WiMAX: Broadband Wireless Internet Access

By

James Boyd

Submitted to
the Faculty of the Information Engineering Technology Program
in Partial Fulfillment of the Requirements for
the Degree of Bachelor of Science
in Information Engineering Technology

University of Cincinnati
College of Applied Science

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James C. Boyd	Date
Professor John F. Nyland, Faculty Advisor	Date
Patrick C. Kumpf, Ed.D. Interim Department Head	Date

Acknowledgements

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Abstract

This particular project is installing a WiMAX-class Point-to-Point (PtP) broadband wireless connection between two college campuses as a proof of concept. The product chosen uses 5.8 GHz full-duplex radios with a range of 1 to 40 miles and a data rate of 45 Mbps (90 Mbps aggregate both ways). Lessons learned from this project will help develop the business plan for deploying future Point-to-MultiPoint (PtMP) installations on the campus and PtP between all university campus sites. These installations have the potential to save the university thousands of dollars in Internet and fiber optic access fees currently provided by telephone and cable companies. Simply by owning the PtP and PtMP broadband wireless network, the university will dictate their own bandwidth availability, enhancements and costs over the lifetime of the network.

WiMAX: Broadband Wireless Internet Access

1. Statement of the Problem

Employers, governments, and educational institutions at all levels have become reliant on broadband access to the Internet. This access is primarily for the exchange of business information, financial transactions, and special services on a daily basis. The Internet revolution has created the need to develop innovative networking technologies in order to transport and deliver content rich environments to the end user at work, home, and school (8).

Business and government institutions recognize that access to the Internet means increased knowledge, awareness and economic opportunities for employees, citizens and students. Local telephone, cable, and satellite providers supply this connection via their infrastructure for as much as a few hundred to several thousand dollars per month. These connections are provided for access to the Internet and exclusive access between buildings and campuses using Virtual Private Network (VPN) and the Internet as its Wide Area Network (WAN) medium. The realization is that not all areas of the community are reachable by current broadband Internet Service Provider (ISP) technologies. Dial-up speeds of 28-56 Kbps via telephone lines are too slow for residents and small businesses to experience the rich content provided by community and university Web sites. Citizens and students, who require connection speeds of at least 200 Kbps to 1.5 Mbps, can pay as much as $50 -$100 per month for broadband access, when and where it is available (14, p1).

The University of Cincinnati has many connections to the Internet via copper and fiber optic leased lines. These include T1, T3 and tiered high speed fiber optic links between campuses. The university pays tens of thousands of dollars annually to lease these lines and maintain support contracts; they will never own these connections and always be at the mercy of the telephone companies who provide them. Broadband Wireless Access (BWA) technologies offer a way to provide equivalent or better service at a fraction of the cost and the university will benefit from owning and controlling their own network (2). The College of Applied Science at 2220 Victory Parkway only has a 20 Mbps fiber optic leased line between the campus and UC Main Campus. The network connection reaches near full utilization during peak periods and is insufficient for new projects and classroom labs that aim to deliver VPN and other E-learning opportunities and applications to benefit students and faculty.

2. Description of the Solution

Implement a fixed Point-to-Point (PtP) network for the University of Cincinnati (UC) between the Campus Services Building (CSB) at 2900 Reading Road and the College of Applied Science (CAS) at 2220 Victory Parkway. The CSB site has a large Gigabit backbone to UC Main Campus that can be utilized by the new wireless connection from CAS. This will help CAS triple their bandwidth from 20 to 65 Mbps between networks for a nominal one-time cost and allow the university to immediately meet additional application and network demands. This multi-path wireless redundancy will also act as a backup or failover to the wired solution in the event a service provider cable is severed or the connection link goes down. (See Figure 1.)

For the PtP installation, a pair of 5.8 GHz license-exempt radios will be installed at each campus operating at approximately 1 mile apart with Line Of Sight (LOS) between them. A predicted data rate of 45 Mbps full-duplex will be achieved assuming optimum configuration of radios, antennas and related network hardware. The prototype will co-exist with their current copper and fiber optic leased lines. It will allow the university to own a larger piece of their Wireless Wide Area Network and explore opportunities where fixed WiMAX-class hardware can provide voice and data link solutions between and all over campuses.

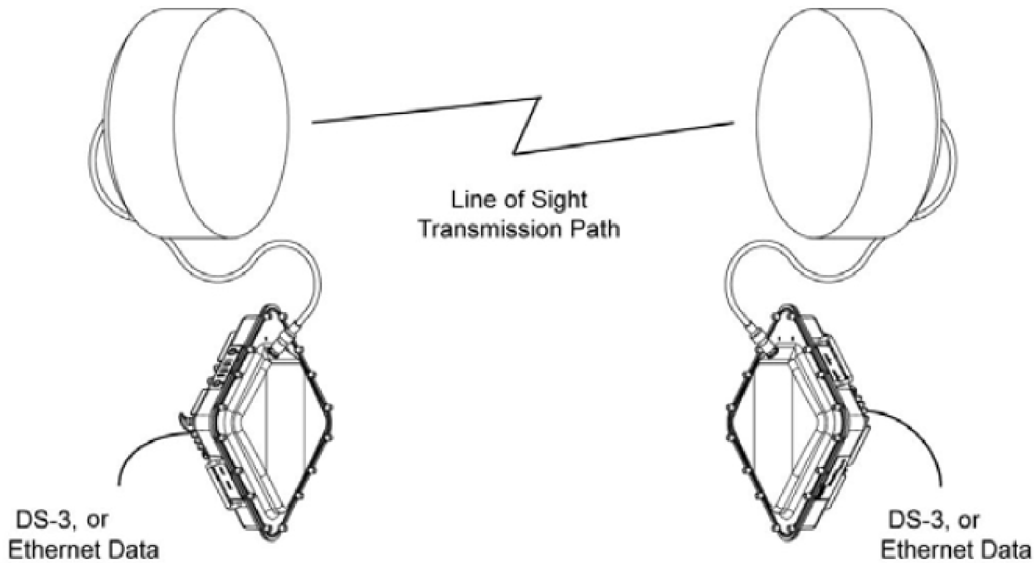

Figure 1. Typical TeraBridge 5845 PtP installation

Future PtP installations from UC Main campus could include UC Raymond Walters campus, approximately 9 miles Near Line Of Sight (NLOS), and UC Clermont campus, approximately 26 miles NLOS. Point-to-Multipoint (PtMP) installations could follow as soon as late 2006 for access to students and citizens in surrounding areas via Customer Premise Devices (CPE). (See Figure 2.)

