Informatics Technology for Use in HIV/AIDS Treatment in Resource-Poor Settings

Michael Rodriguez, Mark Spohr, Theo Lippeveld, Michael Edwards

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MEASURE Evaluation

Carolina Population Center
University of North Carolina
at Chapel Hill
123 W. Franklin Street
Chapel Hill, NC 27516
Phone: 919-966-7482
Fax: 919-966-2391
measure@unc.edu
www.cpc.unc.edu/measure

Collaborating Partners:

Macro International Inc.
11785 Beltsville Drive, Suite 300
Calverton, MD 20705-3119
Phone: 301-572-0200
Fax: 301-572-0999
MEASURE.Evaluation@orcmacro.com

John Snow, Inc.
1616 N. Ft. Myer Drive, 11th Floor
Arlington, VA 22209
Phone: 703-528-7474
Fax: 703-528-7480
measure_project@jsi.com

Tulane University
1440 Canal Street, Suite 2200
New Orleans, LA 70112
Phone: 504-584-3655
Fax: 504-584-3653
measure2@tulane.edu

Futures Group International
2605 Meridian Parkway
Durham, NC 27713
Phone: 919-313-7722
Fax: 919-313-7523

Funding Agency: U.S. Agency for International Development
Washington, DC 20523-3600
Phone: 202-712-4959

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Table of Contents

Glossary of Technology Terms

Bar codes	The machine-readable (scannable) version of a universal product code (UPC), the standard 12-digit identification code identifying both product and vendor.
Biometric	A measurement that reflects an anatomical component unique to an individual (e.g., fingerprint, retina, voice wave).
CD-ROM/ CD-RW	Compact discs are magnetic storage discs that can be "read only memory" (CD-ROM) or "read-write" (CD-RW), which allows information to be appended to the disc multiple times.
Data mining	Database applications that look for hidden patterns in a group of data that can be used to predict future behavior.
Data dictionary	A file that defines the basic organization of a database.
DSL	Digital subscriber line, the type of broadband connection that brings information to homes and businesses over ordinary telephone lines.
Ethernet	A local area network (LAN) architecture that allows multiple computers to be connected to each other with wires.
EMR	Electronic medical record
FTP	File Transfer Protocol, a communication protocol used with the Internet.
Flash drive	A small, portable flash memory storage drive that plugs into a computer's USB port.
Flash memory	Computer memory that can be erased or programmed in blocks, rather than smaller bytes, thus allowing faster processing than routine memory composed of bytes.
FOSS	Free and open source software. (A good place for obtaining FOSS is at www.opensource.org)
GPRS	General Packet Radio Service, a technology used by Global System for Mobile Communications networks.
GPS	Global positioning system, a means of determining geographic locations using a network of satellites.
GSM	Global System for Mobile Communications, a leading digital cellular system.
HL7	Health Level Seven, one of several standards developing organizations (SDOs) operating in the healthcare arena. HL7's domain is clinical and administrative data.
HTML	Hypertext markup language is the authoring language used to create documents posted on the World Wide Web.

HTTP	Hypertext Transfer Protocol, a communication protocol used with the Internet.
ICT	Information and communications technology, a broad category of tools facilitating the collection, storage, analysis, transmission, and display of data.
IP	Internet protocol, a standard for packets of data to be "addressed" for shipment over the Internet, used in conjunction with transport control protocol (TCP).
IT	Information technology.
LAN	Local area network.
Metadata	Information that describes how, when, and by whom a particular set of data were collected, and how the data were formatted.
MPI	Master patient index.
OS	Operating system
PDA	Personal digital assistant, a portable handheld device that combines computing, telephone/facsimiles, Internet, and networking features.
PDT	Portable data terminal, a handheld device for capturing and storing data in the field, generally for a single purpose.
PEPFAR	President's Emergency Plan for AIDS Relief.
RFID	Radio frequency identification, technology similar to bar codes that allows items to be "tagged" and recognized using a radio frequency reader.
RHINO	Routine Health Information Network, created by the MEASURE Evaluation project, the World Bank, and John Snow, Inc., promotes high quality and practical approaches to the collection and use of routine health information in developing countries. The network is funded by the U.S. Agency for International Development and offers a Web site at: www.rhinonet.org.
Smart cards	A plastic card about the size of a credit card containing electronic memory and used for transporting data.
SMS	Short message service, available on digital GSM networks.
SMTP	Simple Mail Transport Protocol, an Internet e-mail protocol.
SQL	Structured query language, a standard method for sending requests to a database for information retrieval.
TCP	Transport control protocol enables two host computers to establish a connection and exchange data, typically used in conjunction with IP.

USB Universal serial bus, a plug-and-play interface between a computer and add-on devices, such as mobile phones, audio players, scanners, and printers.

WAN Wide-area network, a network that uses high-speed, long-distance communications technology (e.g., telephone lines and satellites) to connect computers over long distances.

Wi-Fi Wireless fidelity, a transmission method for sending data via radio frequencies rather than through wires or cables.

XML Extended markup language is a specification that allows designers to create their own customized tags, enabling the definition, transmission, validation, and interpretation of data among applications and organizations.

Executive Summary

The President's Emergency Plan for AIDS Relief (PEPFAR) is a large-scale effort to promote HIV/AIDS prevention, treatment, and care services in the resource-constrained countries that are the most afflicted by the epidemic. One of the areas of greatest potential impact for improving the infrastructure in these countries is in the realm of information and communication technology (ICT) tools. Collecting, managing, and analyzing patient-related information in an efficient and consistent manner at all levels of the health systems (i.e., ministerial, district, and facility levels) could potentially enhance the effective allocation of scarce resources (e.g., anti-retroviral therapy drugs, nursing staff, etc.), improve patient management, evaluate treatment protocols, and ultimately have a beneficial impact on the clinical outcomes for people living with HIV/AIDS. In addition, the ability to evaluate the impact of development funds expended under PEPFAR is a key goal for the United States government.

While widely recognized for their potential benefits in the health care sector, technology tools have not been widely or systematically evaluated for their potential applicability to HIV/AIDS clinical and tracking programs in resource poor settings. Several in-depth evaluations of a single aspect or type of technology (e.g., using hand-held devices called personal digital assistants [PDAs] as electronic questionnaires) have been recently undertaken with promising findings, but few evaluations have focused on the HIV/AIDS field and apparently none have sought to catalog or evaluate multiple technologies. With PEPFAR countries conducting their evaluations of program needs and resource allocations, technology tools to facilitate such efforts are critical.

In 2004, the U.S. Centers for Disease Control and Prevention (CDC) commissioned this paper from MEASURE Evaluation with the goal of identifying information technology showing the potential to facilitate the collection, analysis or evaluation, and dissemination of data necessary for delivering high quality HIV/AIDS care in the countries targeted under PEPFAR. MEASURE Evaluation launched a research effort to identify potential technology tools for inclusion in this paper, with a goal of locating tools that have the potential to improve health information collection, management, and use. Some of these technologies are currently being used in the health care field and have been field tested in resource poor settings. Others have potential for use in the health care field and should be further investigated. As with any instrument, the true value of technology tools is only fully realized when the information gathered with them is fed back into the programmatic evaluation, planning, and management process. This paper is the resulting product of that research and distillation effort. The true testament of this paper's utility will be measured by the extent of use of its research, recommendations, and application in the field.

Part 1 — Case Studies

In an effort to maximize the utility of this report to field personnel, it has been organized around hypothetical case studies that are intended to demonstrate the types of situations to which the technologies reviewed in more detail could potentially be applied and to outline potential methods for evaluating the technologies for the reader's particular situation. The case studies presented below are not meant to be exhaustive, merely to convey to the reader practical situations that will hopefully illustrate ways to evaluate situations in which such technologies can be utilized.

These case studies refer to specific technologies. Each of these technologies is discussed in detail.

In order to create a structure in evaluating different technologies with a wide range of application, it is useful to attempt to categorize them. The following categories of technology tools are highlighted in order to describe each of the tools discussed effectively and to assist readers in determining the most appropriate technologies for their environments and situations:

Data collection and display — These features refer to the "human interface" to technology tools. These systems include a display screen and a way to input information through such devices as a keyboard, a touch screen, via voice, etc. Important considerations to be reviewed include the ability of the display screen to be viewed, the ease of data entry and retrieval, the logical presentation of information, and tools provided to assist the user in making decisions about the information collected and displayed.

Data communication — How data are transmitted from one device to another or from one location to another falls into the realm of communication. Key issues to be addressed here concern the speed, reliability, and security of information being transferred.

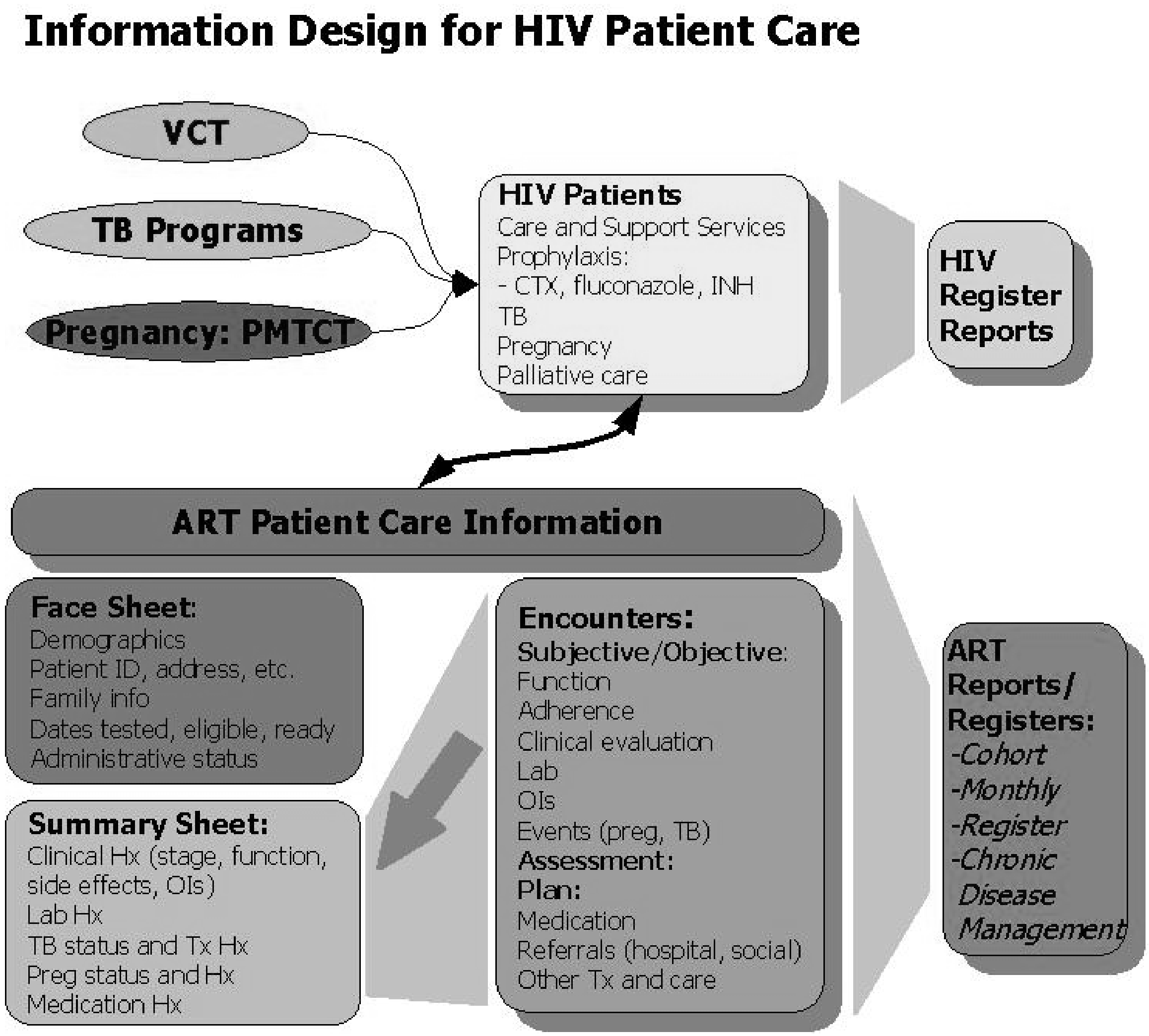
Data storage — Technologies for storing data are rapidly changing and improving, providing significant opportunities to utilize high-capacity storage devices with improved security and durability, while prices continue to decline. Simple data storage solutions, such as paper, must still be considered for appropriate situations.

Patient identification — A system to identify each patient through a unique patient identifier is of critical importance, particularly in situations where patient populations are mobile; where highly-sought-after medical treatments are in short supply, such as antiretroviral drugs; and when patient privacy is paramount. Important considerations include cost, security, and durability.

Data management — Information in electronic format has the potential to provide comprehensive and rapid assessments for management, monitoring, and policy making. A key consideration must therefore be given to how data are stored, organized, retrieved, analyzed, and communicated in order to be of use to analysts, program managers, and policy makers.

It is important to remember that these categories are not meant to be limiting, but rather define specific areas that are useful to be considered when evaluating technology tools for use in the field. There are other non-categorical aspects affecting many of the decisions made for selecting the appropriate technology tools that are equally important, such as environmental constraints. These broader issues will be addressed in this paper.

Case Study: A Clinic Operating in a Remote Village



In this hypothetical case study, a recently established voluntary counseling and treatment (VCT) and antiretroviral (ART) clinic that serves a rural area is identified by survey as having a population of 10,000 HIV-positive individuals. The clinic registers HIV-positive patients and incorporates legacy data from paper VCT registers in the area. The clinic also identifies patients eligible for ART treatment and initiates treatment. About 120 people a month receive VCT. Staff members are a physician, two nurse practitioners, and a registration/data entry clerk. The clinic has electricity but with intermittent outages, and does not have a land-line telephone. Because of the remote location, technical support is difficult.

The clinic collects local information to identify, qualify, and manage treatment of HIV-positive patients. This includes data on VCT, ART preparation, ART management, tuberculosis (TB) treatment, and palliative care. The clinic also reports on activities to a district office and arranges the logistics of drugs and other supplies.

