Chapter 1: Introduction

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It's not just about what are inside these slides but more about what I taught you during my lecture session.

Focus more on those!

Contents (4 hrs)

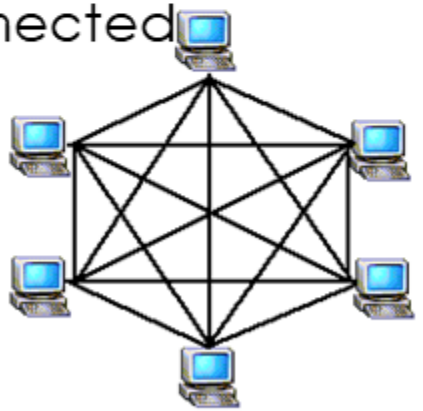
1. Public –switched telephone network (PSTN)
2. Network topology
3. Central office switch
4. Subscriber telephone
5. Subscriber loop
6. Telephone conversation, hierarchical networks
7. Comparison between analog and digital transmission
8. Transmission impairments (distortion, noise, interference, crosstalk, echo, singing, jitter)

Telecommunication - definition

- **Tele**: at distance, remote
- **Communication**: exchange of information
  - Transmission/reception of information by wire, radio or em-systems
- Telecommunication networks carry information, signals among entities which are geographically for apart
  - Information may be any signs, signals, writings, images, sound or intelligence of any nature
  - An entity may be a computer, human, a facsimile machine, tele-printer, data terminal etc
- Connectivity in telecommunication networks is achieved by use of switching system

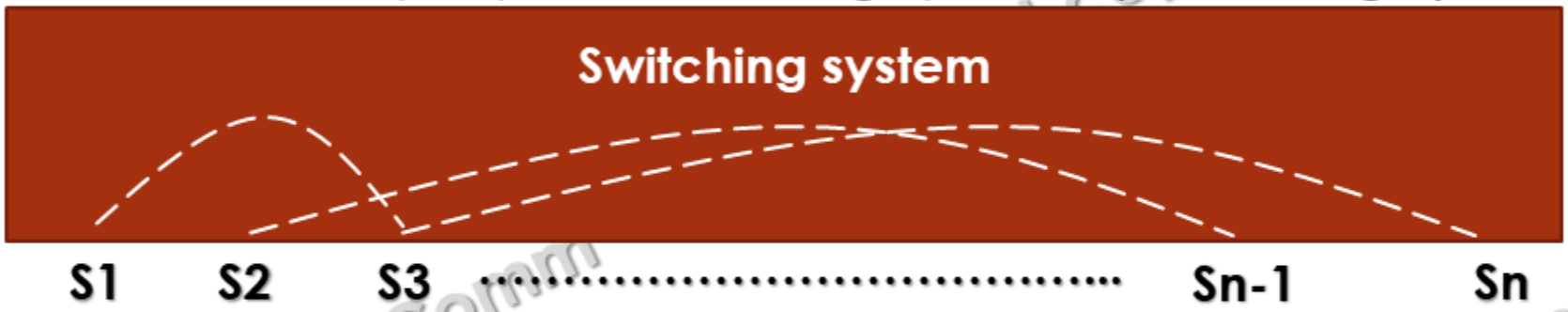
Evolution

- First electrical communication – Telegraph, 1837 in Great Britain and 1845 in France (Wheatstone and Morse)
  - Use of Morse code (dot and dash)
- Alexander Grahm Bell, 1876, demonstrated his telephone set and possibility of telephony i.e. long distance communication
  - First telephone exchange at New Haven, Connecticut in 1878
  - Point to point telephone connection (mesh network-fully connected network)
  - Requires some sort of signalling too
    - To make a call
    - To show if someone is busy or not
  - Cost and complexity for e.g. for n users, n(n-1)/2 link, for n=50, 1225 links.



Evolution (contd...)

- Practical use of Bell's invention on a large scale or even moderate scale not only requires telephone sets and pairs of wires but also a proper switching system (exchange)



- With the use of **Exchange**, Subscribers aren't directly connected but connected via switching system
  - only one link per subscriber is required between subscriber and switching system
  - Total no of such links is equal to no of subscribers connected to the system.

Evolution (contd...)

- Signalling is required
  - to draw attention of switching system to establish and/or release a connection
  - Also enable switching system to detect whether a called subscriber is busy and if so, indicate the same to the calling subscriber
- Functions performed by a switching system in establishing and releasing connection are known as control functions

- 1900s,wireless, Marconi
- 1940s, video transmission through wireless media
- 1980s, optical fiber

Nepal - history

- Any form of telecommunication services dates back to 1970 BS (1913 AD)
- However, formally provided mainly after establishment of 'Mohan Akashwani' in 2005 BS
- Later as per the plan formulated in the First National Five year plan (2012-2017 BS)
  - Telecommunication Department was established in B.S. 2016
- After the enactment of Communications Corporation Act 2028, it was formally established as fully owned Government Corporation called Nepal Telecommunications Corporation in B.S. 2032 for the purpose of providing telecommunications services to Nepalese People

Nepal - history

- Nepal Telecommunication Corporation was transformed into a Nepal Doorsanchar Company Limited (NDCL) from Baisakh 1, 2061.
- NDCL is a company registered under the companies Act 2053 with 85% government share.
  - However, the company is known to the general public by the brand name Nepal Telecom (NT) as a registered trademark
- Installation of 25 lines automatic exchange in Royal Palace – 1935 AD
- Distribution of telephone line to general public – 1955 AD
- Beginning of International Telecommunications Service using HF Radio to India and Pakistan – 1964 AD

Nepal - history

- First Automatic exchange in Nepal (1000 lines in Kathmandu) – 1965 AD

- **Telephones - PSTN**: 644,347 (May 2013)
- **Mobile Subscribers:** 18,137,771 (May 2013)

PSTN (Public switched telecommunication network)

- The aggregate of the world's circuit-switched telephone networks that are operated by national, regional, or local telephony operators, providing infrastructure and services for public telecommunication.
- Consists of telephone lines, fiber optic cables, microwave transmission links, cellular networks, communication satellites, and undersea telephone cables, all interconnected by switching centers, thus allowing most telephones to communicate with each other.
- Originally a network of fixed-line analog telephone systems, the PSTN is now almost entirely digital in its core network and includes mobile and other networks, as well as fixed telephones

Network services

- PSTN
- Public switched telegraph network (telex)
- Private networks for voice and data (PTO- public telecomm operator)
- Cellular radio networks
- Public data networks (PDN)
- Special service networks

PSTN (contd…)

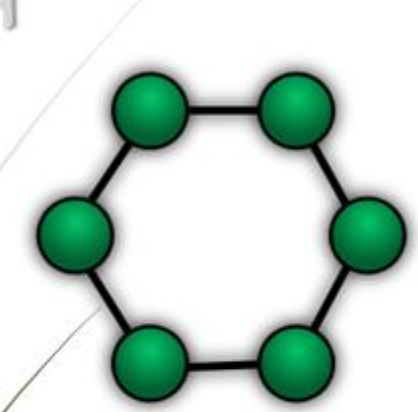
PSTN can be categorized as:

- Network designed for voice communication
- Primarily on circuit switched basis, duplex connection
- Full interconnection among individual networks
- Largely analog at local loop level
- Digital at backbone level
- Generally provisioned on a wireline, rather than wireless
- Switched bandwidth, 64Kbps or 300-3400 Hz for analog exchange

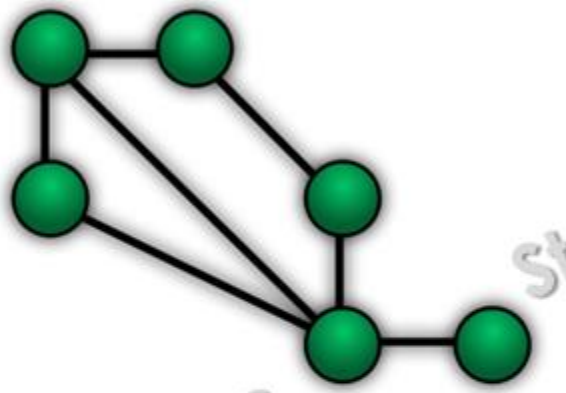
Network topology

- Arrangement of the various elements (links, nodes, etc.) of a computer network or biological network
- Can be depicted, physically or logically
- **Physical topology** is the placement of the various components of a network, including device location and cable installation
- **Logical topology** illustrates how data flows within a network, regardless of its physical design.
- Distances between nodes, physical interconnections, transmission rates, or signal types may differ between two networks, yet their topologies may be identical.

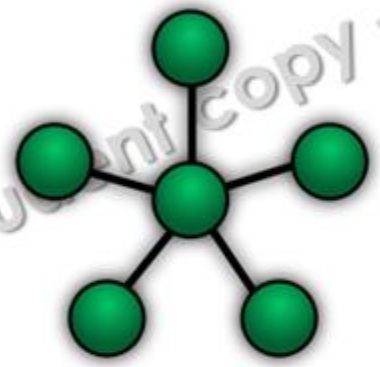
Network topology (contd…)



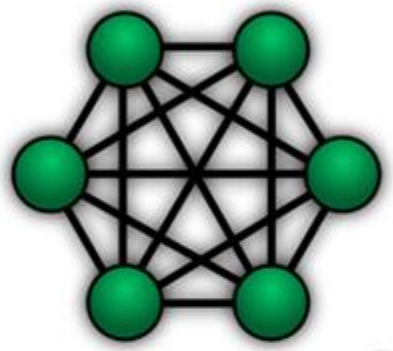
Ring



Mesh

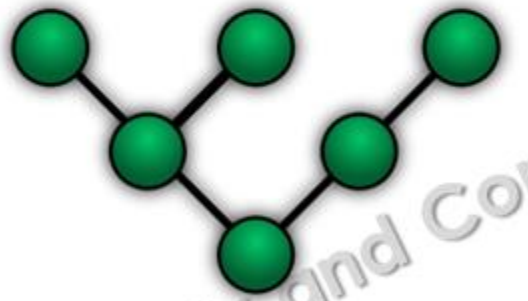


Star

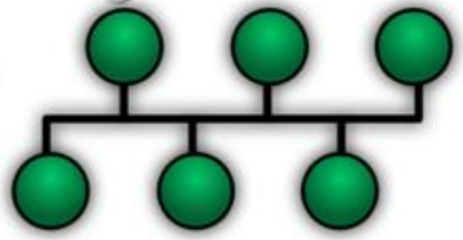


Fully Connected

Line



Tree



Bus

Network topology

1. Bus topology (LAN)

- Inexpensive to implement, single wire
- High cost of managing network
- Single point of failure – cable

Bus Topology

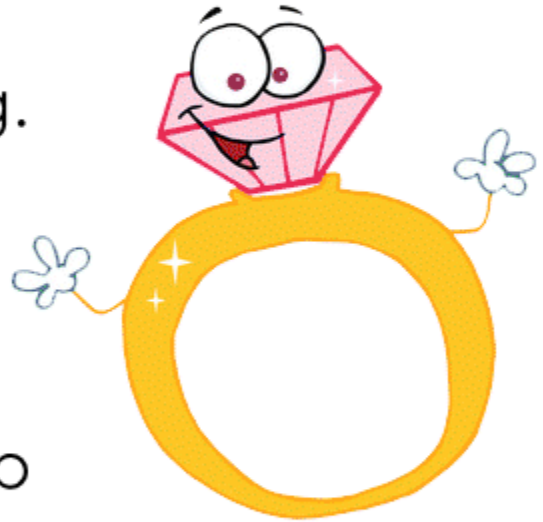
- Computers and other network devices are cabled together in a line.
- Collisions are common.

