Instrumentation II (III/I)

Course Code: (EX - 602)
(Module#5)

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Chapter#5

Data Acquisition and Transmission

✓ Class Outline

1. Introduction
2. Transmission Media
3. Data Acquisition System

Introduction

Analog Transmission

- content is not concern rather shape of the signal which is information (information is modulated).
- Amplifiers can be used which might amplify noise too.
- Attenuation over distance causes difficulty to recover.

Digital Transmission

- concern with content rather than shape of the signal.
- repeaters can be used to add power for long distance transmission.
- repeaters extract and re-transmit bit pattern over the distance.
- noise has minimal effect as error can be removed at intermediate repeaters.

Introduction

Advantages of digital Transmission over Analog

- increased immunity to noise
- flexible operation.
- low cost of LSI/VLSI technologies
- common data format for all types of signal
- security and privacy is high.

Disadvantages of digital Transmission over Analog

- complex circuitry
- High bandwidth requirements.

Introduction

Analog Communication System

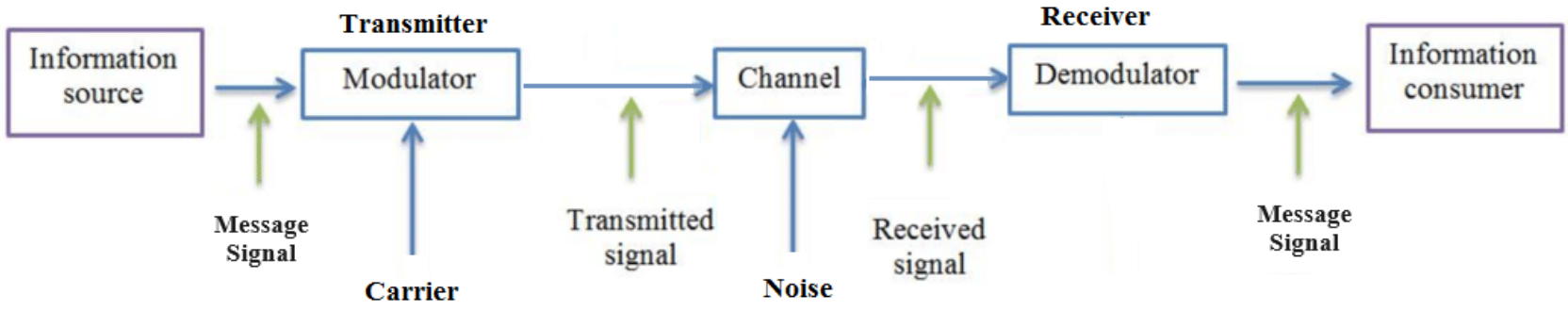
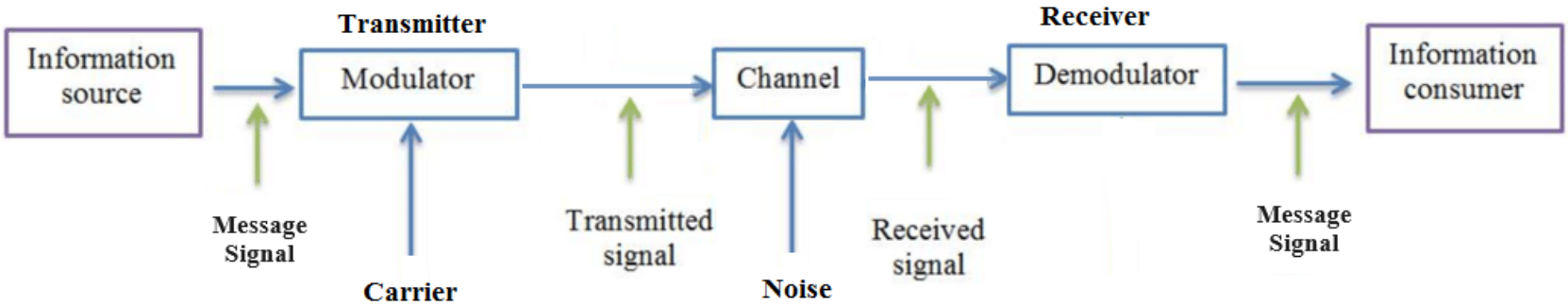


Fig. 1 Analog Communication System

- message signal is analog, signals are from analog sources such as speech(microphone), video shooting.
- generally, analog signals are time continuous that means it has been defined for all time instance.
- message signal is modulated with some carrier frequency by modulator at transmitting end.

Introduction

Analog Communication System...



Analog Communication System

- message (from channel) is demodulated at demodulator at receiver and forwarded to receiving destination.
- modulation is the process to make the signal suitable to transmit through the given channel.

Introduction

Digital Communication System

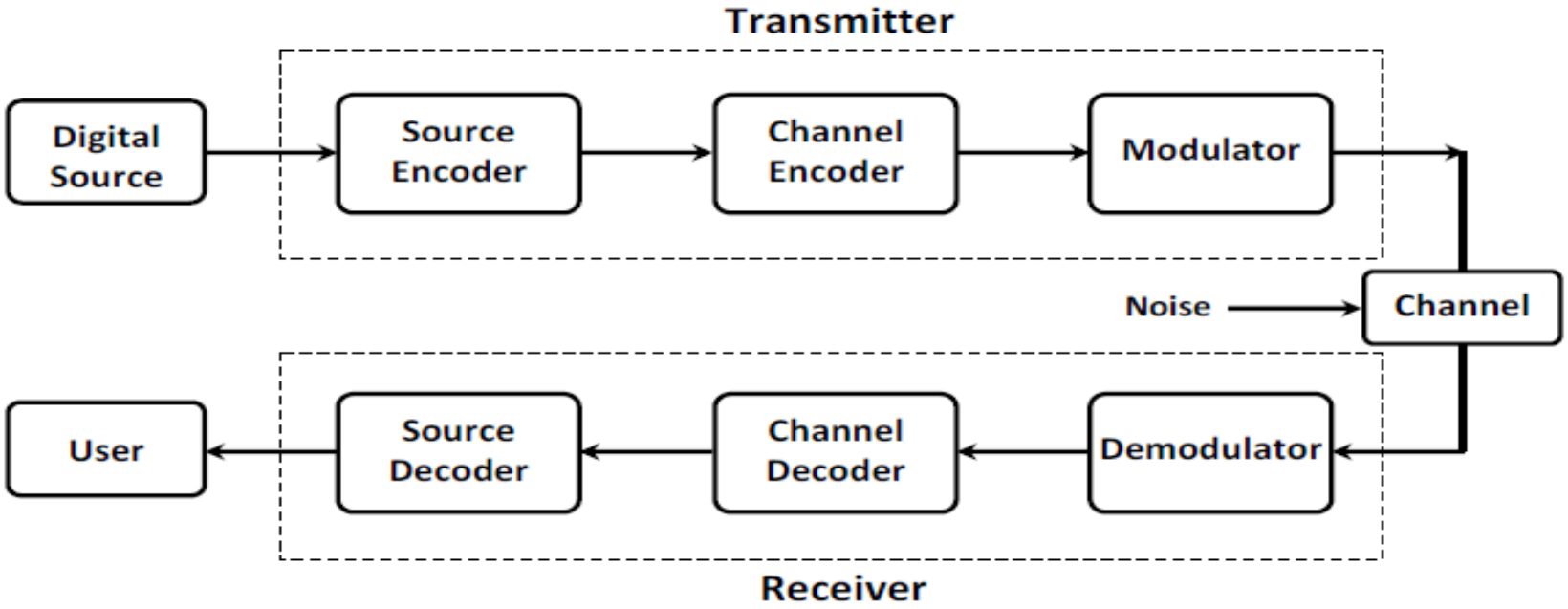


Fig. 2 Digital Communication System

- digital/discrete source signals are equivalently represented in binary pattern in source encoder.
- efficient source encoder completely removes the redundant bit at encoded signal.

Introduction

Digital Communication System...

- channel encoder adds some redundant bit to binary information – redundant bit helps the receiver to detect (correct) the error at channel decoder.
- modulator modulates the binary signal to make the signal suitable for transmission (Binary frequency shift keying, Binary phase shift keying, Binary amplitude shift keying).
- digital signals are mapped to signal waves.
- channels are physical medium to transfer signal to the receiver.

Introduction

Digital Communication System...

- Generally, noise due to transmitting devices is neglected while channel noise are considered.
- demodulator recovers back the digital or binary signal from the waveform.
- channel decoder removes the redundant bit added by channel decoder making source information bit error free.
- source decoder recovers back original discrete/digital signal from binary signal, and signal is forwarded to destination.

Transmission Media

- Guided media – wire
  - ✍ cable, fibre, twisted pair cable
- Unguided media – wireless
  - ✍ radio wave, micro-wave, bluetooth
- transmission media is important for guided transmission while bandwidth of antenna is important for unguided transmission.

Design Factors:

- bandwidth - higher the bandwidth equivalents to higher data rate; correspondingly, higher cost
- error models are major concern for error free transmission and minimal attenuation.
- interference is another factors to be considered at wireless transmission.

Fiber Optics

- is cylindrical guided line.
- it consists three major parts or layers: core, cladding, and jackets (sheath).
- it is dielectric (non-conductor of electron) waveguide made of glass or plastic.

