Tele-Health in India

Landscape of tele-health infrastructure at points-of-service in India

INTERNATIONAL TELECOMMUNICATION UNION

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Dr. P. S. Ramkumar

Acknowledgements

This report, *Landscape of Tele-Health Infrastructure at points-of-service in India*, was commissioned by the ITU Telecommunication Development Bureau (BDT), ICT Applications and Cybersecurity Division. It was prepared by Dr. P. S. Ramkumar (psramkumar@airtelmail.in).

The author and the ITU Telecommunication Development Bureau (BDT) would like to express their gratitude to the several esteemed institutions (Rural Technology and Business Incubator, IIT Madras, Sanjay Gandhi Post-Graduate Institute of Medical Sciences, Amrita Institute of Medical Sciences, Centre for Development of Advanced Computing, Indian Space Research Organization, Regional Cancer Care Centre, Sir J. J. Group of Hospitals, Apollo Telemedicine Networking Foundation, Health Highway, INFOLIFE Technologies, Prognosys Medical Systems, Gangaram hospitals, Ojus Health Care, Nanavati Hospital, Neyveli lignite corporation hospital, Meenakshi Mission Hospital, Narayana Hrudayalaya, Arvind Eye hospitals, Sri Sathya Sai Institute of Higher Medical Sciences, Shankar Netrayala, Sri Ramachandra Medical College, Schizophrenia Research Foundation, World Health Partners, Reliance Health, Health India TPA services, NeuroSynaptics, Frost & Sullivan, Society for Administration of Telemedicine and Health Informatics) from whom the information, experiences, learning and suggestions could be obtained through discussions and publications in journal and web-sites, and aggregated into useful insight for Tele-Health planning in developing countries.

Special thanks to Senior leaders (Shri.B.S.Bedi, Ex-Director – Ministry of Information Technology and Advisor-CDAC, Prof. S.K. Mishra Head of Endocrine Surgery dept. and Nodal officer of SGPGI Telemedicine program, Smt.Sangitha Reddy, Executive Director Apollo Hospitals and MD Apollo Health Street, Shri. Sandeep Sinha Deputy Director, Health Care practice, South Asia and Middle East – Frost & Sullivan, Dr. Prem Nair, Medical Director – Amrita Institute of Medical Sciences and Research Centre, Padma Shri Jhun Jhun Wala, Prof of Electrical Sciences and Head of TENET group at IIT Madras, Dr.Vikram Chatwal, CEO, Reliance Health, Prof. Leonid Androuchko professor of Telecommunications , University of Geneva and rapporteur of the Tele-Health study group of ITU for referring this effort to the relevant personnel/organization/information needed for this study.

We would like to acknowledge with gratitude the valuable time and insight contributed by staff members of various organizations during interaction and active discussions in this effort. We sincerely regret if names of any organizations or individuals have been missed out by oversight and wish to convey our grateful thanks to them.

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1 Background

Health care is one of the most important dependencies for economic sustainability and growth of a country. While India has made significant strides of economic growth in the last two decades, there is a steep growth of health spending alongside. This is partly due to increased health awareness and infrastructure but mainly due to increased incidence and prevalence of diseases. For example the current economic loss due to the lost disability adjusted life years (DALY) is estimated at >200 Million life years in India and disease incidence is expected to double by 2015 [1]. Considering the present population and per-capita GDP [2], the increase in economic loss of productive life years in this period translates to $200 Trillion in India alone! In countering this depletion of productivity, there is an acute shortage of physicians (1 per 1000 people) and nurses (0.8 per 1000 people) and care facilities (1 bed per 1000 people) [3] in the country. The spread of available workforce is also disproportionate across various regions, varying from 0.25 to 2.3 per 1000 people [3], with over 70% of the population in rural areas and over 60% of health care work force in urban areas. Growth rate of human resources and hospitals significantly lags the disease incidence rate, and hence the gap in demand versus supply is widening at an alarming pace. Most health awareness education camps are still being conducted in form of folk dances/drama and counselling/consultation camps by teams of experts who physically travel to various regions. It is not practically possible to arrest this widening gap in a reactive care paradigm through traditional methods of building more additional hospitals and human resource.

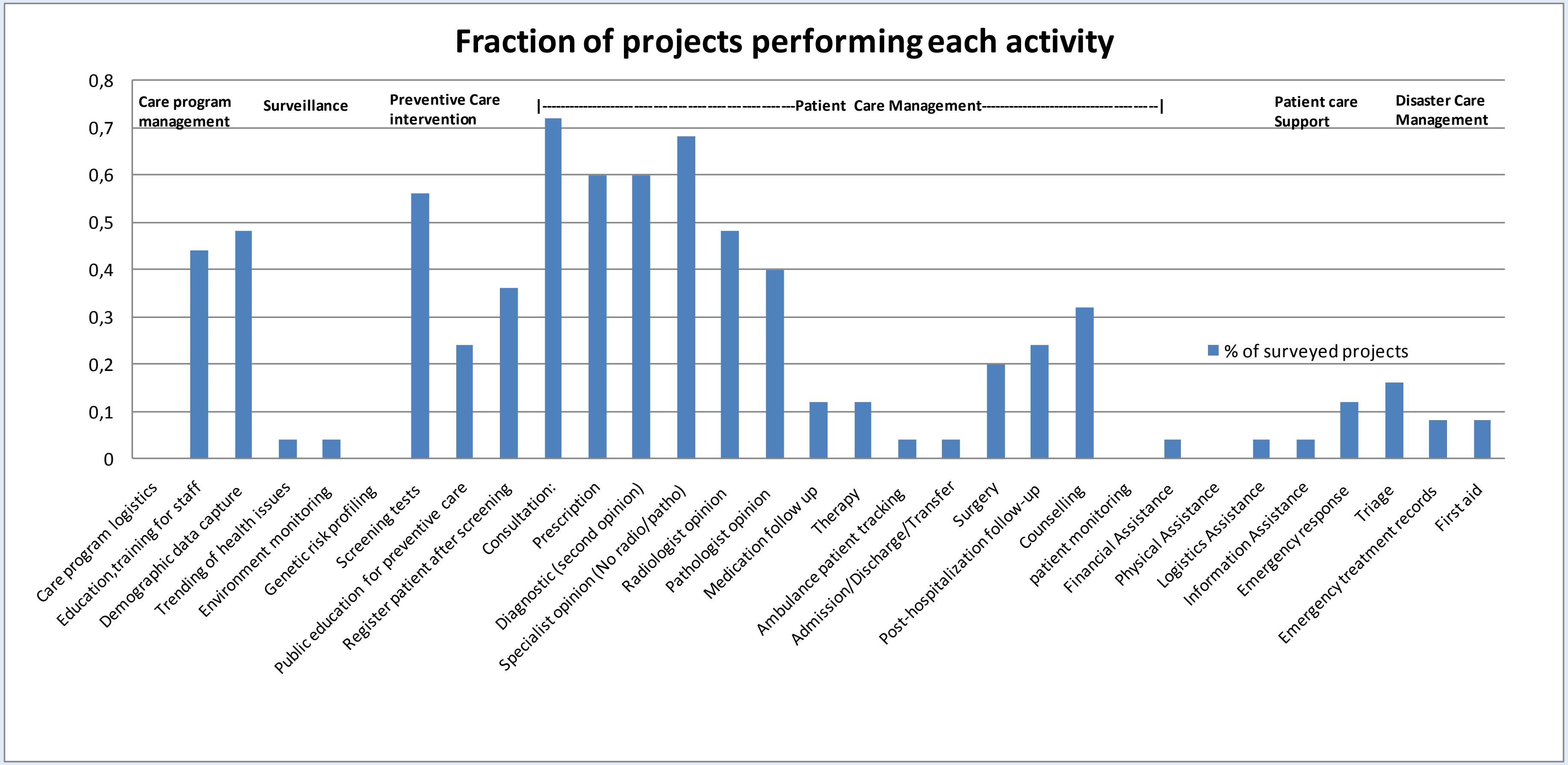
If patients and staff such as health workers and nurses in one region could consult experts in another region without having to travel physically, there would be better utilization of available resources, and faster proliferation of awareness to prevent further widening of the gap. If lesser skilled health workers could be trained to handle more complex jobs without the educator having to reside or travel physically to the training camps, it would help rapid generation and upgradation of human resource. If there were a means of monitoring the environment frequently enough and take proactive steps to avoid/treat disease outbreak without having to depend on an annual census data, it would arrest the growth of the demand-supply gap at an early stage. The effectiveness of such measures depends directly on timely exchange of relevant information between the demand and supply. Adoption of Information and Communication Technologies (ICT) is the only way to accelerate bridging of this demand supply gap without physically shifting the resources. This is because it enables electronically connecting the citizen to the care provider residing in different localities. It can also accelerate generation of additional resources in various level of competency. While ICT adoption could cover a broad scope of activities in the field of health, this paper focuses on Tele-Health defined by ITU as "the use of communications and information technology to deliver health and health care services and information over large and small distances" [4]. Tele-health is expected to enable transfer of different kinds of information needed for patient monitoring, education and medical interventions in delivery of health care. It should have the capability to provision resources and integrate their interactions from different personnel, entities and locations. From merely taking demographic information to performing remote surgery, the associated technologies have demonstrated with adequate accuracy, stability and capabilities. Identifying this as the way forward, a number of e-Health initiatives have been launched in India, in both public and private sector [5][6].

While India has established itself as a global information technology hub providing outsourced services to the whole world, its internal proliferation of IT enabled services in health care delivery is very less relative to the demands of its population. Back end IT infrastructure such as state of art data centres, IT and medical personnel, high bandwidth connectivity are available and scalable in the cities. Most of the country's 750+ tertiary care hospitals (300 beds+) have automated their internal processes to various extents (billing/administration/supply chain management/electronic medical records/CRM/lab information system/etc.). However most of the 44000+ secondary and primary care centres [7] do not have any process automation intersect with Information and Communication Technology. Over the last decade or so, several initiatives that have attempted adoption of tele-health in different segments of the care process have gained significant experience and learning. Majority of the challenges in adoption of tele-health comes from the user-end (client-end) scenarios both in urban and rural settings. These challenges arise from the diverse usage scenarios in health delivery as applied to the diversity of population in India. This has triggered innovative work-around in the projects that have to deal with them (some of which is sighted in this study). By aggregating the learning from these projects one can expect that the solutions can be reused or linked together to accelerate proliferation of services, as well as influence standards as applicable to such demography. With this point of view, this paper presents observations from a field survey of computing and communication infrastructure at the point of care from tele-health projects in India. Although India has started supporting tele-health outsourced BPO and KPO services in form of tele-consulting, tele-reporting and transcription services to other countries such as Africa, United States, Malaysia, etc., the scope of study in this paper is limited only to the extent of tele-health services for health care delivery in India. Although there could be more examples and instances of tele-health infrastructure adoption in various applications beyond those covered in this survey, the data gathered and analyzed here provides useful application patterns, proof points of alternative strategies and solutions to adoption barriers in proliferating tele-health services across diverse demography.

2 Method

A survey of real-life application scenarios was conducted covering over 26 tele-health initiatives from a mix of private, government and NGO managed care delivery organizations across India (Reference list in Appendix I). Together these projects have serviced over 200000 patients in various aspects of preventive, curative and palliative phases of care delivery. They have created tele-H=health networks that aggregate the skills and facilities of primary, secondary and tertiary care across rural villages and urban cities. Several thousands of entities have become part of these networks, consisting of hospitals, clinics, diagnostic labs, insurance claims administrators, medical colleges, call centres, pharmacies, etc., in districts and states of India. From publications, site visits, web-sites and in some cases interviews with their staff, a study was undertaken to identify the activities, transactions and type of information exchange that take place within the activities. Various usage models and infrastructure employed at the point-of-care were surveyed from ongoing tele-health projects to identify the adoption pattern of connectivity and end-user platform technologies for various services. The surveyed projects together intersect over 85% of the overall types of transactions identified, with one or more intersecting projects per transaction as shown in the Figure 1. Most of the data is inspected for proof points and in a few cases to make observations of statistical significance where possible. This is a sparse data set in the sense that none of the projects would perform all the listed transactions and there are some transactions which none of the surveyed projects perform at all. But the available data has yielded important observations, proof points, patterns and indicators as discussed below.

FIGURE 1: Distribution of projects sampled across various transactions



3 Observations

3.1 Care Coverage

Figure 2 shows the number of projects intersecting with each type of transaction and color coded based on the type of connectivity they are using. Similarly Figure 3 shows the number of projects intersection with each type of transaction and color coded based on the type of user-end platform they are employing. Majority of the projects were focussed in preventive intervention and patient care management in a reactive mode (when patients report problems), while less than 5% of them focus on proactive surveillance, patient support and disaster management services. In a health management process of a large scale, it would be beneficial to use the same infrastructure in surveillance and assist the planning and steering the investments dynamicallyin preventive and curative programs.

3.2 Connectivity

Out of projects surveyed, about 60% used satellite connectivity (384 Kbps to 512 Kbps), around 25% used ISDN (128 Kbps to dual line 256 Kbps), 8% used ADSL (256 KBPS), 8% used HDSL (1 Mbps), while PSTN and wireless 2G and 3G links were used by only one project each. All of them used bandwidth of 1 Mbps or less at the point of care. In about 20% of ISDN users, ISDN was used as a standby line in addition to satellite connectivity. This is in a sharp contrast with expectations that remote sites of most projects would have utilized the country’s base of over 560 Million mobile + DSL landline connections. Although India is witnessing the world’s fastest growth of telecom connectivity, it has reached only 175 Million of the 750 Million + people in rural areas [8]. India has OFC backbone network covering more than 85% of the terrain across 0.6 Million villages (with an average spacing of 25 Km and average 200 households).

