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DEPARTMENT OF CSE
(Accredited to National Board of Accreditation)

OMD 553 - TELEHEALTH TECHNOLOGY

III YEAR – V SEMESTER

LECTURE NOTES – UNIT – 2

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UNIT II TELEMEDICAL TECHNOLOGY

Principle of Multimedia-Text, Audio, Video, Data, Data Communication and network, PSTN, POTS, ANT, ISDN, Internet, Air / Wireless communications. Communication infrastructure for telemedicine-LAN and WAN technology. Satellite communication, Mobile communication.

PRINCIPLE OF MULTIMEDIA

- Multi=numerous | Media=medium | Multimedia=Multiple Modes of Mediums

- Multimedia content uses a combination of different content forms such as:

Text, Audio, Images, Animation, Video, Interactive content

TYPES OF TELEMEDICINE INFORMATION

Telemedicine Information is of four distinct types:

- text and data;
- audio;
- still (single) images;
- video (sequential images).

Table 3.1 gives telemedicine examples of these types along with their typical file size in kilo- or megabytes following digitisation.

The wide range of electronic files sizes from these sources suggests the need to match the choice and performance characteristics of the telemedicine equipment to the clinical need. Under- and over-specification of systems can otherwise lead to disappointment and premature abandonment of a promising project.

Table 3.1. Typical examples of telemedicine information (after Falconer [21])

Source	Type	Typical file size
Patient notes	Text	< 10 KB
Electronic stethoscope	Audio	100 KB
Chest X-ray	Still image	1 MB
Foetal ultrasound (30 s)	Video	10 MB

1. T**ext and Data (non-medical patient data):**personal data, admission and discharge information, payments, insurance status, disease history
2. **Audio:** auscultation(listening to the sound) of heart sounds, sounds from respiratory movements
3. **Still (single) images :** e.g., X-ray, CT, MRI images(radiology), Dermatolgoy images, pathology images such as tissue, cellular specimens
4. **Video (sequential images)** : e.g., images of patient, echocardiography and video-conferencing

1. Text and Data (non-medical patient data)

- Can be classified as

i.Electronic documents

- ✓ Reports, correspondence or medical records which are of ASCII/Unicode text and numerical information can be transmitted directly in digital format
- ✓ This digital file is a read-only file.
- ✓ Can be edited in word processor, database or spreadsheet.

ii. Paper Format

- ✓ This type of document is digitized for transmission with a scanner or a document camera.

iii.Image format

- ✓ Can be read using Optical character recognition (OCR).
- ✓ Looks in a bitmapped format and cannot be edited.

iv. Text information needed before or after tele-consultation can be send as a document through post or emails with attachment

I. Transmission of Data

→ most of the clinics, hospitals store the medical records in the electronic form

→ This helps the doctors to retrieve information about Patients at any time.

→ Prescriptions are given to patients in the Printed form and their records are electronically retained.

→ The electronic records includes

① EMR [Electronic Medical Record]
② EHR [Electronic Health Record]
③ PHR [Personal Health Record]

EMR

① Electronic Medical Record is an electronic record of health-related information on an individual that can be created, Stored, managed and consulted by authorised persons within a Particular healthcare organisation

② This facilitates:

ⓐ Access to patient data
ⓑ clinical notes
ⓒ Lab tests
ⓓ Prescriptions
ⓔ Schedule of Procedures
ⓕ Processing of claims.

Functions of EMR

1. Patient charting → information relating to the visit of the Patient, history, complaints, review, Personal details etc.
2. Oral Communication Systems
3. Document / Image management System
4. Clinical decision-making Support System
5. Patient Portal
6. Statistics and reporting.

Categories of EMR

① Direct digital record: [info directly available in electronic format as a database]

② Scanned / imaged record.
   - → records initially in Paper / hardcopy
   - → Eg: X-ray film, ECG graph
   - → Later scanned or converted to digital format.

EHR

↳ Electronic Health Record is an electronic record of health-related information on an individual that is created, managed and consulted by authorised medical Professionals across more than one healthcare organisation

→ This gives more comprehensive view into a Patient's health and history.

→ It helps care Providers to issue alerts regarding health maintenance requirements of Patient.

→ It is a fundamental building block of all applications based on the use of ICT

→ It enables to share the medical records of Patients across various healthcare Providers irrespective of the geographical locations.

PHR

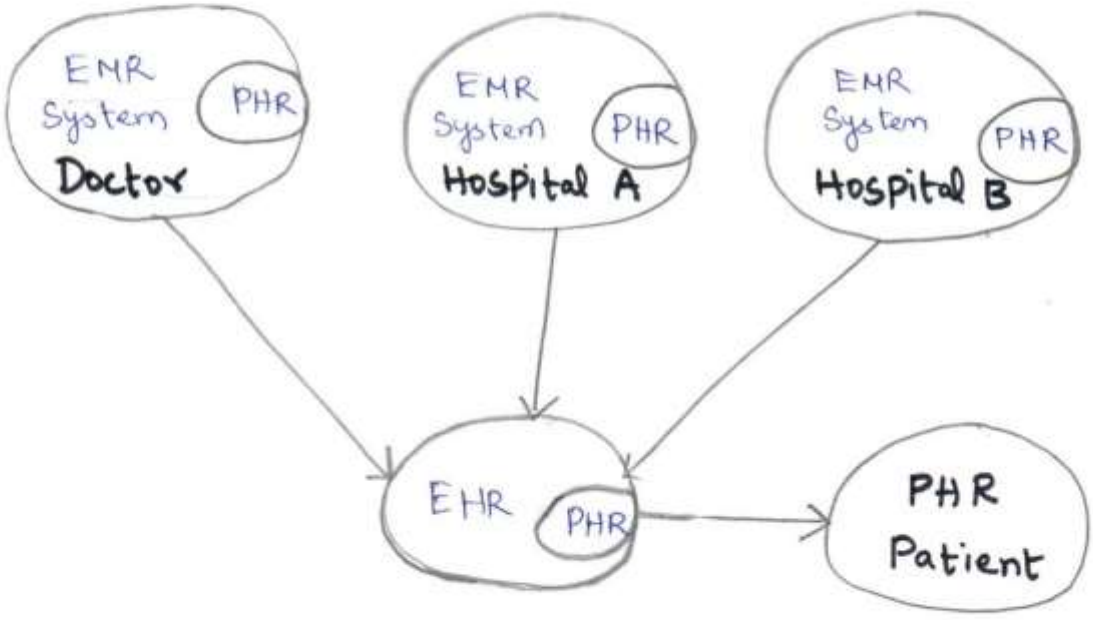
↳ Personal Health Record includes personal data, entire health related information regarding Past and Current Problems and illness, Prescriptions, allergies

→ The individual has to decide as to what information is stored in the PHR and who should be allowed to access it.

Standards for Medical Data Exchange:

1. HL7 (Health Level 7)
2. DICOM (Digital Imaging and Communication in Medicine)
3. ISO TC 215
4. NCPDP (National Council for Prescription Drug Programme)

Relationship between EHR, EMR, PHR



2. **Still (single) images**

- Still image quality is defined by the **size of a pixel (picture element) in an image and the number of grey or colour levels**.
  - ✓ These parameters are determined by the quality of the scanning device which uses photosensitive, charge coupled diode (CCD) transducers to digitise the image
- **Flat-bed scanning devices** scan at up to 1200 dots or pixels per inch (dpi)
- new breed of digital cameras can easily produce a 35 mm size transparency image with 1000 x 1200 pixels
- Each pixel is allocated a fixed number of bits to represent its grey-scale level or colour- usually up to **8 bits (255 levels) for grey-scale and up to 24 bits (16.77 million levels) for colour (depth).**
- if the number of bits is **too low then both grey-scale and colour images lose resolution and tend to monochrome (varying tones of only one colour) pictures in which detail is lost in amorphous blocks**
- amount of computer memory or disk space needed to store a high- resolution image, and the bandwidth and time taken to transfer it.
- For example, The American College of Radiologists (ACR) has defined two categories of teleradiology images; **small matrix or low-resolution systems must digitise 500 pixel x 500 pixel x 8 bit images, while for large matrix or high-resolution, systems the required image resolution is 2000 pixel X 2000 pixel X 12 bit**
- A single image file at the low resolution (ultrasound, magnetic resonance, nuclear medicine) standard is therefore about **250 KB**.
- Single image file at the high resolution (digitised radiographic films and computed radiography) standard takes **4 MB, a factor of 16 times the small matrix file size.**
- If a radiologist wanted a **full 24-bit (true) colour image** of the high matrix image the file size would be **12 MB**.

II Transmission Of Still Images

* One of the most important fact in Telemedicine is acquisition and transmission of medical images like X-rays, CT, MRI.
* These images are first converted into digital form.
* A digitised image is stored in the computer as a Pixels.
* Each Pixel when represented as a bit, would have one of the two states [ON or OFF]
* This corresponds to only two colors [BLACK or WHITE]

Types of Digitising Methods

1. Digitising analog images
2. Computer - generated images
3. Photographic imaging

① **Digitising analog images:-**

* Analog images are converted into digital format by using a Conventional Scanner.
* Charge Coupled Devices (CCD) and laser based Scanners are used for digitising X-ray images

2. Computer-generated images :-

* In modern digital radiography systems, X-ray, ultrasound, CT, MRI are readily available in the digital format that can be stored in the computer directly.

3. Photographic Imaging :-

* High Quality cameras with high resolution can be used for high quality image acquisition.

* Data from these cameras can be transferred to a PC using USB cables.

Need for Image Compression

* Still images are generated in telemedicine in field of radiology, Pathology, dermatology, etc.

* As the transmission time depends on the image file size, various methods to reduce the amount of memory required for storage and transmission becomes necessary.

* Apply some kind of compression algorithm to reduce the size of the image file.

* The term 'data Compression' refers to data encoding and 'data decompression' is called decoding

Types of Data Compression

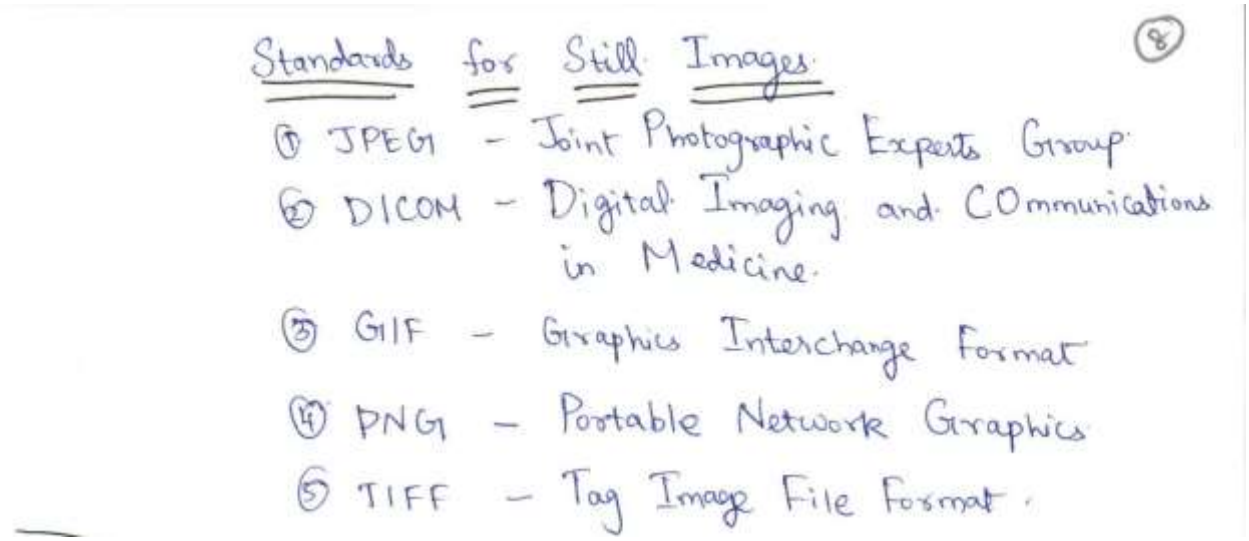
① Lossless Compression
② Lossy Compression.

① Lossless Compression:-

* Here the data is compressed without any loss of data in the compression Process.
* Commonly used Algorithms are
  ① Arithmetic Coding
  ② JPEG 2000
  ③ Run Length Coding
  ④ Hauffman Coding.

② Lossy Compression:-

* Here the data does not have to be stored Perfectly and some loss of information is acceptable.
* Eg:- Videoconferencing - where there could be an acceptable amount of frame loss in the delivery of images in real time.



3. **Video (sequential images)**

- There are two widely used formats for analogue video

i. **The National Television Standards Committee** (NTSC) system adopted in North America and Japan, having **525 lines per picture and a frame rate of 30 pictures per second**

ii. **The Phase Alternating Line** (PAL) system used throughout Western Europe and Australasia, having **625 lines per picture and a frame rate of 25 pictures per second.**

iii. **Common Intermediate Format** (CIF) is a format introduced to provide **compatibility between NTSC and PAL** and offers a lower resolution of 288 lines per picture at 30 pictures per second.

iv. France, Russia and the former Warsaw Pact countries have a third system, **Sequential Couleur a Memoire (SECAM)** but this appears to find little use in telemedicine.

III Transmission Of Video

* In Telemedicine System, for Proper medical diagnosis and treatment of the patient, the video images of the patient is necessary.
* Digital Video is a Sequence of "Still images" or "video frames", which are displayed in a rapid Sequence of 30 frames Per Second.
* This would take up lot of memory.
* Hence some kind of Compression techniques should be applied.
* Video Compression is usually done with special integrated Circuits called "Codecs" [COder/DECoder]

Video Codecs functions

* Converts analog video signal to digital signal.
* Reduces the requirement of digital bandwidth for transmission by compressing digital information.

Video Compression Technology

1. Discrete Cosine Transform (DCT)
2. Vector Quantisation (VQ)
3. Fractal Compression (FC)
4. Wavelet Transform (WT)

(1) DCT :-

* It is a lossy compression Algorithm
* It samples an image at regular intervals and analyze the frequency components Present in the sample.