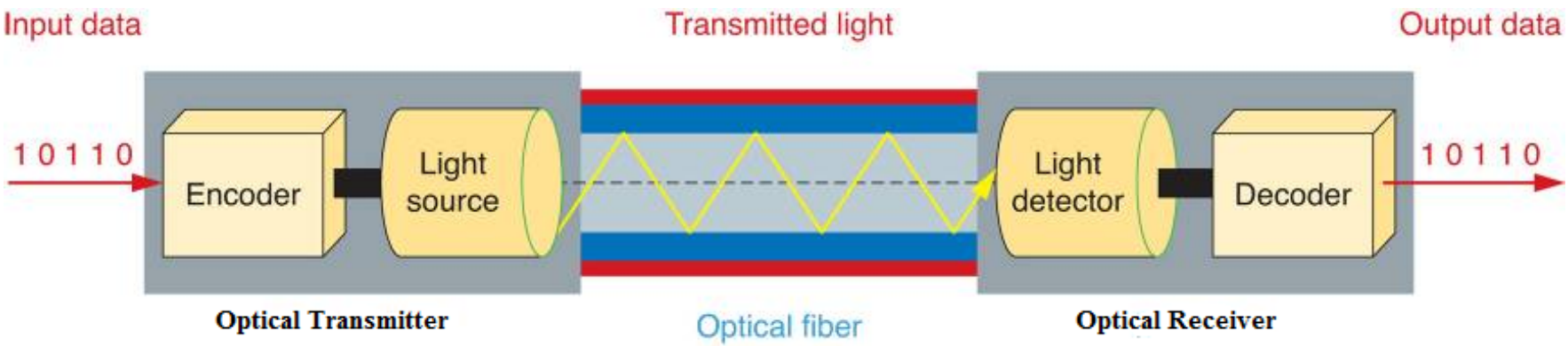


Fig. 3 Optical transmission

Fiber Optics...

- it uses the characteristics of light ray transmission – total internal reflection ($n_1 > n_2$).
- signal through fiber optics is free of channel tapper because of jacket and transmission direction.

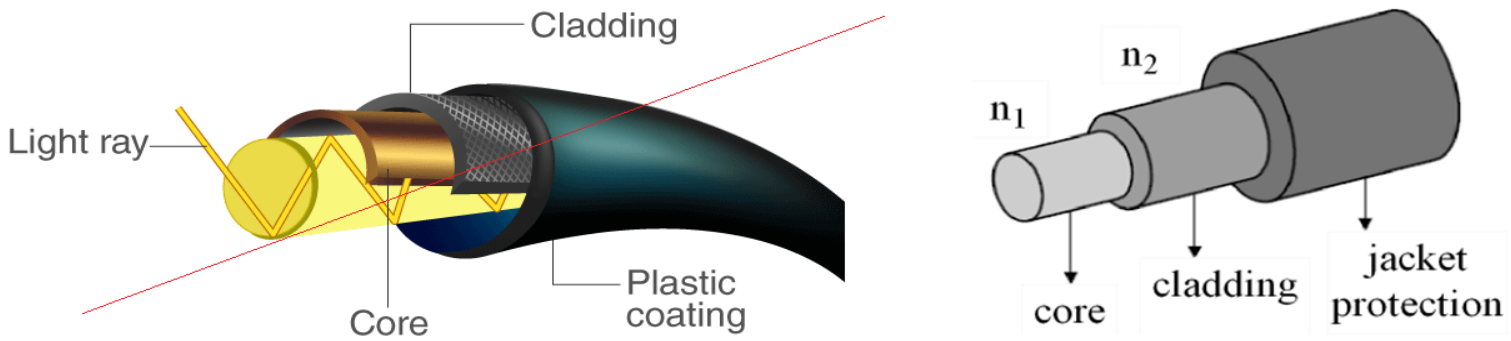


Fig. 4 Fiber Optics

Fiber Optics...

- Depending up on number of information carrying signals through core, optical fiber can be categorized in two mode:

  $\Rightarrow$ single mode fibers and multi-mode fibers.

Single mode Fibers

- single signal per fiber (cable TV, Telephone)
- small cores (9 micron in diameter)
- transmit infrared light emitted from laser.
- core diameter is in the order of light wavelength injected.
- it has high bandwidth, so high speed transmission.

Fiber Optics...

multi-mode Fibers

- many signals per fiber (in computer network)
- larger cores (62.5 microns in diameter)
- transmit infra-red light from LED
- they are not suitable for long distance due to larger dispersion and so higher attenuation.

- As shown in Fig.3, an optical communication, there is need of signal conversion – electrical to optical at transmitting end and optical to electrical signal at receiving end.
- optical transmitter converts electrical to optical signal while reverse process at optical receiver.

Fiber Optics...

- Depending up on the refractive index distribution, optical fibers can be grouped into step-index and graded-index fiber.

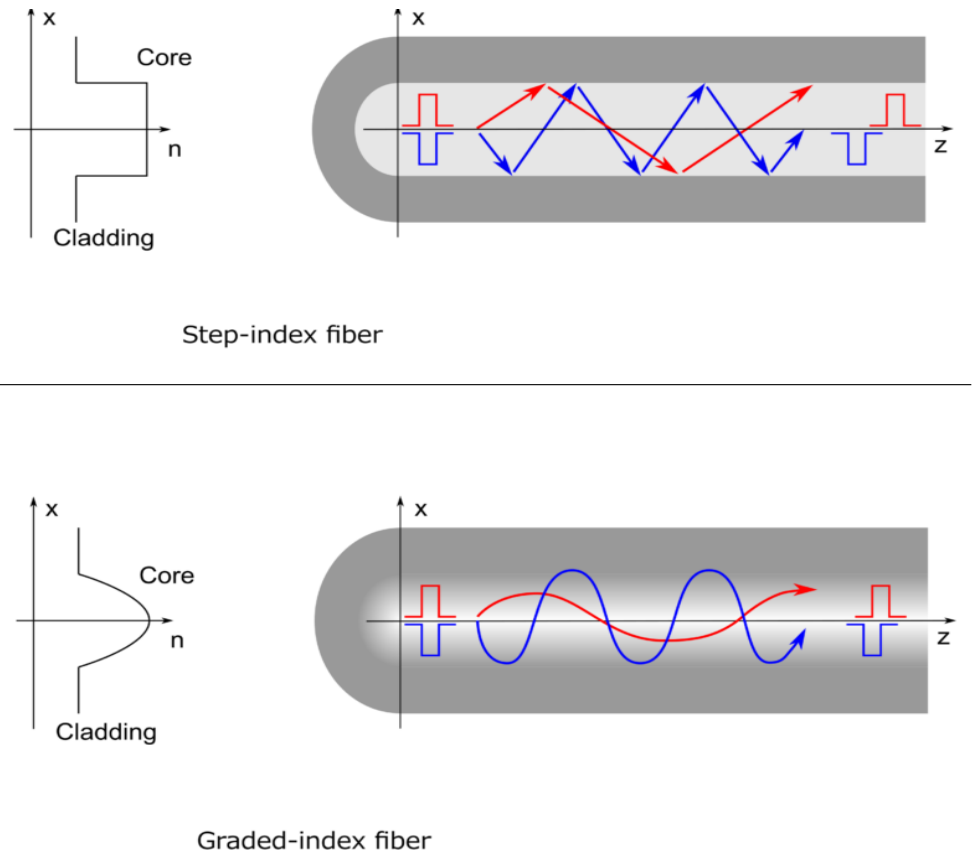


Fig. 5 ⓐ Step-Index and ⓑ Graded-Index Fiber Optics

Fiber Optics...

✍ Step-index optical fiber

- core and cladding has uniform refractive index say n_1 and n_2
- signal passes through core using total internal reflection at core-cladding boundary.

✍ Advantage

- cheaper and has large Numerical Aperture (NA) $\left(\text{NA} = \sqrt{n_1^2 - n_2^2}\right)$
- NA is the measure of ability to capture light.
- long life time.

✍ Disadvantage

- lower bandwidth, higher light dispersion and smearing of signal pulse.

Fiber Optics...

✍ Graded-index optical fiber

- core has not uniform distribution of refractive index equivalently number of layers within core.
- Refractive index gradually decreases while moving towards cladding interface.
- however, cladding has uniform refractive index.
- because of non-uniform distribution of refractive index in core, light propagate in the form of skew rays or helical rays.

✍ Advantage

- dispersion is low, higher bandwidth, easy to couple with optical source.

✍ Disadvantage

- expensive and very difficult to manufacture.

Fiber Optics...

✍ Advantage of Optical Fiber

- Thinner
- less expensive because it can be formed from sand.
- higher bandwidth and less probability of attenuation – low transmission loss.
- light weight
- immunity to interference.
- electrical isolation
- signal security.

✍ Disadvantage of Optical Fiber

- Requires skilled manpower for installation.
- difficult to repair and maintain.
- higher equipment and manufacturing cost.
- optical splicing is difficult (joining to optical cable is difficult)

Fiber Optics....

✍ Application of Fiber Optics

- in communication where higher bandwidth is needed.
- medical applications such as endoscopy.
- in military communication because of higher signal security.
- TV application which needs higher bandwidth.

Satellite Communication

- Use of satellite as repeater.
- it consists of ground station for transmission or receive, and satellite in space for receive and retransmit as repeater.
- it has number of transponders to listen different frequency spectrum and retransmit towards receiving station on the earth ground.(transpondor = receive, amplify and re-transmit)
- In frequency division, uplink and downlink has different frequency band which significantly avoids interference between uplink and downlink signals.

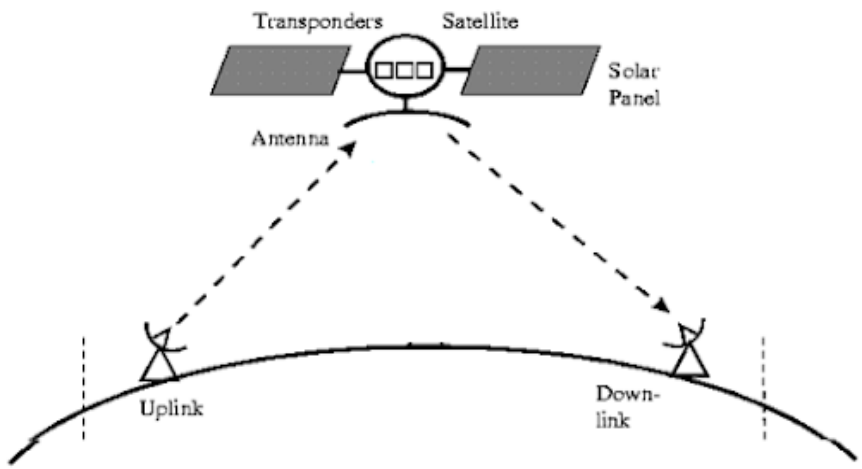


Fig. 6 Satellite Communication

Satellite Communication...