With cellular coverage radius of 5 km thereafter, the tele-density falls off rapidly and the last 10 to 15 KM forms most of the holes in connectivity from mobile coverage point of view [13]. Even available connectivity suffers from poor Quality of Service(QOS), line dropouts and speeds dropping to few tens of Kbps. India has opened up its 3G spectrum recently and these issues may be addressed eventually with adoption of WIMAX/LTE technologies. The bigger challenge is that the interim period may be long enough for health related economic burden to grow as mentioned in the introduction, by over $200 Trillion! It is hence very necessary to utilize available infrastructure to rapidly proliferate surveillance and preventive care services to arrest disease incidence and prevalence. Mapping type of transactions to connectivity requirements is very important to plan services according to current connectivity and later evolution of the telecom infrastructure.

FIGURE 2: Distribution of connectivity standards used across various transactions

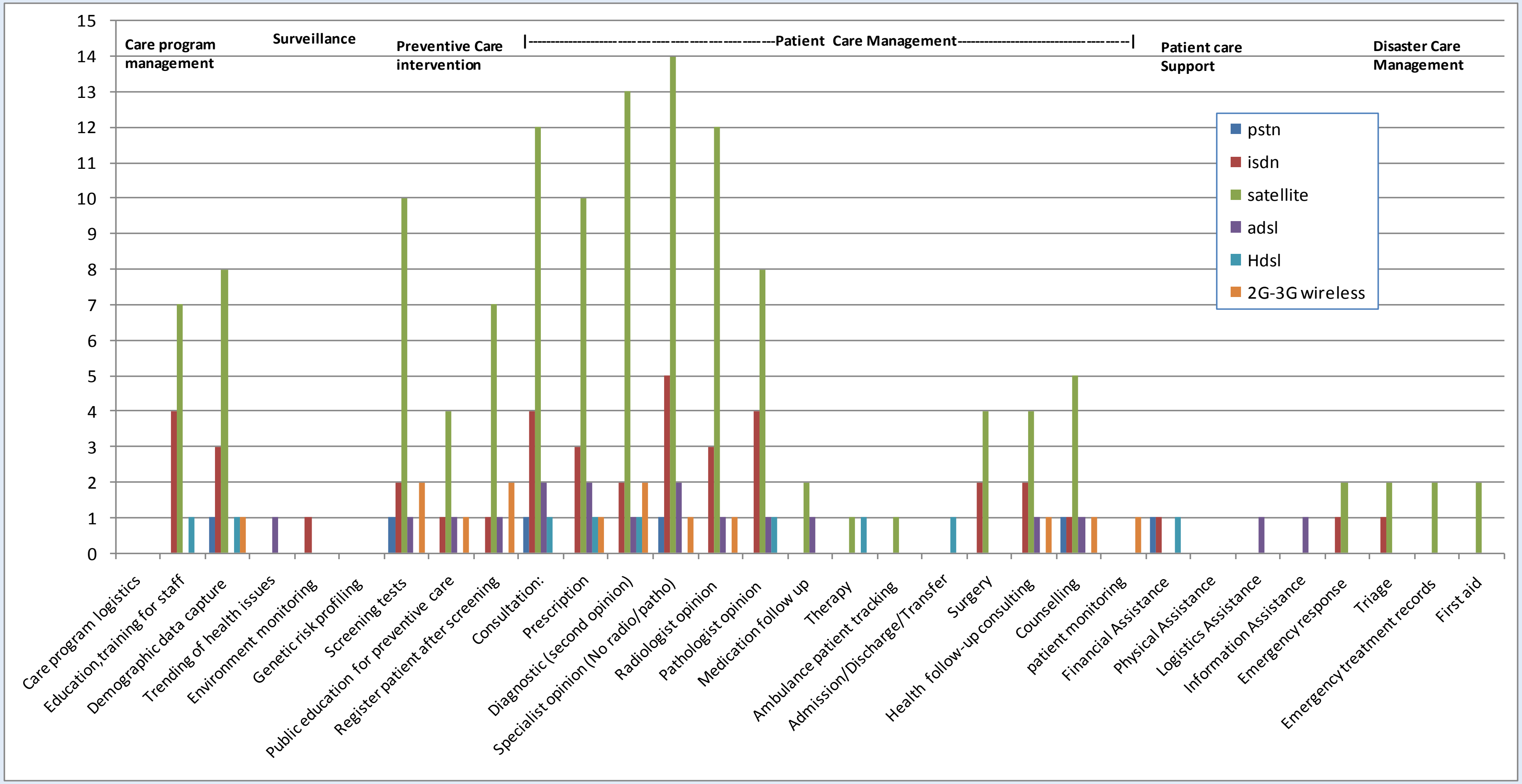
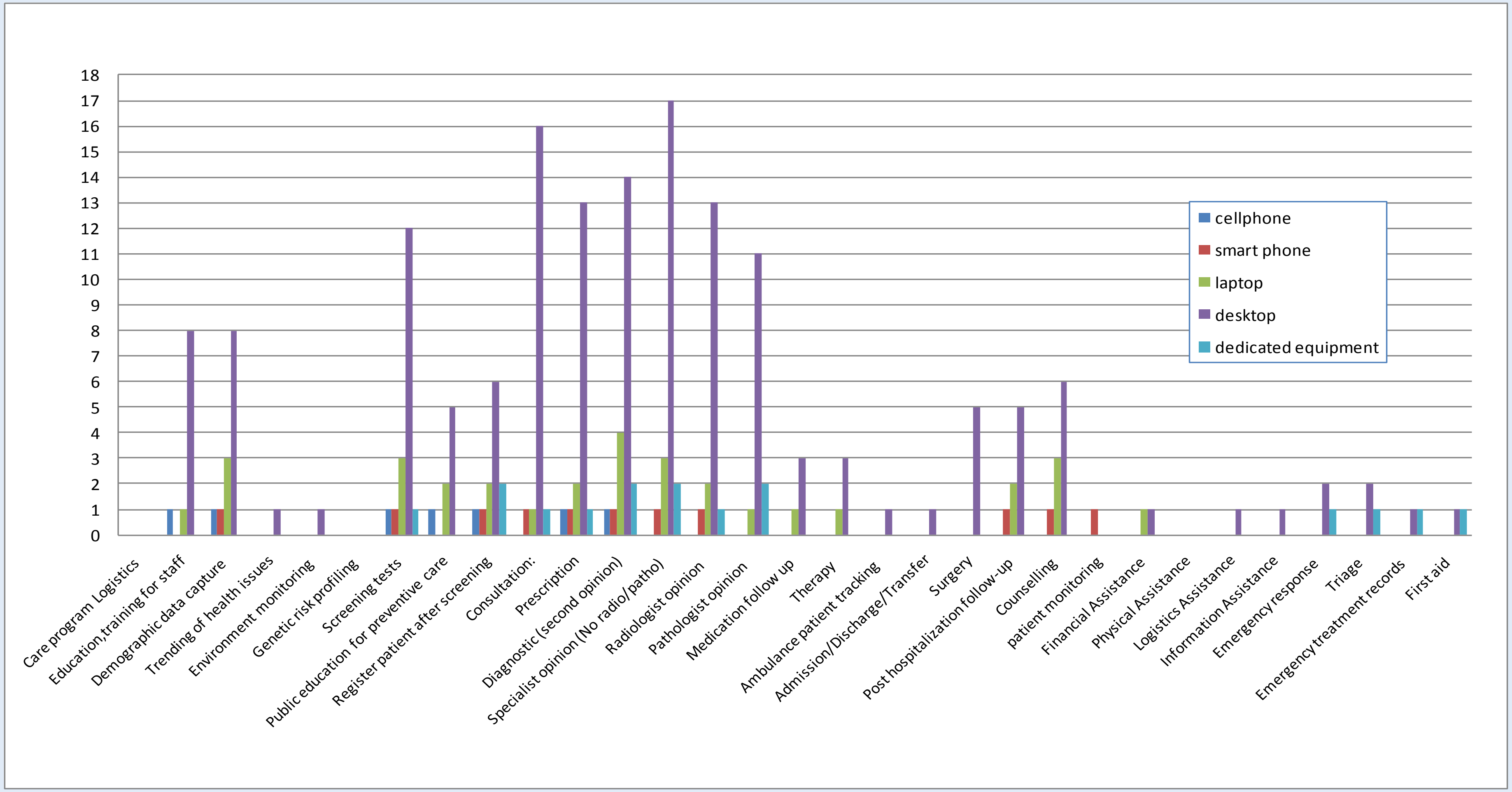


FIGURE 3: Distribution of client platform usage across various transactions

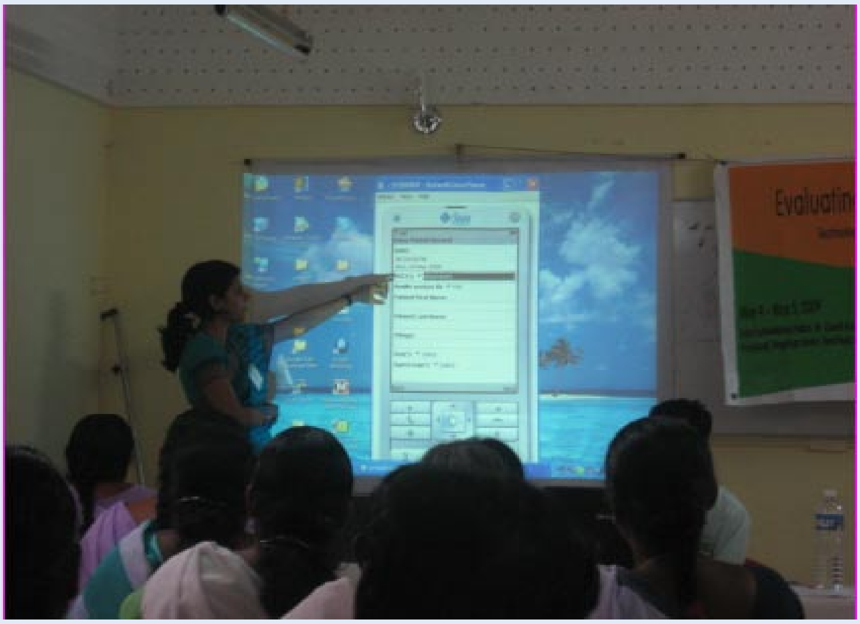


3.3 Usability

With over 525 Million [8] subscribers to mobile 2G services, mobile phones have far outpaced Personal Computers. This also implies the number of people familiar with cell phone usage are far more than those with PC familiarity and the learning curve on a cell phone seems to be smaller. However, across 26 major projects, the map is dominated by desktop computers. Among these projects, none deployed smart phones, and only two projects employed cell phone based transactions, while a majority of them [19] used desktop computers, and few of them [4] used laptops and [3] dedicated video conferencing equipment. One of the major reasons for this adoption pattern was that most data entry is still in central locations such as kiosks, clinics, offices, ambulances, etc., typically equipped with desktop computers and used only by trained staff, if any. Also, with the small screen size, high resolution images such as Radiology and Pathology data are not presentable with clarity. The screen also limits the layout flexibility and the amount of icons and text to avoid clutter. Smart phones have larger writable screens and mobility but cost almost twice that of a desktop computer. The 2.5G bandwidth also poses constraints on the data size that can be downloaded within a meaningful timescale for a user.

The keys with their overlaid characters may be used to enter a few measurements such as BP, blood glucose in scenarios of patient monitoring but found cumbersome beyond a few words, for example in filling typical medical reports and forms. However, it is very important to identify which services are suitable to the cell phone and enable them without waiting for smart phones/laptops to become pervasive. With knowledge of the transaction types that can be delivered effectively using cell phones /smart phones/laptops/desktops, services can be launched accordingly as the infrastructure evolves. However, in one case, the Directorate of Public Health and Preventive Medicine at Chennai India and the Rural Technology and Business Incubation Centre at IIT have studied the usability of simple text-screen cell phones for disease surveillance, and found it easier and faster to train data entry to health workers on cell phones than on computers (see Figure 4) and hence dropped an endeavour to use computers in favour of using ordinary cell phones [18][19][20].

FIGURE 4: Training session for cell-phone based demographics capture (Courtesy: RBTI- IIT Chennai)



3.4 Intelligibility

Out of a population close to 1.17 Billion, India has about 450 million people who are not literate[9], over 1 Billion cannot understand English [10], less than 100 Million urban computer literate population. With a total of about 2.16 Million health work force [3], the fraction of computer literate workforce is correspondingly far lesser than required for proliferation computer automation in tele-health in its present form to establish communication between staff and patients. It also comes in the way of generating human resource by educating and training human resource remotely (TV based education is being used, but is not interactive as in computer based training). This calls for usage of alternate human interfaces to the system such as speech, handwritten and iconic interfaces instead of the alphanumeric keyboards. However, none of the projects used these interfaces and there is hesitation to make new investments in the near term to replace current systems with such capability. In most cases, the care providers have addressed this gap using verbal communication and video conferencing as a preferred choice of both staff and patients, with computer literate staff being employed at hospitals to key in their handwritten documents.