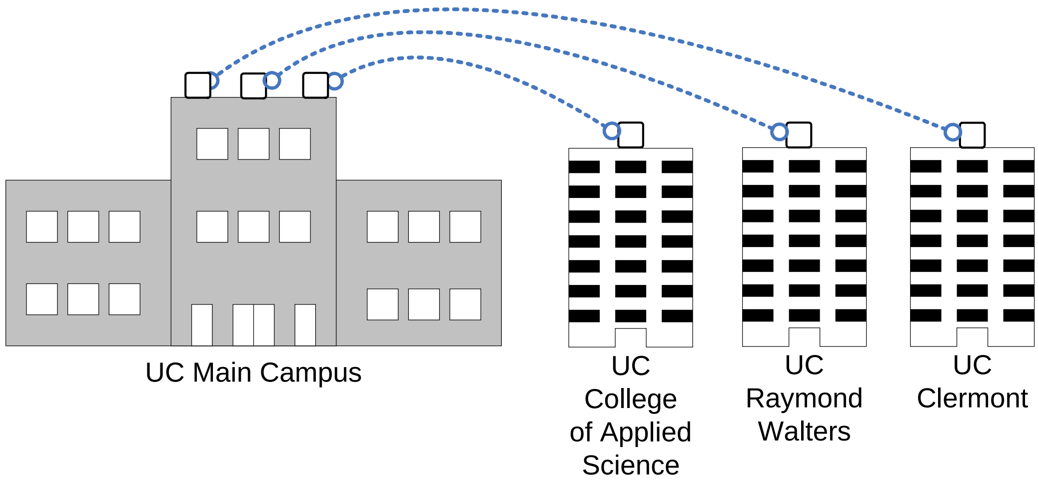

Figure 2. Several PtP installations between campuses

BWA technologies have been evolving since the late 1990s to provide institutions with fast and secure wireless access to the Internet or between buildings and campuses. Manufacturers have adopted their own proprietary standards for developing this hardware and operate in a range of licensed and license-exempt pre-WiMAX frequency bands; 2.5 GHz and 5.8 GHz. 3.5 GHz is not available in North America yet (9).

2.1. User Profiles

The university will have four primary user-roles for this PtP bridge prototype.

Vendor Support

The vendor will maintain enough permission to the system to honor the Support Level Agreement (SLA) between the university and the manufacturer. This will be used in times of emergency if the system should fail and UCit administrators can not support or restore the system to a working state. This may include remote or on-site support and will be at the discretion of UCit when negotiating the SLA. UCit reserves the right to grant or deny access to anyone in order to safeguard data and the integrity of the network.

Technical Engineer

The technical engineer will be responsible for surveying, installing, configuring and testing the radios and PtP bridges. This person will coordinate mounting locations and network termination points with the UCit staff in order to present a seamless installation. All technical standards and guidelines will be followed that are associated with the university and the hardware vendor in order to provide and maintain a working prototype.

Administrator

The administrator will be a university staff member, preferably from UCit. This person will be present at all times during the installation and retain all documentation of the final product. This role will be responsible for continued performance monitoring, configuration, and improvements made to the system. The administrator will have full rights to perform these duties and to assign other users and administrators to the system rights to perform any role necessary to use or support the system in a capacity within his power. Enhancements to the system will be coordinated between the administrator, the university, and the vendor. These enhancements may include but are not limited to the addition of other PtP networks to campuses, buildings, or PtMP systems to the region.

Users

The users will consist of a combination of students, faculty, and anyone that is authorized to share data on the UC network. Access to the network will be from existing computers in offices, computer labs, and classrooms that are authorized to be on the UC domain. These users will access information between the campuses just as they did before. They will not necessarily be aware if they are using the wired or wireless PtP system because it is an infrastructure that is behind the scene. (See Figure 3.)