(2) VQ :-

* It is a lossy compression Algorithm.
* It Processes an array of data
* It then Compresses the redundant data.

(3) Fc :-

* It is a lossy compression Algorithm
* Basic idea is to break an image down into smaller tiles

4. WT :-

* It is similar to the Fourier transform which takes a signal in time domain and represents it in frequency domain.

Video Compression Standards

1. MPEG Standards [Moving Picture Experts Group]
   * MPEG-1 : Compression of Moving Pictures
   * MPEG-2 : Compression of Interlaced Video
   * MPEG-4 : Multimedia & Web Compression
   * MPEG-7
   * MPEG-21
2. ITU Standards
   * H-120
   * H-261
   * H-263

4. Audio

- PSTN /POTS can be used to transmit sound (e.g. speech) to establish a remote diagnosis.
- An analogue sound is digitised by sampling its amplitude at discrete time intervals to recreate the waveform.
  - ✓ The discrete nature of the digitisation process introduces quantisation or amplitude round-off errors as the digital sample value approximates the analogue signal at a given instant
  - ✓ quality (ease of understanding) and bandwidth (capacity to carry information)
- Digital signals can be trans mitted over networks for large distances without degradation

Creative Labs SoundBlaster card

- A sound cards that slot easily into a PC are available for this purpose and, once installed, no special equipment other than a suitable microphone is needed for teleconsultations.
- These cards can also receive audio output directly from medical peripherals such as an ultrasound scanner

IV. Transmission Of Audio

* Telemedicine Systems have audio channels for Stethoscope or Doppler ultrasound.
* Audio is also used for Conversation and medical diagnosis in Telemedicine System.
* Telephones based on analog transmission are Subject to noise and there is loss of Quality of information, when transmitted over long distances.
* Audio Signals are first digitised and Compressed before they can be Combined with digital video and other information.
* A Sound Card in a PC is quite adequate for Capturing audio to meet the requirements of a telemedicine system.
* Hence it is Preferable to use an ordinary telephone line for transmission of the audio Part of the session.

Audio Compression Technology

* PCM (Pulse Code Modulation)
* ADPCM (Adaptive Differential PCM)
* CVSD (Continuously Variable Slope Delta)

5. Still Image and Video compression

- Digital images can be compressed by **hardware or software before transmission**
- Image compression can be **lossless(data is not lost) or lossy (some data is lost, especially redundant information)**
- Lossless
  - gives full resolution of the original image
  - Compression ratio is 1.5-3:1
- Lossy
  - Compression algorithm **discards data to achieve higher compression ratios**. Therefore decompression cannot recover the original image with its full definition.
  - Mostly used in Video and audio.
  - Compression ration is 20-100:1
  - Except in radiology applications, lossy compression is acceptable for telemedicine work.
  - Lossy compression standard for still images is JPEG(Joint Photographic Expert Group)
- JPEG
  - can operate on any number of colours
  - Digital video files , JPEG compression ration is 100:1
- MPEG(Moving Picture Expert Group)
  - Used for video images
  - Uses a form of **Frame Differencing or Motion Prediction**
    - Only small part of video image change from one frame to next(while decompressing ,frame sequence can be recaptured by storing the difference between successive frames and adding these to a decompressed base image)
  - MPEG is an **asymmetric codec**, taking longer time to compress the image for making less storage size, so that decompression is more efficient and faster.
- telemedicine data and compression ratios

Data type	Single image size	Uncompressed file size (MB)	Compressed file size (KB)	Compression ratio
Radiograph	2000 × 2000 × 12	5.7	285	20 : 1
Pathology microscope image	800 × 600 × 24	1.44	96	15 : 1
Dermatology image	1280 × 1024 × 24	3.9	980	4 : 1
CT data set (20 images)	256 × 256 × 8	1.3	650	2 : 1

Typical telemedicine data and compression ratios

6. Data

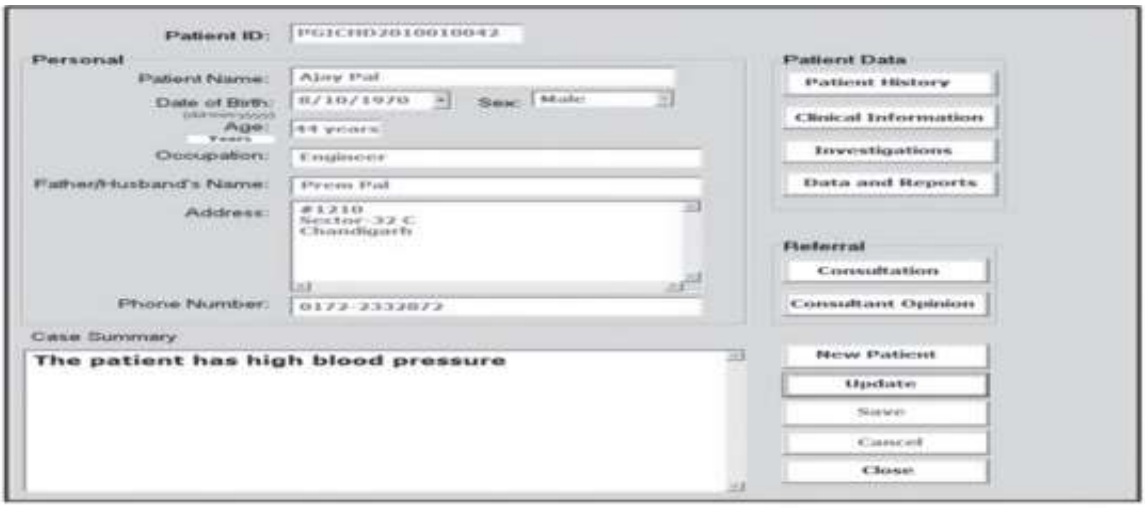
Data: “Signature” of Information
Information: Processed data

- is categorized into five classes

1. Data related to a patient's personal information
2. Data related to a patient's medical information
3. Data for Patient's Management In Telemedicine
4. Data related to the Physicians
5. Data for System Management

1. Data related to a patient's personal information

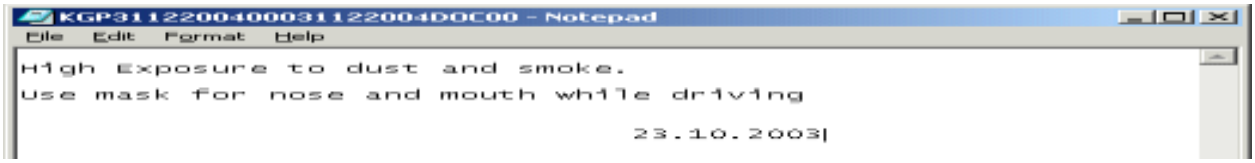
- first step in telemedicine
- includes information related to Patient's name, address, sex, age etc. Important information is an unique identity number(called as pat_Id)



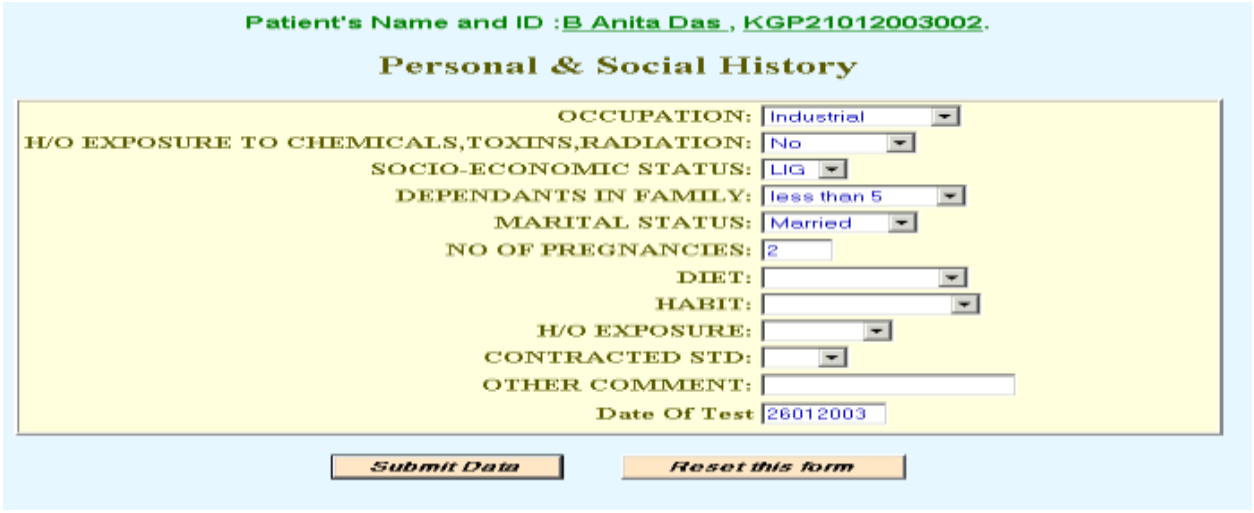
Screen shot of a typical patient data sheet normally generated in a hospital.

2. Data related to a patient's medical information

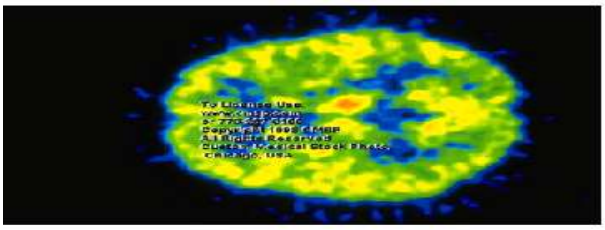
i. Ordinary text(e.g., prescriptions)

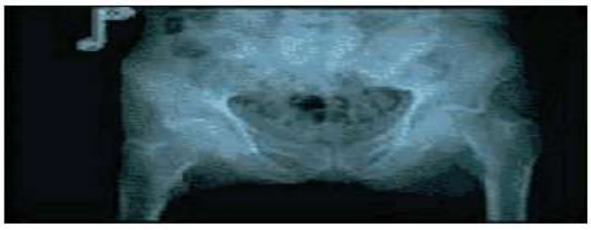


ii. Structure text(e.g., test reports)

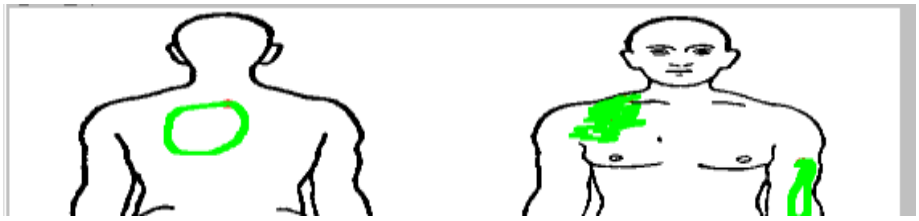


iii. Digital images(e.g., Xray's)



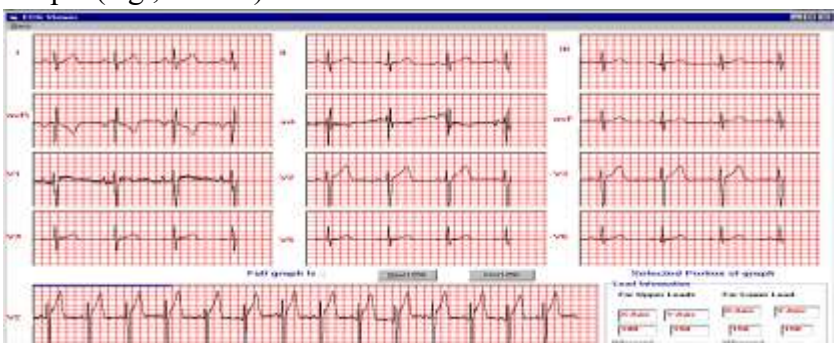


iv. Graphics primitives(e.g., Polygons, lines etc)

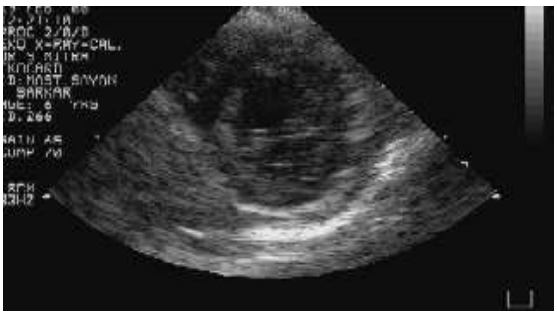


Leprosy patches: represented as contours(bounding the shape)

v. Graphs(e.g., ECG's)

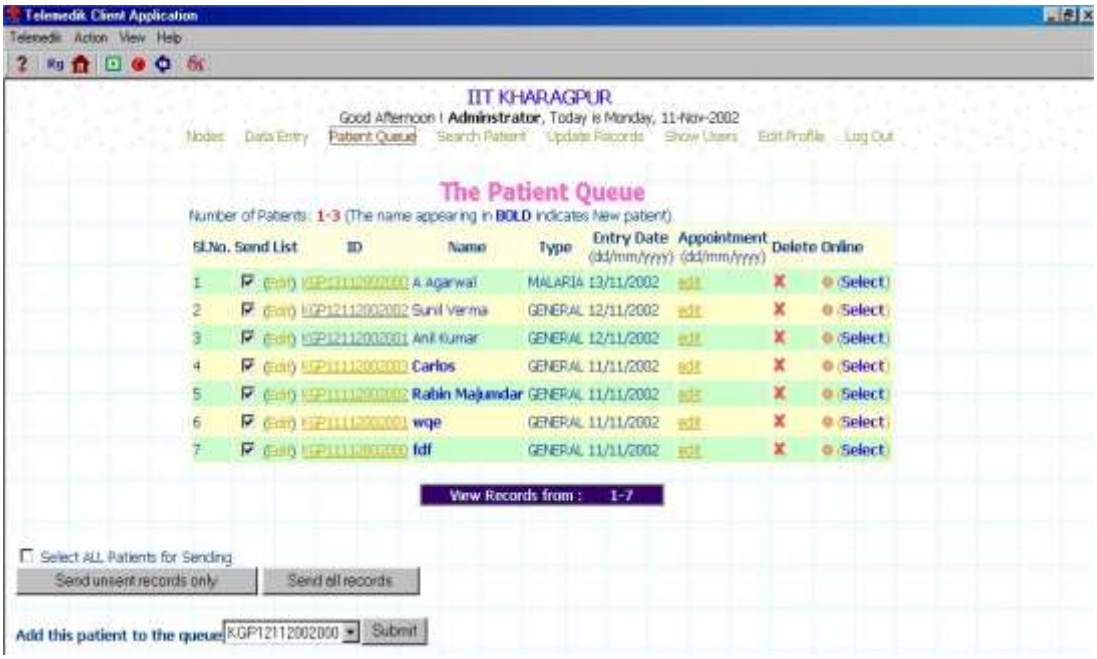


vi. Video clips(e.g., ultra-sonograms)