Major components in satellite communications

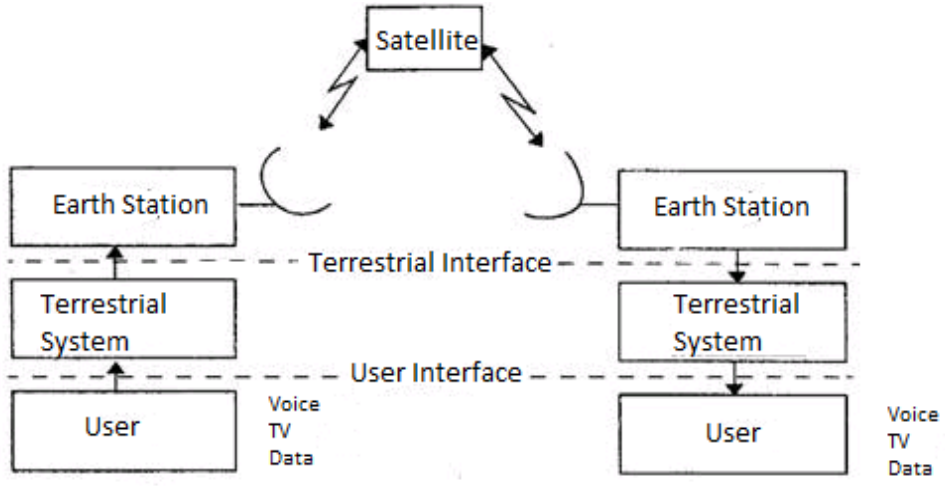


Fig. 7 Elements in Satellite Communication

① Space Segment

1. satellite
2. means for launching satellite
3. satellite control center for station keeping of the satellite.

② Ground Segment

1. Earth Station – transmitting and receiving equipment, antenna system.
2. terrestrial system
3. user terminal and interface networks.

Satellite Communication..

LEO, MEO, GEO Satellites

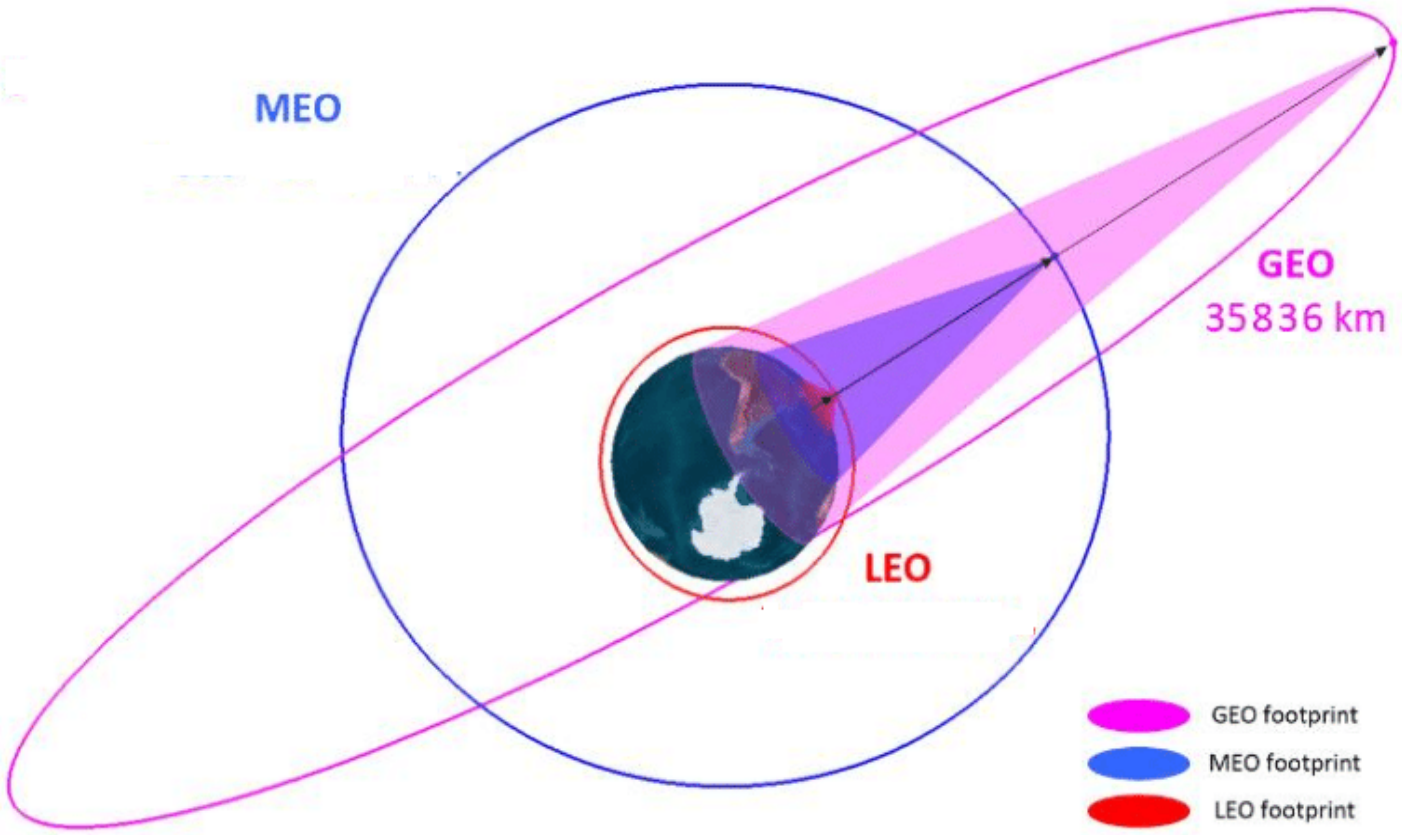


Fig. 8 Different Earth Orbit and its coverage

Satellite Communication...

✍ Low Earth Orbit (LEO)

- satellite are much closer to earth
- at distance of 500 to 1500 Km above the earth surface.
- only 15 to 20 minutes of exposure to certain earth station.
- larger number of other LEOs are necessary for complete communications

✍ Advantage

- better signal strength due to short distance – better point to point communication.
- small coverage area, so waste of bandwidth can be avoided.

✍ Disadvantage

- LEO network is needed for full operation – costly.
- higher effect of Doppler shift - (change in effective frequency for source has velocity comparable to signal) due to short distance.
- Atmospheric content can have effects on LEO satellite.

Satellite Communication...

✍ Medium Earth Orbit (MEO)

- at a hight of 8000 Km to 18000 Km from earth surface.
- MEO is visible usually 2 to 8 hours to a station in earth.
- has larger coverage than LEO.

✍ Advantage

- Fewer MEO satellite are enough to make complete network.

✍ Disadvantage

- Larger delay time and weaker signal strength compared to LEO satellite.

Satellite Communication...

✍ Geostationary Earth Orbit (GEO)

- satellite orbits at a hight of 35,836 Km above earth surface along the equator.
- GEO is relatively stationary for a portion in earth surface, so 24 hours of visibility.

✍ Advantage

- it has larger coverage almost one fourth of earth surface.
- 24 hours of exposure to particular earth station or surface.
- suitable for satellite broadcast.

✍ Disadvantage

- higher delay and weaker signal.
- centered above equator, so difficulty in polar region broadcasting.

Satellite Communication...

Service Types (Application Areas) of Satellite

Application areas of satellite link can be categorized with examples as follow:

✍ Fixed Service Satellite (FSS)

- Point to Point Communication.

✍ Broadcast Service Satellite (BSS)

- Satellite Television;
- also called Direct Broadcast Service (DBS)

✍ Mobile Service Satellite (MSS)

- satellite phones.

Satellite Communications...

Different kinds of satellite use different frequency bands:

Channel Naming	***Frequency Range***	***Application Areas***
① L-Band	1 – 2 GHz	MSS
② S-Band	2 – 4 GHz	MSS, NASA, Deep Space Research
③ C-Band	4 – 8 GHz	FSS
④ X-Band	8 – 12.5 GHz	FSS, BSS
⑤ Ku-Band	12.5 – 18 GHz	FSS, BSS
⑥ K-Band	18 – 26.5 GHz	FSS, BSS
⑦ Ka-Band	26.5 – 40 GHz	FSS

Satellite Communications...

Advantage of Satellite

- larger coverage area compared to terrestrial system.
- Frequency multiplexing or time multiplexing could increase the bandwidth capacity.
- transmission cost is not distance dependent.
- precised communication between satellites.
- higher bandwidth (available) can be used for satellite link.