2.2. Design Protocols

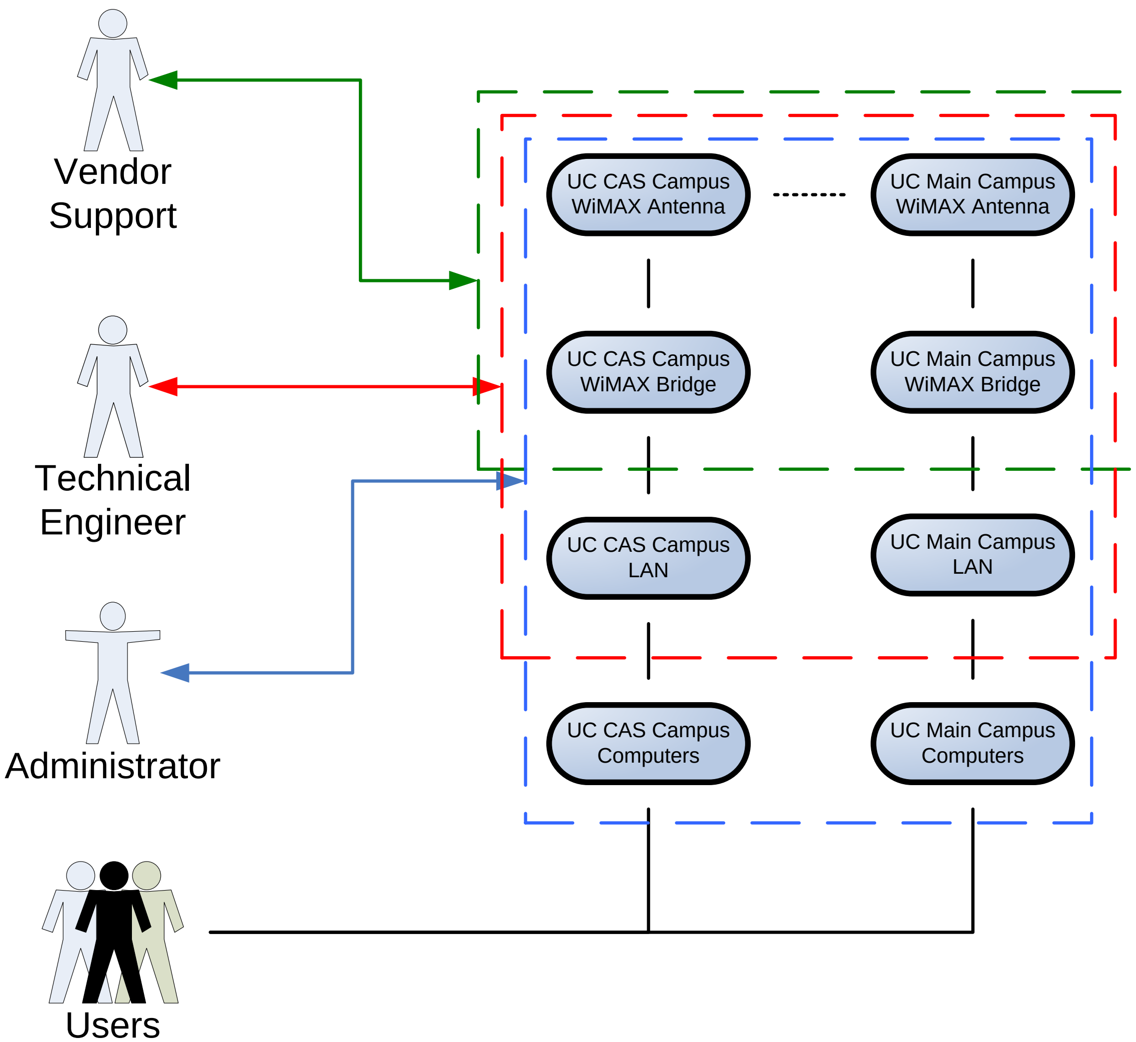

Figure 3. Use Case Diagram

2.3. Network Design

The design of this system consists of components supporting a PtP broadband wireless installation between UC CSB and UC CAS campuses. (See Figure 4.) Campuses such as UC Raymond Walters and UC Clermont can be reached via the same technology. Many fixed WiMAX-class PtP and PtMP products were researched and considered for the solution including Aperto Networks Packewave600, Redline AN-30 and AN-50e, Proxim Tsunami and TeraBridge™, and AirSpan AS-MAX. The chosen design within budget for this installation is a TeraBridge™ 5845 PtP wireless bridge. Local distribution, installation and support are available from OneSource Building Technologies in Sharonville, OH.

Terabeam™ Wireless is a worldwide leader in PtP and PtMP hardware and is a holding company with two primary operating subsidiaries; Proxim Wireless Corporation and Ricochet Networks, Inc. Terabeam™ conducts its wireless hardware business through Proxim Wireless and its wireless service provider business through Ricochet Networks, a Wireless Internet Service Provider (WISP). Their Tsunami MP.16 3.4-3.6GHz point-to-multipoint product is WiMAX Forum Certified™ for service provider networks outside the United States. The 3.5 GHz band is not permitted in the United States at this point. Overall, the TeraBridge™ 5845 is a high performance, cost-effective solution with a reliability rating of up to 99.999 in PtP installations.

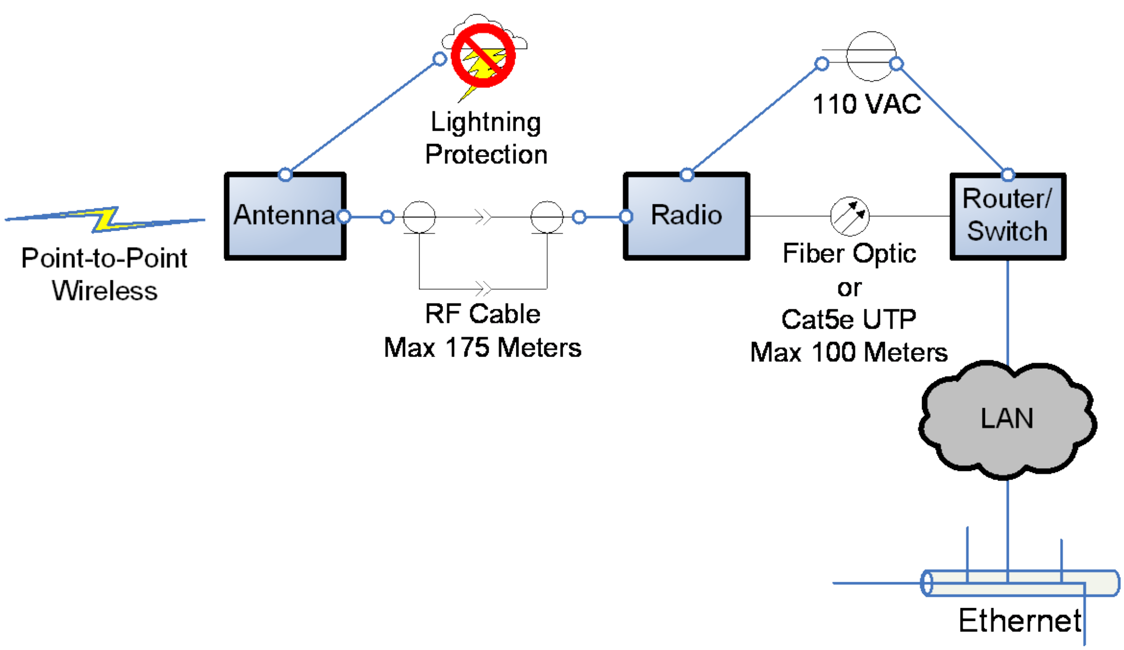

Figure 4. Network Design Layout at Each Campus

2.4. Network Layout

The TeraBridge™ 5845 is an industrial strength weatherproof radio unit that is mounted outdoors near the antenna or indoors at a location within reach of administrators to configure and service. Radios are purchased in like pairs and installed at each end of the PtP network. For this installation, the radios will be mounted indoors where they can be easily reached by administrators for configuration, troubleshooting and service. Various antenna styles are available but must match the frequency range of the attached radio.

The chosen antenna is a 5.8 GHz, 24 inch diameter parabolic antenna from Radio Waves Corporation. The parabolic antenna design provides the greatest reliability in delivering an RF signal between buildings with minimal interference and signal loss. The antennas are mounted outdoors on a rooftop or the side of a building and within 600 feet of the radio which are connected via a low-loss RG-8 type coax cable. Minimizing the length of cable between the antenna and the radio will result in less signal loss. The radio is powered by a 110 VAC to 48 VDC power supply and grounded with a special lightning surge protector kit. The radio has two 10/100 Base-T Ethernet ports for connection back to the LAN. Category 5e or Category 6 Unshielded Twisted Pair (UTP) cabling is connected between the radio's Ethernet ports and the LAN switch/router up to 100 meters away. The ports can both be used for Ethernet data as failover and redundancy to each other, or one can be used for Ethernet data and the other for Simple Network Management Protocol (SNMP), web management or to daisy-chain with another TeraBridge™ 5845 in cascade. Fiber optic cabling can be used to increase this usable distance and eliminate Electro-Magnetic Interference (EMI) inherent to copper cabling. Fiber optic cables also eliminate the possibility of transient voltages from lightning strikes damaging the switch or router. Copper cable can be used to run the distance, and a media transceiver interjected at the switch or router location. Before the radio is connected to the switch/router, the device is configured via the Ethernet or Serial Craft port that launches a Graphical User Interface (GUI) web interface for configuration. This network layout and connection is repeated at each campus. The direction of antennas will be aimed and calibrated toward each other for optimal signal strength. A voltmeter is used on the Receive Signal Level Indicator (RSSI) port to verify signal strength when aligning antennas.