In some projects, handwritten medical documents are scanned and uploaded to the database as images to bridge the gap of typing and computer literacy in remote workers. In some cases optical character recognition technology has been tried to scan and index specific sections of the image based on their character based section-headings. Although the image files would require a lot more storage and bandwidth than text entry, this cuts time and learning curve for the medical personnel, and so it works out! However, the survey could not find any examples of adoption of character recognition technology equipped with medical vocabulary to digitize the handwritten content input from the images. In one initiative, Infolife [43] provided document management system with electronic writing pads to doctors for entering notes, prescriptions, etc. on the paper attached to these writing pads and retain paper copies as per legal requirements while the pads generate digital copies that can be saved in databases and used for circulation. They claim this path to have minimal resistance from the system, since it works within legal requirements without modifying the current writing practice of Doctors/nurses and can be added to existing desktop/laptop computers at a fraction of the cost of replacing them with tablet PCs.

3.5 Communicability

With over 22 officially recognized languages and over 1600 “mother tongues”, linguistic diversity seems a major barrier in the way of a patient in one region being able to talk to a doctor in another region, creating a need for language translators. Although electronic language translation technology has taken great strides, its application to Indian languages is still limited mainly to academic interests. Even though most of Indian languages have a common phonetic base, none of the projects employed such technologies, as the task of transliteration itself is still a very complex process and not perfected yet [17], especially in health care segment which demands the highest levels of accuracy and speed. The populations of people using these languages are also not large enough to attract major private sector investments for research and development of suitable translation tools in a standardized approach. In most cases this gap has been practically addressed by care providers by routing of data and services to citizens to doctors in the same linguistic zone and between zones the communication takes place between staff mostly in English. There are also some instances of using desktop multi-party video conferencing (at least a three party system) with real-time involvement of human interpreters from remote areas at much lower costs and errors than translation of offline records [69].

3.6 Affordability

Commercial adoption of tele-health is yet in infancy and economically sustainable business models have not yet taken firm roots, hence the need for pioneering efforts from not-for-profit institutions to move forward the ICT adoption wave front with a social view point. This is ratified by the fact that only about 10% of the projects surveyed are run by private, for-profit organizations while the rest are funded by the government or not-for-profit organizations. The Indian space research organization (ISRO) has led the way [36] by providing free satellite connectivity, along with telemedicine devices, computers, video conferencing equipment and software completely free of charges. The Centre for Development of Advanced Computing (CDAC), has developed low cost Telemedicine and Hospital Information Systems applicable to general telemedicine and in particular to Cancer Care Management Network across government-owned regional cancer centres of the country [35]. To make such models commercial viable and scalable to the entire population, given the current affordability of about of $1 to $2 per person per month [13], sustainability cost of the network equipment and infrastructure should be maintained below $320 per month. At least one initiative [58][59] has demonstrated partnership with an innovative insurance program (collects $2 to $4 per person per year and covers medical expenses up to $4000) employed tele-health encounters to screen over 50000 patients and delivery hospitalization and surgery for cardiac patients.

There is a need for a system integrator role to provide a single window interface for planning, deployment and maintenance of appropriate mix of various technologies based on the care provider’s needs. With this the care providers can avoid the burden of technology assessment and reduce risk in capital investments. World Health Partners has demonstrated such an arrangement with a private sector technology company which offer complete technology support (biomedical devices, computers, software) packaged as a service with implementation, training, maintenance and back-office support in a purely entrepreneurial model equipped with has serviced over 30000 patients and growing [67] to [71].

3.7 Reliability

Almost all of the Tele-Health deployments in rural areas claimed to be under-utilized due to shortage of electric power supply. India generates only about 64% of its current electric power demand [14], out of which 93% of the demand is met in urban areas and only 52% of the demand in met in rural areas. More than 44% of rural India faces power cuts of 12 to 15 hours a day [15][16]. In this situation, merely inducting ICT infrastructure modernization for health care will fail in justifying its utilization rate. The charge to discharge rate ratio of battery backup UPS technologies will not suffice in such settings without local power generation facilities. This adds significant additional cost in facilitating health care provider in delivering services to about 360 Million people in rural India. All projects surveyed had either UPS or UPS + diesel generator backup as a standard part of the infrastructure, and can be provided environment friendly and cheaper alternative of solar power in future deployments in regions where sunshine is not an issue. Most of the tele-health software utilized stateless TCP/IP protocols for data transmission overlaid with their own session management protocols for stateful restoration from link failures and inordinate transmission delays. In about 10% of the projects parallel connectivity was employed as a standby arrangement using ISDN lines. There does not seem to be any QOS tracking as applied to tele-health sessions. Such benchmarks, if available will be helpful for care providers to rank and rate performance of their telecom service providers.

3.8 Data Security

Most of the implementations have provided different levels of data access security – username-password based, role based and entity based access restrictions. In about 10% of the cases, data transmission security has been adopted by employing either a virtual private network (VPN) layer or HTTPS protocols. There is a degree of reluctance from hospitals to connect electronically with external systems, suspecting data privacy and security issues with regard to patient and business sensitive information. In most cases the Hospital Information Management Systems (HIMS) employed in the hospitals had no direct linkage with the tele-health network software. Although the tele-health software used claims to provide HL7 interface [46], most of the records generated from the hospitals (such as diagnostic reports, discharge summaries, etc.), had to be procured from the patients and either re-entered or scanned to upload into the tele-health network purely at the patient's risk. Although facilities have been provided in respective databases to configure encryption of data for storage security, there is no mandate for adoption.

3.9 Portability

Mobile vans/ambulances (see Figure 5) retrofitted withtTele-health units seem have been utilized for surveillance, patient screening camps as well as disaster care management scenarios such as triage and emergency treatment in remote and difficult terrains [33][60][61][63][64]. Portable frameworks have UPS and power generators, minor-OT; patient vital sign monitoring, diagnostics lab facilities from bio-chemistry to X-Ray, dermoscope and ophthalmoscope; tele-consulting desks; optical lens and medicine dispensing systems; location tracking, etc., within the mobile vans with satellite connectivity. In such scenarios, portability seems to be of higher importance than mobility from a usage model perspective, wherein laptops and desktop PCs are found to score over mobile/smart phones.

FIGURE 5: Mobile Tele-ophthalmology/Tele-mentored surgery vans (courtesy: Shankar Netrayala and Amrita Institute of Medical Sciences

3.10 Bio-medical interface

Almost all initiatives participating in tele-consultation provide for scanning/photography of old medical records and radiology films into a digital data base as well as capture diagnostic measurements of patient’s vital signs such as heart rate, BP, weight, temperature as well as camera images of affected areas. In over 50% of such projects this data acquired and stored offline as a pre-preparation for consultations, while the rest enable real-time measurements. In most cases, although the software provided interfaces to acquire images from CT/MRI/ultrasound/dermoscope/ etc., using TWAIN interface standard and convert them into DICOM file format. AIMS and SGPGI teams have [25][26][34] attempted tele-mentoring and tele-CME of live surgery (in one case surgery was inside a mobile van), using streaming video for conferencing and monitoring proceedings of the surgery, and have recommended a minimum of 384 KBPs for video conferencing with along with a standby alternative connection, and 1 Mbps for monitoring surgery proceedings. An initiative of Narayana Hrudayalaya [56][57] has used real-time ECG monitoring for screening/diagnosis of cardio vascular diseases of thousands of patients saving unnecessary travel and provisioning timely intervention, while tele-ophthalmology projects of Aravind Eye hospitals and Narayana Netralaya [61][63], were found to be using images from remote fundus cameras and slit lamp for ophthalmology screening. While all the above used standard, off-the-shelf equipment, NeuroSynaptics has innovated solutions [76], demonstrating usage of a web camera for live screening of cataract patients and employed an ordinary stethoscope modified with digitization interface for remote inspection of heart and respiratory sounds. Pathology slides images from microscopes were photograph with digital camera attachments and send in a similar manner to radiology images. There is no evidence of high-end imagery such as virtual-slide technology being applied for high resolution full slide digitization in remote pathological reporting scenarios.

3.11 Interoperability

Although the projects together address more than 200 000 patients from different regions of the country and network personnel and facilities from over 1000 pharmacies, 300 hospitals, over a few hundred clinics, it seems also the functional capabilities of many projects are limited to their own networks. Most of them maintain their own patient medical records across their network. The survey did not find any longitudinal electronic health records being shared between these networks electronically (although technically possible), but in most cases patient did not have to produce earlier health records as long as they consult within the same network. There are projects which are providing consultation, but do not have facilities for example, to do a tele-mentored surgery. Some projects which focus on patient/staff education are not connected with projects that are into surveillance, although their collaboration could help sourcing syllabus that is relevant to their target demography and avoid rest of the clutter in study materials. Excellent examples of disaster preparedness were sighted from some projects wherein complete kits for addressing specific disease outbreaks have been modularized and accommodated into mobile van form-factor, which can be replicated by all networks operating in disaster prone areas. In most cases the patients were given a common identification number registered across the network, independent of registrations and Ids generation inside hospitals. A paradigm shift from silos of excellence to collaborative care delivery perhaps needs a value-exchange model that would incentivize reliable, professional sharing of information and services across such networks to rapidly expand the coverage, so as to enable the patient with continuum of care across such boundaries. Although this has been achieved in the banking sector where one can use an ATM of any bank to draw cash from any of the banks hosting their account with a small service charge, it is not yet enabled in the health care provider space.

3.12 Digitization of old records

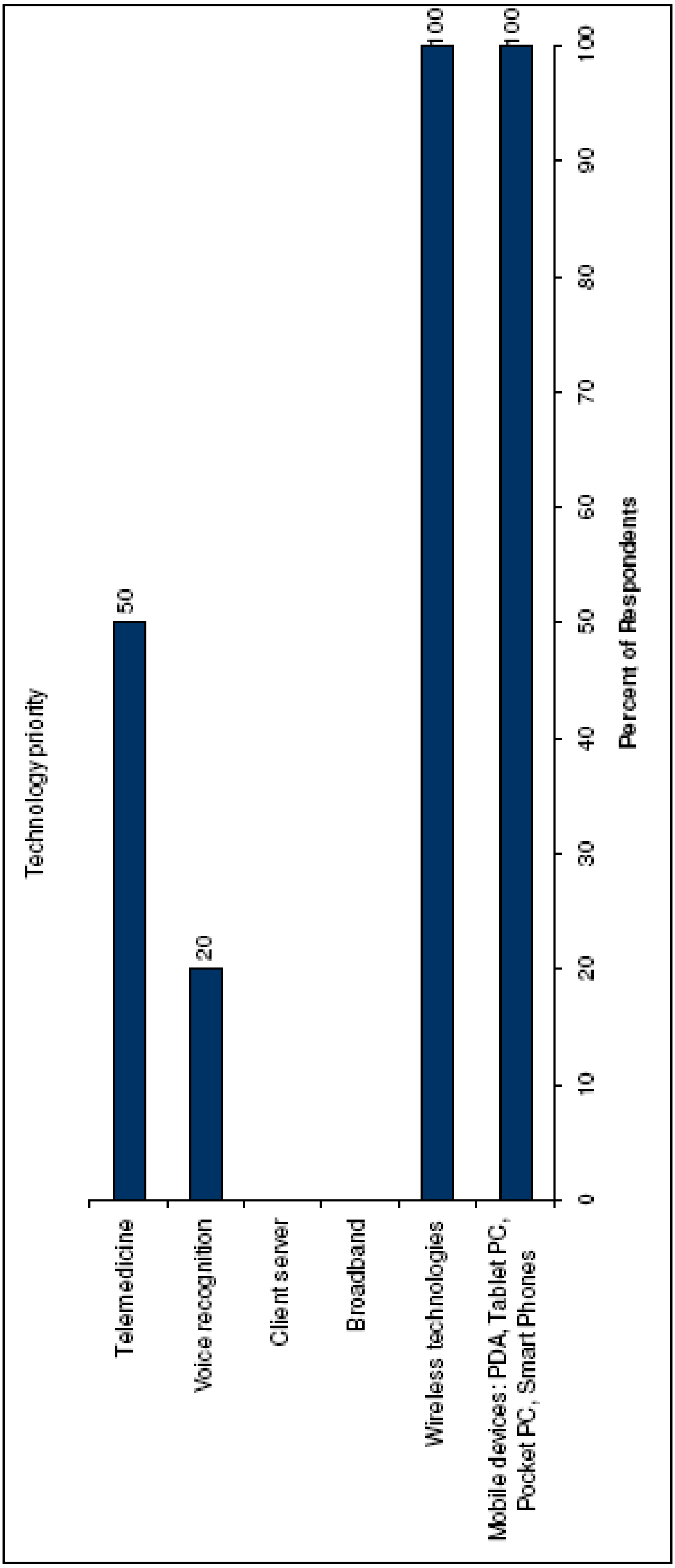
It is mandatory for care providers to archive patient records for at least 10 years and most of these records are in hard copy paper or film prints. Almost all tele-health applications provided digital entry of data for future records and also interfaces for scanning and uploading of old paper and film records and in some cases old digital records such as images, photos, etc., into electronic medical record of the patients. Some chains of hospitals such as Apollo and Manipal groups have begun converting their legacy records into digital form reducing their burden of record maintenance and ready accessibility. This is an important step for establishing care continuity as the health care system transitions from hard-copy to digital database, as well as for using the data for research without sacrificing the patient identity. In one example, Infolife has carved out a complete business model of scanning old hard copy records and then indexing various fields such as patient history, demographics, etc., from the scanned records into their document management system using optical character recognition technology, claiming to have converted over 15 Million health and forensic records.

