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COST EFFECTIVE WIRELESS COMMUNITY NETWORKS AND INTERNET CONNECTIVITY IN REMOTE AND RURAL AREAS IN ZIMBABWE

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Abstract

The hype regarding the Internet has been difficult to keep pace with, since the World Wide Web's (WWW) graphical introduction to the world in 1994, in almost all developed and a few developing countries. The purpose of this paper is to examine ways in which Internet connectivity can be achieved with minimal cost and accessibility in unreachable remote rural areas in developing countries, especially Zimbabwe. Shared wireless networking can play an important role in minimizing connectivity, setting up and ongoing costs of network connectivity while maximizing its potential benefits. This paper guides and offers a beginners look at wireless connectivity in the context of community networking. It also provides basic information to local community leaders about computer networking in general.

Introduction

For many people, the need to know about computers and computer networks has come about very quickly. At this point, Community Networking has received little attention in Zimbabwe and developing countries at large. Using wireless connectivity to develop base level networking has received even less. Few private consultants are discussing wireless Internet connectivity infrastructure and even fewer are aware of the availability of wireless networking. Representatives of local exchange companies (local telephone companies) are naturally in the business of selling wired phone and data services, and so they are unlikely to discuss wireless networking options.

Legislation has been passed in most countries to provide for great savings on high-speed data circuits for state universities, colleges; public schools, libraries and telemedicine centers. For example in USA, Texas, in 1996, legislation was passed creating a "universal service fund" to assist rural (K. Joon Oh)[1], impoverished school districts and libraries defray the cost of connecting to the Internet. Networking remote equipment so it can be monitored and managed at a distance has been extremely difficult, due to cost and infrastructure limitations. Intelligent wireless gateway hardware and management software, combined with improvements in wireless data networking technology, lower airtime prices and expanded coverage are making reliable, cost-effective remote device management a reality [2].

As Matthew Gast [3] advises from a technical perspective, deploying a wireless LAN is a considerable undertaking that requires significant planning and not simply a matter of identifying user locations and connecting them to the backbone. Wireless networks require far more deployment planning because of the nature of the radio link to cater for unexpected interference from each connected environment. This paper seeks to instill ideas for existing opportunities for establishing Internet connectivity to remote areas and work a basis for establishing a planning platform to community leaders and other responsible authorities.

With the wide and massive awareness campaigns that swept the whole globe about the Y2K compliance, Zimbabwe was not left out. The government, since year 2000, embarked on campaigns and donations of computers targeted at state universities, polytechnics and teachers colleges, training centers and government schools (Sunday Mail Zimbabwe September 2007)[4]. The vision behind this was information resources availability to all students and pupils, poor as well as rich, communication to points around the world and Internet connectivity throughout the country.

However Rogers (2000)[5] has noted that the Internet has mainly diffused in urban areas among the comparatively wealthy and educated. He noted that much of the infrastructure needed for the rapid diffusion of the Internet is not found in the rural areas. Many villages in Zimbabwe do not have central electricity or telephone service and no one in these rural areas can afford to own a computer. Although the government is trying its best by donating computers even to rural schools in Zimbabwe but as Moffett (1997)[6] found that an inadequate telecommunication infrastructure is a major obstacle in the way of Internet development in Central Asia, it is the same situation in Zimbabwe. There are not enough telephone lines in all provinces across the country. Insufficient links with educational, health and other institutions especially in the rural areas also impede the Internet diffusion in Zimbabwe. This challenge can be explained under two scenarios:

i. Urban community

In urban schools, colleges, universities and training centers, the current position is that one can connect to the internet through TelOne (a government parastatal that provides telecommunication services) leased lines (T -I) or dial-up connections. However the question that remains is, are there such connections of T-I lines to every organization? If the T-I lines are not available, is there capital to buy and install the physical equipment for the infrastructure to complete connectivity?

ii. Remote and Rural communities

This becomes a bigger challenge to the government and policy makers as a whole because these places are unreachable/inaccessible and have no infrastructure for Internet connectivity at all.