3. Research

The initial surveyed structures for this prototype were Calhoun Residence Hall (CRH) in Clifton and the CAS Admin building. Although CRH offered the greatest opportunities for access to UC's core network and a true LOS of the CAS Admin building, it also had many existing wireless microwave service provider radio antennas on its roof. The high levels of radiation at the roof level posed a threat to individuals with prolonged exposure to the area. Therefore, UC enforced their safety policy on the project prohibiting the use of its building for this particular PtP prototype until further notice. Establishing an alternative location with access to a high speed network to the main campus and LOS to CAS became the next great challenge. (See Figure 5.)

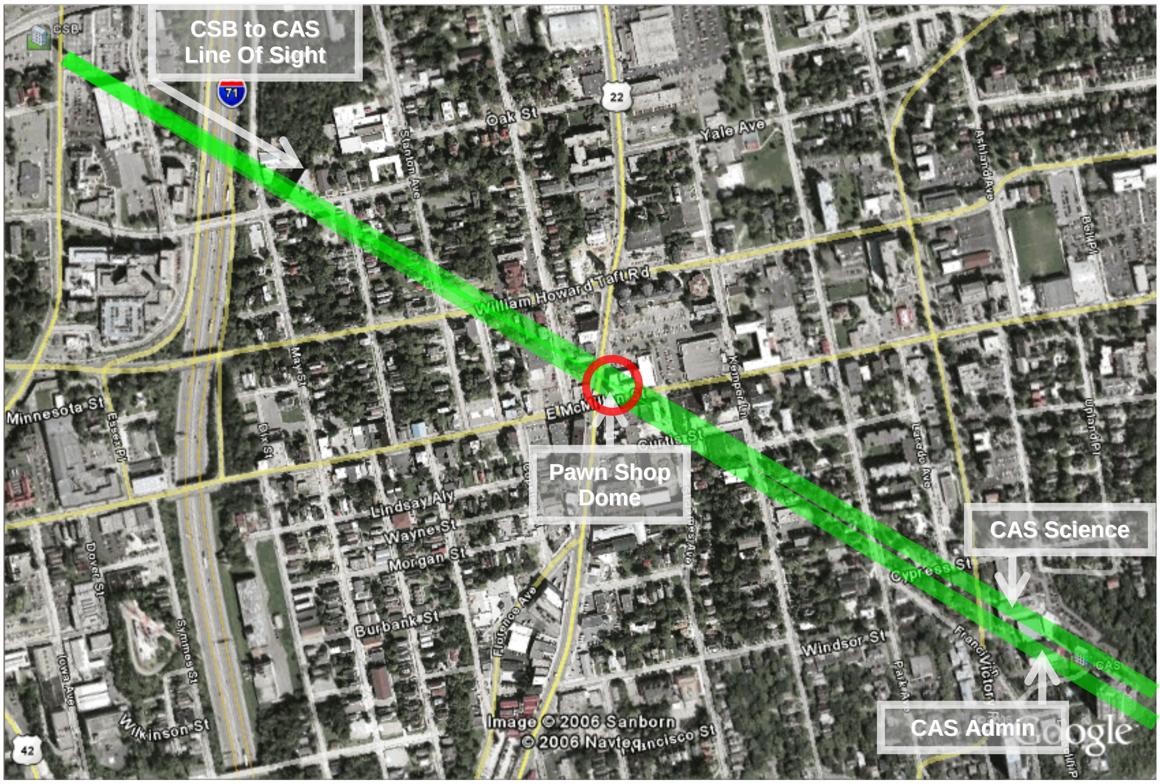

Figure 5. Google Earth Line Of Sight Survey Between Campuses

The following are attempts to establish that connection between CAS and CSB buildings. Image taken from 1 mile away on CSB tower roof looking SouthEast to CAS, 11-balconies are seen on EdgeCliff Point condos behind CAS, lowest is 12th floor from ground level, CAS Admin Penthouse roof surface is level with 11th floor of EdgeCliff Point. A 25G tower of approximately 20-30’ above the roofline of the CAS Admin penthouse roofline is the recommended solution. (See Figure 6.)

Figure 6. Physical Line Of Sight Survey From CSB to CAS

An orange flag and flashing strobe were place on the penthouse roof of the CAS Admin building. (See Figure 7.) From the tower ledge on the CSB roof, we could not see the orange flag or flashing strobe light. We could not confirm nor guaranteed LOS to the CAS Admin or Science buildings. However, an opportunity exposed itself by looking beyond the speculated location of the CAS Admin building and across to the EdgeCliff Point Condominiums complex directly behind it. Eleven condominium balconies from the roof could be seen past the point of obstruction from the CSB roof. From the CAS Admin building, it was clear that the roofline at the 13th balcony from the top of the condominiums, 2 stories short of LOS with CSB.

Figure 7. View from CAS Admin to CSB

Permission was received from EdgeCliff Point Condominium's site manager, Mr. Steiner, to access the 12-14th floor windows for visual and photographic confirmation. LOS was achieved on the 12th floor, and improved even more one floor higher to the 14th floor. There was no 13th floor in the condo building, floors skipped from 12 to 14. (See Figure 8.)