Network topology

2. Ring topology

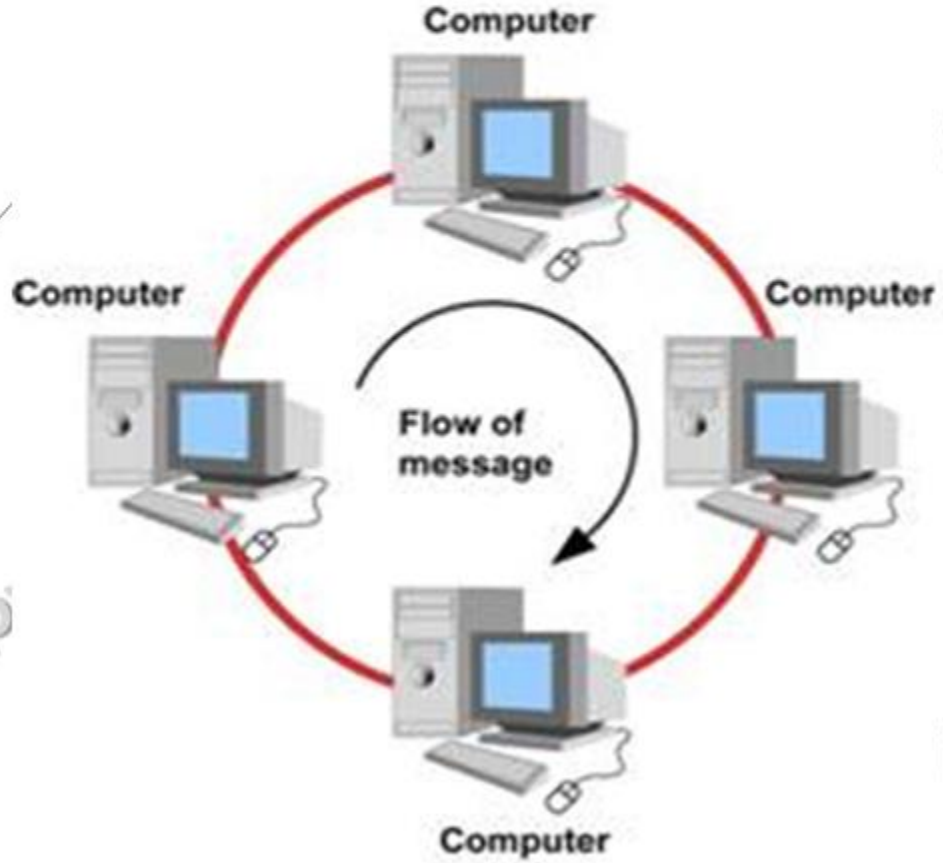
- Computers and other network devices are cabled together with the last device connected to the first to form a circle, or ring.
  - This category includes both ring and dual-ring topologies.
- Useless for normal telephony
- Each device of right acts as repeater to keep signal strong as it travels
- Every node is critical link

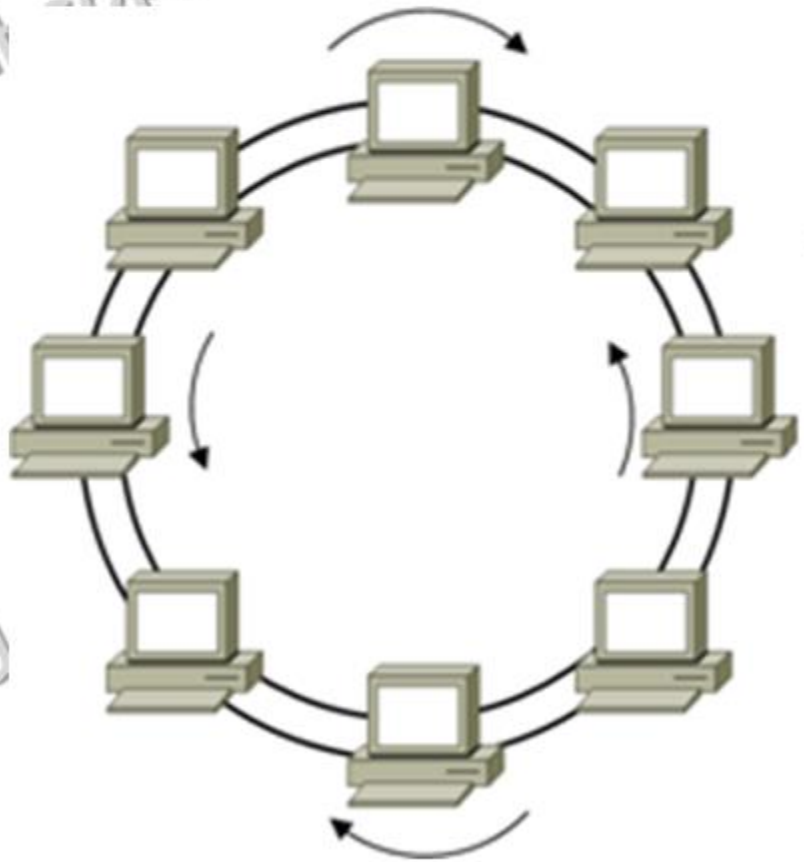
Ring Topology



Network topology

- Single ring topology and dual ring topology





Network Topology

3. Star topology

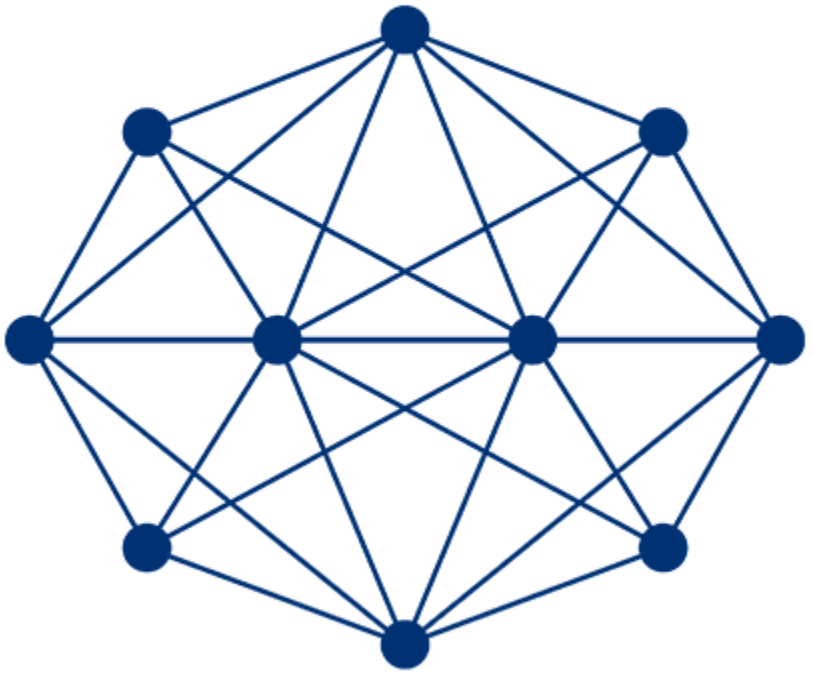
- each node (like workstations, printers, laptops, servers etc.) connected directly to a central device called as a network switch.
- Each workstation has a cable that goes from its network card to a network switch.
- Adv: simplicity of addition of nodes
- SPOF: hub
- For telephony, for two way communication, no of lines reduces to N = n from N=n(n-1)/2

