Telemedicine System

Telemedicine is the remote communication of information to facilitate clinical care.

Exchange of Information at a Distance

- Voice
- Image
- Video
- Graphics
- Elements of Medical Records
- Commands to a surgical robot

Examples

- Data related to a patient's personal information
- Data related to a patients medical information
- Data for patient management in Telemedicine
- Data related to the doctors
- Data for system management

Technologies Involved

- Medical Instrumentation

  Sensing Bio-medical Signals,
  Medical Imaging, Measurement of Physical
  Parameters e.g. Body Temperature, Pressure etc.

- Telecommunication Technology

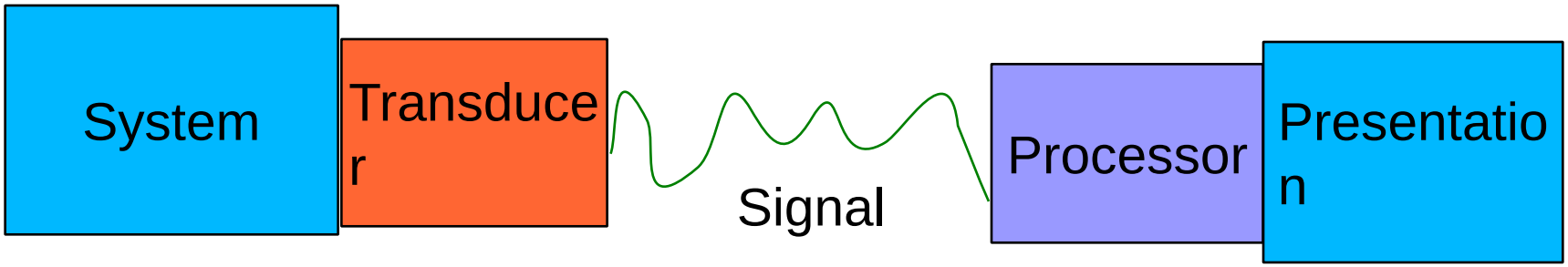
  Trans-receiver on different communication
  channels and network such as, on wired network,
  wireless medium etc.

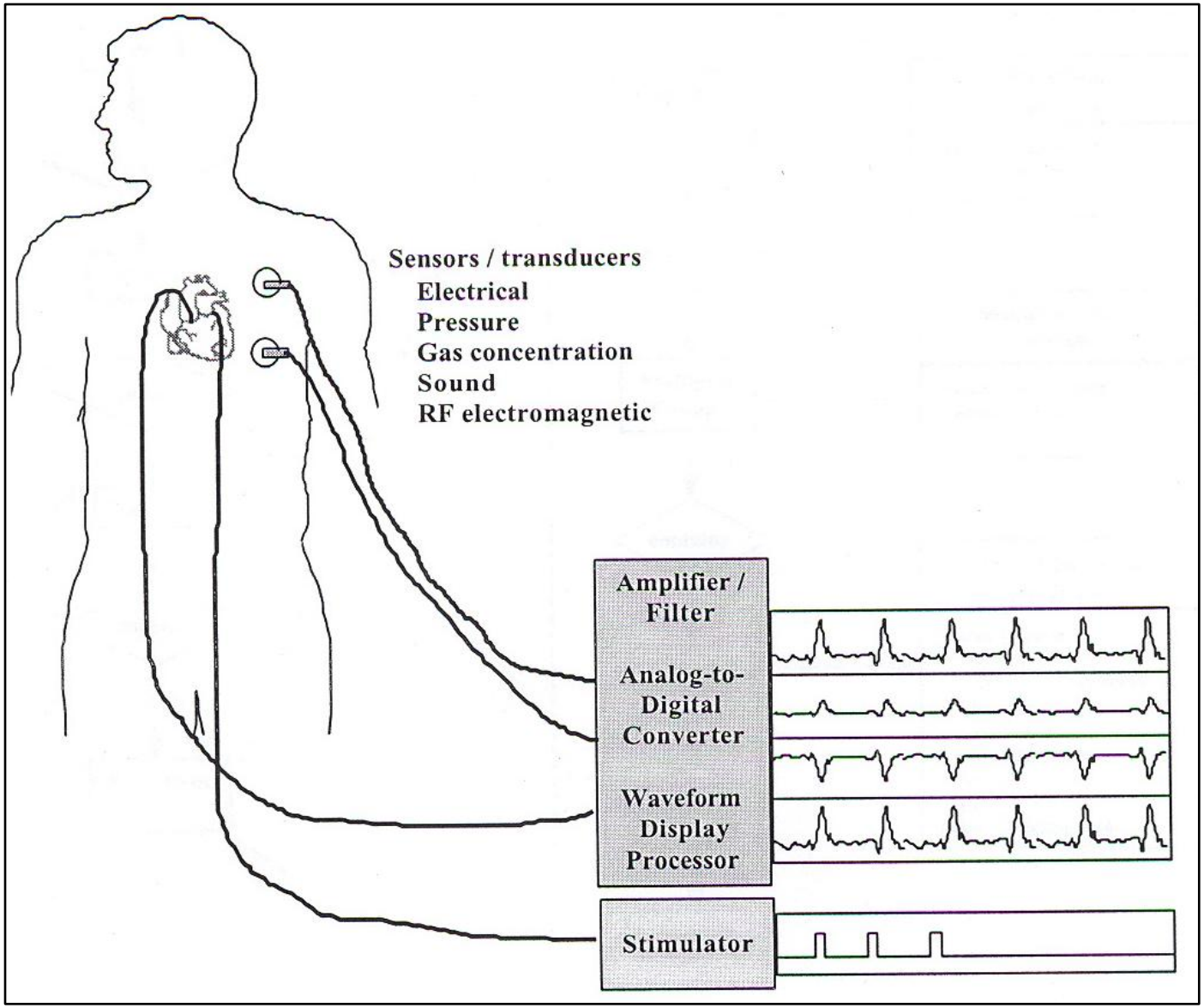
- Information Technology

  Information representation, storage,
  retrieval, processing, and presentation.

Medical Information and data

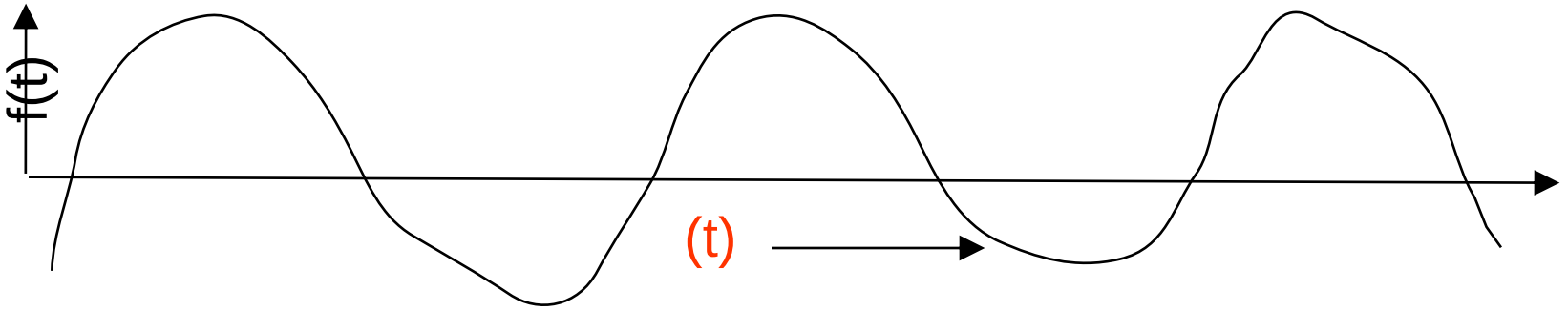
- Data: “Signature” of Information
- Information: Processed data



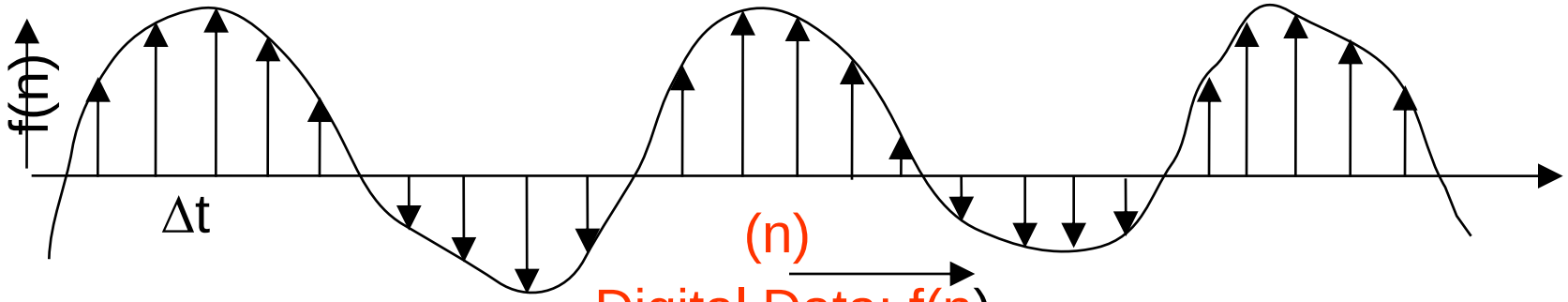


Waveform Acquisition Model

Analog and Digital Data



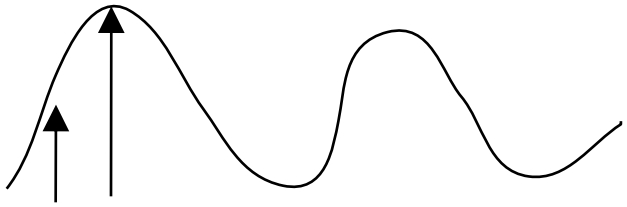
Analog Data: f(t)



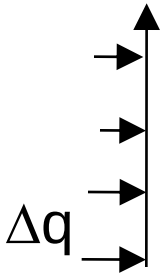
Digital Data: f(n)

Analog to Digital Conversion

- Sampling
  Sampling Rate
- Quantization
  Quantization Level



Δt



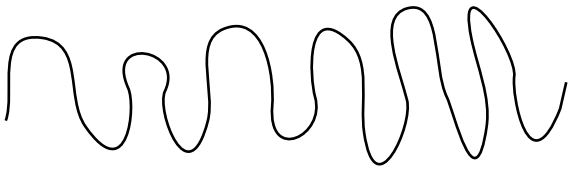
Δq

Value=4

Signal Bandwidth

- How fast the signal changes?

Slow variation



Fast variation

Bandwidth is the measure of *range of frequency* components present in the signal.

Nyquist sampling rate= 2* Bandwidth of the signal

Data Size: Voice

- Band width: ~ 4 Khz
- Minimum Sampling Frequency: 8 Khz
- Bits per sample: 8 bits (for 256 levels)
- Minmum data rate: 8000x8 bits per second = 64 Kbps

Data Size: ECG

- B.W. ~ 100 Hz.
- Minimum Sampling Frequency: 200 Hz.
- Bits per sample: 8 (for representing 256 levels)
- Data rate: 200x8 bits per second = 1.6 Kbps

Data Size: Video

- Number of frames per second: 15 fps
- Resolution of a frame: 480 x 640 pixels
- Bits per pixel: 24 bits (for colored video)
- Data Rate: 480x640x15x24 bits per second = 110.6 Mbps

Data Compression

- Alternative description of data requiring less storage and bandwidth.

Uncompressed
1 Mbyte

Compressed (JPEG)
50 Kbyte (20:1)

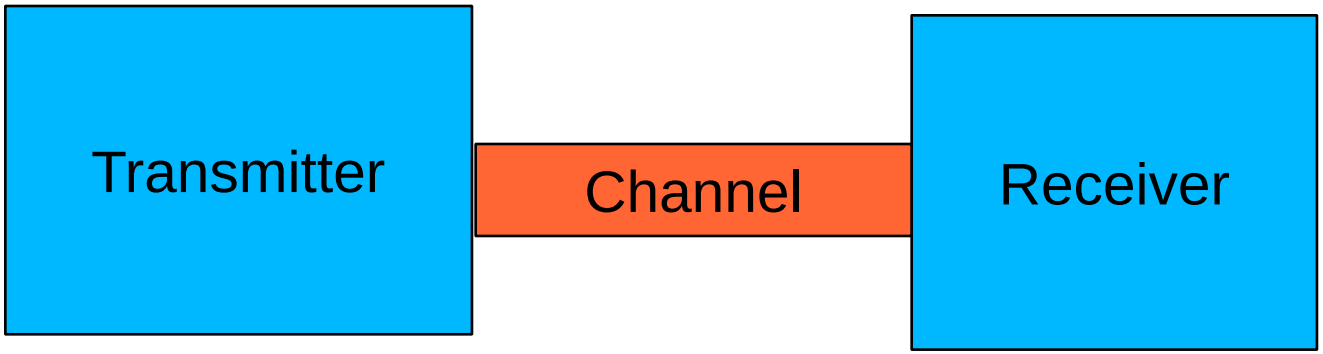
Compression Standards

- Lossy and Lossless Compression
- Data: ZIP
- Audio: MPEG
- Still Image: JPEG, JPEG-LS, JPEG-2000
- Video: MPEG-2, MPEG-4, H.263

Band-width requirements of different compressed multimedia data

Type of Multimedia Data	Bandwidth
Usual data	100bps~2kbps
Image	40 Kbps~150 Kbps
Voice	4 Kbps~80 Kbps
Stereo Audio	125 Kbps~700 Kbps
VCR quality video	1.5 Mbps~4Mbps
3D medical images	6 Mbps~120 Mbps
HDTV	110 Mbps~800 Mbps
Scientific Visualisation	200 Mbps~1000Mbps