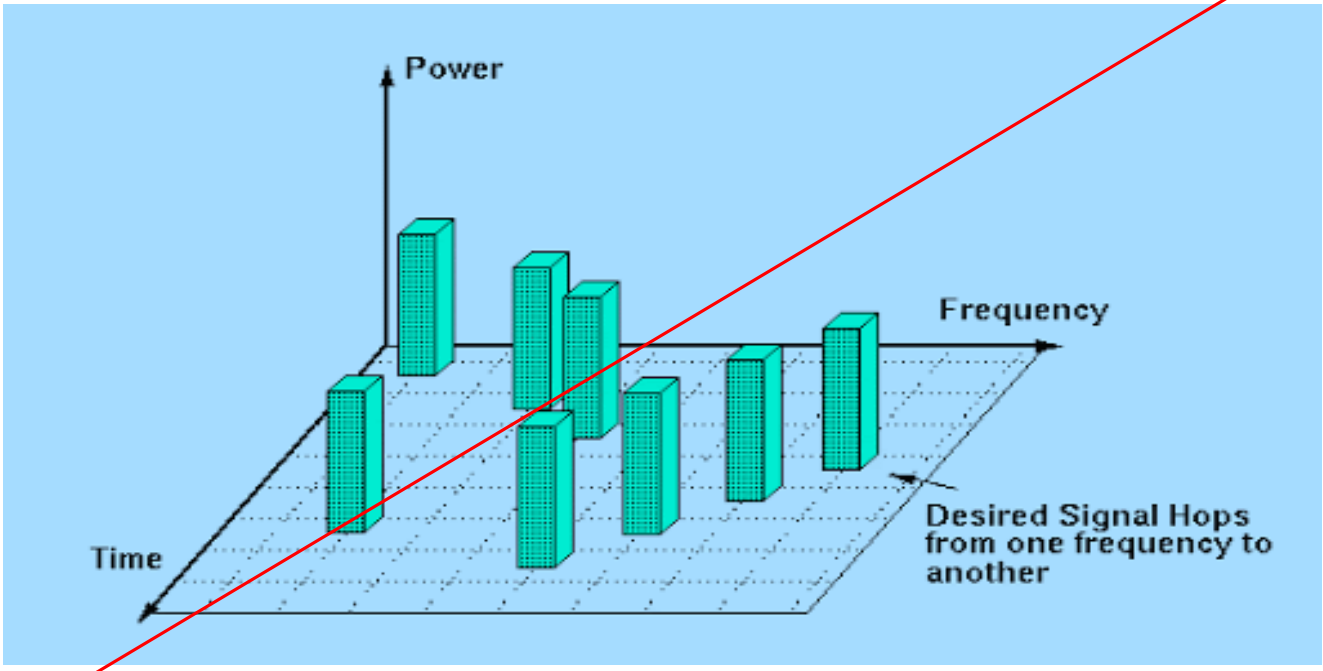
Disadvantage of Satellite

- Bandwidth available is being gradually decreased.
- satellite projection to orbit is costly.
- larger propagation delay in satellite communication compared to terrestrial communication.

Bluetooth

- is global standard radio frequency, physical level agreement/protocol, free of cost (open wireless).
- Bluetooth was standardized as IEEE 802.15.1; Bluetooth Special Interest Group (SIG) maintain specifications.
- used in short-range point-to-multipoint voice and data transfer (transmission can be done through solid, non-metal object).
- it has minimal coverage of 10cm to 10m; however, increasing transmission power could cover 100m.
- can facilitate ad-hoc networks in both stationary and mobile environment.
- communication frequency is 2.45 GHz (2.402 GHz to 2.48 GHz), signal strength of 1mW, for use by industrial, scientific and medical devices.

Bluetooth...



- it uses spread-spectrum frequency hopping.
- it can randomly hop 79 frequency bands.
- transmitter can change frequencies 1600 times every second.
- it can create personal area network (PAN) or piconet.

Bluetooth...

✍ Characteristics of Bluetooth

- operates in 2.45 GHz
- uses Frequency Hopping Spread Spectrum (FHSS) where radio transceiver hop frequencies in pseudo-random fashion.
- non line-of-sight (LOS) transmission is possible through non-metallic object (wall); omni-directional transmission.
- built in security (without tapping probability).
- support max 8 devices with one master and rest as slave.
- easy integration of TCP/IP network.
- regulated by government for use free of cost.

Bluetooth...

Bluetooth Connection

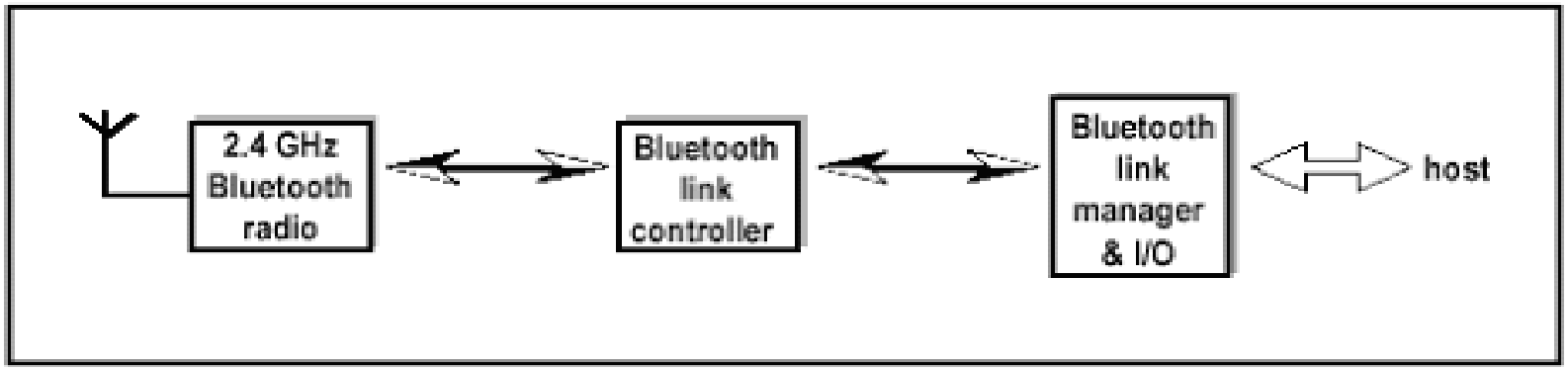


Fig. 9 Different functional blocks in Bluetooth System

- connection is maintained until they are (a) broken, (b) out of coverage, and (c) deliberate disconnect.

Bluetooth Class	***Max Power***	***Range(Approximate)***
Class 1	100 mW / 20 dBm	100 m
Class 2	2.5 mW / 4 dBm	10 m
Class 3	1 mW / 0 dBm	1 m

Bluetooth...

Bluetooth Radio: | Bluetooth Connection

- **Wireless Transmission:**
  Sends/receives data packets wirelessly.
- **Frequency Hopping:**
  Utilizes frequency hopping spread spectrum for transmission.
- **Power Management:**
  Controls power levels for efficient energy usage.

Bluetooth Link Controller: | Bluetooth Connection

- **Connection Management:**
  Establishes, maintains, and terminates connections.
- **Packet Formation:**
  Constructs and segments data packets for transmission.
- **Error Correction:**
  Implements error correction techniques for data integrity.

Bluetooth...

Bluetooth Link Management: | Bluetooth Connection

- Connection Setup:

  Initiates connection establishment and authentication.

- Security Enforcement:

  Enforces authentication, encryption for secure connections.

- Power Management:

  Implements power-saving features for energy efficiency.

Bluetooth...

Bluetooth Packet Format (out of syllabus)