What are the most limiting factors in choosing appropriate technology tools to enhance the operations and management of such a remote clinic? How important is the intermittent electricity issue? What about the staff's computer and data skills? Are there effective ways to improve the capture, storage, evaluation, and reporting of data in this setting?

This clinic is located in an area with weak infrastructure, so use of any technology is tenuous. Consequently, systems should be designed to operate from paper records when the technology is not available due to lack of power or other technical difficulties. However, there are distinct advantages to using technology in this setting in terms of managing patients and logistics. Appropriate technologies should be considered.

Data Collection and Display

The primary data needs in this clinic are for a patient register and maintaining ART records.

A computerized register makes the task of recording, finding and updating, and reporting information on a large number of patients easier than a paper system. This can be done with a simple "register" database on a desktop computer. Because a computer will not always be available, paper printouts of the data should be produced for use during those times. Alternatively, the register can also be reproduced on a hand-held personal digital assistant (PDA), which can operate on battery power during outages. The PDA has a small screen and limited data entry capability, so it is not the ideal primary data-gathering tool. However, it can provide patient search and update capability whenever a desktop computer is not available.

Maintaining ART records involves having detailed patient information in the form of longitudinal medical records available at the point of care. Traditionally, this has been done with a paper record stored at the clinic or carried by the patient. However, there are advantages to having the information electronically since the information can be retrieved more easily than paper records. The computer also has the ability to provide intelligent analysis and treatment advice. In this clinic, a PDA can provide portable information at the point of care, can operate on battery power, and can provide analysis. The information on the PDA can be synchronized with master storage on the clinic's desktop computer.

PDAs are inexpensive, reliable tools for collecting basic patient information in a setting with limited access to dependable electricity. Batteries typically recharge with as little as an hour or two of electricity access and last for about five days when fully charged.

Data Communication

As a government-funded service, the clinic is required to submit quarterly reports to a district office on services provided, including patients seen, tested, and treated. The district health office does not have access to the Internet or a robust information management system, although it does have several older computers. Clinic reports on paper are typically submitted, but have the office has the capacity to read electronic reports and is developing an electronic district health information system.

As previously mentioned, the clinic does not have a land-line telephone but mobile telephone coverage may be available. However, the clinic should not rely on mobile telephones to submit periodic reports and facilitate logistics of drugs and supplies. A better option is to submit the information using such data storage devices as computer disks (CDs) or USB memory sticks. These devices can store a complete backup of the clinic's data, which can be submitted along with summary reports. The resulting off-site storage of clinic data is a valuable backup in case of catastrophic loss of data at the clinic. The district can also use the data set to perform more detailed analysis of the data, such as analysis of service quality or patient status issues. These analyses can be used to improve services at the clinic.

Data Storage

The clinic needs to store clinical patient records for approximately 660 patients. It needs to track tests administered and their results, and will eventually need to monitor ARV regimens and supplies. In this clinic configuration, primary data storage is on a desktop computer. These data can be backed up daily to a writable CD or a universal serial bus (USB) memory stick. Selected data are backed up (synchronized) with data on the hand-held PDA computers. The desktop computer can also print paper copies for storage in the clinic or to be given to patients. Printouts provide a backup database.

Patient Identification

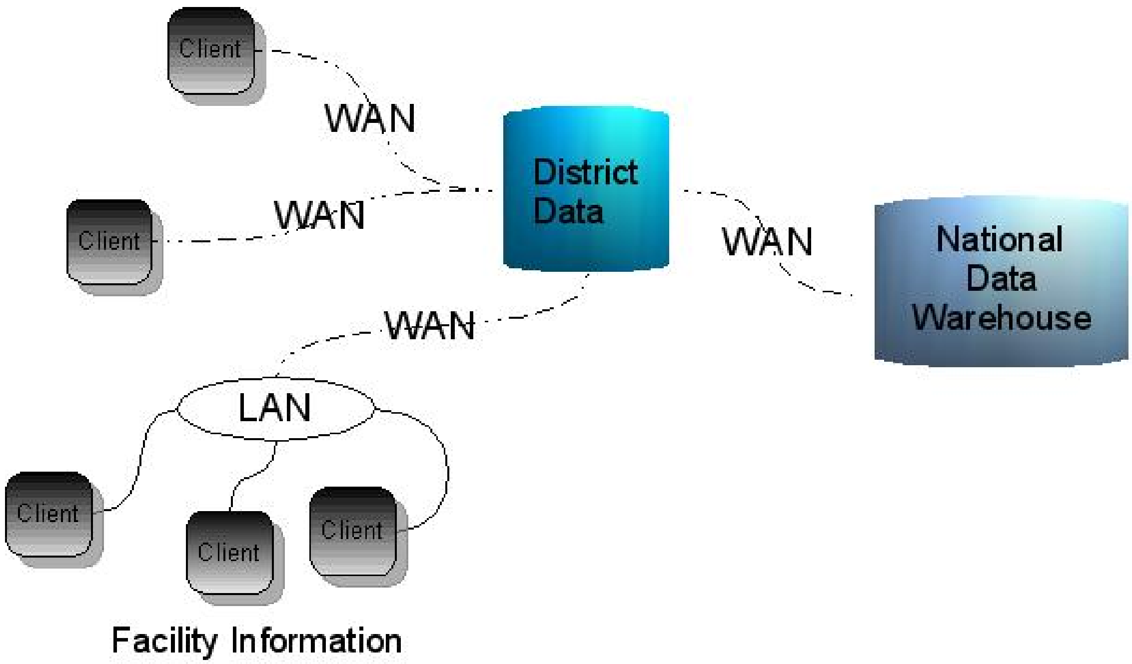
Since there is no national or regional patient identifier for the region, the clinic must design its own patient identification system. For VCT, patients need not be assigned a formal identifier since they can be identified adequately from their name, birth date, address, or similar information. The clinic identifier stays in the clinic, so is confidential. HIV-positive patients should be assigned a clinic identification number to track pre-ART activities with care and support activities. For confidentiality reasons, the clinic may not want to issue an identification document unless this is a regional clinic identifier that does not carry any connotation of HIV status. A common medical clinic identification card is usually suitable.

For ART care, it is important to have a reliable patient identifier to ensure that all records for each specific patient are linked, and to assure that drugs are properly dispensed to the right patients. For patient confidentiality purposes, any identification material given to the patient should not carry any expressed or implied HIV status information. This is commonly done by using a standard clinic registration card for all patients in the region. Because of the importance of unique patient identification, biometrics such as a photograph or description should be on the card. More advanced technology (e.g. bar codes, radio frequency identification [RFID], or fingerprints) can be considered, but these require significantly more resources than this rural clinic is likely to have.

Data Management

The clinic's staff probably has some experience working with a paper register system and hopefully has some computer experience. However, training to use the desktop computer and PDA software, including data synchronization and backup procedures, is typically needed. An important factor in ease of data management is to have simple, reliable software. Clear, well-defined procedures are also essential. Initial training plus reinforcement of data quality checks in a process of continuous quality improvement is the best approach.

Case Study: A District Level Health Administrative Office Receiving Data from 22 Facilities



This hypothetical case study looks at a district health office, typically the next administrative level above clinics.

The district health office is the primary management unit of the health system. It has direct authority and responsibility for service delivery in its area. Because of this, it can have a profound impact on the quality and efficiency of health services. However, in order to do this, it needs good information, based on timely and accurate data.

A more basic issue is the selection of appropriate indicators. Indicator selection is usually done at the national level but districts may have some discretion to add their own indicators. A minimal number of indicators appropriate for district level monitoring is the best approach. Information technology can improve the quality and timeliness of the information.

The data for the district originates at the clinic-level facilities. A good system allows the people at these facilities to collect data easily and be able to send data to the district for analysis, as well as to national level offices. These data are usually summary information rather than individual patient data. The summary information comes from routine activities that are typically recorded on registers of patient visits.

A modem telephone network connection can be a good method to submit district reports, assuming the clinics have reliable electric power and land-line telephones. Some of the facilities may have access to higher speed communications. A few facilities may need to submit paper reports because they do not have computers or telephone connections. It is important to design systems with a manual paper data route, since electronic systems are not completely reliable.

Data Collection and Display

Given this situation, a wide area network (WAN) system is a good option. Data entry is usually done on a computer at the clinic, which connects electronically to the district for sending data and receiving reports. Since this wide area network connection may not always be available, the system should be designed to allow batch electronic submissions of data and receipts of reports rather than continuous or "real-time" submissions as data or reports are generated.

A clinic may have only one desktop computer. Larger facilities with a better infrastructure, however, may have several computers, which could justify having a local area network (LAN) for data entry and retrieval from a common local database. These larger facilities can also consider installing computer-based patient registers. A computer patient register improves accuracy by recording patient visit data directly on the computer, where this information can be checked easily for accuracy and completeness. Other sites will compile summary information from paper registers manually and enter the summary numbers into a local database.

The advantages of a WAN system are improved data quality due to computer data verification, improved timeliness of data, and automatic analysis and reporting of results giving prompt feedback. If the clinics and other local facilities use electronic patient registers, the district office can also use these for a more detailed analysis of service delivery and quality.

Data Communication

This case assumes a WAN established primarily through land-line, dial-up modem computer connections. This configuration is sufficient to batch send and receive data and other reports. If the technology is available, high-speed data connections that are continuous (i.e., are "always on") can be used to improve the speed of access. However, until continuous high-speed connections can be guaranteed, systems should not be configured to require constant communication with the district database. Instead, clinics should rely primarily upon their local data storage.

Dial-up modem connections are fairly reliable and easy to troubleshoot. High-speed wired connections (such as a digital subscriber line [DSL]) can be more problematic if they are not well-supported by technicians. Wireless technologies for high-speed access are currently limited to LANs. Mobile phone wireless data access is not generally reliable and is usually low speed and, therefore, has limited usefulness for the volume of data involved in district reporting.

Data Storage

This system stores data at each facility on a local personal computer or in a LAN database. With a WAN to the district office, data are transmitted to the district for analysis and backup. The local facilities also make copies of their databases on storage media, such as CDs or USB memory sticks.

The district office many have several computers in a LAN connecting to its single database. This database should be backed up to a writable CD for permanent storage, and preferably stored off-site in case of fire or other disaster. These data can also be sent electronically to regional and national levels for storage.

Patient Identification

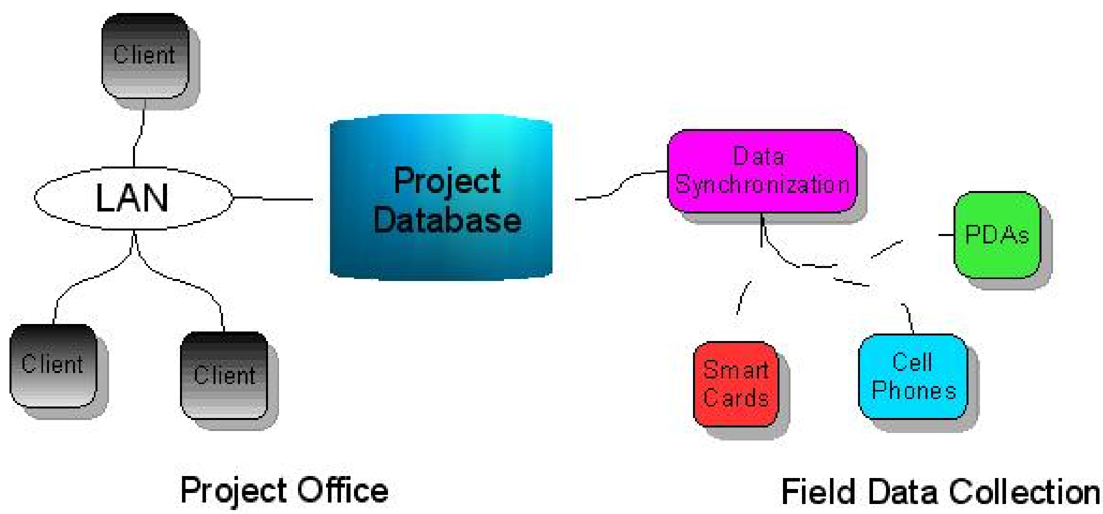
Individual patient identification is usually not an issue at the district level because only summary aggregate information is submitted. However, any clinic services that depend upon continuity of care (such as prenatal or ART care) will benefit from the ability to identify individual patients when they return for care. For these purposes, a patient identification system, such as a card with a photo or description and an identification number, is sufficient. The identification number should be entered into the register system or the individual medical record system at the facility when the patient visits so that the patient's medical history can be viewed at the point of care. This improves patient care. Patient identification is best organized at a high level to provide uniform indicators and transportability. In order to avoid stigmatization, any identification should not explicitly or implicitly imply any specific medical condition.

Data Management

Although district staff members typically have extensive experience working with a paper register system and some computer experience, intensive training will be necessary on the use of specific desktop computer software. Data entry and verification procedures are crucial to ensure accurate data. Training should also include operation of the WAN, including clearly defined procedures for connecting, sending, and receiving data. Data synchronization and backup procedures need to be defined. An important factor in ease of data management is to have simple, reliable software.

This kind of data system requires a dedicated information technology (IT) staff to maintain the computers at the district level and at service facilities. This includes troubleshooting hardware problems and maintaining LAN, WAN, and data backup and transmission processes. In addition, IT staff should understand the database and work with the district staff to produce reports and maintain the district data warehouse. It is likely that this system will not be confined to just one district within a region or country, so IT staff could be used to serve wider geographic areas.

Case Study: A Mobile Medical Van Serving Remote Areas



One of the major goals of PEPFAR is to provide VCT services. VCT helps people living with HIV/AIDS to prevent spreading their infections of others. They can also be monitored for disease progression and can receive social and medical support services. A mobile clinic is a good way to provide VCT to people in remote areas.

The information system for a mobile clinic serving HIV patients is usually built around an HIV register. The clinic must track people served, submit reports, and register those who are HIV-positive so that they can receive further services. A system of paper registers is commonly used but this has several drawbacks. The paper information cannot be easily searched to retrieve individual patient information, it is tedious to use for compiling reports, and paper records cannot be easily copied for backup or use at multiple sites.

