White Paper
Rural Connectivity

Cost-effective Rural Broadband: A Vietnam Case Study

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Executive summary

Beginning in 2006, Intel, the United States Agency for International Development (USAID), and the Vietnam Data Communication Company (VDC) formed a public-private partnership in a joint effort to introduce WiMAX (World Interoperability for Microwave Access), into Vietnam. This partnership included the delivery of broadband access to the remote village of Ta Van in Lào Cai province located in north-west Vietnam. The Ta Van project utilized the IPSTAR satellite network for linking the village to the Internet. Distribution throughout the village was accomplished via the deployment of a single WiMAX base station and several remote subscriber stations (SS) located across Ta Van. In addition to Internet access, the joint project included voice services through Voice over Internet Protocol (VoIP), complete with PSTN integration that allows for calls throughout the Lao Cai province.

The implementation at the Ta Van Village provides a valuable laboratory for addressing a range of issues relating to providing broadband Internet and voice services to remote-rural locations across Vietnam. But beyond Vietnam, the project demonstrates a viable solution set for most of the Southeast Asia region being served by the IPSTAR satellite system. Lessons learned in this deployment also provide a model approach for reaching well beyond the region, where there is a growing world commitment for reaching into rural communities with the provision of broadband and voice services aimed at improving socioeconomic conditions.

Introduction

The primary focus of the joint Intel, USAID and VDC project was to demonstrate that it is both technically and economically feasible to bring broadband Internet access to remote regions using commercially available wireless Internet Protocol (IP) technology.

The resulting project was deployed in two phases. The first phase of the project used WiMAX technology linked to a fiber-optic backhaul to bring broadband Internet access and Voice over IP (VoIP) services to residents of Lào Cai city in north-west Vietnam.

Building on this experience, the second phase of the project was deployed in Ta Van, a remote village two hours away from Lào Cai city and near the mountain town of Sapa. Ta Van village has only two fixed-line phones, limited mobile phone coverage and no Internet access.

Unlike the first phase of the project, the Ta Van network was deployed using a broadband satellite connection, in combination with WiMAX and Wi-Fi technology. This solution set succeeded in providing broadband Internet access and telephony service to the whole village.

Project objectives

There were three major objectives for the second phase of the project:

1. Demonstrate that the technology is mature enough to be deployed in the most challenging of environments.
2. Prove the economic feasibility of the deployment by using only commercially available equipment at realistic prices.
3. Illustrate the educational and economic benefits that broadband Internet access and affordable VoIP communications can bring to underserved rural areas.

Technologies

Wireless Broadband Technology

While wired broadband technologies such as Digital Subscriber Loop (DSL) and cable are well-established in developed markets, the limitations of wired technologies impedes the roll-out of broadband in emerging economies.

For example, wired technology requires a well-established infrastructure that is often not available in emerging countries, particularly outside urban areas. DSL lines, in particular, require good-quality copper lines that are often limited to several kilometers of a telecommunications exchange. Furthermore, with the rise of mobile telephony, many countries simply no longer deploy fixed copper lines.

Thus, in many areas, using wireless technology such as WiMAX to deliver broadband Internet access is often the only option. WiMAX is designed to deliver high-speed wireless Internet access for fixed, nomadic and mobile deployments. It is based on the IEEE 802.16 family of standards and enjoys industry-wide support. WiMAX can provide several Mbps of wireless Internet connectivity over several kilometers.

WiMAX with satellite backhaul

While WiMAX is suitable to tackle the challenges put up by "last mile" connectivity – the final leg of linking a communications provider to a customer – it still requires a suitable backhaul connection. A backhaul transports data between distributed sites and centralized points over long distances.

In many rural areas, a fiber-optic backhaul is often not available. Point-to-point wireless backhaul solutions such as microwave links may provide good bandwidth in some areas but they are not always cost-efficient. In many areas, wireless backhaul solutions require multiple "hops", with each hop requiring a tower, sophisticated networking equipment and separate backup power. It is thus often not economically-feasible to extend network access to these rural areas.