Signal Transmission



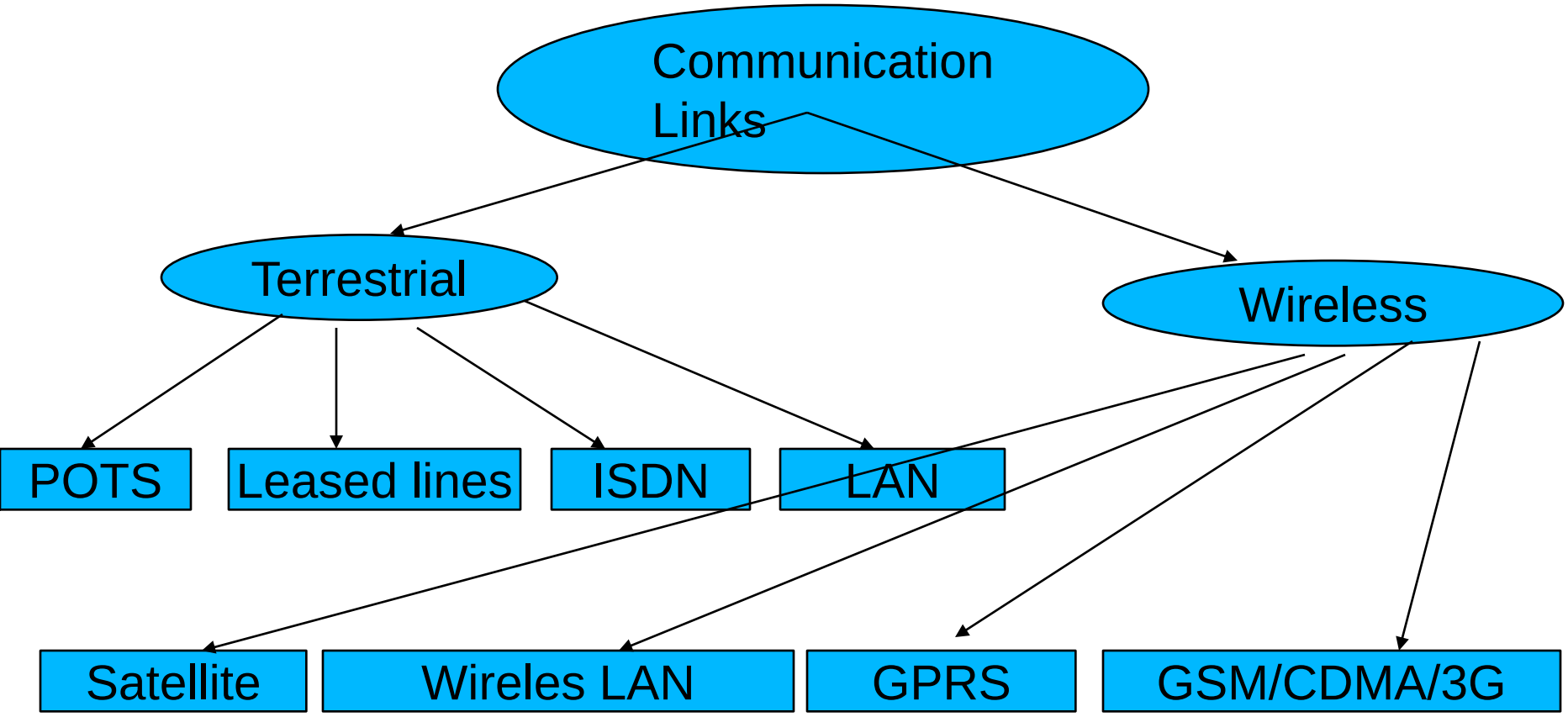
$x(t)=A.\sin(\omega.t)$

$y(t)=\alpha.A.\sin(\omega.t+\phi)$

Channel Bandwidth

- How fast the system responds?
- *Range of fequencies* transmitted by the channel.
- *Modulation* is the process of translating signal's bandwidth into a channel's bandwidth.

Communication Channels



Early systems

- 1920 (USA): Transmission of ECGs and EEGs on ordinary telephone lines.
- 1920 (USA): Medical advice services for sailors based upon Morse code and voice radio.
- 1950’s (USA): Telepsychiatry between a state mental hospital and the Nebraska Psychiatric Institue using microwave link

Early systems

- 1950’s (USA): NASA and the US Public Health Services developed a joint telemedicine programme to serve the Papago Indian Reservation in Arizona.
- 1960’s (USA): Two-way closed-circuit television systems to facilitate both the transmission of medical images such as radiographs as well as consultations between doctors.
- 1970’s (USA): Paramedics in remote Alaskan and Canadian Villages connected with hospitals in distant towns and cities using the ATS-6 satellite systems

Early systems

- 1971, Japan: First time implemented in two areas: Nakatsu-mura and Kozagawa-cho, Wakayama using telephone line for voice and Fax transmission and CATV system for image transmission.
- 1972, Japan: Between Aomori Teishin Hospital and Tokyo Teishin Hospital over 4 Mhz TV channel and several telephone lines.

Other systems came up for teleradiology

in several places in Japan like, Nagasaki, Tokai etc.

Applications in different forms

- Information exchange between Hospitals and Physicians.
- Networking of group of hospitals, research centers.
- Linking rural health clinics to a central hospital.
- Videoconferencing between a patient and doctor, among members of healthcare teams.
- Training of healthcare professionals in widely distributed or remote clinical settings.
- Instant access to medical knowledgebase, technical papers etc.

Telemedicine Systems: Developed at IIT Kharagpur

- TelemediK
  - TelemediK V1.0, V2.0, V3.3, V2004, V2005
  - A peer to peer application.
  - Facilitates specific care for different diseases such as dermatology, hematology, orthopedics, pediatrics, oncology, cardiology etc.
  - Online graphics communicator
    - Peer to peer discussion
    - Annotation of patient images and profile images.
    - Text chatting

Aim of the Telemedik System

- Information management
  - **Patient information**
  - **Medical data (signs, symptoms, test reports, etc..)**
  - **Appointment scheduling**
  - **Archival and retrieval of patient records**
- Low cost solution
  - **Using ordinary telephone line**
- Service to large population
  - **Through public health care delivery systems**
- Development of knowledge-based system
  - **For decision support**
  - **For training and education**

Key Principles

- Avoid Adhocism : Preorganisation of Patient Data
- Minimize online data transfer
- Patient Management with Database support

Technical issues over Low Bandwidth

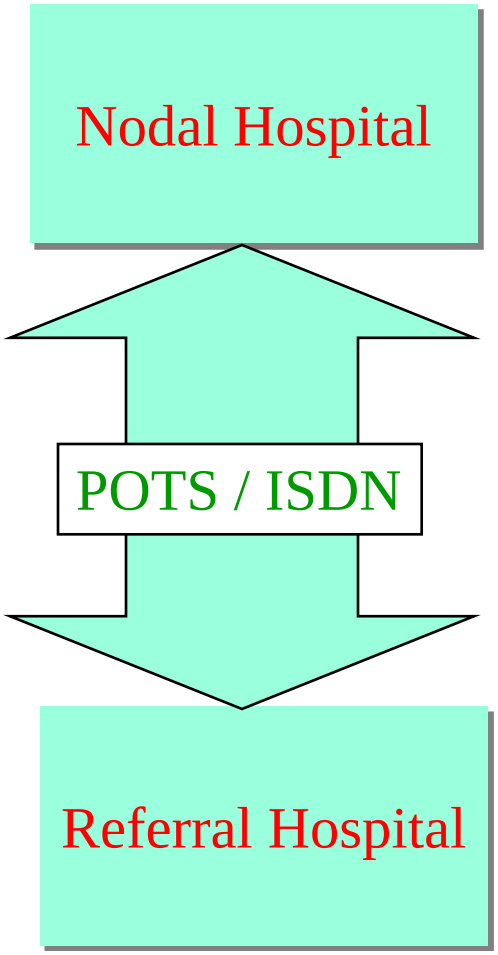
Problem

- Longer time for data transfer
- Poor video quality

Solution

- Store and forward policy
- Transferring sequence of still images

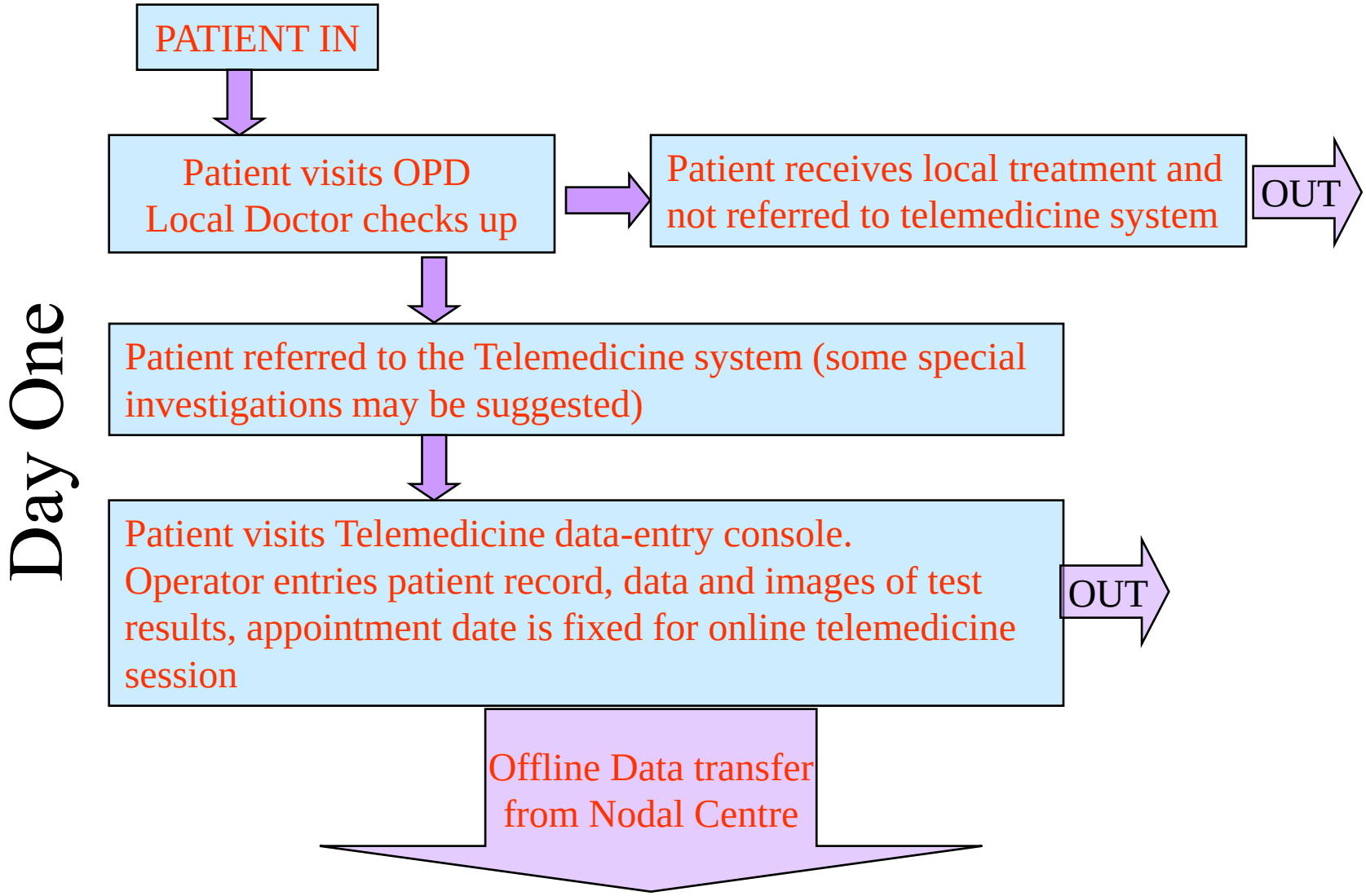
Requirement Specification



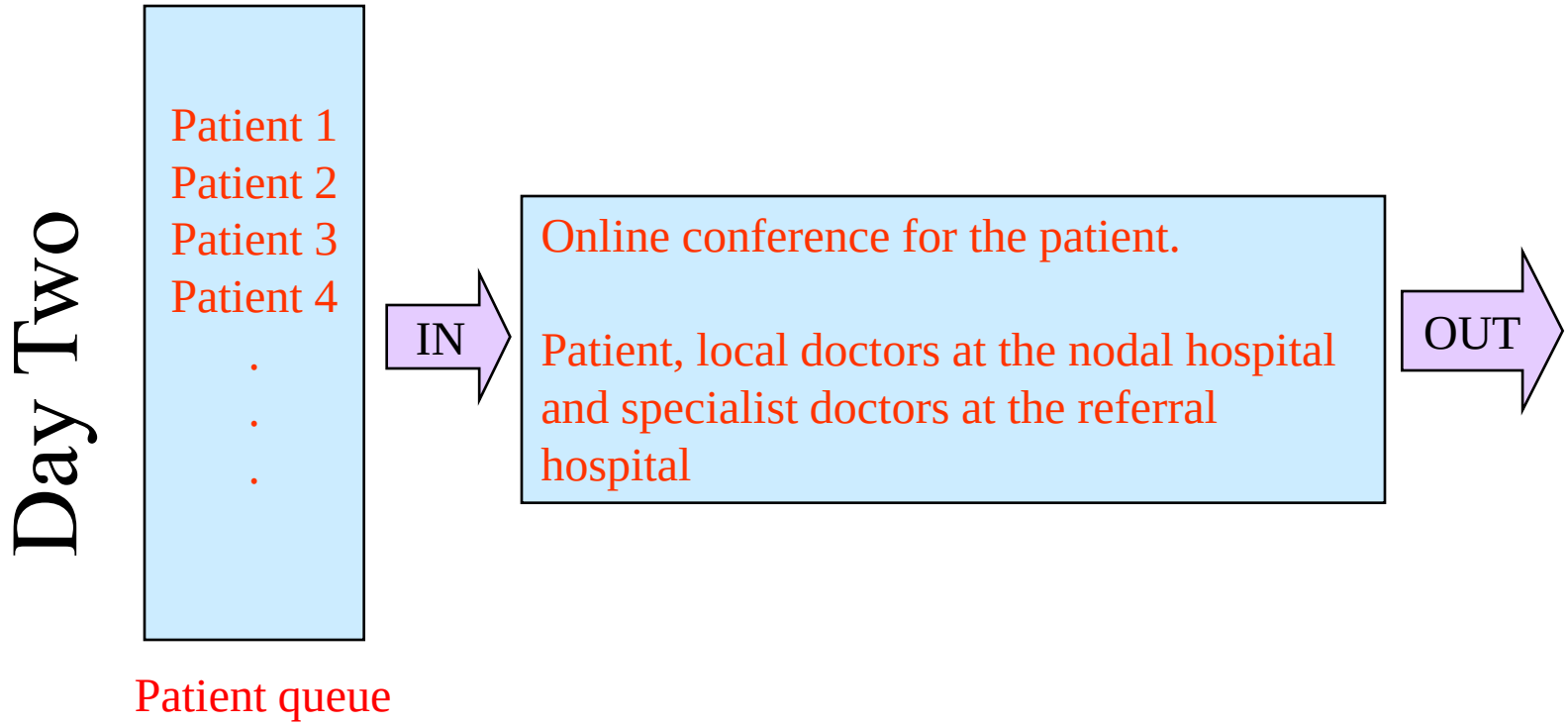
- A patient getting treated
- A Doctor
- A remote telemedicine console having audio visual and data conferencing facilities

