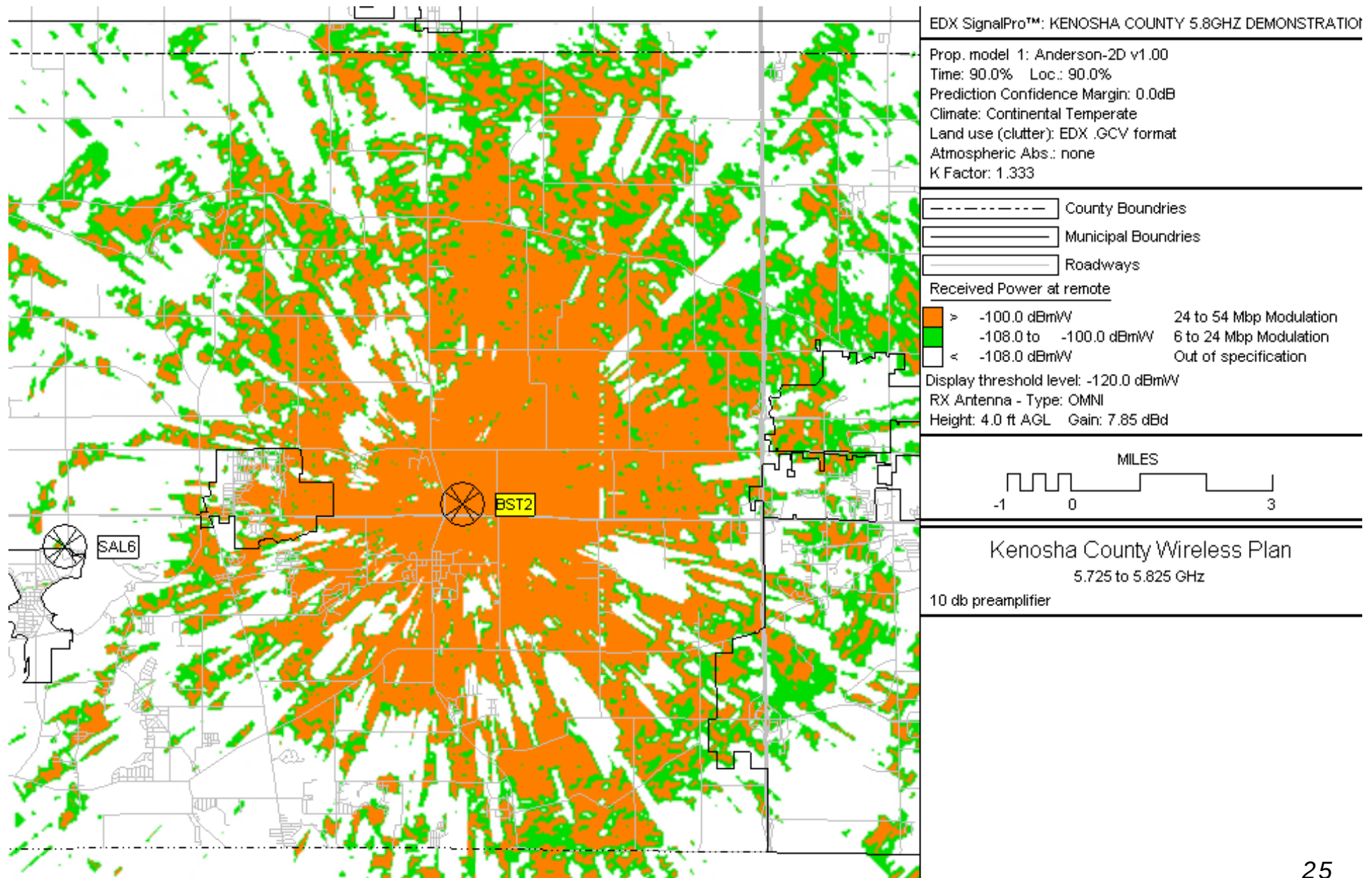
4.9 GHz Geographic Coverage Table

No.	Latitude Degrees	Latitude Minutes	Decimal Latitude	Longitude Degrees	Longitude Minutes	Decimal Longitude	Distance (miles)	Signal	Noise	SNR	Download Throughput (TCP Mbps)	Upload Throughput (TCP Mbps)
1	42	34.573	42.5762167	87	58.645	-87.9774167	3.3	-74	-95	21	12.1	12.7
2	42	34.187	42.5697833	87	58.927	-87.9821167	3.04	-86	-94	8	4.4	4
3	42	34.636	42.5772667	87	59.796	-87.9966	2.34	-71	-94	23	12.2	12
4	42	34.952	42.5825333	87	58.803	-87.98005	3.25	-87	-94	7	4.4	4.1
5	42	36.593	42.6098833	87	59.537	-87.9922833	3.69	-79	-94	15	10.7	11
6	42	36.272	42.6045333	88	0.423	-88.00705	2.92	-77	-94	17	10.4	11.7
7	42	36.717	42.61195	88	1.322	-88.0220333	3.01	-74	-94	20	11.7	12.5
8	42	37.931	42.6321833	88	1.796	-88.0299333	4.27	-77	-94	17	11.3	12
9	42	34.729	42.5788167	88	1.871	-88.0311833	0.77	-63	-94	31	12.2	12.6
10	42	34.94	42.5823333	88	3.031	-88.0505167	0.91	-62	-92	30	11	11.9
11	42	36.477	42.60795	88	3.072	-88.0512	2.61	-76	-92	16	11.8	10.9
12	42	38.018	42.6336333	88	3.418	-88.0569667	4.41	-75	-93	18	11.2	9.9
13	42	37.592	42.6265333	88	4.78	-88.0796667	4.31	-82	-93	11	8.2	8
14	42	36.185	42.6030833	88	5.408	-88.0901333	3.33	-71	-93	22	12.2	11.9
15	42	35.795	42.5965833	88	5.988	-88.0998	3.46	-74	-93	19	12.1	12.6
16	42	34.979	42.5829833	88	3.708	-88.0618	1.32	-63	-93	30	12	11.8
17	42	34.978	42.5829667	88	5.225	-88.0870833	2.46	-72	-94	22	10.9	11.1
18	42	35.36	42.5893333	88	5.394	-88.0899	2.77	-76	-93	16	11.9	11.9