In both cases, more personnel with technical expertise will be required to maintain equipment and software, either as paid staff or contracted services. More and more frequent technical training for staff will be required. The recent exodus of technical experts in search of economic refuge to other countries worsens this need. Equipment, which in many cases is acquired through grants and donations, must be repaired and eventually replaced. All this technological advancement comes at a time when taxpayers are becoming more and more reluctant to increase their tax burdens. With costs rising, and sources of funding becoming more constrained, how will the fine line of providing access to the best technology to all Zimbabweans be achieved without creating fiscal chaos in other areas of the country's budgets? Armed with basic understanding of shared computer networks, leaders can make adequate budgetary preparations and determine the direction of future network growth.

Linking remote communities to the so-called communications highway by landline or by any of the available fixed-line systems is simply expensive and financially not viable, Tech-ware (2007) [7]. The paper looks at shared wireless networking as a cost effective solution for Internet connectivity in remote rural Zimbabwe. Tech-ware (2007)[7] argues Long-Range Wireless LAN as a cost-effective solution for rural Internet access. Sprayberry [2], points out that high-speed wireless WAN gateways can provide a cost effective alternative to landline data connections by utilizing the GSM network. With three mobile telephone operators in Zimbabwe (NetOne, Econet and Telecel) with existing networks, providing coverage in most remote areas in the country, wireless networking is a cost effective option to provide Internet connectivity in remote rural Zimbabwe.

The Need for Community Networks

Computers have become part of the normal office landscape over the past fifteen years. Many office functions have been converted from paper to electronic form. Centralized databases have been created. Computer networks have been developed so that users at one computer can store and retrieve data on another computer in a centralized area. This centrally stored data can be shared among multiple computer users resulting in less staff required for routine clerical tasks. However more knowledge is required of existing staff, knowledge of basic computer operation, word processing, and spreadsheet software resulting also, more staff or contracted assistance being required to maintain these computers and networks.

As one looks at the balance sheets showing increasing expenditures for computers, networks, and Internet connectivity, one might wonder whether all of this technology is really beneficial. What benefits are provided? Table 1 below lists some of the present and future benefits computer technology provides to the two most common information-related entities in a community: the public schools and the public library. Current budget levels are not adequately enough to support all the technology we currently use. So how can we minimize increasing costs and maximize the effectiveness of revenues already collected from the community and other state and federal sources?

Table 1. Benefits of Computer and Network Technology

In schools, computers and computer networks:

▪ Provide a means of educating students in computer use (office skills and technical support) for future workforce development
▪ Support a computer science curriculum
▪ Provide effective access to electronic materials
▪ Support instruction with drill and practice and role-playing exercises
▪ Facilitate student record management
▪ Facilitate communication among teachers, administrators, and school staff
▪ Provide a means of professional communication among colleagues
▪ May reduce clerical tasks (for teachers and administrative staff)
▪ May facilitate communication between the school and the community
▪ May provide a means of extending the classroom to remote areas, such as the home
In public and computer libraries
▪ Provide control over materials (automated library system), including over dues, inventory, and collection development
▪ Provide effective access to electronic reference materials
▪ Provide access to a wide variety of information resources over the Internet
▪ May reduce clerical tasks
▪ May provide access to computer services for those without computers at home
▪ May provide a means of extending information services to remote areas, such as the home

In the past, municipal, district, and state governments have functioned independently-most of their functions were carried out without regard to the functions of other entities.

As we use technology more often to enhance and expand our governmental services and operations, however, one of the primary answers to the rising cost of providing technologically- based services lies in finding common needs for infrastructure and sharing as many as possible. So, as we think of connecting the public agencies in our communities to the Internet, why would we think of building separate "roads" to the Internet for each agency? Yet, that is our current mode of operation. City offices, for administrative, police, and other operations, get one connection. District offices get another connection. The public school district gets another. And the public library gets a fourth. Some larger communities also have state-supported colleges or universities which also have an additional connection.

The Need for Sharing

Organizations like city and district governments, school districts, and colleges have similar problems. It's difficult to think of sharing our stuff with other agencies, mainly because the constituencies are so different. All these agencies are generally supported by local and state tax dollars. As stewards of public funds, we should all make a concerted effort to minimize the cost and maximize the potential use of technology in our organizations-especially when one considers the fact that none of us has enough funding to do everything we need or would like to do anyway.