3. **Data for Patient's Management In Telemedicine**

- Relates to patients waiting for telemedicine. Contains information about
  - Patients stored in a Patient_Queue
  - Patients can be enqueued in patient_Queue both in nodal(through data organizer) and referral centers(through data transfer)



4. **Data related to the Physicians**

- Contains information about
  - Doctor's Personal Information
  - Unique Identification Key

5. **Data for System Management**

- User's list at different levels is maintained.
- Password file is manage
- Maintaining the valid users list, maintains log files for data transfer, on-line telemedicine session

DATA COMMUNICATION AND NETWORKS

- **Telecommunication is a major component** of a telemedicine system.
- Telemedicine demands a **continuous and reliable communication link for exchange of information which can be categorized into three eras**

a) First era

- telecommunication era was started in 1970's , where applications were dependent on broadcast and television technologies
- Telemedicine did not make much used of these technologies

b) Second era

- Started during the late 1980's =>digitalization in telecommunication.
- Digitalization=>various communication mediums ranging from telephone lines to ISDN lines were developed provides better data transmission
- The operational cost was high
  - ✓ communication media(e.g., devices, lines) or providing high bandwidth was difficult
  - ✓ Bottleneck for spread of telemedicine, remained at pilot level

c) Third era

- ✓ Telemedicine is supported by the internet technology
- ✓ Cheaper and accessible to an increasing user population
- ✓ New opportunities were provided as enhanced speed and quality was offered by Internet , 3G/4G mobile telephony.
- ✓ Satellite , wireless technologies like WiMAX provides cheaper solutions .

- Time frame is the important consideration in telemedicine. For real-time=> immediate response is needed, store and forward=> can be transmitted even at a slower rate
- Various **telecommunication technologies** available are given below

TYPES OF TELECOMMUNICATION TECHNOLOGY / NETWORKS

1. POTS / PSTN
2. ANT
3. ISDN
4. LEASED LINES
5. SATELLITE COMMUNICATION
6. WIRELESS COMMUNICATION

Telecommunication options

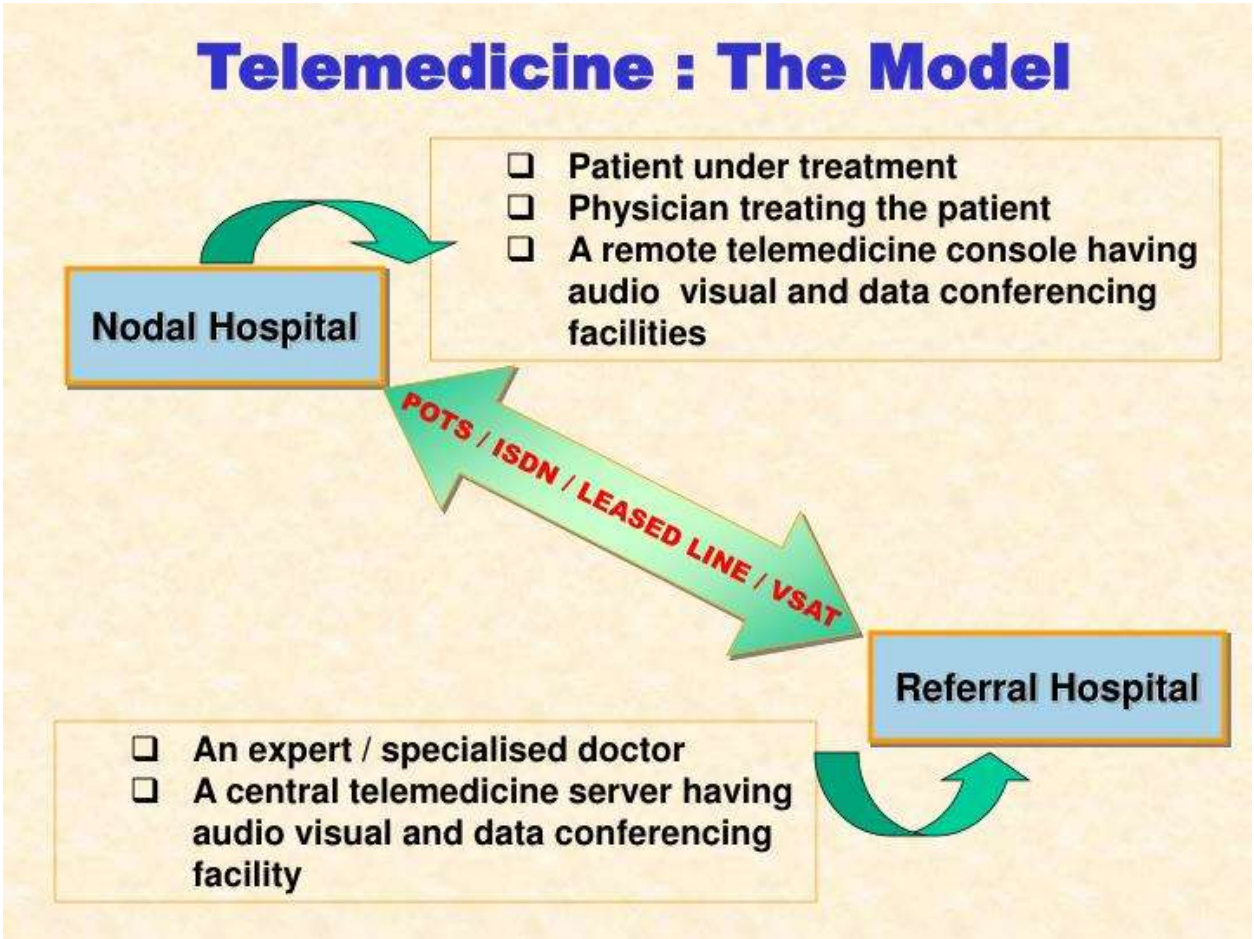
System	Data transfer rate	Advantages/disadvantages
PSTN	56 Kbps	Cheap, ubiquitous ,slow ,not suitable for high resolution
ISDN (basic rate)	128 Kbps	Cheap, flexible, slow, patchy availability
ISDN (Primary rate)	< 2 Mbps	Fast, high quality Expensive, patchy availability
Satellite	< 2 Mbps	High quality, remote access, expensive

Wireless	< 2 Mbps	Convenience, free movement, new technology, limited standards
Microwave	< 20 Mbps	Good quality, inexpensive to run, line of sight only, short distances
Leased lines	64 Kbps-50 Mbps	Reliable, expensive, inflexible
ATM, DSVD, ADSL	155 Mbps	High bandwidth, expensive, may be superseded

PSTN / POTS

(Public Switched Telephone Network)

The Public Switched Telephone Network (PSTN), also known as **Plain Old Telephone Service (POTS)**, is the wired phone system over which landline telephone calls are made. The PSTN relies on **circuit switching**. To connect one phone to another, the phone call is routed through numerous switches operating on a local, regional, national or international level. The connection established between the two phones is called a **circuit**.



Overview of PSTN

PSTN (public switched telephone network) is the world's collection of interconnected voice-oriented public telephone networks. PTSN comprises all the switched telephone networks around the world that are operated by local, national or international carriers. These networks provide the infrastructure and the services for public telecommunication.

This is the system that has been in general use since the late 1800s. It's the aggregation of circuit-switching telephone networks that has evolved from the days of Alexander Graham Bell.

Using underground copper wires, this legacy platform has provided businesses and households alike with a reliable means to communicate with anyone around the world for generations. Today, it is almost entirely digital.

The phones themselves are known by several names, such as PSTN, landlines, Plain Old Telephone Service (POTS), or fixed-line telephones.

How PSTN works

A public switched telephone network is a combination of telephone networks used worldwide, including telephone lines, fiber optic cables, switching centers, cellular networks, satellites and cable systems. A PSTN lets users make landline telephone calls to one another.

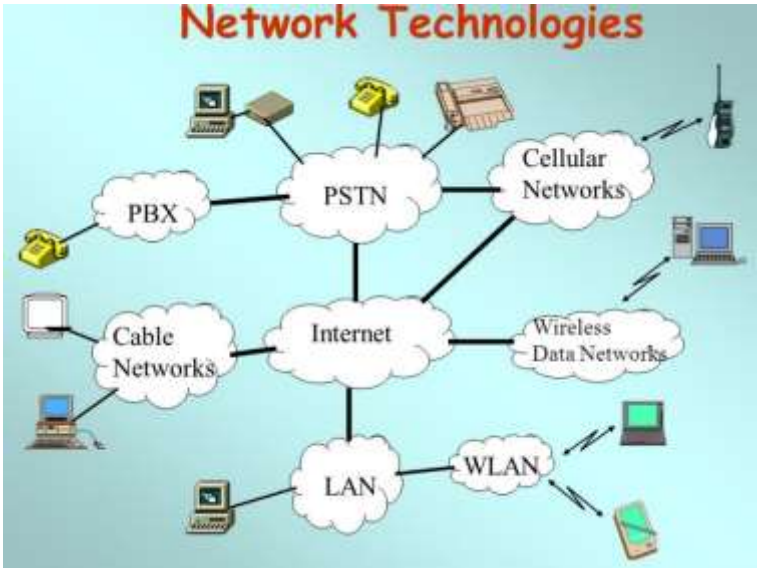
A PSTN is made up of switches at centralized points on a network that function as nodes to enable communication between two points on the network. A call is placed after being routed through multiple switches. Voice signals can then travel over the connected phone lines.

The PSTN phone line is used with traditional dial-up network modems to connect a computer to the Internet. Dial-up Internet connections support up to 56 Kbps. In the early days of the Internet, this was the main method for home Internet access but it became obsolete with the introduction of broadband Internet services.

PSTN structure

The traditional PSTN has a hierarchical architecture and a star structure. The individual subscriber lines are connected to a local exchange, which communicates with trunk exchanges as well as main and central exchanges. The lines within a local exchange typically

have the same area code. A user who wants to call a number outside the local exchange has to add an area code. To make an international call, a user has to dial the country code.



Advantages:

Very robust
Simple for the customer - plug in a phone and it just works.
voice quality is exceptional.
Pervasive (meaning it's everywhere)
"paid for"
works when the power is out.
connections between two points are dedicated.

Disadvantages

The infrastructure is "older" CAT3 copper wire and can't run high speed data reliably.
The infrastructure was designed to carry 3Khz analog voice
The infrastructure has been spliced and patched back together over the years.
It's extremely expensive to replace it.
Nobody (no company) makes circuit switched "phone switches" anymore.
Subject to outages from things like falling trees, which cellular service is not.
Doesn't support mobility.

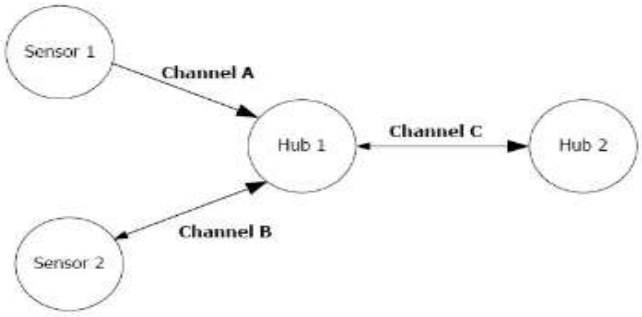
ANT(ADAPTIVE NETWORK TOPOLOGY)

- **Ultra-low power, short-range wireless technology** designed for **sensor networks and similar applications.**

- Allow **short-range wireless communication** in **point to point or more complex network topologies.**
- ANT was **designed for low bit-rate and low power sensor networks.**
- Proprietary protocol is developed by Canadian company Dynastream Innovations Inc. a subsidiary of GPS personal navigation firm Garmin.
- This protocol can be used for many application such as collection, automatic transfer and tracking of sensor data within sports, wellness management and home health monitoring application such as in heart rate monitors, speed sensors and small GPS devices.
- Uses 2.4Ghz, ISM(Industrial,Scientific,Medical) band
- ANT accommodates three types of messaging: broadcast, acknowledged, and burst.

1. **Broad cast**
   - is a **one-way communication** from one node to another (or many).
   - The receiving node(s) transmit **no acknowledgment**, but the receiving node may still send messages back to the transmitting node.
   - This technique is suited to **sensor applications** and is the most economical method of operation.
2. **Acknowledged messaging**
   - confirms receipt of data packets.
   - The transmitter is informed of success or failure, although there are no retransmissions.
   - This technique is suited to control applications.
3. **burst messaging**
   - a multi-message transmission technique using the full data bandwidth and running to completion.
   - The receiving node acknowledges receipt and informs of corrupted packets that the transmitter then re-sends.
   - The packets are sequence numbered for traceability.
   - This technique is suited to data block transfer where the integrity of the data is paramount.