Satellites on the other hand can be deployed easily to any location on earth. The great operational cost though, has made it cost-prohibitive. However, this is no longer the case with the recent deployment of new satellites that deliver dedicated IP bandwidth at reasonable cost.

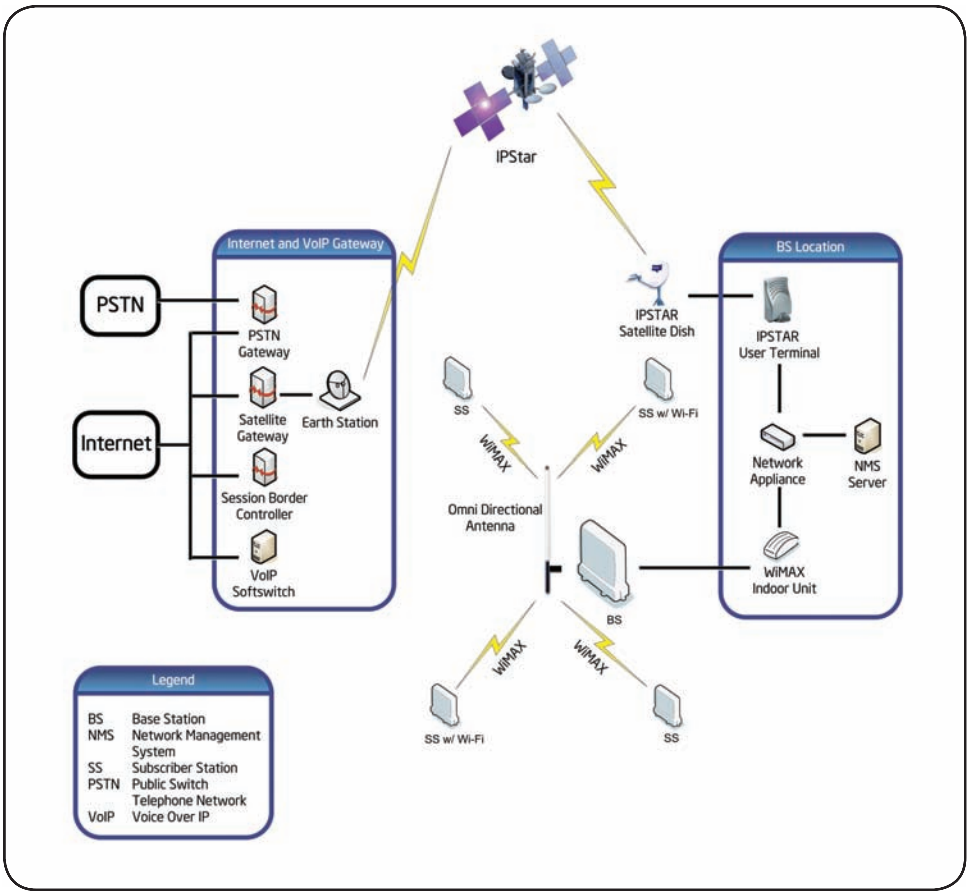
IPSTAR is such a satellite, delivering pure IP bandwidth to the Asia-Pacific region by using the latest modulation and beam-forming technologies. The broadband satellite's overall bandwidth capacity is 45 Gbps and it can provide a bandwidth of up to 4 Mbps down and 2 Mbps up to an individual end user location.

By combining a satellite backhaul with broadband wireless technology, connectivity can be distributed to many users rather than a single user as is done in traditional deployments. This increases the economic viability of such a deployment in rural areas.