3.13 Commerce

A majority of the government and NGO driven initiatives are delivering care free of charge. Other commercial projects have cash collection agents periodically visit the care delivery centres, with a centralized billing system that could capture transaction entries from all tele-health ventres on the network. Initiatives of Health Highway [42] and Health India TPA services [73] have provided electronic insurance claims processing services on tele-health networks connecting over 1000 clinics, primary care centres, general and tertiary hospitals. They verify claims information from prescriptions, discharge summary, bills, treatment plans, medication order, diagnostic data, diagnostic report, treatment charts, investigation notes and insurance claim forms from insurance admin in a given centre. A majority of the content is text (entered by the insurance admin), and scanned images of relevant documents process images. Cashless cards and electronic payment gateways have been interfaced to the system in cities for direct reimbursements to the patient and collection of insurance premiums.

3.14 Technology investment

Projections of Frost and Sullivan [44][45] indicates up to 5% growth in IT adoption in about 40% of health care providers in the next couple of years. Over 60% of the IT budget is currently being spent on hardware, and over 25% in software. In the coming years, this spending is expected to shift to managed services with the capacity build up of outsourced hosting, cloud computing and wireless mobile infrastructure. Industry investments into technologies has been influenced accordingly, with top focus areas being mobile devices, PDA, tablet PCs, smart phones, etc., and wireless infrastructure components. Tele-Health application and device technologies seem to be the third highest attraction for technology industry, with vendor preference favouring international players for device technologies and local players for tele-health application software and database. In most cases the current tele-health applications were in form of two/three tier client-server applications and very few web-based applications. Recent developments are to hybrid models wherein web-based interfaces are provided for thin-client compatible usage scenarios, while retaining thick client interfaces to deal with thick client-specific I/O tasks such as device interfaces, graphics intensive presentations, etc. Most recent emphasis has been on mobile phone embedded client technologies and one should expect a variety of mobile health applications to sprout in next two to three years, although not much is visible yet.



Source: Frost & Sullivan

3.15 Support services

Many of the initiatives are found to outsource information support services to private call centres. In a different example, World Health Partners [69][70] have provided their own centralized call centres with CRM tools and a front-office support system schedules and routes patient traffic to different consultants based on a queuing system, with optional facilities to wait for a particular doctor (useful in follow up consultations). These centres are equipped physicians providing consultations and primary screening and patient referral support over video conferencing to over 30000 patients from various tele-health centres in rural areas across the country. The system enables the consultants to refer the cases to specialists in several tertiary hospitals linked on to their tele-health network and consolidate electronic medical records of a patient. They have successfully experimented providing information and logistic support for patients to book admissions and ambulances in the referred hospitals, booking travel tickets and accommodation and filing insurance claims, etc. Once such services are brought into main-stream utility, it will form a crucial link in supporting care continuity between primary care and tertiary care centres in a tele-health network.

3.16 Training

Pioneering initiatives are underway (AIMS, SGPGI, Apollo Hospitals, etc.) [23][26][28][34][41] in collaboration with other hospitals, have demonstrated routine usage of tele-health networks for imparting skills training and academic health education to remote medical staff from virtual class rooms (see Figure 6) and operation theatres linked by dedicated video conferencing equipment. While for surgical training and live shows a minimum of 1 Mbps was recommended, for other aspects a multi-party video conferencing links of 384 kbps was found sufficient. The candidates also take tests and certification exams remotely using the same network. Most projects involved in counselling and consultation to impart health awareness informally to the patients, but there is no sample of any project conducting formal virtual health awareness campaigns for large groups of population using the tele-health media.

FIGURE 6: Continued medical Tele-education (courtesy: SGPGIMS)

4 Conclusion

The survey has taken into account important suggestions, achievements and methodologies from about 26 real-life projects pioneered by various reputed organizations, through interactive discussions and literature published in journals and the web. In Appendix I, a few case-studies are discussed in order to cite examples of specific infrastructure adoption pattern in different phases of real-life care management process. Appendix II indicates a list of links to reference material in form of publications and websites of organizations and initiatives of relevance in this study. From within the collected information, the study has revealed several gaps and Innovative solutions in proliferating tele-health infrastructure across the country, which can be summarized as follows:

1. Transmission of vital signs and video conferencing data have been demonstrated at 64 Kbps links.
2. Proprietary design of sub-$250 multi-parameter vital sign monitors have been developed to address affordability.
3. Technology for transformation of legacy printed records into digital data base at speeds of over 5000 pages per day with optical character recognition are being employed.
4. SMS and Web-based routine data capture for demographic, environmental surveillance and patient monitoring have been demonstrated using sub-$100 cell phones.
5. All tele-health activities have been demonstrated satisfactorily under 384 Kbps bandwidth except tele-mentored surgery (recommended at 1 Mbps).
6. Tele-health in the country began as pioneering effort with the support of ISRO's satellite based network has begun spreading on other public and private Telecom networks, using ISDN/DSL/GPRS connections.
7. Software applications are migrating from pure client-server architecture to hybrid models wherein web-based interfaces are provided for thin-client compatible usage scenarios, while retaining thick client interfaces to deal with thick client-specific I/O tasks such as device interfaces, graphics intensive presentations, etc.
8. Electronic writing pads, low cost scanners and digital camera interface have been adopted to counter computer-literacy barriers.
9. Multiparty Video Conferencing has been utilized with real-time human translators to counter linguistic barrier.
10. Mobile Vans with various functionalities from screening to minor OT have been deployed routinely to reach out to remote rural areas.
11. Satellite connectivity has linked remote islands, difficult terrains and rural areas to specialists in tier-1 cities.
12. Electronic payment gateways have been interfaced to counter burden of manual cash collection logistics.
13. Power generators and UPS have become a default part of the infrastructure both in urban and rural areas to counter energy crisis.

14. Application level session management protocols as well as standby mode connectivity have been adopted to counter link breakdowns and transmission delays.

15. VPN and HTTPS protocols have been employed for transmission security.

16. Combinations of login based, role based and entity based authorization for various operations with data such as access, creation, modification, deletion, replication, encryption, storage, transmission, delegation, printing, etc.

17. Automatic queuing and routing mechanisms have been introduced for traffic management and load balancing within tele-health networks.

18. Networks have delivered various services such as disease surveillance, screening, counselling, consultation, diagnostics, tele-mentored treatment and surgery, tele-reporting, registration and admission of patients, providing information, logistics, financial and educational support to patient, education and mentoring of remote medical staff and students, electronic payment collection, etc., which intersect with over 85% of tele-health transactions.

19. Several proof points of benefits have been demonstrated in terms savings in travel time, expense and effort of patients; timely intervention and containment of disease outbreaks and emergency; generation of additional workforce such as nurses and paramedics with interdisciplinary knowledge of technology usage and care delivery; proactive care delivery; reduced human error and misplacement of patient data, etc.

20. System integrators have begun to take up role of single-window technology service provider to the care providers thereby reducing the risk of investments and burden of maintenance.

There is also ample scope for further exploration in some key aspects that could accelerate adoption of tele-health system summarized below:

1. A systematic exploration of health care information transactions achievable at various connectivity bandwidths and user-end platforms will probably induce a much wider usage of cell phones, smart phones and wireless connectivity in to capitalize on its affordability, simplicity, mobility and availability across the country.

2. At the policy level a tremendous boost to proliferation is possible if voice/video/image records endorsed by biometric signatures become recognized by governing policies as equivalent to type written and handwritten records. It will break down major barriers in learning curves of literacy, linguistic diversity and typing skills. The risk of information security in this case seems much less than the present system of hard-copy records vulnerable to manual handling which uses only handwritten signature as an authentication. From a technology standpoint, such a change is immediately adoptable with current technologies and will involve probably take lesser time to implement and train the end-user. Such a paradigm shift would be worth considering the widening gap between demand and supply of health services.

3. Video conferencing seems to be the pivotal application in promoting acceptance of tele-health by doctors and patients alike. If the onset of 3G technologies enables video conferencing on mobile phones it will form perhaps the most crucial catalyst for rapid proliferation of tele-health. All other services and transactions as seen above (except surgery) are possible within the bandwidth 3G can provide.

4. The system will immensely benefit by introduction a layer of service integration by entities that aggregate different tele-health services, infrastructure services, governance and financial support services from various participating entities into backend services. Such a layer can provide a packaged proactive care program, offered as a single window service to the patient and take care of revenue collection and distribution among the constituent service providers improving outreach, load balancing and affordability through aggregation of demand and supply.

5. Billing systems for tele-health services can become multi-tier and very complicated as the systems matures. It will save time and cost in jump starting tele-health commerce management by integrating with proven technologies such as Telecom billing and Insurance claims management software platforms such that transaction based fees can be converted into subscription based fees eventually.

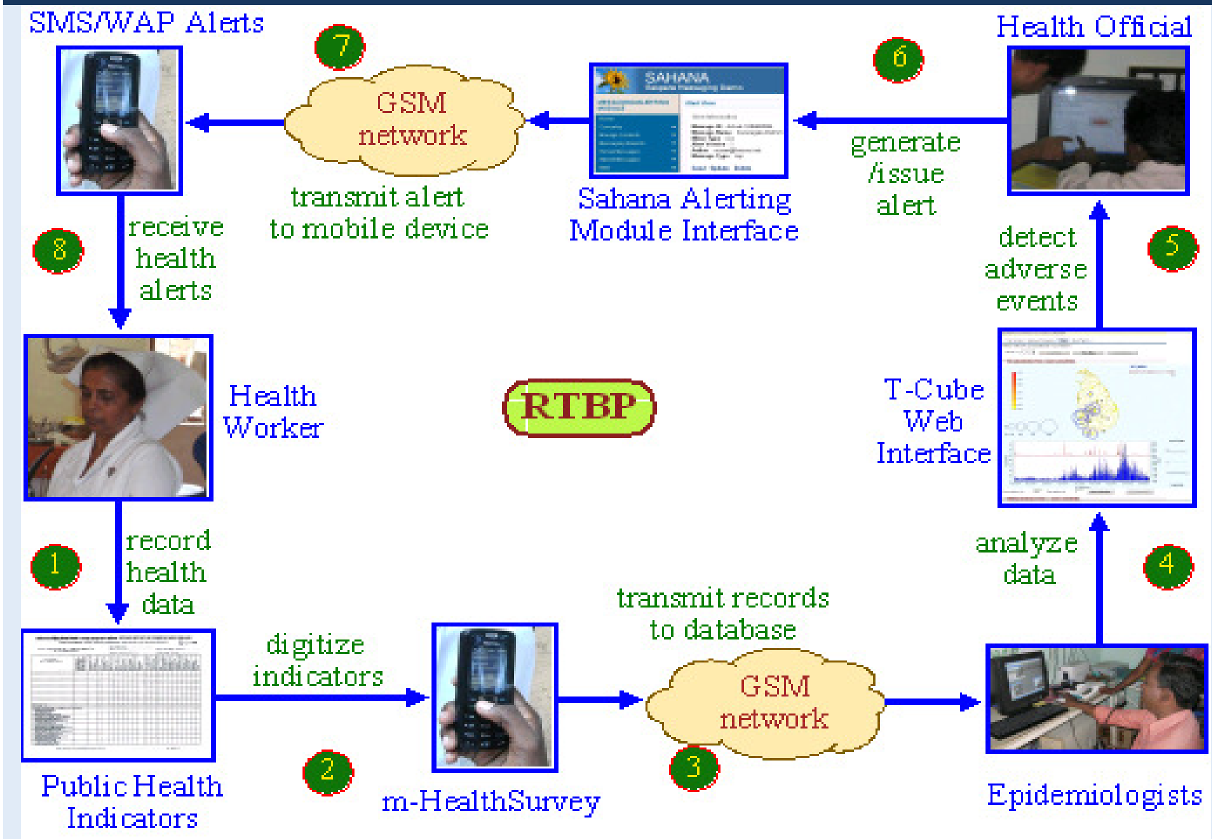
Appendix I: Case study examples

The first is an example of mobile tele-health application in disease surveillance project of the Government. The second is an example of tele-health in a large network delivering routine curative/palliative care delivery linking rural and urban entities and personnel, run by a not-for-profit organization. The third case study is an example illustrating tele-health infrastructure adoption in education to medical personnel, by medical education institutions. The fourth is a an example of a commercial tele-health network used for preventive and routine care delivery run by a private for-profit agency in urban corporate settings. The fifth example is a Social initiative of tele-health for disaster management and mobile care delivery. The sixth case study is an example of a private sector collaboration experimenting with mobile and 3G based tele-health services. The selection of projects in this discussion is random and purely to illustrate a variety of tele-health infrastructure adoption and does not mean any preference or comparison with other projects.

Case Study 1: Real-Time Bio-Surveillance Program (RTBP): Directorate of Public Health and Preventive Medicine, Tamil Nadu, India

This project [18] [19] [20] is a collaboration of IITM's Rural Technology and Business Incubator (RTBI), LIRNEasia, Sri Lanka, National Centre for Biological Sciences, Bangalore and Department of Health and Family Welfare, Tamil Nadu. The Directorate of National Vector Borne Disease Control Programme in India publishes the status on their website, from data being collected through paper-based system. Health workers in Primary Health Centre (PHC) and Health Sub Centres (HSC) carry to the field 20 registers weighing almost ten kg to aid in documentation of health information. The Village Health Nurses (VHN) and Sector Health Nurses (SHN) consolidate weekly health record statistics gathered from the field at the PHC level and send it to the office of the Deputy Director of Health Services (DDHS), at the district level. They in turn will prepare a location and week wise disease monthly count details and share it to the Directorate of Public Health and Preventive Medicine (DPHPM), at State level. It takes one month for DDHS to communicate the disease count details to the directorate located at state level. DPHPM would like to reduce this turn-around time for early intervention.