- **Picture of simple ANT Network**



- Works efficiently in **embedded systems that are based on peer to peer or star network topology.**
- Uses very **short duty-cycle** technique and **deep-sleep modes** for very low power consumption

- ANT can be configured to spend long periods in a low-power "sleep" mode (consuming of the order of microamps of current), wake up briefly to communicate (when consumption rises to a peak of 22mA) during reception and (13.5mA during transmission) and return to sleep mode. Average current consumption for low message rates is less than 60 microamps on some devices.
- Ant transceivers **use small cell-type batteries** which could operate up to three years in low use application
- ANT+ facilitates the collection, automatic transfer and tracking of sensor data for monitoring all involved nodes and devices
- ANT+ is already integrated into a lot of mobile phones

ISDN

INTEGRATED SERVICES DIGITAL NETWORK

PSTN means "**Public Switched Telephone Network**," and **ISDN** means "**Integrated Services Digital Network**." ISDN overcomes the drawback of PSTN.

1. PSTN lines are analogue while ISDN lines are digital.

2.When comparing the two networks, the PSTN lines are used for small companies and ISDL are

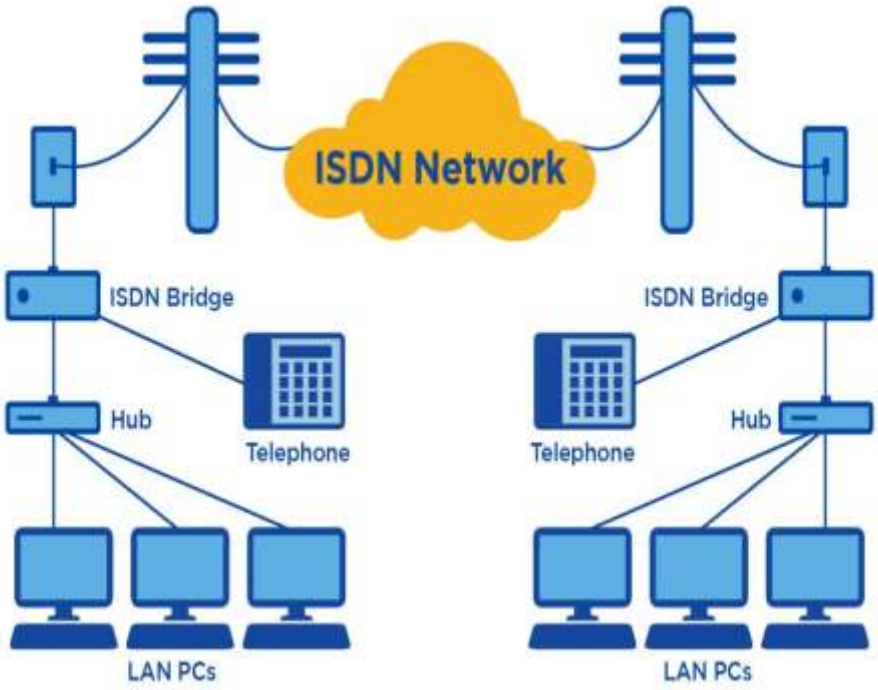
used for bigger companies.

3.The ISDN provides 128 kbit/s, which is really good for the Internet. PSTN has a disadvantage

that it does not make the most possible use of the broadband.

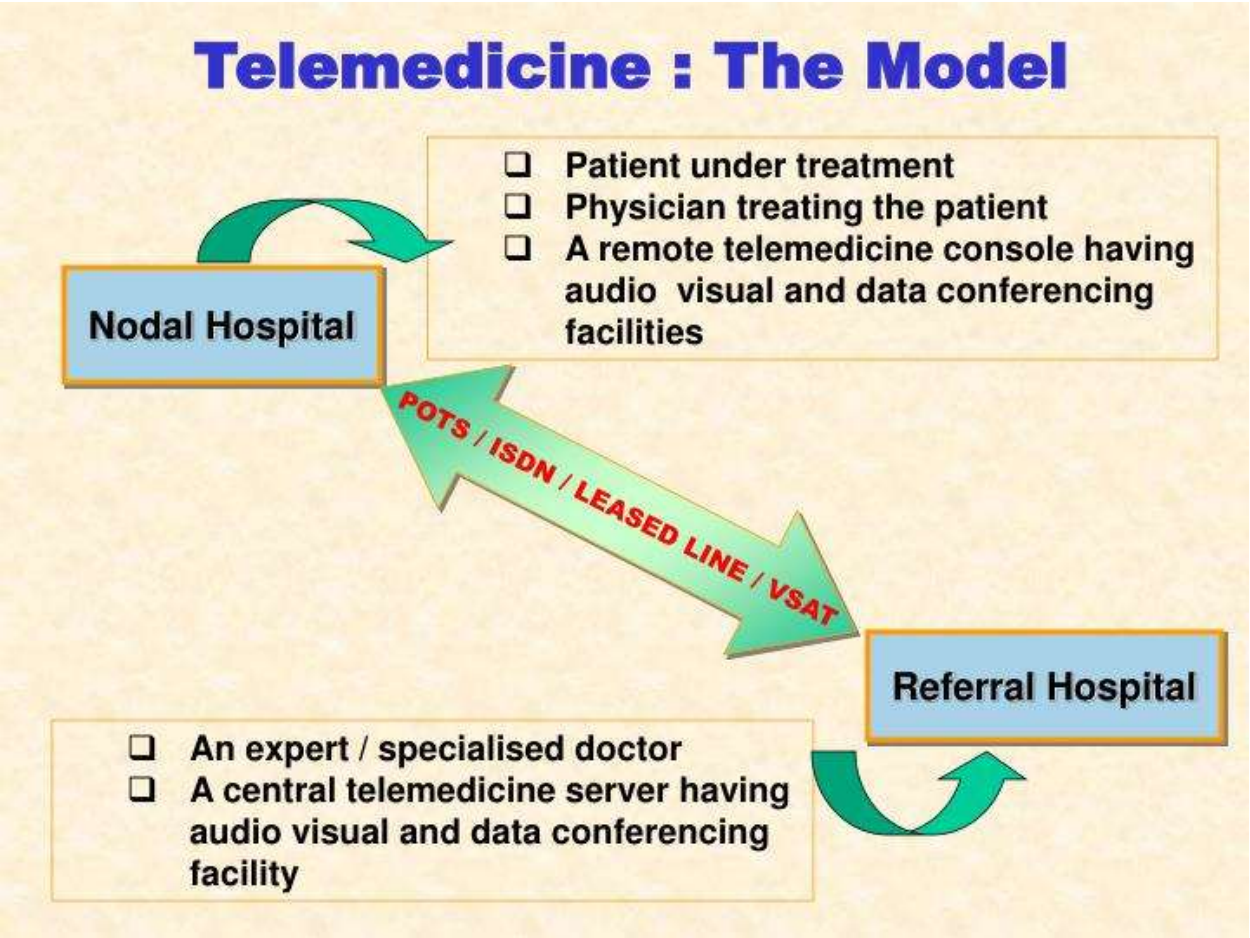
4.While PSTN does not allow two simultaneous connections, it is allowed in ISDN service.

5.When using ISDN, one can make faster calls than when using the PSTN.



Overview of ISDN

- Operates over **copper based telecommunication networks**, provides **higher data speeds and better quality than analog transmission.**
- The term **"integrated services" => allows any form of data from voice to faxes and internet web pages to data files to be carries over the digital system.**
- is a **circuit switched telephone network system**, which also provides **access to Packet switched networks**
- **Noise, distortion, echoes and crosstalk** present in POTS are **not present**
- Presently available between all major cities
- Offers **better security and good quality** services
- ISDN is **preferred where higher speed terrestrial data line is required for telemedicine for data transfer/exchange**
- ISDN links are **better** than PSTN for **data throughput but are not comparable with the satellite link**
- For ISDN line, interface units are available in the form of a PC add-on card or an external stand-alone unit
- These units available in the form of 64kbps or multiple modules. For higher speed than 128kbps, multiple external units are used with as many lines



ISDN Configurations

- types of ISDN services
  a. Basic Rate Interfaces(BRI)
  b. Primary Rate Interface(PRI)
  c. Narrowband ISDN (N-ISDN)
  d. Broadband ISDN (B-ISDN)
- These services are composed of 'B' and 'D' channels
  i) 'B' or 'Bearer channels'
    - ✓ used to carry voice and data information
    - ✓ minimum bandwidth of 64kbps

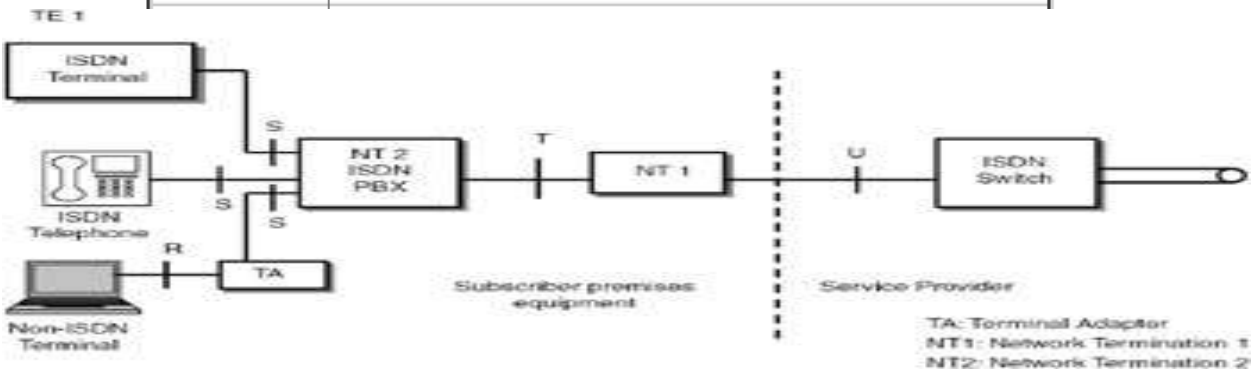
  ii) 'D' or 'Data channel'/'Delta Channel'
    - ✓ used for carrying signaling and control information
    - ✓ handles signals at 16kbps or 64kbps, depending on the service type

a) Basic Rate Interface(BRI)

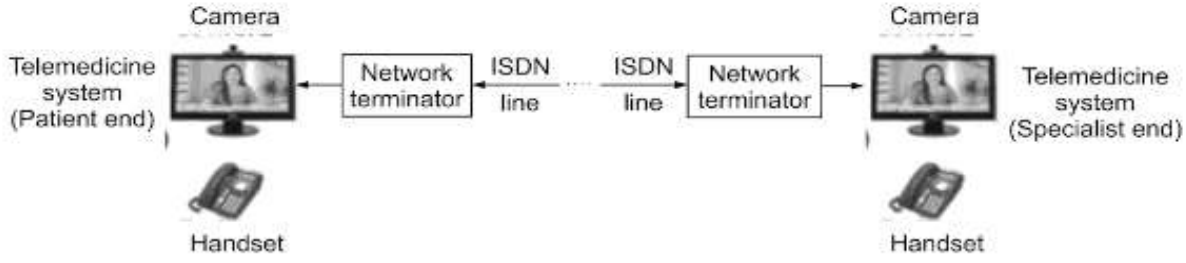
- Comprises of **two 'B' channels**(one up and one down) of 64kbps bandwidth and **one 'D' channel** with a bandwidth of 16kbps(provides total bandwidth of 144kbps).
- Services accessed using phone line=>subscriber must be within 5.5 km of the telephone company, if not repeaters must be used
- is **designed** to meet mostly the **requirements of individual users**(home)=>called entry level service

- **For telemedicine** application, requiring transmission of video images, **6 channels each of 64kbps are used to get upto 384kbps bandwidth**
- Two terms associated with ISDN Network
    a. Line Termination(LT) : defined as the network end of line
    b. Network Termination(NT)
        - ✓ Refers to the user end of the network
        - ✓ is a small connection box
        - ✓ Converts the two wire lines coming from the network(U interface) to four wires(S/T interface).
        - ✓ S/T interface can provide up to eight terminal equipment , but only two are used at any given time.
        - ✓ The terminal equipment are telephone, fax, computers or video conferencing equipment.
- **Table** that shows the interface used in ISDN with its pictorial representation

Electrical interface	Between what two points
U interface	Central office and NT1
T interface	NT1 and NT2 devices (such as a PBX)
S interface	NT1 or NT2 and ISDN devices (such as a telephone or terminal adapter)



➢ **Pictorial** representation ISDN line in telemedicine

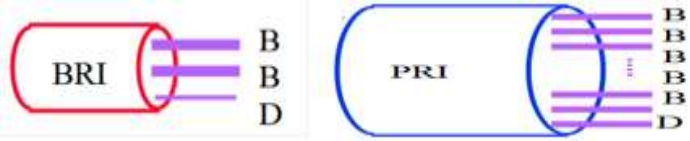


Application of ISDN lines in telemedicine.

b) Primary Rate Interface(PRI)

- For users requiring **higher bandwidth**, therefore needs larger number of channels than BRI.
- intended for **larger users**(used by enterprises and offices, internet service providers)
- No. of **B channels required depends upon the bandwidth necessary for a particular location**

- PRI uses multiple channels, the direction can be configured in order to accommodate whichever needs the most bandwidth
- The Primary Rate Interface consists of 23 B-channels and one 64- Kpbs D channel in the United States or 30 B-channels and 1 D-channel in Europe
- Pictorial representation of PRI



- There are two configurations
  a. E1 Line
     - ✓ In Europe and Australia, a configuration of 30 B channels at 64kbps each and two D channel at 64kbps (one for signaling and one for controlling) has been adapted=>called as **30B+D ISDN**.
     - ✓ The aggregate **data rate for 30B+D ISDN is 2.048Mbps.**
  b. T1 Line
     - ✓ In North America and Japan, a configuration of 23 B channels at 64kbps each and one D channel at 64kbps has been adapted=>called as **23B+D ISDN**.
     - ✓ is a high speed data circuit with 4 wires (2 for transmitting , 2 for receiving)
     - ✓ Can transmit and receive data at a rate of 1.54Mbps.
     - ✓ Transmission rate of T1 is 100 times faster that modem operating at 14.4 kbps.
     - ✓ Most computers uses T1 connection that support up to 200 and above users
     - ✓ is capable to **transfer good quality motion images, can send and receive real-time full motion video and voice=> can provide data transfer to healthcare services**
- No much difference in T1 and E1 lines , except the no. of channels
- Cannot provide T1/E1 line for individual residences, because it uses Alternate Mark Inversion (AMI) as transmission protocol which necessitates the use of transceivers every 1000 m from the central exchange and every 2000m thereafter

Advantages of ISDN

ISDN is a telephone network based infrastructure, which enables the **transmission of both voice and data simultaneously**. There are many advantages of ISDN such as −

- Facilitate the user with multiple digital channels. These channels can operate concurrently through the same one copper wire pair.
- ISDN provides high data rate because of digital scheme which is 56kbps.
- ISDN network lines are able to switch manifold devices on the single line such as faxes, computers, cash registers credit cards readers, and many other devices. These all devices can work together and directly be connected to a single line.
- ISDN takes only 2 seconds to launch a connection while other modems take 30 to 60 second for establishment.