Developing a shared network infrastructure among all public entities is a reasonable joint venture. A shared infrastructure makes possible the sharing of services as well. For example, where informational databases are required-in public libraries, school libraries, and college/university libraries-some database subscriptions would be of interest to all entities. Rather than subscribe to them separately, a joint subscription could be purchased. Remote access to the databases could be provided to city and district government offices as part of the process. The cost of such subscriptions will usually be lower when taken collectively rather than individually, plus the scope of access could be increased. But shared services are not the only benefit.

And it includes the staff skills required to make the best use of the computer resources. Developing a community-wide network also offers the opportunity for public entities to share personnel resources. While a small city government or a small school district might find it impossible to have a network administrator/technician on staff, two or more entities can share the cost. This potential benefit in sharing personnel increases as today's environment, the perception of efficient expenditure of current funding may be required before future funding increases are approved. Sharing personnel in Zimbabwe is also a great advantage since most qualified personnel have left the country for greener pastures and is difficult to find them. Besides benefit from sharing staff and services below is a descriptive of some of the benefits of having shared networks:

Cost Effectiveness- The Internet is a network that is characterized by momentary bursts of traffic followed by periods of low activity. As the WWW has grown, this characteristic has increased. When a user requests a web page, there is a small request packet sent across the Internet. Then there is a delay while the computer at the other end processes that request. Traffic is fairly steady while the web page's text and images are downloaded. On a high-speed network connection, this occurs very quickly if the Internet itself is not congested. Then there is a relatively long period of time when the user does nothing on the network, taking a minute or two to view the page that was just displayed.

Because of this characteristic, a high-speed Internet connection can support hundreds of users at the same time. Pages for some users are fetched while other users are reading their pages. When a school district in a small, rural community installs a high-speed data circuit for Internet connectivity, much of the *potential* of the line is unused. Classroom instruction takes up much of the school day. This situation involves a data circuit that is *under-utilized*.

Another feature of Internet connectivity is that a few computers can be added to a high-speed link with very little impact on the existing users. With an under-utilized link, adding a few more users results in almost no difference in the download times of web pages for existing users. Even on a fully utilized link, adding a few users adds only a minor delay in the reception of web pages by existing users.

If the school district has an under-utilized high-speed connection to the Internet, and the local public library also pays for Internet connectivity through a separate, generally much lower-speed Internet connection, one can say the community is over committing its resources. If the school district and the public library cooperate, the few library computers can be added to the school's high-speed connection without significantly affecting performance seen on school computers. If the connection between the school and the public library is over a wireless network connection, then there is no additional monthly expense incurred for the public library Internet connection.

Increased Bandwidth- Another scenario involves the benefits of sharing two or more high-speed Internet connections. Let's say the school district and the local community college were interested in maximizing the benefit of their connections. First, if both organizations regularly utilize over half the *bandwidth* of the individual connections, sharing a single connection will probably not be an option. However, the entities can still benefit from sharing. By creating a third connection between the two entities, the two separate connections can be shared. If one connection becomes saturated with traffic, excess traffic can be rerouted to the other link. This effectively provides more bandwidth to both entities at peak usage levels. But this is not the only benefit of two sharing disparate connections.

Reliability/Redundancy- When two separate connections are available, and one of the connections fails for any reason, all traffic can be routed across the other connection. This concept can be extended further if each entity uses a separate Internet Service Provider. If one Internet Service Provider experiences technical difficulties and its service is unavailable, another link is available to route traffic. Just as in the original Internet design, this redundancy provides for a more reliable service. Existing resources are used more effectively.

Shared Expertise- As mentioned earlier, when two or more entities build a cooperative network, it may be possible to hire full-time technical support" personnel. For many organizations, this is not feasible to do alone. There are many factors to consider besides the cost of personnel, but having access to adequate system support is very beneficial.