FIGURE 7: Data flow in Tele-Surveillance of public health indicators (Courtesy: RTBI-IITM)



The RTBP address this gap through an ICT system (see Figure 7), that incorporates the collection of clinical information through mobile phones for the purpose of detecting disease outbreaks before reaching epidemic states. The project aimed at mobile based entry for the VHNs and initially web-based data entry applications being run on PCs at PHCs, but considering the constraints faced at PHC in respect of human resource availability for web-based data entry (OPD number, date & time of visit, village name, patient's name, age and sex, diagnosis, symptoms, prescription, etc.), and also frequent failure of internet connectivity, PC based data entry was dropped and switched over to mobile phone data entry at PHC level as mobile found familiarity required much lesser learning curve and resistance.

A java (J2ME) based local application and data base tables hosted on the mobile phone enable local archival of the entered data and buffered transmission to centralized Linux based APACHE server and MYSQL data base. This application takes care of reconnecting and transmission in case of link failures or GPRS service failures and also uses SMS as an alternative channel when GPRS is unavailable. The data is uploaded through cell phones by PHCs and is inspected on desktop Web-based application by epidemiologists under DDHS routinely. The results of their study are uploaded to a website in form of health status indicators. The Health Department Officials (linked on the network through a dedicated DSL connectivity), monitor the indicators and generate alerts to health workers on their phones, upon detection of adverse events from the indicators. The health worker consults the health department on cell phone and takes necessary corrective action as directed.

The target site was Sivaganga district, one of the most economically backward districts located in southern part of rural Tamil Nadu, involving four PHCs (Nerkuppai, Thirukostiyur, Keelasevalpatty and Sevanipatty) and 25 HSCs covering a rural population of over 68 000 people. 25 female workers aged between 41 and 50 with less than 28% per cent having up to 12th standard education attended various short terms training courses on reproductive child health, HIV/AIDS etc. They were trained in application installation and configuration, submission of data and transmission of patient data using a Java-based application on GPRS-enabled mobile phones to a central database for storage and analysis with technical support from RTBP.

At the end of two-day workshop, all the health workers had become acquainted and interested to collect the health data independently. The project team initiated data acquisition and analysis week-wise/disease-wise and found health workers were taking typically 2 minutes to fill one form. Data collection rates improved from 300+ cases (manual) to 2500+ cases (cell-based) uploaded per week. Over 36000 records were collected in six months and records with any type of content error were marked as noisy records. The ratio of noisy to clean records was shown to improve from 1:1 to 1:10 over 24 weeks of usage. However, RTBP researchers conclude the health workers have acquired the ability to enter data through m-Health Survey application using just a low end-end text-based mobile phone, and recommend further improvement to be achieved in error rates through more intensive training and simplification of the process of the data entry submission.

Type of node in Tele-Health Network	Type of transactions	Infrastructure components employed
Four Primary Health Centres	Upload public health indicators from villages	Low end Text-based Mobile phone using J2ME embedded mobile client GPRS link with SMS fall-back
Office of the Deputy Director of Health Services	Analyze district wide data, aggregate results and publish trends, indicators and alerts	Desktop PCs with Web browser
Directorate of Public Health and Preventive Medicine	Analyze state wide trends, indicators, alerts and call PHCs for directing responsive measures through talk, data and messages on mobile phone	Desktop PCs with Web browser, MYSQL Database server, Java application on Linux and APACHE server, Mobile phones using J2ME embedded J2ME client

Case Study 2: Sustainable Tele-Health Network for Preventive and Curative Interventions – World Health Partners & Neurosynaptic Communications, Uttar Pradesh, India

This project is a tele-health initiative of World Health Partners in collaboration with private and NGO resources harnessing technology and existing social and economic infrastructure [76], [67] to [71]. In this project, village entrepreneurs invest in setting up service centres where they earn income by linking with city based doctors to provide health care to rural clients. More serious cases are referred to higher level of private care providers which also earns them an incentive which is normally a percentage of the fee that the client pays. Local communities are mobilized through advocacy-building and other social activities including word-of-mouth campaigns, mass-media and infotainment and social marketing of user-friendly health services. The operational strategy of WHP divides skills, resources and competencies on the basis of location and interconnects them to either provide care or facilitate care by a service network as shown in figure below. Neurosynaptic Communications is the technology partner of WHP providing end-to-end ICT platform and services (biomedical devices, computing and communication system hardware and software as well as tele-health application software, see Figure 8).

FIGURE 8: Preventive and curative care Tele-Health Network (Courtesy: NeuroSynaptics)

A typical village health centre has a two-room arrangement, one in which the consultations happen and the other serving as a waiting area for patients. The centres are owned by rural entrepreneurs, all women, and are linked via either ADSL (256 Kbps, shared-1:4) or when that is not available, through VSAT (64 Kbps). The town based clinics and labs also form an integral part of the network use regular internet services. The central medical facility (CMF), which is increasingly becoming a virtual network, also needs simple broad band. The CMF's arm in Delhi, which is also the control centre of the operation, uses a leased line HDSL (2 Mbps) link. Utilizing a proprietary, cost-effective diagnostic system and Tele-Health Software developed by NeuroSynaptics, the project has integrated live streaming of vital parameters (such as ECG, NIBP, heart rate, blood oxygen, temperature, etc.), and other details in a patient's electronic medical record (EMR) such as doctor's notes, prescriptions, bills, scanned records of past reports, etc., and video conferencing onto the centre's application screen, within 64 Kbps bandwidth. Utilizing customized versions of G.723.1 speech coding and H.264 video coding methodologies, the system will also be able to use in the coming days for three-party conferencing mode within 64 Kbps wherein interpreters will be employed in live consultations to bridge language barriers. The system utilizes Client-Servers applications with Linux based servers and Windows client platforms, MySQL data base and an application level proprietary encryption for data security. The patients visit Village Health Centres and Consult Rural Providers, most of them informally qualified, for minor ailments. For more serious conditions, the VHCs help in connecting the patients to call centres in Delhi and Patna cities which station counsellors and general physicians. These centres provide primary consultation and prescribe diagnostics/therapeutic treatment. The project will add a specialist component in the coming weeks.

The project is scheduled to move toward a dual system of general pool and appointments-based consultations. In the general pool, the patients will follow a first-cum-first-serve queue. With the appointments, they will schedule the consultation time on a web-based system. The call centre refers clients who need more than therapeutic care to tertiary hospitals where the providers can access the medical records on a case by case basis. These Centralized Electronic Medical Records (EMR) are updated with patient details at each encounter at any service centre and case sheets/discharge summaries/bills/etc., are uploaded into the EMR by paramedics at the call centre. A centralized billing system for various services at any service provision point in the network will facilitate electronic settlement between providers. WHP maintains an efficient supply chain that ensures that medicines that are prescribed by the providers are easily and readily available. The organisation also deploys preventive maintenance and repair teams to keep the equipment in good repair. Almost all centres are equipped with UPS and generator backup for power supply and the project is testing out solar powered UPS systems. A centralized control facility utilizes a Customer Relationship Management System (CRM) for data analytics, MIS and audit control of the network. The rationale for charging the patient has been based on the low income levels among the communities in the project area. Currently, a consultation with free follow-up for five days costs the patient $1 but increasingly the project will move toward breaking even for clients above poverty line and targeting subsidies only to the poor. Over the last two years, this network has established a revenue-share based supply chain that links about 1200 villages in three underserved districts of Uttar Pradesh, covering about 4 Million people with preventive and curative services delivered through a collaboration of various entities and workforce – about 1200 women rural health workers, 127 village health centres, 14 urban medical clinics, 9 diagnostics centres, 1800 pharmacies, with over 25 general physicians and paramedics hosted at a call-centre like facility in Delhi and Patna. Experiments to enable village level providers to connect patients from their homes with doctors in cities using cell phones have been successful. Future adoption of such paradigms is expected to integrate this data also into the current EMRs.

Type of Tele-Health node	Type of transactions	Infrastructure components employed
127 Village Health Centres and 14 urban clinics	Patient registration, referral to call centre/specialist, primary diagnostic measurements and upload to patient EMR, primary care intervention	Bio-medical devices: ECG, NIBP, Heart Rate, SPO2, thermometer; Desktop PCs with Windows and proprietary Tele-Health client application; conferencing with G.723.1 and H.264, Telecom: 256 Kbps DSL with 64 Kbps VSAT fall back, UPS with power generator
1200 Health workers	Home visits for medicine supply, care follow up and data gathering into EMR	Mobile phones with GPRS/SMS/MMS
Central Medical Facility (2 locations)	Patient history, symptoms capture; primary consultation and diagnosis; prescription for treatment, second level diagnostics; referral to specialist; Tele- support for patient logistics; Billing, auditing, MIS, collection, supply chain management, etc.	Desktop PCs with proprietary client application, CRM software, 2-tier client-server system with Windows client and Linux server and MYSQL database, connectivity: DSL 2Mbps link
1800 Pharmacies	Medication supply based on electronic prescription	Desktop PCs with internet browser, pstn/isdn/dsl links
9 Diagnostic labs	Upload diagnostic reports and data onto EMR	Desktop PCs with Tele-Health client app and internet browser, DSL connectivity
Hospitals	Upload admission, discharge and transfer documents billing and insurance related information into EMR	Desktop PCs with Tele-Health client app and internet browser with DSL links

Case Study 3: Remote Continued Medical Education (CME) Network – Sanjay Gandhi Post Graduate Institute of Medical Sciences (SGPGIMS), Lucknow, India

SGPGIMS is a leading government medical education institute attached to several super speciality tertiary hospitals [21] to [32]. In one initiative, SGPGIMS is spear-heading several pioneering initiatives of tele-health in form of continued education, disease surveillance and other allied area in collaboration with a number of hospitals across the country. In the field of continued medial education for junior doctors, nurses, paramedics and health workers several milestones have been demonstrated spanning from virtual classrooms to live shows of surgeries in OTs.

Utilizing a propriety Tele-Health Client-Server platform with document sharing and video conferencing capabilities over 128 Kbps ISDN telephone lines, SGPGIMS has hosted several live tele-CME sessions using tele-medicine software with video-conferencing. For example, weekly sessions on various aspects of Rheumatology such as laboratory test interpretation, radiology image analysis, and clinical case discussions followed by questions regarding diagnosis and management. Multimedia medical record of the cases to be discussed were prepared and sent a day prior to the scheduled date. On the scheduled time the discussions on the cases transmitted earlier was carried out over video-conferencing. At the end of study the participants were asked to give their response a questionnaire circulated to them.

The network also imparted distant education on the subject of Radiology to the postgraduate students of Radiology of SCB Medical College, Cuttack. Radiological images were transferred prior to main consultation and conference, followed by discussion and at the end of the study period the participants were asked to give their response to the questionnaire circulated to them. The Tele-CME program was found useful to more than 75% of the participants in distant and remote areas possible, however it was felt that for transmission of moving images, as for operative procedures, a minimum of 384 Kbps is mandatory. Further, utilizing 512 Kbps satellite links (see Figure 9), live surgery images were transmitted live to SCB Medical College over 1500 Kms away at Cuttack, Various sessions' included- clinical grand rounds (CGR), live demonstration of open and endoscopic procedures (See Figure 10), guest lectures, endocrine pathology and endocrine radiology. Each session was followed by a discussion with the remote attendees and they were asked about programme quality and effectiveness.