"Mobile" WiMAX for fixed deployments

There are two variants of WiMAX based on two versions of the IEEE standard, 802.16-2004 and 802.16e-2005. They are often referred to as "fixed" and "mobile" WiMAX respectively. Mobile WiMAX, although intended for mobile users (such as cell phones), has significant performance and cost advantages that make it equally applicable to fixed deployments as well. Mobile WiMAX has features such as Hybrid Automatic Repeat Request (H-ARQ), Channel Aware Scheduling, Multicast-Broadcast Services, Advanced Antenna Systems MIMO (Multiple Input Multiple Output) and Beam Forming, all of which lead to increased spectral efficiencies (higher bandwidth) and improved link budgets (greater range). More importantly these benefits are equally applicable to fixed and mobile users. Thus, Mobile WiMAX is preferred even in fixed usage models such as rural deployments.

Figure 1: Wireless network architecture at Ta Van village, Vietnam



Wireless network architecture at Ta Van village

A shared 2Mbps down and 512kbps uplink from IPSTAR was used as the satellite backhaul at Ta Van. This was connected to a WiMAX network, which used a star topology with a single Airspan MicroMAX* base station delivering broadband connectivity to multiple users at the village.

In the past, such a network would have required a good civil infrastructure with reliable power source and a climate-controlled environment to house both the satellite and WiMAX equipment.

However, the IPSTAR satellite system requires only one Very Small Aperture Terminal (VSAT) satellite dish and a small indoor user terminal. WiMAX base station equipment is now available in small form-factors that can be used outdoors. For example, the Airspan MicroMAX base station contains all the necessary radio and electronic circuitry in one compact outdoor unit, only requiring one small indoor unit for switching and power.

As the IPSTAR satellite provides limited backhaul, the objective of the network architecture was to provide WiMAX coverage in a cost-effective manner. Hence, a single omni-directional antenna was deployed to provide good coverage over several kilometers in Line of Sight (LOS) conditions.

Thus, in the Ta Van network architecture, only four components needed to be installed outdoors at the base station location:

1. A VSAT antenna

2. An omni-directional antenna

3. One Airspan MicroMAX base station

4. A Lightning protector

The indoor components of the base station are deployed without the need for air-conditioning. It consisted of:

1. The satellite user terminal

2. The indoor unit of the Airspan MicroMAX base station

3. An Edgewater Networks multi-function network appliance

A small UPS provides backup power and protection against power surges. Though a PC running Network Management Software (NMS) is not required, it is highly recommended to manage the local network. It has also proved valuable for remote maintenance. All the equipment is very compact and has minimal power requirements, and can be deployed in very rudimentary environments.

Two types of subscriber stations (SS)[1] – basic SS and SS integrated with Wi-Fi – were deployed in user locations. The basic SS provides a single Ethernet connection, which is connected to a switch or a Wi-Fi access point to provide indoor connectivity.

The integrated Wi-Fi SS provides the same wired Ethernet connection but also integrates a Wi-Fi access point into the same chassis. Thus, WiMAX provides the last mile access, while Wi-Fi provides the last meter access. Furthermore, an integrated unit provides good outdoor Wi-Fi coverage that can be utilized for Wi-Fi bridges.

