Data Connectivity of Rural District Health Offices

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1.0 Introduction: What's Needed

In many developing nations, healthcare is typically provided by rural district health offices, which may not have data connections to other health centers in the area. However, being able to exchange data between central health facilities and remote field offices is critically important:

- To provide interaction among healthcare professionals so they can solve day-to-day problems
- To retrieve patients' medical records
- To transfer medical records to a central database
- To provide a video/audio link for
  - Remote diagnosis and treatment
  - Consultations with psychiatrists
  - Continuing education/instruction for paramedical staff
- To alert offices to emergencies and outbreaks and:
  - Identify outbreaks
  - Report on the status of the outbreaks
  - Transmit/Distribute educational materials for the public
  - Establish requirements for appropriate levels of medical and personnel resources

Data connectivity should have the following characteristics:

- Bidirectional data transfer at the same speed in each direction
- Ability to store and forward data
- A suitable data transfer rate at a suitable cost structure for an application in a specific location
- Networks should be easy to connect and expand (perhaps with mesh topology)
- Technology used should be known, tested, tried and reliable

- Components readily available worldwide, and standardized to avoid being locked into a single vendor

Creating maps of the region of existing connectivity is a useful starting point. Lack of a communications infrastructure and power grid may be an important challenge. Carefully consider using approaches that already exist and technologies that are available. Potential technologies to consider include:

- Cellular: CDMA, CDMA2000, GSM, GPRS, UMTS, HSPA
- Wi-Fi, WiMAX
- Mesh networking
- DSL
- Fiber
- Satellite (VSAT or BGAN)
- Delay-tolerant networking/vehicular wireless burst switching networks
- Laser communications
- Pyroelectric detector arrays
- Antennas of varying types
- PAN, Bluetooth

Each of these should be checked for their operational feasibility and their applicability to this project in the next two years.

2.0 Environmental Description

Using one health clinic for every 5,000 people as a guide, Africa and India, with a population of about 2,000 million should have about 400,000 health clinics. Other developing nations have another 500 million people or so with little or no healthcare services[1].

[1] Types of health centers vary significantly. In Uganda, for example, such centers have about four different levels of care. Most of them hardly have any resident doctors: it is not unusual to find one doctor serving 6 to 10 centers, rotating from one to another.

Connectivity sources in developing countries have the following characteristics:

- Cellular coverage: Global System for Mobile Communications (GSM) is the most prevalent system, and coverage is extensive. Devices can be deployed immediately. However, most GSM installations handle voice only and offer no meaningful data services. This is changing rapidly as a result of the deployment or improvement of General Packet radio Service (GPRS) or even Third Generation (3G) data service. (Reference 1)
- Internet penetration: though rising rapidly, penetration is typically still very low. Penetration in Africa varies from 10% in Nigeria to 1.4% in Zimbabwe. India has an average of 5.3% (Reference 2).
- Wi-Fi penetration: Though high in the U.S. and other developed countries, Wi-Fi penetration typically is very low in developing countries. Public Wi-Fi is limited to airports and some public buildings in major towns. With its relatively low price and wide choice of equipment, Wi-Fi is the most popular technology for local- and wide-area networking in connectivity projects.
- Connectivity among clinics and health offices: Usually only voice calls are handled; data connectivity is negligible. Some governments, however, are trying to roll out connectivity to key government institutions, including health clinics
- Electric power is only available in about half the areas where it is needed. Power generators often suffer from prolonged breakdowns because of a lack of spare parts and knowledge by local staff of preventive and corrective maintenance. One estimate is that about half of all equipment placed in the field fails in the first year of service. Also, connections to the power grid are often problematic. Frequent outages and high fluctuations in voltage lead to unstable networks and services, and dramatically shorten the life of network equipment and end user devices.
- For certain clinical uses a network between clinics is much more useful than the ability to communicate between a local clinic and a central location.

3.0 Shorter-term Challenge (about one to two years)

This section describes short-term requirements for improving the use and maintenance of what may be found available in remote district health offices. But today, the vast majority of rural health offices in developing countries are located in remote regions with no data network infrastructure. Where data networks exist, they have been built by foreign aid organizations, each with specific goals in economic, educational and healthcare development. In the near term, these organizations are the most likely funding sources for building data connectivity. However, these organizations are focused on their own goals, which may not always be consistent with the long-term needs of rural health centers. Though one may build data connectivity to meet immediate needs of the sponsoring organization, it is wise to consider the long-term requirements of the health offices.

Short-term solutions for connecting rural health centers must be:

- **Appropriate for what the health offices do**
  Healthcare communities have their own culture and work processes for acquiring and applying medical information. Therefore, choose Information Technology (IT) applications to derive the most benefit at each stage of the network's development. For rural health offices, data may be generated manually or via PDAs, cell phones, PCs or laptops. Consolidated data may then be transmitted to the next-higher-level office. Medical information taken from the Internet and directions from higher level offices are transmitted through the computer and portable devices. Applications should be expanded as data connectivity and computational capacities grow. Distributing medical information and doctor's directions to lower-level offices, e-mail and transmitting simple patient records can be very beneficial initially. Internet connectivity is the most effective way to meet these requirements, with Bluetooth, Wi-Fi, or infrared connection appropriate for local access. However, whatever the type of connectivity to be designed, should be based on what's available locally.