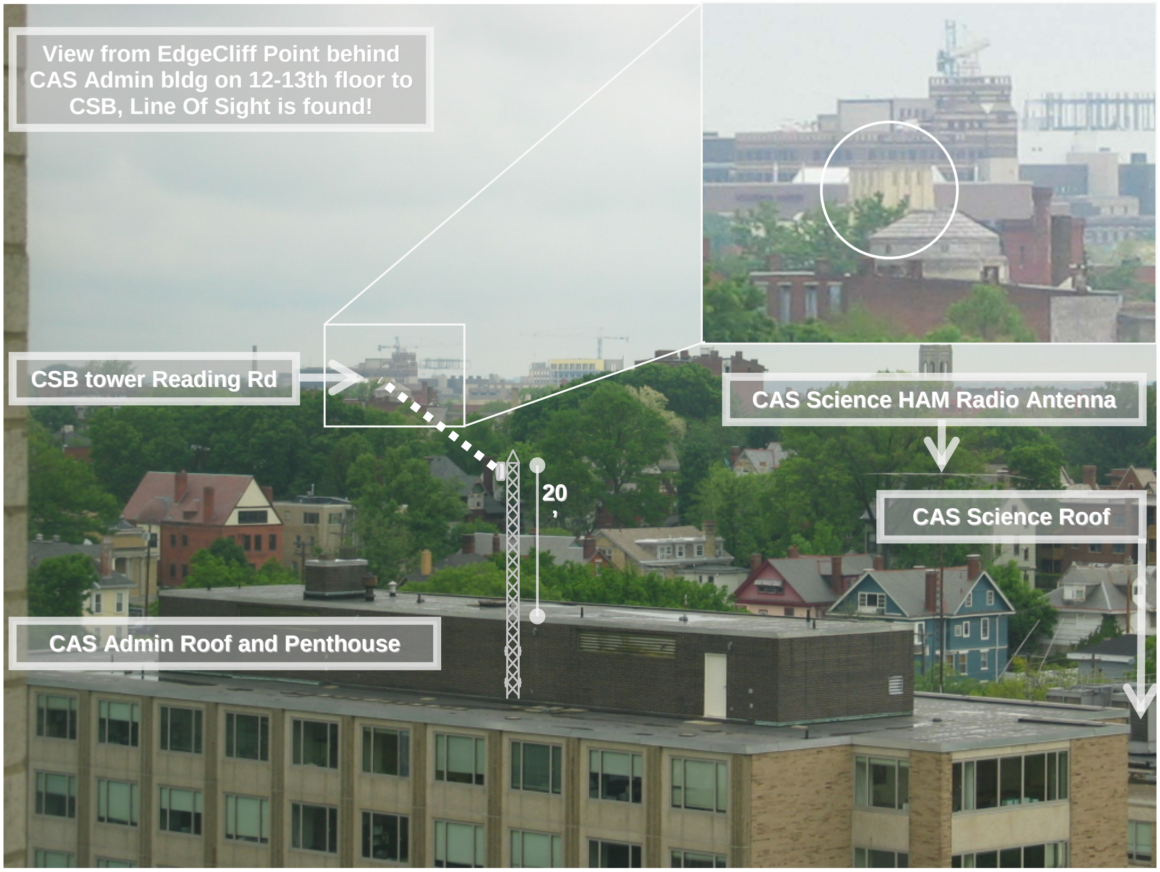

Figure 8. EdgeCliff Point Condos 12th floor, view across CAS Admin to CSB

4. User Interface

4.1. Hardware Interface

The TeraBridge™ 5845 hardware interface consists of several ports on the rear of the radio unit. They are clearly marked for ease during initial configuration via the serial communications port or the UTP Ethernet port. (See Figure 9 and Figure 10.) Once the radio device is on the network, configuration changes can be performed and monitored online via the web Graphical User Interface (GUI).

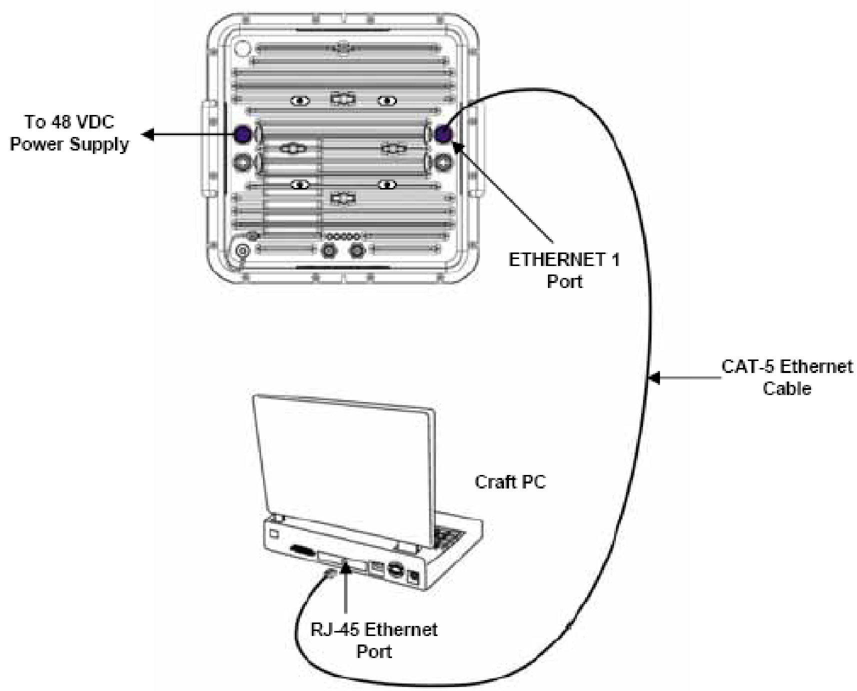

Figure 9. Initial configuration via RJ-45 Ethernet Port

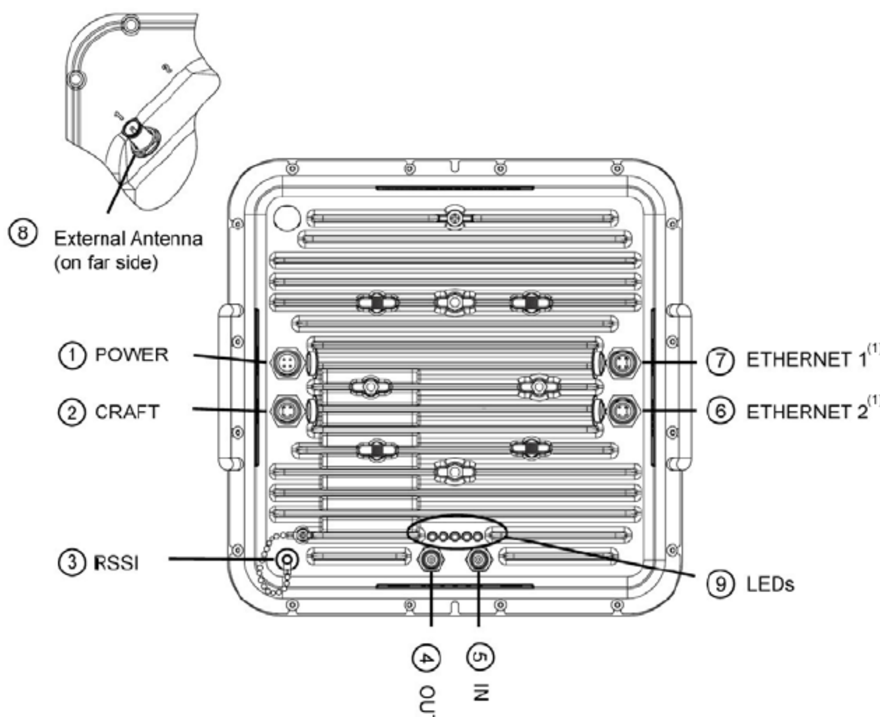

Figure 10. Complete port diagram for TeraBridge 5845

4.2. Software Interface

Prior to purchase, a decision was made to operate in the UNII-ISM 5.8 license-exempt frequency band. The 2.5 licensed and 5.8 license-exempt were the only products available at the time, 2.5 bands can be very expensive to license, especially in a PtMP environment. When the user receives the unit, the final channel(s) within the band are configured via software. The antenna and radio are connected to a network infrastructure that supports DHCP, DNS, and/or Internet Information Server/Service (IIS). The PtP wireless connection behaves like a "wire in the sky" between buildings. Basic configuration includes the IP Address, Subnet Mask and Default Gateway. (See Figure 11.)