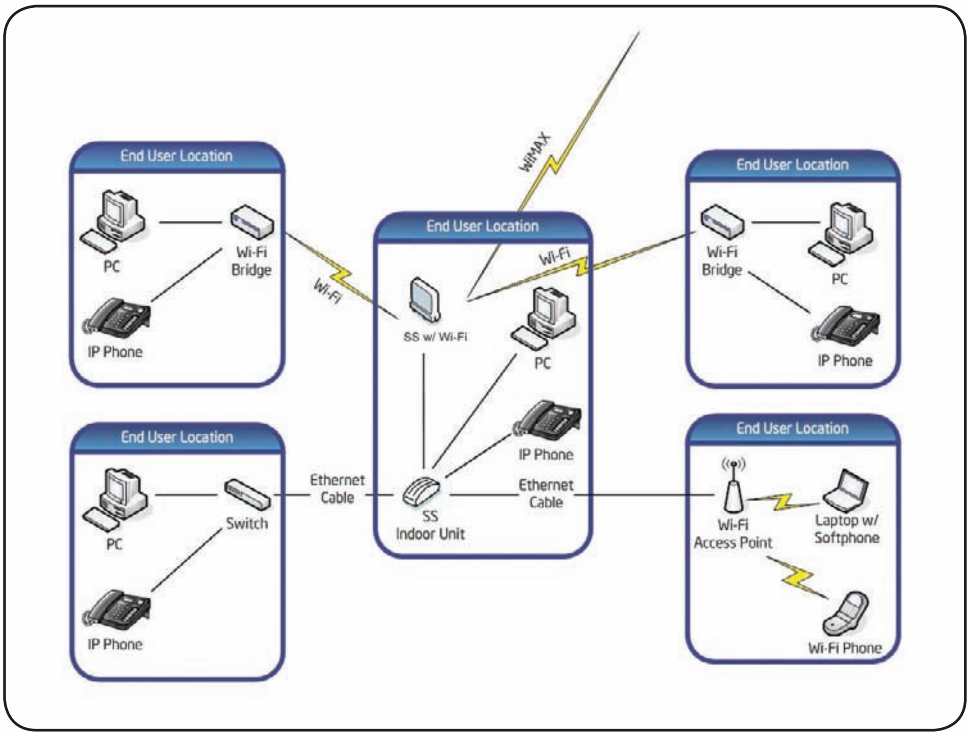
[1] A subscriber station is also referred to as Customer Premise Equipment (CPE).

One SS, multiple end-users

One of the current challenges of WiMAX is the high cost of subscriber stations. The cost of SS is expected to drop once high-volume production starts and true interoperability enables operators to mix-and-match equipment from different base station vendors and SS vendors.

In the meantime, the high cost of the SS tends to inhibit the mass-deployment of WiMAX networks in rural areas. However, the Ta Van project has allowed us to learn that in many cases, one SS can deliver broadband connectivity to several end-users. Figure 2 illustrates how this shared architecture was achieved at Ta Van village.

Figure 2: One SS, multiple end-users



An integrated Wi-Fi SS was mounted in a suitable outdoor location. Using outdoor Ethernet wires and Wi-Fi bridges, multiple households were connected to the single SS. A Wi-Fi bridge receives a Wi-Fi signal, distributing it via the built-in switching capability. This solution was delivered cost-effectively by using a standard access point and open source firmware such as DD-WRT (see http://www.dd-wrt.com).

Thus, using a combination of wired and wireless connections, a single SS can easily support five or more end-users, reducing the cost-per-user dramatically. However, it should be noted that this is only a temporary solution until WiMAX subscriber stations are available at the same price points as Wi-Fi equipment.

VOIP TECHNOLOGY

It is generally accepted that delivering voice capability is the "killer application" in communication technology. The centerpiece of IP networks is the ability to deliver such voice capability cost-effectively with VoIP technology.

While mobile telephony has experienced tremendous growth in many countries, VoIP offers a significant cost advantage, particularly when used for long distance and international calls.