Shared Training- When two or more entities cooperate, it is possible to share the cost and benefits of staff training. For example, it may cost less to bring a trainer onsite to perform training for key staff of both entities than to pay a per-seat training charge when sending individual staff to training sessions. Also, it- is possible to share the knowledge staff receives at outside training sessions with members from other organizations. Such cooperation maximizes the benefit of training funds.

Centralized Administration- When developing a computer network involving multiple entities, one entity usually acts as the administrative agent for the entire network. While there will be meetings involving administrators from all entities, and while there will be work for members of all entities, one entity usually deals with procurement, installation, and maintenance issues with the various vendors. This prevents duplication of work, which is common when each entity must perform these duties to administer separate Internet connections.

Wireless Networking

As one begins to look at any type of network resource - especially the Internet in a remote, rural public school or library, connectivity, setting up and ongoing cost will be a major determinant in the sustainability of the project. Tech-ware (2007)[7] argues that wireless network connectivity is an attractive alternative to cabled, also called wire line, connectivity. With the pressure public agencies feel to maximize the usefulness of taxpayer dollars, wireless networking is even more attractive. In this section we will explore the basic questions surrounding use of wireless connectivity to create or extend a community network. What is wireless networking? When is it appropriate to implement? What is required to implement it? How does it compare to other alternatives?

So far we have spoken of computer networks as a group of computers connected by physical cabling, either network cabling inside a building or telephone lines or data circuits outside a building. Traditionally, such connectivity has used copper wires to carry the electrical signals. Over the past two decades, fiber optic has become commonly used and is included in this class of "wired" connectivity. Over the past few years, a new way to create network connections has emerged which does not use wires. It is called wireless connectivity.

Wireless networking allows computers and peripherals to communicate using radio frequency (RF) transmissions rather than over conventional network cabling. Using wireless Ethernet adaptors, any device capable of being used on a regular computer network can be accessed over a wireless connection for task ranging from file and printer sharing to multimedia and Internet access [7].

Wireless connections all use some form of radio waves, called microwaves at the higher end, to carry data from a transmitter to a receiver. Four different categories of wireless communications are generally used for network connectivity: radio, microwave, infrared, and satellite. Satellite is different from microwave only because its transmitter/receiver is not earth-bound. All wireless technologies use standard computer networking technology saddled over a wireless medium: airwaves. Because signals are transmitted across space, there is no cable between network access points, and, therefore, no monthly line charges for leasing a physical wire. This is wireless connectivity's major advantage (Robert L. Williams 1999)[8]. For one form of wireless communications, however, there is an additional benefit. Radio frequencies are available which do not require a license and payment of license fees.

Radio Frequency Communications

Radio frequency (RF) communications technology is' based on the same technology that radio and television broadcasting uses. One of RF wireless' benefits is that it uses unlicensed frequencies [9]. However, this also means that many users might potentially try to use the same frequencies. In these cases, it is up to the various entities involved to work together to avoid interfering with each other's communications. While this might be seen as a major detriment to RF communications, a research which was carried out in America through private and military investigation into the use of RF technology over the past four decades has provided a solution for minimizing or eliminating interference and for providing security over a radio link [10]. For most small communities considering wireless network connectivity, RF wireless provides the most cost-effective, secure means of communication. [11]. In the remainder of this paper, we shall be speaking solely of RF wireless when we use the term wireless. Let's take a look at its benefits and disadvantages and see when it is the most appropriate type of connectivity.

Appropriateness

By using the word *appropriateness*, we have already assumed that wireless networking is not the best alternative in every situation or for every segment of the community network. There are some distinct characteristics that make wireless optimal for some connections:

Low Cost- [11] The major benefit of wireless data connectivity is its extremely low initial and ongoing cost. Because no physical lines or circuits are involved, there are no ongoing monthly expenses for leasing a line. The only ongoing cost incurred is maintenance of existing equipment, which is similar regardless of the type of connection used. This absence of monthly lease fees can result in large savings in telecommunications costs.

However, private fiber optic connectivity may also provide zero monthly fees-if no *right-of-way* fees are incurred. In such cases, if the cost of fiber installation is close to the cost of wireless connectivity, or less, a fiber optic connection represents the more effective option.