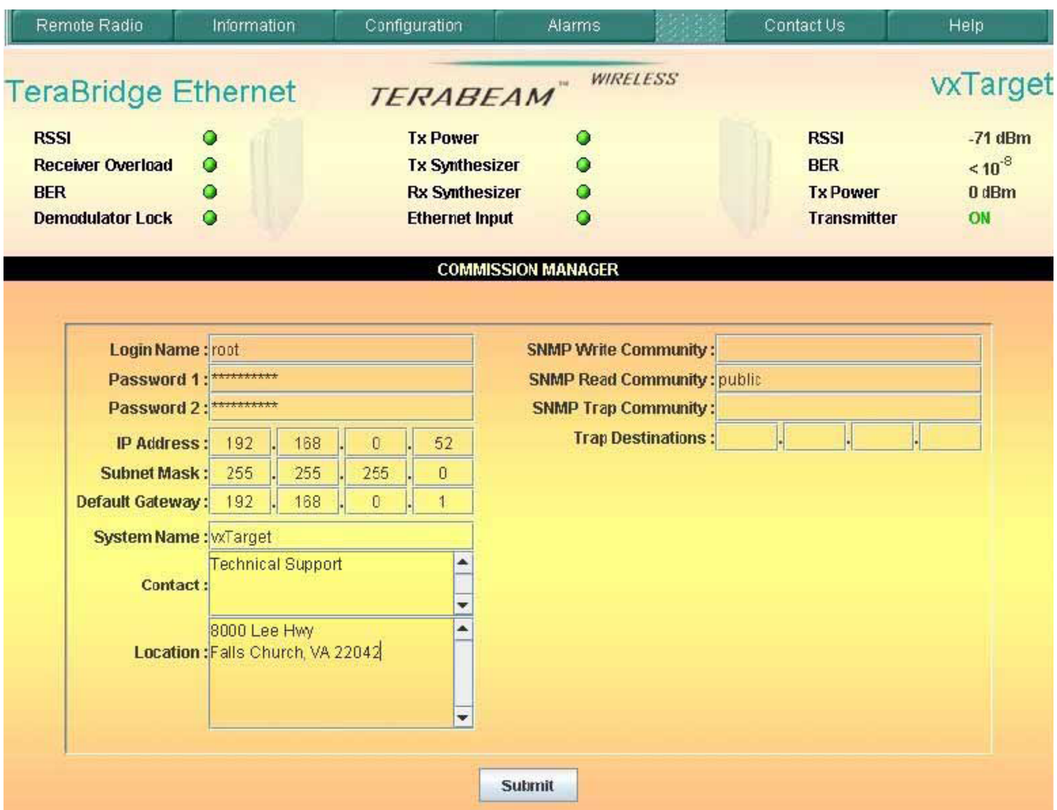

Figure 11. TeraBridge™ 5845 Configuration Screen

4.3. Help

Help is available from the following resources;

- o TeraBridge™ Online Help Menu (See Figure 12.)
- o TeraBridge™ 5845 User Manual, Version 2.0 January 2006
  - TeraBridge_5x45_v2.0_UserManualJan2006.pdf
- o Proxim TeraBeam™ Technical Support – Falls Church, Virginia
  - 1-888-297-9090, 9 AM -6 PM EST
  - http://support.proxim.com
- o OneSource Building Technologies – Sharonville, Ohio
  - 1-888-787-8324, 8:30 AM - 5 PM EST
  - http://www.onesourcebt.com

Figure 12. TeraBridge™ 5845 Help Menu

5. Project Schedule and Budget

5.1. Project Schedule

A detailed Senior Design Microsoft Project schedule can be seen in Figure 13.