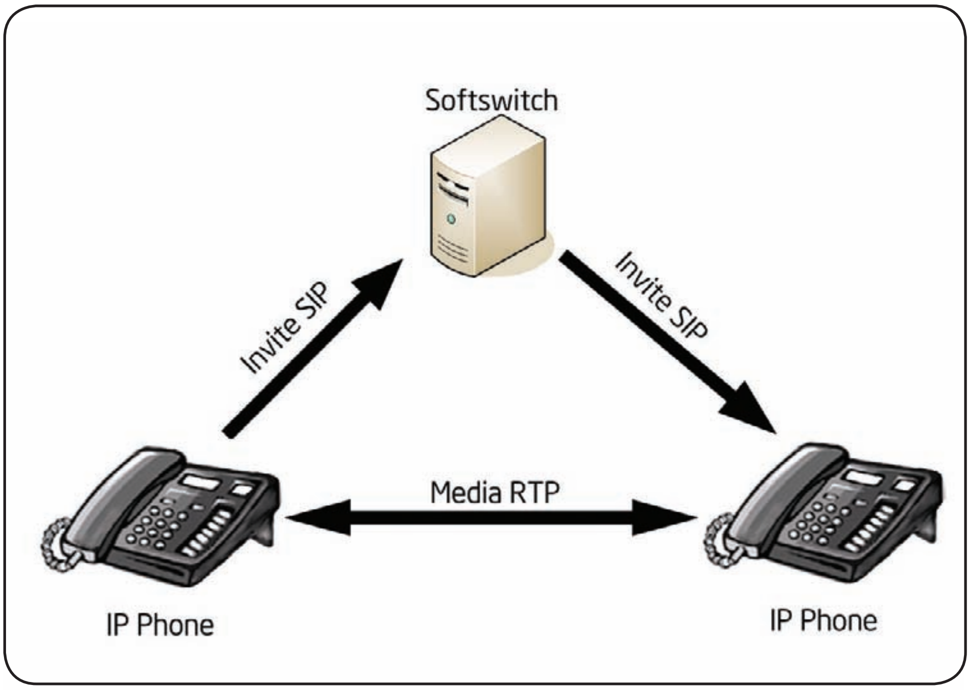
Though several protocols can be used to deliver voice over IP, Session Initiation Protocol (SIP) has emerged as the leading technology. To date, there are many different SIP end-user devices including wired and wireless SIP phones and Analog Telephone Adaptors (ATA) – all available at affordable prices. In addition, software-based SIP "softphones" that run on PCs or PDAs are widely available for little or no cost.

In a SIP network, media gateways handle the connection to the Public Switched Telephone Network (PSTN), so that the network can be seamlessly integrated with the traditional fixed-line or mobile phone network.

For the Ta Van and Lào Cai city deployment, a LignUp Communications Application Server was deployed in Hanoi, while the media gateway was deployed in Lào Cai city. This enabled an efficient connection to the PSTN.

SIP is used to establish the connection between two end points (phones). In general, end-user devices register with a central switch. The central switch then connects the two end devices; once the connection is established, a separate protocol (usually Real Time Protocol [RTP]) delivers the audio or media. Figure 3 illustrates a simplified SIP session. After a call is established using SIP, the end devices (phones) connect directly and communicate in a peer-to-peer manner.

Figure 3: Simplified SIP session



A major challenge to SIP use is that the end device often is hidden behind a firewall, rendering a direct connection between the two phones impossible.

There are two methods to overcome this issue.

1. The first is to use a Session Border Controller (SBC). This device sits on the public Internet and serves several purposes. One purpose is to act as an intermediary between the two phones located behind a firewall. Thus, rather than communicating directly, the two phones exchange the media traffic via the SBC. The SBC maintains the session and handles the challenge of the firewall. SBC offers most advantages in larger deployments.

2. The second method is to use an Application Layer Gateway (ALG). This network device sits between the end-user point (phone) and the public Internet and acts as the "public interface". The ALG thus handles all SIP communications with the central switch and other end points. In addition, the ALG allows the media (voice) traffic for local phone calls to remain local. Thus, if a user within Ta Van calls another user within the village, the central switch establishes the call but the voice traffic remains within the realm of the ALG. Hence, though the setup for a local call generates traffic (< 100 kb) that traverses via the satellite, the media (voice) does not. Thus, an ALG creates an efficient local telephone system.

In the Ta Van deployment we deployed the second method, by using an integrated network device by Edgewater Networks. This device combines most required network functions such as firewall, DHCP server, traffic shaper and ALG. It is a cost-effective device as it is the only network device required in this architecture.

The only limitation of the device is that it must handle all NAT functions (Network Address Table). This is restrictive in larger deployments, where an SBC is more suitable.

There are additional advantages of the Edgewater Networks device. Firstly, since it contains all the required network elements, it simplifies the network architecture and reduces cost. Secondly, it provides a crucial "survivability" function. This function caches the switching information for local end points. Thus, if the satellite link is disrupted, end-users can complete local calls even though the central switch is unavailable. This increases the robustness of the network. Furthermore, the Edgewater Networks device offers traffic shaping functionality and Quality of Service (QoS) features.