A mobile van may not be able to support a standard desktop computer but could still use a computer information system to register and retrieve patient information. For example, a PDA that has a copy of the patient register could be used to retrieve patient records and enter new patient information. The amount of data entry is relatively small for an HIV register, so a PDA is feasible for serving people living with HIV/AIDS. A PDA can operate on batteries during the van's rounds and can be recharged from the van's battery, if necessary. The HIV register will need to be synchronized to a desktop computer database at the project's headquarters for backup, analysis, and reporting. The project office can support more than one mobile team from a desktop computer database.

If reliable cell phone service is available, a cell phone can be used to send and receive data between a van and its project office, provided only a small number of patients are involved. This can be done in real time to enter and retrieve data or done in batches before or after visiting areas where the cell phone service is not available. In order to display the information properly and provide adequate data storage, a PDA device will be necessary. The PDA can be used in conjunction with a cell phone or could be a device that combines PDA and cell phone functionality. This system requires a high level of technology development and support capacity, and should not be undertaken if adequate support can not be assured for the duration of the project.

Data Collection and Display

A hand held PDA is a good solution for data collection and display of HIV register information and to collect information on the mobile team's activities. This can operate on battery power and can be used autonomously or connected to a cell phone for data communication. The PDA database can be synchronized to a desktop computer at the project's headquarters, where analysis and reporting can be done. Multiple PDAs can be synchronized on the desktop.

Data Communication

The primary data communication method in this case study is physically transporting a PDA device from the field to the project's office for data synchronization. An alternative is to use a PDA with a memory card and transport the card to the project office. Most PDAs support memory card use and this gives added flexibility, since multiple cards can be with each PDA.

Using cell phones for data transfer removes the need to transport data physically. If the infrastructure and technology support staff are available, this can be a desirable feature.

Data Storage

The primary database would reside on the desktop computer. This can be a single computer or on a LAN with multiple computers having access to the database. The database should be backed up periodically. PDAs also store a copy of the database for use in the field. The PDA copy can be a complete copy or a subset tailored for the area of activity.

Patient Identification

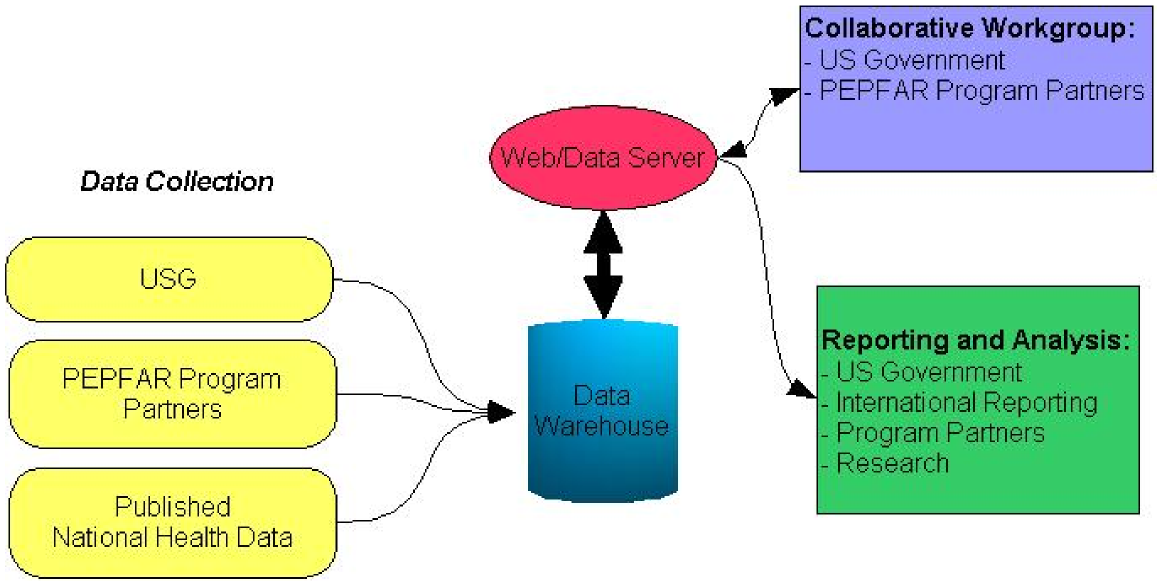
Patient identification is a major issue when dealing with HIV/AIDS. Patients who are registered as HIV positive will need to be identified so that they can be tracked to receive support services. In the absence of a national identification card, this issue is problematic. The best alternative is to use some form of identification that does not carry any indication or connotation of HIV status. If there is any other form of identification in common use, such as a general medical clinic registration card or even a card issued for non-medical purposes (such as a work permit or social benefit registration card), then one of these can be used for identification. Alternatively, patient identification can rely on information that the patient knows, such as name, address, home village, and birth date. Even if some of this information is missing or inaccurate, a computer can be used to search for the best match and locate this patient's records.

Data Management

Field workers will need to be trained in data entry and retrieval on the hand-held PDA. The amount of data entry in the field is limited, so the interface with the PDA should be fairly simple. Procedures to synchronize the data from the field with the project office should be clearly defined and people at the project office should be trained to perform this function. If the option to use cell phone data communication is used, keep in mind that this is a more complex system requiring significant technology support and adequate training staff.

Staff at the project office will also need to be trained in procedures to back up the primary database. Data analysis and reporting procedures can be set up to be done routinely with proper training. In order to provide advanced analysis and "ad hoc" reporting, a person trained in database analysis should be available to the project. The project will also require a technology staff to maintain the desktop computer (and optional LAN), as well as the field PDAs.

Case Study: Numerous Partners and Subcontractors Submitting Reports



A hypothetical U.S. Agency for International Development (USAID) mission within a country served by PEPFAR has 72 funded prime partners that are required to report to the mission on a quarterly basis. Many of the partners have sub-partners. The mission in turn submits reports to USAID in Washington on a semi-annual basis. The plethora of funding sources, projects, and contractors involved in aid work presents a huge management problem. The mission must monitor the activities of all of its partners to ensure appropriate use of funding and to report results.

A data warehouse can help track information on projects, partners, and monitoring indicators. The data warehouse consists of related data tables that contain information on the various aspects of the projects, along with data analysis and presentation tools. The data warehouse needs to be designed to track relevant project, partner, sub-partner, funding, and monitoring indicator data. Ideally, it will contain an Internet interface for access by partners, allowing them to update information and report results. The data warehouse should also include data analysis tools for analyzing compliance and performance. If the funding agency has defined an electronic reporting format, reporting can be automated.

Because the offices of the various partners are physically dispersed but are likely to have good Internet connections, the best design for this case study is a database with a Web-based interface. The hardware consists of an Internet Web server computer, which contains a relational database. All access to the data warehouse can be achieved through the Internet. Because this is a Web-based approach, this server can by physically located anywhere. The Web-hosting location should be selected based on the electrical power, communications, and environmental infrastructure, as well as the availability of technical support for this equipment.

Data Collection and Display

The interface to the data warehouse is through the Internet using standard Web-browser software. This means that access is available at any location that has is an Internet connection. The browser interface requires no special software for access. It provides a graphical interface for data entry and data presentation. All of the partners can use this to enter and access their information. The funding source can use the interface for query, analysis and reporting.

Data Communication

The data warehouse depends on the Internet for all of its communication. In most countries, there is a good Internet infrastructure in place in the major cities. One advantage of relying on the Internet is that it is one technical piece that doesn't need to be directly managed since technical support is part of the infrastructure.

Data Storage

The primary data storage is on the Web server hardware. This can be backed up periodically at the Web server site to tape, writable CD, or remotely over the Internet.

Data Management

The Web interface can be customized for partners to an easy to use series of data entry and viewing forms. Partners will need to be trained to access the system and enter and retrieve their information. The funding agency will also have a series of forms for analysis and reporting and the staff will need to be trained to use these. In addition, the funding agency should retain database professionals to configure, maintain, and assist with advanced queries and analysis.

Key Findings

The spectrum of technology tools available for application in the field of health care and specifically in the care, treatment, monitoring, and evaluation of HIV/AIDS programs is limitless and no single review could consider them all. However, a number of key observations are important to consider when selecting the most appropriate tools for research or field use:

- A number of large-scale evaluations have shown the efficacy of using PDAs.
- In HIV/AIDS programs, there is significant potential to use PDAs for data gathering, clinical monitoring, and as resource guides.
- Technologies such as cellular telephone data communication, global positioning system (GPS) devices, bar codes, and smart cards are promising, but have not been widely tested.
- Technologies such as RFID and biometrics (such as fingerprints) may be useful in certain situations, but this remains to be demonstrated.
- Few technology tools have been tested specifically in HIV/AIDS programs in resource poor environments, although they have been used in related health care services in these environments.
- In settings where new technologies have been pilot-tested, there appears to be little resistance at the local level to the introduction of these technologies. However, training and support issues must be addressed.

Opportunities

A number of specific technologies present significant opportunities for application in the HIV/AIDS program field. Based on cost, portability and mobility, and simplicity of implementation, these promising technologies warrant further research and consideration:

- Wireless telephone technology and connectivity (cell phones) provide an opportunity to distribute text and data using short message service (SMS) and general packet radio service (GPRS) protocols.

- With the ease of customization, the mobility, and the increasing storage and ubiquitous connectivity (i.e., wireless connectivity), PDAs present a tremendous opportunity to provide electronic data collection functions in remote locations, as well as to provide data and clinical decision support at the point of care.
- Smart cards that contain medical records and embedded security features has clear potential in the HIV/AIDS clinical realm.

Challenges

Mobile or portable technology tools face some of the same challenges in implementation and support that are inherent in such stationary technologies as computers and database servers. Not to be forgotten are the issues that can ensure successful implementation and on-going sustainability of these tools in the field:

- Additional field testing of identified technologies in resource poor environments, and with HIV/AIDS programs specifically, is needed.
- Locally relevant resources (including language appropriate resources) must be available for the technology tools utilized.
- Specific staff to maintain and support PDAs or other peripheral technologies must be designated and adequately trained to ensure long-term viability of these technologies.

The remainder of this paper provides details about the technology tools previously highlighted, including operating features, development trends, and costs. This discussion includes tools that have been evaluated in research settings, with particular attention on those that may be applicable to use in HIV/AIDS programs in resource poor environments.

Part 2 — Specific Technologies

PEPFAR is a large-scale effort to fund HIV/AIDS prevention, care, treatment, and research activities in 15 developing countries. One of the areas of greatest potential impact for improving the capacity of these countries is in the realm of information and communication technology (ICT) tools. Collecting, managing, and analyzing patient-related information in an efficient and consistent manner at all levels of the health systems (i.e., ministerial, district, and facility levels) can enhance the allocation of scarce resources (e.g., antiretroviral therapy drugs, professional staff, etc.), improve the monitoring and evaluation of treatment protocols, and ultimately have a beneficial impact on the clinical outcomes for AIDS patients.

One of the key areas where resource poor countries face great challenges in improving their HIV/AIDS planning, treatment, and research programs is in identifying, evaluating, and acquiring the plethora of ICT tools currently available in the market place or emerging as potentially applicable to their programs. In an effort to provide the decision makers and program managers with more of the information resources they need, this paper examines a host of issues related to the potential application of established and emerging technologies to the delivery of quality care to HIV/AIDS infected individuals. This paper's review builds on an initial inventory paper titled *President's Emergency Plan for AIDS Relief Software Inventory Report*, which evaluated desktop PC and server-based systems for monitoring clinical activities. The PEPFAR inventory report and related information is available on the RHINOnet.org Web site:

http://www.rhinonet.org/tikiwiki/tiki-index.php?page=ART+Inventory

Some of these technologies have been implemented and have been shown to be useful; others have yet to prove their value fully. Technology implementation in the unique environment of developing countries, where the infrastructure to support technology, electric power, communications, and human resources are limited, is discussed.

Infrastructure constraints — It is imperative to maintain a realistic perspective on the problems and challenges faced when implementing ICT in resource poor environments. Mid- to long-term implications need to be evaluated and planned for accordingly. The evaluation of peripheral ICT tools for potential application to HIV/AIDS clinical environments also needs to maintain a perspective of skepticism that every potential solution is appropriate. In an assessment titled *Health, HIV/AIDS and Information and Communication Technology: A Needs Assessment*, the D.S. Bateson Consulting group surveyed individuals and organizations providing health services in developing countries (with a particular emphasis on Africa) on the question of ICT promotion in health and in particular in the fight against HIV/AIDS. The group provided clear, concrete recommendations:

> For HIV/AIDS, initiatives to promote and capitalize on ICT should focus on three areas:
>
> 1. Creation and dissemination of preventive public health information in community based projects for educating the public and specific target groups, and making use of more common ICT: radio, television, video, CD-ROMs and printed material.
> 2. Application of ICT to improving the access to information, education and communication for health workers in particular at the community and rural level.
> 3. Enhancing the population health (epidemiology) and research capacity of developing countries towards evidence-based decision making should be

promoted.[1]

In addition, the assessment recommended that projects "should build onto existing systems and infrastructure wherever feasible to capitalize on existing investment, contribute to building the bigger system picture and re-enforce local capacity development."[2] While recognizing the power and potential for ICT in developing countries, the survey results clearly point toward focusing on the information and communications "channels" as opposed to the "technology" when implementing solutions. Project managers must carefully plan for the limitations within their infrastructure environment so that patient and data flow will be maintained. Alternative information and communication technologies have the potential to work around gaps in existing power and communications infrastructure. For example, low power battery operated devices, such as handhelds, can be used where reliable electrical power is not available. In addition, devices that can store and forward information can be used to communicate asynchronously when connectivity is not available continuously.

Support and Maintenance — Technology requires trained people to implement and maintain the systems. This can become problematic in low resource environments. Technology should be evaluated from the aspects of reliability and availability of support personnel as well as ease of use.