FIGURE 9: Tele-CME network (courtesy: SGPGIMS)

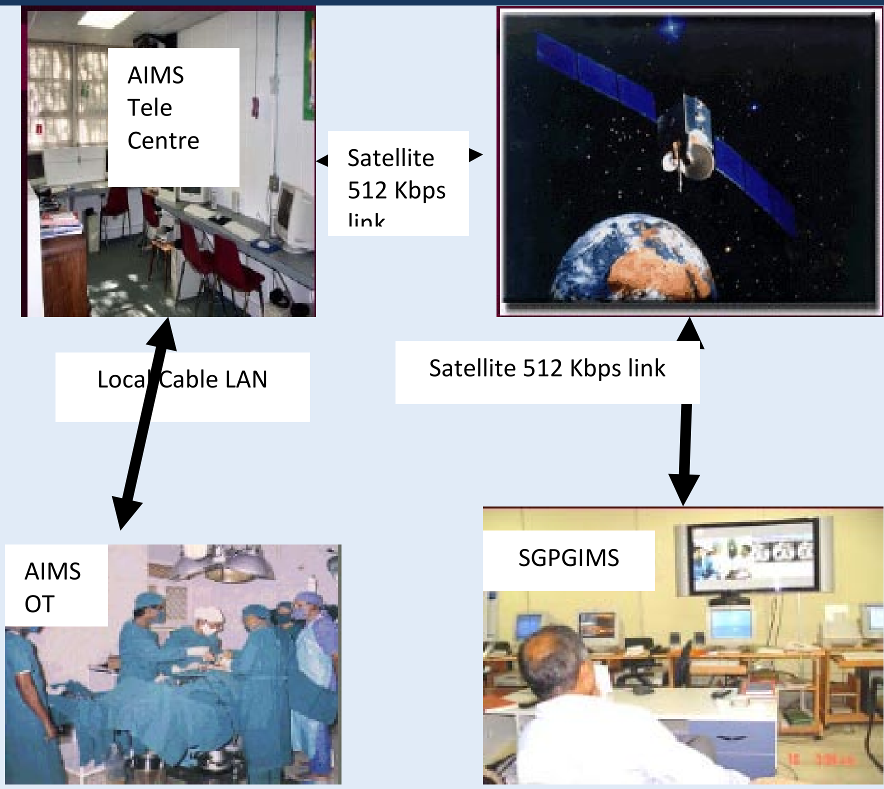
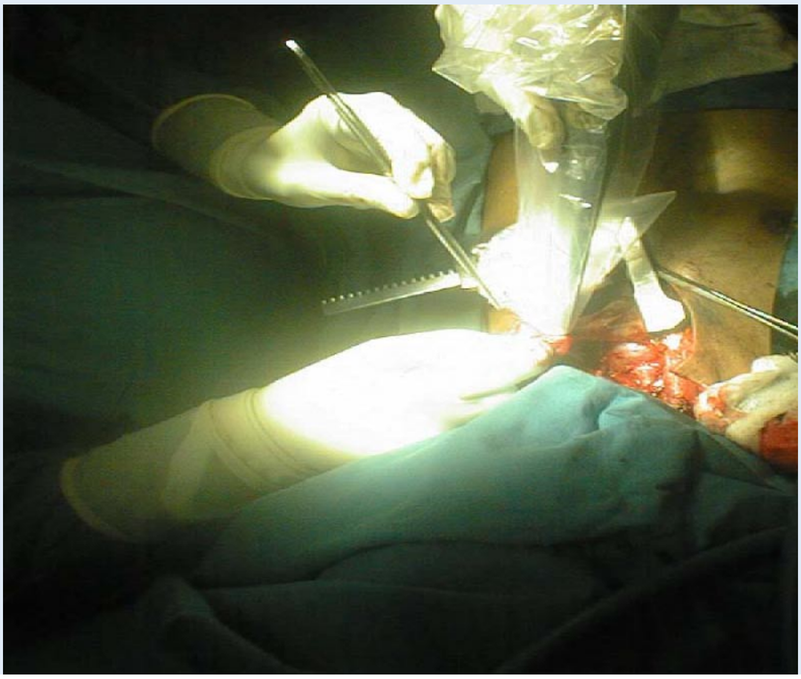


FIGURE 10: Live Surgical procedure demonstration in Tele-CME (Courtesy: SGPGIMS)



In another initiative SGPGI has performed disease and environment surveillance and provided preventive care through the use of their tele-health platform. Using video conferencing and small laboratory with a microscope and bio-chemical analysis facility at the Mela Hospital during Kumbh Mela, Allahabad, UP, connectivity was established between SGPGI and Mela hospital (70 Bedded) and Swaroop Rani Hospital, Allahabad, and the state health laboratory, Lucknow, through ISDN (128 KBPS) links. Few equipment (e.g.refrigerator, incubator) along with necessary stains (Gram stain, Leishman stain, ZNS, etc.), the transport media and culture media were sent from the Microbiology Lab, SGPGI, Lucknow. Residents and technical staff were sent at regular intervals and especially on and around bathing days. Patients with respiration tract infection, gastroenteritis, fever, trauma, cardiac and dermatology issues had telemedicine consultation. The specimens which could not be processed at Mela Hospital were transported to the SGPGI. Besides the patients, strict monitoring of the water and food was also done.

In suspected cases of Gastroenteritis few fecal samples collected from a group coming one particular area of a state grew Vibrio cholerae and were confirmed both serologically as well as from the national center (NICED, Calcutta). Immediately through teleconferencing the results were communicated and management was done by the Mela doctors. Due to strict monitoring of the water through coliform counts at SGPGI and also OT test in the Mela, the outbreak did not spread and was controlled. The next common patients were with cough. They were mostly suffering from COPD or allergy. H.influenza could be isolated from some of them. The Sangam water examined before the mela started did have some coliforms and also the free-living amoeba. However, every week and after the bathing day the flowing water did not grow any pathogenic organism. Similarly the outbreak of diarrhea following contaminated food in a nearby police camp was prevented by strict monitoring and controlled within 2-3 days. Thus online telemedicine could really help and the infectious diseases could be controlled.

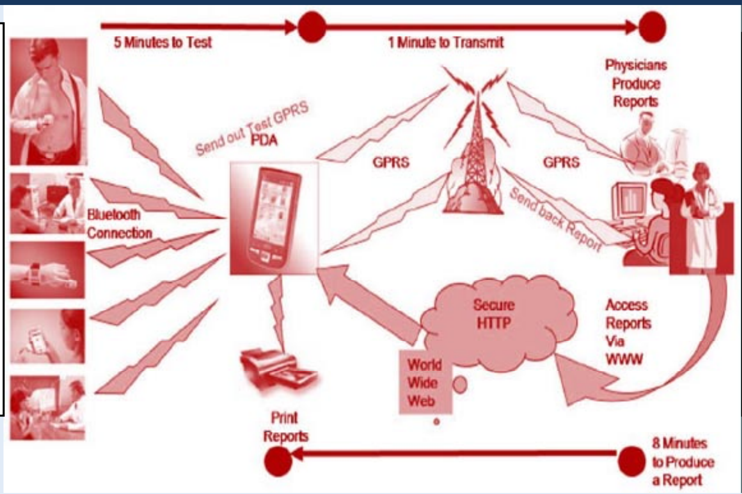
Type of node in Tele-Health Network	Type of transactions	Infrastructure components employed
SGPGIMS Lucknow, SCB Medical College Cuttack	Tutorials on utilizing electronic medical records, remote radiology image analysis and clinical case analysis	Desktop PCs with Windows and proprietary Tele-Health client application; Video conferencing PTZ cameras and monitors with G.723.1 and H.264, Telecom: 128 Kbps ISDN Connection for video conferencing and desktop data sharing, 512 Kbps for live surgery video, all centres equipped with UPS and power generator
Mela Hospital, Swaroop Rani Hospital, Allahabad	Patient screening, disease incidence and environmental monitoring, primary care and referral to SGPGI for specialist consultation	Desktop PCs with Windows and proprietary Tele-Health client application; Desktop video conferencing application using Webcam, monitors and 128 Kbps ISDN connections, all centres equipped with UPS and power Generator, microscope and bio-chemical analysis facility

Case Study 4: Urban Tele-Health Network – Ojus Health Care, Bangalore, India

This is an example of an urban tele-health network initiative being managed in a subscription based commercial model by Ojus Health Care private limited [48][49]. The initiative is utilizing mobile information management technologies to provide affordable healthcare in both managed care and self-care paradigms (see Figure 11). Focussing on health care of corporate citizens and their families, the team specializes in managing their health utilizing convergence of allopathic and alternative systems of medicine at Ojus clinics linked with diagnostic labs and speciality hospitals. The network has hosted six clinics, some of which are in corporate campuses such as the International Tech Park, Bangalore and Techno Park, Trivandrum and some hosted inside companies having significant employee base such as Texas Instruments, SAP Labs, HCL Perot Systems, etc. These clinics serve as service points for first aid, preliminary diagnosis, medicine dispensing, bio-sample collection, tele-consulting/counselling as well as nodal points for payment collection.

FIGURE 11: Ojus Preventive and Palliative care network (Courtesy: Ojus health care)

Ojus clinics
ECG
NIBP
SPO2
SPIRO
TEMPERATURE
BIOCHEMISTRY
FILM SCANNING
EMR INTERFACE
VIDEO CONFERENCING



Main centre
PACS
TELERADIOLOGY
TELEMEDICINE
EMR
VIDEO CONFERENCING
BILLING AND COLLECTION
INFORMATION AND SUPPORT

The initiative is focussing on delivering comprehensive health care interface to IT professionals who maintain a distinct life style of potential health risks and work in a highly competitive environment that induces lesser physical exercise but mentally stressful work habits, which also impacts their availability as a care taker of the sick people and chronic ailments of elderly people in their families (to a large extent in India, families of parents and adult sons stay together in joint families). The network provisions holistic primary and preventive care combining Ayurvedic massages and other relaxation procedures including yoga and meditation with tele-counselling, special domiciliary post-natal care of mother & child and domiciliary medical services for senior citizens. Special programs include training, monitoring and management of occupational medical problems such as neck and back strain, carpal tunnel syndrome, computer vision syndrome and stress. The employee-centric programs run in a subscription model wherein the subscription can be paid in cash/cheque by the employee or subsidized by payments from the employer. The annual subscription is < USD 30 per year per individual and the economics of the model enables setting up a clinic in regions with more than 1000 members. Within these revenues, the initiative has been able to provide preventive, maintenance, palliative support to subscribed members for all common ailments as well as chronic conditions of osteoarthritis, cancer, diabetes, aardiac diseases.

The clinics are managed by paramedics/nurses on full time roles and physicians on part-time basis, to capture symptoms, history, allergies, preliminary examination results in electronic medical record of the patient. They organize tele-consultation with specialist doctors, collecting diagnostic samples from patients at office or homes and instituting periodic therapy/self-care training. The network has tied up with external diagnostic labs, hospitals and specialists who provide services on a need basis, at additional charges directly borne by the patient. One of their clinics provides palliative care therapy at additional charges, for terminally ill cancer patients and chronic osteoarthritis patients with a state-of-art cytrotron equipment (see Figure 12).

FIGURE 12: Ojus preventive and palliative care Network facility (Courtesy: Ojus health care)

The post-therapy follow up is possible by patients/care takers being able to record their experiences and observations on the EMR. The patient condition are remotely monitored 24 X 7 and alerted upon detection of anomalies in their patterns. All records generated in the care process such as prescription, discharge summary, diagnostic data, investigation notes, health monitoring indicators, etc., are maintained in a web-based EMR, which can be accessed ubiquitously by the employee using internet.

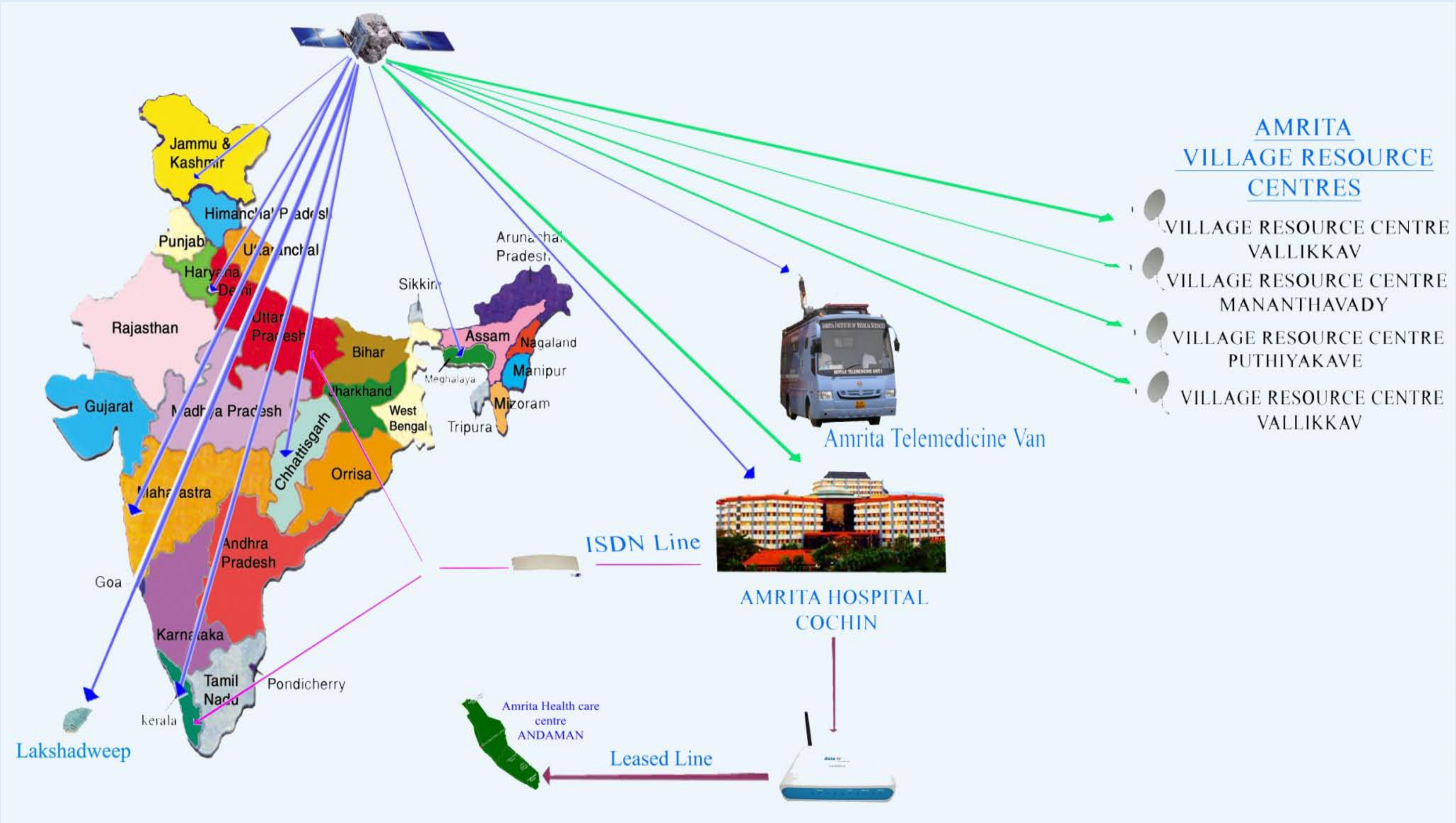
The system utilizes H.264 based point-to-point desktop-video conferencing between clinics and specialists. Portable bio-medical equipment with Bluetooth interface have been used for basic diagnostic measurements such as ECG, NIBP, spiro, glucometer, pulse oximetry, etc., to acquire data onto a cell phone in the vicinity. The cell phone in turn hosts a Java based client software to aggregate data from various instruments and transmit over GSM/GPRS link into the patient's EMR hosted in a centralized MYSQL data base. Paramedics and nurses can carry these equipment to residential locations of the employees and conduct routine tests. Physicians contracted from various hospitals can get access to the diagnostic data on a referral basis and send analysis reports back to the clinics within a very short turnaround time of a few minutes. A propriety Linux-Java based application provides for EMR, PACS, tele- consulting, videoconferencing and tele-monitoring utilities in its care delivery process. The initiative is delivering care to over 15000 registered employees of several companies in cities of southern India. The same model can be extended to any establishment, which can provide a base of more than 1000 members, such as residential flats, schools etc.