ID	Task Name	Duration	Start	Finish
1	**Senior Design Project**	**175 days**	**Wed 9/28/0!**	**Tue 5/30/06**
2	**Assignments SDI**	**40.5 days**	**Thu 10/6/05**	**Thu 12/1/05**
3	Assignment Due: Progress Report 1	4 hrs	Thu 10/6/0	Thu 10/6/0
4	Assignment Due: Area of Inquiry	4 hrs	Thu 10/20/0	Thu 10/20/0
5	Assignment Due: Progress Report 2	4 hrs	Thu 11/3/0	Thu 11/3/0
6	Assignment Due: Draft Proposal	4 hrs	Thu 10/27/0	Thu 10/27/0
7	Assignment Due: Final Proposal	24 hrs	Thu 11/10/0	Mon 11/14/0
8	Assignment Due: Oral Presentation	4 hrs	Thu 12/1/0	Thu 12/1/0
9	**Assignments SDII**	**41.13 days**	**Thu 1/12/06**	**Fri 3/10/0**
10	Assignment Due: Project Description	4 hrs	Thu 1/12/0	Thu 1/12/0
11	Assignment Due: Design Protocols	4 hrs	Thu 1/19/0	Thu 1/19/0
12	Assignment Due: User Interface Design (Sig)	4.5 hrs	Thu 1/26/0	Thu 1/26/0
13	Assignment Due: Project Timeline	4 hrs	Thu 2/2/0	Thu 2/2/0
14	Assignment Due: Project Budget (Sig)	4.5 hrs	Thu 2/9/0	Thu 2/9/0
15	Assignment Due: Project Risk Plan	4 hrs	Thu 2/16/0	Thu 2/16/0
16	Assignment Due: Project Unit Testing	1 day	Thu 2/23/0	Thu 2/23/0
17	Final Presentation (Group 1) (Sig)	1 hr	Thu 3/2/0	Thu 3/2/0
18	Final Presentation (Group 2)	1 hr	Thu 3/9/0	Thu 3/9/0
19	Assignment Due: Final Report (Sig)	1 day	Thu 3/9/0	Fri 3/10/0
20	**Research feasible Senior Design project**	**111.13 days**	**Wed 9/28/0!**	**Thu 3/2/06**
21	Research Senior Design Topics	3 days	Wed 9/28/0	Fri 9/30/0
22	Interview community for broadband needs	3 days	Mon 10/10/0	Wed 10/12/0
23	Research WiFi and WiMAX technologies	3 days	Mon 10/10/0	Wed 10/12/0
24	Research funding	3 days	Tue 11/1/0	Thu 11/3/0
25	Receive funding	1 day	Wed 2/15/0	Wed 2/15/0
26	Meet with advisor, John Nyland	1 hr	Thu 1/12/0	Thu 1/12/0
27	Meet with advisor, John Nyland for signature	1.33 hrs	Thu 1/26/0	Thu 1/26/0
28	Meet with advisor, John Nyland for signature	1.33 hrs	Thu 2/9/0	Thu 2/9/0
29	Submit KSTC ICC Concept Pool Fund Application $25K	1 day	Wed 3/1/0	Wed 3/1/0
30	Meet with advisor, John Nyland for signature	1 hr	Thu 3/2/0	Thu 3/2/0
31	**Implement WiMAX technology**	**175 days**	**Wed 9/28/0!**	**Tue 5/30/06**
32	**Research vendors and technology experts**	**16 days**	**Sun 1/15/0**	**Mon 2/6/06**
33	Interview Aperto Networks	1 day	Mon 1/30/0	Mon 1/30/0
34	Interview Tropos Networks	1 day	Tue 1/31/0	Tue 1/31/0
35	Interview Airspan Networks	1 day	Wed 2/1/0	Wed 2/1/0
36	Interview The Spectrum Firm	1 day	Thu 2/2/0	Thu 2/2/0
37	Research RF spectrum availability	2 days	Sun 1/15/0	Tue 1/17/0
38	RFP to vendors	2 days	Mon 1/23/0	Tue 1/24/0
39	Prepare proposal for funding requirements	2 days	Wed 2/1/0	Thu 2/2/0
40	Meet with Steve Stephens of EZONE to tweak presentat	1 day	Mon 2/6/0	Mon 2/6/0
41	**Presentation to EZONE in Grant County**	**94.5 days**	**Wed 9/28/0!**	**Tue 2/7/06**
42	Burn CDs and Print hardcopies for attendees	4 hrs	Tue 2/7/0	Tue 2/7/0
43	Dan Humpert accompany during presentation	4 hrs	Wed 9/28/0	Wed 9/28/0
44	**Presentation to UCit Department**	**9.5 days**	**Mon 2/6/06**	**Fri 2/17/0**
45	Burn CDs and Print hardcopies for attendees	4 hrs	Thu 2/9/0	Thu 2/9/0
46	Receive offer from client	4 hrs	Fri 2/17/0	Fri 2/17/0
47	Dan Humpert accompany during presentation	4 hrs	Mon 2/6/0	Mon 2/6/0
48	**Conduct RF survey**	**1.5 days**	**Mon 3/20/0**	**Tue 3/21/06**
49	Borrow or lease spectrum analyzer	1 day	Mon 3/20/0	Mon 3/20/0
50	Identify customer base station locations	1 day	Mon 3/20/0	Tue 3/21/0
51	**Choose vendor and technology**	**24 days**	**Mon 3/27/0**	**Thu 4/27/06**
52	**Request final quote for purchase order**	**24 days**	**Mon 3/27/0**	**Thu 4/27/06**
53	Order Equipment via credit card or PO	1 hr	Mon 3/27/0	Mon 3/27/0
54	Receive and Inventory Equipment	1 day	Thu 4/27/0	Thu 4/27/0
55	**Install hardware**	**8 days**	**Fri 4/28/0**	**Tue 5/9/06**
56	**Install base antennae (Location #1)**	**8 days**	**Fri 4/28/0**	**Tue 5/9/06**
57	Locate or install 110V AC	1 day	Fri 4/28/0	Fri 4/28/0
58	Install mast and mount antenna	1 day	Mon 5/1/0	Mon 5/1/0
59	Install 802.16 router	1 day	Tue 5/2/0	Tue 5/2/0
60	Connect coax cabling	1 day	Wed 5/3/0	Wed 5/3/0
61	Connect lightening and surge protection	1 day	Thu 5/4/0	Thu 5/4/0
62	Performance testing	3 days	Fri 5/5/0	Tue 5/9/0
63	**Install base antennae (Location #2)**	**8 days**	**Fri 4/28/0**	**Tue 5/9/06**
64	Locate or install 110V AC	1 day	Fri 4/28/0	Fri 4/28/0
65	Install mast and mount antenna	1 day	Mon 5/1/0	Mon 5/1/0
66	Install 802.16 router	1 day	Tue 5/2/0	Tue 5/2/0
67	Connect coax cabling	1 day	Wed 5/3/0	Wed 5/3/0
68	Connect lightening and surge protection	1 day	Thu 5/4/0	Thu 5/4/0
69	Performance testing	3 days	Fri 5/5/0	Tue 5/9/0
70	**Research continuous improvement**	**7 days**	**Wed 5/10/0**	**Thu 5/18/06**
71	Contingency week for completing late network prototype	7 days	Wed 5/10/0	Thu 5/18/0
72	Complete feasibility study for deployment	7 days	Wed 5/10/0	Thu 5/18/0
73	**Bind Senior Design Project**	**1 day**	**Fri 5/19/0**	**Fri 5/19/0**
74	Print hardcopy and E-mail to appropriate contacts	1 day	Fri 5/19/0	Fri 5/19/0
75	Send to printing company	1 day	Fri 5/19/0	Fri 5/19/0
76	**Prepare for Expo**	**7 days**	**Mon 5/22/0**	**Tue 5/30/06**
77	Take digital still and video images	1 day	Mon 5/22/0	Mon 5/22/0
78	Prepare documentation	1 day	Tue 5/23/0	Tue 5/23/0
79	Print poster size drawings of implementation	1 day	Wed 5/24/0	Wed 5/24/0
80	Print documentation	1 day	Thu 5/25/0	Thu 5/25/0
81	Prepare booth at Expo	1 day	Fri 5/26/0	Fri 5/26/0
82	Install CPE device at Expo	1 day	Mon 5/29/0	Mon 5/29/0
83	Run demo connected to UC or Grant County Network	1 day	Tue 5/30/0	Tue 5/30/0

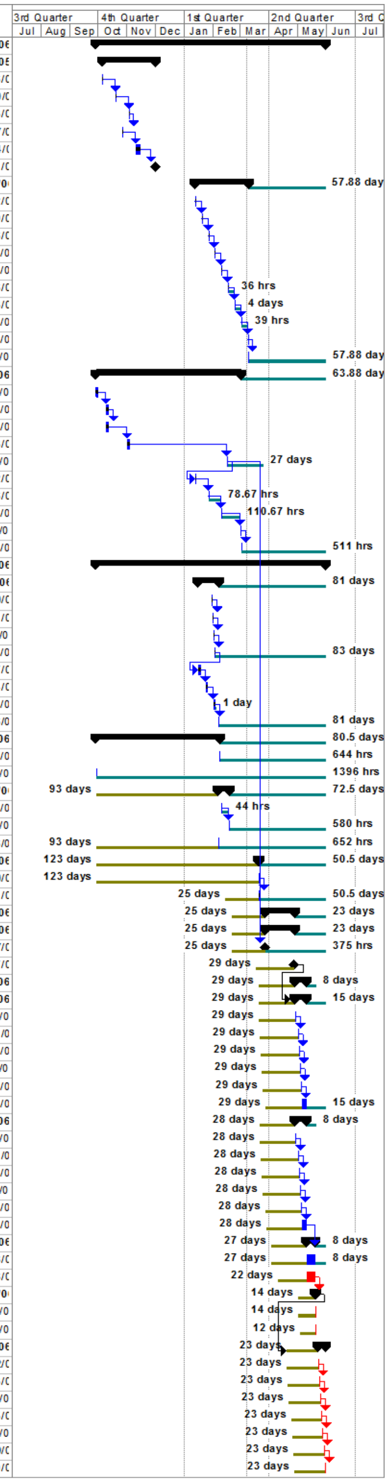

Figure 13. Project Schedule

5.2. Project Budget

The Return On Investment (ROI) can be recognized within the first 6-12 months given the low Total Cost of Ownership (TCO) versus wired alternatives from copper and fiber-optic service providers. The TCO of a broadband link is some cases can be lower than "owning" the copper and fiber-optic network as well. Giga-link wireless solutions with speeds up to 2.5Gbps are available as a feasible option as well. (See Figure 14.)

