Preliminary Budgetary Estimates for Gustavus, AK.

Vivato (rjc) 2/12/05

Prepared for

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Introduction

The town of Gustavus has built and now operates a wired (DSL) and wireless network to link the high-speed connection located at the Library to homes and businesses. The Gustavus Community Network (GCN) is a municipal Internet Service Provider owned and operated by the City of Gustavus. See: http://gustavus.ak.us/Network/index.htm

The dense forestation and lack of convenient high altitude locations, for deployment of broadband radio equipment, has impeded the build out of the GCN. See: http://gustavus.ak.us/Network/broadband/OtherBroadband.htm

The following budgetary design is presented for review and comment. A final design will result from more detailed investigation covering the deployment area, client applications and expected usage profile. Final site selection and coverage estimates require site visits and negotiation with lease holders.

Scalable, Open Platform

A major benefit to the Vivato Wi-Fi system is that it can easily integrate into existing networks, either wired or wireless. All Vivato smart antennae use standardized 802.11, 10/100 Ethernet and TCP/IP protocols and can communicated easily to other standardized network equipment. This allows fast and inexpensive setup and avoids having to use proprietary equipment and software. These smart antennae also communicate to any standard 802.11 PDA, laptop, VoIP handset or handheld client device. Any off-the-shelf Wi-Fi device is able to communicate to the wireless network without modification or specialized software.

The Vivato Wi-Fi system can grow and expand on an as-needed basis. The design and architecture allows for single or multiple antennae to be added when extra bandwidth or coverage is required. This pay-as-you-grow system design minimizes capital investment and allows the network to scale with user demand.

Wireless LAN Components

As shown in Figure 1, the network consists of wireless equipment added to a standard data communications network. Typical Wi-Fi equipment is limited to a range of 50 to 100 meters between standard access points (MicroCells) using omni-directional antennas and laptop clients in an open environment. This range amounts to a circular coverage area of approximately one hundredth of a square mile. High-gain omni antennas can be added to increase range and coverage — at the expense of lower throughput due to increased levels of received interference [1]. A high-gain sectored antenna (typically 90° or 120°) can be used to spatially reduce the effect of interference, but this configuration suffers from decreased coverage area due to the smaller field of the simple sector antennae in addition to an increased level of noise and interference.