Type of node in Tele-Health Network	Type of transactions	Infrastructure components employed
Six Ojus Clinics	Patient registration, referral to call centre/specialist, primary diagnostic measurements and upload to patient EMR, primary care intervention	Portable Bluetooth interfaced Bio-medical devices: ECG, NIBP, Glucometer, Spirometer, SPO2; Desktop/Laptops PCs with Windows and proprietary Linux-Java-Jboss based Tele-Health web application with client device drivers and presentation layer software; Desktop video conferencing with H.264, Telecom: GSM/GPRS; Power: UPS with generator; Programmable therapy devices – Cytotron
Ojus main centre	Specialist consultation and reporting	PACS, Tele-Radiology, pathology, EMR, Java applications hosted on Linux-Jboss, Telecom: DSL, OFC scalable to 10 Mbps. Desktop video conferencing with H.264

Case Study 5: Disaster Management and Proactive care in Tele-Health Network – Amrita Institute of Medical Sciences(AIMS), Kerala, India

This is a social initiative of AIMS employing different network infrastructures and collaborators for various scenarios of health care delivery (see Figure 13) with each type of network connected in different colour lines) [33][34]. In one model, AIMS participates as a Tertiary multi-speciality hospital as part of a country wide network linked through VSAT connectivity of 384 KBPS), addressing specialist consultation and diagnostics requirements of patients referred from other hospitals in the network. The Indian Space Research Organization is the technical partner managing the network and providing a bio-medical kit, to measure patients vital signs, the associated computer hardware and tele-medicine software across the member hospitals as well as satellite connectivity, completely free of cost. Using this infrastructure, Amrita collaborates with over 60 hospitals from near and far flung areas, such as the islands of Lakshadweep and Andaman, the hilly terrains of Kashmir are part of the routine consultation and continued medical education programs that run on the network.

FIGURE 13: Multi-Hospital Tele-Health networks for preventive curative and disaster care management: (Courtsey: AIMS)



In a second model, AIMS has established Village Resource Centres (VRC) at various locations in Kerala and Tamil Nadu and Andaman. The VRCs interact with the Expert Centres of AIMS at Kochi and Ettimadai on a regular basis for providing a variety of services such as e-learning in medical IT and computer training, awareness campaigns of health and hygiene as well as telemedicine consultation services to enhance employability of the residents of villages and empowerment of women in rural areas while proliferating preventive care at the grass roots of the society. While the content and e-learning software is developed by AIMS, the connectivity to this network is provided through ISRO's satellite network. The network has been able to address cases of Diabetes/Glucoma/CleftLip/Dengue /Chikungunya/Spirialis. Remote specialists deliver advice and education to junior doctors, patients and care takers in remote villages to manage chemotherapy follow-up care, nephrology, palliative care, post operative eye care, pain management, stroke rehabilitation, skin disease monitoring and psychiatry.

In a third model, AIMS has focussed on containment and prevention of disease outbreaks in disaster situations. It has developed complete disease specific packages of infrastructure, training material and medicine that can be hosted into stand alone units and mobile vans (AMTU) readily deployable in disaster zones. The air-conditioned mobile Telemedicine Van Unit has state of the art videoconferencing capability (adopting H.264 and G.711 compression, H.323/SIP protocol) and a wide range of equipments for echocardiography, cardiac treadmill, gastroscopy, colonoscopy, retinal camera, ultrasonography, X-ray radiography, electrocardiography, biochemical testing with a semi auto analyzer, light microscopy and a digital photography. The output from these devices in form of raw binary streams and Jpeg image snapshots is all linked to PC based data acquisition and transmission to specialty hospital for expert opinion. The AMTU is connected to a control unit with extended C band satellite connectivity for uninterrupted telemedicine linkup in all weather conditions to any health care centre that has a telemedicine facility. It is also equipped with the Amrita Health Information System (AHIS) telemedicine suite for electronically storing and transmitting patient data, including medical images through HL7 and DICOM interface to central data base and Amrita HIS.

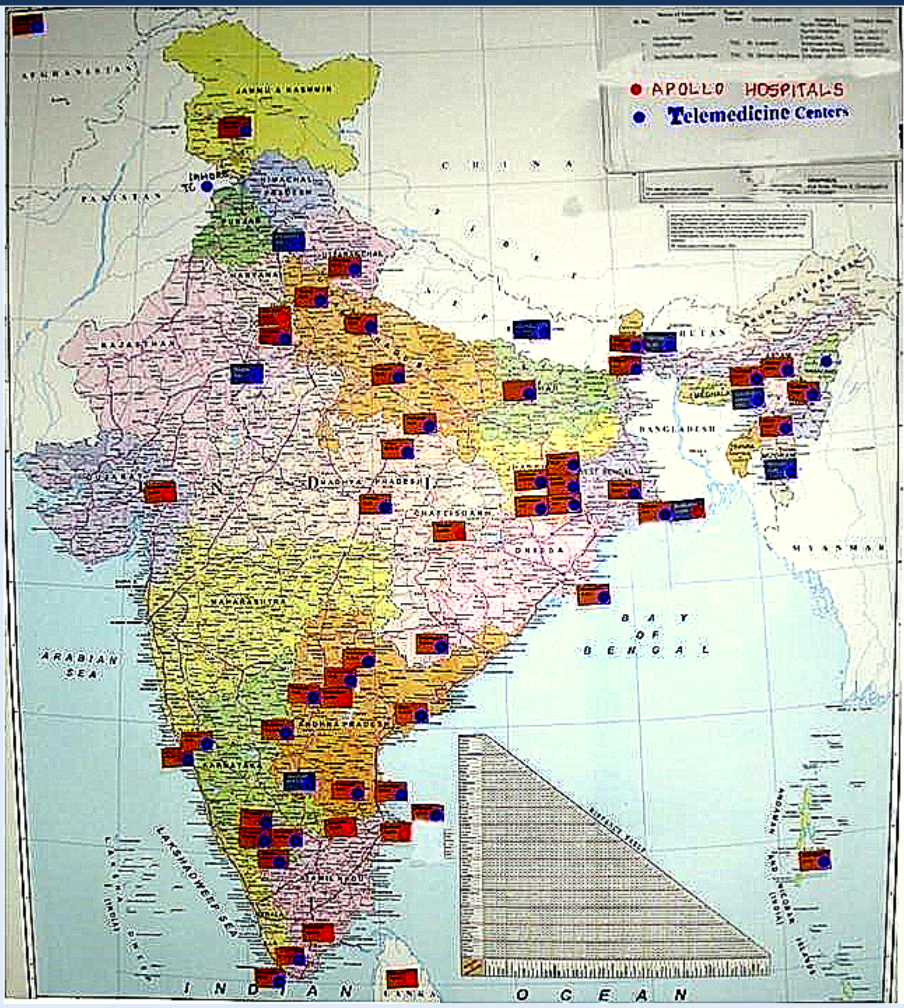
The tele- health system is built out of Java based open-source applications that run on Linux utilizing JBOSS Server, Windows-XP clients and MYSQL database. With AMTU or any other hospital that can connect to its network paramedics, physicians and specialists are brought together to take stock of ground situation, plan and deploy solutions including crash-course training of local paramedic/health worker staff counselling, consulting, screening tests, emergency surgeries, rehabilitation, etc., in a triage mode. AIMS has contributed its expertise using this network in several disaster situations (for example, to thousands of victims of tsunami in Kerala, earth quake in Gujarat, floods in Bihar, etc.) In all these models and endeavours the services are delivered totally free under the free sponsorship of Indian Space Research Organisation (ISRO) and health care providers expenses borne by Mata Amrithanandamayi charitable trust.

Type of node in Tele-Health Network	Type of transactions	Infrastructure components employed
AIMS and 60 other TERTIARY HOSPITALS on the network	Patient registration, specialist, primary diagnostic measurements and upload to patient EMR, primary care intervention, disaster management	Desktop/Laptops PCs with Windows client and Linux-Java-Jboss server based Tele-Health application; Desktop Video conferencing with PTZ-camera, H.264 and G.711 compression, H.323/SIP protocol, Telecom: ISRO VSAT (384 Kbps/1 Mbps on special demand), Power: UPS with Generator
AMRITA KRIPA VILLAGE RESOURCE CENTERS	Patient registration, specialist, primary diagnostic measurements and upload To EMR, distance education delivery	Desktop/Laptops PCs with Windows-Java based Tele-Health client application; PTZ camera with Desktop videoconferencing, Telecom ISRO VSAT(384 Kbps)/ISDN 128 Kbps/Leased line (2 Mbps to Andaman island), biomedical devices ECG, NIBP, thermometer
AIMS mobile telemedicine unit	Patient counselling, screening, tele-consultation, diagnosis, minor surgery, therapy, medication	Bio-medical devices for echocardiography, cardiac treadmill, gastro copy, colonoscopy, retinal camera, ultrasonography, X-ray radiography, electrocardiography, biochemical analysis, light microscopy and a digital photography; videoconferencing capability (adopting H.264 and G.711 compression, H.323/SIP protocol); extended C band satellite connectivity(min 384 Kbps)

Case Study 6: Private Sector Tele-Consultation network – Apollo Hospitals Group, India

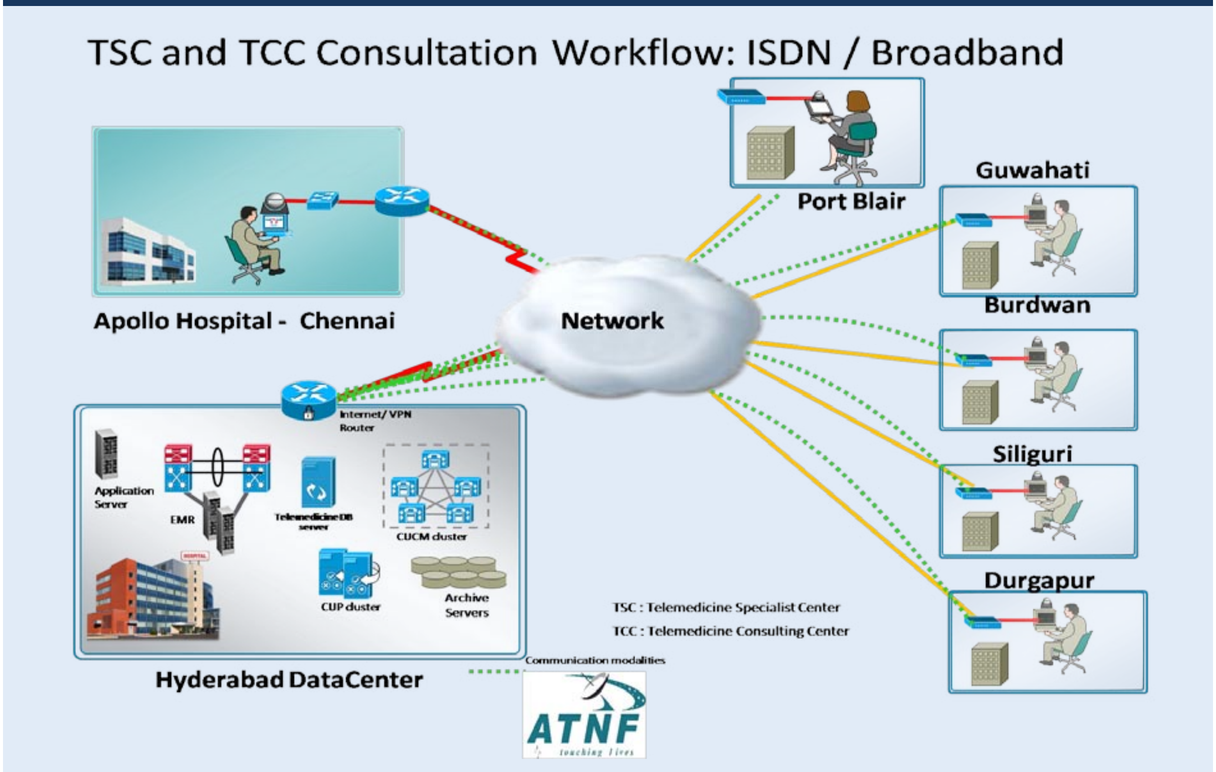
This case study is an example of initiative run by Apollo Hospitals Group, a private enterprise owning a chain of over 45 tertiary hospitals, over 110 Telemedicine centres and 740 pharmacy outlets across the country. Now known as the Apollo Telemedicine networking Foundation (ATNF), it was the first in the country to setup a Rural Telemedicine centre in 1999 in Aragonda (in Andhra Pradesh). Today, ATNF is perhaps India's largest private turnkey provider in the area of telemedicine with over 150 telemedicine centres in India and abroad. ATNF works with multiple entities including the Central and State Governments, medical bodies, private and public sectors and offers customized solutions addressing telemedicine support for primary, secondary and tertiary level of healthcare. The telemedicine centres serve as information kiosks as well as out-patient consultations with physicians and specialists and occasionally for some emergencies, disaster management and critical care. Apollo Hospitals connected to these telemedicine centres provide the specialized medical care. The expenses of care delivery are mostly borne directly by the patient, except in some cases where government programs pay partially or fully, especially for the underprivileged classes of the society.