- **Capable of being integrated into the larger telecommunications network**
  Any dedicated connection provided initially should be designed to be integrated readily into the general telecommunications network as soon as the service becomes available. This will make it less costly and easier to support such connectivity in the long term. Telecommunications networks, particularly wireless versions, are rapidly spreading in the developing world. Thus, the anticipated availability of network facilities should be considered when building the connectivity.

- **Supportable by local personnel**
  Perhaps one of the biggest challenges for equipment acquisition is being able to maintain and sustain the equipment. Training staff to use the equipment is essential. It is even

more essential to have trained support personnel who are not likely to leave the job. There are many cases of failure because well-educated personnel turn out to be "too good" and move on to better jobs in the cities. Once this aspect of support is factored in, the choice of equipment and technologies may have to favor simplicity and the local support that's available. The involvement and ownership by the local community of all aspects of a new facility's operation is key to self-sustained growth in a developing country.

- **Affordable in its initial and on-going costs**
  The cost of building and maintaining connectivity must compete for scarce funds with other worthy projects. Minimizing costs for a system's life span can usually be achieved by relying on a mix of locally available materials, the latest mass-produced equipment plus a dose of improvisation.

- **Continuous Operations**
  Proposed solution should be delay tolerant to the intermittent loss of connectivity (internet or power).

- **Develop case studies**
  To provide a road map for the project, develop several case studies for a couple of different connection scenarios, such as Wi-Fi networks, GSM modems, VSAT, etc. For the case studies, one location in Africa and another in India are recommended.

- **Demonstrate a solution**
  A potential solution meeting the requirements above, need to be developed and demonstrated before anything is deployed in the field. Detailed user guides that provide a technical overview and as well as a general cost summary need to be prepared.

Example: A case study for a short-term challenge:

Though it's difficult to build a model case because of the differences among countries and regions, it may be useful to consider a case analyzing how data connectivity can be built today for a district's rural health offices. The following example has been assembled from information culled from various reports on current sub-Saharan regions. It does not represent any real case, but many of its salient points apply to most of the health offices in that part of the world.

Our example is for one of the region's poorest districts; it has seen little economic growth for several years. The literacy rate hovers around 20%, with less than half the children finishing elementary school. There are over 10,000 HIV/AIDS patient in the district. As in many other districts in this region, HIV/AIDS and malaria epidemics are overloading the already deficient healthcare system. And though it has seen relative peace, the central government invests little money in economic development let alone in health offices.

Health offices in the region are organized by districts. Each district has a headquarters with an affiliated hospital, and supports 10 rural clinics in the surrounding area. The district's system is the only healthcare facility for 100,000 people in the area, with the district headquarters supporting 20,000 people from the immediate towns. Each remote rural clinic supports about 8,000 people.

A district hospital has 100 beds, 6 doctors, 12 nurses and 30 other support personnel, including clerks and paramedics. The rural clinics, some in hilly terrain, are 10 to 20 km away from the district headquarters. A clinic typically has one nurse and five support personnel. A visiting doctor comes once a week to treat outpatients. Erratic voice telephone service barely reaches the locality and there are no phones at the rural village clinics. Electrical service, limited to the town center, is undependable for most of the day. Even though cellular services are spreading rapidly in major cities of the region, there is little chance for cell phone or other services to come to the remote districts in the next few years.

As for foreign aid organizations, they judge that winning the fight against AIDS and malaria is a prerequisite for economic development. Consequently, they focus their efforts on distributing and administering medicine and malaria nets for beds. The agencies have enough medication for everyone who needs it, but they face difficult administrative and logistics problems in this remote district where the health offices cannot use their aid effectively. They want to find more effective ways to increase the efficiency of the medical personnel and facilities through better information collection and distribution.

Application of IT and data connectivity to the health offices could lead to remote diagnoses by doctors who could then transmit their instructions, fast access to health records, and rapid information collection and distribution to the entire staff. This, in turn, could lead to more efficient use of the care providers and medicines that are available. Up-to-date information on the use and inventory of the clinic's materials, as well as better monitoring of medical results, will also be a big step forward. Even with the international effort to reduce the cost of drugs, antiviral medication for HIV/AIDS alone will cost over $2 million a year in this district ($200 per patient). Any gain in efficiency through implementing Information and Communications technology (ICT) could pay back its cost in a short time. Data connectivity is the key link in the implementation.

Start modestly by providing a PC to each rural clinic and 10 PCs to the headquarters. Connect these PCs through Wi-Fi/WiMAX (modified for long distance applications of 10 to 100 Km by TIER (Reference 3). To connect this TIER network to the Internet, a router/gateway at the headquarters can be linked to a VSAT station. A shared 256-kb/s Internet connection is available at a VSAT station 30 km away for a monthly charge of US $500, and the headquarters location can be connected through a series of directional antennas. Add portable hand-held devices like PDAs, as more funds become available. An approach of using Internet access and standard technologies will meet all the requirements listed above, if everything is implemented carefully. Involve local personnel from the beginning, and use local materials for towers, poles and lightning protection.