- An expert/ specialized doctor
- A central telemedicine server having audio visual and data conferencing facility

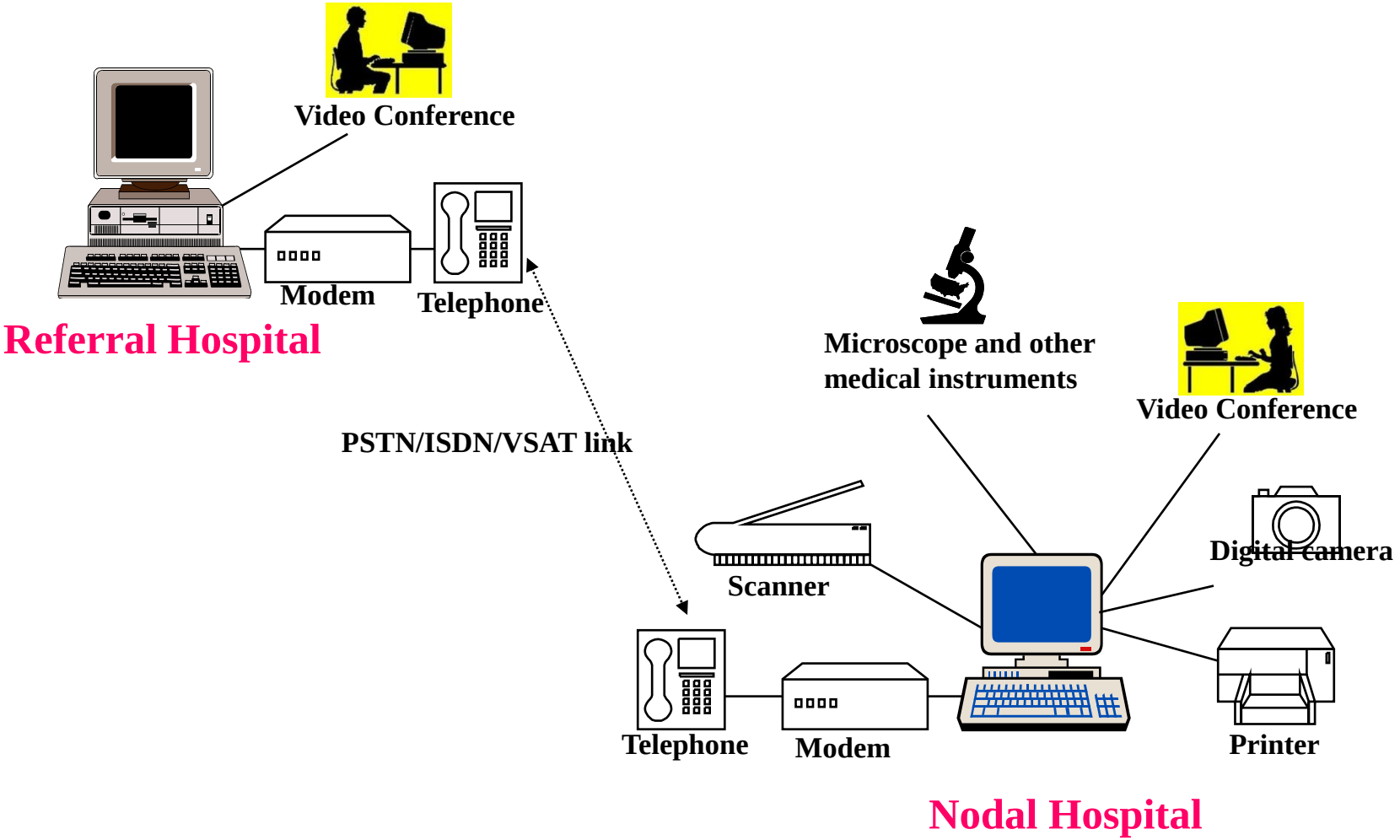
Sequence of Operation



Sequence of Operation



Hardware Configuration

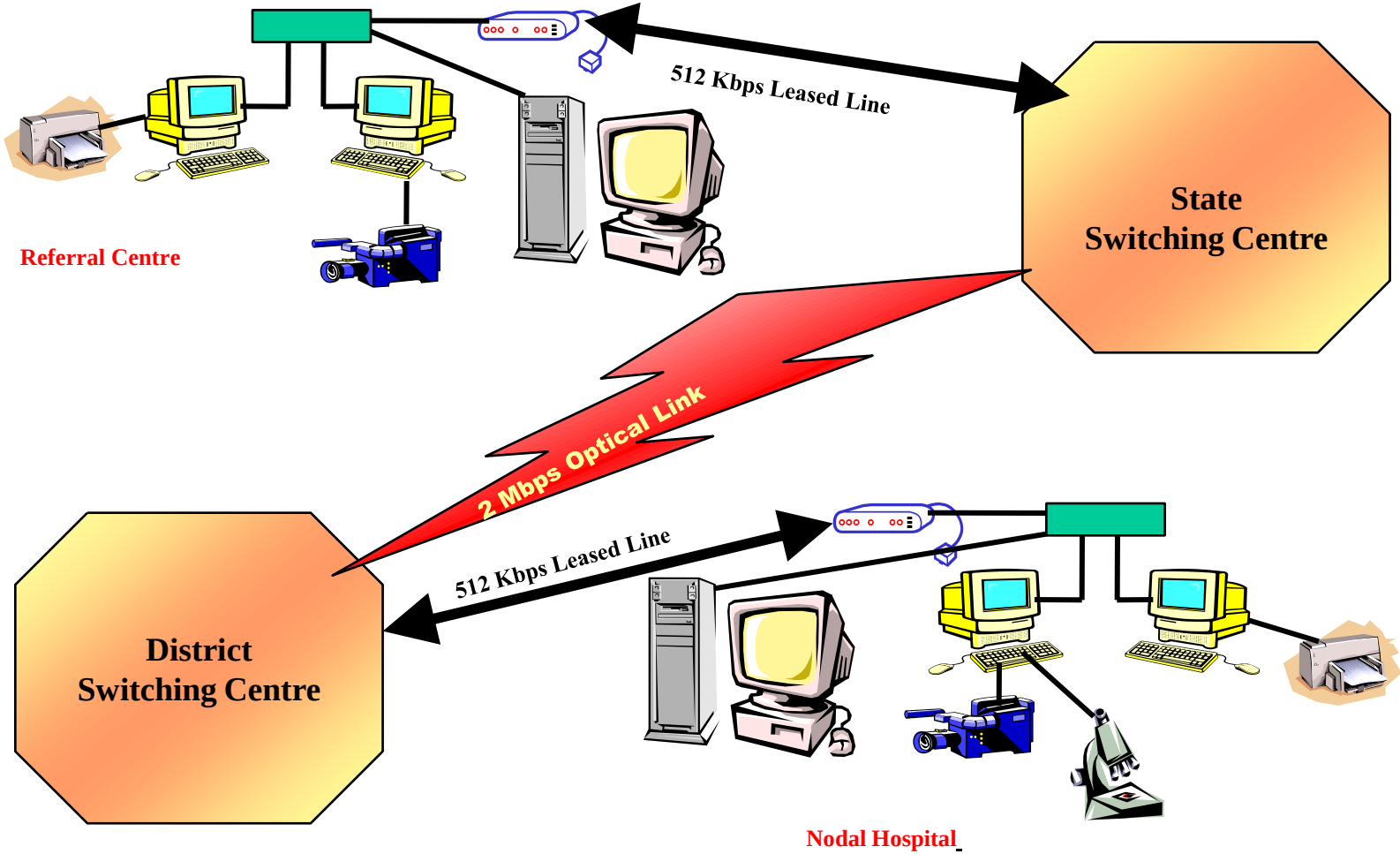


Software Modules

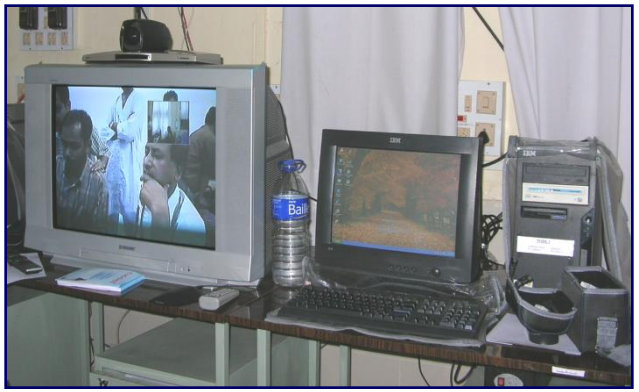
Offline Activities

Online Activities

Schematic Diagram for Telemedicine using Leased Line



Video and Data Conferencing

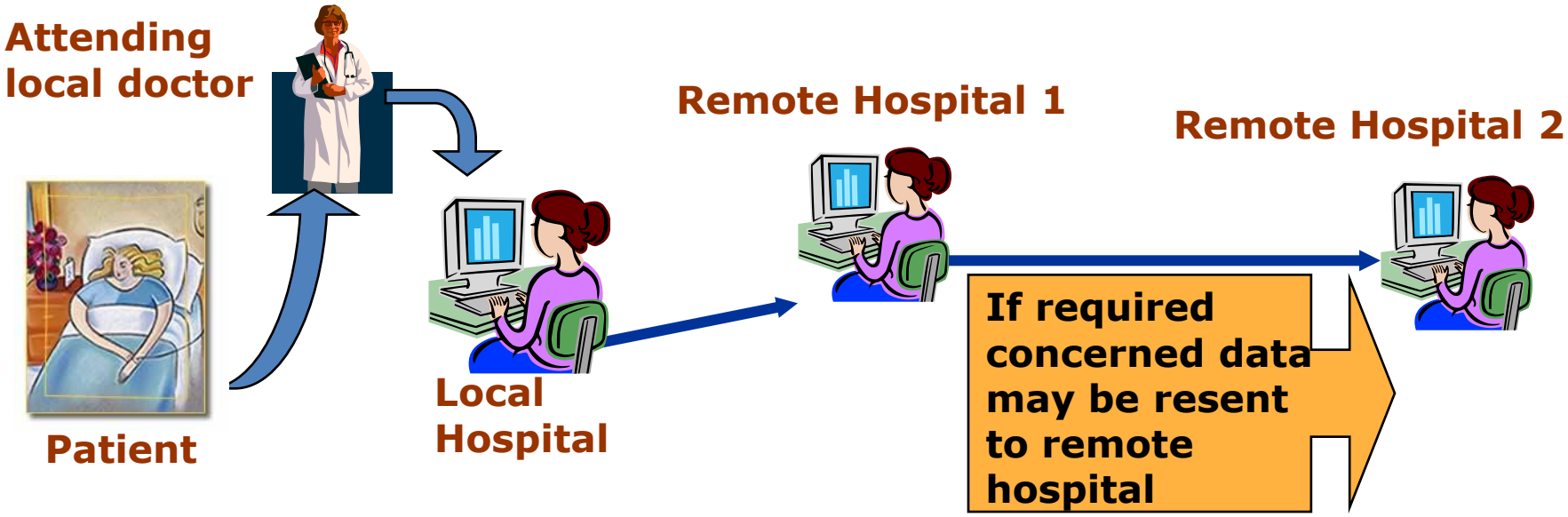


Doctor

Patient

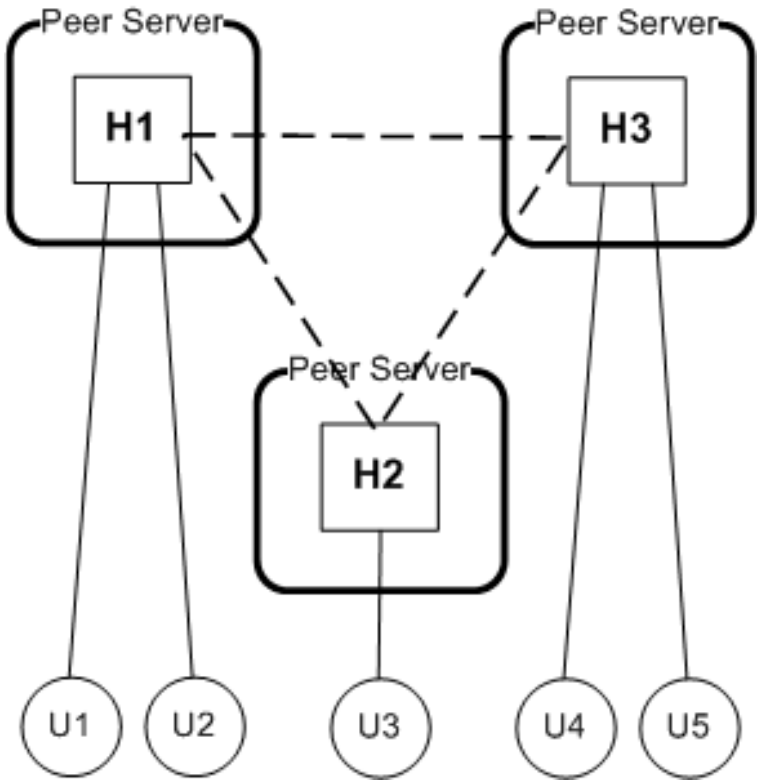
Multi-Reference in Tele-consultation

A center acting as local asks for tele-consultation with a remote center which can again be able to consult with another remote center.