Because of this, particular attention should be given to training and support. Systems that are simple to set up and use are preferred to those which are complex and require extensive training and maintenance. The "keep it simple" principle should be of primary importance. When assessing data sets, one should select systems that have been simplified to collect only the minimum necessary information. Systems that rely on support from outside a country are less desirable than those that do not have this constraint, and these systems should not be selected unless there is a sincere commitment to provide the training and institutional support necessary to establish an in-country support infrastructure that will become self sufficient. The selected technology should be implemented with a comprehensive training and support plan.

Software issues — Although this paper primarily covers hardware technology, information systems include computer software. Software is often imbedded within a hardware device, making it transparent to users. However, in the case of devices such as PDAs and tablet PCs, decisions will need to be made regarding software applications. In the storage of information, database software will need to be specified. This decision has its own set of evaluation and use issues.

Complex software applications can run on PDAs and tablet PCs. It is important to select software that meet functional requirements, user interface ease of use, and has proper support for these devices. Local support for training, maintenance, and modification is important. (The PEPFAR inventory report previously mentioned elaborates on these software issues.)

If requirements cannot be met with existing software (or modifications to existing software), it may be feasible to design and build custom software. This is a difficult task that should not be undertaken lightly. It is almost always easier to acquire or modify existing software. However, if the resources and skills are available, custom software can be a viable option.

Software design and development is beyond the scope of this paper, but there is one design principle that is particularly relevant for developing country environments — the minimum data set. Often there is a tendency to design software that is more complex than necessary, and to collect more information than is necessary. The reasoning often stated is that as long as the system is being implemented, additional information or functionality might as well be included. This can become a

[1] D.S. Bateson Consulting, Inc. Health. HIV/AIDS and information and communication technology: a needs assessment, May 2002. Unpublished: 46.
[2] Ibid.

path to failure.

For example, there will be the additional burden of training and implementation for each additional piece of information or functionality added to the software. These can easily become so numerous that a new system cannot be reasonably implemented. At the start of designing software, it is crucially important to determine the *minimum* data set and functionality necessary to perform the task. This minimum set should be the design goal. When selecting or designing software, highest priority should be given to software that meets the minimum design set, rather than selecting software with the most “bells and whistles.”

One type of software that can be particularly attractive in a low resource environment is free open source software (FOSS). This is software that is provided with the source code that can be used to maintain and upgrade the application. It allows users to take advantage of the shared software development efforts of others. FOSS offers the potential to develop local capacity for maintenance and enhancement and is therefore more “development friendly” than closed software. FOSS is also free of purchase or licensing costs. One needs to consider the total cost of ownership, which includes not only the initial acquisition cost, but also the lifetime cost of maintenance and upgrades as well as training and support. Because of the free acquisition cost and the ability to develop local maintenance and upgrade capacity, FOSS often has the lowest total cost of ownership.

As with Part 1 of this paper, the specific technologies that follow are organized under the following headings:

Data collection and display — Important issues are user interface design, ease of data entry, presentation of information, and decision support. Related technology issues are portability, power (battery life), ruggedness, reliability, and cost. Data collection and display technologies in this paper include PDAs, cellular phones, tablet PCs, and portable data terminals (PDTs). Collecting information on paper forms is discussed, including ways to import data into computer systems

Data communication — Communication technology encompasses wired telephone and computer communication, wireless telephone and computer communication, and a wide variety of technologies that physically move data storage media from one location to another (sometimes called “sneaker-net”). Current communication protocols include cell phone (GSM, GPRS) and the Internet (FTP, HTTP) protocols, and e-mail (SMTP) protocol. Higher level protocols include XML and HL7, a health-specific protocol.

Data storage —Important storage issues include backup, access, and security of the information from unauthorized access. Sending data for administrative use and protecting patient identification information are important concerns. Media include smart cards, floppy discs, compact discs with read-only memory (CD-ROM), compact discs with read-write capability (CD-RW), flash memory, and paper (including forms that can be scanned for electronic use).

Patient identification —Good technologies are available that can be used with a master patient index (MPI) to ensure accurate identification. However, some technologies are of marginal or questionable value in developing country environments. Patient identification technologies include a variety of biometric methods: photographs, fingerprints, iris or facial recognition, dental, dynamic signature, hand geometry, and speech are some of the more commons methods. Portable devices that patients can carry to identify themselves (which may include biometric information) include smart cards, RFID, bar codes, and paper ID cards.

Data management — Data must be organized, communicated, stored, and analyzed in order to be of use. The data management section discusses information management tools and technologies to make data more useful.

Additional technologies — This category includes GPS, RFID, and bar codes, promising “niche” technologies that can be useful in certain situations.

Data Collection and Display

- Personal digital assistants (PDAs)
- Tablet personal computers (PCs)
- Experimental devices (HP digital pen, reusable paper)
- Paper

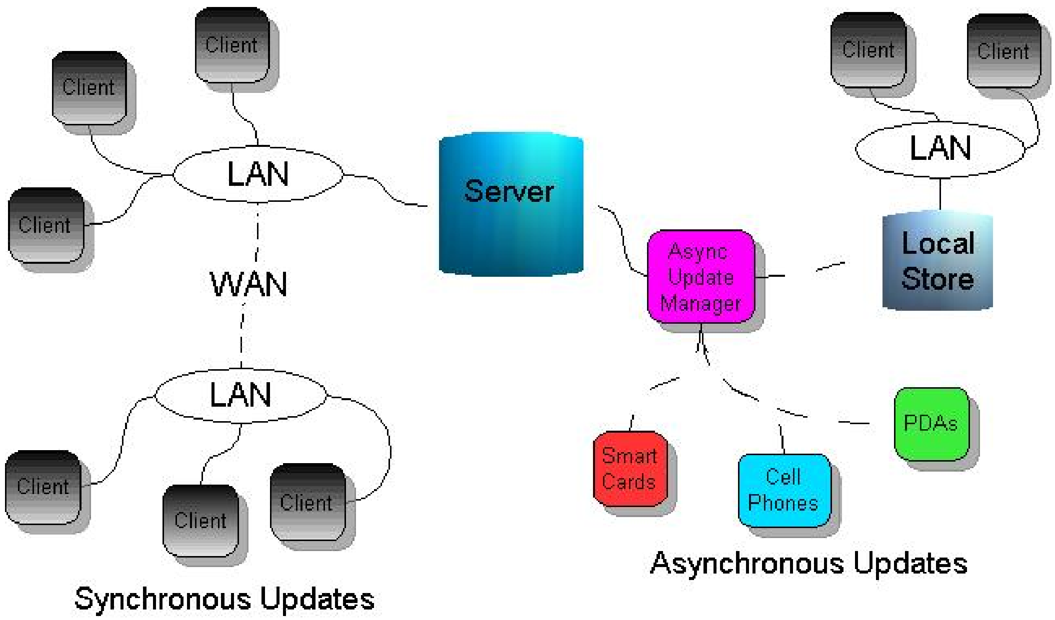
Data collection and display is the human interface to the information system and is crucially important to the system's success. The basics of this interface include a display screen and a method of input to the system. Screen sizes vary from the "full size" (15 in or 36 cm diagonally), the standard on most desktop systems, down to much smaller screens (4 inch or 10 cm diagonally) that need to be carefully designed to present information. Input methods include keyboards (both full size and miniature), touch screens, and handwriting recognition. Voice input is occasionally available but not widely used because of technical and operational limitations. Voice input is most likely to be found on telephone applications, where the necessary voice processing power can be provided in a fixed location.

This section reviews data collection and display systems that are very portable. While robust, desk top systems lack portability due to size and power requirements. The primary reason to use smaller, lighter, and low-powered devices is to provide information manipulation beyond the constraints of fixed locations. Resource-poor countries have a pressing need for information access in remote locations. Many clinics do not have reliable power and communications services. The devices in this category can provide a viable solution to providing information in these environments. They are small, portable, and operate on batteries. In addition, many of these devices are low cost relative to PCs (e.g., $100 to $400 per device versus $1,000 to $5,000 per PC) which makes them more suitable for wide distribution. Of course, portability can lead to problems with data and device security so deployment needs to be planned carefully with trusted systems and proper training of individuals.

These small devices, because of their usually limited data storage capacity, depend to a greater extent on data communication features. The developers of these devices have adopted a variety of innovative technologies for moving data into and out of the units. These communication technologies include wireless (mobile telephone and wireless fidelity [WiFi] are the most common) and various asynchronous technologies including memory cards and wired upload/download. Asynchronous connection refers to a connection where the device (e.g. a PDA) is not continuously connected to a data source (e.g. a PC). In a typical asynchronous operation, the device would be loaded with needed data, sent out for use, and then connected to update the information. The connection can be local, such as in the case of a wired telephone dial up, or may require the physical transport of the device or a memory card to a location with a connection.

Figure 1 shows the universe of potential communication among health information systems. On the left, there is a LAN and a WAN that comprise traditional information systems. In the center is a server, which is the primary data storage location and is also part of traditional information systems. The right side of the diagram illustrates communication using asynchronous technology that is discussed in this paper. It should be noted that the "async update manager" function is defined as the interface between these new devices and the server. This async update manager takes care of the issues related to the fact that these devices will not be connected to the server at all times. These issues include sorting out which data need to be stored on the peripheral device and how the information that is collected remotely will be synchronized with data in the server. These issues should be addressed by each individual device and the solutions will vary widely depending on how the device and information is used.

Figure 1: Universe of Potential Communications among Devices



Discussion of data collection and display technology is divided into two parts: PDAs, which are sized to be held in one hand and use small screens and keyboards; and tablet PCs, which are roughly the size of a sheet of paper and have larger screens and full-size keyboards.

Personal Digital Assistants (PDAs)

PDAs provide data collection, display, storage and analysis. Although initially envisioned as a PC replacement, PDAs quickly became complementary to PCs, with the capability of capturing data as a mobile device yet able to synchronize data with a PC. Introduced in the mid-1980s by such companies as Psion (Psion Organizer) and Apple (Newton Message Pad), PDAs have long held the potential to expand computing – be it data capture, storage, retrieval or analysis – to locations well-beyond the confines of an office or clinic examination room. The basic Palm Pilot was launched in the late 1990s by Palm Computing with the ability to store calendar, address book, and other personal data. Since then, the industry has grown to encompass hundreds of PDA models made by dozens of companies worldwide, running on multiple platforms and with seeming unlimited functionality. Prices range from as low as U.S. $70 to over U.S. $1,200 for standard PDA devices, with an average of approximately U.S. $400.

The basic functionality of the PDA that makes it useful in a wide variety of settings is its ability to collect, store, and display information in a scaled-down format on a very compact device while disconnected to electricity or a network. Requiring relatively small amounts of memory (as small as 8 megabytes [MB]) and operating on batteries, they can store and display volumes of information in databases, text format, and graphics. They are designed to be "instant on" without a "boot" process, making them fast and convenient to use. They provide information in the field, while still maintaining the essential function of synchronizing (or backing up) content with PCs utilizing a network, serial or

USB port, modem, wireless or infrared connection. Thus, the PDA can be utilized as a field tool to gather information, which can then be aggregated, analyzed, and reported on using PC-based tools.

However, limited keyboard capability makes the entry of large amounts of text tedious. Applications should be designed to avoid extensive text entry.

Battery life for PDAs vary, depending on the type of batteries used and the PDA settings utilized. Most current PDAs have a cycle-life (between charging) of about seven to 10 hours of continuous use. Other battery and charging options are available to extend that time. The explosion in wireless technology over the last five years has also spurred the growth of PDA-related products, making access to Web-based information and sending/receiving information from networked devices far simpler.

Over the last few years, a number of companies have developed lines of “rugged PDAs” that are made to withstand harsh environments, such as extreme temperatures. Some device manufacturers have also begun making PDAs that are waterproof, can withstand high levels of vibration, and are durable enough to withstand high impact drops. These devices typically have more limited functionality, such as basic data entry and display for one program only, and are targeted towards specific sectors, such as conducting inventory management in low-temperature freezers. As would be expected, prices are also significantly higher compared with standard PDAs, ranging from approximately U.S. $500 to U.S. $2,000 per device.

Uses — As PDAs have become more popular and memory capacity has expanded, many companies have recognized the opportunity to piggy-back on the mobile nature of the device to provide useful information away from the PC and have developed versions of their products (or the products themselves) to be compatible with PDAs. Included among these companies have been those in the health and medicine fields, which have expanded in sophistication in lock-step with the expanded capacity of PDAs. The first entrants into this arena has been healthcare companies that provide medical reference information, such as that found in the *Physicians' Desk Reference*, an annually published guide to drugs that contains over 3,000 printed pages and weighs close to 10 pounds in its hardcover edition.

Today, medical professionals can download this reference tool to their PDAs (as mobilePDR) directly from the Internet for use at the point of patient care and with far greater ease. In a study published by the *Journal of American Informatics*, 60% of physicians surveyed reported that it took 10 seconds or less time for them to find information on their PDAs, which finding the same information in the published book took between one and five minutes. In addition, the ease with which cross-references to other drugs (e.g., for drug interaction checks, contraindications, etc.) can be made is far more effective on a PDA than in a reference book, and the information can be updated automatically when synchronized through an Internet connection. Another finding in the study showed that clinical usage of PDAs can save not only time but also improve that quality of care provided and reduce preventable medical errors. Fifty percent of physicians using a similar ePocrates drug prescription and reference tool reported that its use prevented one to two errors per week and helped physicians keep track of new drugs and guidelines more effectively.[3]

The handheld computer or PDA market closely parallels the rest of the computing world in that there are multiple products, but specific operating systems (OS). The primary OS upon which the PDA markets are built are the Palm OS, made by PalmSource; Windows CE (Pocket PC) from Microsoft; and Linux OS from Linux. In addition, the Symbian OS has become a popular system for use with data-enabled mobile phones. An overview of the major PDA operating systems follows, with a

[3] Rothschild JM, Lee TH, Bae T, Bates DW. Clinician use of a palmtop drug reference guide. *J Am Med Informatics Assoc.* 2002; 9(3):223-229.

summary of the primary PDA devices utilizing each system.