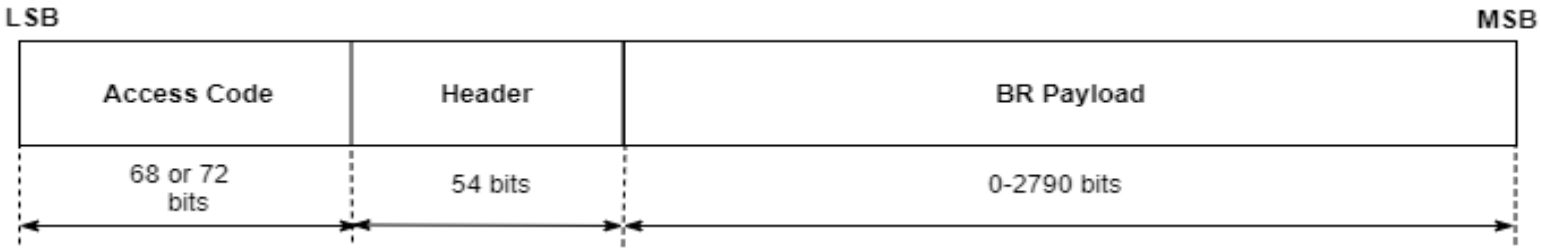


Fig. 10 Basic Rate Mode packet format in Bluetooth

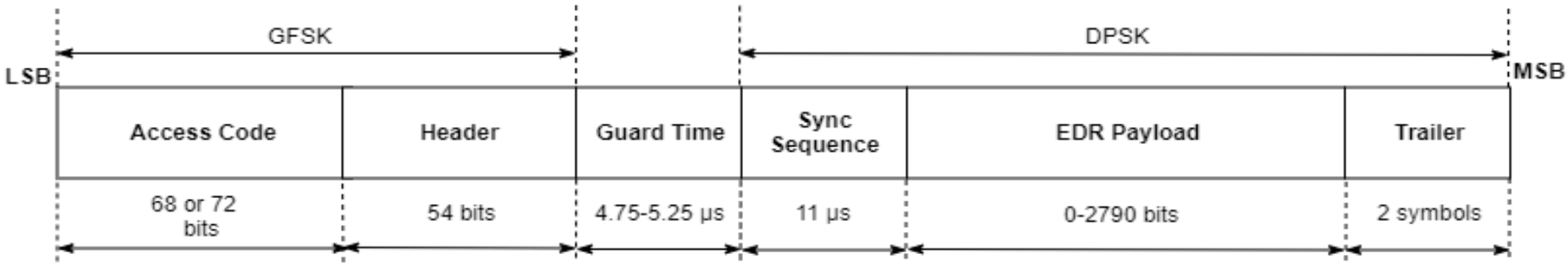
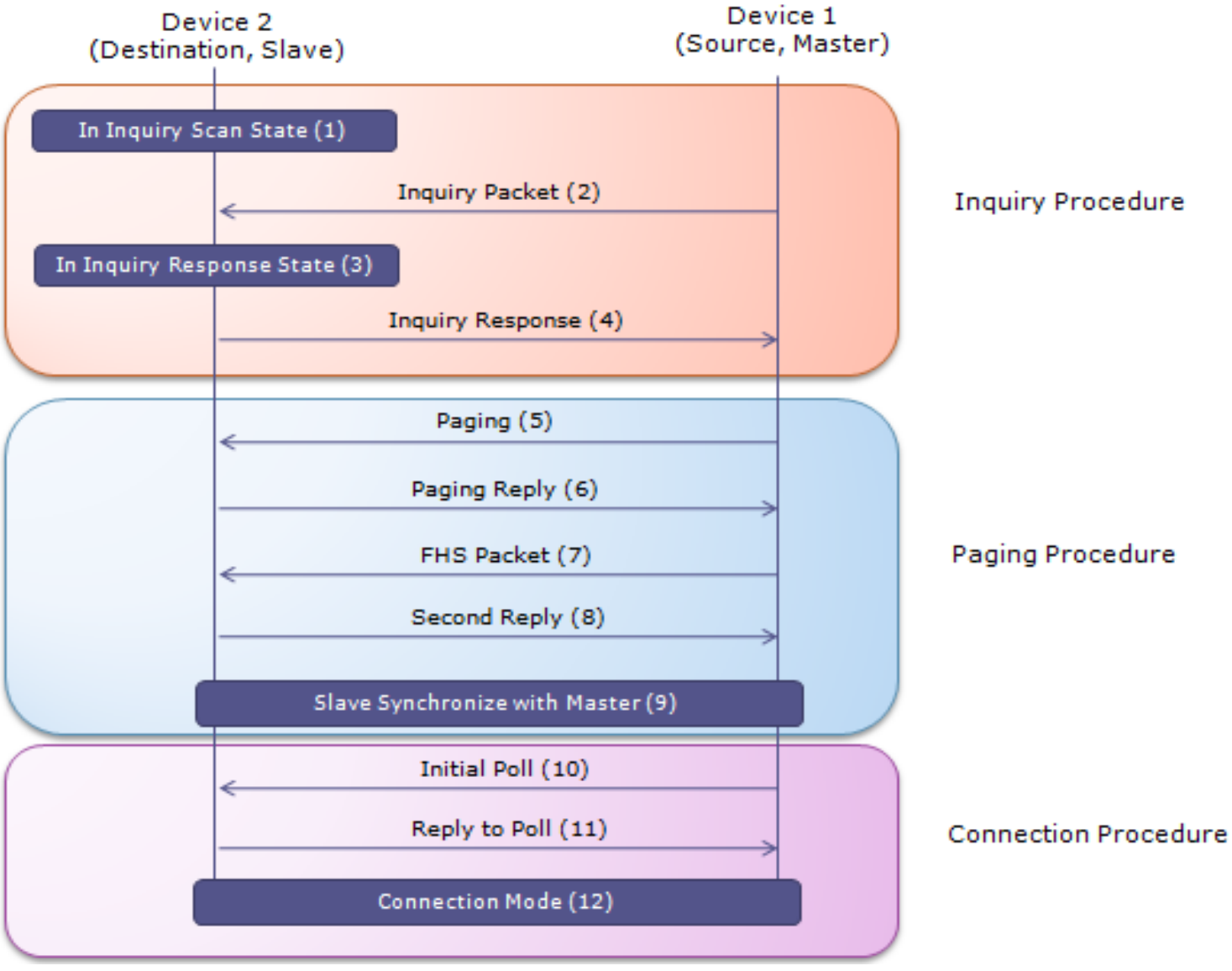


Fig. 11 Enhanced Data Rate Mode packet format in Bluetooth

Bluetooth...

Bluetooth Connecting Process



Bluetooth...

Bluetooth Connecting Process...

#1 ✍ Inquiry:

- when two unknown bluetooth devices come together, one must run inquiry to discover other.
- once inquiry request send, the request will be responded with its address and other information (type of device) if necessary.

#2 ✍ Paging (connecting):

- once the address of each is known to each other, connection is formed and forming the connection is paging (Frequency Hopping Synchronization (FHS), clk info).

#3 ✍ Connection:

- once the paging is completed, devices enter to connection state.
- at connected mode, active participation is possible to communicate ie data transfer.

Bluetooth...

Different Connection Mode

#1 ✍ Active Mode:

- regular connection mode where the device can actively transmit or receive data.

#2 ✍ Sniff Mode:

- power saving mode – less active or reduced activities
- slave sleeps for predetermined time, recurring, and listen master only after preset values (eg: 100 ms).

#3 ✍ Hold Mode:

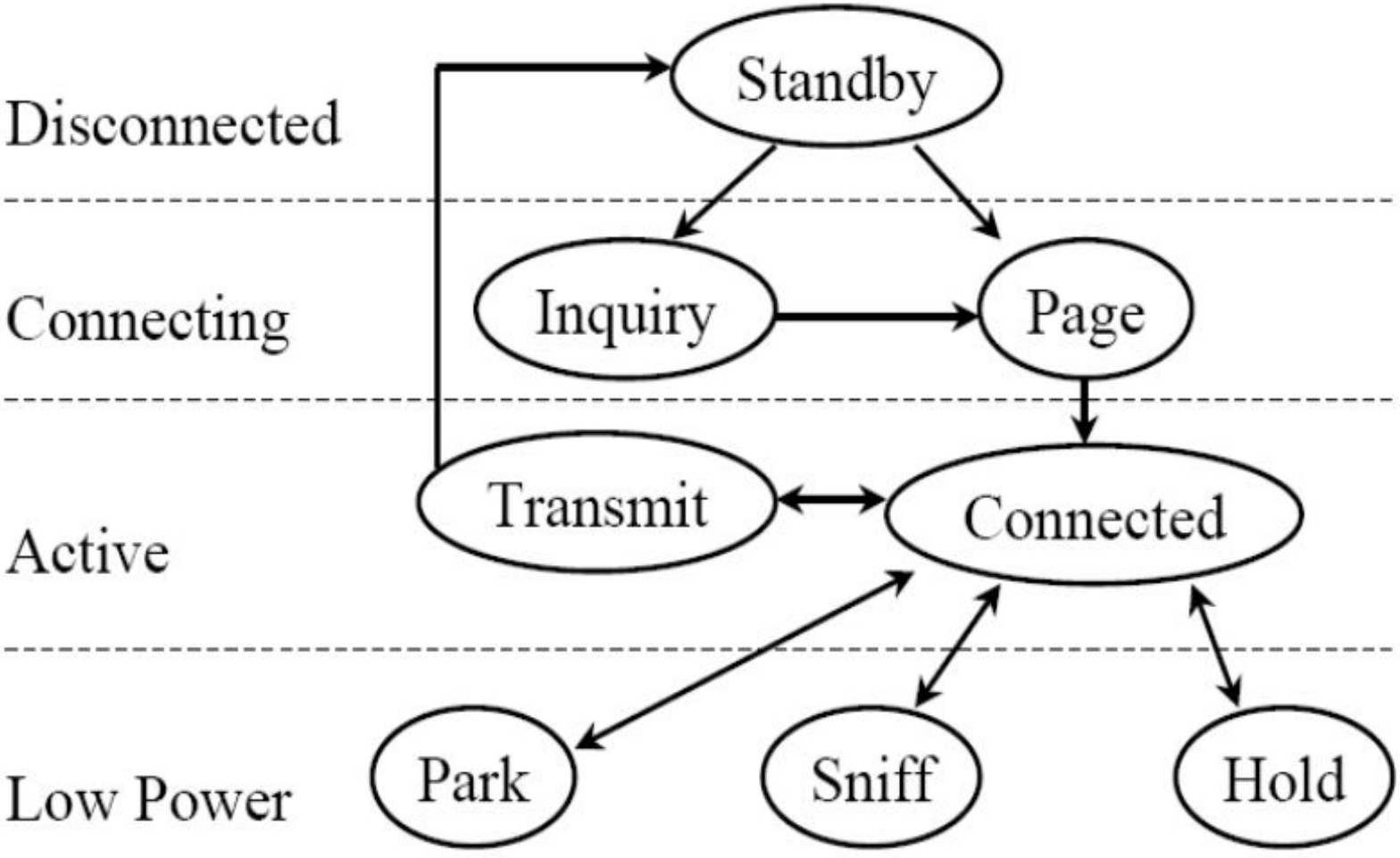
- power saving mode (stop transmission for other tasks)
- slave sleeps for one fixed predetermined time interval .
- master can command device to hold.

#4 ✍ Park Mode:

- deepest sleep mode.
- it sleeps until master command to wake up at T-beacon time.

Bluetooth ...