A quick analysis estimates the initial cost at around US $125,000. Annual recurring costs total about $8,500, including a satellite connection plus maintenance. Here's a breakdown:

- WiMAX access from clinics thru directional antennas/poles: 10 at $30,000 each
- Headquarters access-point equipment (router, antenna, tower): $10,000
- Long-distance backhaul Wi-Fi connection to the VSAT station: $10,000
- Computers: $24,000 (20 at $1,200 each)
- Software/installation/training: $20,000
- Solar power package $25,000: 60W panels with 50-Ah batteries for clinics (10 at $2,000 each); a 150W panel with 120-Ah batteries at headquarters ($5,000)
- PDAs (optional): $20,000 (100 at $200 each)

The annual amortized cost for a complete installation for this district will be $15,000 to $30,000 for its 5-to-10 year lifespan, bringing the total annual cost to less than $40,000. These estimates include installation, operation and maintenance. Various studies of ICT's impact on healthcare estimate that the increase in operating efficiency alone could be between 15% and 30%. For an early implementation in a developing country, the increase may be even higher.

For an aid organization administering a $2 million program annually, this could make for a very convincing case for more investment and expansion in this region. Also recognize that perhaps a bigger advantage of ICT is the opportunity to deploy new services and functions heretofore impossible to provide.

4.0 Longer-term Challenge (about three to five years)

This section is used as the basic guidelines for further development that requires innovation and adds significant value to existing practices. To install comprehensive data connectivity, the following basic requirements must be met:

- **Extend the cities' backbone connectivity to rural areas:**
  In many developing countries, backbone networks exist and link major cities. The challenge is to make connectivity available in rural areas where as much as 90% of the population may live. Currently, the most cost effective way to extend the backbone is through cellular technology. And though cellular coverage in growing fast, by far the largest part of Africa is still not covered (Reference 4). Technologies that could also be used include for extending the backbone include satellite communications, WiMAX, and Wi-Fi.

  Many of the general technical issues relating to backbone connectivity are being solved by mobile telecom vendors and, increasingly, they are rolling out the first mile to the end user. However a huge need still remains for technologies that could help a rural healthcare institution (e.g., clinic) manage its costs or even turn it into an income generator. (Rural coverage does not often provide a viable business case for network operators and may only be provided if required by license obligations.) For example, the area of wireless ISPs (WISPs) that handle billing, provide local VoIP calling and expand automatically through mesh networking has a huge potential to provide backbone connectivity and is still on the technology frontier.

  An interesting overview of current broadband infrastructure in Africa, including an estimate of the budget required to cover all of Africa. (Reference 5).

  The National Education and Research Networks (NREN) that interconnect universities and research organizations are believed to play an important role in the early development of backbone connections. See the Association of African Universities for more information (Reference 6).

A more recent document, "The Commonwealth African Rural Connectivity Report," reports on new initiatives on the continent. (Reference 7).

- **Establish viable business models:**
  Since it is expensive to extend connectivity to rural areas, the ability to share bandwidth reliably among users is critical. Components such as billing software and network/bandwidth management software are basic requirements. Low-cost technology that can be deployed by a local organization without the involvement of the government is key. Use of unregulated spectrum can accelerate deployment. If governments must be involved, "buy-in" in the project must be achieved up front. A shared usage model can be the key: instead of enabling connectivity for 300 people in a community, enable connectivity for 10 and share those access points by all 300 people

  Establishing a profitable business model can facilitate sharing of services between humanitarian and commercial needs. Communications has become a key factor for human beings whether poor or rich. It is common to find peasants in rural areas maintaining an expensive mobile phone but complaining that they have no soap or sugar at home. This means that even the poorest of the poor can help pay for the new facility.

  It is advisable that the future activities focus on developing a wireless ISP (WISP) that can create businesses around bandwidth sharing. Note that the Wireless Africa Initiative describes business models for WISPs (Reference 8).

- **Monitor and maintain:**
  In remote areas, it is critical that the network and its equipment be always monitored so that a problem can be diagnosed as it begins to occur, and action taken to prevent a failure. Local people must be trained as technicians, so that they can perform basic maintenance functions such as replacing equipment or re-aligning an antenna.

  Network deployment is always the easy part. Making it all work is more difficult and optimizing it so it works really well requires a good understanding of multiple layers of protocols, from the physical layer to the application layer. There are usually so many combinations of options that untrained personnel will probably never be able to find the exact combination to make it work really well. In addition, diagnostics are often poorly done, which renders the task of troubleshooting much more difficult.

Practical experience shows that it is easier to find and train technicians to troubleshoot hardware, align antennas, replace cables or plug in equipment. The bigger challenges lie in configuring the network and LANs with IP addresses, DNS, NAT for LANs, and routing, etc. (DHCP, which can assign IP addresses automatically, helps to a certain extend). These configuration parameters go bad when the operating system gets corrupted, which is always a problem.

Consider using the new hardware designs that come with built-in maintenance sensors, for example, the Ubiquity router with its built-in LED Wi-FI reader, which makes it easier to re-point a misaligned Wi-Fi antenna. This integrated unit also has fewer things that can break. For more information on monitoring and troubleshooting wireless networks, see the document, "Beyond Pilots: Keeping Rural Wireless Networks Alive" at the following location. (Reference 9).