Palm OS — Palm Computing launched as both the device maker and OS developer in the mid-1990s. Through a series of spin-offs and acquisitions since then, they currently operate as two separate companies: PalmSource as the OS developer; and palmOne as the PDA device maker. The Palm OS platform is licensed to multiple PDA companies today, including palmOne, and accounts for approximately 40% of the worldwide market.[4] The current version is Palm OS v5 (which can be viewed at http://www.palmsource.com/index.html).

Typical PalmOS devices have a screen resolution of 160x160 dots per inch (dpi) at the low end to 480x320 dpi in more expensive devices. Screens are available in both color and monochrome. Most models use handwriting recognition or on-screen pop-up keyboards for data entry, while some models are available with miniature keyboards. The efficient Palm OS devices can run with as little as 8 MB of memory but usually have 32 MB or more. Memory can usually be augmented with removable flash memory cards. Some Palm OS models are integrated with other devices, such as telephones (Palm Treo) or GPS (Garmin).

Until recently, Sony was a significant brand in the PDA marketplace, using the Palm OS platform, but in 2005 withdrew from that market in the United States and Europe. Its Clie line still accounted for nearly 8% of worldwide shipments in the second quarter of 2004, but that figure is expected to decline moving forward.[5]

Additional PDA makers using the Palm OS include Garmin (prices in the range of U.S. $500 to U.S. $600), which incorporates GPS software into its product, Aceeca, which specializes in “rugged” PDAs to withstand harsh conditions (sometimes referred to as “RDAs”), and Symbol Technologies, which has incorporated scanning and bar coding technology into its handheld devices.

Windows CE OS (PocketPC) — Microsoft Windows CE 1.0 was released in 1996 for minimalist computers and embedded systems, designed to compete with the Palm OS. Subsequent versions of Windows CE were released in 1997 (2.0), 1998 (2.1), 1999 (3.0), and in 2003 (.NET). Microsoft currently refers to this class of platforms as the “Windows Mobile” brand. As with Palm Computing, Microsoft has subsequently licensed its OS to PDA device makers. The Windows CE OS now accounts for 40% of the worldwide PDA OS marketplace.[6]

Handheld devices that utilized the Windows CE platform are known generically as “PocketPCs.” This refers to the scaled-down version of many of the Microsoft (MS) software products that have been tailored to the Windows CE environment, such as MS Word, Excel, and PowerPoint. As with the PalmSource OS devices, most PocketPCs have the option of either keyboard or handwriting for data entry, can be synchronized with PC based programs via serial, USB, infrared or wireless ports, and have a wide range of memory capacity and feature options including wireless access, e-mail and SMS text messaging capacity. Typically the PocketPCs contain more memory (from 64 MB to 128 MB) and require higher processing speeds (minimum of 266 MHz) to run programs, with prices ranging from around U.S. $200 to U.S. $700 depending on features.

The leading device maker of PocketPCs is Hewlett Packard (HP), which consolidated the Compaq iPaq product line with its HP Jornada line after the merger of HP and Compaq in 2002. As of the second quarter of 2004, HP devices accounted for 24% of the worldwide PDA shipments and ranged in

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[4] Gartner, Inc. Gartner says first quarter 2004 results show PalmSource and Microsoft in a virtual tie for no. 1 ranking in worldwide PDA operating systems market. 2004. Reproduced by WindowsForDevices.com, Ziff Davis Media, with permission. Retrieved September 27, 2005, from http://www.windowsfordevices.com/news/NS8063885791.html

[5] ibid.

[6] ibid.

price from about U.S. $250 to U.S. $650. Other leading PocketPC makers include Dell, with its Axim series of devices in the U.S. $200 to U.S. $400 price range, Toshiba and Viewsonic.

Linux OS — As with other segments of the computer world, an open source operating system option exists for the PDA sector. Embedded Linux, the open source Linux version that has been developed for embedded systems, has made rapid advances as a major "third alternative" to the Palm OS and MS Windows CE OS for handheld personal computing devices. In the past several years there have been numerous announcements of Linux-based handheld computers and PDAs for both general purpose and specialized mobile computing applications. The most well-known device maker that has adopted the Embedded Linux OS for its PDAs is Sharp Electronics, which has incorporated the system into its Zaurus line. Additional PDA makers utilizing the Embedded Linux OS include Softfield Technologies in Canada and G.Mate, a South Korean company that introduced its Linux-based PDA in 2001. In addition, installation of the Embedded Linux platform for the iPaq has been supported by HP.

PDA healthcare software applications — While the functionality of the handheld devices – mobile data collection, storage and display, wireless connectivity, real-time data analysis in the field – plays a key role in their potential to improve clinical care and reporting for HIV/AIDS programs in resource poor environments, achieving that potential may be largely be determined by the software applications available to run on the PDAs. As previously noted, a wide range of companies have recognized the potential of PDAs to expand their own products' reach, including many in the healthcare field. Numerous healthcare companies have developed software programs to run effectively in a PDA environment. Most of the software developments for handheld computing devices aimed at the healthcare marketplace are compatible with palmOne products (or more precisely, to work with the Palm OS), due in large part to Palm OS being the first successful entrant into the PDA market. As others have entered the arena, software developers have adapted their programs to work with one or the other system or sometimes even both Palm and Windows CE. To date, only a small number of healthcare related software programs exist for the Linux-based PDAs.

As is the case with most software designed for developed countries, these applications are of limited usefulness in developing countries where there is a much smaller range of drugs available and the types and manifestations of disease are different. However, porting applications such as local formularies and treatment guidelines can be very effective in providing useful information at the point of care.

As noted above, one of the essential benefits of the PDA is its ability to store resource information and/or patient data in a compact, portable device in remote locations. For application of this concept to the HIV/AIDS program environment, this is equally true. As an example, one could put treatment protocols and the entire WHO patient minimal data set for AIDS patient care on a PDA and easily store thousands patients' data. The minimal data set can be easily displayed in a user friendly interface on the small screen PDAs. For program monitoring, one can collect facility register information for monitoring care. The small size, freedom from constant power connection, and store and forward data storage are ideal for use in low infrastructure environments. In another example of relevance, the HIV/AIDS related glossaries and drug databases published by the U.S. Department of Health and Human Services through AIDSinfo are available for free download and usage on a PDA. AIDSinfo's Glossary of HIV/AIDS-Related Terms and Drug Database can both be utilized as searchable information resources via a PDA (http://www.aidsinfo.nih.gov/mobile/).

Dimagi (www.dimagi.com) is an innovative company that has developed several PDA applications for use in developing countries. One, Ca:sh, is a mobile electronic medical record (EMR) system for outreach workers in large communities. The Ca:sh system provides a cost-effective means of providing up-to-date medical information to visiting healthcare workers at the point of care. Media

Lab Asia, in collaboration with the All India Institute of Medical Sciences, is currently field-testing Ca:sh in rural India. This was originally developed for Linux running on the iPaq but is being ported to the Palm OS because of the lower cost of Palm devices. In addition, they have developed HIV Confidant which is a PDA-based system for secure dissemination and deanonymization of HIV test results. Invented by the Africa Centre for Health and Population Studies, and implemented by Dimagi, this system is currently being field-tested in South Africa. Some of their software is available as open source so it can be enhanced for local use. They also have commercial software, DiaBetNet which is an innovative interactive self-management tool for children with juvenile diabetes. This system has successfully completed a phase 1 clinical trial and is being enhanced for commercialization in collaboration with a major healthcare corporation.

A Boston-based not-for-profit organization, SATELLIFE (www.healthnet.org), led a project that provided PDAs and training to physicians, medical students, and community volunteers in Ghana, Uganda, and Kenya in order to demonstrate their utility as a healthcare tool in developing countries. According to an independent evaluation of the SATELLIFE project conducted by Bridges.org, the PDAs proved to be useful tools for both health data collection and for information dissemination, an inexpensive alternative to PCs, and easily integrated into the daily routines of the healthcare professionals.[7] While the evaluation concluded that there is enormous potential for PDAs to improve health service delivery and health information collection, the absence of locally available technical support (i.e., for repairs and usage support), widespread bandwidth and interconnectivity, and locally relevant health information are challenges that must be overcome for PDAs to be widely adopted for healthcare in African countries.[8]

PDA software development — PDAs are general purpose computers and, as such, one can develop software to run on them. There are several programming environments that make it easy to develop software so it is feasible to develop custom applications to meet specific needs. The whole discipline of software development is complex and skilled people are necessary to design and program the software but this capability is available even in most developing countries. Software development was also discussed in the original white paper on ART systems. Here are a few PDA-specific software development environments:

For the PalmOS:

- Pendragon Forms (http://www.pendragon-software.com/) – visual forms – commercial software.

For Windows CE (PocketPC):

- Microsoft .NET (www.microsoft.com).

Cross platform (both PocketPC and PalmOS):

- CASL (www.caslsoft.com) – a visual forms and database language – commercial software
- Waba and SuperWaba (http://www.superwaba.com.br) a small Java-like language (FOSS)
- Code Warrior (http://www.metrowerks.com/mw/default.htm) – C language – commercial software.

[7] Bridges.org. Case study: The SATELLIFE PDA project. 2003. Retrieved 27 September 2005 from http://www.bridges.org/iicd_casestudies/satellife/
[8] ibid.

Tablet PCs

Table PCs can collect, store, and display data, and can provide data analysis. The tablet PC is about the size and weight of a typical notebook computer. The tablet PC is fitted with a touch-sensitive screen for handwriting capture and interaction. The handwriting is digitized and can be converted to standard text through handwriting recognition, or it can remain as a picture of the handwriting and drawing. As with a PDA, the stylus also can be used to type using a pen-based key layout where the lettered keys are arranged differently than the typical QWERTY keyboard found on most PCs. Tablet PCs also typically have a full size keyboard and/or a mouse for data input. Slate PCs are notebook computers that accept input from an electronic pen and do not have a keyboard. Slate PCs are particularly useful in situations where keyboards are awkward or unnecessary. Typically, slate PCs can decipher clearly written block letters and translate them into their ASCII equivalents. To date, however, slate PCs cannot fully handle script writing.

Like standard notebook PCs, the PC tablet operates on either an AC adaptor or via a rechargeable battery, with usage times ranging from about three to five hours between recharges. They are generally smaller than standard notebook PCs, a bit lighter, but still provide such features as wireless connectivity, a robust microprocessor, and abundant data storage space. They are generally slightly more expensive than notebook PCs, ranging from about U.S. $1,500 (USD) to U.S. $3,500, depending on the configuration. Their primary enhancement over the notebook is the ability to input data using the digital ink technology. This latter function is particularly relevant to health care, where physicians are notoriously reluctant to use keyboards, preferring instead to take written notes or dictating them for transcription.

However, adoption of these units has been slow due to their high cost, low battery life, and fragility. The “digital ink” capability is of questionable value since this produces unstructured free text which is of limited value due to the difficulty of analysis and organization. The lack of tailored applications is also an issue, although the tablet PC will run most standard Windows PC applications, which do not take advantage of the special features of the tablet PC.

The tablet PC is intended to mimic the use of a paper notepad or clipboard and EMR software companies have developed products that take advantage of that feature. Providing a larger and more robust data interface than PDAs, the tablet PC is now the preferred platform for many EMR vendors.

Experimental Devices (HP Digital Pen, Reusable Paper)

Hewlett Packard (HP) has an interesting technology that combines precision printed forms (from HP laser printers) with a smart “digital pen” capable of reading the form and capturing information as it is written. The pen is then connected to a computer and the information is saved. This technology may be useful where there is adequate infrastructure to support it.

Several other technologies are being developed to make a reusable paper that can be easily erased and reprinted. Xerox has a technology called Gyricon, which uses a thin layer of transparent plastic in which millions of small beads are randomly dispersed. The beads are "bichromal," with hemispheres of two contrasting colors (e.g. black and white, red and white). When voltage is applied to the surface of the sheet, the beads rotate to present one colored side to the viewer. The image will persist until new voltage patterns are applied. Currently, this technology is in prototype stage but has the potential to reduce paper consumption.

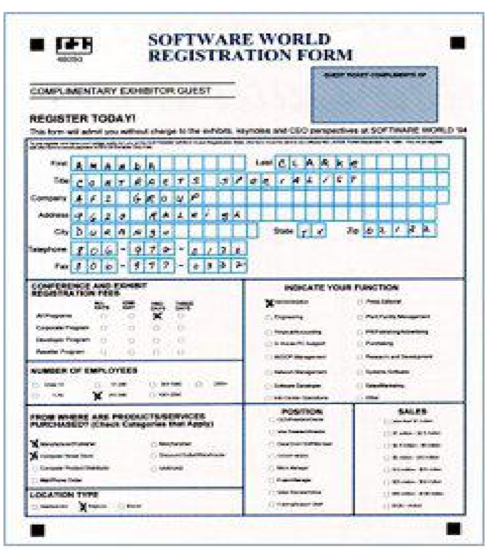
Paper

Paper is the traditional method of data collecting and storage, but it suffers from bulky size and weight and is relatively fragile. In addition, the main drawback of paper is that the information is not available electronically, which means that it is difficult and labor intensive to organize and retrieve.

Using paper to collect, display, and store data has been done for thousands of years, and is still widely used. Paper is often touted as being cheap, simple, and reliable. Compared with other information systems, however, paper is not as cheap, simple, or reliable as many presume.

Paper costs money and time to design, print, transport, stock, and store. It is subject to waste through physical damage, as well as becoming obsolete (forms, for example, that are no longer current). Paper is dumb. It does not understand or evaluate the information printed on it, as some electronic systems automatically do. For example, paper forms readily accept incomplete or clearly inaccurate information that a software program would not allow. It is a tedious process to compile information stored on paper. Paper is often lost. Since the original can only exist in one location and is cumbersome to copy, paper-based information often isn't where it's needed. It's expensive and slow to send information on paper. Paper is dead. That is, the information on paper can not be easily retrieved and used. It is very cumbersome to transfer information from paper to computer software that can analyze or communicate the information. Paper doesn't count. Information on paper can't be easily tallied or aggregated. It must be entered into a computer for analysis and this provides an opportunity for introducing errors.