Star Topology

Network topology

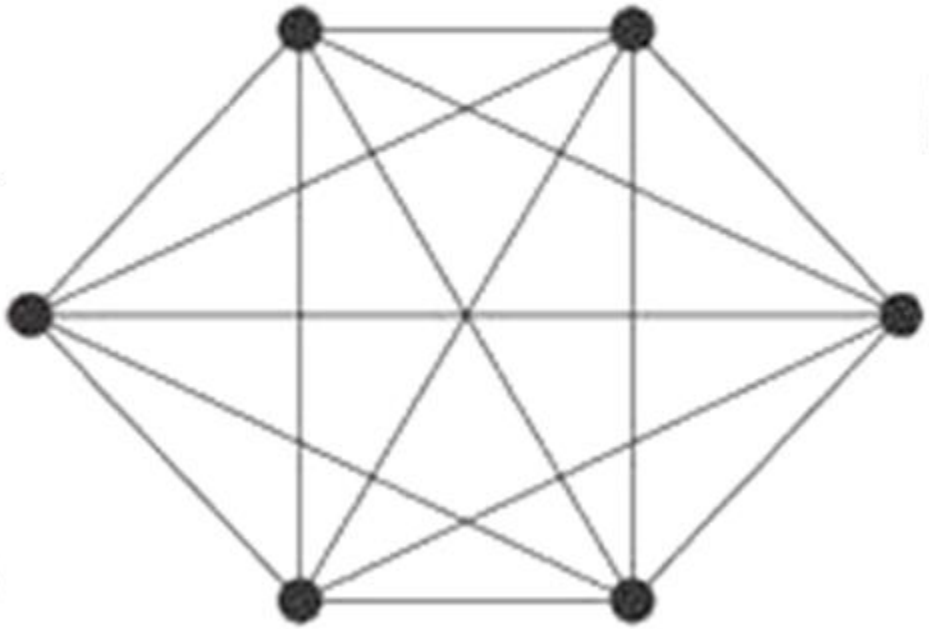
4. Mesh topology

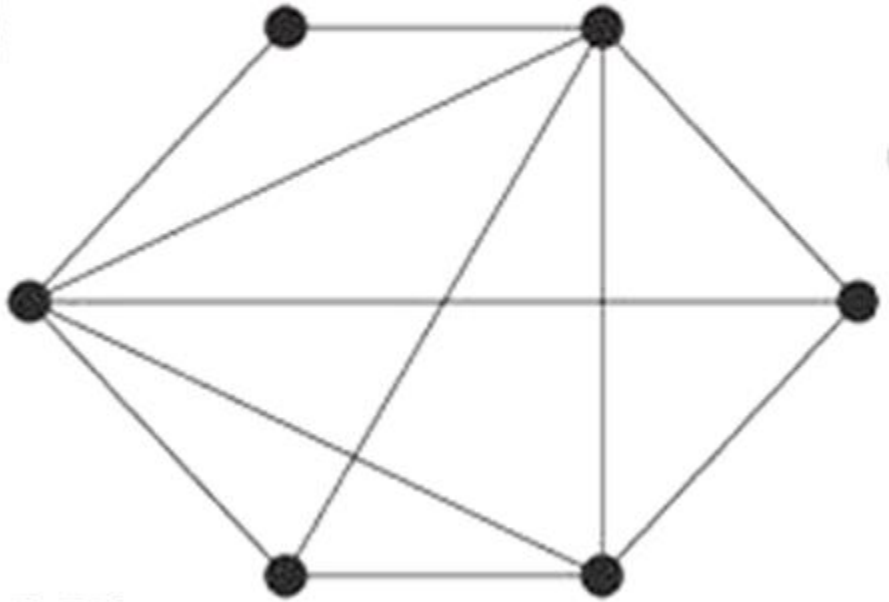
- similar to the star topology but provides redundancy between devices in a star topology.
- A network can be fully meshed or partially meshed depending on the level of redundancy needed.
- helps improve network availability and reliability.
  - However, it increases cost and can limit scalability, so one needs to exercise care when meshing



Network topology

- Full mesh topology and partial mesh topology

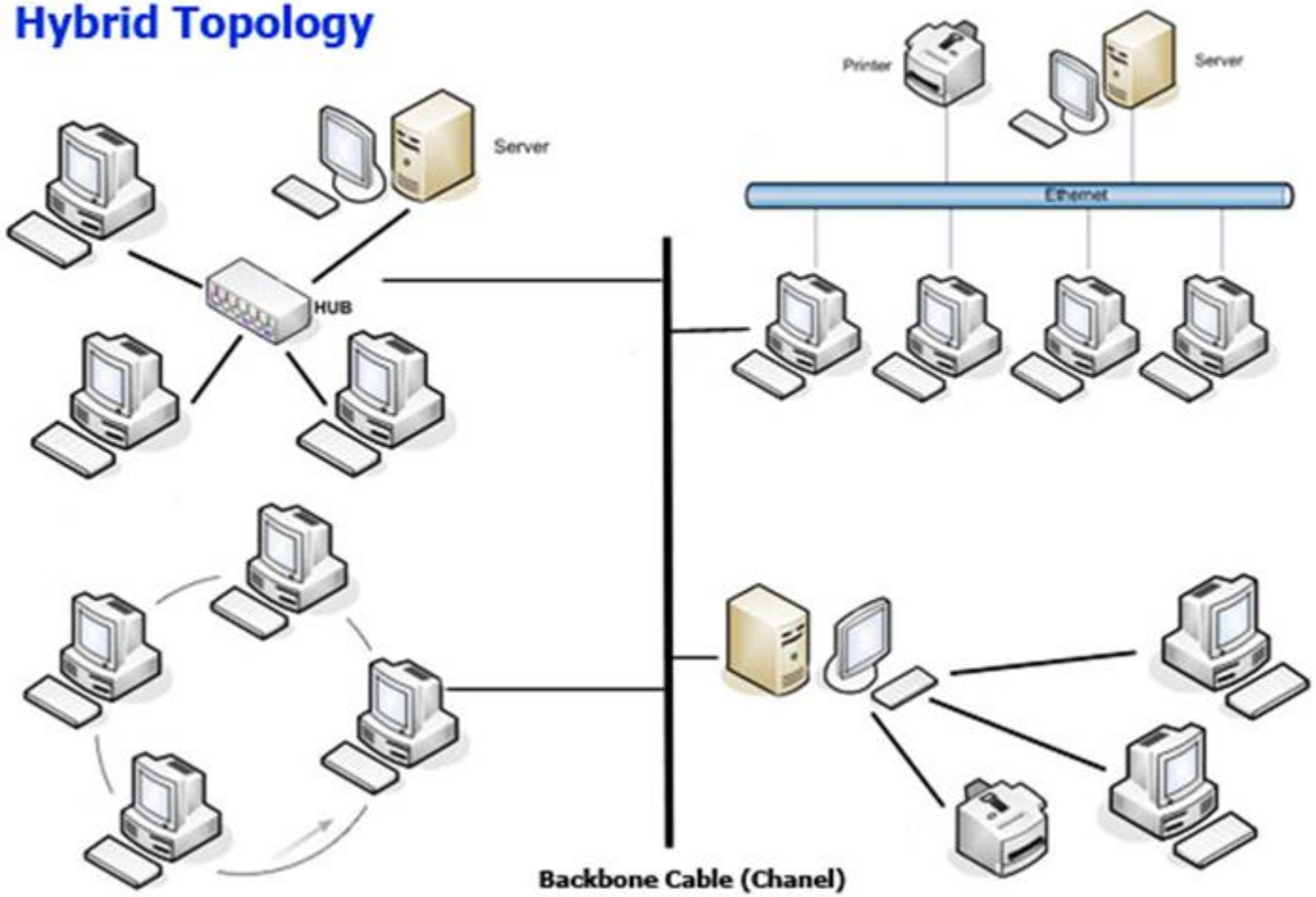




Network topology

5. Hybrid topology

- contains more than one topology
- Internet is the best example of largest Hybrid topology.