19	42	34.45	42.5741667	88	5.652	-88.0942	2.69	-78	-92	14	11.9	11
20	42	33.614	42.5602333	88	1.845	-88.03075	0.92	-64	-90	26	22.8	13
21	42	33.297	42.55495	88	2.3	-88.0383333	1.11	-67	-91	24	22.9	12.8
22	42	32.565	42.54275	88	1.825	-88.0304167	2.02	-87	-92	5	11.6	8.1
23	42	32.347	42.5391167	88	2.615	-88.0435833	2.2	-79	-92	13	18.6	11
24	42	32.319	42.53865	88	0.81	-88.0135	2.65	-88	-92	4	8.4	7.9
25	42	32.31	42.5385	87	58.693	-87.9782167	3.93	-81	-93	12	15.8	11
26	42	32.123	42.5353833	88	0.049	-88.0008167	3.22	-85	-93	8	12.3	8.3
27	42	31.031	42.5171833	88	1.352	-88.0225333	3.84	-85	-92	7	12.5	8.9
28	42	32.768	42.5461333	88	0.06	-88.001	2.68	-78	-92	14	21.3	12.2
29	42	33.284	42.5547333	88	0.459	-88.00765	2.06	-83	-94	11	12.4	8.1
30	42	34.046	42.5674333	87	58.656	-87.9776	3.27	-82	-92	10	15.9	9.9
31	42	34.064	42.5677333	88	0.5	-88.0083333	1.71	-73	-93	20	21.3	12.6
32	42	33.92	42.5653333	88	2.899	-88.0483167	0.51	-60	-93	33	15.9	12.1
33	42	33.428	42.5571333	88	2.873	-88.0478833	1	-89	-94	5	3.8	3.7
34	42	32.837	42.5472833	88	3.016	-88.0502667	1.69	-80	-94	14	11.3	10.4
35	42	31.818	42.5303	88	2.975	-88.0495833	2.83	-84	-94	10	11	7.8
36	42	31.272	42.5212	88	4.015	-88.0669167	3.67	-80	-93	13	13	11.5
37	42	32.07	42.5345	88	4.216	-88.0702667	2.91	-72	-94	22	16.1	12.7
38	42	32.35	42.5391667	88	3.494	-88.0582333	2.35	-80	-94	14	11.9	11.1
39	42	33.18	42.553	88	3.313	-88.0552167	1.41	-65	-94	29	16.7	11.3
40	42	34.092	42.5682	88	6.242	-88.1040333	3.19	-80	-92	12	12.5	11
41	42	34.077	42.56795	88	4.499	-88.0749833	1.71	-82	-93	11	12.2	9