Several technologies, however, can improve upon paper documents. Collectively, they have the goal of improving data collection on paper by making it easier to get paper information into computers where it can be easily analyzed and manipulated.



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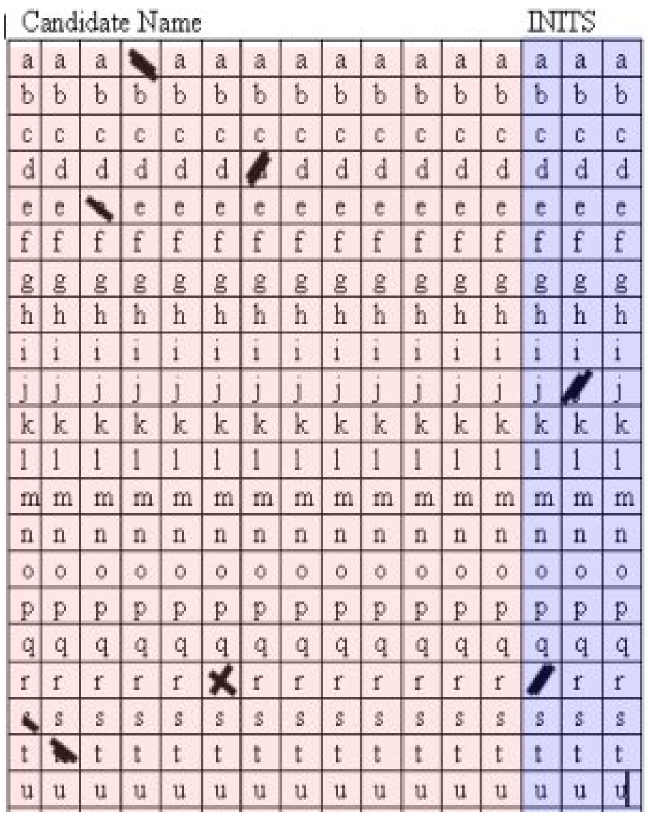
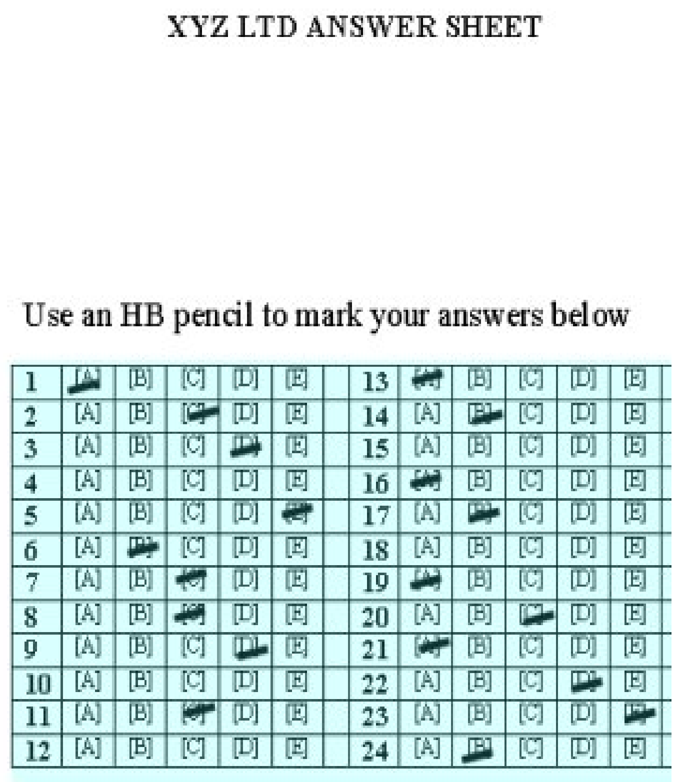
Scanning forms — The most common way to get paper into a computer is to optically scan it into an image. Scanners can range from simple manually operated devices costing about U.S. $100 to fast automatic scanners that can read hundreds of pages a minute and cost thousands of dollars. There is a clear trade-off here between speed and cost and it is easy to match your needs to the capabilities of the scanner. Fax machines combine scanning with communication.

More important is what happens to the scanned image produced by the scanner. Much scanning software just stores the image (a picture of the paper) but this doesn't really help much since the information on the paper is not available for computer analysis. Smarter software will attempt to read the information in the image and store it as data fields. This is a complex process and it is highly dependent on both the capabilities of the software to analyze the image and the structure of the form.

A lot can be done in designing a form to make it easier for the computer to analyze the image. One of the most common methods is to have areas on the form that can be filled in to indicate a response. One might have a box to check next to a label for “Male” and another next to a label for “Female”. It is more complex it one needs to “read” letters and numbers. The form can be constructed so that the user writes a single character in a separate box. This makes it easier for the computer to read the characters but there is still a non-trivial error rate. Bar codes can also be printed on forms so that the computer can recognize the form.

There are many different computer software programs that make combine the functions of form design, scanning, and analysis. Several projects successfully use scanned forms for data collection. One of these is the Columbia University AIDS project which has an extensive set of paper forms that are scanned for data entry into a database.





Data Communication

- Wired systems: (land-line) telephone and Ethernet wired network
- Wireless systems: cellular telephone, WiFi and WiMax, and satellite

Electronic information can be easily transported and copied to multiple locations. Standards or protocols are the methods that make communications possible. Messaging systems and networks systems are the main areas of data communication, and are discussed in this section. (A more detailed discussion of technical background and issues of data communications is in Annex A: Data Communication Technology.)

"Messaging" is a general term for communicating information from one location to another in discrete packages, called messages. Health care delivery involves the management of information. Information about the patient, and information from laboratories and ancillary care workers are routinely needed. Patients are mobile, lab and ancillary care is often located in a remote location from a clinic, and care providers move from one location to another. These conditions help illustrate some of the many ways that messaging can be useful within health care delivery systems.

In addition, health system managers need aggregated information. For this need, information must be assembled, organized, and communicated. This does not need to happen in real time. Often information is generated over a period of time and only needs to be available at a later date. For instance, a patient may have a lab test with blood drawn. The specimen may be sent to a remote lab for analysis. The results need to be reported to the patient, perhaps during another visit to the clinic, which could be several weeks after the patient's initial visit. In another example, a district health manager needs monthly reports of clinic activities and patient status. This information is collected throughout each month, but does not need to be sent to the manager until the end of the month.

Messaging systems are suitable for this type of information. One should examine the relative cost, speed, latency, and data capacity of each of these to select the method that would be best for a particular situation. For example, in the case of communicating lab information from a remote lab where the patient is not expected back for several days, a high latency system, such as paper, would be adequate. However, it should be kept in mind that paper information may not be as reliable as electronic information, since a paper form is subject to corruption during transcription and can easily be filed incorrectly or lost. In some settings, a more reliable option may be an electronic messaging system, such as a cell-phone messaging format or e-mail.

Messaging formats include e-mail and cell phone SMS and GPRS. There are other specialized messaging formats, such as fax and protocols that run over the Internet (see the Table 1, next page, for a comparison of methods).

Wired Systems

Networks can be divided into local area networks (LAN) and wide area networks (WAN). LANs are usually implemented with a wired Ethernet or a wireless WiFi system, and are typically limited to a specific facility. Due to wiring limitations and WiFi range limits, a LAN is typically confined to an area of approximately 1,000 meters in diameter. Both Ethernet and WiFi are low cost, highly reliable, and provide high speed options. WiFi has somewhat higher initial cost, but this is often offset by the savings in not having to install wiring.

Table 1: Summary of Data Communication Methods

	Speed	Sync/Async Latency	Distance	Reliability	Cost
Telephone					
POTS (dial-up telephone)	+	Sync	+++	++	+
SMS (cell)	++	Async-short	+++	++	++
GPRS (cell)	++	Async-short	+++	++	++
Network					
Ethernet (wired)	+++	Sync	+	+++	+
WiFi	+++	Sync	++	++	++
WiMax	+++	Sync	+++	++	++
Other					
Satellite	+++	Sync	+++	++	+++
Fax	+	Async-short	+++	++	++
Sneaker-net	PT*	Async-long	+++	+	+
E-mail	+++	Async	+++	+++	+
Paper	PT*	Async-long	+	+	+

Notes: Scale ranges from one "+" for low to three "+" for high. "Async" indicates messaging methods whereas "Sync" indicates continuous real-time communication.

* PT stands for "physical transport" non-electronic data transport.

Wide area networks or WANs are more problematic because of the distances involved. These networks involve more than one facility, possibly in different cities, and depend upon telephone systems or satellites to connect the network. As such, the cost of using these services and the speed of data transmission are issues to consider. Charges will vary with the amount of data transferred and the speed of transmission. The advantage of a WAN is the real time access to information throughout the entire system. However, one should consider that, for most uses, using a messaging system to send information is cheaper.

Telephones — Where an existing infrastructure of telephone land-lines exists, this system can be used for data communication. This network is often referred to as POTS (plain old telephone system). Inexpensive modems can be attached to dial-up telephone lines for data transfer. The speed of these connections is relatively low and can be problematic if the quality of the telephone system is poor. The telephone system can be expensive (especially for long distance) depending on the country. Access to a telephone infrastructure may not be widely available in some resource poor countries.

When land telephone lines are available, they are suitable for intermittent (asynchronous) data transfer, such as sending and retrieving periodic reports. This system is not suitable for continuous data transfer, such as would be needed for an electronic medical record database from a remote server.

Land line telephone access to the Internet is a viable inexpensive option if a local Internet service provider (ISP) is available. Internet access can be used to send e-mail as well as access Web applications for data entry and retrieval.

Wireless Systems

Cellular telephones — Cellular telephones are a type of wireless communication that is most familiar to mobile phone users. They can collect and display data, store data, provide voice and data communication, and provide messaging. These telephones are called "cellular" because they use a telecommunications system composed of base stations that divide a service area into multiple "cells." Cellular calls are transferred from base station to base station as a user travels from cell to cell.

With cellular wireless data services, it's possible to receive faxes, browse the Internet, send and receive e-mail or transmit text messages all on a wireless phone. Some even include built-in digital cameras, spreadsheet software, GPS location services, and music features. GPRS is a service that allows information to be sent and received across a mobile telephone network at theoretical maximum speeds of up to 171.2 kilobits per second (kbps), or about three times as fast as the data transmission speeds possible over today's fixed telephone line telecommunications networks. The faster wireless networks mean that Internet services formerly available only via desktop PCs connected to a land-line are becoming available anywhere that a signal can be sent and received via a cellular telephone.

According to the United Nations Development Programme, cellular phone subscribers outpace the breadth and expansion rate of telephone mainline services in many resource-poor countries. For example, 12 out of the 14 countries targeted for HIV/AIDS resources assistance under PEPFAR have higher rates of cellular subscribers than mainline subscribers. In a number of these countries, cellular service outpaces mainlines by ratios of 3:1 or greater, including in Mozambique (14:5 per 1,000 people), Tanzania (22:5), and Cote d'Ivoire (62:20).[9] Such a movement also provides a measure of opportunity to utilize such mobile technology for the dissemination and utilization of healthcare technology.

Cellular phones depend on local infrastructure. There must be local wireless stations in order for them to work. In addition, local factors such as terrain and buildings can interfere with the radio signal. The devices themselves have a very small display screen, limited numeric keypad, and limited memory. Only simple messages can be composed and displayed. However, if the cell phone is attached to a more capable device, such as a PDA or PC, it can use the enhanced memory, display, and keyboard of these devices.

Cellular phones have developed much more robust capacity for sending text messages, data, and for accessing the Internet than mainline telephones, which still require the use of a computer system to perform most of these functions. Cellular phones can be used for communication of patient information, lab reports, referrals, and program reporting, as well as for distributing clinical advice, guidelines and best practices information (e.g., Satellife).

Cell-life (http://www.cell-life.org/) is a South African company that uses an innovative combination of cell phone SMS, databases, and geo-location software to provide active management of AIDS patients.

WiFi and WiMax —WiFi is a radio version of Ethernet. It uses base stations that have a range of up to 500 meters at a speed of up to 10 Mbps. Specialized antennas can increase this distance. It is a fast inexpensive method to implement a LAN. A new standard, called WiMax, has the potential to increase the range of WiFi dramatically, up to 50 km.

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[9] United Nations Development Programme. *Human Development Report 2004, Cultural Liberty in Today's Diverse World.* New York: United Nations Development Programme, Human Development Report Office, 180-183; 2004.

Wired Ethernet is the most common media for a LAN, using wires, switches, and hubs to transmit information from one computer to another. It is also very fast, even in the older 10 Mbps version. New versions run at 100 Mbps and 1000 Mbps (Gigabit Ethernet). An Ethernet LAN is very reliable and relatively inexpensive.

WiFi would be an option to consider in a busy clinic where electronic medical records are routinely used. WiMax is not currently widely available, but is expected to increase the range of network access and could become a low cost substitute for satellite network access.

Satellite Internet — Satellite Internet access is available through specialized providers. This service is generally used when other methods of communication are not available. It is expensive, since it requires a specialized ground station and has high monthly operating fees. The speed varies, from 9,600 bps and up, depending on the provider and services purchased.

Because of its cost, satellite Internet is not suitable for most HIV/AIDS program activities. The expense may be justified, however, for a regional or national center to facilitate information collection and reporting as well as mobilizing resources from international sources.

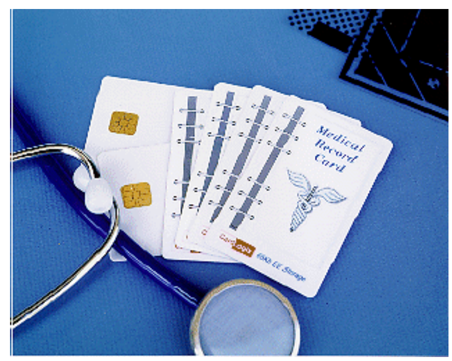
Data Storage

- Smart card
- Flash memory
- Other storage (floppy disc, CD-ROM, CD-RW)

Smart Card

The smart card is a portable data storage device that can also be used as a patient identification tag. The device is a credit card-size device that contains a computer memory chip. It was originally developed for financial applications, such as storing money or credit. Because of this, it includes rigorous data encryption and security protocols. Smart cards are available containing various amounts of memory, typically in the range of 2 kilobytes (KB) to 128 KB. This is sufficient to store an individual patient's medical record in text format and condensed biometric identification information, such as a fingerprint. The smart card is very sturdy, reliable, and can withstand physical abuse, including exposure to water. Smart cards are relatively inexpensive, making them suitable for issue to individual patients and, when necessary, replacement.