TelemediK Model

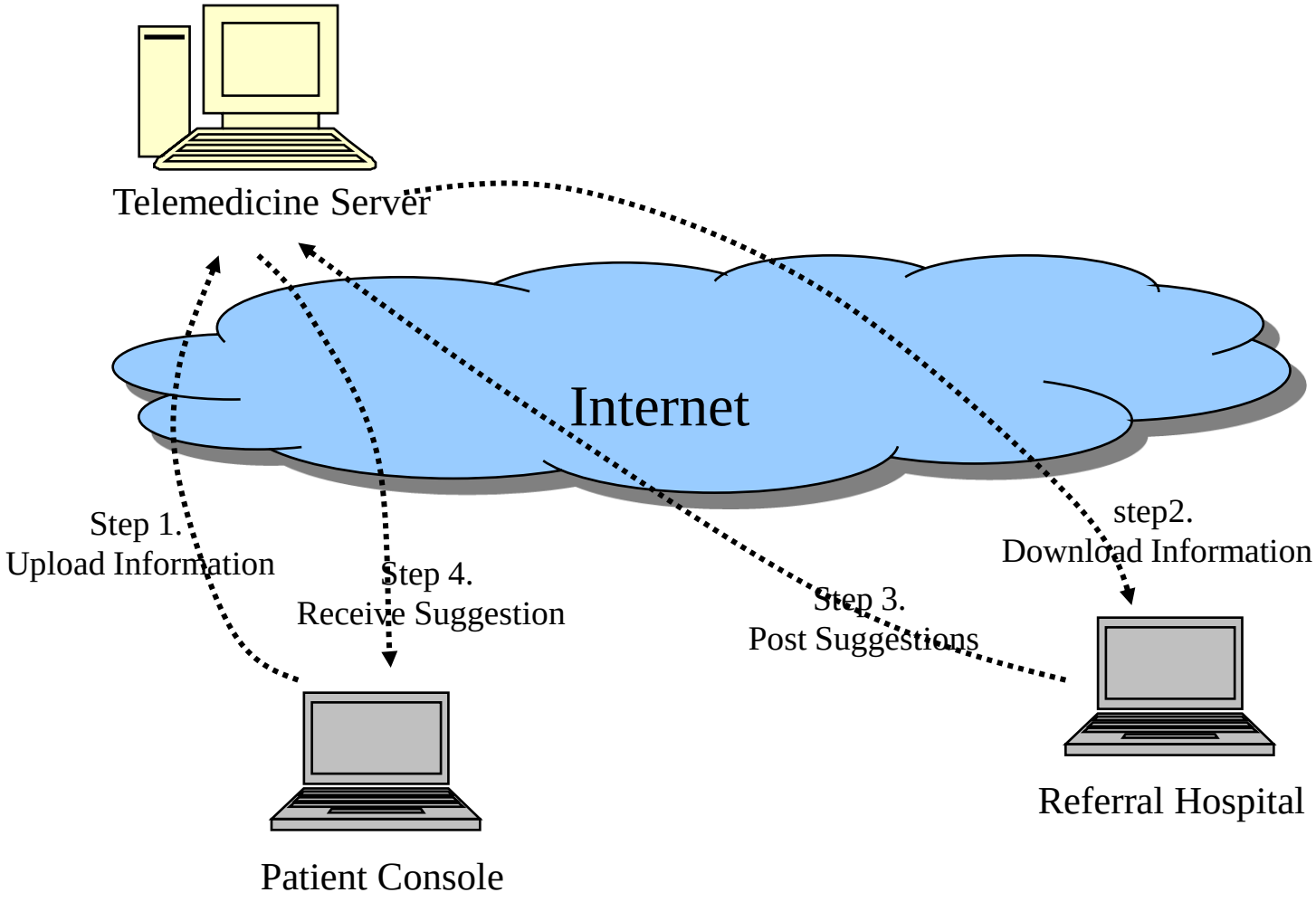
- Based on peer-to-peer network topology.
- Physical transmission of patient medical records.
- Symmetry in tele-reference.



Limitations:

- Duplication of records incurs increased storage cost.
- May violate data consistency.
- High bandwidth requirement.

Telemedicine over web

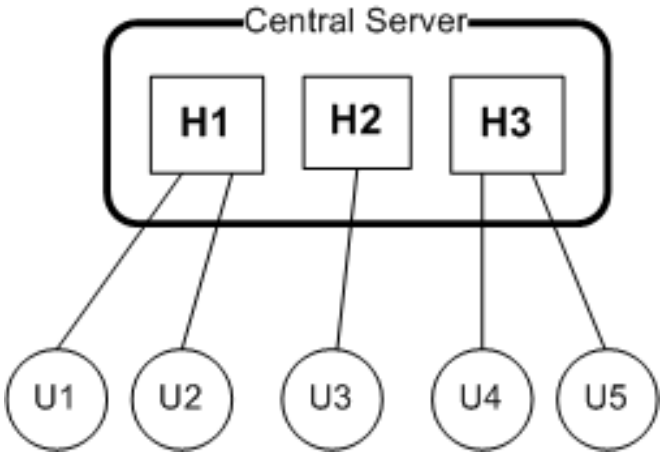


Web based telemedicine system

- iMediK
  - iMedik V2007, V2008, V2009.
  - Client interfaces are mostly provided through internet browsers.
  - Supporting care of same set of diseases as handled by TelemediK.
  - Additional Diseases like HIV Pediatrics and Drug resistant tuberculosis.
  - Online graphics communicator
    - Conference among multiple participating doctors.

iMedik Model

- Based on the Central server model.
- Usually deployed at in the public network like WWW.



Limitations

- No physical separation of records.
- Needs higher configuration.
- Security threats prevail.
- Less or no fault tolerance.
- Requires uninterrupted connection to external links.

Four Layer Architecture

Features of iMedik

- Multi-tier secure telemedicine system.
- Focuses on service oriented approach.
- Facilitates health care services through Internet.
- Salient features
  - Encompasses all the features of TelemediK.
  - Completely browser based interface.
  - Complies with
    - HIPAA security standard
    - EPR standard proposed by National Task Force for Telemedicine Standards, MCIT.

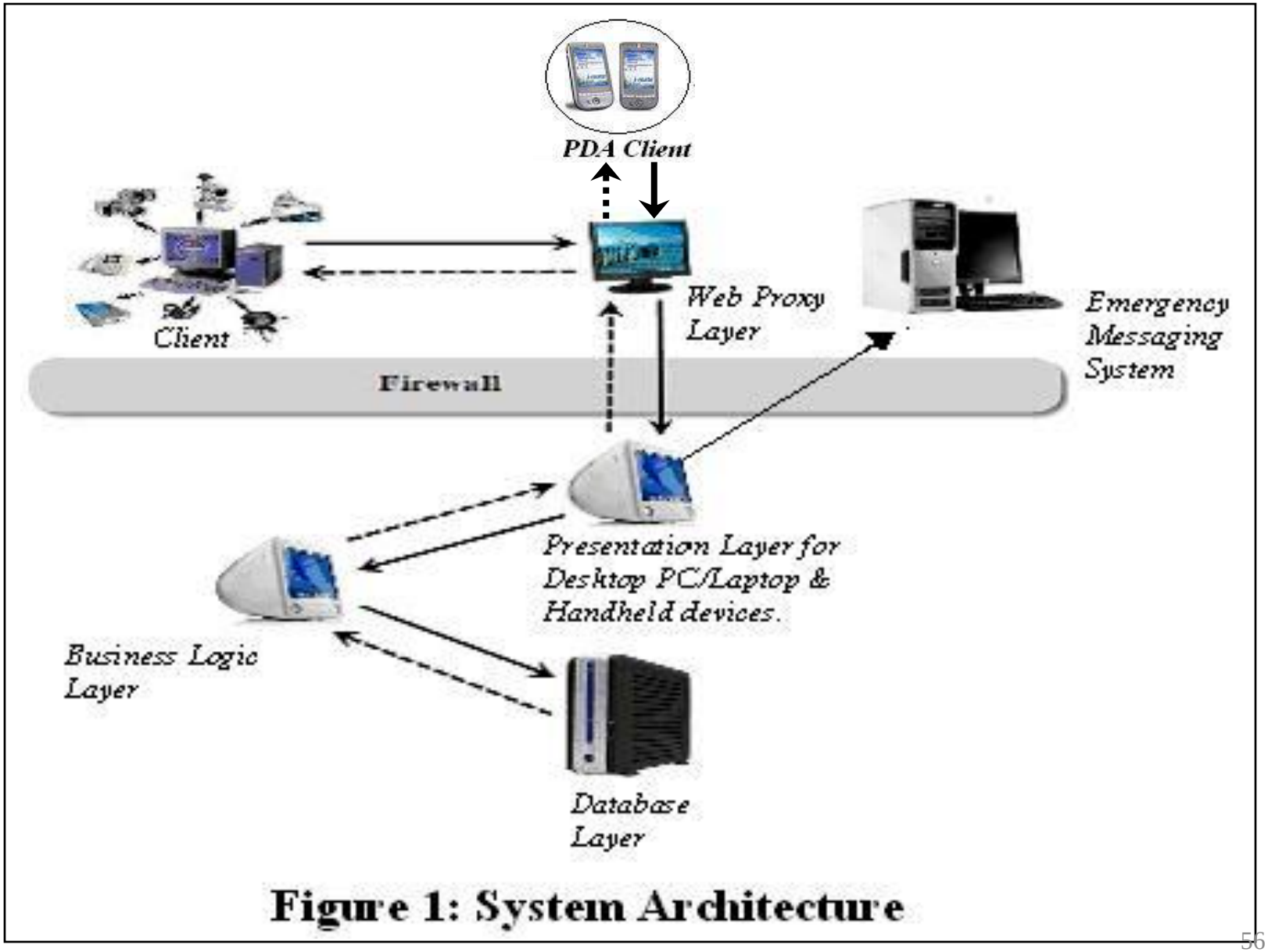


Figure 1: System Architecture

Architecture

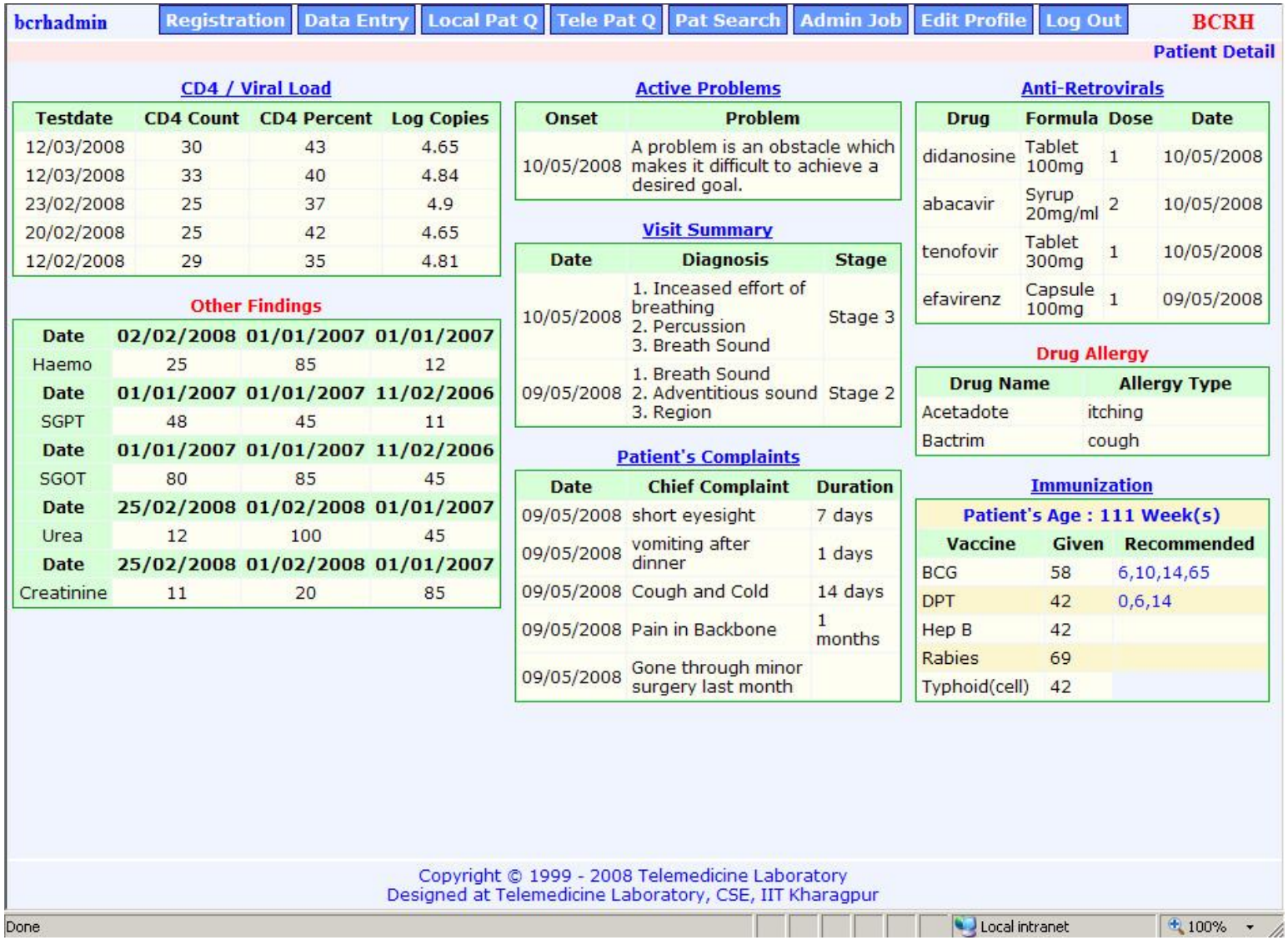
- Web Proxy Layer
  - Only layer that resides in public domain
  - Intercepts all requests / responses between the client and web server
- Presentation Layer
  - Responsible for building page template
  - A sub part of the layer is Wireless Medical Information Access Server (WMIAS)
  - The WMIAS builds customized web pages for handheld devices

Continued …

- Business Logic Layer
  - Core of the application
  - Performs all database operations
- Database Layer
  - Hosts the clinical database.
  - Allows storage of files (Size > 100MB), such as MR and CT data.