- **Establish common standards and protocols:**
  A lack of standards makes it difficult to set up and configure equipment. Use of a mix of open source and proprietary applications and designs is a major issue and should be avoided. The IEEE could play a significant role in developing standards for applications, protocols, and systems that could be used in providing data connectivity for rural health offices because of its stature in this area.

  While it is a good idea to try to create standard protocols that are accepted by everyone, this is a painstaking and time-consuming work. The obstacles —commercial, political, technical, inertial and more—are many.

- **Ensure privacy for medical data:**
  Activities focused on connectivity for transmitting medical data should not be limited to physical connectivity. Healthcare has much more stringent requirements than ordinary rural telecommunications services. Being able to trust that the medical service and related records that may be transmitted among rural health centers will remain secure and private is critical. Under the heading of trust come Quality of Service and Security and Privacy, based on definitions from National Institute of Health (NIH) and World Health Organization (WHO).

Technology that allows clinics to synchronize and mesh their data together asynchronously could be really powerful. InSTEDD, whose mission is to harness the power of technology to improve collaboration for global health and humanitarian action, has developed a technology called MeshX that can help with that.

- **Fit into the local culture**

  The acceptance of the technology by all parties involved should be also considered seriously.

  Management of change is particularly difficult when it relates to the delicate topic of health. People may be afraid of technology and not trust new techniques. Furthermore, some places in developing countries differ in the way they consider illness and medicine. Religious or supernatural beliefs may lead people to reject modern medicine and constitute an obstacle for the implementation of electronic health, or eHealth, activities. (Reference 10).

5.0 Applicable Technologies

This section discusses today's most commonly used technologies, as new solutions that will be developed will build on top of the current state of the art. Recognizing that there are different levels in a network that are of relevant to data connectivity for rural district health offices, the following discussions are centered around: fixed backbones and international gateways, last mile solutions, and local area networks.

Fixed Backbones and International Gateways

The Internet as known in the developed world is basically a dense network of fiber optic cables connecting exchange points, and forming national and international backbone networks. Fibers run over land or under sea and support data rates up to hundreds of Gigabits per second. Prices per bit are low as generally there is an abundance of bandwidth together with an open and competing market. In the south, and most notably in Africa, only a few fiber back bones exist and access to these cables via international gateways is typically in the hands of a few monopolists that charge very high fees for bandwidth. Since 2002, a submarine cable connects eight countries in West Africa with Europe. A new cable called EASSy is expected to become operational in 2009, and will close the loop around Africa by extending SAT-3/WASC/SAFE to countries in east Africa and will finally land in Sudan. (Reference 11) for a map of world's submarine cables. Cables over land connecting other areas and land locked countries hardly exist. (Reference 12)

As a result, 90% of Africa's internet connection is realized by satellite connections such as VSAT that relay the data to European and American Exchange points. Satellite coverage is around the world and VSAT terminals can be installed virtually everywhere, but it comes at very high cost and poor network performance.

Last Mile Solutions

In developing areas, landline wired networks such as fixed telephony networks and Internet fiber backbones hardly exist. If such an infrastructure exists, it typically only connects the major urban areas. Further than a few miles away from a district telephone exchange, data connections like DSL do not work. Thus, the health offices in the rural areas typically have no other option than a wireless connection. The common options are satellite communications, fixed wireless access with WiMAX or Wi-Fi, or mobile GSM/UMTS networks. In addition a new concept of delay tolerant networking is also discussed.

- Satellite communications: VSAT dishes give direct internet access to a European or American gateway and can be installed directly at the site. A Ku-band dish is reasonably small and affordable (5,000 -10,000 USD), but monthly charges are high with charges around $500 US per month for a shared 256 kbps connection. The network performance is often poor with high delays and congestion in shared connections.

- Fixed Wireless Access: Technologies like WiMAX and (long distance) Wi-Fi can connect sites to a local Internet Service Provider (ISP) tens of kilometers away with a point-to-point connection using high masts and high gain directional antennas. The local ISP is typically connected to the Internet by satellite (e.g. with a bigger C-band dish), or may be fortunate enough to have a connection to a backbone cable network. The network performance of WiMAX and Wi-Fi is much better than the performance of satellite (with bandwidths of 1-10 Mbps and hardly any delay). Prices depend on the internet connection of the ISP and on the local situation.