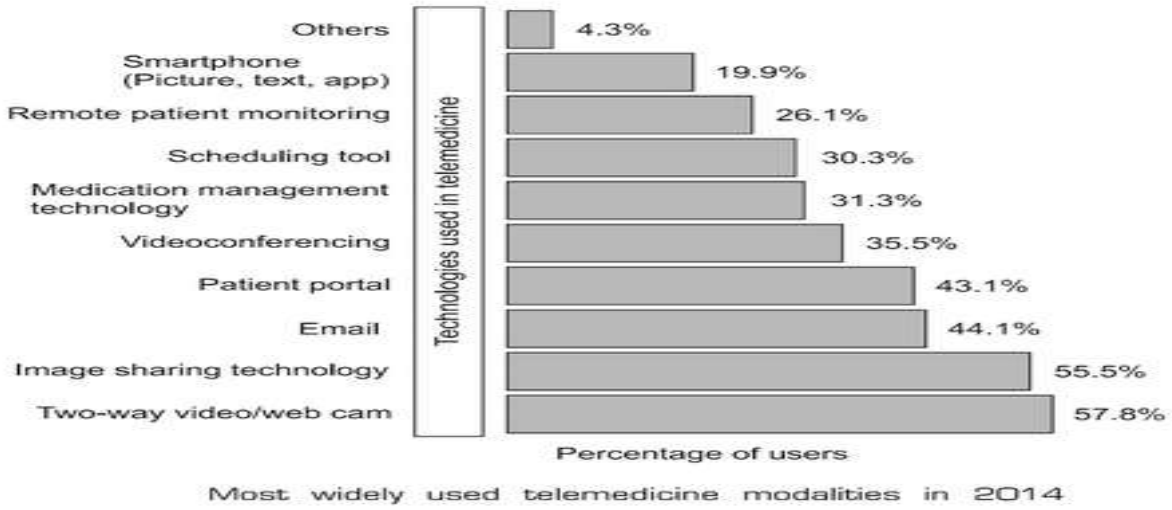
Disadvantages of ISDN

The disadvantage of ISDN is that it requires specialized digital services and is **costlier.**

However, the advent of ISDN has brought great advancement in communications. Multiple transmissions with greater speed are being achieved with higher levels of accuracy.

INTERNET IN TELEMEDICINE

- Internet can be **used for telemedicine** purpose to
  - ✓ Establish **connectivity through ordinary personal computer** and mobile phones
  - ✓ **Exchange electronic mail** between **patients, attending doctors and specialists**
  - ✓ Post information for the benefit of other to access and update it frequently
  - ✓ Access and transfer multimedia information which includes sound, data , images and video
- Examples of internet usage with reference to telemedicine are
  1. Remote diagnosis and consulting
  2. Patient care and support
  3. Medical information access
  4. Emergency/epidemic (a widespread occurrence of an infectious disease in a community at a particular time) support
  5. Teleworking opportunities for the disabled
  6. Preventative care information and guidance
  7. Continuing medical education and training
- Internet is useful for situations where a clinician may require access to data from a patient's home or from the clinic during off office time before giving some clinical advice(a radiologist may like to view an x-ray image before advising on a fracture seen by a junior doctor in the emergency department)
- Internet provides greater facility **to transfer medical image files with the development of compression techniques**.
- **High quality videoconferencing and audio technology** tools proves highly beneficial for remote consultation and diagnosis over internet.
- **Emergency response during natural disasters/epidemics** can be done by Internet.
- Three common communication technologies widely used in telemedicine through internet are **two-way video, image sharing technology and email**



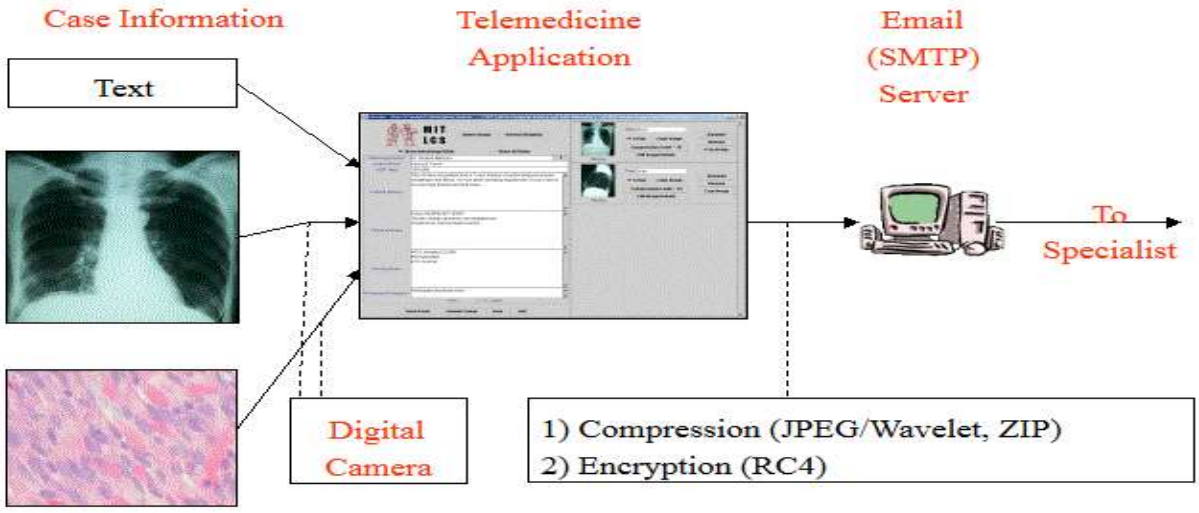
Most widely used telemedicine modalities in 2014

- E-mail (a service to communicate through a network).

- Cost effective teleconsultation
- Current email-application for telemedicine include
  1. Communication between physicians aiming at
     - ✓ Performing diagnosis on a set of patient information(telediagnosis)
     - ✓ Prescribing therapy
     - ✓ Exchanging generic medical information
  2. Communication between physician and patient aiming at
     - ✓ Giving to the patient test results and interpretations
     - ✓ Obtaining from the patient anagraphic (meaning scrambled) data
     - ✓ Instructing the patient about medications
     - ✓ Giving pre - and post- operative instruction
  3. Communication among medical professionals and medically related equipment providers
     - ✓ This application has its own medico legal and ethical issues
- Any form of communication must aware of patient's privacy(e.g., a physician discuss any case, they should use privacy-enhance mail or should not reveal patient's name)

TeleMedMail Software

- simple way for **physicians and healthcare** workers to send medical images over the Internet to specialists
- Developed in **java 1.2** and allows **text entry, image processing, image and data compression and data encryption.**
- Can **run on Linux, also runs in windows**. Facilitate **store and forward**
- developed independently by physicians in South Africa, Ghana, USA, Britain, Norway
- Currently under evaluation in South Africa and Peru, Brazil as well as the US.
- it requires 4 pieces of software in addition to the camera's own system. 1) a photo-editing program such as Photoshop, Paint shop etc., 2) an HTML editor to organize the case and images, 3) a Zip utility such as WinZip archive of all the files, and 4) an email program.



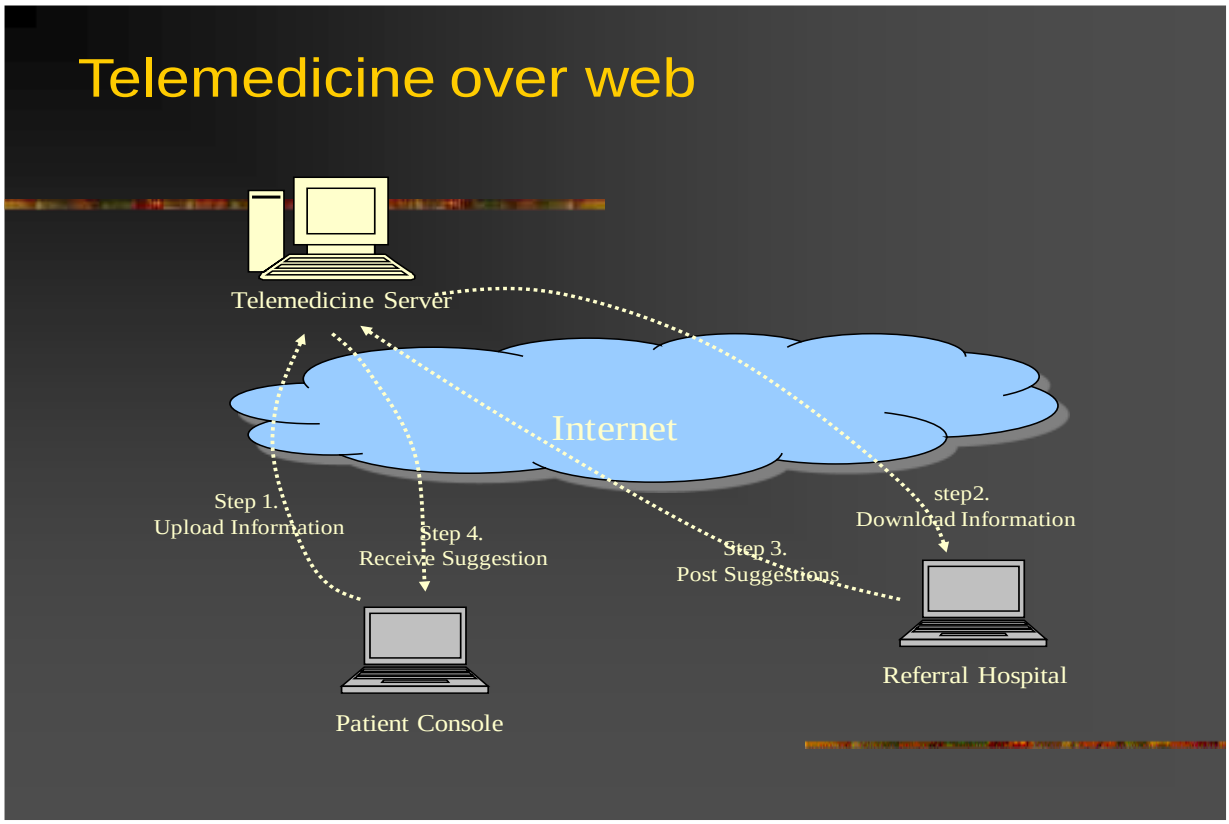
e-mail based telemedicine system

- ✓ When the case is sent, this software generates a **HTML page containing the textual description of the case and thumb nail sized views of the clinical images**
- ✓ This file is compressed, encrypted (RC4=>**Rivest's cipher, Ron's code**)and sent to specialist.
- ✓ RC4 is the world's most widely used stream cipher.
- ✓ At the receiving end, the specialist unzips and views the file.

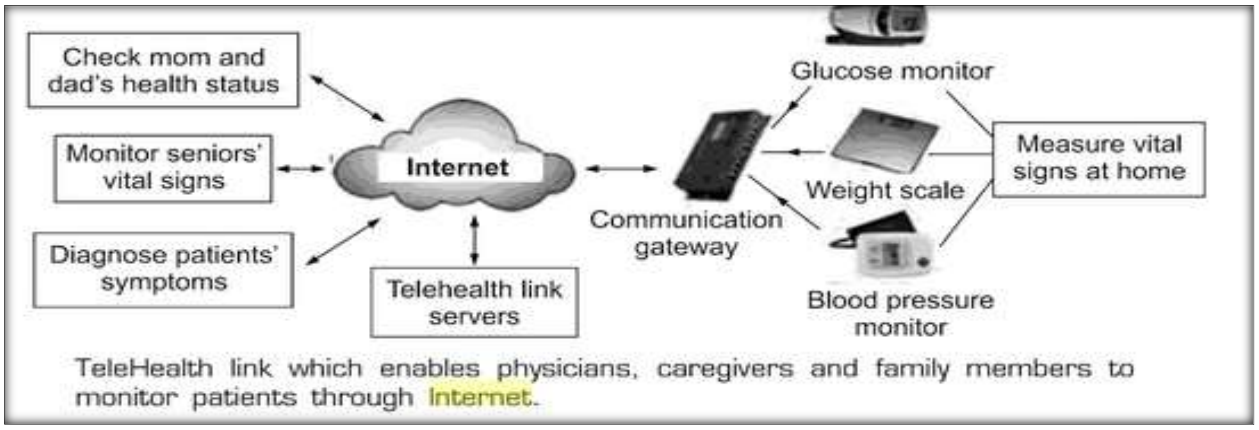
- Constraints using email
  i. Inappropriate in emergencies
  ii. is vulnerable to hacking
  iii. Confidentiality is another risk(e.g., in doctors office=> a nurse can be asked to read email and record. Care must be taken while discussing psychiatric, HIV status, abortion decisions etc.,)
  iv. Raise questions on privacy , authenticity of information

iPath(Internet Pathology Suite)

- ✓ A **point-to point telepathology system, allows realtime telemicroscopy across firewalls**
- ✓ Developed at the University of Basel, in 2001
- ✓ Open-source, internet based platform for telemedicine
- ✓ Permits **online presentation and discussions of cases within registered user groups**
- ✓ After four years, the telepathology network has over 700 active users
- ✓ 6,300 cases with a total of about 39,000 images have been diagnosed
- ✓ started as a small project for hospitals in Switzerland has become a global network.