To access the information, the card is inserted into an inexpensive card reader device that is attached to a computer. The computer can be a PC, PDA, tablet PC, or similar device. The computer can both read information from the card and write to the smart card's memory chip.



Chips used in these cards fall into two categories: microprocessor chips and memory chips. A memory chip can be viewed as small floppy disks with optional security. Memory cards can hold from 103 bits to 64,000 bits of data. They are less expensive than microprocessor cards, but provide a lower level of data management security. They are suitable for low- to medium-security uses. The smart card includes security and encryption to prevent unauthorized access. However, there are multiple proprietary methods to access the information. This lack of universal standards can be an impediment to adoption. IBM has proposed its JCOP system as an open standard but this still pending.

Smart cards are also available in contact type and wireless type. The contact type has electrical contacts that must make contact with a reader in order to transfer data. Wireless types include an antenna and need only be placed in close proximity to a reader.

Worldwide, several billion smart cards are distributed each year. They are used in financial transactions as a stored value card, telephone systems (GSM mobiles and payphones), mass transit, and for identification. They are also used extensively in health care. As an example, Germany has distributed over 80 million cards for health care.

There are several limitations to consider:

Lost card — Since the patient carries the card, it can be lost or destroyed. A lost card cannot be accessed without the proper security codes, so there is little risk of unauthorized disclosure of information. If the patient looses their card, it can be re-created from the information that is backed up at the facility and a new card issued.

Forgotten card — If the patient forgets to bring his or her card, the information is usually still available at a health facility in other databases. Consequently, information from the current visit can be recorded in the facility's database and the patient's card could be updated later, during the patient's next visit.

Stigma — An important issue in HIV/AIDS programs is stigma. Possessing an "AIDS card" could lead to stigmatization. Consequently, patient cards that do not specify HIV/AIDS or provide access to a broader range of purposes avoid the problem. For example, a proposed smart card system in South Africa would also be used by 5 million pensioners, in addition to those receiving HIV/AIDS services. In Zambia, a proposed smart card would be introduced first for use in antenatal clinics, but could also be used when receiving HIV/AIDS services.

Standards — A current lack of consistent standards for smart cards makes data portability problematic.

The smart card is ideal for storing the longitudinal HIV/AIDS medical information, which is crucial to quality care. In this application, the card would be read at a treatment facility and updated with new laboratory or treatment information. It is also suitable for managing a patient's therapy.

Data from the card can be duplicated at the facility and transmitted electronically for backup. The data can also be aggregated for program management and planning. The advantage of electronic information is that it can be easily copied and communicated so that it can be available in multiple locations. This provides a reliable backup to ensure against loss as well as making the information readily available for administrative purposes. Typically, patient information is stored on the card, at the treating facility, at a district or regional level, and in a central database. When communication links are available, the information can be readily available at all of these sites and can easily be transmitted from one facility to another. Communication links do not need to be continuous or high speed. Since the amount of information from any given facility is small, a low speed asynchronous communication link is sufficient. Even in the absence of communication links, physical transport of the information on a storage media (such as a CD or flash memory) can provide a reliable "sneaker-net" communication path.

One very attractive advantage of the card is that it is a patient-carried portable medical record. In many developing countries, there is a tradition of each patient maintaining possession of his or her own medical record, which the patient brings to a clinic when receiving medical care. The advantage of this is that a person can be treated at different medical facilities and each facility has access to the person's medical record. This is expected to be an important issue for AIDS care. Many symptomatic AIDS patients return to their home area. As they are treated and recover, they will likely want to travel to a different area for work. A portable medical record is important in this scenario.

Pilot implementations of smart cards are taking place in South Africa, Malawi, and Zambia. In South Africa, a system of smart cards has been used for some time nationally to process pension plan payments. Net1 Aplitec, in conjunction with John Snow, Inc., has begun a pilot test to use the smart card in AIDS care. For treatment outside a clinic, the card is read by a portable reader device carried by a healthcare worker. Both the patient and practitioner are provided with cards so that information from a medical visit in the field can be stored on both cards. The health practitioner then brings his updated card back to a central location, where the patient's record is stored and synchronized. In Zambia, a new system of health care smart cards is being developed in cooperation with the CDC. The cards are to be used initially with antenatal care clients and will be expanded to HIV/AIDS and other health care programs.

There are several standards and many proprietary formats for smart card health data. One international standard that is in wide use is the G8 Health Card, which is widely used in Germany and Austria and has been proposed for use in the United States among people served by the U.S. Veterans Administration.

Flash Memory

Flash memory is a small computer chip packaged in a plastic carrier with an electrical connector that provides data storage. They typically have large capacities, up to 1 gigabyte (1,000 MB). Popular formats include compact flash, memory stick, secure digital, smart media, and USB. All of these memory devices are designed to connect to a computer (PC or PDA) that can read and write the information. The device itself is small and fairly sturdy.

The memory card data format is a standard computer file system that can be read by most computer devices. The formats do not usually contain any security or data encryption capabilities, so these capabilities must be provided by the host computer's software.

Their large capacity makes them suitable for storage and transport of data from a large number of patients, such as would be found in a clinic. They can be used to aggregate information from facilities and physically transport the information to the district or regional level.

Because of their high capacity, these devices are relatively expensive and would not be generally suitable for use by individual patients. Such large storage capacity is not generally necessary for an individual patient medical record. However, as costs come down, they may become competitive with the cost of smart cards. These devices are not as durable or as impervious to dust and water as smart cards. Their large memory, small size, and portability makes them ideal for transferring information from one site to another, such as would be needed to update a central database with records from remote clinics.

Other Data Storage

Floppy discs have been used for data storage and transport but suffer from fragility, unreliable storage, and limited capacity. They should not be considered for new systems.

Compact discs (CD-ROM) have a high data capacity and are relatively durable if protected from physical abuse. They are suitable for backup copies of important data and for transferring large amounts of information, and they are inexpensive. There is a variant that can be re-written a number of times (CD-RW) that may be re-used, but these tend to be less reliable than CD-ROMs and should probably be avoided for permanent storage.

Patient Identification

- Photographs
- Fingerprints
- Iris and retinal scans
- Facial recognition
- ID cards
- Other ID systems (speech, signature, hand geometry)

Patient identification is important for several reasons. Patients need to be identified to ensure eligibility for services. In addition, whenever there is a longitudinal medical record, the patient needs to be matched to that record. Problems matching patients to medical records include duplicate records where a single patient has more than one medical record (each may contain only a part of the complete record), missing records, and cross-linked records where more than one patient is linked to the same record. All of these record problems can lead to improper treatment with potentially dire consequences.

Various methods of patient identification have been used. Traditionally, a paper card with the patient’s name and a record number provides basic identification. However, these cards can easily be switched among patients, leading to errors. The general solution to this is biometrics. Biometrics is the science and technology of authentication (establishing the identity of an individual) by measuring the person's physiological or behavioral features. It can be as simple as noting the color of eyes, height, and weight. More complex biometrics includes the use of photographs, fingerprints, or iris scans. When a person registers to receive services, one or more if his or her physical characteristics are obtained, processed by a numerical algorithm, and entered into a database. When a registered person wishes to be identified later, the person’s features match the stored characteristics.

In HIV/AIDS programs, patient identification is important because of the dangers associated with misidentification of patients (potentially wrong diagnosis and treatment). Also, because of the high cost of the treatment, dispensing drugs to the right patients is essential.

Photographs

Photographs provide very effective identification and are probably the most commonly used form of biometric identification. The technology to capture photographs is well established and reliable. Digital photographs can be easily duplicated and communicated. Many clinics that use photos report that photographs enhance the retention rates for identification cards since patients value the card and it is not easily used by another person.

Digital photographs can be easily implemented using inexpensive digital cameras, ink jet printers, and standard paper. The photo can be laminated to a card to improve durability. More expensive equipment can print the photograph and other information on a plastic card directly. The digital photos can also be stored electronically for future reference.

Fingerprints

Fingerprints have long been recognized as a unique identifier. The difficulty in their use has been in having individuals trained to “read” the fingerprint. Fortunately, there are now inexpensive devices (typically costing less than U.S. $50) that can automatically read a fingerprint when it is pressed on a small device. The computer performs a fingerprint analysis that is similar to that performed by a human and expresses the "reading" as a small text string that describes the pattern of the print. The image of the fingerprint itself does not need to be stored.

The low cost of this kind of reader and its high specificity and reliability make it good candidate for use where positive identification is essential.

As previously mentioned, South African company (Net1 Aplitec) is proposing a smart card patient medical record and identification system. This card also incorporates a fingerprint reader for improved patient identification. The smart card and fingerprint identification system are already widely used to process pension plan payments to 5 million people in South Africa.

Iris and Retinal Scans

Iris and retinal scans take advantage of the fact that each individual's iris and retina have unique patterns. The equipment is more expensive and more cumbersome than fingerprint equipment, and the process may not be as accurate. For these reasons, it is probably better to use other options until this technology becomes more reliable and its costs are reduced.

Facial Recognition

Facial recognition systems work by measuring characteristics (distances and sizes) of facial features. There are several methods of analyzing faces: eigenface, fisherface and the Hidden Markov model. These methods are still in the early phase of development and in many cases are considered experimental. Currently, they all have a high error rates if not used in a highly controlled environment. Because of these factors and the high cost, it is not recommended that facial recognition systems be implemented in resource poor environments.

Table 2 compares various aspects of biometric identification methods.

Table 2: Summary of Patient Identification Technologies

	Uniqueness	Counterfeiting	Cost	Reliability	Ease of Use
Photograph	Very good	Easy	Very Low	Good	Easy
Fingerprint	Very good	Difficult	Low	Good	Easy
Iris and retinal scan	Good	Difficult	High	Fair	Fair
Facial recognition	Very good	Difficult	High	Fair	Difficult

ID Cards

A paper or plastic ID card can include patient name, number, and demographics. With the advent of inexpensive digital cameras and printers, a color photograph can be added, which greatly increases the security of the card by making it difficult to forge or alter for use by another. The paper ID card can also contain a bar code for machine readable ID.

Other Identification Systems

These additional identification systems should be considered experimental until proven in use:

- Dynamic signature identification measures the unique motions a person uses to create a signature. It would have limited usefulness in locations where signatures are not routinely used.

- Hand geometry uses unique physical measurements of the hand to identify a person. It is currently used in some high-end identification systems, but is probably not practical for routine use due to cost and reliability issues.
- Speech recognition analyzes the spectrum of speech and uses a person's unique speech patterns to identify the individual.

Data Management

Data must be organized, communicated, stored, and analyzed in order to be of use. Data that is not properly managed and organized are useless. Information in electronic form has the potential to provide comprehensive, rapid assessments for management, monitoring, and policy. However, it is imperative that this information be accessible and structured for analysis. Data management is an entire discipline. Some basic concepts will be introduced to help planning and evaluation. For a more in-depth discussion of the underlying data concepts, see the Annex B: Database Concepts.

In addition to the specific data that these technologies collect, it is necessary to have good quality and breadth of information about population health and health system activities for use in management, planning, and policy. Existing health information systems often produce fragmented and incomplete information that is difficult to use. One innovative approach that has been widely adopted in the private sector in developed economies is the establishment of a data warehouse and a support unit to collect, prepare, analyze, and publish the information.

Data warehouse — A data warehouse is a place where data are stored. However, the organization and structure of the warehouse is crucial. In comparison to a physical warehouse that stores goods, one can imagine a clean well organized warehouse where one can instantly locate anything needed. A good data warehouse is similar in that the data have been cleaned of errors and irrelevant values. The data are also organized neatly so they can be found reliably. And just as a physical warehouse has neat, well-defined labels, a data warehouse will have well-defined data values.

Data dictionary and metadata — A data dictionary, just like a dictionary of words, gives clear definitions of data fields. Allowing different people to use different definitions for a data field can be confusing, just as it would be if different people used different definitions for the same word. The data dictionary contains definitions and descriptions of data. In the whole, this body of knowledge is referred to as metadata. Metadata are often described as "data about data."

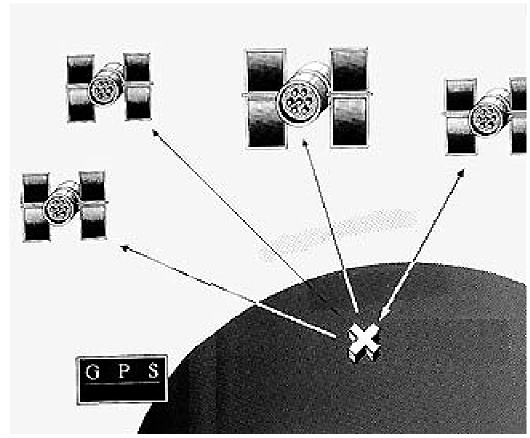
Query and reporting — Of course, the purpose of saving data is to analyze and interpret them so that they can be used in management, planning, and policy development. In order to do this, a database is queried to produce a data set, which is can ultimately become part of a report. Most organizations have standard reports that give pre-determined information about activities. Often, these report on standard indicators. In addition to the standard reporting, it is useful to have the capability to perform "ad hoc" data analysis by running queries. Most modern databases are organized around a relational model and most use a query language called structured query language (SQL), which is a powerful method to analyze data.

Data mining — Whereas data queries and reports give information on indicators and parameters that are determined to be important, the science of data mining can uncover things that one had not thought to ask. This is an exciting field of data exploration that looks for associations and anomalies in data that might be of significance. It is too complex to describe in detail here, but these capabilities can be useful in systems.