- Mobile Wireless Networks: Cellular network technologies like GSM/GPRS (2nd Generation) and UMTS/HSPA (3rd Generation) are rolled out quickly throughout the world. Especially developing continents like Africa experience an uptake of mobile networks and services that have never been seen before. Innovative services like mobile-banking, mobile-trading and e-health based on (simple) mobile phones are taking up fast and prove to contribute to social and economic development. In some countries like Uganda, coverage of cellular networks extends throughout the country, but usually coverage is limited to urban areas and major towns and roads. Rural deployments, if existing, follow from a mobile network operator's license agreement, as masts in these areas typically are not yet economically profitable. recent map of coverage (Reference 13)

All mobile networks offer voice and SMS services, typically based on GSM technology. GSM network operators usually also offer GPRS data services, but typical data rates are limited (10-50 kbps) and the service appears to be unreliable in many countries. UMTS networks are also deployed and offer faster data services with typical data rates of 128 kbps in addition to voice and SMS. HSPA is an extension on UMTS and makes even faster data rates of typically 1 Mbps possible. The coverage radius of cellular networks varies from a few hundred meters in dense urban deployments up to tens of kilometers in rural areas. Typical data rates will however, quickly decrease at longer distances from the mast. The major benefit of mobile technology is a terminal that is low cost, robust, and energy efficient. A simple mobile phone can be operated by basically everybody (including illiterate persons), is, with costs as low as US$25, affordable for large parts of the world, can easily be charged with solar energy and is relatively suitable for harsh environments. These advantages explain the success of mobile phones in developing countries when compared to the slow uptake of Internet via PC's. GSM and UMTS modem cards (with USB and PCMCIA interfaces) are available to connect laptops and desktops to cellular networks.

- <u>Delay Tolerant Networks:</u> Many rural areas are too remote to connect to a local ISP with long-distance Wi-Fi or WiMAX. If an area is sparsely populated, the national mobile operator may not be willing to invest in a GSM or UMTS mast in the area. If there is no externally sponsored stakeholder that can pay the high cost of a VSAT, an option may be to create a delay tolerant network, also called a vehicular wireless burst switching network. In such a network, data is transported in an automatic store a forward manner by (e.g. public busses that service the village). The bus will automatically pick up and deliver new data packages at every stop and transfer packages over the Internet when it arrives in the district main town that has a connection to the Internet. Obviously, this only works for data services that are not time critical such as e-mail, attachments and

SMS. Popular databases and static web pages can in addition also be cached locally in the village. (Reference 14).

Local Area Networks: Ethernet and its wireless version Wi-Fi are by far the most popular technologies to build local area networks (LAN) and wireless local area networks (WLAN), respectively. Typically, these networks are used to share an internet connection with several computers in a building or in a group of nearby located computers. Let's consider a typical African rural settlement with a health clinic. The connection to the Internet is provided by a local VSAT, or a wireless point-to-point Wi-Fi or WiMAX connection to a local ISP some tens of kilometers away. The connection may be located at the administration building of the local health clinic. A few computers and a printer in the administration building are connected to a fixed Ethernet network with cables. The nearby pharmacy and a few staff houses are connected wirelessly with Wi-Fi. External rooftop antennas are attached to the routers to increase the coverage.

To maximize the utilization of the connection, and to share to high cost of the connection, the hospital considers sharing the connection with the local nurse school and the community centre that wants to open up an internet café. With such a community network, a Voice over Internet (VoIP) service can be set up that allows for free calls within the community and low rate national and international calls. Note: that VoIP is not always allowed by the national law. If the wireless local network will be extended, it makes sense to make use of a mesh network topology where messages dynamically hop from station to station to reach their destination. Thanks to the hopping nature of mesh, the network range can be extended and the network becomes more robust. Difficulties in such an extended community networks are network management, administration and billing.

PDA's or smart phones can also be connected to the local area network to allow direct and fast access to the local information system and Internet connection. Most terminals nowadays have a Wi-Fi interface, but Bluetooth or infrared interfaces can also be used if distances are not more than several meters.

Monitoring and Management Technologies: To effectively deliver data connectivity, data networks must be monitored and managed. Physical devices must be monitored for failures. In some cases monitoring software can support remote repairs. In other cases it must alert field technicians to visit and repair the devices. Network bandwidth must also be managed and throttled to assure bandwidth availability to all users. Network management software often incorporates billing features so that users can be charge based on data usage. There are many commercially available network monitoring and management software systems and a variety of standards for interacting with physical devices. A successful connectivity solution will incorporate network monitor, management, and billing functionality.

6.0 Financial Considerations

- A price target for the proposed solution is one of the first needs to be established.
- Foundation funding may be available for product development, but the target price should include a fair return to the manufacturer to ensure its continued product support and service availability.
- Most small organizations can only afford a monthly Internet cost of about $40 to $60. The charge also depends on whether the government would help support the cost. To put things in perspective, teachers and nurses in many Africa countries earn between $100 and $300 a month. We won't have a real win unless the cost is so low that the organization or community could ultimately support the Internet on its own. As a result, to defray costs you must factor in how a clinic or school could use its Internet connection to generate income. A WISP would help here. (This assumes a situation where the government provides no funding for connectivity.)
- The cost structure should be appropriate for the solutions and the region.
- A price target for proposed solutions to deliver services free at the point of use should be employed. Current evaluation of technology adoption has shown that free health services via the use of cell phones has led to increased uptake/usage of the systems as opposed to the low adoption levels witnessed with cost-intensive services (Skinner, 2009).