5.8 GHz Geographic Coverage Map



5.8 GHz Radio Propagation Map





Stages III and IV Field Test

- Ad Hoc, Peer-to-Peer Communications
 - Off-line testing
 - Field testing
- System Test
 - Public Safety Vehicles
 - Public Safety Network
- New Features Tested
 - Peer-to-Peer Ad Hoc Dynamic Mesh
 - Multiple Frequency Selection
 - Geo Messaging
 - New Wireless TCP



Technical Summary

4.9/5.8 GHz Combined Broadband Wireless Communications System

- Demonstrated
 - 4 mile radius geographic coverage
 - 10-30 Mbps throughput performance
- Final Demonstration
 - Peer-to-Peer Communications
 - Final System Test



Northern Wisconsin Broadband Action Plan

- Telecom Infrastructure Planning for Northern Wisconsin
 - Whole Region
 - Sub-Regions
 - County-by-County
- Planning Structure
 - Target Years
 - Objectives and Standards
 - Inventory Services, Existing Infrastructure and Performance
 - Needs
 - Plan Design
 - Plan Verification – Field Test
 - Plan Implementation



Northern Wisconsin Broadband Action Plan—continued

- Action Program
 - Prepare Regional Plan
 - Select Pilot Counties
 - Funding for Pilot Counties
 - 4.9 GHz public safety
 - 700 MHz public safety
 - Commercial Network
 - 0.9/5.8 GHz
 - RFP for ISPs
 - Pilot Network Operation
 - Public Safety
 - Commercial



Rusk County Combined Public Safety / Commercial Broadband Wireless Network

County Characteristics

- Total area – 931 square miles
- Population – 15,347 people, 7,609 households
- Population density – 17 per square mile
- Household density – 8 per square mile
- Terrain – Extremely wooded

Available Frequency Bands

- Public safety – 780 MHz, 4900 MHz
- Commercial unlicensed – 915 MHz, 2400 MHz, 5800 MHz
 - Need for Base station tower sharing
 - Rusk County terrain mandates 780 MHz, 915 MHz combination
 - Less forested Kenosha County supported 4900 MHz, 5800 MHz combination



Rusk County Combined Public Safety / Commercial Broadband Wireless Network —continued

Rusk County Public Safety Broadband Wireless Network Plan (780 MHz)

- Nineteen (19) Base Station Sites
 - 14 new
 - 5 existing
- Performance
 - Symmetric 20 Mbps
- Estimated Cost – \$650,000 infrastructure only
- Vehicular Radios – \$2,000 each