Item	Product Description	Model	Qty	Price	Total
1	Terabeam Wireless - TeraBridge 5.8GHz ISM 45Mbps Full Duplex Wireless PtP Radios	terabridge5845	1	$7,646.47	$7,646.47
2	RadioWaves 5.8 GHz 2ft Parabolic and Radome Antennas, Cable/Mounting Kits, Lightning Protection Kit	rw58kit	1	$2,557.44	$2,557.44
3	Vendor assisted installation, configuration and link testing	na	1	$2,190.00	$2,190.00
4	UC Student Services	na	1	$0.00	$0.00
5	UCit Staff Services	na	1	$0.00	$0.00
				Total	**$12,393.91**
				Budget	**$15,000.00**
				Remain	**$2,606.09**

Figure 14. Project Budget

6. Project Resources

This proposal was reviewed with Mark Faulkner at the University of Cincinnati on several occasions (2). Professors Dan Humpert and John Nyland have supported and encouraged the research and implementation of the project and have contributed to its success. The university has initiatives to research and deploy wireless technologies that provide value to the University of Cincinnati and surrounding campuses. Funding was approved in early March to move forward with a PtP WiMAX-class prototype between campuses. I have formed several relationships with BWA vendors who are either WiMAX certified or working to develop WiMAX certified hardware, such as Aperto

Networks, Redline Communications, Proxim Wireless (Terabeam Wireless), and OneSource Building Technologies (4).

7. Proof of Concept

Broadband wireless vendors are striving to meet the latest trends in broadband wireless access over great distance by standardizing on 802.16 variations of WiMAX. Pre-WiMAX integrators have been producing proprietary hardware on the premise of 802.16 technologies and have deployed globally. These integrators have provided hundreds of customers with PtP and PtMP products, such as Aperto Networks PacketWave Wireless Bridge. They are able to save these companies large amounts of money by providing the opportunity to "own" their network versus "leasing" their network from service providers (9).

I have coordinated conferences and equipment trials to confirm that the PtP installation I am proposing is a feasible concept. Funding was secured with the University of Cincinnati to move forward with installing phase one of a PtP WiMAX-class installation between campuses during the final Senior Design term.

8. Deliverables

The following deliverables were completed by the assigned project date in May 2006. Completed installation is contingent upon UCit change of scope to instead use the PtP TeraBridge 5845 product for their WiFi-mesh backhaul on main campus. The CAS to CSB PtP installation may not become a reality due to this change of scope, but the feasible solution including research, design and procurement of the prototype model is the finished product of this senior design project as of June 1, 2006.

1. A Point-to-Point Broadband Wireless Connection will be established between UC Main campus and UC OCAS campus approximately 2.5 miles apart
    - Met: Feasible prototype was implemented at ground level and demonstrated to be working as expected. Approvals to install tower, radios and antennas on buildings at UC impeded final installation as well as a change of scope from UC to instead use this configuration as a backhaul to their WiFi-mesh initiatives. UCit has chosen for the meantime to take delivery of this configuration and learn from it in a test lab environment before proceeding with installation
2. Radios and antennas (2.5 GHz licensed or 5.8 GHz license-exempt) will be mounted at each campus and connected to their Local Area Network
    - Met: 5.8 GHz license-exempt UNII-ISM design was chosen
3. A minimum data rate of 18.7 Mbps peak per sector will be achieved for upstream and downstream data, unless the university decides to channel transmission differently during final testing, thus reducing peak rate
    - Met: Actual data rate is 45 Mbps full-duplex or 90 Mbps aggregate
4. All temporary or permanent coax, Ethernet and fiber optic cabling will be installed according to manufacturer specifications and university guidelines
    - Met: Temporary ground level installation was performed and demonstrated
5. The wireless connection will be secure and reliable according to manufacturer claims
    - Met: All claims and warranties from the manufacturer seemed valid

6. Enhancements to the original prototype design will be recorded for reference and financed by future projects
    - Met: Enhancements would include additional links between campuses, higher throughput rates from different available radios and experimenting with this PtP design as a backhaul solution to WiFi-mesh initiatives on main campus
7. Assuming all outstanding invoices are paid in full by the university, all hardware, support documentation, and warranties will be provided to the university upon closing of the project in May
    - Met: Hardware, receipts and documentation are available to UCit for pickup or delivery from OneSource Building Technologies

Complete documentation of the system is a project deliverable and is considered published in the form of this Senior Design submission with attached presentations and research documents on CD. University of Cincinnati IT staff will assume ownership of the product design and involvement with its installation, configuration, and testing from this point forward.

9. Milestones

1. February 7 – Meetings begin with UCit for PtP project and financial sponsorship
2. March 8 – Received financial sponsorship UCit
3. March 14 – Site Survey Calhoun, CSB and CAS
4. April 25 – TeraBridge Hardware arrives at OneSource Building Technologies

5. April 28 – Setup, configure and test PtP hardware on ground level at OneSource Building Technologies
6. May 15 – Line-Of-Sight established between CSB and CAS Campuses, submit proposal for feasibility
7. May 19 – Tech Expo, Best of Networking, Best of IT
8. June 1 – Present final Senior Design presentation

10. Conclusion

This is the first WiMAX-class PtP deployment of its kind at the University of Cincinnati. When fully implemented, the college will own and operate a reliable broadband Wireless Wide Area Network (WWAN) and experience a ROI within 6-12 months due to the low TCO of the system. The potential exists to convert or supplement all wired lease lines with wireless for voice-data requirements. Many UC campuses could be connected via WiFi-mesh and WiMAX PtP and PtMP solutions. Recommendations are to continue vendor relationship with OneSource Building Technologies and stay current with "WiMAX-certified" product developments that are on the horizon for late 2006 and beyond.

See attached CD for all Senior Design presentations and documentation related to the UC Point-to-Point installation and Northern Kentucky Municipal Point-to-MultiPoint research.

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15. Attached CD ROM with complete WiMAX project research and presentations

Appendix A

TERABEAM WIRELESS TeraBridge 5x45 User Manual, rev 2, January 2006