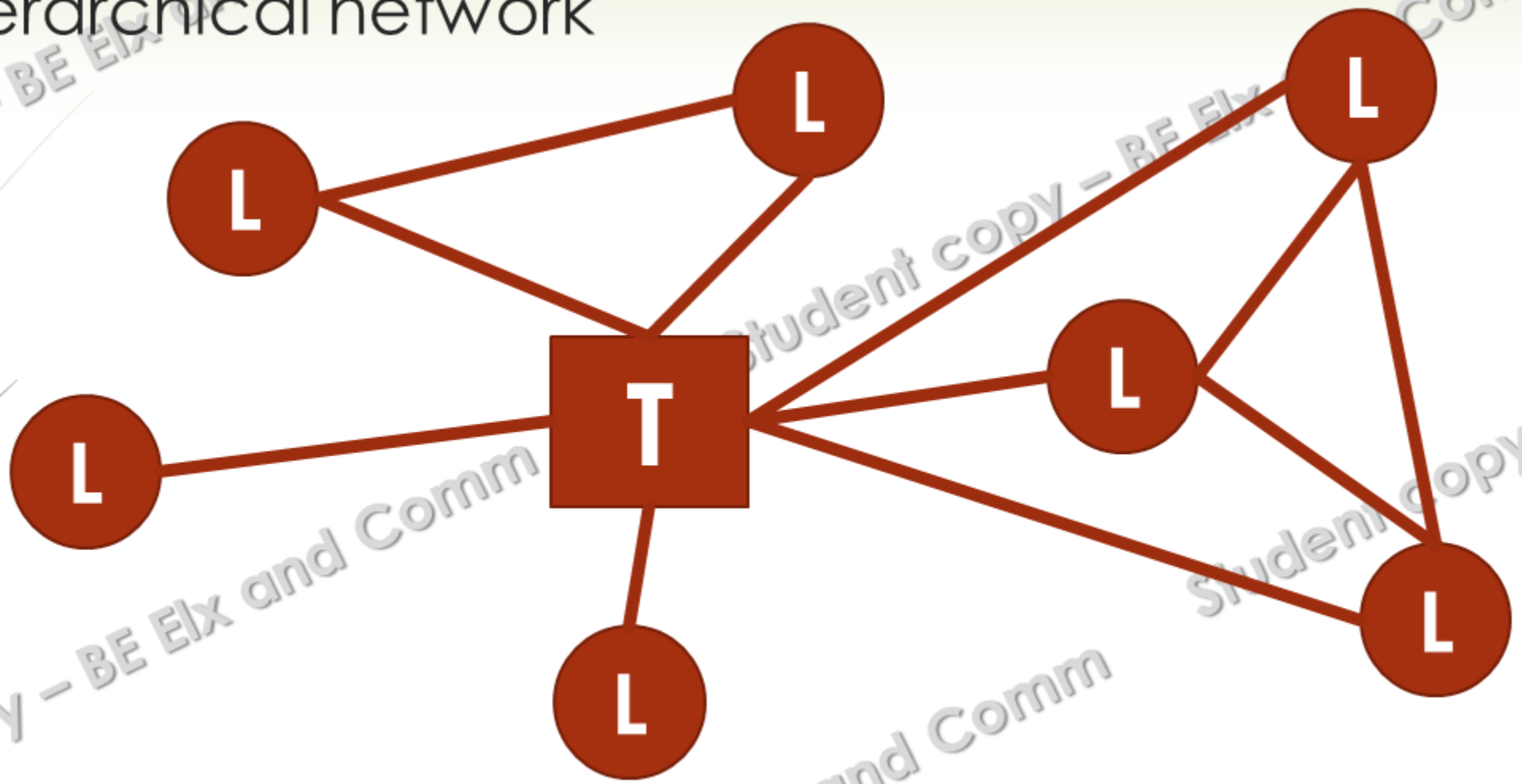


Network topology

Tree topology

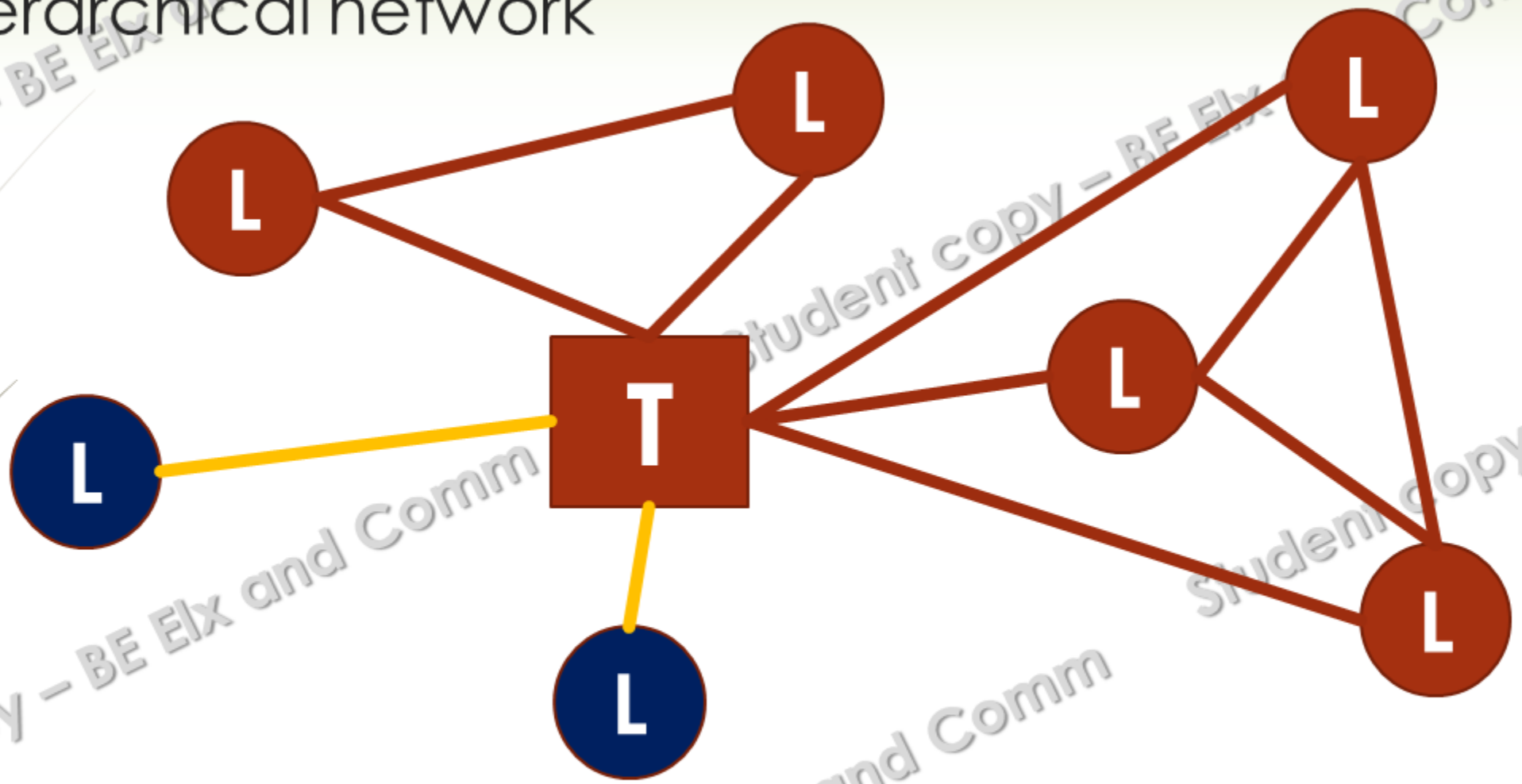
- Based on hierarchy of nodes
- **Hierarchical network**
  - With growth in coverage area by star network and the no of stations served by it, line costs increases and it becomes economic to divide network into several smaller networks
- If an area is served by several exchanges, customers on each exchange will wish to converse with customers on other exchange
- It becomes necessary to provide circuits between the exchanges
  - These are called junction circuits and they form junction networks

Hierarchical network



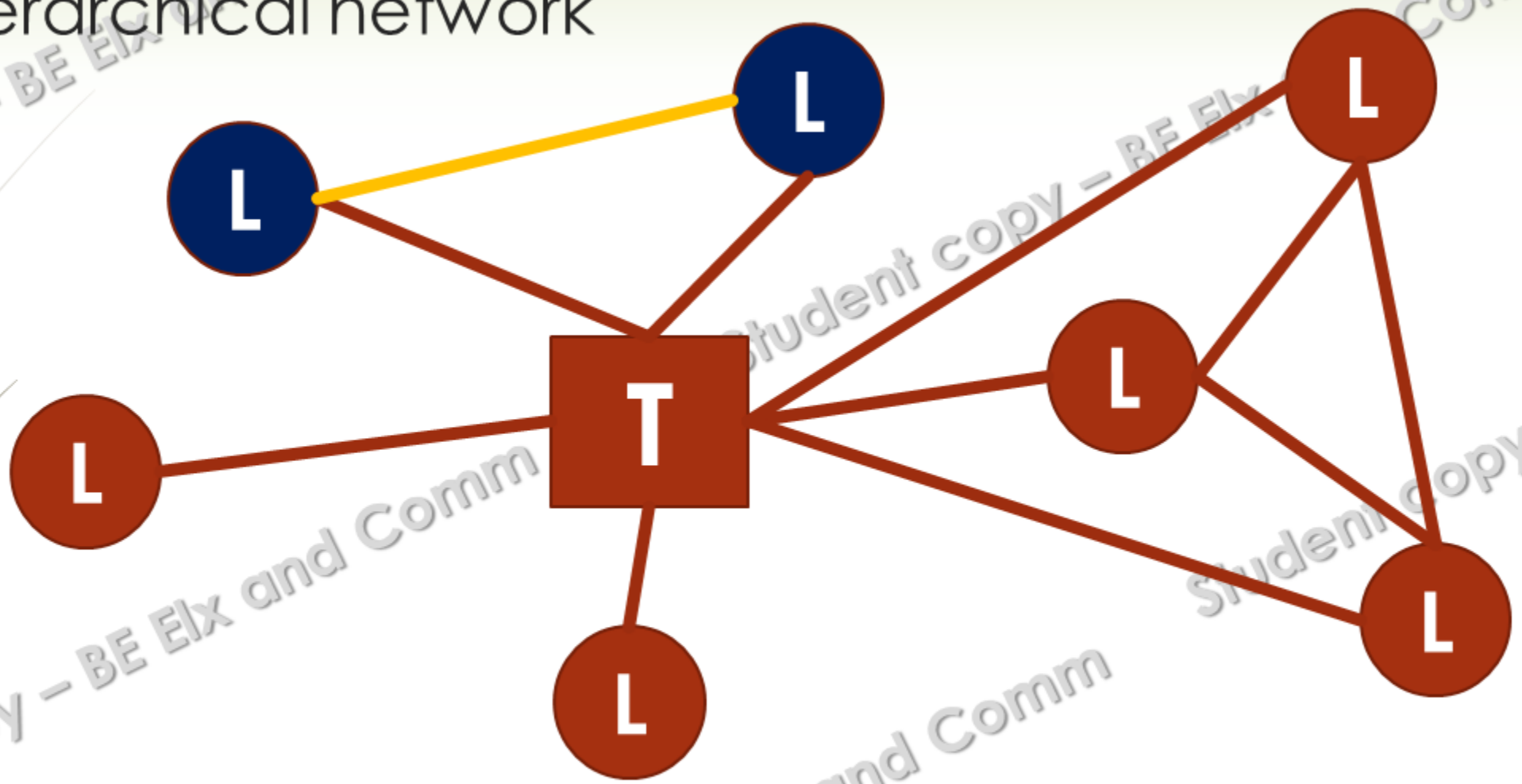
- T – tandem exchange
- L- Local exchange

Hierarchical network



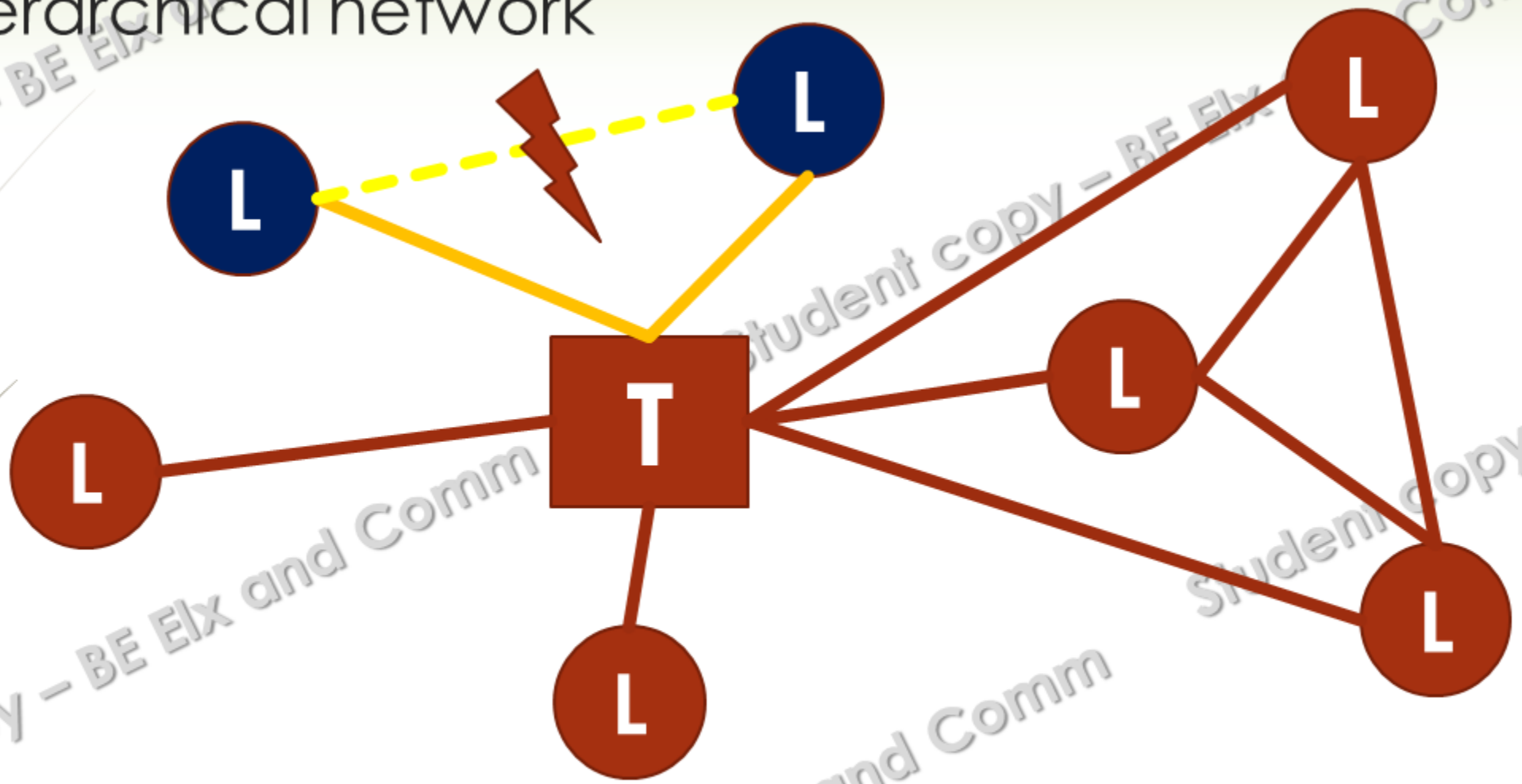
If the cost of junction exchange is high, it will be uneconomic to connect all exchange directly and cheaper to connect customers of local exchange via a central switching center called Tandem exchange.