Lessons Learned

Internet And Voip Usage

Initial feedback on the positive impact of modern communications technology has been encouraging.

Though situated in a remote region, Ta Van residents took to the Internet quickly. There is usually at least one person in a household who knows how to use computers and the Internet. That person usually is a son or daughter who used PC's at school or university, and then teaches other members of the family. Thus, knowledge of using a PC and the Internet is not an issue.

For many users in Ta Van, the Internet quickly became one of the primary sources of news because other sources of news such newspapers are limited due to the remoteness of the village. The residents use Internet chat and VoIP to communicate with friends and families in other parts of Vietnam. Entertainment usages include on-line music and even video as well as games.

The nurses at the local health station use the Internet to search for medical and pharmaceutical information. A national agricultural institute conducted an informal workshop in one farmer's house to show other farmers on how to use the Internet to find crop disease information.

Tourists are also surprised to find Internet access at this remote location. While staying at the guest house, they use the Internet to send e-mail, update their travel blogs, and upload photos. Tourist guides use e-mail to communicate with their clients and to get referrals, hence increasing their business.

The owner of one of the local guesthouse plans to deploy additional PCs, effectively setting up a small cyber café. He expects to increase his revenue through the sale of drinks and handicrafts.

Overall we found that the village residents' use of the Internet and VoIP is higher than we expected. Daily usage for the existing 12 locations often exceeds 500MB.

In addition, our observations indicate that Internet access is more important to rural areas such as Ta Van. This is due to the fact that alternatives for news, communications and entertainment are limited, and thus the Internet provides a lifeline otherwise not available elsewhere.

Reliability

The technology has proven to be remarkably reliable. The experienced outages have been due to power outages. While we do have an Uninterruptible Power Supply at the base station, all end user locations depend on the same power grid. Thus during a power outage, the base station continues to operate but no end user location can utilize the network to the unavailability of power on their end.

Limited Bandwidth

In any satellite deployment, backhaul bandwidth is limited and often the most expensive component. User education is thus crucial in avoiding bandwidth intensive activities. At Ta Van, the strong community network allowed users to be educated on how to avoid bandwidth intensive applications such as video streaming or P2P traffic.

Besides education, the WiMAX network is configured to limit the bandwidth of each SS. This prevented any single user from taking up the entire satellite bandwidth. A caching device was not considered as the small number of users did not justify the cost.

Latency

An inherent limitation of geo-synchronous satellites is latency. That is the time it takes for a signal to cover the distance from the user station to the satellite and then to the satellite gateway. In addition to this limitation, WiMAX and Wi-Fi networks introduce additional delays.

Overall latencies of 580ms to over 1,000ms roundtrip were observed. For normal Internet activity this latency is not noticeable. However, for VoIP services, latency can be a significant issue. Though it is generally assumed that latency of over 500ms makes a normal voice conversation difficult, we found latency not to be a issue. The bigger problem for Ta Van residents was jitter.

Jitter

Jitter occurs when data packets arrive out of order. This is only an issue for time-sensitive applications, particularly audio applications. Jitter manifests itself in poor audio quality. Though jitter may be minimized by implementing QoS on both ends, this does not completely eliminate the problem. In the Ta Van deployment, QoS was implemented on the Edgewater Networks device as well as on the satellite gateway, and we found that generally the audio quality ranged from acceptable to excellent.

Operational Support

Though the Ta Van project was designed as a proof of concept and had limited operational resources, operational support became critical, particularly in the initial phase. It did not take long for PCs to be infected by viruses that generated undesirable traffic. VoIP in particular requires a reliable backend infrastructure and components such as the media gateway and the softswitch server in production-quality environments to ensure reliable service and good audio quality.

Cost of developing a sustainable model

One of the key objectives of the Ta Van project was to demonstrate that it is feasible to deliver broadband connectivity at reasonable cost to even the most remote rural area using commercially available equipment.