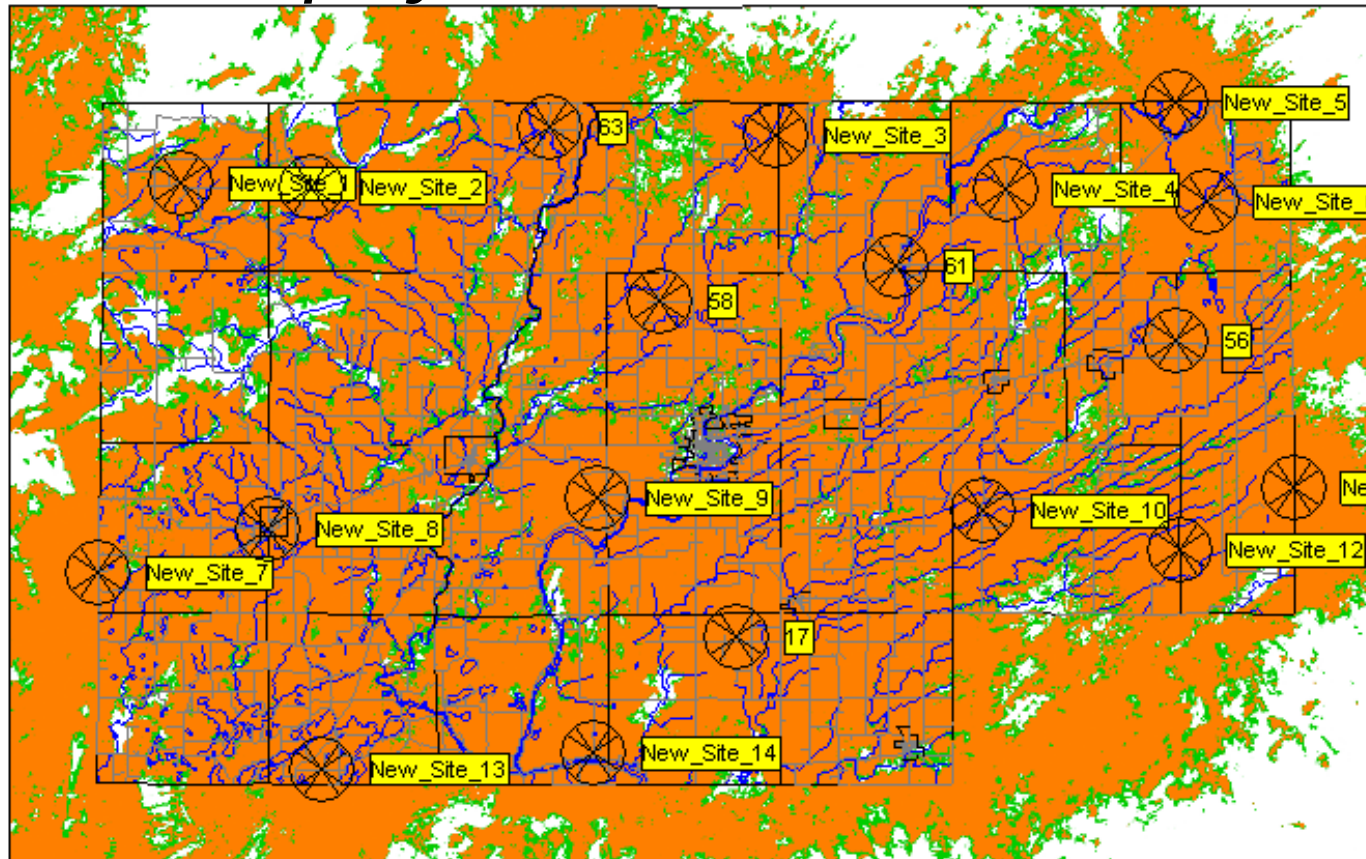
Rusk County Combined Public Safety / Commercial Broadband Wireless Network — continued

Rusk County Commercial Broadband Wireless Network Plan

- Shares public safety base stations
- Performance
 - Symmetric 20 Mbps
- Cost – \$75,000 infrastructure only
- Fixed user CPE
 - \$400 each

Map 1

Rusk County Broadband Public Safety Wireless Network



EDX SignalPro™: RUSK COUNTY 780MHZ NOMADIC ACCE

Prop. model 1: Anderson-2D v1.00
Time: 90.0% Loc.: 90.0%
Prediction Confidence Margin: 0.0dB
Climate: Continental Temperate
Land use (clutter): EDX .GCV format
Atmospheric Abs.: none
K Factor: 1.333

Legend:
— bndry
— Roadways
— Waterways

Received Power at remote

> -115.0 dBm/W	24 to 54 Mb modulation
-123.0 to -115.0 dBm/W	6 to 24 Mb modulation
< -123.0 dBm/W	Out of specification

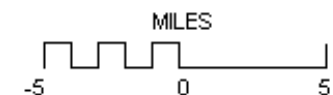
Display threshold level: -125.0 dBm/W

RX Antenna - Type: OMNI

Height: 4.0 ft AGL Gain: 4.85 dBd

Notes

Base Station Tx Power: 33 dbm/W
Base Station Antenna Gain: 16 dbi
Base Station Height: 100 feet
Mobile Antenna Gain: 7 dbi
Remote Tx Power: 33 dbm/W