Hierarchical network



Direct junction between two local exchange is economic when there is a high community of interest between their customers or when distance between them is short

Hierarchical network

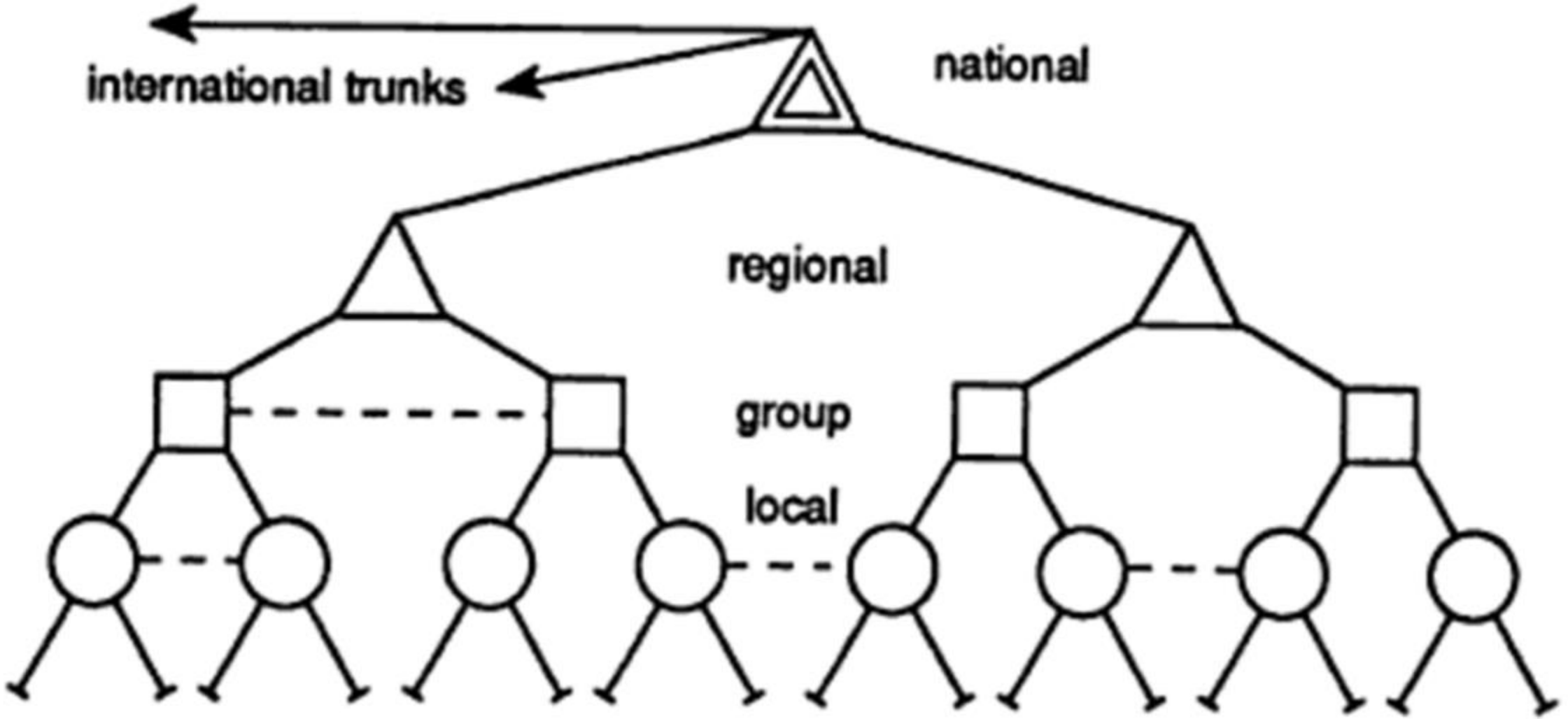


Automatic alternative routing (AAR) – If an originating exchange is unstable to find a free circuit on direct route to destination exchange, it automatically routes the call through higher level of exchange

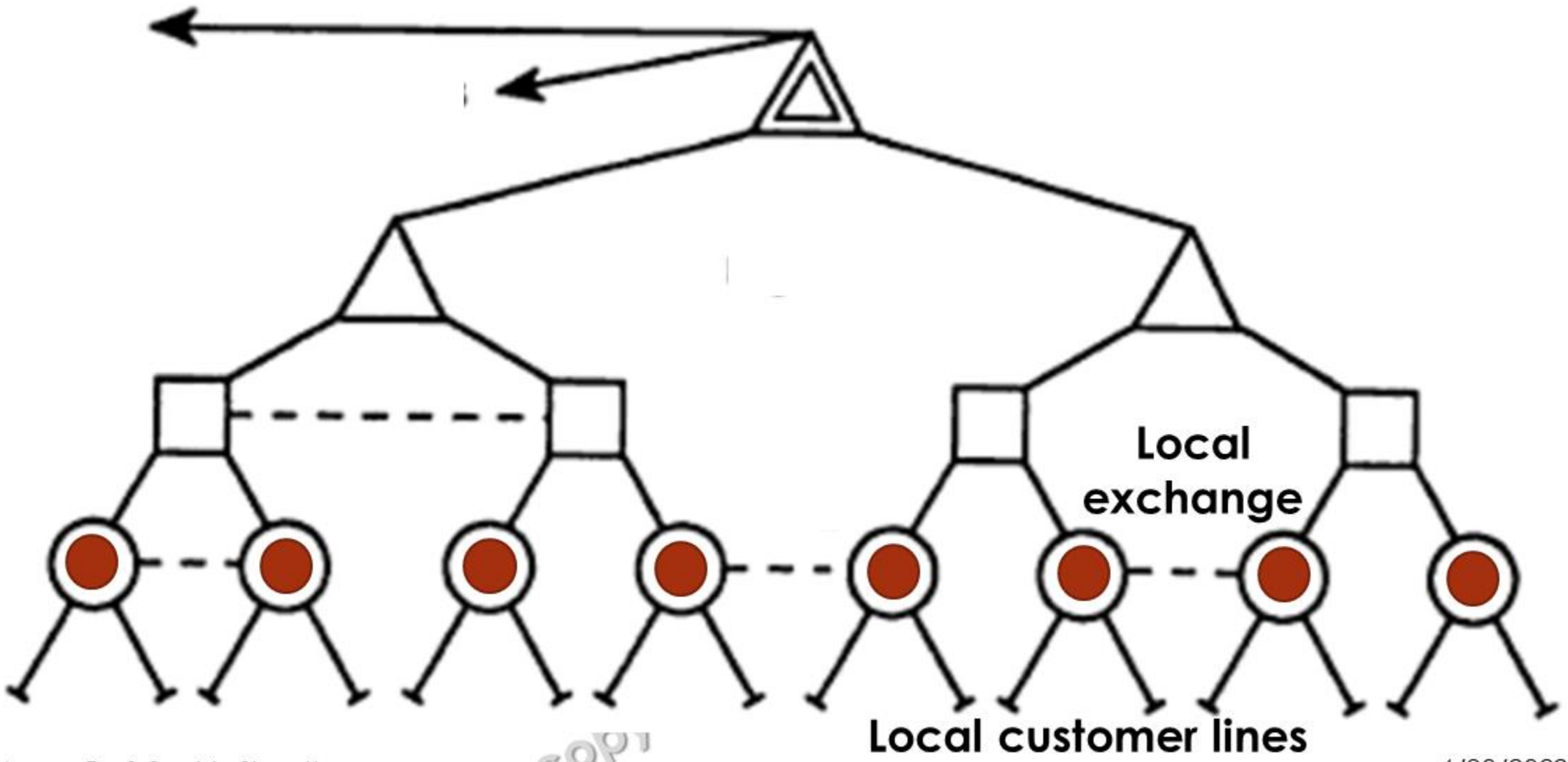
Hierarchical network

- Different areas of the country are interconnected by long distance circuits that form trunk network or toll network
- Uneconomic for all trunk exchange of country to be fully interconnected.
- Routing between different areas provided by tandem connections via trunk transit exchange
- For larger cities, even this is insufficient and hence needs higher level of switching centers – Tree network