7.0 Related Humanitarian Needs

Providing reliable electricity continues to be a critically important challenge in most resource-poor countries. We recognize that there are additional humanitarian needs such as transportation and financial infrastructure, and availability of trained personnel. Large cities may face periods of blackouts or brownouts, but in rural areas, not having electricity is the norm, not the exception. Deploying sophisticated electronic equipment, such as PCs and laboratory test equipment, requires comprehensive examination of the environment and systems design based on worst-case scenarios. Here is a pair of typical-use cases:

- **Case 1**:
  A rural health center has a catchment area that serves about 10,000 people. The center is staffed with a medical officer (one day a week), a clinical officer (three days a week) and a nurse and a clerk (five days a week each). The facility provides acute as well as chronic health care, performs routine surgeries, but usually refers most difficult and severe cases to a district hospital about 100 km away. The health center building, built two years ago, is wired for electricity, but the tap to the power grid has not yet been made. The district and provincial governments have promised electricity, but nothing has happened and it is unclear when it might happen. The assumption is that the health center may have to find a self-sufficient way to power its equipment.

  The staff would like to have electricity for lights so that patients could be seen not only during daylight hours, but when it is dark. They would also like to use a computer to keep track of their patients, especially those on anti-retroviral therapy, since these patients require careful monitoring over their lifetimes. Finally, the staff would like to run simple lab tests and use microscopes to determine the cause of illness, and also keep a refrigerator to maintain their cold chain (necessary for vaccines).

- **Case 2:**
  A district health center has a catchment area of about 50,000 people. The center has 50 beds, a medical staff composed of several doctors, nurses, medical and laboratory technicians and clerks. The health center is a referral center for surrounding rural clinics, and is responsible for running laboratory tests. The health center also maintains several computers for patient monitoring and tracking pharmacy inventory. Electricity is available most of the time. However, numerous brownouts and blackouts occur, often without warning. The health center has lost several pieces of computer equipment and laboratory equipment due to electricity problems. The center staff would like to be able to rely on the equipment and electricity so they can better serve the people.

These two cases represent probably the vast majority of electricity problems faced today in resource-poor countries. There is either no electricity, or there is unreliable electricity. The two cases require different approaches.

8.0 Relevant Activities Already Underway

- **AED SATELLIFE:**
  For over 20 years SATELLIFE (a global health information network that is now part of the nonprofit Academy for Educational Development) has been working to provide innovative applications of information and communications technology to health professionals in areas where AIDS and malaria are common. Since 2003, they have been working in Uganda on testing and implementing a project called the Uganda Health Information Network (in collaboration with the country's Makerere University Medical School and the International Development Research Center of Canada). The project is aimed at expanding and supporting health data collection and analysis from field locations (in Rakai and Mbale) and transmitting it to a central location in Kampala. The network consists of handheld Palm PDAs distributed to health workers in the field; relay devices called jacks developed by WideRay Inc., and installed at central facilities; and a central server in Kampala. Connection between the PDAs and jacks is by infrared beam, and between the jacks and central server via GSM cellular telephone and the Internet.

  Since the project was launched, 350 handheld PDAs have been deployed in the field along with nine jack locations. The initial deployment has demonstrated the following:

  - The network technology is viable and can be supported locally by Uganda Chartered HealthNet. End users were also successfully trained to use the technology.
  - A cost effectiveness study indicated a 24% savings over manual data collection and transmission
  - Data collection was improved, reaching close to a 100% compliance rate versus the national average of 63%.
  - Healthcare workers now have regular access to useful information, including continuing medical education materials.

Major technical challenges that were overcome related to: significant modification and upgrade of the Wideray devices to solve stability, storage and email issues; introduction of solar-powered recharging to solve power supply problems; selection of a quality-conscious cellular phone company and ISP; improved software for generating forms.

Some of the key lessons learned for the HTC after reviewing the SATELLIFE effort include:

1) The SATELLIFE project confirmed that the Data Connectivity Initiative is both an appropriate humanitarian project with real benefits, as well as a solvable technological challenge.
2) To be successful, the Data Connectivity Initiative will need very strong partnerships with an in-country health provider, (a government agency) and in-country technical and administrative resources.
3) To be successful, a strong partnership is needed with equipment manufacturers, if they're to help overcome the numerous technical challenges that will emerge.
4) The architecture effort will require analysis of an end user environment in order to develop detailed system requirements. Unless other user environments are available, it is strongly suggested that the Uganda Health Information Network be used as a surrogate for these requirements.

- **The Aravind effort**

  Aravind is a collaborative effort among an Indian hospital network, researchers at the University of California-Berkeley and Intel Corp. It allows eye specialists at Aravind Eye Hospital in Theni, India, to interview and examine patients in five remote clinics (at up to 50 miles from the hospital) using high-quality video conferencing. At the remote clinics, a nurse trained in eye care first sees the patient and then a five-minute web camera consultation takes place with an Aravind doctor. If the doctor determines that a closer examination is needed the patient is given a hospital appointment. The underlying technology used employs IEEE 802.11 Wi-Fi. The Berkeley group developed new software to extend the range of Wi-Fi and by using directional antennas achieved network speeds up to 6 Mb/s at distances up to 40 miles. These are speeds 100 times faster than dial-up and distances that are 100 times as far as traditional Wi-Fi can reach.