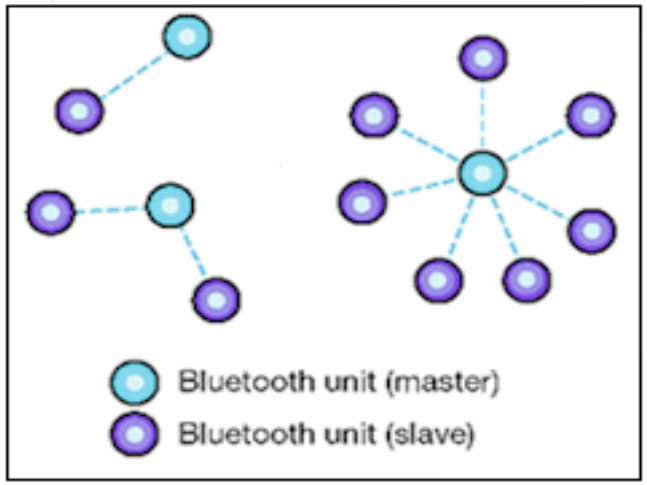
Different Operational State of Bluetooth Device



Bluetooth Network Topology

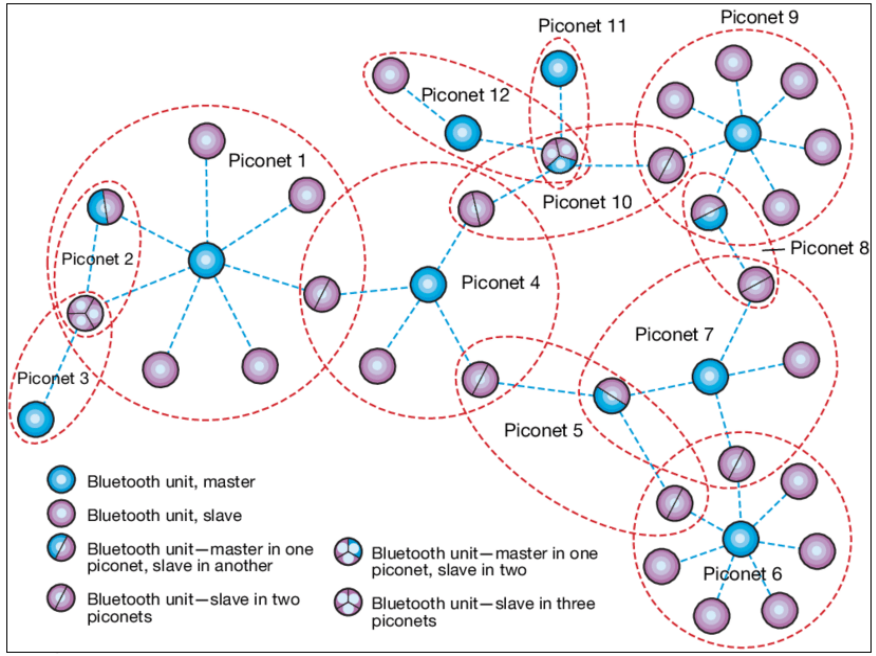
piconet

- max 8 devices (one master and 7 slaves).
- Master/Slave, frequency hopping;
- up to 7 active slave and up to 255 parked slaves;
- no central network structure; only Ad-hoc network.



scatternet

- inter-connected piconets; one master per piconet.
- a few devices shared between piconets.
- no central network structure; only Ad-hoc network.



Bluetooth ...

Bluetooth Protocol Stack

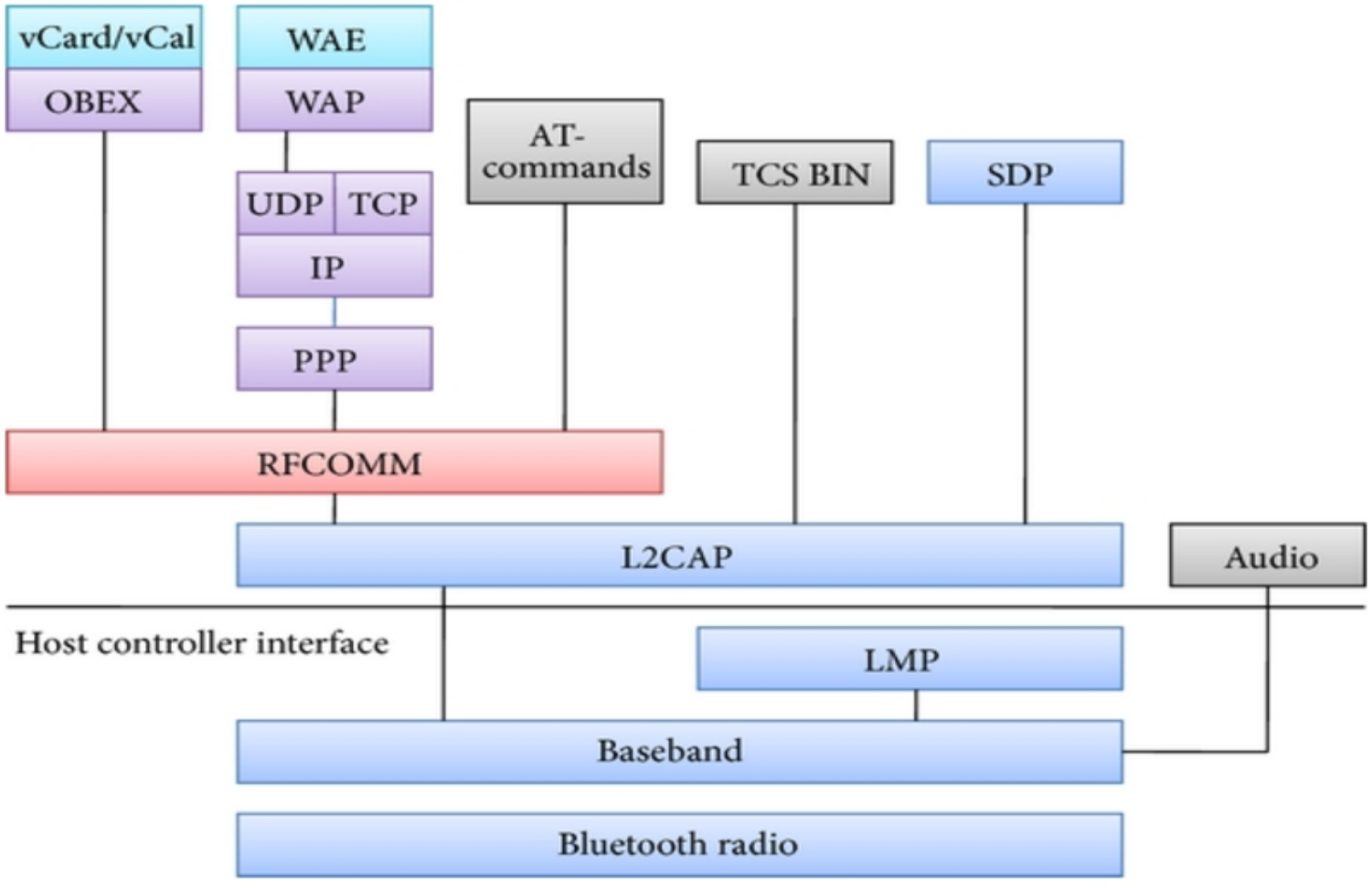
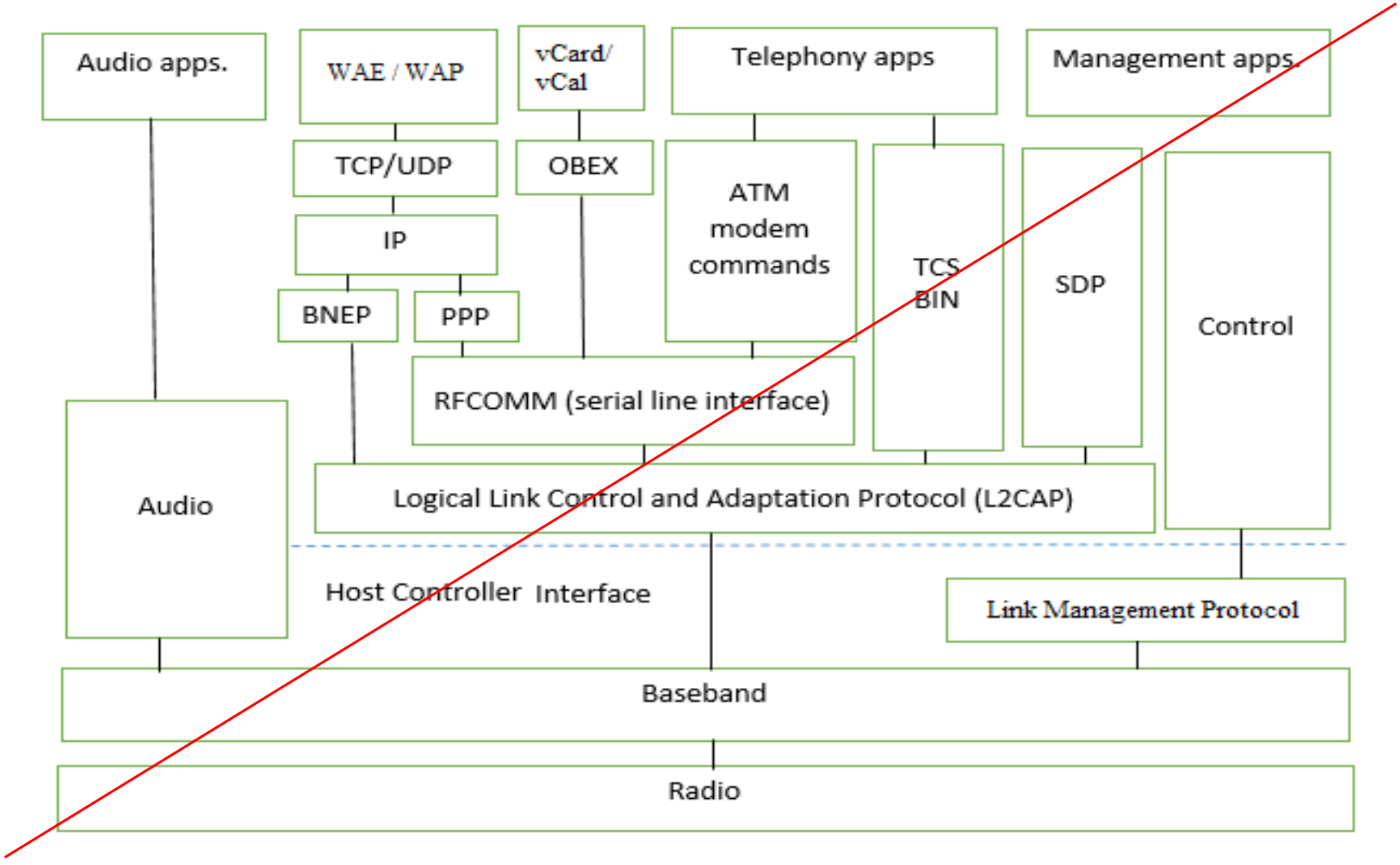


Fig. 12 Bluetooth Protocol Stack

Bluetooth ...

Bluetooth Protocol Stack...



Bluetooth Protocol Stack

Bluetooth..