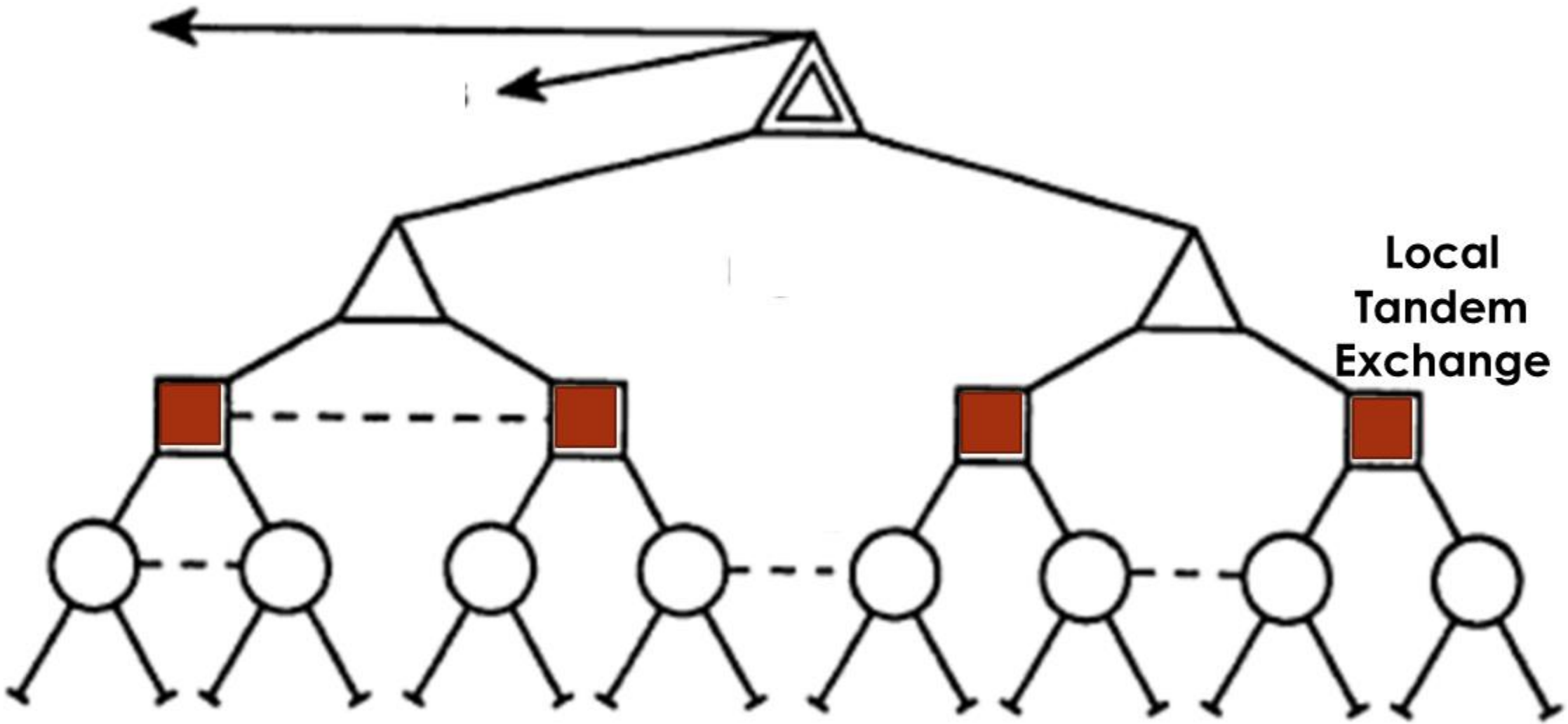
Hierarchical network



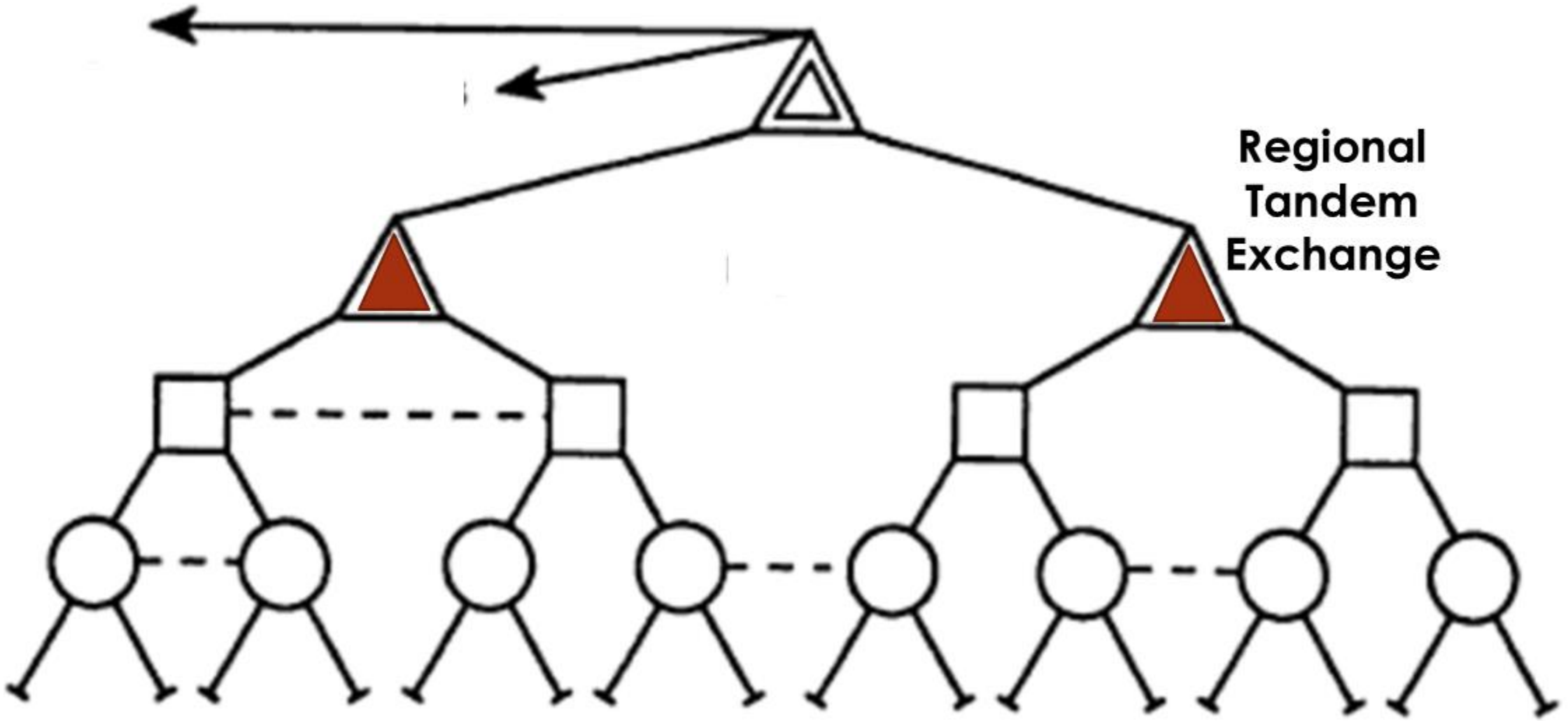
Hierarchical network



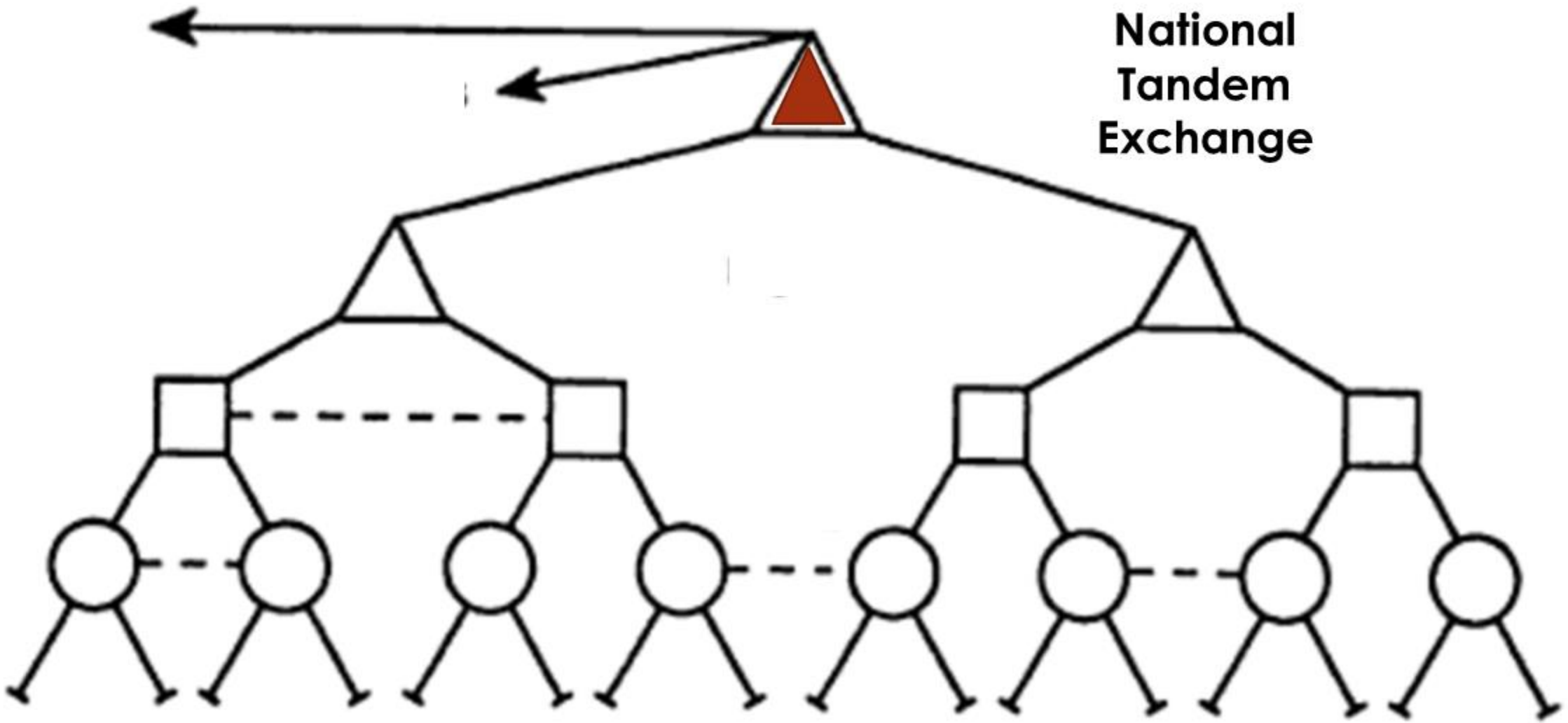
Hierarchical network



Hierarchical network

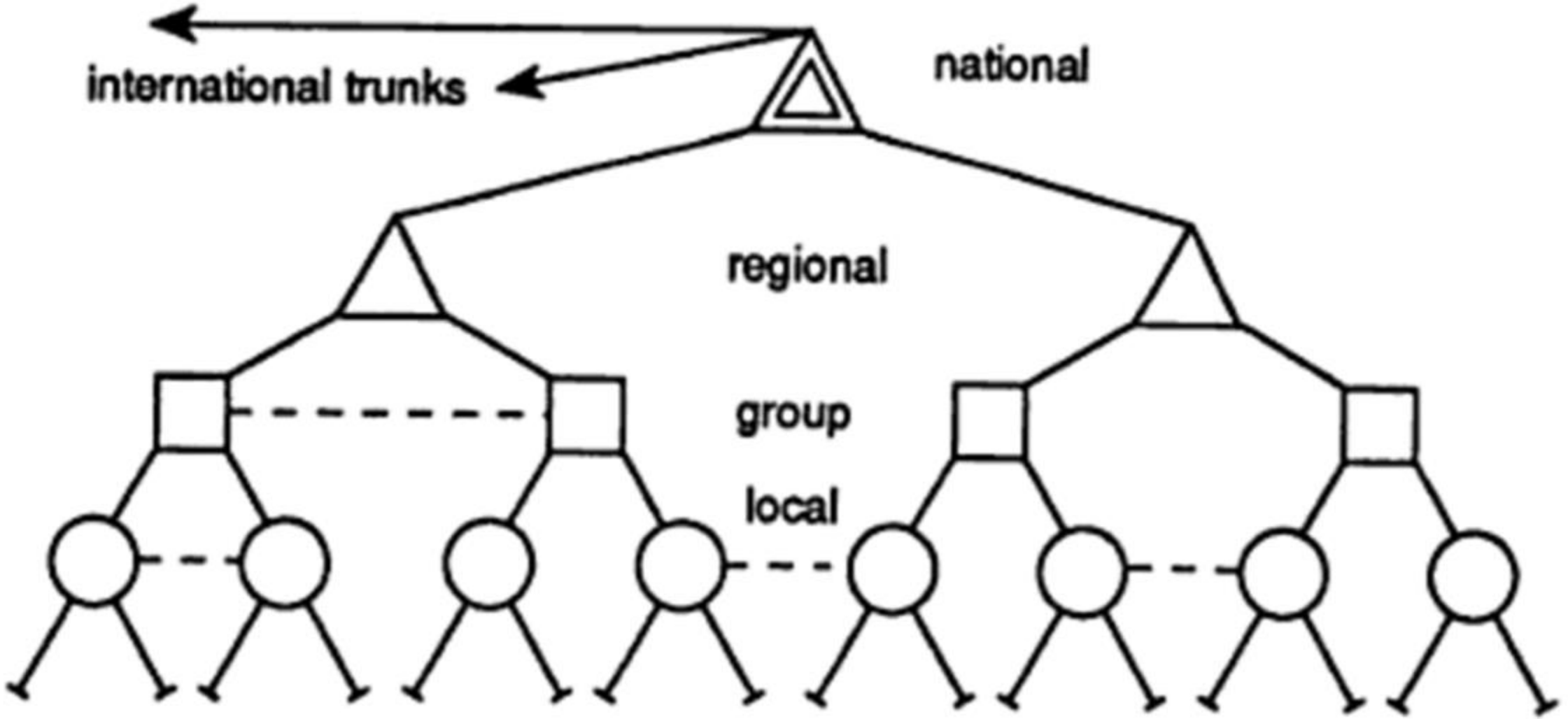


Hierarchical network



International Gateway Exchange

Hierarchical network



Hierarchical network

1. Local network

- Connects customer stations to their local exchange
- Subscriber distribution network, customer access network or customer loop