Bandwidth- One of the primary concerns when creating a computer network is speed, or transfer rate. How much data can be sent across the connection in a specific period of time? The more data that can be transferred, the better the connection is for end users. The terms most commonly used to describe the transfer speed of a connection are bandwidth, throughput, line speed, and data transfer rate. They tend to be used interchangeably. General wireless networking equipment provides data throughput of about 1Mbps. Since this is about two-thirds the speed of a T-I line, and about eight times the speed of an ISDN line (BRI), wireless provides a viable high-speed option to leased lines. This provides a high-end solution for sharing Internet connectivity.

However, other network services may be beneficial over a community network. Examples include sharing file servers, applications, CD-ROM information databases, local organization information, and others. In these cases, the 1Mbps throughput of wireless may prove to be too slow. High-speed wireless, sometimes called *wireless Ethernet*, can help [9]. Data throughput of 5-7Mbps can be gained over short distances via bridges using higher frequencies. So, where high throughput is necessary, wireless connectivity may not be as appropriate a solution as private fiber optic cable. Especially where the base cost for both - is similar, appropriateness can only be determined after a careful analysis of the potential benefits of each method of connection.

Line of Sight Considerations- One other significant factor affecting the appropriateness of wireless connectivity is the line-of-sight requirement. With current developments in wireless connection, with a distance- of 60km range transmission is possible. (Tech-ware 2007)[7]

Benefits

Low Ongoing Costs- Wireless technology offers several advantages. Foremost is their low ongoing cost. Ongoing costs are charges just for the use of the transmission medium (zero for wireless). One must also budget for anticipated maintenance costs. For example, equipment configuration updates might be needed, or electrical problems might cause loss of configuration. For routers and bridges, the cost of such maintenance will be similar for each connectivity type.

Ease of Implementation- A second benefit of unlicensed RF wireless connectivity is speed of implementation. When procuring a T-1 circuit, an organization must wait for delivery and installation by the local phone company. Wireless connectivity can be fiber-installed as quickly as the procuring agency can complete the paperwork with the wireless vendor and schedule an installation.

Effective Base-Level Data Transfer Rate- When fiber optic connectivity proves to be too expensive to install initially, wireless provides very good base-level connectivity. Wireless allows an organization to begin networking at about T-1 speeds and update that throughput as funding becomes available.

Mobility- One benefit of wireless will be apparent only when an organization needs to move an office. In wireless connections, the antenna can be taken down and the equipment moved to the next site. Only the cost of setting up and realigning the antenna will be incurred.

Redundancy (in Future Growth)- In many cases, a wireless network can be established as an interim technology. As more and more cabling infrastructure is required in the future, it may become either necessary or more cost effective to install private fiber optic cabling as the backbone of the community network. By leaving the wireless link in place as an active secondary link, it will provide base level connectivity if the fiber link ever fails. Emergency traffic can still be routed. Using a wireless link while it is cost effective today will provide an efficient backup link tomorrow in the event of technical problems.

Budgeting for Wireless Connectivity

Once radio frequency wireless has been chosen as a potential solution for network needs, the big question is "How much will it cost?" In this section we focus on the cost of implementing wireless connectivity. The cost components can be broken down into four basic areas: preparation, equipment, installation, and maintenance.

Preparation/site survey

When an organization looks at connecting to other computer networks, regardless of the type of connection ultimately used, a preliminary investigation must be carried out during the initial phase of creating a WAN. For wireless connectivity, the preliminary investigation is called a *site survey*. A complete site survey investigates the following areas of implementation: Radio frequency interference, Line of sight, Antenna and tower requirements and Structural problems.

A site survey also includes the determination of clear line of sight for all sites involved in the wireless network. If line of sight is not technically available, the technician performing the site survey will determine what other options might provide clear line of sight. Depending on funding, there may be multiple options.

A final option is the use of a *repeater link*. If line of sight cannot be established feasibly between two sites, separate antennas/towers and wireless units can be erected at a third site. This site must have clear line of sight to the two original sites. In this scenario, the alternative wireless unit receives a signal from one of the original sites and re-transmits it, or *repeats* it, to the other site.