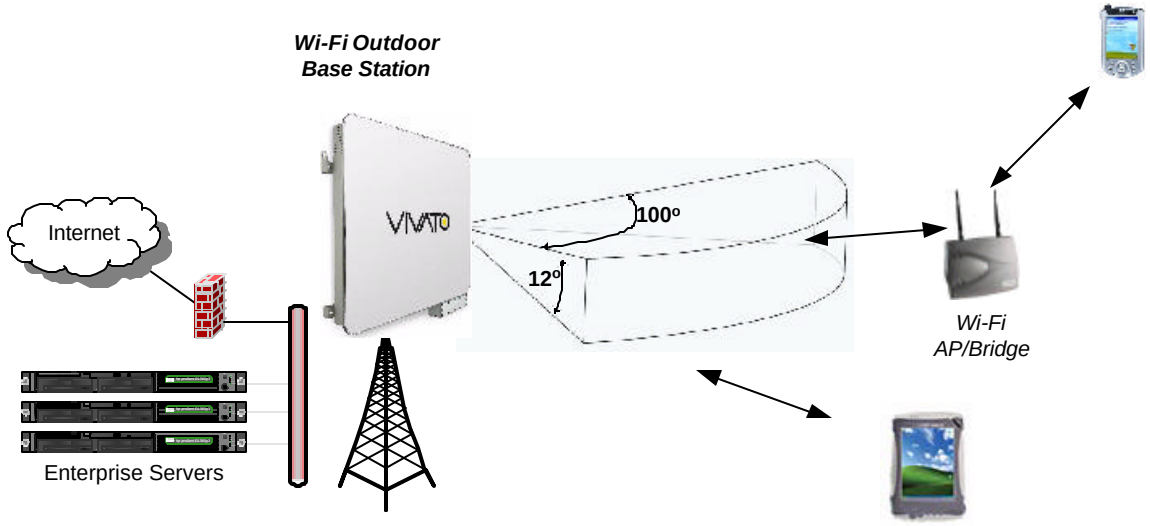

Figure 1. Long Range High Coverage Wi-Fi

Vivato phased array Wi-Fi base stations combine the long range and interference rejection of a high-gain narrow beam antenna and the coverage advantage of wide field-of-view sector antenna by electronically synthesizing many individually pointed, high-gain antenna beams. As a result, a single base station mounted on a 30-meter tower, or building rooftop, can cover an area of nominally 1.2 square miles (in a 100 degree pie shaped area) for outdoor hand held Wi-Fi clients. Unlike conventional Wi-Fi equipment, multiple base stations can be located on the same mast to increase this coverage. Under these LOS (Line of Sight) conditions this is a coverage area of 4.9 square miles per site. The expanded coverage capability from a single location greatly reduces both the time to deploy, initial capital cost and the operating cost of the wireless network.

This increased coverage is achieved through the use of a sophisticated high gain phased array antenna. The increased coverage does not require the use of high power high cost client equipment. Client portability is supported since there is no need to be tethered to a wall socket for power or use a large client antenna. Additional range can be achieved with the use of a client antenna (17 mile ranges have been deployed in rural areas).

Vivato is unique in that it has been granted the authorization to use point to point transmit power rules by the FCC. The proprietary Vivato phased array base station transmits a packet of data to the end user through the use of a narrow 6 degree wide antenna pattern. Very little energy is transmitted in the remaining 354 degrees of coverage area. Assuming a typical client transmit power of .1W the ability to use the FCC point to point rules allows a balanced Effective

Transmit Power (EIRP) of 25W for Vivato phased array base stations. This is 40 times greater than the balanced EIRP of a standard microcell of .6W. Standard microcells must comply with FCC point to multi-point rules.

The 2.4GHz band is shared with other users of the band that include other WiFi users, cordless phones and other data systems. Vivato base stations are very efficient users of this spectrum. Data is transmitted in a narrow beam making the other 354 degrees of coverage area available to other users while a packet is being transmitted in the 6 degree beam pointed at the customer. At the same time the interference caused by users in those 354 degrees of coverage is rejected by the antenna pattern and therefore has little impact on coverage or capacity. In contrast a standard microcell (access point) using an omni directional antenna sends a signal in all directions even if the intended user is directly north of the micro-cell. At the same time other users who may be south of the site could interfere since they typically would not be able to "hear" the users north of the site and would think the channel is clear and available for use.

Vivato Wi-Fi microcells / bridges (high performance outdoor APs) can be added where needed to provide additional connectivity to clients that are out of direct range due to distance, shadow fading, or building wall attenuation. While the omni directional coverage of the Vivato microcell is the same as any other high performance outdoor AP Vivato microcells are unique in several ways:

- Each microcell can be configured and is FCC certified for the use of high-gain directional antennae to increase the range of both the Mesh backhaul links and links to client devices.
- Each Vivato microcell utilizes two independent WiFi radios allowing complete flexibility in the choice of RF channel to maximize capacity or avoid interference.
- All Vivato outdoor products are engineered and tested for use in severe outdoor environments. This includes the use of heating, engineered cooling and certified NEMA4X enclosures.

The network designer will typically add a few microcells to a network to address specific coverage or capacity issues. This reduces the total number of wireless devices and associated management and maintenance needed for full coverage.

This Base Station / Micro-Cell network configuration has the advantage of limiting the number of wireless backhaul links which introduce unwanted latency and jitter and adversely affect applications such as wireless VoIP. Limiting the use of mesh deployment (dynamic site to site back haul) increases the network capacity available to customers maximizing the number of customers that can be supported by each base station. The Vivato Micro-Cell product uses two Wi-FI radios, so the backhaul and service can use different channels. These design concepts in conjunction with the Vivato smart antenna's ability to reject interference allow the deployment of high quality robust wireless systems that successfully operate with other users in the band.

Vivato Base Station and Micro-cell Coverage

Increased coverage due to the use of Vivato Wi-Fi Base Stations (VP2210) can drastically reduce the overall equipment needed. This "mesh where you need it" combination of extended range Base Stations and Vivato Micro-cells (VA2210) keeps the complexity low, while providing the largest and most efficient wireless coverage at the lowest net cost. This budgetary design does not define micro-cell locations. Micro-cell locations are typically chosen after initial deployment to mitigate coverage holes, extend coverage and provide in building coverage. Since the enhanced coverage range is achieved through the use of the high gain Vivato base

station antenna standard power client devices are supported in these long range applications with no modifications.