- The lower three layers in secure zone (inside the firewall)
- Only the Web Proxy Layer is in the Demilitarized zone (outside the firewall)
- HIDS (Host Based Intrusion Detection System) can be deployed in each of the layers in secure zone to control illegal access

Summary of Patient Records



bcrhadmin | Registration | Data Entry | Local Pat Q | Tele Pat Q | Pat Search | Admin Job | Edit Profile | Log Out | BCRH

Patient Detail

CD4 / Viral Load

Testdate	CD4 Count	CD4 Percent	Log Copies
12/03/2008	30	43	4.65
12/03/2008	33	40	4.84
23/02/2008	25	37	4.9
20/02/2008	25	42	4.65
12/02/2008	29	35	4.81

Other Findings

Date	02/02/2008	01/01/2007	01/01/2007
Haemo	25	85	12
Date	**01/01/2007**	**01/01/2007**	**11/02/2006**
SGPT	48	45	11
Date	**01/01/2007**	**01/01/2007**	**11/02/2006**
SGOT	80	85	45
Date	**25/02/2008**	**01/02/2008**	**01/01/2007**
Urea	12	100	45
Date	**25/02/2008**	**01/02/2008**	**01/01/2007**
Creatinine	11	20	85

Active Problems

Onset	Problem
10/05/2008	A problem is an obstacle which makes it difficult to achieve a desired goal.

Visit Summary

Date	Diagnosis	Stage
10/05/2008	1. Inceased effort of breathing 2. Percussion 3. Breath Sound	Stage 3
09/05/2008	1. Breath Sound 2. Adventitious sound 3. Region	Stage 2

Patient's Complaints

Date	Chief Complaint	Duration
09/05/2008	short eyesight	7 days
09/05/2008	vomiting after dinner	1 days
09/05/2008	Cough and Cold	14 days
09/05/2008	Pain in Backbone	1 months
09/05/2008	Gone through minor surgery last month	

Anti-Retrovirals

Drug	Formula	Dose	Date
didanosine	Tablet 100mg	1	10/05/2008
abacavir	Syrup 20mg/ml	2	10/05/2008
tenofovir	Tablet 300mg	1	10/05/2008
efavirenz	Capsule 100mg	1	09/05/2008

Drug Allergy

Drug Name	Allergy Type
Acetadote	itching
Bactrim	cough

Immunization

Patient's Age : 111 Week(s)

Vaccine	Given	Recommended
BCG	58	6,10,14,65
DPT	42	0,6,14
Hep B	42	
Rabies	69	
Typhoid(cell)	42	

Done | Local intranet | 100%

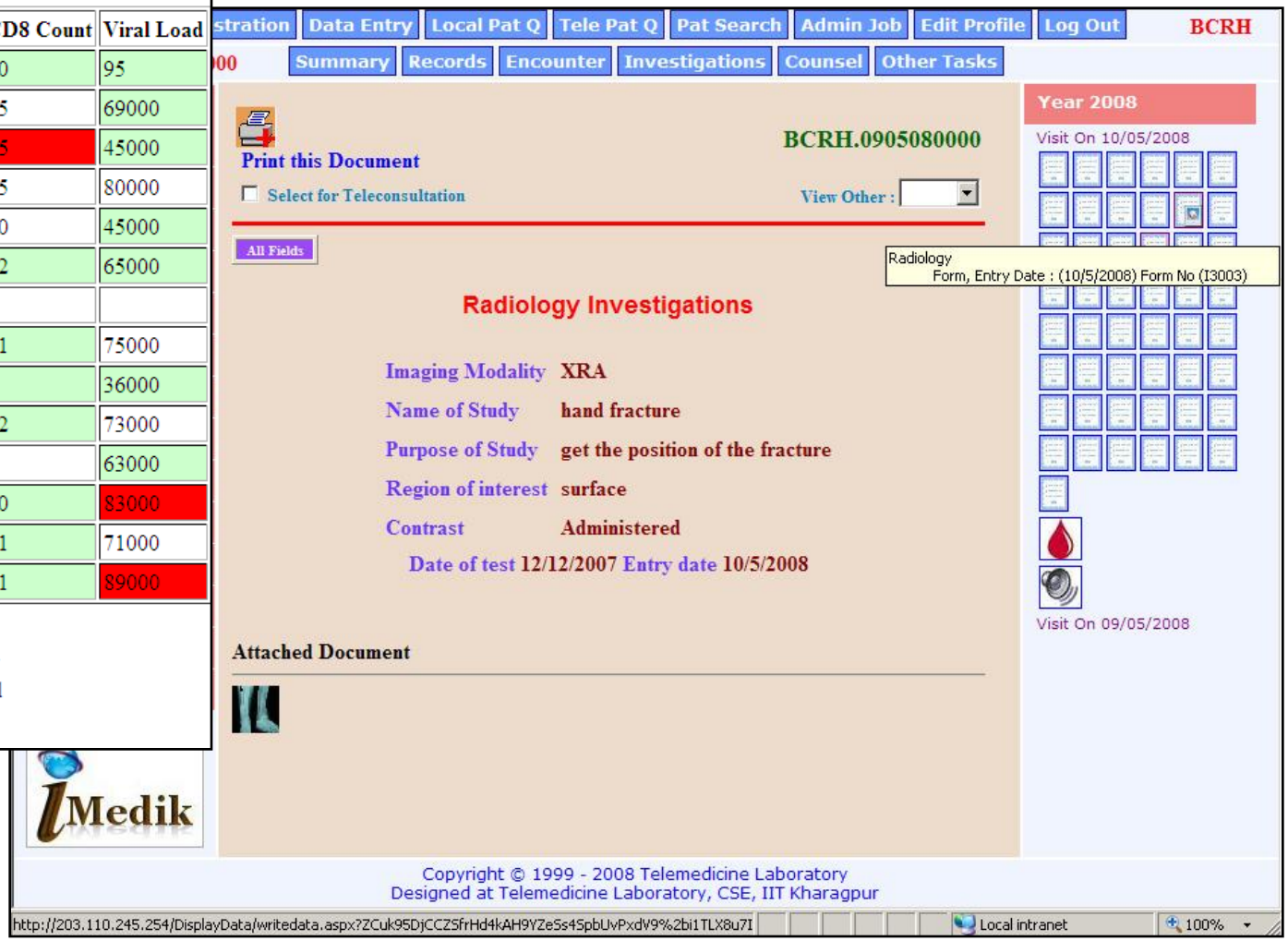
Visit wise patient record display

Patient record browsing

CD4/Viral Load

Test Date	CD4 Count	CD4 Percent	CD8 Count	Viral Load
01/08/2008	55	65	20	95
12/03/2008	33	40	55	69000
12/03/2008	30	43	85	45000
23/02/2008	25	37	55	80000
20/02/2008	25	42	50	45000
12/02/2008	29	35	22	65000
01/02/2008				
01/02/2008	20	45	11	75000
01/02/2008	17	43	1	36000
01/02/2008	18	39	22	73000
02/12/2007	15	36		63000
01/01/2007	12	25	10	83000
01/01/2007	11	11	11	71000
01/01/2005	11	11	11	89000

Below Normal
Above Normal
Normal



Mobile Healthcare

- Client interfaces for PDA and mobile phone.
- SMS based Emergency messaging system.
- Developing instruments with mobile interfaces.

Use of Mobile Devices in Telemedicine

Limitations Of Handheld Devices

- Limitation of computational resources
    a. Limited memory capacity
    b. Slow execution speed
- Small screen size
- Input device (Stylus)

Solutions

- Client Server based approach
- Data filtering
- Partitioned image display for large images
- Buffer management

Wireless Medical Information Access Server

- Patient data browsing
  a. Text data
  b. Image data
- Prescribing drugs and advice

Patient Queue in Desktop Computer

bcrhadmin | Registration | Data Entry | Local Pat Q | Tele Pat Q | Pat Search | Admin Job | Edit Profil | g Out | BCRH

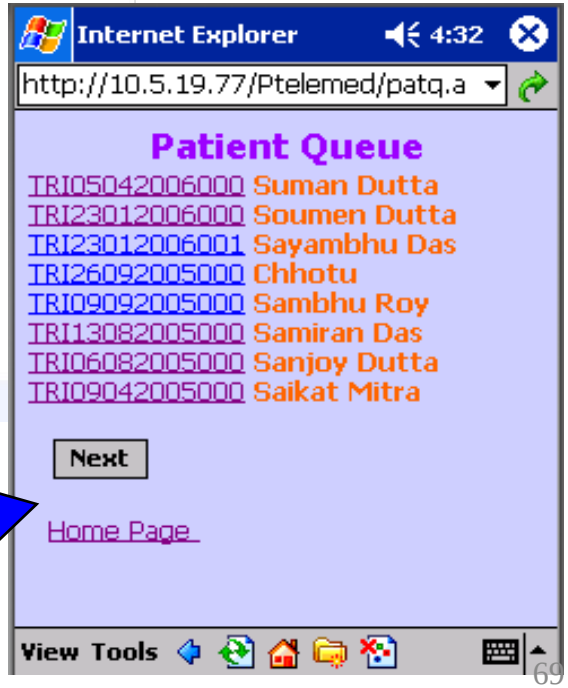
The Local Patient Queue

Number Of Patient(s) in Queue : 6

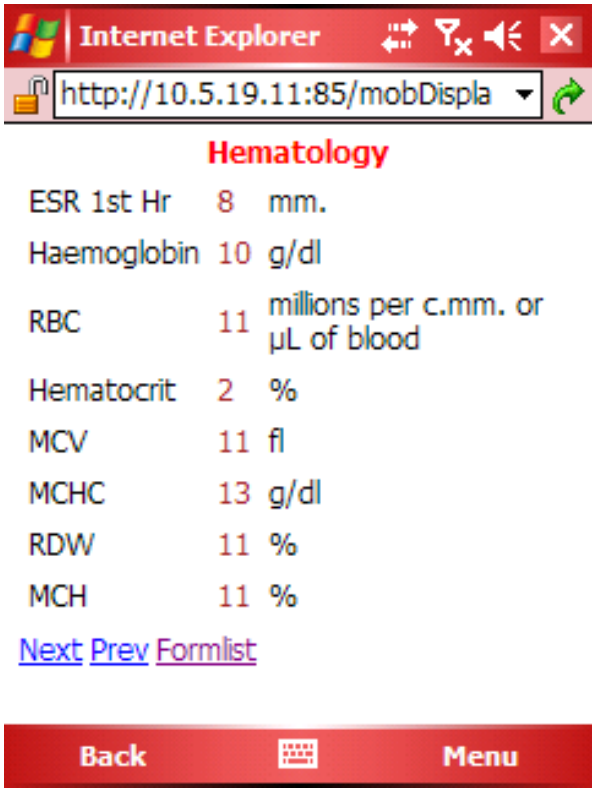
Choose Physician: Jaydeep Bhattacharya (BCR | Assign | Delete Selected Patient

Sl. No.	Patient ID	Summary	Disease Category	Entry date	Assigned Doctor	Select
1.	BCRH.1405080000	summary	General Medical	5/14/2008	Jaydeep Bhattacharya	☐
2.	BCRH.1205080000	summary	Pediatric HIV	5/12/2008	Indranil Pattanayak	☐
3.	BCRH.1005080002	summary	Pediatric HIV	5/10/2008	Indranil Pattanayak	☐
4.	BCRH.1005080000	summary	Pediatric HIV	5/10/2008	Indranil Pattanayak	☐
5.	BCRH.0905080001	summary	Pediatric HIV	5/9/2008	Indranil Pattanayak	☐
6.	BCRH.0905080000	summary	Pediatric HIV	5/9/2008	Indranil Pattanayak	☐