Additional Technologies

The following technologies can be useful in niche applications to perform certain functions. They are included here since they may be encountered, and their uses and limitations should be understood.

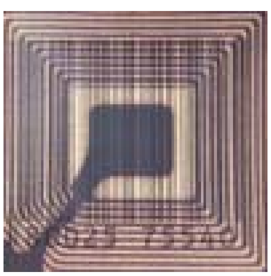
Global positioning systems (GPS) — GPS use a series of satellites in orbit around the earth. A GPS receiver uses signals from these satellites to calculate the position of the receiver on earth. This gives very precise location information (typically five to 10 meters accuracy) using a relatively inexpensive receiver (less than U.S. $150). This position is expressed in longitude and latitude coordinates that can be plotted on local maps to provide spatial data.



GPS systems have proven very useful in a variety of health care needs, such as locating health facilities and comparing them with population centers to judge availability of services. GPS systems have also been used to track the location of patients, which can be useful for epidemiology investigation.

The GPS radio signals are only available outside of buildings, and require no obstructions to the clear sky. Severe weather may also reduce the signal.

Radio frequency identification (RFID) tags — RFID is a technology for electronically readable identification and data storage. The RFID device itself is a small computer circuit (as small as a grain of rice) that can contain digital information. It is generally designed as a passive device that does not require a power source and is very durable. The device is read (queried) by exposing it to a radio frequency and it responds by sending its digital information through a radio frequency signal. Devices usually contain a simple serial number (typically 64 bits = 19 digits) that the devices transmit when queried. However, some devices have a memory that can be changed to store small amounts of information. Simple RFID tags are very low cost (less than U.S. $1 each). The devices to read the tags are relatively inexpensive (less than U.S. $100).



RFID tags have been proposed for identifying patients. A patient would carry an identification card that contained an RFID tag. For inpatient settings, patients might wear wristbands with RFID tags, used to track the patient throughout the hospital and to verify that medications are being administered correctly.

A RFID tag is an inexpensive way to give each patient a unique and confidential ID number that cannot be altered. RFID tags that can store information can also be used to for patient demographic and medical information. There is an implantable RFID tag called VeriChip that can be used for permanently attached identification. However, this raises many privacy and security issues.

Tags could also be used to track drug distribution systems, which can often be complex and difficult to monitor. High value items such as drugs and medical devices must be accounted for carefully throughout their distribution route. When done manually, this can be tedious and prone to error. Attaching an RFID tag to a container of drugs gives the container a unique ID number. This number can be recorded automatically when the container enters a warehouse. The advantage of RFID is that the tag does not need to be visible or in contact with the reader. When the tag passes near a reader, the number is recorded. A shipment containing a large number of RFID tags can be read all at once by placing the shipment near a reader – all of the serial numbers will be recorded accurately. Similarly, when an item leaves a warehouse, it can be read automatically and logged. RFID readers can even be used to scan for concealed items, to help control theft.

The RFID tags are designed to be read without contact, from a distance of a few centimeters to several meters (depending upon the reader device). However, the radio signal from the device is weak and can be unreliable due to any of the many factors that can interfere with radio waves.

There is also the issue of unintended access to the device. There can be privacy and security issues associated with unauthorized access to the data. It is interesting to note that the recent design to put RFID tags in passports includes a radio frequency shield in the cover of the passport so that it can only be read when the passport is opened.

Bar codes — Most of us have seen a bar code, since these have been widely used for many years on most merchandise manufactured in developed countries. Bar codes can be used for patient identification to create a machine readable number. They have the advantage that they are very inexpensive, since they can be created by most computer printers. They can also be read by simple, inexpensive devices (typically costing less than U.S. $50), and can be made more durable by laminating the code in clear plastic.

For patient identification, a bar code is reliable and provides in a difficult-to-alter ID tag. They are also very useful in maintaining supplies, since they can be used to uniquely identify items and reliably record these numbers. However, bar codes require an optical reader that is held relatively close to the code to enable a reading. The codes can be obscured by a physical obstruction or damaged.

Magnetic stripes — Magnetic stripes are commonly used on credit cards, which are “read” by “swiping” the card through a magnetic strip reader. The magnetic stripe reader devices are relatively simple and inexpensive (less than U.S. $50). Magnetic stripes are relatively durable. Standard magnetic stripe cards have up to three “tracks” and can store several hundred characters of information.

A magnetic stripe can be used on a patient identification card to store a name and identification number. It provides a reliable, difficult to alter, electronic tag. It can also be used to store a limited amount of additional information.

Limitations include the concern that the stored information can be damaged by magnetic fields or by physical damage to the magnetic stripe area. The amount of information that can be stored is limited to several hundred characters.

Conclusion

This paper has reviewed emerging and existing technologies that have the potential for application in resource poor environments to address HIV/AIDS program needs. Each of the technologies has strengths and weaknesses. Appropriate opportunities may justify investment in these systems.

Deployment of systems should be based on proven technologies with clear benefits. Pilot testing of promising technologies (e.g., PDAs, smart cards, data-enabled cellular phones) in HIV/AIDS programs and resource poor settings needs to be conducted. The social, human resource, and political considerations in each of the environments where the technologies could be applied will play a big role in the success of any technology deployed. What this research effort has clearly shown is that planning for deployment of emerging technologies should be taking place now, rather then being delayed.

For further information and continuing updates, visit the Routine Health Information Network (RHINO) Web site (www.rhinonet.org).

Annex A: Data Communication Technology

This is a technical discussion of data communication protocols so that the issues involved can be better understood. Only the essential concepts and terms are discussed.

When discussing data communication protocols, one needs to address such technical issues as bandwidth, latency, reliability, and synchronous/asynchronous communication. Bits and bytes should also be explained. A bit is the smallest piece of digital information, represented as a 0 or 1. Communication channels are usually specified as the number of bits per second (bps) and can also be expanded to kilobits per second (Kbps = 1000 bps) and megabits per second (Mbps = 1 million bits per second). A byte is usually considered to consist of 8 bits and is sufficient information to represent a single character of text. Actual throughput of a communication channel depends on additional factors such as latency and protocol overhead. The terms bps, Kbps, and Mbps refer to data transmission speeds.

Asynchronous data transmission — Asynchronous data transmissions are those that are executed at a different time from an event involving the data (i.e., without a regular or predictable time relationship to a specified event). In this paper, the term is used to mean any series of communications where there is no link to real time events. This means, for example, that a message could arrive at some arbitrary time later than when the message was generated. This time lag could be minutes, hours, or days.

Syncrhronous communication — By contrast, synchronous communication refers to data transmission in which there is a regular, real time link between message generation and receipt, and also implies that there is an order of operations.

Data communication technologies include: fax, satellite connectivity, telephone transmission, plain old telephone service (POTS) lines, wireless phone protocols, Global System for Mobile (GSM) communications short message service (SMS) text, general packet radio service (GPRS), wired computer network methods (Ethernet), wireless computer communication methods (WiFi).

Communication protocols are the specific formats that enable smooth communication. Most of the current protocols originated with the Internet but they can also be run on local networks. These protocols include: Simple Mail Transfer Protocol (SMTP) for E-mail, File Transfer Protocol (FTP), and Hypertext Transfer Protocol (HTTP).

Media — Media refer to the technologies of information transfer. They can be wired or wireless electronic transfers, or information can be recorded on some physical device and physically transported.

The wired telephone land line is traditionally used for voice communication but can be used for data when used with a modem which converts data to tones. The data transmission speed of a standard land line is limited to a maximum of 56Kbps although it is often less due to poor quality connections. The switched telephone network can potentially reach anywhere that the infrastructure is installed but cost can be high for long distances.

The mobile wireless telephone removes some of the limitations of wired telephone systems but still requires infrastructure installation locally. The current standard GSM mobile system is inherently digital, rather than analog so can be readily adapted for sending data using the SMS and GPRS protocols. SMS is limited to short (160 character) messages. GPRS is suitable for longer messages at a speed of 9600 bps. Future generations of mobile phone service can provide higher data transmission speeds.

Wired Ethernet is the most common media for computer local area networks (LAN). Since it requires wires, the maximum distance is generally limited to about 1000 meters. It uses switches and hubs to transmit information from one computer to another. It is very fast, even in the older 10 Mbps version. New versions run at 100 Mbps and 1000 Mbps (Gigabit Ethernet). It is very reliable and relatively inexpensive.

WiFi is a radio version of Ethernet. It uses base stations that have a range of up to 500 meters at a speed of up to 10 Mbps. Specialized antennas can increase this distance. It is a fast inexpensive method to implement local area networks. A new standard called WiMax, has the potential to dramatically increase the range of WiFi.

Satellite Internet is available through specialized providers. This service is generally used when other methods of communication are not available. It is expensive since it requires a specialized ground station and has high monthly operating fees. The speed varies from 9600 bps and up depending on the provider and services purchased.

Physical transport of media containing information is often deprecated but in many cases is a very feasible option where other communication methods are not practical. A large amount of information can be stored on a physical medium such as a disk or memory card and this can be physically transported from one location to another. Of course the speed is significantly slower than electronic communication since it depends on physical transport but the bandwidth is high since large amount of data can be transported. Paper has long been used in physical transport communication links but lacks the machine readable feature of electronic media.

Protocols — This refers to the format of the information and the communication between sender and receiver. A protocol ensures that the receiver can understand the information, controls the transmission, and confirms delivery.

Transport control protocol (TCP) is the foundation of the Internet and specifies the protocol for Internet communication. It is used as part of the Internet Protocol suite and is usually referred to as TCP/IP. The protocol is very simple and robust. It can run on any media at any speed. Higher level protocols, such as HTTP (used for web pages), FTP, and SMTP are application layers that run on TCP. These protocols are useful for real time communication with a database.

Asynchronous message-based protocols (SMS, GPRS, SMTP E-mail, fax, physical transport) are useful for transmitting non-real time information such as laboratory results or sending patient records from one clinic to another.

Annex B: Database Concepts

Relational database — The standard method of storing information is a relational database. A database consists of a collection of tables. Each table can be thought of as a spreadsheet page with field names across the top and entries of data in a row. A database contains many of these "flat" tables. The power of a relational database is that these individual tables can be related to each other using key values.

As an example, one can have a table of patients and each patient has an ID number. Another table can contain laboratory tests for patients. Each patient can have one or more lab tests. Each laboratory test in the laboratory table can be related to the patient table by the patient's ID number. Another table can contain information from patient clinic visits. Again, each patient can have more than one clinic visits and these are related to the patient by the ID number.

The power of a relational database is that it allows information to be organized with these relationships. It is then possible to look at all of the information for each patient that is related from the various tables. Most modern databases use this relational model.

Structured query language (SQL) — SQL is a standard method of extracting information from relational databases. The SQL standard language defines a standard method of querying a database to extract records and at the same time records can be aggregated.

On-line analytical processing (OLAP) — OLAP defines a set of characteristics for a database and tools that facilitate analysis of data. The OLAP goes beyond a particular database structure by defining characteristics that make data easily accessible. OLAP was originally defined by Dr. Ted Codd, a database pioneer. His original definition included 18 rules defining desirable characteristics for data analysis. Others have boiled these down to a simpler set of five rules (Fast, Analysis, Shared, Multidimensional, Information) designated with the acronym FASMI:

- FAST means that the system is targeted to deliver most responses to users within about five seconds, with the simplest analyses taking no more than one second and very few taking more than 20 seconds.
- ANALYSIS means that the system can cope with any business logic and statistical analysis that is relevant for the application and the user, and keep it easy enough for the target user.
- SHARED means that the system implements all the security requirements for confidentiality (possibly down to cell level) and, if multiple write access is needed, concurrent update locking at an appropriate level.
- MULTIDIMENSIONAL is our key requirement. The system must provide a multidimensional conceptual view of the data, including full support for hierarchies and multiple hierarchies, as this is certainly the most logical way to analyze businesses and organizations.
- INFORMATION is all of the data and derived information needed, wherever it is and however much is relevant for the application.

OLAP goes beyond the queries that can be performed on a relational database using SQL. OLAP uses a data structure that is called a "cube" to express its multidimensionality. Most often, the data that goes into the cube for analysis comes from the existing relational and flat file tables where information is collected and stored.

This information is presented to gain familiarity with the terms. Remember, the whole purpose of data is to be able to perform analysis and find out information. OLAP takes data the next step by defining characteristics that enable analysis. It is not a single technology but rather a set of goals that various technologies strive to achieve.

Annex C: Resources

Here are links to additional resources that may be useful. The RHINO Web site at www.rhinonet.org contains additional references and links in the areas of monitoring and evaluation, software, and technology, and is updated routinely. It has sections for resource files, images, forums, and Web pages, as well asa directory of links to additional resources on the web.

ART Software White Paper:

http://rhinonet.org/tikiwiki/tiki-index.php?page=ART+Inventory

PalmOS Hardware and Software:

http://www.palmsource.com/index.html

Microsoft Windows CE (PocketPC) Hardware and Software:

http://www.microsoft.com/windowsmobile/downloads/pocketpc.mspx

Linux Medical News:

http://www.linuxmednews.com/

Open Source Software:

http://sourceforge.net/

PDA Software and Information: SATELLIFE

(www.healthnet.org)

PDA and EMR applications: Dimagi

(www.dimagi.com)

Ca:sh EMR:

Media Lab Asia, (www.medialabasia.org)

All India Institute of Medical Sciences (www.aiims.org)

AIDSinfo's Glossary of HIV/AIDS-Related Terms and Drug Database (PDA):

(http://www.aidsinfo.nih.gov/mobile/).

The links below provide additional resources for software development:

For the PalmOS:

Pendragon Forms (http://www.pendragon-software.com/) – visual forms – commercial software

For Windows CE (PocketPC):

Microsoft .NET (www.microsoft.com)

Cross platform (both PocketPC and PalmOS):

CASL (www.caslsoft.com) – a visual forms and database language – commercial software

Waba and SuperWaba (http://www.superwaba.com.br) a small Java-like language (FOSS)

Code Warrior (http://www.metrowerks.com/mw/default.htm) - C language – commercial software