The chart below illustrates the coverage to a standard client device under various conditions from a base station elevation of 130 feet including 15dB of loss due to trees and 15db of gain due to the use of a high gain client antenna.

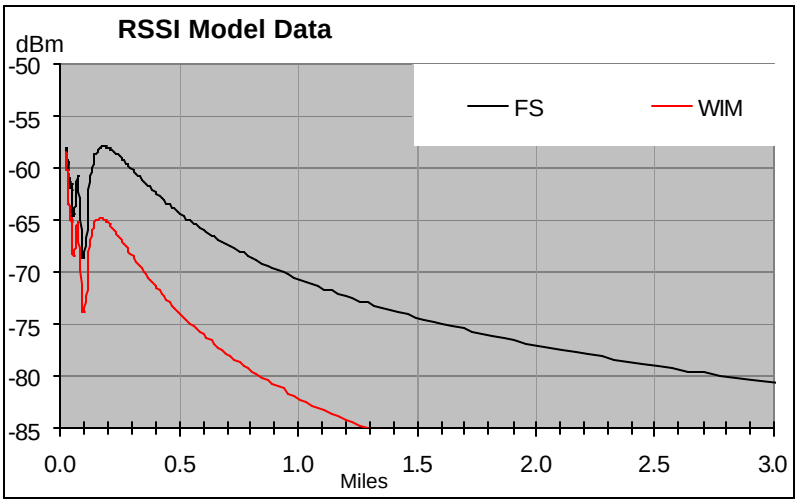

Figure 2. Base Station coverage using a 100 foot site.

Figure 2 illustrates the likely coverage radius from a 130 foot site. For this estimate a client device with a 15dBi gain antenna and a .1W transmit power is assumed. A 7dB link margin is included to compensate for the negative effects of movement and reflections. An additional 15dB of loss is added to compensate for the high level of tree coverage in the area. For simplicity we will consider only coverage at the 11Mbps channel rate at -85dBm. The dips in coverage close to the site are caused by the antenna pattern and are typically not measurable in a real deployment due to reflections and scattering. Several different conditions are shown:

FS	Free space is the coverage likely to a user who can see the site and is located on the third floor (or above) behind plain, clear glass or on a roof top.
LOS	Line of Sight estimates a user who can see the site who is located near the ground.
WIM-LOS	Walfisch-Ikegami-LOS estimates a user near the ground along a street with buildings on both sides.
WIM	The Walfisch-Ikegami urban model estimates coverage on the street, in an average sense, where the user can not see the site (NLOS).

Coverage from this 130 foot site can range from 1.3 to over 3 miles depending on the location of the user. These ranges have been demonstrated in various Vivato deployments.

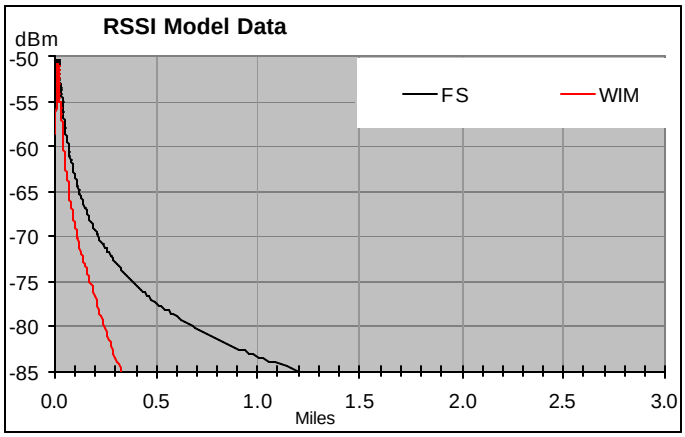

Figure 3. Micro-cell coverage using a 40 foot site.

A Vivato micro-cell is nominally the same as any other omni directional access point on a pole top. Typical coverage is shown in figure 3. Coverage from this 40 foot site can range from .3 to 1.2 miles depending on the location of the user. Using a short site height the number of customers who have either FS or LOS situations is very small due to blockage from buildings, vehicles, trees and other ground clutter.

A Vivato micro-cell utilizes two independent 2.4GHz radios. Typically the back haul frequency and radio is different than the radio and channel used to provide a connection to the local area. This flexibility is important because it allows the use of the cleanest channel for back haul and moves the local traffic to a separate channel so capacity is not reduced by sharing the back haul and local service channel.