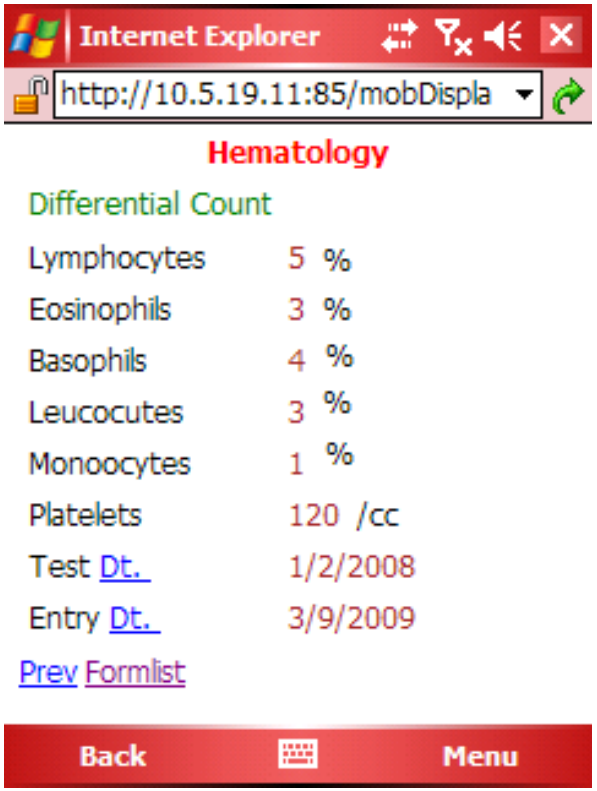
Patient Queue in PDA



Test Reports

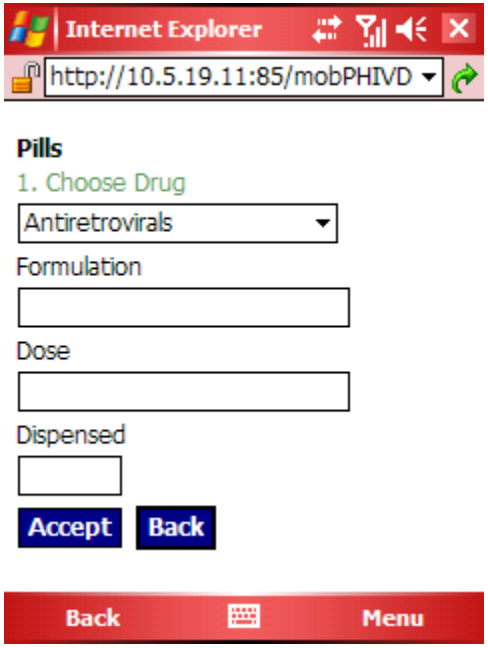


Fragment 1



Fragment 2

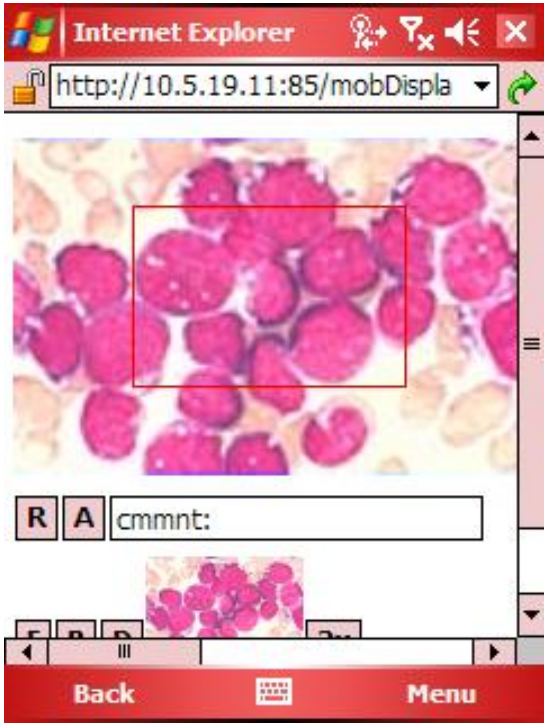
Prescription Writing Form



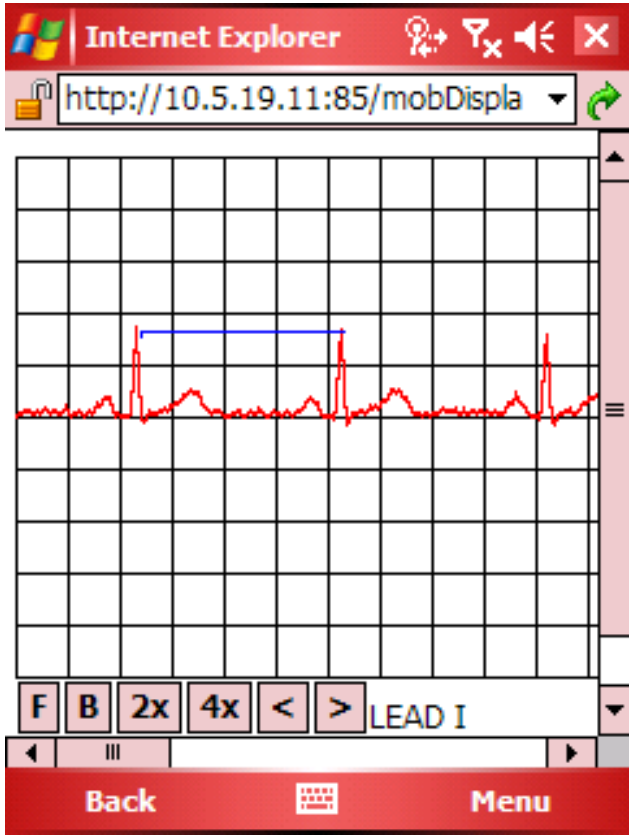
Multimedia data in PDA

- Viewing & Marking of image
- Profile Marking application
- ECG Viewer application
- Display of Graphs and Charts

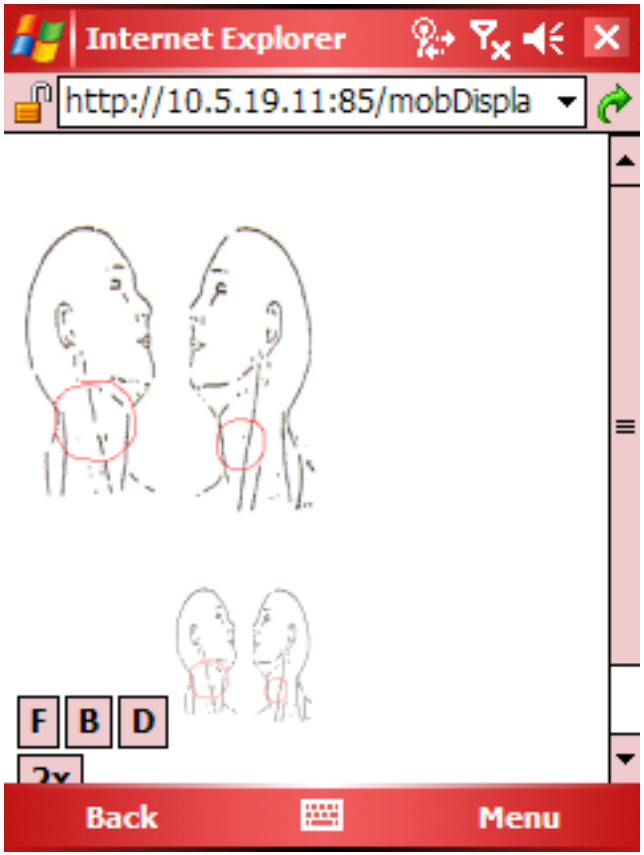
Zooming & Marking of Image



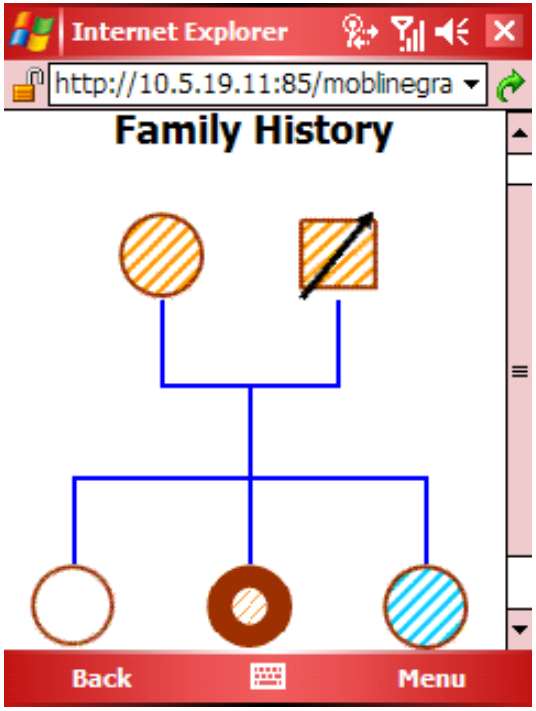
ECG Data Display



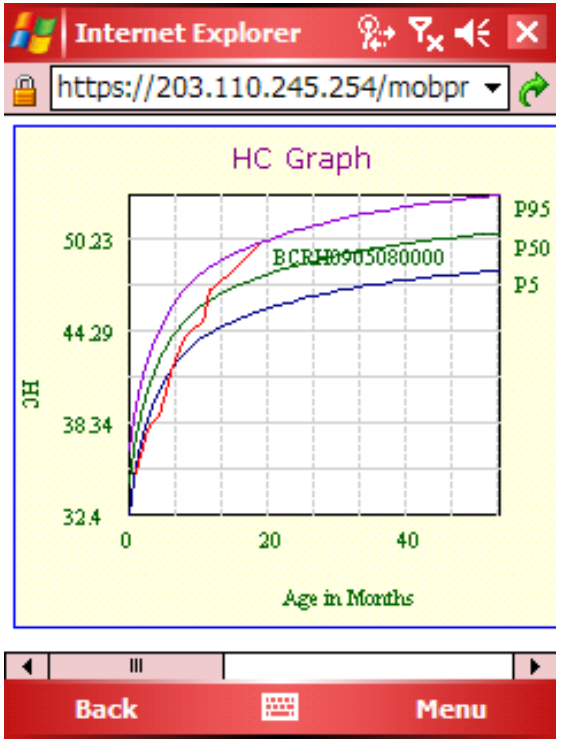
Skin Patch Viewer



Graphs & Charts



Family History Tree



Growth Chart

Emergency Messaging Service using *iMedik*

- Sends SMS to doctors' cell phones to inform him/her about any emergency or patient referral.
- Follows the same multi-tier architecture
- EMS server resides outside the firewall intercepting incoming / outgoing messages

EMS Architecture

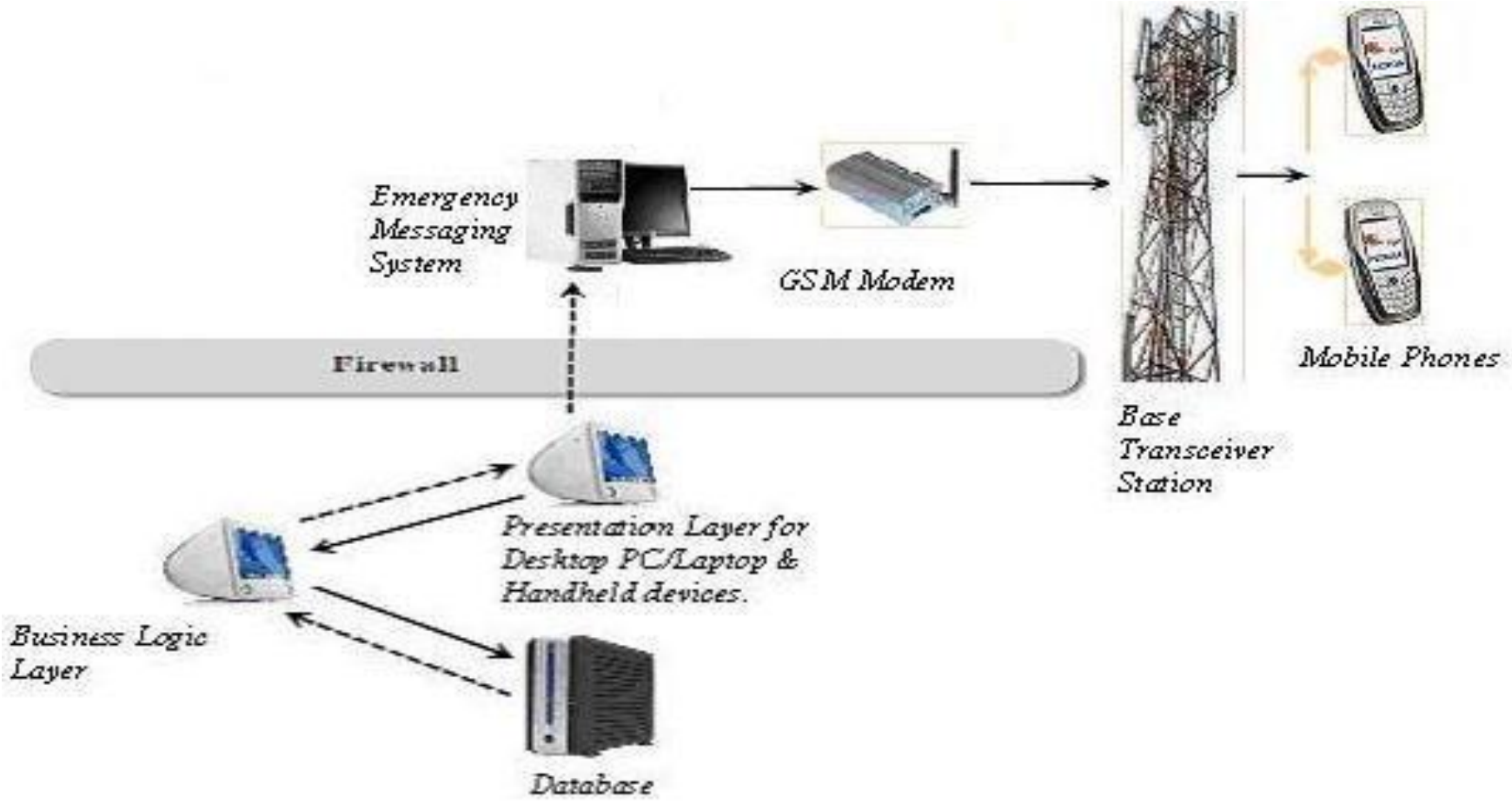


Figure 2: System Architecture For Emergency Messaging System

Message Classification

Message Type	Code
Emergency (Alert)	ALR
Reminder	REM
Regular	REG
Referred Patient	REF
Acknowledgement	ACK
Group	GRP

Example of Message Length Reduction

ALR12:32|01:02
Attend Cardiac Patient. Blood pressure suddenly becomes very high. Some abnormality found in ECG.
Priority = High
Dead Line = 20Minuts
Location = Male Ward
Room-102,Bed-14
Blood Pressure =180/140
Temperature = 98
Pulse Rate = 95
Hemoglobin Count = 8.3

Original Message
262 Char

ALR12:32|01:02
Pri = HI
Dead Line = 20 M
Loc = Male Ward
Room-102,Bed-14
B.P. =180/140
Temp = 98
Pulse Rt = 95
Hemoglobin Cnt = 8.3
Attend Cardiac Pat. B.P. suddenly becomes very hi.
Some abnormality found in ECG.