Costs- A site survey may take as long as a full day for a single link (two sites) or two-to-four days for larger networks. Any existing radio frequency usage can be discovered through a process known as *spectrum analysis* and this adds significantly to the cost.

Equipment

The cost of wireless equipment is straightforward. Questions regarding equipment are mainly related to the throughput desired, the strengths of the features provided, and whether a mast or radio tower is required to elevate the antenna.

Wireless Bridges

The key component of a wireless network link is a device called a wireless bridge. A combination of a network bridge and a radio transceiver, the bridge is a component on the local network. It examines all data traffic. It sends any data bound for the network on the other side of the wireless link to the radio transceiver. The transceiver then alters the signal and sends it to the antenna, where it is transmitted to the antenna on the other side of the link.

Antennas

Antennas actually emanate the signal from the radio transceiver in transmit mode and receive the signal at the other end of the connection. There are basically two different types of antennas for wireless networking: directional and omni-directional.

A single-link, *point-to-point*, connection uses two directional antennas pointed at one another. Wireless connections with a central site and two or more remote sites being linked are called *multi-point* connections. Multi-point connections generally use an omni-directional antenna at the central site because it transmits in all directions, all the remote sites can pick up its signal. Each remote site has a directional antenna aimed back at the central site antenna. Because the energy of an omni-directional antenna must go in all directions, it diminishes quickly.

Masts and Towers

The more costly aspect of antenna installation is the mast or tower required to achieve line of sight. In rare cases, usually over short distances, line of sight can be established with the antennas mounted directly to the rooftop of both buildings. But, usually, some form of mast is required to raise the antenna to a sufficient height to achieve line of sight.

Accessories

There are several other components included in a radio wireless connection. A lightning arrestor is connected between the antenna and the wireless bridge to prevent damage to the unit that might be caused by a lightning strike. Also, an emissions filter might be used to reduce extraneous noise. Finally, where masts or radio towers are required, there may be need for extension cables to connect the antenna to the bridge. Extension cables will also be required when the wireless bridge is located inside the building far away from the point where the primary cable enters the building.

Installation

Installation is the last cost component in implementing wireless network links. Hiring a certified installer is highly recommended because experienced installers generally provide a better alignment of the antennas at each connection site, providing the best throughput possible over the wireless link.

Installation generally includes the following services: building/erecting the masts or antennas, mounting the antenna, drilling through the building and running a cable from the antenna to the wireless bridge, setting up and configuring the wireless bridge and aligning the antenna and testing the connection

Maintenance/Ongoing Costs

Organizations generally pay annual maintenance fees for "mission critical" equipment such as routers and bridges. If a router or a bridge goes down, maintenance fees usually provide the organization with next-day replacement of malfunctioning equipment.

However, in situations where four or more wireless bridges are purchased, it may be more cost-effective, and timelier, to purchase an extra unit. The initial cost of the extra unit will be recovered over the course of two-and-a-half years or less by not having to pay the maintenance costs. Having an extra unit immediately available should an active unit fail greatly reduces the duration of downtime.

Case Study: Community Network Configuration and Budgeting

In this section we are going to illustrate some of the common ways shared wireless networks might be implemented in small communities. For each case study there is a short description of the significant details involved in creating the network, a diagram depicting the network, and a detailed budget of the initial costs of equipment and any ongoing costs involved. A break even analysis is carried out to show a comparison of the costs in establishing the same network using dedicated data circuits- T -1 lines.

Case study 1: Simple Point-to-Point Link.