Pictorial representation of Internet contribution in TeleMedicine



WWW applications in Telemedicine

- Information published on WWW can reach a wide number of readers=> powerful communication medium to provide appropriate information: physicians, patients, providers etc
  a. Multimedia for undergraduate and postgraduate education
  b. Multimedia for continuing education through
     - ✓ Networked implementation of CME(Continuing medical education) credit materials
     - ✓ WWW access to medical database(for ease of use)

c. Interface for remote access to databases such as Medline, Genbank etc.

Internet problems

- **Amount and quality of information** available to patients on the internet
  - ✓ information is not **screened and delivered by professionals**
  - ✓ efforts at international level to **ensure authenticity of the quality of medical information**=> health information posted , must disclose authorship and credentials, dated , references , citation and sources for content.
- **Complexity** of some information , coupled with the broad range of reading and interpretation capabilities among the diverse community.
- Some websites use personal data collected from consumers.
  - Several health-related websites , set up ethical guidelines to protect consumers and regulate online advertising, content, sponsorship and privacy issues
- **Unauthorized access, security of the information and quality of content on the web**

SNAPSHOT 1
An Overview of Broadband's Impacts on Telemedicine

Increases the Range of Telemedicine	*Facilitates In-Home Care*	*Decreases Costs*	*Enhances Care for Children, Seniors & People w/ Disabilities*
▪ Broadband-enabled telemedicine tools extend the range of healthcare to rural and unserved parts of the country. ▪ Telemedicine tools assist in leveling the playing field vis-à-vis quality of care across all demographics and geographies.	▪ The wide availability and increasing affordability of broadband enables the use of effective in-home diagnostic, monitoring, and treatment services. ▪ Seniors in particular will benefit from these tools by having the ability to receive more care at home.	▪ Broadband enhances the use of EHRs, which can lead to annual savings of $80 billion. ▪ Early disease detection via these tools can save billions of dollars. ▪ Telemedicine reduces costly medical errors and decreases unnecessary patient travel.	▪ Broadband-enabled telemedicine provides effective and affordable care to rural and low-income children. ▪ Tools and services have been crafted for use by senior citizens and people with disabilities, leading to vast savings.

AIR/WIRELESS TECHNOLOGIES

- Healthcare personnel require **realtime access** to accurate patient data, including clinical histories, treatments, medication, tests, laboratory results and insurance information=> solution is Air/Wireless technologies

- is a **new and evolving area** in telemedical , telecare , which enables delivery of healtcare and **exchange of medical information and knowledge <u>anywhere and anytime</u>**.
- Overcomes **geographical, temporal and organizational barriers** to provide remote diagnosis , monitoring and transfer of medical data and records.
- Advantages over wired technologies
    1. Ease of use
    2. reduce risk of infection
    3. reduce risk of failure
    4. reduced patient discomfort
    5. enhanced mobility
    6. low cost of care delivery

- **Application of wireless technologies** in telemedicine
    1. Monitoring for **critically ill patients** under observation in intensive care and recovery rooms
    2. Monitoring of **old people in old age homes** and assistance systems for chronically sick persons
    3. Sending **reminders to senior citizens** and patients undergoing treatment
    4. Monitoring **performance of implanted devices** and monitoring fitness data
    5. A wireless telemedicine system used in **disaster or mass-casualties** scenarios can support, control and monitor patients in large area by transmitting patients vital signs.

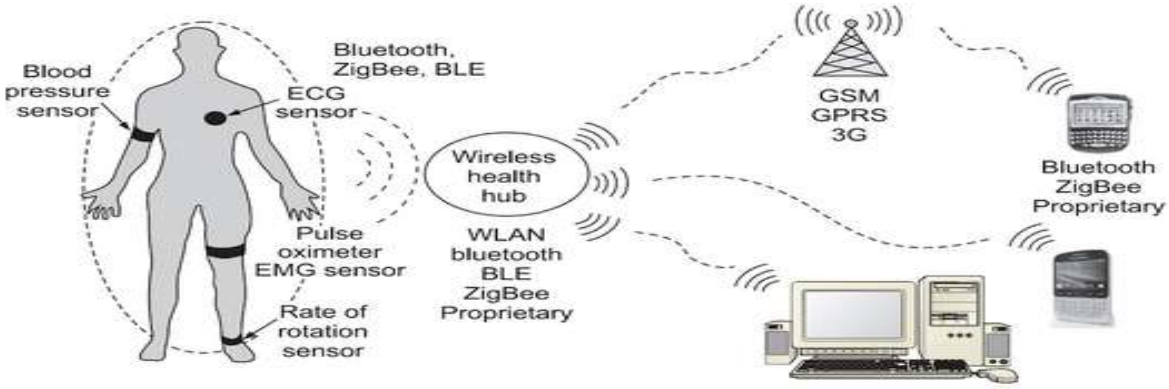
- **Wireless communication in hospital setups(**Wireless network)

    1. In older hospital buildings, it is not possible to install cabling for wired LAN
    2. the information about the moving patients , can be accessed by the staff on the move, resulting in great relief from mobility issues
    3. can be installed at places where the wires cannot reach=> offering flexibility in installations
    4. Allows to configure various topologies => providing scope for scalability
    5. Wireless LAN can be designed to work in independent network as well as already existing terrestrial LAN
- Long life miniature batteries and micro electronics
    - ✓ Availability of wide range of wearable devices
    - ✓ Data can be acquired and transmitted anywhere while the patient is on the move
- Standardization in the field of medical technology
    - ✓ Undertaken by IEEE
    - ✓ Already introduced several standard for wireless technologies
    - ✓ E.g., IEEE802.3 => Ethernet(wired), 802.11 => WLAN which is the base line of WI-FI standard, 802.15=>WPAN used in ZigBee
    - ✓

Types of Wireless technologies in telemedicine

- Pictorial representation of **different types of wireless technologies**

i. Wi-Fi – Wireless Local Area Network
ii. WiMAX – Worldwide Interoperability in Microwave Access
iii. Bluetooth
iv. Bluetooth Low energy
v. Zigbee
vi. ANT
vii. Ultra-Wide Band (UWB) Technology
viii. Wireless Networks



Different wireless technologies used for telemedicine.

- Wireless technologies are classified into two categories
  1. **line-of-sight**
     - Point-to-point microwave and broadband satellite technologies
  2. **Non-line-of-sight**
     - They do not require line-of-sight between the transmission hub and receiving equipment
     - Cellular technologies like Universal Mobile Telecommunication system(UMTS), Wi-Fi, WiMAX
- Healthcare providers use **ISM band frequency spectrum since it is license free**. The only requirement is **the product developed must satisfy the rules that govern this part of spectrum**
- New Standards such as ZigBee/IEEE 802.15.4,Bluetooth, BLE and ANT are used in Medical domain along with other proprietary technologies=> sub-1 GHz or 2.4 GHz
- **two popular technologies** that provides **wireless network** are
  - ✓ Bluetooth and WLAN
  - ✓ they have **different focus and areas of application**
  - ✓ Bluetooth **minimizes the requirement of cables** over a short-range
  - ✓ in telemedicine, it **eliminates the wires starting from the sensors** applied on the patient's body

1. Wi-Fi – Wireless Local Area Network (Trademarked term meaning IEEE 802.11x standard)

- Popular wireless networking technology=> wireless Fidelity is not the short name of Wi-Fi

- Uses radio waves to provide wireless high-speed internet and network connectivity.
- Allow data, voice as well as video applications.
- Work on the principle of Carrier Sense Multiple Access /Collision Avoidance (CSMA/CA)
- Coverage area 50-300 m
- WLAN utilize Radio Frequency technology for transmission and reception of data between computers
- provides mobility=>because wires are not needed
- WLAN 802.11a/b/g/n standards are used in present day wireless commercial products
- Wi-Fi uses **Star topology**
- Security Protocols developed by WLAN 802.11 standards are

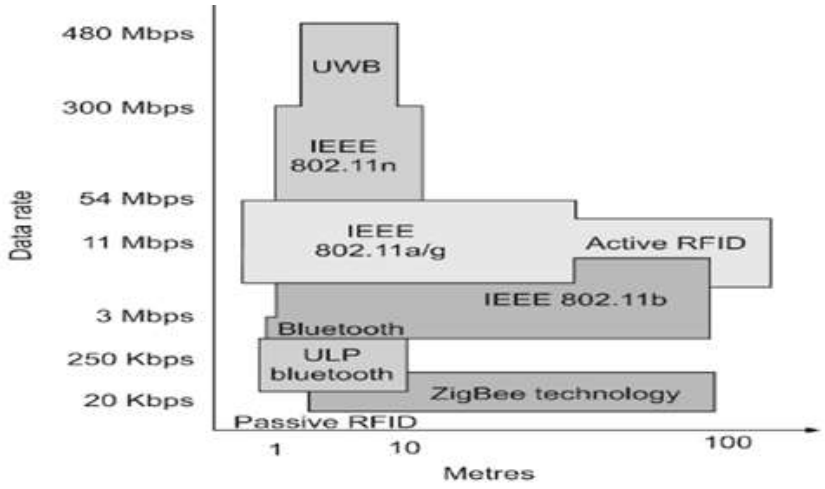
a. **Wired Equivalent Privacy (WEP)**
   - ✓ data transmitted over the LAN is protected by encrypting it.
   - ✓ In 2003 , announced by Wi-Fi Alliance that WEP had been superseded by Wi-Fi Protected Access(WPA)

b. **Wi-Fi Protected Access (WPA)** (Wi-Fi Protected Access (WPA) is a security standard to secure computers connected to a Wi-Fi network.,802.11i)
   - ✓ Provides improved data encryption based on temporal key integrity protocol.
   - ✓ addresses the weakness of WEP by including a per-packet mixing function, a message integrity check, an extended initialization vector, and a re-keying mechanism.
   - ✓ Also provides user authentication

Specifications	*Data rate (maximum)*
802.11	1 or 2 Mbps in the 2.4 GHz band
802.11a	54 Mbps in the 5 Ghz band
802.11b/High rate/Wi-Fi	11 Mbps (with a fall-back to 5.5, 2 and 1 Mbps) in the 2.4 GHz band
802.11g/Wi-Fi	54 Mbps in the 2.4 GHz band

IEEE 802.11 Wireless protocols and their associated data rates

- Various wireless standards for medical applications with their respective data rates, especially with reference to WLAN.



Potential wireless standards for medical applications. The graph shows the range vs data rates for various standards

- Technologies most relevant to telemedicine are
  a. **Wireless Body Area Network(WBAN):**A Wireless Body Area Network (**WBAN**) is a special purpose sensor network designed to operate autonomously to connect various medical sensors and appliances, located inside and outside of a human body)
  b. **Wireless Personal Area Network(WPAN)**:A WPAN (wireless personal area network) is a personal area network - a network for interconnecting devices centered around an individual person's workspace - in which the connections are wireless. Typically, a wireless personal area network uses some technology that permits communication within about 10 meters - in other words, a very short range. One such technology is Bluetooth, which was used as the basis for a new standard, IEEE 802.15.
- ✓ Data rate of these two technologies is around 1Mbps, but depending on protocol , power consumption and device class, data rate vary from a few Kbps to few Mbps

2. **WiMAX – Worldwide Interoperability in Microwave Access**

- a wireless broadband technology that delivers Wi-Fi type connectivity over a **much greater operating range , provides a point-to-multipoint .**
- Given by WiMAX Forum=> to promote **conformity and interoperability**.
- Description of WiMAX : A standards-based technology enabling the **delivery of last mile wireless broadband access as an alternative to cable and DSL(Digital Subscriber Line)**

- **Two types of WiMAX**

i) Line-of-Sight(LOS)
  - point to point connectivity
  - Do not permit a large consumer service coverage area

ii) Non-Line-of-Sight(NLOS)
  - point to multipoint
  - Provide large consumer service coverage area

- is a family of wireless communications standard **based on IEEE 802.16**

- Refers to providing **fixed, portable and mobile wireless** broadband connectivity without the need for direct LOS
- **Comparison of Wi-Fi and WiMAX**

Wi-Fi	*WiMAX*
Range: 300 m, covers a coffee shop, one floor of an office building, a home	Range: 9 km, covers a small city with one base station
Throughout: 11 Mbps	Throughout: 72 Mbps
Security: Limited	Security: Multilevel encryption
QoS: Limited	QoS: Dynamic bandwidth allocation, good for voice and video

Comparison of Wi-Fi and WiMAX

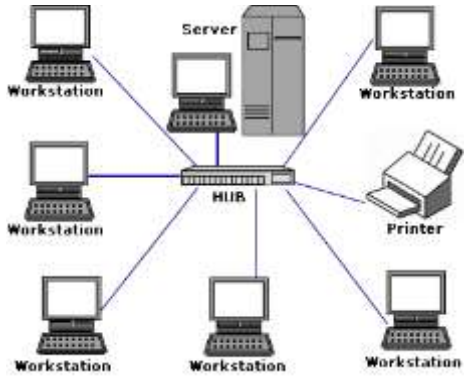
- **Challenges of wireless Technology in Telemedicine**
  - ✓ reliability
  - ✓ Low power requirement of wireless devices
  - ✓ Node Failure
  - ✓ Transmission delay
  - ✓ Different types of network communication infrastructure and data integrity
  - ✓ Need less consumption of energy as wireless devices mostly are wearable and battery operated.
  - ✓ Comfort level of patients when they use wireless operated gadgets => Devices must be unobtrusive (small and light weight)
- **5 primary parameters** that form the basic requirement of wireless based medical devices are
  1. Range: The distance over which the device, must operate.
  2. Data: The quantum of data that is required to be exchanged.
  3. Speed: Throughput required to meet clinical requirements.
  4. Frequency: How often the data needs to be transferred.
  5. Power: Whether the device is battery or mains operated.