Compressed Message
208 Char

Message Formatter

- **Message Indentation and Fragmentation**

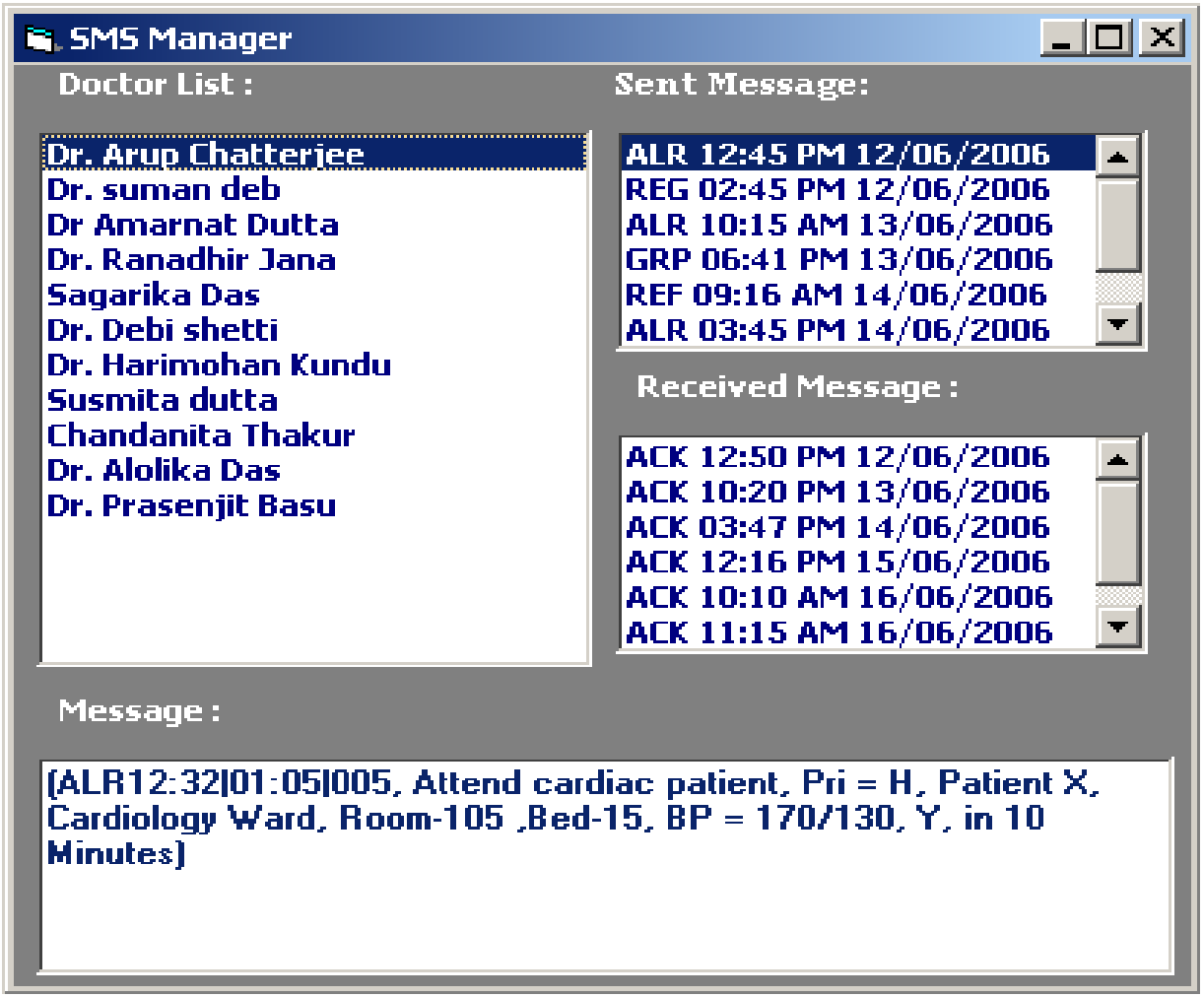
ALR12:32|01:02|Frg 1/2
Pri = Hi
Dead Line = 20 M
Loc = Male Ward
Room-102,Bed-14
B.P. =180/140
Temp = 98
Pulse Rt = 95
Hemoglobin Cnt = 8.3

Fragment 1
135 Char

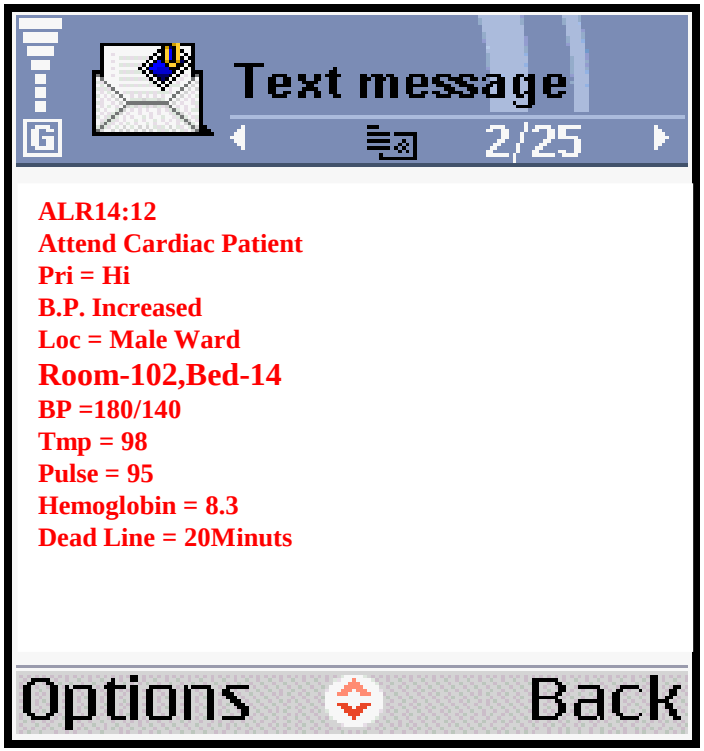
ALR12:32|01:02|Frg 2/2
Attend Cardiac Pat. B.P. suddenly becomes very hi. Some abnormality found in ECG.

Fragment 2
103 Char

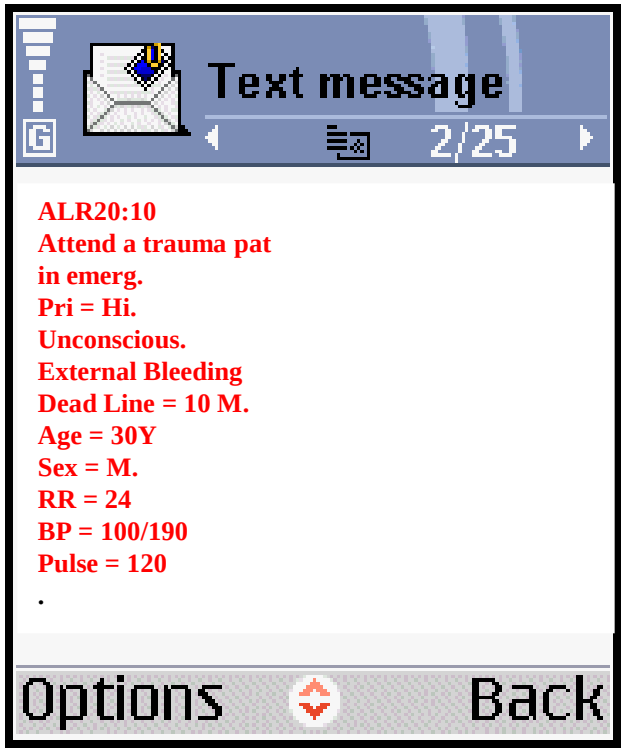
SMS Message Management



Example Emergency Message

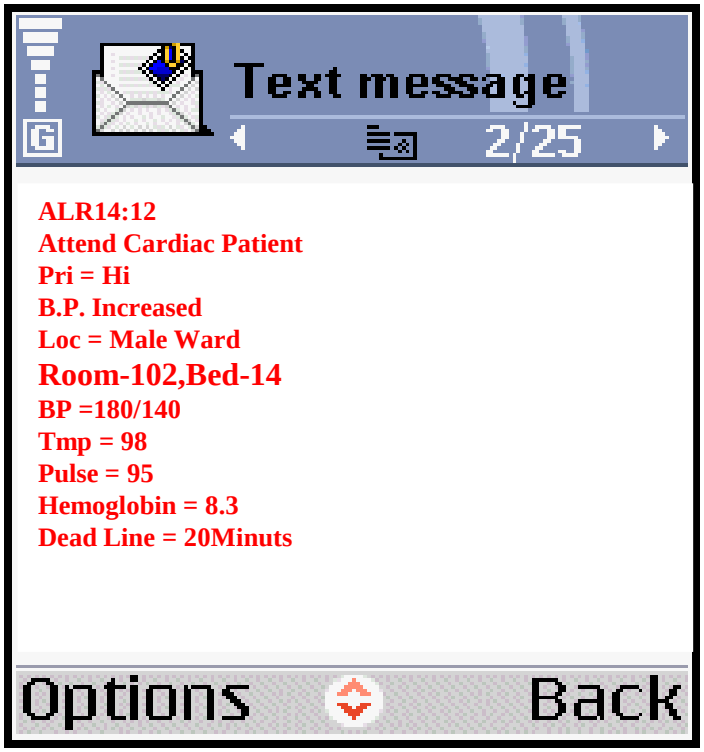


Emergency message for attending a patient admitted in hospital.

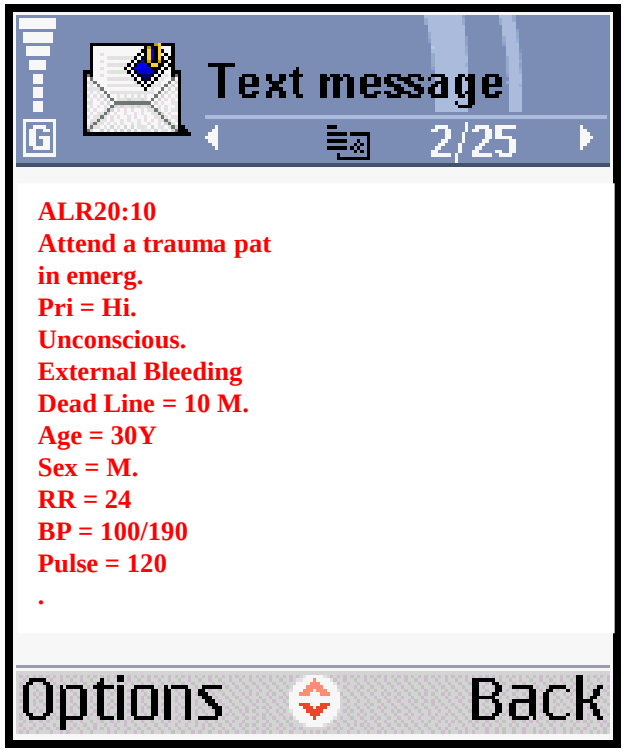


Emergency Message for attending a patient of accidental emergency.

Emergency Messaging



Emergency message for attending a patient admitted in hospital.



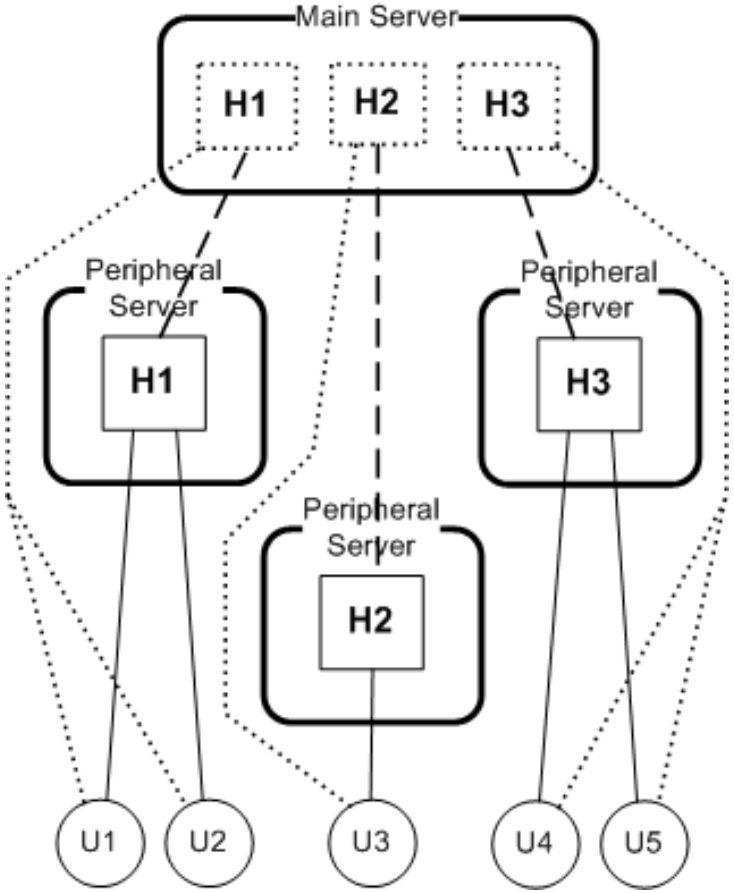
Emergency Message for attending a patient of accidental emergency.