This case study shows a network being created between a public library and a local public school district. In many communities, a de facto relationship already exists between these two entities. The public library provides research materials and some curriculum support for student research projects e.g. Accelerated Reader program. Creating a communications link between the two provides several benefits:

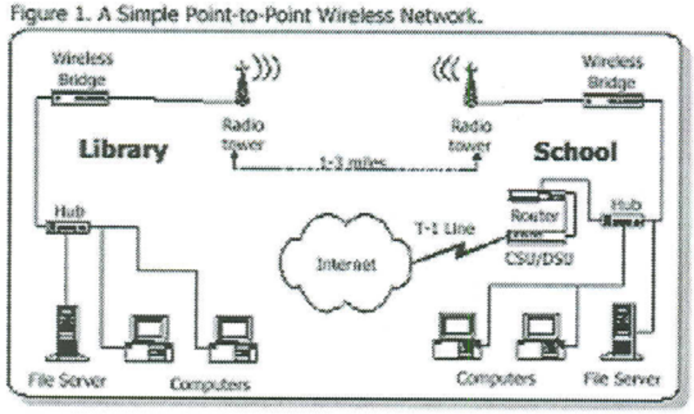
- a direct means of sharing information in each entity's library catalogue

- a means of sharing other electronically-based information resources, such as periodical databases (as licensing allows)
- a means of maximizing the effectiveness of taxpayer dollars in providing access to the Internet

In this example, a single wireless link is created between the public library and the school district's high school. The two entities will share the district's Internet access. The high school has a leased T-1 line connected to an Internet Service Provider (ISP). In this simplest of scenarios, no provision is made for network security through the use of firewalls. In some cases the expected risk of outside attack is extremely low, so the addition of firewalls is seen as an unnecessary expense. (We recommend thoroughly reviewing security risks before making such a decision.) Terrain is level, and only a few trees present themselves between the two buildings. A 20-foot mast, secured to the rooftop with guy wires, is installed on top of each building to raise the antennas above any interference from the trees.

Figure 1 is a diagram of the components involved in the network. In this, and the succeeding diagrams, all devices used to raise the antenna are represented as towers.

Figure 1. A Simple Point-to-Point Wireless Network.



The general budget for this scenario is presented in Table 2. Project costs are separated for the library and the school. In a real setting, where the wireless link is installed strictly for the benefit of the public library, all the initial costs associated with the project are usually born by the library.

Table 2: Budget Allocation for a Point-to-Point Connection

Component description		**Wireless cost**	**t-1 cost**
Library:			
RF Wireless Bridge, 2Mbps	$	1500	0
Directional Antenna		250	0
Lightning Arrestor/Protector		200	0
External Cable, 100ft		100	0
20ft Mast, with Installation		800	0
Initial Site Survey, no Spectrum Analysis		200	0
Wireless Installation (halfday) + expenses		400	0
External cable, 100ft		100	0
T-l CSU/DSU		0	1000
Router		0	2000
v.35 Cable		0	100
Installation and testing		0	0
T-1 line installation		0	500
10Base-T Category 5 Patch Cable, 10ft		0	20
Library Total:		**3650**	**3620**
School:			
RF Wireless Bridge, 2Mbps	$	1500	0
Directional Antenna		250	0
Lightning Arrestor/Protector		200	0
External Cable, 100ft		100	0
20ft Mast, with Installation		800	0
Initial Site Survey, no spectrum analysis		200	0
Wireless Installation (halfday) + expenses		400	0
T-l CSU/DSU		0	1500
Router (assume 2nd port on existing router)		0	0
v.35 Cab1e		0	100
Installation and testing		0	500
School Total:		**3450**	**2100**
Total One-time Costs		7100	5720
Annual Connection Fee (T-l)		0	2150
Total First Year Cost		**7100**	**7870**