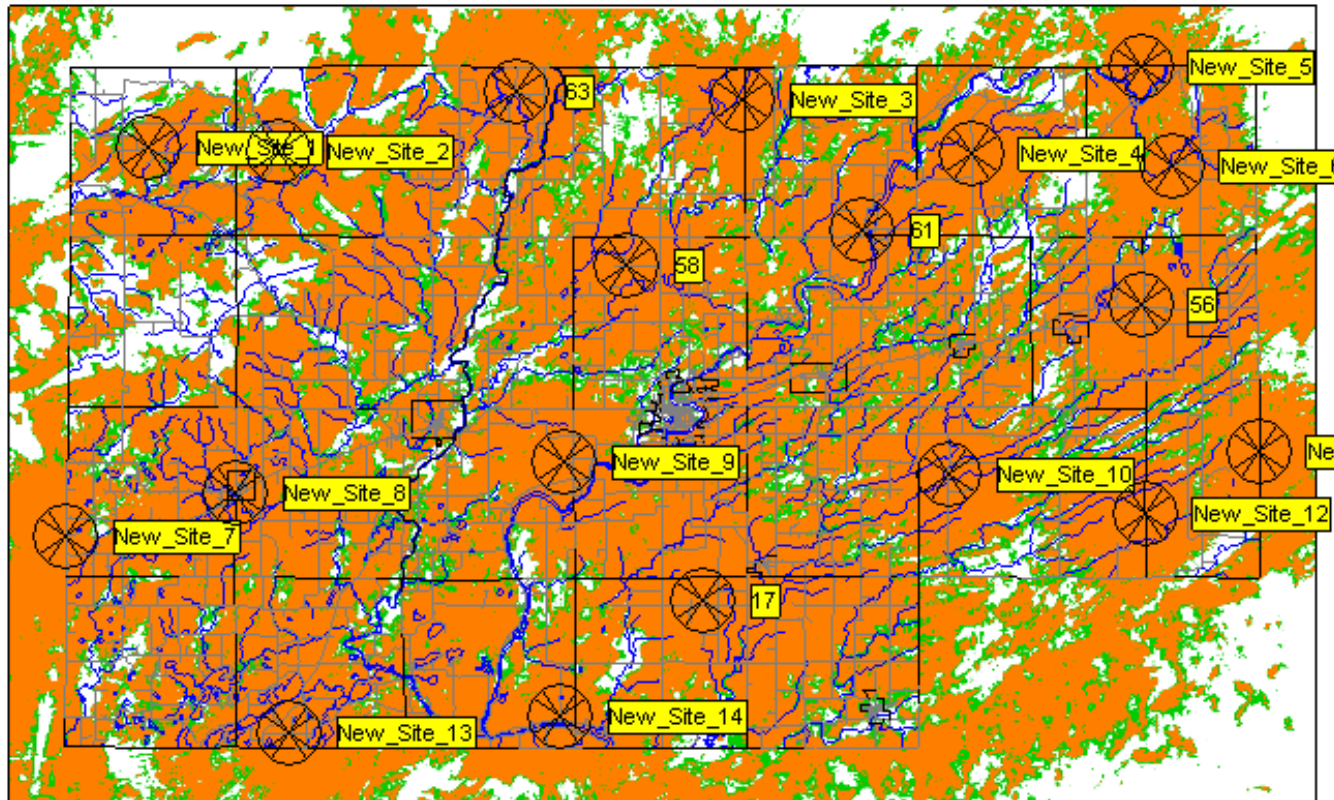
Rusk County 780 MHz Wireless Network

Nomadic Users

With 35 db preamplifier

Map 2

Rusk County Broadband Commercial Wireless Network



EDX SignalPro™: RUSK COUNTY 928MHZ FIXED ACCESS I

Prop. model 1: Anderson-2D v1.00
Time: 90.0% Loc.: 90.0%
Prediction Confidence Margin: 0.0dB
Climate: Continental Temperate
Land use (clutter): EDX .GCV format
Atmospheric Abs.: none
K Factor: 1.333

bdndry
Roadways
Waterways

Received Power at remote

> -115.0 dBm/W	24 to 54 Mb modulation
-123.0 to -115.0 dBm/W	6 to 24 Mb modulation
< -123.0 dBm/W	Out of specification

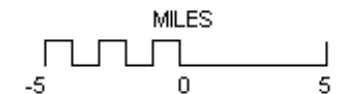
Display threshold level: -125.0 dBm/W

RX Antenna - Type: DA

Height: 10.0 ft AGL Gain: 9.85 dBd

Notes

Base Station Tx Power: 22 dbm/W
Base Station Antenna Gain: 14 dBi
Base Station Height: 100 feet
Remote Antenna Gain: 12 dBi
Remote Tx Power: 24 dbm/W



Rusk County 928 MHz Wireless Network

Fixed Users

With 35 db preamplifier