While a detailed discussion of sustainability is beyond the scope of this paper, we do want to outline the cost components of this architecture, and show a potential model for sustainability.

The cost components of this architecture can be separated into a capital expenditure and operational expenditure. For simplicity, we focus on the network components for capital expenditure, while the operating expenditure component focuses primarily on the satellite costs and personnel costs.

Capital Expenditure**

A wireless network designed to support an estimated 40 end-users, similar to what has been deployed in Ta Van can be delivered for less than US$20,000 at current prices.

The base station equipment cost is about USD $12,000. This includes the cost of the actual WiMAX base station for $6,000, including equipment such as the antenna, lightening protection, network device, satellite equipment and miscellaneous items. This does not cover the costs of any associated structural work as it is assumed that this can be delivered at low cost in rural areas and can be provided by the community.

If a combination of WiMAX subscriber stations, Wi-Fi bridges and outdoor Ethernet cables are used to connect 4-5 users to each subscriber station, the cost per user is projected to be $200 each to connect 40 end-user locations for a total of about $8,000.

Operating Expenditure**

The cost of the satellite connection is the primary deciding factor for this model. The cost of a traditional satellite solution is often prohibitively expensive. However, IP-based satellites such as IPSTAR provide broadband connectivity at substantially less cost. The cost of the satellite transmission though, is only one factor that influences pricing. Other factors include the in-country cost of connecting to the Internet as well as operational costs. Thus, the cost of delivering Internet connectivity not only depends on the satellite technology but also on the country it is delivered.

Furthermore, broadband satellites rely on an over-subscription approach. This occurs where a single link is shared across several users based on the assumption that only a subset of users accesses the Internet at the same time. This is also known as the sharing ratio. A lower sharing ratio means better overall connectivity, however as one would anticipate, this results in a higher cost. Thus, the cost for satellite backhaul varies greatly depending on these factors.

A 2 Mbps down, 512 kbps up link can support more than 40 users, assuming a reasonable satellite sharing ratio is used. With a range of $1,000 to $ 1,600 for 1 Mbps of satellite link, broadband Internet including VoIP can be delivered for a monthly cost ranging from $25 to $40 per household.

It should be emphasized that if other forms of backhaul such as fiber or wireless backhaul are utilized, the operational expenditure for backhaul will be reduced dramatically due to the higher capacity and lower running cost of these solutions as compared to satellite.

Business Model

There are several critical elements required in order to achieve a financially-sustainable business model. These include; 1) a single IP-based broadband solution that is capable of providing shared services throughout the community, 2) a convergent wireless network approach where a single network can provide both Internet and voice services (through VoIP), 3) voice services both within the rural community as well as with the national network/s, and 4) central-shared services such as VoIP, including PSTN interface, central and likely pre-paid billing, Internet access, etc.

This approach captures the maximum amount of business possible from across the rural community, secures the near-immediate revenue stream that can be generated by providing high-demand voice services, and gains maximum benefits from the economies of scale and scope through the central pooled resources that can support hundreds of communities. The approach also minimizes the demand for technical support required at the community level, again with the result being improved service and lower support costs.

Furthermore, many countries have started to extend their universal service funds (USF) to cover not only voice communications but also data communications in rural areas. As this deployment model provides both voice and data communications, it is an ideal vehicle to achieve the objectives set by USFs, which is to ensure that rural areas are not left behind by their metropolitan counterparts when it comes to accessing modern communications technologies. Thus, USF funds can contribute to the long-term sustainability of these types of deployments by supporting the capital or operational expenditure.

Summary

From the onset of the project, there were three major objectives: Demonstrate the technology; develop a cost model for effective sustainability; and showcase the benefits of broadband Internet access to rural areas.

After overcoming initial technical issues, the first and second objectives have been met with satisfaction. Not only has the technology proven to be robust, we have also demonstrated that it is possible to provide broadband Internet services to remote areas where only rudimentary infrastructure exists.

** Figures provided by participating vendors in the project.

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