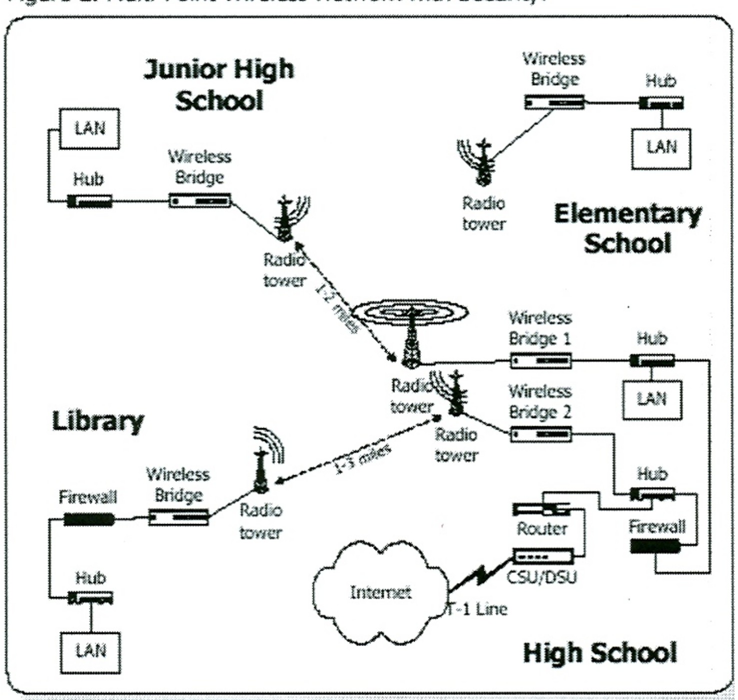
Break-even analysis

In this scenario, notice that the break-even point in the comparison between a wireless and T -1 network link will occur in less than two years.

Case study 2: Multi-Point Network

By converting one end of the wireless link to an omni-directional antenna, a simple wireless link can easily be turned into a multi-point connection. In this example a wireless WAN is created among the public library and the various public school campuses: one elementary, one junior high/middle school, and one high school. Figure 2 is a network diagram of the resulting WAN. Table 3 includes the budgetary requirements to implement it.

Figure 2. Multi-Point Wireless Network with Security.



First, a firewall is installed at the library and the high school campus (which maintains the Internet connection for the school district). In addition, a separate directional antenna and wireless bridge is installed at the high school site to communicate to the library (using a different spreading code to totally isolate the wireless signals). A separate hub is used to connect the external networks (the public library and the Internet) to the firewall. The only change required to add other nonschool sites is the substitution of an omni-directional antenna for the directional. The primary antenna communicates only with remote school sites.

Breakeven analysis

In this case, the wireless costs break even in about two years and six months. For the sake of illustration, we assumed that a decision has been made to secure both school and library resources.

Table 3: Budget Allocation for a Multi Point Connection

Component description	**Wireless cost**	**t-1 cost**
Library:		
RF Wireless Bridge, 2Mbps	$ 1500	0
Directional Antenna	250	0
Lightning Arrestor/Protector	200	0
External Cable, 100ft	100	0
20ft Mast, with Installation	800	0
Initial Site Survey, no Spectrum Analysis	200	0
Wireless Installation (halfday) + expenses	400	0
External cable, 100ft	100	0
T-l CSU/DSU	0	1000
Router	0	2000
v.35 Cable	0	100
Installation and testing	0	0
T-1 line installation	0	500
10Base-T Category 5 Patch Cable, 10ft	0	20
Packet-Filtering Firewall	1500	1500
Firewall Instillation and Configuration	400	400

Library Total:		**5550**	**5520**
School:			
(4) RF Wireless Bridge, 2Mbps	$	6000	0
(1) Directional Antenna		750	0
(1) Omni-Directional antenna		300	0
(4) Lightning Arrestor/Protector		800	0
(4) External Cable, 100ft		400	0
(3) 50ft Mast, with Installation		1000	0
(1) 40ft tower, with installation		900	0
(1) 20ft mast, with Installation		800	1500
Initial Site Survey, no spectrum analysis		200	0
Wireless installation (1.5 days) + expenses		400	100
Network hub to connect public resources		750	0
(3) T-1 CSU/DSU		0	3000
(2) Router (assume three free serial ports)		0	4000
(3) v.35 Cable		0	300
(2) Installation & testing		0	1500
(4) T-1 Line Installation		0	1000
Packet Filtering Firewall		1500	1500
Firewall Installation and Configuration		400	400
School Total:		**14200**	**11700**
Total One-time Costs		19750	17220
Annual Connection Fee (T-l)		0	4360
Total First Year Cost		**19750**	**21580**

Conclusion

Once the rural communities come together to establish a wireless community network, equipment and installation costs will be greatly reduced to affordable figures considering that in most rural areas in Zimbabwe, the set up is conducive in that where there is a school there is probably a clinic, hospital, township or other public institutions nearby.

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