Bluetooth Protocol Stack

#1 ✍ Bluetooth Radio

- defines air interface, frequency bands, frequency hopping specifications, modulation techniques, and transmit power.

#2 ✍ Baseband Layer

- addressing scheme, packet frame format, timing and power control algorithms for connection within piconet.

Bluetooth..

Bluetooth Protocol Stack...

#3 ✍ Link Management Protocol (LMP)

- it is responsible to establish link between bluetooth devices and maintain the link between them.
- it includes authentication and encryption specification.

#4 ✍ Logical Link Control and Adaptation Protocol (L2CAP)

- it adapts/converts upper layer frame to baseband layer frame format and vice versa.
- takes care of both connection-oriented (telephone connection) and connection-less services (packet based communication).

Bluetooth..

Bluetooth Protocol Stack...

#5 ✍ Host Controller Interface (HCI)

- provides a common interface to the baseband link controller and link management protocol, and access to hardware status and control registers.

#6 ✍ Service Discovery Protocol (SDP)

- queries about device information is handled by this protocol
- so responsible for connection.

#7 ✍ TCS-BIN

- It specifies all call control signaling and mobility management procedures; it takes care of establishing speech and data calls.

Bluetooth..

Bluetooth Protocol Stack...

#8 ✍ RFCOMM Protocol

- it is cable replacement protocol (wireless protocol)
- functions as virtual serial port and transport binary data bits.
- basically emulates RS232 specifications over bluetooth radio.
- Point to point protocol (PPP) to transfer IP datagrams, TCP/UDP/IP, OBEX and WAE/WAP protocols are adopted protocol in Bluetooth - defined by other standard bodies.
- OBEX is object exchange protocol developed by IrDA (infrared data association) – similar to HTTP (session level protocol).
- WAE provides Wireless Application Environment and WAP provides Wireless Application Protocol. (bluetooth tethering?)

Bluetooth..

Bluetooth Applications

- wireless control and communication between cell phone and heads free headset or car kit.
- wireless networking between PCs in confined space with little bandwidth (PAN with PCs using bluetooth wireless).
- wireless input connection such as mice, keyboards.
- wireless output device such as printer.
- transfer of files between devices via OBEX (Object Exchange Protocol– binary object file)
- replacement of wired devices with wireless devices: medical equipment, GPS receivers.
- replacement of remote controls which uses infrared traditionally.

Bluetooth..

Bluetooth Advantage

- uses lower power
- can connect various type of devices.
- free of cost frequency band
- Ad-Hoc hardware can be established by Bluetooth connection
- simple, secure and global data transfer.
- less time consumption.

Bluetooth Disadvantage

- Large data transmission is difficult
- Bluejack problems (receive of unsolicited message).

Data Acquisition System

- Data acquisition system is the process of collecting the input data in digital form suitable for analysis and storage.
- Data collection should be timely, accurately and economically.
- Data acquisition system consists:
  1. transducer (sensor)
  2. signal conditioner
  3. data conversion and processing
  4. multiplexer, transmission
  5. storage and display system
  6. software for data processing
- Analog signals are generally acquired and converted into digital form for processing, transmission, display and storage.
- sometime data acquired can be used for controlling a process in process plant.

Data Acquisition System...

- transducer is device that converts input energy of one form into another energy form.
- signal conditioning make signals compatible to forward acquisition; removing unwanted frequency components; amplifying amplitude.

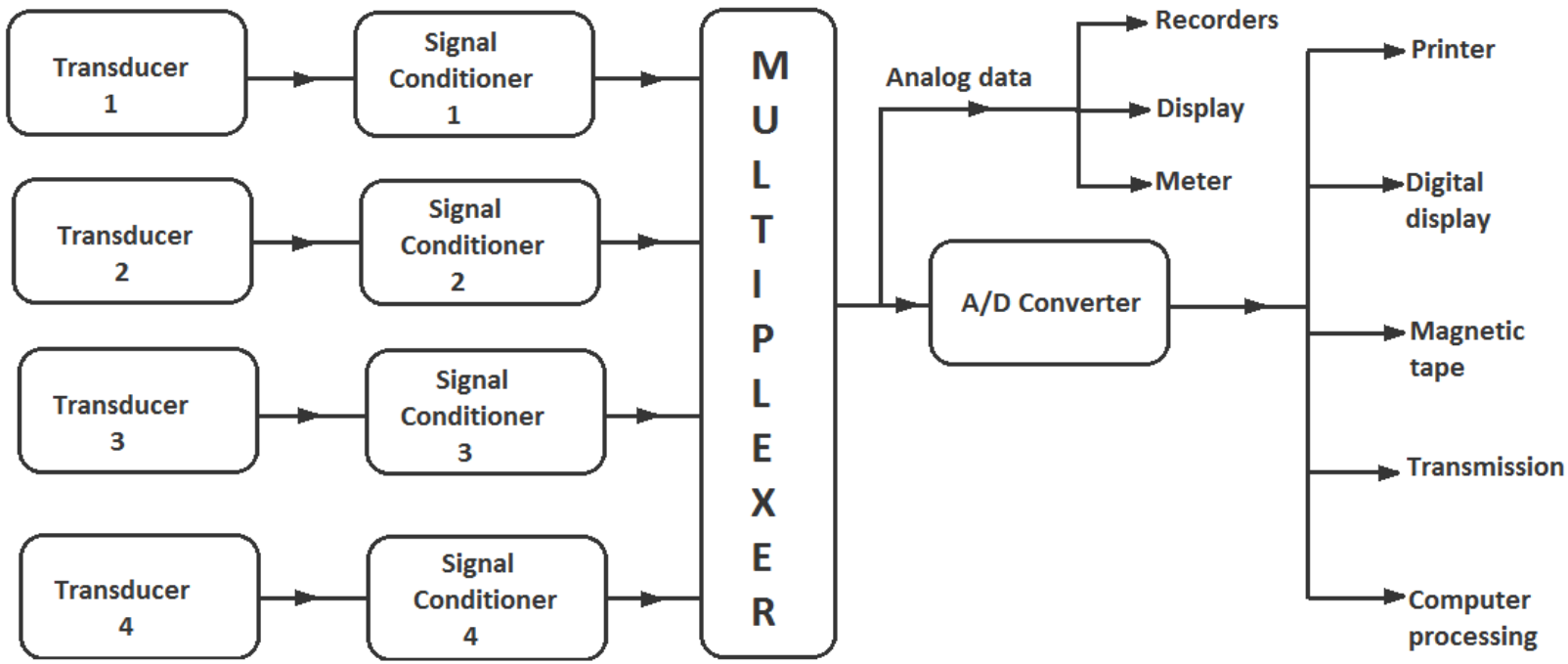


Fig. 13 General data acquisition system

Data Acquisition System...

Data Loggers

- transducers give the measure of some parameters of any process – the parameters can be used for process control after analysis, can be used for further processing.
- automatic data recorder for the readings (parameters) of remote instrumentation system.
- expectation for data logger is as quickly as effortlessly, and accurately.
- our expectation, being data reader at distant place, it should be small battery powered, portable, power efficiently and equipped with microprocessor and internal memories.

Data Acquisition System...

Characteristics of Data Loggers

- modularity: compatible component to many systems.
- reliability and ruggedness: reliable data storage/reading.
- accuracy: data measure should be as accurate as possible.
- management tool:
- Easy to Use:

Application of Data Loggers

- weather station: recording wind speed, wind direction, temperature, relative humidity.
- hydro-graphic recoding: water level, depth, water flow PH, conductivity
- soil moisture level, gas pressure
- environmental monitoring

Data Acquisition System...

Data Loggers...

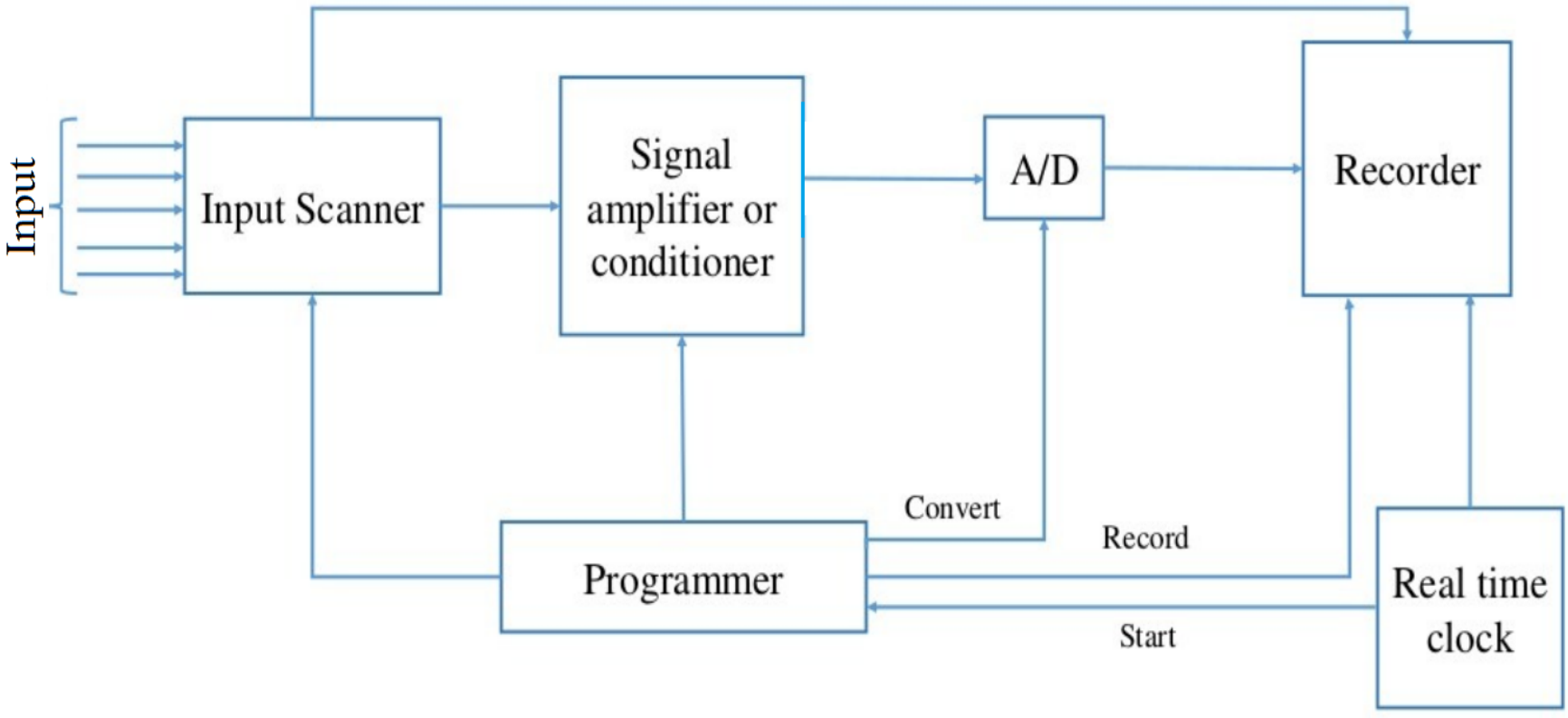


Fig. 14 Block Diagram of Data Logger

Data Acquisition System...
Data Loggers...