COMMUNICATION INFRASTRUCTURE FOR TELEMEDICINE – LAN AND WAN TECHNOLOGY.

LAN - (Local Area Network)

- A LAN provides networking capability to a group of computers which are located in close to each other such as in an office building or a hospital, a campus or a home.
- A LAN is often connected to other LAN, and to the Internet or other WAN.
- LAN connectivity enables high speed data exchange capability between two systems.
- This facilitates diagnostic data exchange between various telemedicine stations inside a medical facility.
- The diagnostic data comprising images and reports can be transferred from several different locations within a building or from any of the nearby buildings in the campus to a review station.

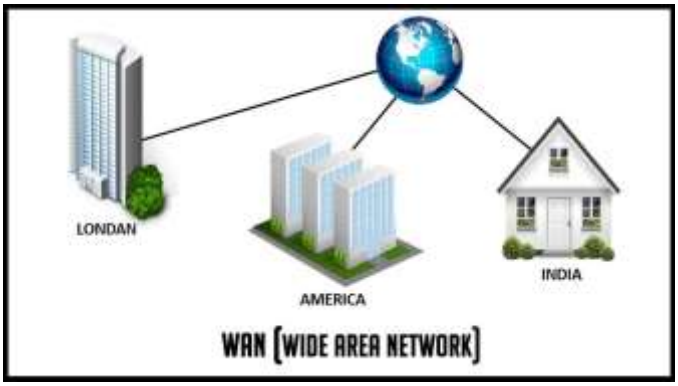
- Example: The transmission of a radiological image of an ICU admitted patient from the Radiology Department back to the ICU workstation for a quick review and action by the attending doctor.



Advantages of LAN	***Disadvantages of LAN***
• Resource Sharing • Software Applications Sharing • Easy and Cheap Communication • Centralized Data. • Data Security • Internet Sharing	• High Setup Cost • Privacy Violations • Data Security Threat • LAN Maintenance Job • Covers Limited Area

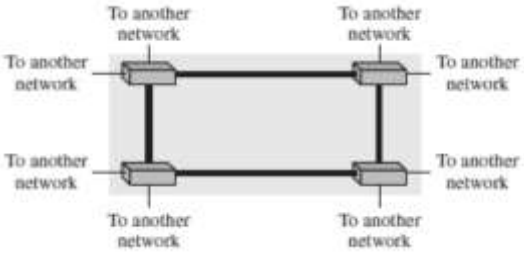
WAN –(Wide Area Network)

- WAN interconnects computers over large distance, which may be over tens to hundreds of miles apart.
- Usually, the system provides for multiple LAN or LAN-to-WAN interconnections that are geographically spread out.
- WAN can be visualised as a network consisting of many LAN's interconnected to create a "super" network.



- Example: Physician from a rural primary healthcare centre sends images of a patient to a radiologist or specialist in a distant location for consultation.
- WAN is operated by the telecommunication service provider.

Point-to-point WAN **Switched WAN**



Advantages of Wide Area Network:	**Disadvantages of Wide Area Network**:
○ Large Geographical area ○ Centralized data ○ Exchange messages ○ Sharing of software and resources ○ High bandwidth	○ Security issue ○ Needs Firewall & antivirus software ○ High Setup cost ○ Troubleshooting problems

SATELLITE COMMUNICATION

- One of the biggest healthcare issues of many countries today is that the poor level of medical services in rural and remote regions. Rural areas generally have worse medical services compared to urban areas and large cities.

- Satellite technology has been widely used for implementing telemedicine in remote and isolated areas to provide high bandwidth connection in the shortest possible time.

- **A satellite is an object that moves around another object.**

- It is used in military units or ships in the seas or oceans.

Functioning of Satellite:

- It functions as a repeater when it is used in a communication network.
- The signal is transmitted up to the satellite from the earth on a particulat frequency.**(uplink)**
- The signal is received by the satellite and retransmitterd back to the earth which is then received at the destination, the earth station**.(downlink).**

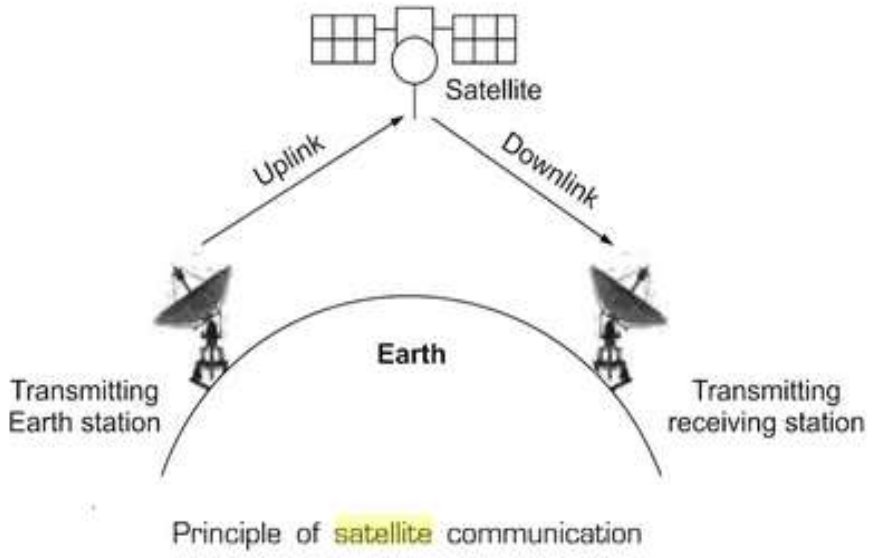


Fig: Principle of satellite communication

Types of Satellites

- Communications Satellite
- Remote Sensing Satellite
- Navigation Satellite
- Geocentric Orbit type staellies – **LEO**(Low Earth Orbit), **MEO**(Medium Earth Orbit), **HEO** (Highly elliptical orbit), **GEO** (Geo-stationary earth orbit)
- Global Positioning System (GPS)
- Drone Satellite
- Ground Satellite
- Polar Satellite
- Nano Satellites, CubeSats and SmallSats

VSAT – (Very Small Aperture Terminal)

- The easiest way to provide a satellite link for a telemedicine network is by using a VSAT.
- VSAT refers to a small fixed earth station.
- It supports any communication requirement relating to telemedicine such as voice, data or videoconferencing.
- The concept of telemedicine implemented by ISRO is shown below.

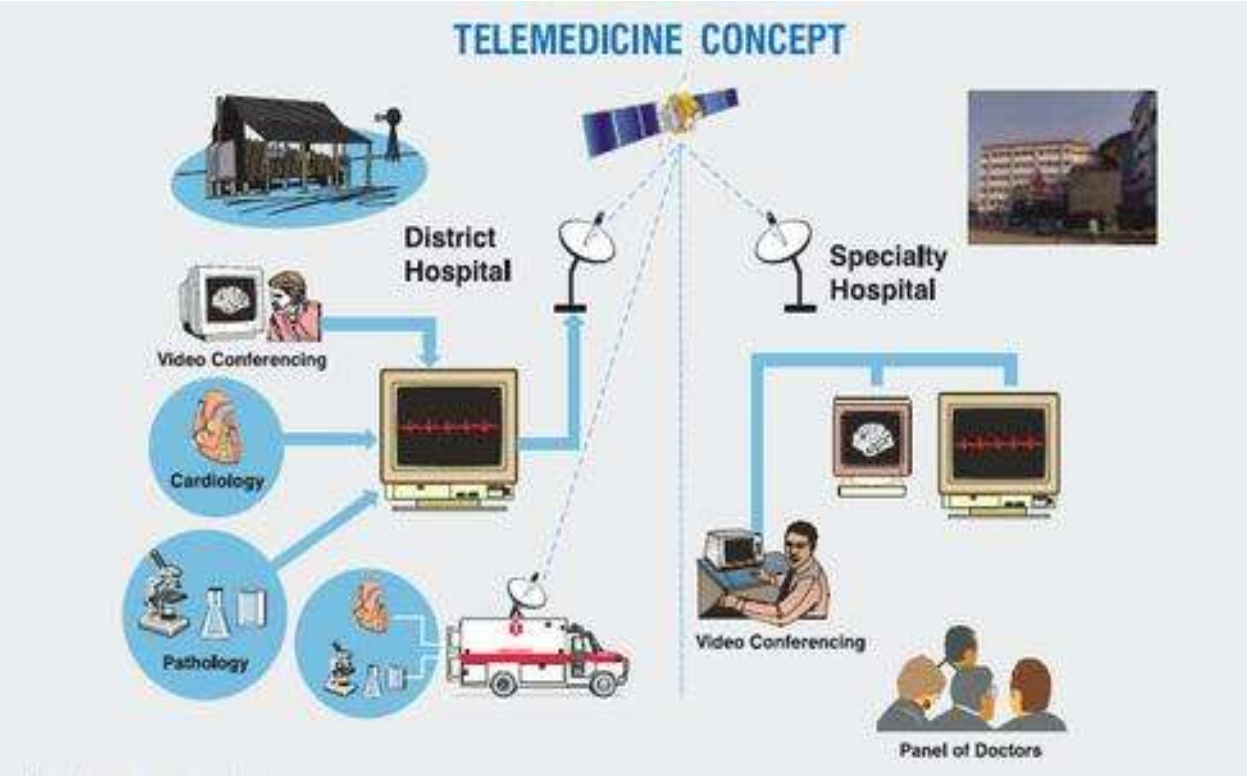


Fig: concept of satellite based telemedicine system used by ISRO

Operation of VSAT

It comprises the following steps:

1. Data from the computer / telephone is sent to the VSAT antenna from where it is beamed to the satellite.
2. The satellite then beams it to the receiving VSAT antenna and then received by the computer / telephone.

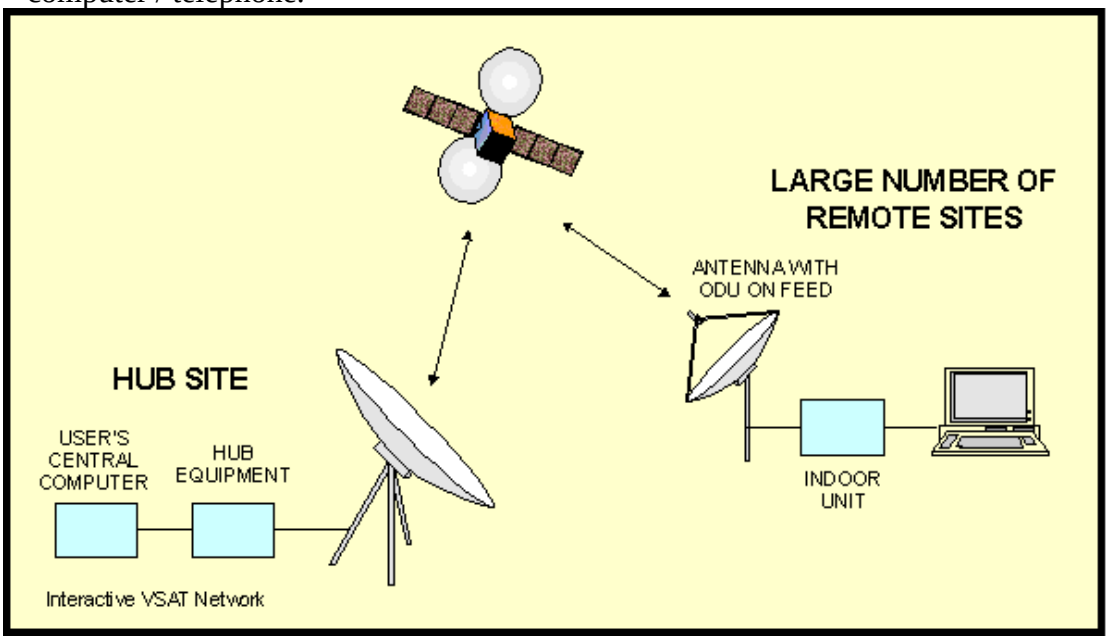


Fig: Principle of VSAT communication system

Modules of VSAT

1. Outdoor unit
2. Indoor unit

Outdoor unit:

- Consists of Antenna and Radio Frequency Transceiver(RFT)
- Antenna **size is 1.8-3.8m** in diameter=>size of the antenna describes the ability of the antenna to amplify the signal strength.
- Main components of antenna are **Reflector, feed horn and a mount**.
  - ✓ Feed horn is mounted on the antenna frame at its focal point by support arms
  - ✓ the Block Up converter (BUC) which is used for transmission, and consists of a local oscillator and a power amplifier
  - ✓ the Low Noise Block Down converter (LNB) which is used for receiving signals.