Distributed Telemedicine System

- iMedik-D (Under development)
- Referral Activities through a Central Server.
- Hybrid Model: For some in-house patient management through the Central Server.
- Hierarchical Distributed system (without any Central server.)

iMedikD Symmetric: Server Model

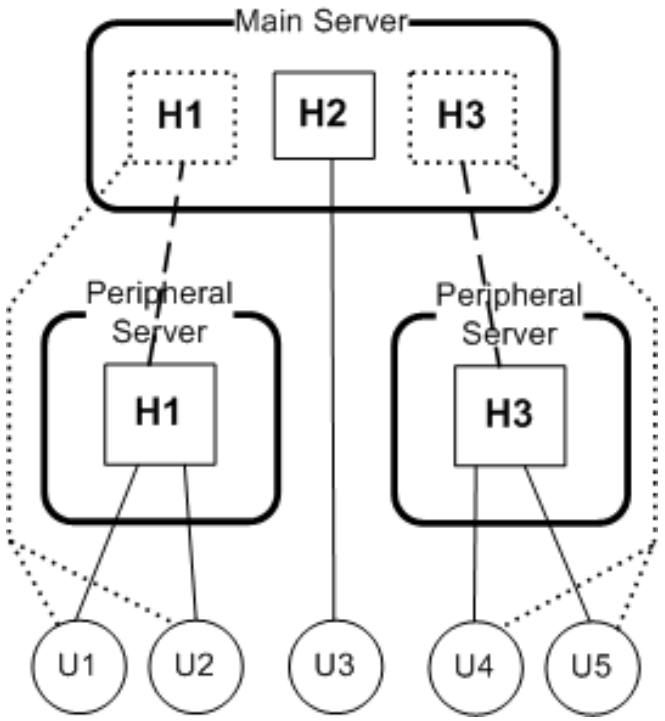
- Two types of nodes - main sever and peripheral server.
  - Multiple peripheral servers connected to one main server.
  - Deployment of hospital EHRs at peripheral servers.
- Symmetric patient referral
- Data segregation partially achieved.



iMedikD Model: Hybrid Server Model

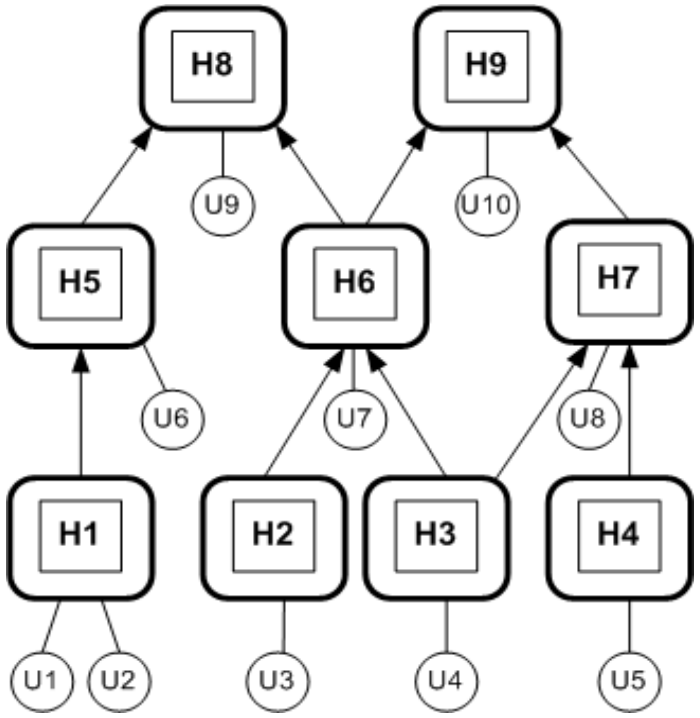
- Combination of centralized server model and distributed server model.

- Supports both the scenarios
  - Organization that can not afford the cost of a PS.
    - Example – H2
  - Organization that can bear the cost of additional PS.
    - Example – H1, H3



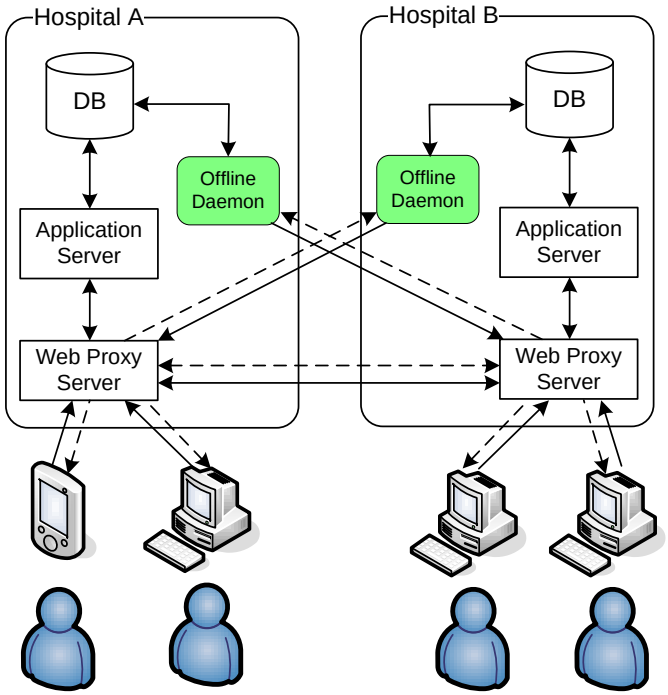
iMedikD Hierarchical: Server Model

- No central or main server.
  - Tele-consultation is carried out in the origin server.
- Hierarchy of reference.
- Each hospital hosts a separate EHR system.
- Can be deployed in the public domain.



iMedikD Hierarchical: System Architecture

- A few additional services:
  - Manage telemedicine network
  - Refer a patient.
  - Fetch doctors information.
- Only reference to data is sent with temporary log in information:
  - Securely.
  - Transparently.



Four Layer Architecture

Benefits of Telemedicine

- Improved Access

  Covers previously unserved or underserved areas.

- Improved quality of care

  Enhanced decision making through collaborative efforts.

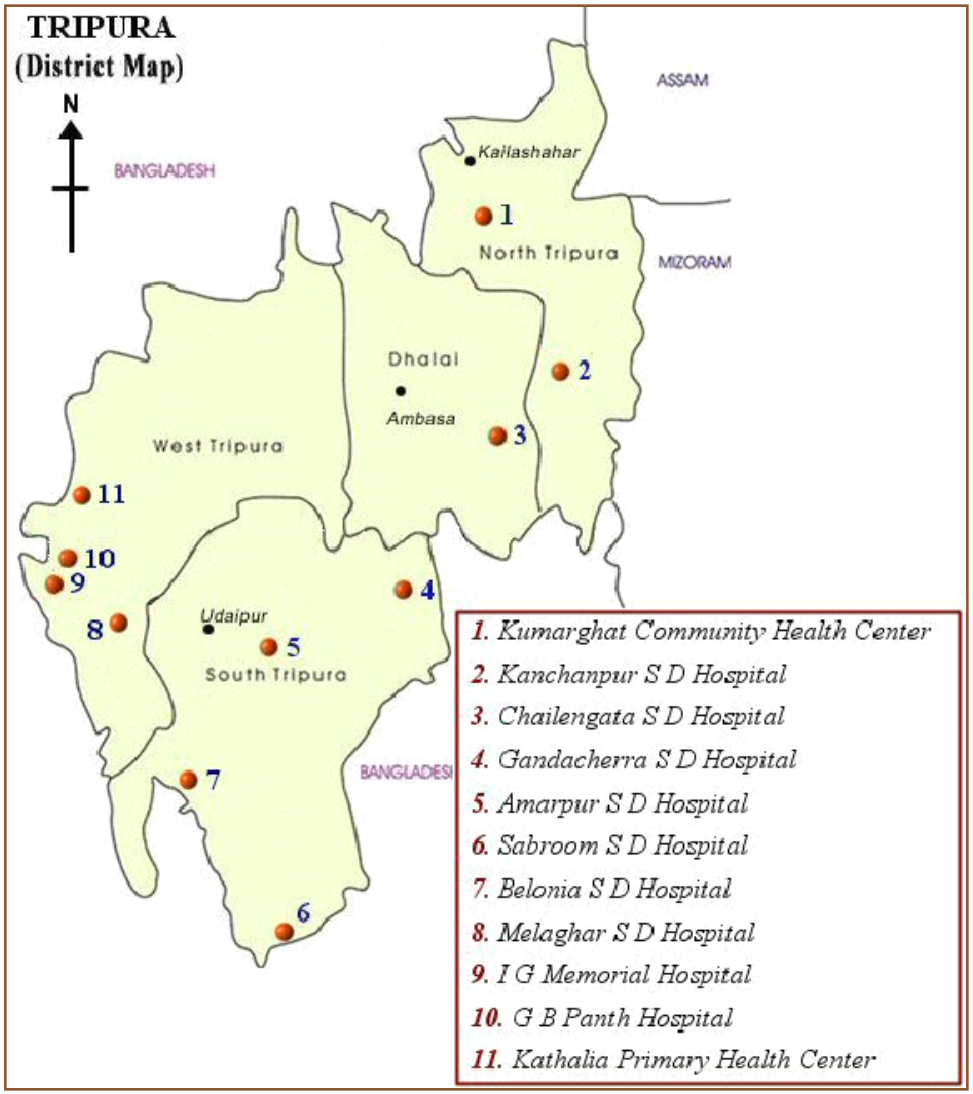
- Reduced isolation of healthcare professionals

  Peer and professional contacts for patient consultations and continuing education.

- Reduced costs

  Decreased necessity for travel and optimum uses of resources.

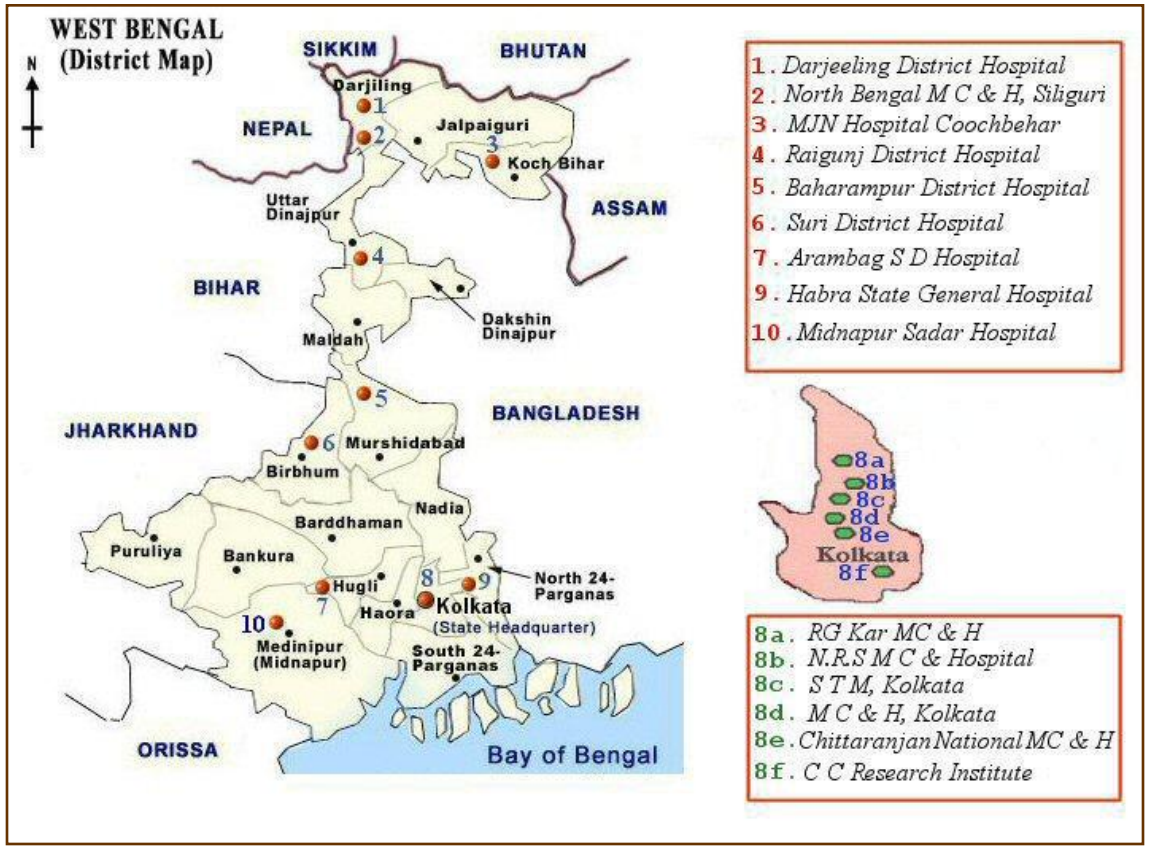
Deployment of Telemedicine - Tripura



TelemediK 2005 deployed in 11 hospitals –

- 2 Referral Hospital in Kolkata
- 9 Nodal Hospital in different districts.

Deployment of Telemedicine – West Bengal



TelemediK 2005 deployed in 20 hospitals –

- 6 Referral Hospital in Kolkata
- 14 Nodal Hospital in different districts.

iMediK installed in Calcutta Medical College in July 2009.

Conclusion

- Telemedicine being increasingly used for providing health care services.
- Effective and efficient in managing resources and time for delivery of health care.
- Telemedicine systems are evolving:

  Peer to peer ► Centralized Server based ► Distributed Systems.
- Looking for a great healthy future of our public health care system in our country.

Thank You