FIGURE 1: Apollo Tele-Health Network



ATNF has developed its own proprietary Web-enabled Telemedicine software suite 'Med Integra', that enables remote transactions between the doctor and patient resulting in prescriptions, treatment plans, medication orders, diagnostic data, diagnostic reports, treatment charts and investigation notes. The system facilitate to consolidate scanned copies of old hard copy records (through interfaces to scanners, camera, etc.), and digital records from directly interfaced with a bio-medical kit (to measure ECG, BP, temperature, heart sound and blood oxygen) into a Patient Electronic Medical Record (EMR) in either 'Store & forward', or on-line transmission. The EMRs are hosted on ORACLE data base managed by the windows application with role based authentication support including smart cards, biometrics, etc. Integration with existing HIS, PACS or other Clinical Support System has enabled the physician to examine different data, annotate the data such as X-ray, ECG, Reports, Advice, etc., and quickly add notes on the patient's progress. To seek the opinion of a specialist- using tele-consultation, the doctor can connect relevant portions of the EMR to the specialist terminal and can exchange text messages and discuss over a videoconference using Windows NetMeeting. The Advice, Reports, etc., that are the outcomes of the tele-consultation are sent back to the presenting doctor, to print and pass on to the patient. There are times when the specialist would work alone, in such cases offline editing of the EMR and subsequent data upload to the peer is possible. The data is exchanged in text and image (DICOM) formats through HL7 protocol between electronic medical records and the main client- server application with WINZIP/WINRAR and a proprietary encryption format, using TCP/IP protocol over any available physical media (POTS/ ISDN/DSL, etc.). The tele-clinics are connected through ISDN links (up to 512 Kbps) and in some cases on ADSL (up to 4Mbps) with the central database and application hosted in commercial data centres.

FIGURE 15: Mesh-network of care flow over star network of Tele-Health Application linking Tele-clinics and hospitals



Staff members at these centres have been selected based on their ability to translate local language to English and handle electronic communication, data entry, and processing and report generation and organize tele-consultations. With their help, the network has been able to perform disease surveillance, consultation, remote diagnostics, counselling, medication tracking, and treatment with hospital and specialist support in over 25 specialties such as Oncology, Cardiology, Nephrology, Neurology, Gynaecology, ophthalmology, dermatology, Orthopaedic, Pulmonologist, Endocrinology, Urology, Psychiatry, etc,. Apart from routine Tele-consultation for usual illnesses resulting from lack of health awareness, Habitual Disorders and low Hygiene(over 58000 consultations have been provided), ATNF has participated in emergency situations such as the Gujarat Earthquake and Tsunami floods in the Indian peninsula. The system can scale from fully electronic, web-based transmission to email and in some cases even hard-copy courier based collection depending on the situation. In 15 villages ATNF is has recently experimented its Telemedicine solution ported on to mobile platforms in collaboration with Ericsson's Gram-Jyothi program in an effort to make Tele-Health services available on a 3G network. Apollo has also entered collaboration recently with Cisco for integration of Cisco's Tele-presence solutions into its Tele-Health network.

FIGURE 2: Mobile Tele-Health experiments

Node type	Type of transactions	Infrastructure components employed
ATNF Tele-Clinics	Registration, primary investigation and diagnostic Diagnostic data upload into EMR, patient referral to specialist	Desktop/Laptops PC; Web-based Tele-Health client with Desktop Video conferencing (PTZ-camera) over H.323 protocol; Telecom- ISDN up to 512 Kbps/ ADSL up to 4Mbps, Power: UPS with Generator; Scanner/Camera based upload of legacy records, biomedical kit with ECG/SPO2/NIBP/Thermometer. Latest versions have Cell-phone based access via 3G (CDMA-HSPA) networks.
Apollo Hospitals	Consulting	Desktop PCs with HL-7 compliant Web-based Tele Health application with PTZ-camera based video conferencing, EMR viewer/editor and data storage in ORACLE DB.

Appendix II: Web-links to Publications/Organizations included in study

[1]	http://www.whoindia.org/LinkFiles/Commision_on_Macroeconomic_and_Health_Bg_P2_Burden_of_Disease_Estimations_and_Casual_analysis.pdf	Generic
[2]	http://data.worldbank.org/indicator/NY.GDP.PCAP.CD	
[3]	http://whoindia.org/LinkFiles/Human_Resources_Public_Health_Force-Final_Paper.pdf	
[4]	http://www.itu.int/itudoc/itu-d/wtdc/wtdc98/docs/62.pdf	
[5]	http://www.sgpgi-telemedicine.org/international%20pub/35_e-%20Health%20Initiatives%20in%20India_skmishra.pdf	
[6]	http://www.ehealth-connection.org/files/conf-materials/Current%20Status%20of%20eHealth%20Initiatives%20in%20India_0.pdf	
[7]	http://www.frost.com/prod/servlet/report-toc.pag?repid=P394-01-00-00-00	
[8]	http://www.trai.gov.in/WriteReadData/trai/upload/Reports/50/IndicatorReport6apr10.pdf	
[9]	https://www.cia.gov/library/publications/the-world-factbook/geos/in.html	
[10]	http://en.wikipedia.org/wiki/List_of_countries_by_English-speaking_population	
[11]	http://en.wikipedia.org/wiki/Languages_with_official_status_in_India	
[12]	http://www.languageinindia.com/aug2002/indianmothertongues1961aug2002.html	
[13]	http://www.itu.int/ITU-D/study_groups/SGP_2006-2010/events/Case_Library_old/asia_pacific/ITU%20India%20Case%20Study%2028%2006%2007.pdf	
[14]	http://www.oecdilibrary.org/docserver/download/fulltext/5kmh3nj5rzs4.pdf?expires=1276234372&id=0000&accname=freeContent&checksum=8684EF1E207B1EA862D42E37D0ECD31C	
[15]	http://www.energybulletin.net/51948	
[16]	http://en.wikipedia.org/wiki/Rolling_blackout	
[17]	http://ltrc.iiit.ac.in/MachineTrans/publications/technicalReports/tr009/anuvad.txt	
[18]	http://www.tenet.res.in/Publications/Presentations/pdfs/Rural%20health-Mar08.pdf	Rural Technology and Business Incubator, IITMadras
[19]	http://lirneasia.net/wp-content/uploads/2010/01/RTBP-SOP-v0.3.pdf	
[20]	http://lirneasia.net/wp-content/uploads/2010/03/ganesan_presentation.pdf	

[21]	http://www.sgpgi-telemedicine.org/abstracts/national/ayyagari.pdf	**Sanjay Gandhi Post-Graduate Institute of Medical Sciences**
[22]	http://www.sgpgi-telemedicine.org/abstracts/national/ayyagari2.pdf	
[23]	http://www.sgpgi-telemedicine.org/abstracts/national/gujral.pdf	
[24]	http://www.sgpgi-telemedicine.org/abstracts/national/chawla.pdf	
[25]	http://www.sgpgi-telemedicine.org/abstracts/national/skm.pdf	
[26]	http://www.sgpgi-telemedicine.org/abstracts/national/amit.pdf	
[27]	http://www.sgpgi-telemedicine.org/abstracts/national/akm.pdf	
[28]	http://www.sgpgi-telemedicine.org/abstracts/national/rn.pdf	
[29]	http://www.sgpgi-telemedicine.org/abstracts/national/pradeep2.pdf	
[30]	http://www.sgpgi-telemedicine.org/international%20pub/32_An%20Audit%20of%20Problems%20in%20Implementation%20of%20Telemedicine%20Programme.pdf	
[31]	http://www.sgpgi-telemedicine.org/abstracts/international/ukmishra.pdf	
[32]	http://www.sgpgi-telemedicine.org/international%20pub/31_Current%20Telemedicine%20Infrastructure,%20Network,%20Applications.pdf	
[33]	http://www.aimshospital.org/hospital/cdh/facilities_telemedicine.php#8	**Amrita Institute of Medical Sciences**
[34]	http://www.aimshospital.org/hospital/cdh/CME_telemedicine.php#2	
[35]	http://210.212.237.165:1500/cdac/templates/nrhm.jsp	**Centre for Development of Advanced Computing**
[36]	http://www.isro.org/scripts/telemedicine.aspx	**Indian Space Research Organization**
[37]	http://www.rcctvm.org/Telemedicine.htm	**Regional Cancer Care Centre**
[38]	http://www.aarogya.com/index.php?option=com_content&view=article&id=5215:rural-maharashtra-turns-to-telemedicine-to-help-patients&catid=206:year-2010&Itemid=3547	**Sir J. J. Group of Hospitals**
[39]	http://www.amritatech.com/jjhospital.html	
[40]	http://ahiltelemed.tripod.com/	**Apollo Telemedicine Networking Foundation**
[41]	http://www.telemedicineindia.com/KeyProjects.htm	
[42]	http://www.healthhiway.com/portal/ImageConnect.htm	**Health Highway**
[43]	http://www.infolifetech.com/	**INFOLIFE Technologies**

[44] [45]	http://www.frost.com/prod/servlet/report-toc.pag?repid=P394-01-00-00-00 http://www.frost.com/prod/servlet/market-insight-top.pag?docid=57274416	**Frost & Sullivan - India**
[46]	http://www.prognosysmedical.com/prodcat.php?id=31	**Prognosys Medical Systems**
[47]	http://www.sgrh.com/product.aspx?id=23	**Gangaram hospital Delhi**
[48] [49]	http://www.ojus.net/net/centers.html http://www.ojus.net/net/mother.html	**Ojus Health Care**
[50] [51] [52]	http://www.nanavatihospital.org/aboutus/press_releases.htm http://www.expresshealthcare.in/201004/market29.shtml http://www.infocera.com/Blackberry_telemedicine_service_to_bring_ECG_report_at_Doctors_fingertips_9411.htm	**Nanavati Hospital**
[53] [54]	http://www.nlcindia.com/news/lifeline_jul_2009.pdf http://www.thehindu.com/2009/01/21/stories/2009012153330300.htm	**Neyveli lignite corporation hospital**
[55]	http://meenakshimission.blogspot.com/2009/05/telemedicine-in-madurai.html	**Meenakshi Mission Hospital**
[56] [57] [58] [59]	http://www.natural-health-journals.com/442/telemedicine-making-healthcare-accessible-to-rural-areas-in-india http://www.narayanahospitals.com/telemedicine.html http://www.narayanahospitals.com/yeshasvini.html http://www.docstoc.com/docs/25177978/Karnataka-Yashaswini-Case-Study-08	**Narayana Hrudayalaya**
[60] [61]	http://www.aravind.org/telemedicine/mobilevan.htm http://www.aravind.org/telemedicine/va.htm	**Arvind Eye hospitals**
[62]	http://www.sathyasai.org/images2009/saiglobalhealth/ssghm09.pdf	**Sri Sathya Sai Institute of Higher Medical Sciences**
[63] [64]	http://www.sankaranethralaya.org/teleophthalmology.html http://laico.org/v2020resource/files/mobile_tele.pdf	**Shankar Netrayala**
[65]	http://www.srmc.edu/telemedicine.htm	**Sri Ramachandra Medical College**
[66]	http://www.scarfindia.org/tele.html	**Schizophrenia Research Foundation**

[67]	http://www.worldhealthpartners.org/resources_press_story_jan25_2010.htm	**World Health Partners**
[68]	http://www.worldhealthpartners.org/resources_press_story_nov25_2009.htm	
[69]	http://www.worldhealthpartners.org/about_servicemodel.htm	
[70]	http://www.worldhealthpartners.org/about_businessmodel.htm	
[71]	http://www.worldhealthpartners.org/program_india.htm	
[72]	http://www.techtree.com/India/News/Reliance_Forays_into_Healthcare/551-68209-547.html	**Reliance Health**
[73]	http://www.healthcare-india.com/StaticContent/services.aspx	**Health India TPA services**
[74]	http://www.onlineinfocom.com/tele_WestindiaPro.html#	**Other**
[75]	http://businesstoday.intoday.in/index.php?option=com_content&task=view&issueid=84&id=6319&Itemid=&sectionid=&completeview=1	
[76]	http://www.neurosynaptic.com/	**NeuroS ynaptics**
[77]	http://www.sathi.org/ http://www.igi-global.com/Cases/CaseDetails.aspx?TitleId=6425	**Society for Administration of Telemedicine and Health Informatics**

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URL:www.itu.int/net/ITU-D/index.aspx

Printed in Switzerland
Geneva, 2010

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09/2010