For the most economical deployment fixed location customers should use indoor mount (best high window or wall) CPE with a nominal gain of 10dBi (this is a 10 inch square by 1 inch thick antenna). In most cases poor coverage can be corrected by moving the antennae to the rooftop where a 15dBi gain antenna is assumed for this analysis. Vehicles are assumed to have roof mount dual or horizontal polarization antennae.

A final design requires site visits, initial lease negotiations and a review of local zoning regulations. Assuming that the identified sites are available the following design rules could be used.

The actual coverage will depend on the location of specific buildings, building construction, location of trees, existing activity in the 2.4GHz band, antennae height, etc. For these locations the ambient noise and 2.4GHz traffic is assumed to be minimal. Only buildings and tree cover should limit coverage.

In Building Coverage

Many buildings in the coverage area (typically within .3 miles for base stations and within .06 miles for microcells) will have sufficient inside coverage to support in building wireless data. In those cases where wireless coverage is desired but not available, the Vivato micro-cell can be used to extend coverage into the building or a client antenna may be used.

The Gustavus Coverage Area

Below is an aerial photo of the central Salmon River Coverage goal. Coverage would be provided from the proposed tower location indicated by the Star. If wired back haul is not available unlicensed 5.8GHz can be used from the Library, shown in figure 5, to the tower.