- **Tsunami Relief Effort**
  In India several members of the IEEE Kerala Section rushed to the southwest coast after a giant tsunami struck nations surrounding the India Ocean. Just days after the massive tidal wave struck IEEE members created a wireless communications network spanning a hundred miles of the worst affected coastline. This network helped in the Relief and Rehabilitation of affected population.

- **eHEALTH**

A project unit of the European Commission, eHEALTH has been engaged in a number of projects in developing countries. Again refer to "Assessing the Opportunities and the Pertinence of eHealth in Developing Countries," by Pierre Buysschaert, European Commission, Unit ICT for Health, February, 2009, at the following location (Reference 15).

The following section describes a few of the projects presented in this report:

1) **Building Europe Africa collaborative Network for applying IST in Health care sector (BEANISH):** The project's goal is basically to build a network in a few African countries between institutions and organizations related to the fight against HIV/AIDS. Practically, BEANISH aimed to build upon an existing network called Health Information Systems Program—HISP —initiated in 1994 by University of Oslo researchers in collaboration with the University of the Western Cape in South Africa. BEANISH developed a version 2 of DHIS in a fully open source environment based on JAVA frameworks. This second version of DHIS is currently the official system in India and will be implemented in Sierra Leone, Tanzania and Malawi in 2009.

2) **Mednet**: An eCare program dedicated to create a medical network that addresses the problem of providing healthcare from a distance. It uses teleconsultation to acquire and store medical images. Then, it transfers the information via Amerhis, a satellite (DVB-RCS)–based communication system developed by ESA and the industry.

3) **Telemedicine Task Force (TTF):** In 2006, a workshop, held in Brussels by the EC and ESA focused on the potential of satellite telecommunications technology to strengthen health systems in Africa. The TTF is mainly composed of representatives from the African Union Commission, the New Partnership for

Africa's development (NEPAD), the World Health Organization (WHO), the EC and the ESA. They called for a pilot project in the first phase of building an eHealth network for the entire continent. The project should last 18 months after it began at the end of 2008. The project will focus on connecting isolated areas in sub-Saharan Africa to medical centers of excellence in order to provide both educational and clinical services. The network being built for applications in the short term should form the core of a future large network.

4) **Balistan Health and Education Foundation**: A Pakistan telehealth facility linking the major hospital in Skardu, the capital of the Balistan region, with medical specialists available in Islamabad (800 km from Skardu). The project required connecting the area via satellite to an Internet service provider. The main constraint is the $2,000 a month needed for satellite connectivity, which could come down considerably with the use of fiber-optic cable connections. Currently being explored is the possibility of using mobile phones with built-in cameras and GPRS/EDGE connection. Phone connections for 24-hours medical-helpline services is already being used for providing first-aid information to the public clinical advice to midwives and other paramedics and linking local transport services in emergencies.

   In addition to this core activity, the Balistan Health and Education Foundation will soon test a prototype developed in Islamabad consisting of distant pre-natal examination and monitoring of rural women. This service would work through sensory equipment handled by local midwives linked through hand-held devices (combination PDA and smart mobile phones) to servers at the Gynecology Department at the district hospital who would offer risk assessment and advice.

- Digital World Forum Project on: Low cost information access devices, low cost broadband access and infrastructure, and Mobile Web for Social Development http://www.digitalworldforum.eu/

- **Other Initiatives**

Other examples of initiatives for low-cost networking in rural developing areas:

- **Meraki**: a company in San Francisco that developed a proprietary plug-and-play Wi-Fi-based mesh system, mainly targeting indoor urban deployments. It is based on MIT's Roofnet technology (Reference 16).

- **Open-Mesh**: an open-source plug-and-play Wi-Fi-based mesh solution that also mainly targets indoor urban deployments, but has accessories for outdoor deployments (Reference 17).

- **TIER Long-distance Wi-Fi**: TIER, a research group at the University of California at Berkeley, is investigating the design and deployment of new technologies for emerging regions. It has developed a Wireless Long Distance Network (WiLDNet) based on Wi-Fi (Reference 18).

- **Wireless Africa Initiative**: Various African partners are working on technology and business models that support community-owned networks. The infrastructure is owned or operated locally so that revenue from local calls stays within the community. The initiative is Led by the Wireless Africa Research Group of the Meraka Institute in South Africa and sponsored by IDRC (Reference 19).

- **Airjaldi**: A social enterprise in India that develops and deploys low- cost open-source wireless networks based on Wi-Fi technology and operates one of the largest networks of this kind (Reference 20).

- **Green Wi-Fi**: An all-volunteer organization that has developed solar-based open-source Wi-Fi mesh access to support education in developing countries (Reference 21).

- **Inveneo**: A non-profit social enterprise that has developed computing and networking systems for rural developing areas. Among other systems, Inveneo sells a long-distance Wi-Fi system and low-power desktop computers (Reference 22).

- **Village Telco**: An initiative that develops a cheap, easy to set up and use a scalable, standards-based, wireless local do-it-yourself telephone company toolkit based on Open-Mesh, analog telephone adaptors (ATAs) and Plain Old Telephone Service (POTS) (Reference 23).