2. Junction network

- Interconnects a group of local exchange serving an area and a tandem or trunk exchange

3. Trunk or toll network

- Provides long distance circuits between local areas throughout the country
- Totality of (2) and (3) is sometimes also called core network, inner core consisting of trunk n/w and outer junction n/w

Hierarchical network

- Below this hierarchy some customers have internal lines serving extension telephones
- These are connected to one another or to the lines from Public exchange by private branch exchange (PBX)
- For data communications, they have LANs.
- VANs (value added network services) – connections to commercial providers of value added network services like voice mail boxes
- Besides, exchange and networks, needs of signalling
- So, telecommunication network mainly consists of:
  - Transmission system
  - Switching system
  - Signalling system

Telephone conversation

- Calling subscriber : one who initiates call
- Called subscriber: one for whom call is destined

Signalling techniques in telecommunication

- Signalling conveys intelligence needed for one subscriber to interconnect with another in that network
- Also provides supervision of call along the path
- Also gives subscriber certain status information, such as dial tone, busy tone and ringing
- Metering pulses for call charging may also be considered a form of signalling

- Classified as:

1. Subscriber loop signalling
2. Interexchange signalling

Subscriber loop signalling

- Functions are to establish, maintain and release telephone conversation
- Five subscriber related signalling functions performed in automatic switching systems

1. Dial tone : respond to the calling subscriber to obtain identification of called party
2. Ringing tone: ring bell of called party
3. Ring-back tone: inform calling party that call is being established
4. Busy tone: Inform calling subscriber, if called party is busy
5. Dial tone: Inform calling subscriber if called party is unobtainable for some reason

Technical structure of telephone office

- Central office switch subscriber telephone
- Details on the path that must be set up to interconnect two telephones and equipment used for this
- Structure can be divided into three section

1. Subscriber loop or subscriber line section
2. Switching section
3. Interexchange transmission plant

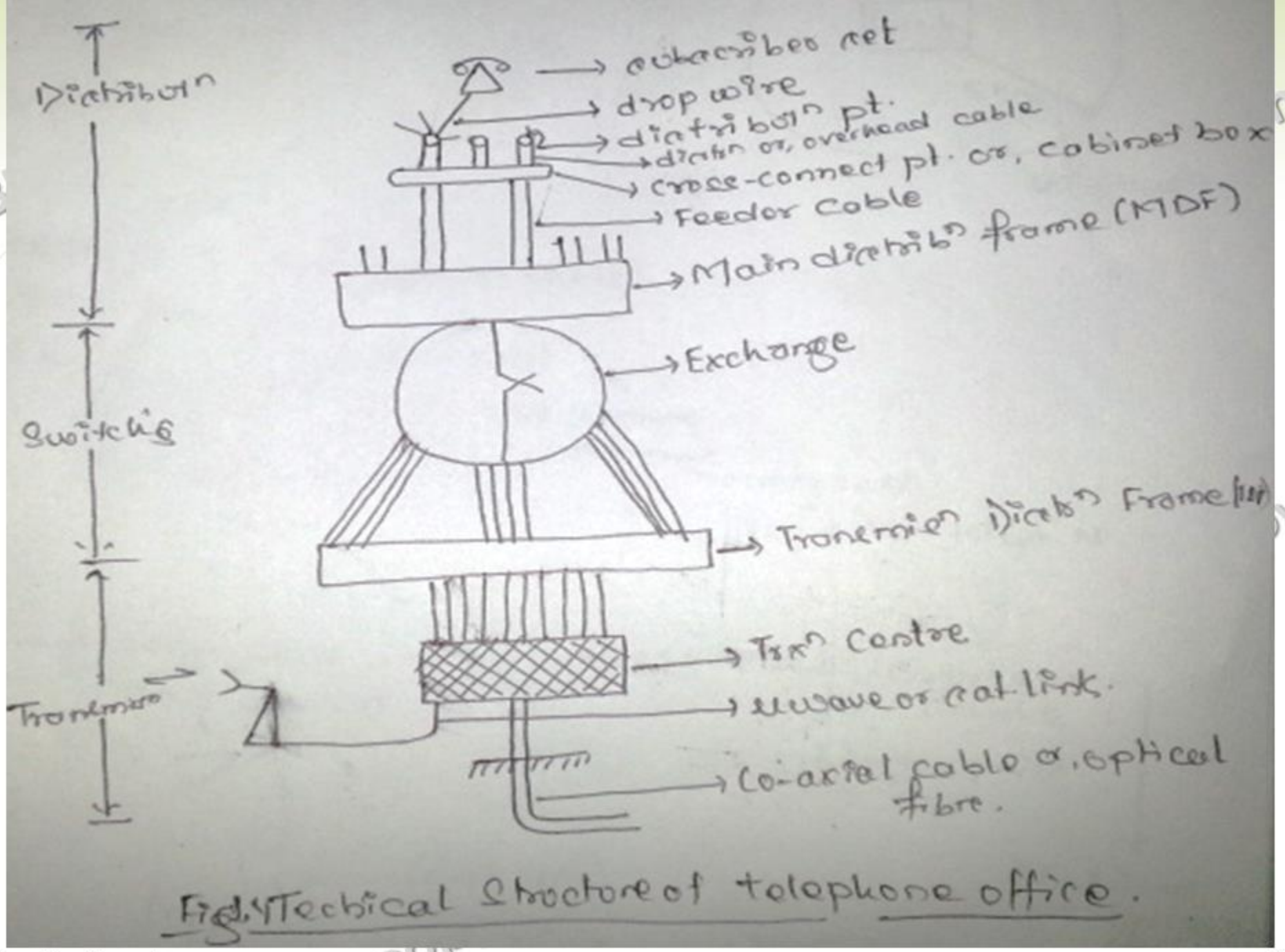
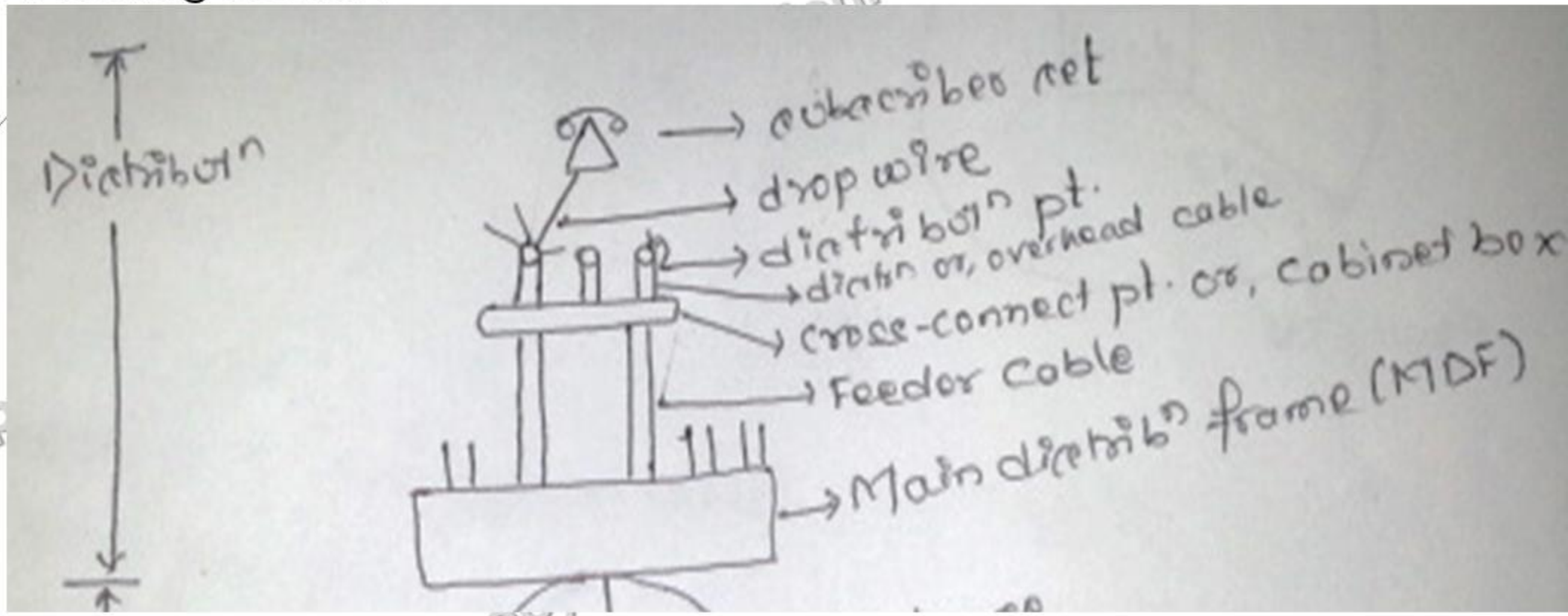


Fig: Technical Structure of telephone office.