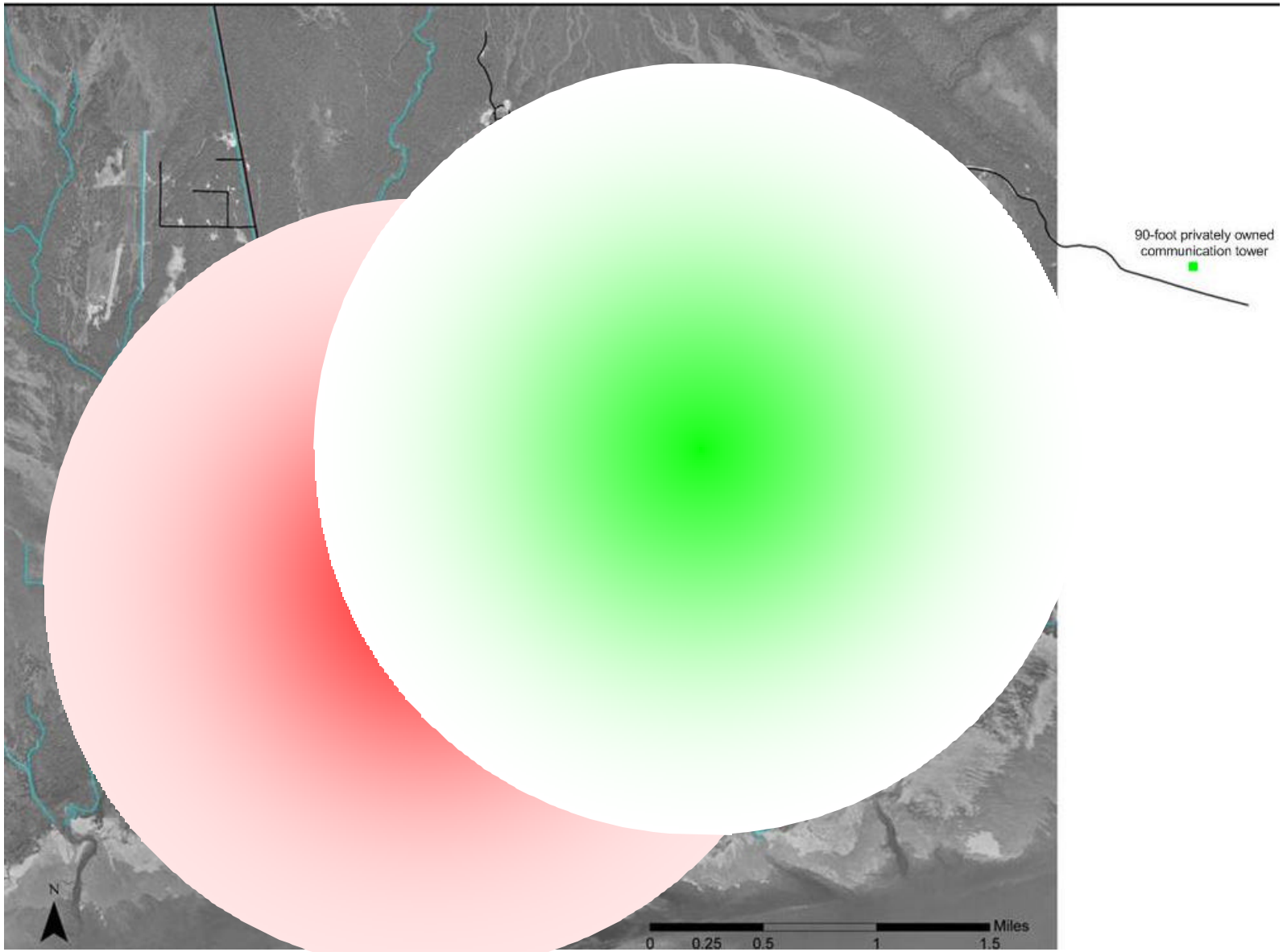

Figure 4. Central Gustavus.

The wide area map below shows the likely coverage for the Park Rd area from a single Vivato panel located on a short structure on the ridge above Park Rd.

Figure 5. Wide area Gustavus.

The Salmon River tower site would mount four base stations providing coverage to most of Gustavos. At greater distances from the tower the signal will be weaker and coverage could be more easily blocked by trees. Some remote locations may require the use of a high location (above the tree level) for the client device.

An additional 4 panels can be mounted on the 125' FM tower to provide coverage to the airport and areas to the east. A site survey is needed to accurately determine the extent of tree cover and the location of likely customers in order to determine the least cost solution that can provide the needed coverage.

The Vivato design philosophy is to optimally utilize base stations, micro-cells and meshing to optimally (in terms of both performance and cost) build a wide area wireless network.

The number of Micro-cells required to fill in the coverage in all areas is an estimate based on the number and coverage provided by the Base Stations, and the desired coverage area. The exact number and locations of the Micro-cells would be determined following placement of the Base Stations and on-street coverage testing.

Vivato System Design

Designs with Vivato products maximize the use of tall sites with Vivato panels that have coverage defined by FCC point to point rules. Low sites (micro-cells) with omni directional antennae are used to fill in coverage holes and to extent coverage into buildings and areas with no tall sites. In this case tall simply means taller than the surrounding buildings. This has proven to be the least cost method of providing WiFi coverage.

The micro-cell radius is limited by FCC point to multi-point rules. In this urban area each site will have an average radius of roughly .15 miles. The deployed coverage will tend towards a star shape with each arm at about .3 miles along streets and the body at roughly .06 miles across

centered on the micro-cell location, usually along a city street. This is the same radius and design concept used for Vivato micro-cells.

Vivato minimizes the use of micro-cells in order to maximize the performance of the system. As the number of micro-cells increases the trend is to have more RF back haul hops which results in increased jitter to the end sites, decreased average throughput per site, and an increased hand off rate for mobile devices.

Jitter. Delay and frame error rate increase in proportion to the number of wireless hops in the link. A typical incremental delay per hop (assuming no retransmission) is roughly 2ms. Jitter and frame error rate are variable and depends on site load and retransmission rate. The parameters can range from negligible at light load to over 10% errors and 2ms jitter for heavy loads.

Throughput. Throughput for mesh systems decreases at roughly 1/ (number of hops)^2. Where each site is equally loaded. One hop reduces capacity by 2, 2 hops reduce capacity by 4, etc. Some mesh systems use out of band backhaul at 5.8GHz. These systems tend to have greater available bandwidth with the constraints being the bandwidth available in the 5.8GHz band and the ability to reach the next cell in the mesh at 5.8GHz which typically has a smaller coverage radius than signals in the 2.4GHz band.

Interference. Interference can be minimized if the best channel can be selected as in a Vivato micro-cell. If the system requires the use of only one channel there may be locations with poor performance due to interference.

Hand off. As the size of a cell decreases, users who move through the network will experience more hand offs (a transfer from one site to the next). At higher speeds or smaller cell sizes, the hand off rate may exceed the ability of the system to track the user and process the handoff.

Capacity

All clients and network equipment use the 802.11b or 802.11g standard. This standard supports channel rates through 54Mbps. At ranges in excess of .3 miles most uses with be using the 11Mbps 802.11b rate since the signal strength will be to low to support the 802.11g rates. The close in users will be able to use the higher g rates. The nominal throughput per RF channel (there are 3 channels) is a function of the location of the customers and the quality of the customer RF equipment. Given that most customers use good quality equipment the Vivato Base Station will be able to deliver in excess of 5Mbps to the service area per base station. Vivato micro-cell typically use one hop to the wired connection so peak micro-cell capacity is half that of a base station.