- DakNet, an example of a delay tolerant network, provided by First Mile Solutions

- The book "Wireless Networking for the Developing World," which can be found online at (Reference 24) is an excellent primer. It shows how much work has already been done in some areas.
- Case studies can be found at (Reference 25).
- ITU's "Connect the World" initiative (Reference 26) and the World Summit on the Information Society (WSIS) (Reference 27).

9.0 Non-technical Constraints

If all problems could be solved through technology, the world would be a better place. Unfortunately, in most resource-poor countries, a number of other issues compound and complicate the problem. Some may be addressed through intervention and dialog, but others are more difficult and require long-term strategies or completely new approaches.

These non-technical issues may be initially divided into internal and external problems—issues caused by and resolved by events and people within the country, and issues, more regional or global in nature, that cannot be resolved by the local citizenry. In addition, some issues are primarily related to the public sector, while others are related to the commercial sector. Often several of these issues are at play at one time, further complicating the situation.

Internal issues may include:

- Politics—who is in power, what are the tribal/religious affiliations of the people in power
- Climate and physical environment—drought or flood, over farming, migration.
- Governmental policies—what is the health policy, the insurance scheme, maternal and child health care policies, etc.
- Others – Stakeholder needs, accountability, transparency and cultural issues.

External issues may include:

- Donor policies—who is providing aid, are there restrictions to what can be done with funds?
- War and refugees—problems caused by cross-border conflicts and displaced people.

- Corporate issues—the companies present in the country, their agents and vendors and the quality of these agents and their equipment, service, supply, etc.

All proposed solutions must take these non-technical issues into account. Technical issues that do not depend on the resolution of non-technical problems may be solved in parallel. But other technical problems may require these other problems to be addressed first and must wait. Complete and comprehensive work plans should be developed before work is started that identify the various issues and what they depend on.

Strategy, Policy and Regulatory Framework

A country must have a telecommunications strategy, policy and regulatory framework that ensures that technology is implemented for the maximum benefit of its people (ITU, 2002). This framework must be developed through a consultative process (involving all the stakeholders) and encourage investment by minimizing barriers to market entry and reducing risk for market players, e.g. through tariff subsidies and suitable regulations on competition and ownership.

Operators and suppliers are likely to benefit from the elimination or reduction of duty paid on imported telecommunications equipment (Hudson, 2006). In the long-term, this will benefit the country; any duties paid on equipment are unlikely to exceed the economic benefits of improving telecommunications access. Countries facing the digital divide are often dogged by corruption. The eradication of corruption at all levels is a prerequisite for creating a framework that is transparent, fair and amenable to economic growth.

The liberalization of the telecommunications sector in many countries has stimulated competition between operators and a consequent reduction in cost to end users (ITU, 2002). An independent (operationally and financially autonomous) telecommunications regulator that ensures a transparent and efficient process for relevant issues (e.g. operator licensing) is critical in ensuring fair competition and increasing connectivity. For example, according to the ITU (2002), Morocco, despite being the poorest country in its region, had the highest telecommunications uptake in recent times largely due to the presence of the region's most independent regulator.

Telecommunication services in developing countries are usually limited to densely populated, urban areas. Regulators must give incentives for extending services to rural areas, e.g. royalties could be given to operators who increase rural connectivity levels. Alternatively, a specific rural licensing process could be developed to give suitable incentives for operators to provide connectivity, as has been implemented in South Africa (Alcatel, 2005).

Based on the authors' experiences in the telecommunications industry, the principles discussed are often challenging to implement in practice. The implementation of regulations is often complicated by the tussle between existing operators and potential new entrants to the market. In fact, the outcome of a regulation process could potentially be counterproductive to bridging the digital divide. For example, in New Zealand, there are two mobile operators – Vodafone and Telecom. For several years, the government has attempted to implement suitable regulations for more mobile operators to enter the market so that costs to end users can be reduced and telecommunications development in rural areas can be stimulated. It is generally agreed that the rollout of an entirely new network is financially unfeasible for new entrants, so the government has attempted to propose a site-sharing regulation; in essence, if new entrants deploy a minimum number of sites in urban areas, they are then permitted to use existing operators' sites in less profitable (e.g. rural) areas by paying a nominal cost (based on the restrictions stipulated by the regulation).Both Vodafone and Telecom argue that this proposed regulation is unfair because they have made huge investments in their networks and the rural sites they have deployed usually do not yield profits. A potential new entrant, Econet Wireless, argues that Vodafone and Telecom are simply trying to fend off competition and are therefore unwilling to cooperate. Such a "site-sharing" regulation, if not implemented with due caution, might have a devastating outcome with respect to bridging the digital divide. Both Vodafone and Telecom might be inclined to completely eliminate the rollout of new sites in rural areas as they could potentially be used by their competition. Consequently, rural areas would lose any telecommunications growth that they might have had if such a regulation would not have been passed. Ultimately, both the government and operators have roles to play in ensuring that telecommunications is implemented so that equality of access is achieved and consumers are charged reasonable prices. The vision of serving society and putting people at the heart of all decisions must unify the different parties. With respect to the situation in New Zealand, a possible solution might be for government to subsidize (partially or fully) the rollout of sites in rural areas. This would stimulate operators to provide coverage to rural areas, while also ensuring fairness in competition between operators.

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