Indoor unit:

- Brain of VSAT
- The IDU is a **single box satellite Internet modem** which is connected to the user's equipment. (Computers, LAN's, routers, telephone instruments, TV's etc.)
- acts as an **interface between the VSAT and the user's equipment**
- Comprises of a set of modulators where carrier signals are superimposed from user traffic signal . The modulated signal is sent to RFT =>up-converted, amplified and transmitted.
- Demodulators separates user traffic signal from carrier signal

Advantages of Satellite

- Wide band capability
- Wide area coverage readily possible
- Distance-insensitive costs
- Counter inflationary cost history
- All user have same access possibilities
- Point to point, point to multipoint (broadcast) and multipoint to point (data collection) are all possible
- Inherently suited for mobile application.
- Compatible with all new technologies
- Service directly to the users premises

Disadvantage of Satellite

- **Design, development, investment and insurance of satellite requires higher cost.**
- **To reach the satellite from Earth, time can vary between 270 milliseconds and return again to 320 milliseconds. This propagation delay can cause an echo over telephone connections**
- **Satellites are not easy to repair and maintain.**
- **Some circumstances like weather or sunspots affect the satellite's signal and can cause interference and make proper operation of the satellite very difficult.**
- **It requires to be monitored and controlled on regular periods so that it remains in the orbit, once it has been launched.**

MOBILE COMMUNICATION

Introduction

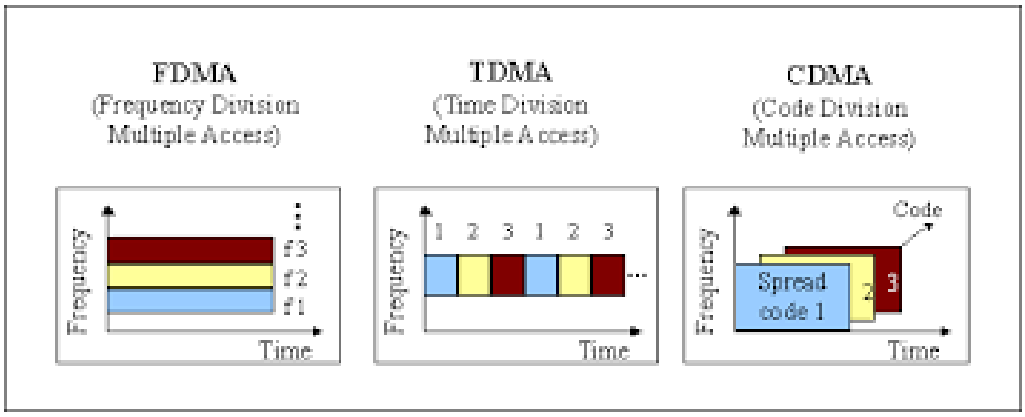
Mobile Communication is the use of technology that allows us to communicate with others in different locations **without the use of any physical connection** (wires or cables). Mobile communication makes our life easier, and it saves time and effort.

A mobile phone (also called **mobile cellular network, cell phone or hand phone**) is an example of mobile communication (**wireless communication**). It is an electric device used for **full duplex** two way radio telecommunication over a cellular network of base stations known as cell site.

A cellular system divides any given area into **cells** where a mobile unit in each cell communicates with a base station. The main aim in the cellular system design is to be able to **increase the capacity of the channel**, i.e., to handle as many calls as possible.

Different ways to allow access to the channel

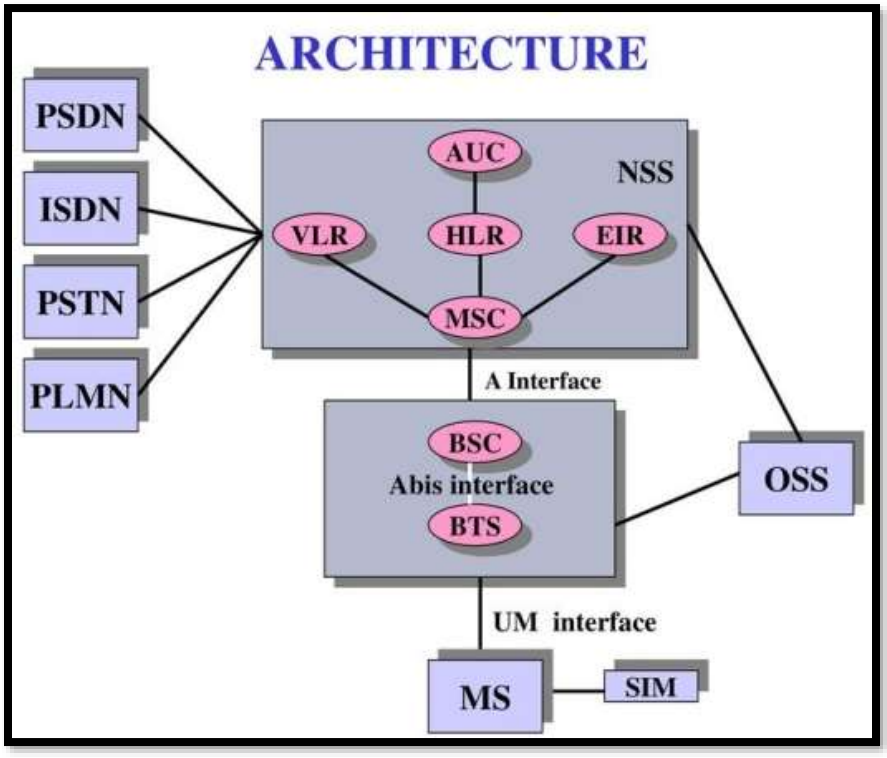
- Frequency division multiple-access (FDMA)
- Time division multiple-access (TDMA)
- Code division multiple-access (CDMA)
- Space division multiple access (SDMA)



GSM NETWORK ARCHITECTURE

The GSM network architecture is grouped into four main areas:

- **Network and Switching Subsystem (NSS)**
- **Base-Station Subsystem (BSS)**
- **Mobile station (MS)**
- **Operation and Support Subsystem (OSS)**



Simplified GSM Network Architecture Diagram

Network Switching Subsystem (NSS)

NSS provide the main control and interfacing for the whole mobile network. The major elements within the core network include:

- ***Mobile Services Switching Centre (MSC):*** The MSC acts like a **switching node** within a PSTN or ISDN, and provides additional functionality to enable the requirements of a mobile user to be supported. These include **registration, authentication, call location, inter-MSC handovers and call routing** to a mobile subscriber.

- ***Home Location Register (HLR):*** This **database** contains all the administrative information about each subscriber along with their last known location. In this way, the GSM network is able to route calls to the relevant base station for the MS. When a user switches on their phone, the phone registers with the network and from this it is possible to determine which BTS it communicates with so that incoming calls can be routed appropriately. Even when the phone is not active (but switched on) it re-registers periodically to ensure that the network (HLR) is aware of its latest position. There is one HLR per network, although it may be distributed across various sub-centres to for operational reasons.

- ***Visitor Location Register (VLR):*** This contains selected information from the HLR that enables the selected services for the individual subscriber to be provided. The VLR can be implemented as a separate entity, but it is commonly realised as an integral part of the MSC, rather than a separate entity. In this way access is made faster and more convenient.

- ***Equipment Identity Register (EIR):*** The EIR is the entity that decides whether a given mobile equipment may be allowed onto the network. Each mobile equipment has a number known as the International Mobile Equipment Identity. This number, as mentioned above, is installed in the equipment and is checked by the network during registration. Dependent upon the information held in the EIR, the mobile may be allocated one of three states - allowed onto the network, barred access, or monitored in case its problems.
- ***Authentication Centre (AuC):*** The AuC is a protected database that contains the secret key also contained in the user's SIM card. It is used for authentication and for ciphering on the radio channel.

Base Station Subsystem (BSS)

The Base Station Subsystem (BSS) is fundamentally associated with communicating with the mobiles on the network.

It consists of two elements:

- ***Base Transceiver Station (BTS):*** The BTS used in a GSM network comprises the radio transmitter **receivers**, and their associated **antennas** that **transmit and receive** to directly communicate with the mobiles. The BTS is the defining element for each cell. The BTS communicates with the mobiles and the interface between the two is known as the **Um interface** with its associated protocols.

- ***Base Station Controller (BSC):*** It controls a group of BTSs, and is often co-located with one of the BTSs in its group. It manages the radio resources and controls items such as

handover within the group of BTSs, allocates channels and the like. It communicates with the BTSs over what is termed the **Abis interface**.

Mobile station(MS)

Mobile stations (MS), mobile equipment (ME) or cell or mobile phones are the section of a GSM cellular network that the **user sees and operates**.

The two main elements are the main **hardware and the SIM.**

The **hardware** itself contains the main elements of the mobile phone including the **display, case, battery, and the electronics** used to generate the signal, and process the data receiver and to be transmitted.

The mobile station, or ME also contains a number known as the **International Mobile Equipment Identity (IMEI)**. This is **installed in the phone at manufacture** and **"cannot" be changed**. It is accessed by the network during registration to check whether the equipment has been reported as stolen.

The **SIM or Subscriber Identity Module** contains the information that provides the **identity of the user to the network.** It contains variety of information including a number known as the International Mobile Subscriber Identity **(IMSI).** As this is included in the SIM, and it means that by moving the SIM card from one mobile to another, the user could easily change mobiles.

Operation and Support Subsystem (OSS)

The OSS is connected to components of the NSS and the BSC. It is used to control and monitor the overall GSM network and it is also used to control the traffic load of the BSS. It must be noted that as the number of BS increases with the scaling of the subscriber population some of the maintenance tasks are transferred to the BTS, allowing savings in the cost of ownership of the system.

GSM Technology for transmission of ECG signal

- Device contains a **signal acquisition module**, a **digital part having a microcontroller and a GSM communication module.**
- It has a hardware and software part
- The hardware has both analog and digital part
- The ECG signal is first given to an instrumentation amplifier and analog filters which remove the unwanted signals
- The output signal of the analog module is given to the digital module, where analog to digital conversion take place.
- The other modules in the digital part are microcontroller, EEPROM for storing samples of the digitized ECG, RS232 interface for communication with PC, a graphic display for displaying signal and heart rate.
- RS232 is also used for GSM communication

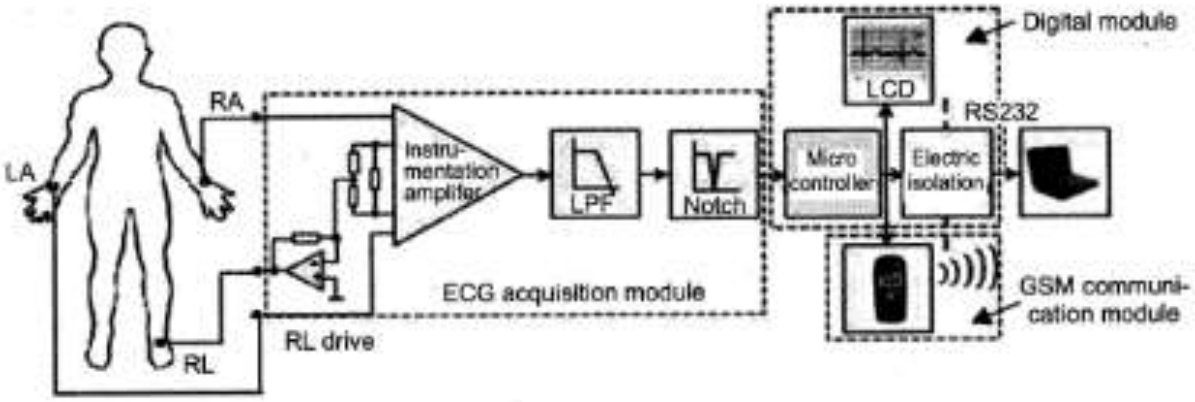


Figure 7.15 Block diagram of the telemedicine system based on GSM communication technology (adapted from Mimouni, et al., 2012).

- **Configuration of telemedicine system for Cardiac application based on 3G wireless Network**

- Consist of **real-time acquisition of Cardiac data with an ECG machine**, **3G mobile phone acting as personal server and medical server** that has access to the internet
- **ECG signal picked up by the electrodes is transmitted via ZigBee/Bluetooth** to the mobile phone which subsequently **transmits it to the base station or internet to the care provider or automatic monitoring and recording system**
- Has **automatic dispatching and acknowledging messaging service**.
- The server sends the message to the mobile phone indicating successful receipt of the packet or it can ask for resubmission if necessary
- It is observed that the **quality of the received signal co-related well with the original transmitted signal.**

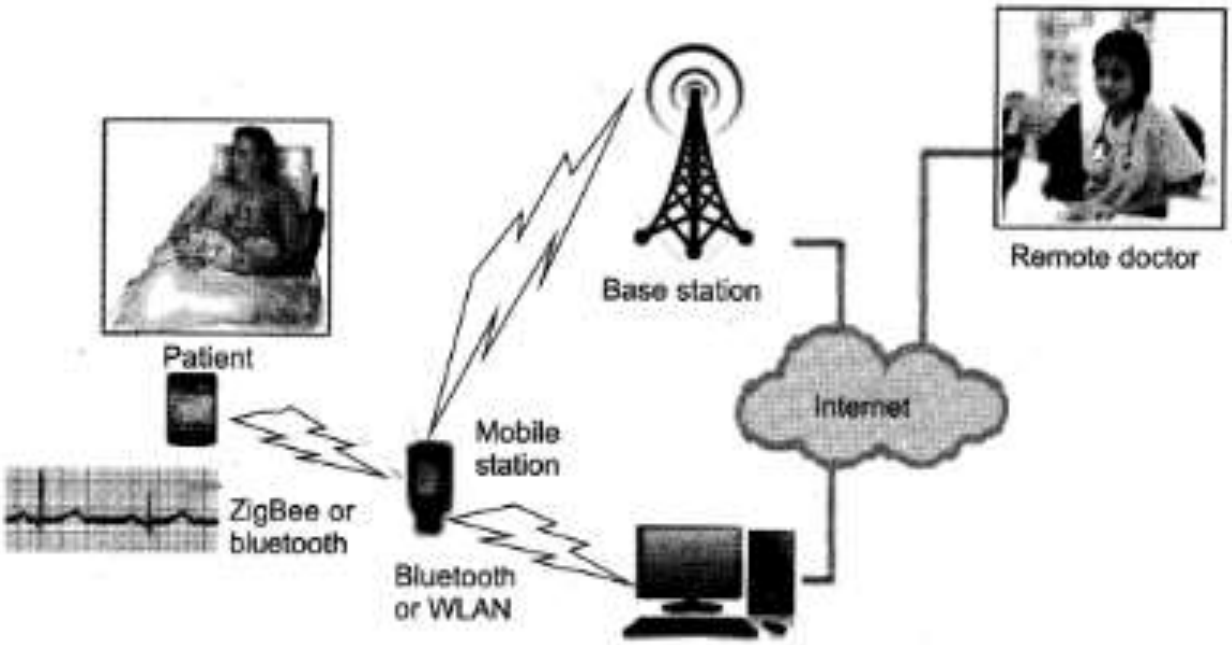


Figure 7.16 Configuration of telemedicine system for cardiac applications based on 3G wireless network.