✍ Input Signals

- input signals may be pressure, AC signals, thermocouple, signals from relay, tachometer pulses

✍ input scanners

- is automatic sequence switch to select signals in turn.
- scanner should have low closed resistance, high open circuit resistance, low contact potential, short operating time, negligible contact bounce, long operation life.

✍ Signal Amplifiers and conditioners

- to adjust gain with low level signals
- it should be precise and stable DC gain, high SNR, high CMMR, low DC drift, low output impedance, high input impedance, good linearity, wide bandwidth.

Data Acquisition System...
Data Loggers...

✍ A/D Converter

- Converts analog to digital data
- it should have better resolution, accuracy, lower conversion time, linearity.

✍ Recorder

- data logger may be typewriter, strip printer, digital tape recorder, computer, magnetic tape.
- should have higher read/write speed;

✍ Programmer

- controls all units of data logger system
- microcontroller or microprocessor based system.
- it should perform: setting amplifier, linearity factor, A/D conversion time, reset logger, record reading channel, identify channel and time of recording.

Data Acquisition System...

Compact Data Loggers(*self study*)

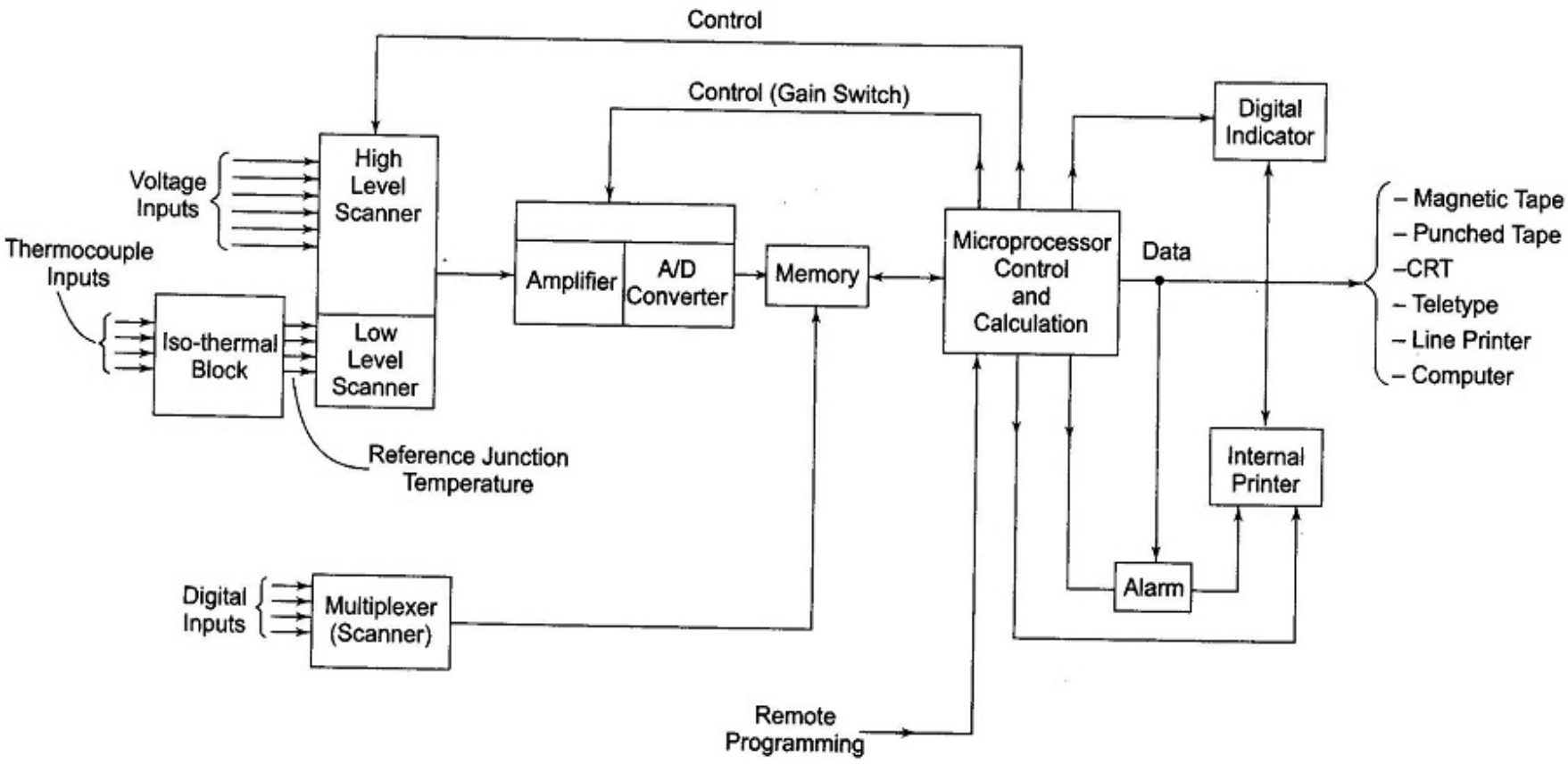


Fig. 15 Block Diagram of Compact Data Logger

Data Acquisition System...

Compact Data Loggers(*self study - explore more*)

- typical compact data logger unit provides 60 data channels
- some manufacturers offers add-on scanners to expand 100 data channels; scan rates at modest is 20 channels per second.
- most units have interface to computer for versatile processing when possible.
- uses built in microprocessor to carry out calculation on amplifiers, A/D converters.
- low level and high level scanner are available.
- milivolt level signals:
  - ✍ thermocouple signals use shielded, twisted pair cable.
- amplifiers and A/D converters are crucial for system accuracy.
- microprocessors are responsible for automatic gain.

Data Acquisition System...

Data Archiving and Storage

✍ Data Archiving

- is moving data that is no longer actively used.
- it can be readily accessible if required.
- data archives are indexed and have search capability so that data or files can be easily located or retrieved.
- make sure there is difference in data backup and data archive.
- data backup means re-storage of data when corrupted or destroyed.
- data archiving is protecting older information which may be used occasionally, not in everyday operation.

Data Acquisition System...

Data Archiving and Storage

✍ Data Storage

- recording data and retaining when needed.
- storage design factors are:
  1. speed of data access
  2. cost per unit data
  3. reliability: data loss when power failure or system crash, physical failure of storage device;

Volatile: loss of content when power is off

Non-Volatile: no content loss when power is off.

Data Acquisition System...

Different type of Data Storage

✍ Primary storage

- fastest media, it might be volatile.
- cache, main memory - RAM or ROM.

✍ Secondary storage

- online storage, non-volatile
- moderately fast to access.
- flash memory, magnetic disks.

✍ Tertiary storage

- off-line storage, non-volatile
- slow access time: tape libraries, optical jukebox.

Data Acquisition System...

Data Compression

- is the process of encoding to represent information with minimal number of bits
- reduces the bandwidth in both transmission and data storage.

Lossy Compression	***Lossless Compression***
when loss is acceptable	when loss is unacceptable
eg: Picture(JPEG), video(MPEG), audio (MP3)	eg: Zip, RAR, PNG, TIFF, video (Huff, AVI)

Data Acquisition System...

RAID: Redundant Arrays of Independent/Inexpensive Disks

- is the way of storing data in disk organization
- high capacity and high speed when multiple disk in parallel.
- high reliability by storing data redundantly, so data can be recovered even if a disk fails.
- main purpose of the RAID is data reliability, availability, performance, and capacity
- except RAID0, higher level RAID provide automatic data recovery at disk failure

✍ Note: Click RAID Description up to RAID-6

Data Acquisition System...

RAID: Redundant Arrays of Independent Disks

Category		Description	I/O Request Rate (Read/Write)	Data Transfer Rate (Read/Write)	Typical Application
Striping	0	Non-redundant	Large strings: Excellent	Small strips: Excellent	Applications requiring high performance for non-critical data
Mirroring	1	Mirrored	Good/fair	Fair/fair	System drives; critical files
Parallel access	2	Redundant via Hamming code	Poor	Excellent	
	3	Bit-interleaved parity	Poor	Excellent	Large I/O request size applications such as imaging, CAD
Independent access	4	Block-interleaved parity	Excellent/fair	Fair/poor	
	5	Block-interleaved distributed parity	Excellent/fair	Fair/poor	Applications requiring extremely high availability
	6	Block-interleaved dual distributed parity	Excellent/poor	Fair/poor	

As you go
Assignment

Assignment Module #5 is available at MS-Team.

Deadline for submission: 3rd July 2024 (*Before 3:00 PM*)