Based on field testing and the current typical Internet usage profile (Nielsen) each Base Station can support a busy hour load of greater than 100 typical browsing internet users. Typically less than 20% of the customer base is active in the busy hour. Therefore a single Base Station can support over 500 customers in the service area or 2000 customers for a four base station site. Specific user experience, customer load and performance will depend on the user equipment, site loading and user application. These are generic estimates from field data; specific usage can vary.

Site Equipment

There are many potential site configurations. Wired or wireless back haul, one, two, three or four Base Stations, battery backup, etc. Rather than defining each specific application it is beneficial to review the generic site diagram as shown in Figure 7.

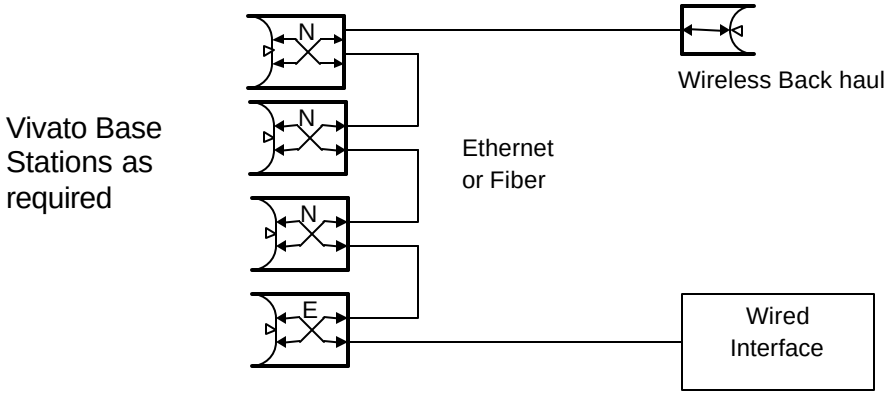

Figure 6. Typical site equipment.

This diagram shows a four Base Station site with wireless back haul (to other sites) and wired back haul to the aggregation point. All equipment is self contained and ruggedized. There is no equipment specific need for protected space. Specific deployment conditions may require additional shielding between Base Stations.

The aggregation point can be some local office or an equipment cabinet that supports the interface to the local ISP or back haul facilities. The specifics of this equipment are dependent on the operator's network design, control and operational specifications.

CPE (Customer Premises Equipment)

Most locations with an LOS (Line Of Sight) path to a site at distances of less than .3 miles will have usable coverage with standard hand held equipment. Locations that are more than .3 miles away and not in LOS may require CPE. CPE is typically customer self-installed at some optimum window or wall. Typically this would consist of standard off the shelf equipment. Typically a small (10dBi) flat panel antenna is used with a wireless bridge that interfaces with the in home Ethernet network. If desired a second access point may be used to provide wireless coverage within the customer premises. Much greater coverage is possible if outdoor mount or second floor CPE is used.

Typical equipment is shown for an indoor mount CPE device. This unit (from Demarc) includes a 15dBi gain antenna, power over Ethernet (POE) and several other features to help improve customer satisfaction and performance. Often this equipment is customer self installed in a second story window or (if required) outdoors on the roof top of chimney.

The use of this type of customer device dramatically improves range and performance which reduce the cost of deployment. The coverage chart below illustrates the ranges that are possible with the use of a high gain antenna at the customer site.

The use of high gain customer equipment greatly reduces the cost of initial installation. As the system grows and more customers are served by each site it may be necessary to "cell split" and add new sites to increase the capacity of the system. As this occurs more customers will be closer to each site and lower gain antenna can be used.

References

[1] Vivato Technical White Paper, “Metropolitan Wireless LAN/Man Deployment”. June 2004, (www.vivato.com/metro/download/MetroWirelessLAN.pdf)

About Vivato - Vivato delivers a complete family of innovative Wi-Fi infrastructure products, featuring Wi-Fi Base Stations, both indoor and outdoor. Vivato's base stations are packaged as a single integrated unit, including the planar phased array antenna and all of the electronics needed to run the Base Station. Simply supply Ethernet and power, and the Base Station delivers beams of Wi-Fi to a large area. For more information please visit www.vivato.com.

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