Technical structure of telephone office

1. Subscriber section

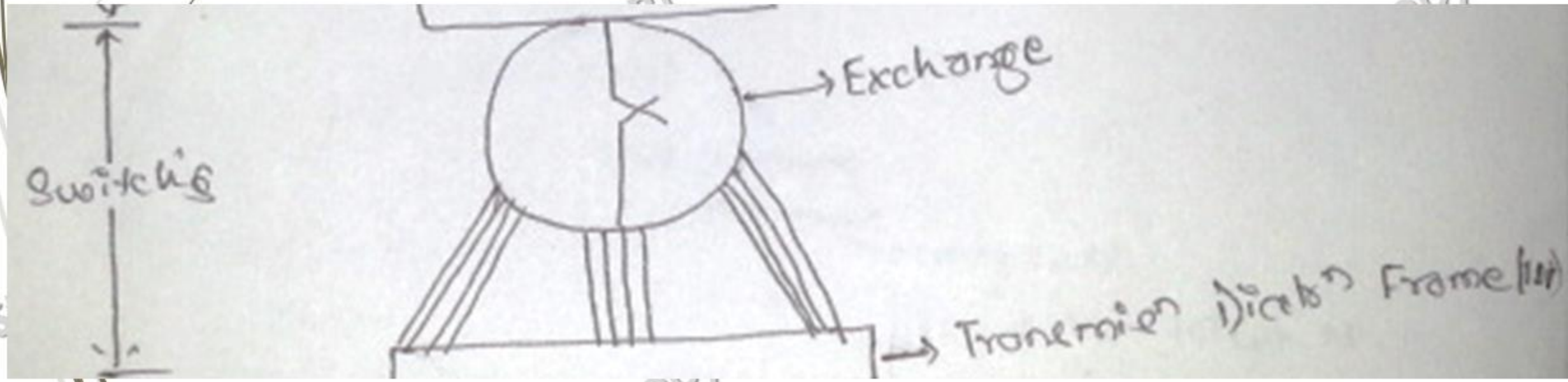
- Section between subscriber telephone set and his local switching section



Technical structure of telephone office

2. Switching section

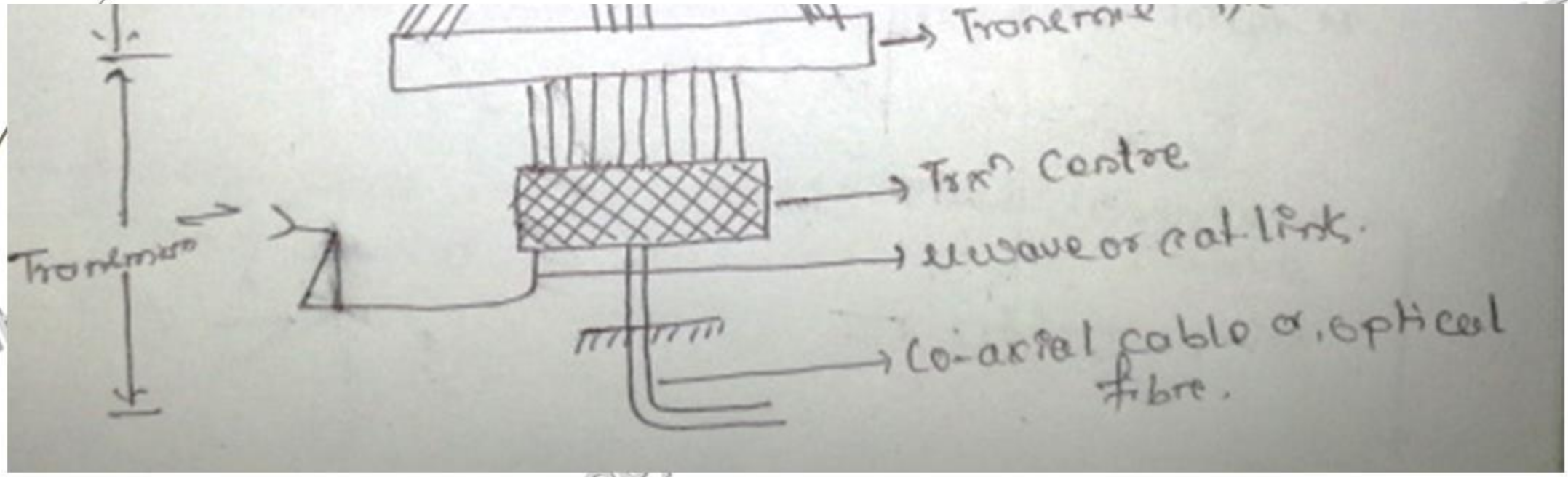
- Enables each calling subscriber to be temporarily connected to the called subscriber either directly if at same exchange (local) or through trunk exchange



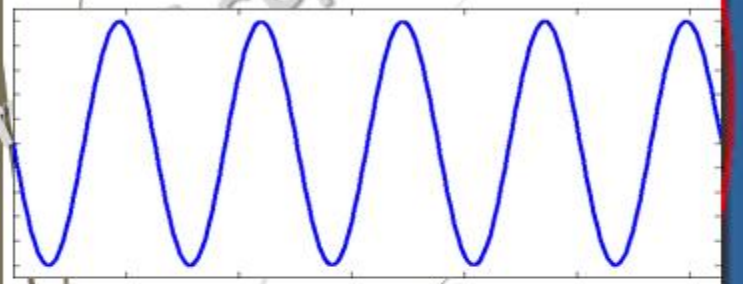
Technical structure of telephone office

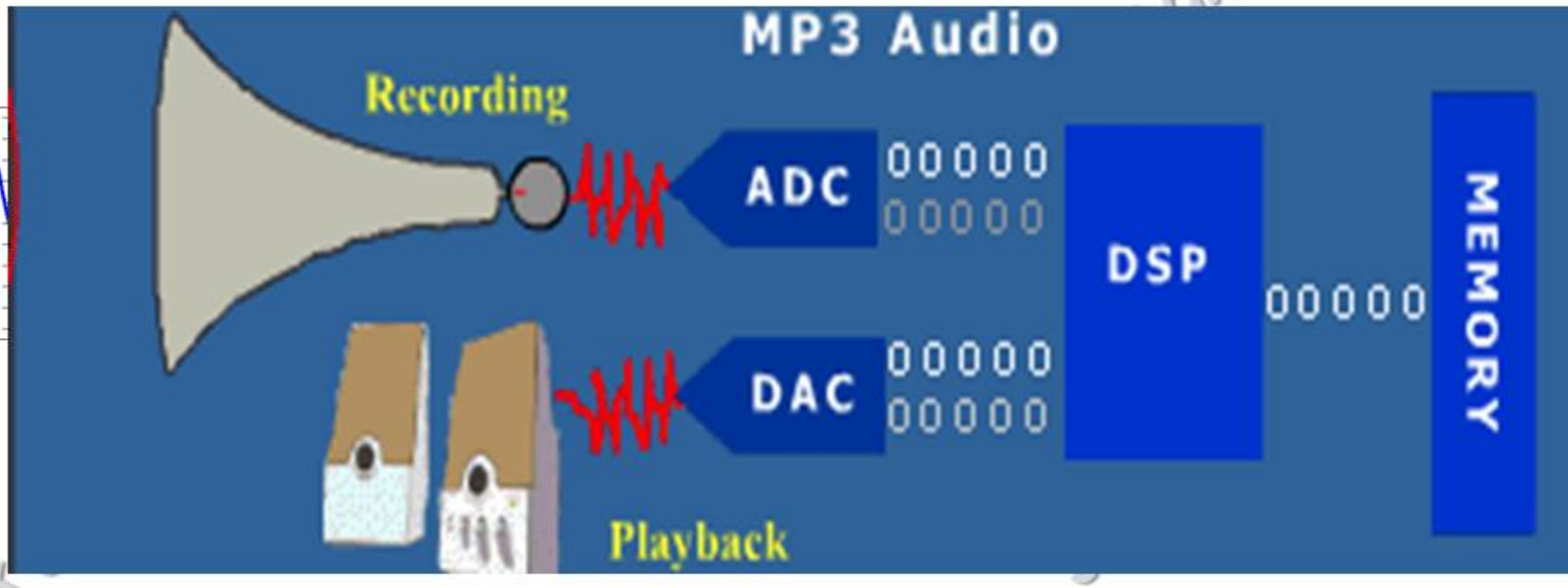
3. Transmission i.e. Interexchange transmission plant

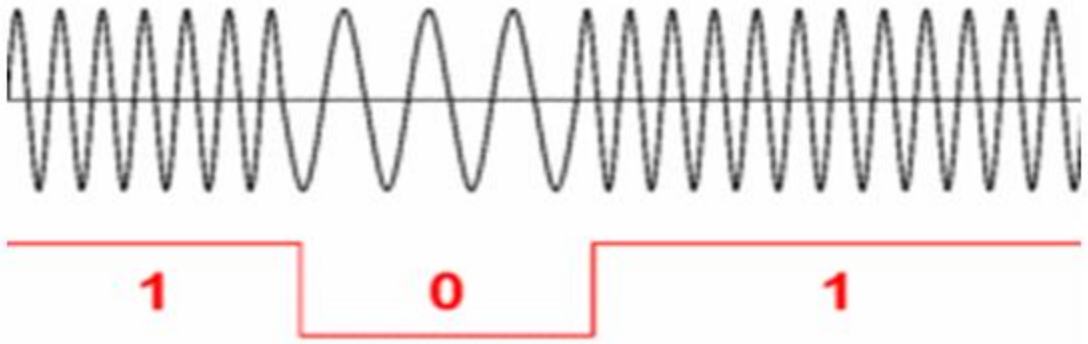
- Part of network between switching centers
- Transmission centers are themselves connected by microwave systems, co-axial cables, optical fibers, etc



Comparison between analog and digital transmission







Comparison between analog and digital transmission

Feature

- Continuously variable, in both amplitude and frequency
- Discrete signal, represented as either changes in voltage or changes in light levels

Traffic measurement

- Hz (for example, a telephone channel is 4KHz)
- Bits per second (for example, a T-1 line carries 1.544Mbps, and an E-1 line transports 2.048Mbps)

Bandwidth

- Low bandwidth (4KHz), which means low data transmission rates (up to 33.6Kbps) because of limited channel bandwidth
- High bandwidth that can support high-speed data and emerging applications that involve video and multimedia

Network capacity

- Low; one conversation per telephone channel
- High; multiplexers enable multiple conversations to share a communications channel and hence to achieve greater transmission efficiencies

Comparison between analog and digital transmission

Network manageability

- Poor; a lot of labor is needed for network maintenance and control because dumb analog devices do not provide management information streams that allow the device to be remotely managed
- Good; smart devices produce alerts, alarms, traffic statistics, and performance measurements, and technicians at a network control center (NCC) or network operations center (NOC) can remotely monitor and manage the various network elements

Power requirement

- High because the signal contains a wide range of frequencies and amplitudes
- Low because only two discrete signals—the one and the zero—need to be transmitted

Security

- Poor; when you tap into an analog circuit, you hear the voice stream in its native form, and it is difficult to detect an intrusion
- Good; encryption can be used

Conversion: Codecs and Modems

Error rates

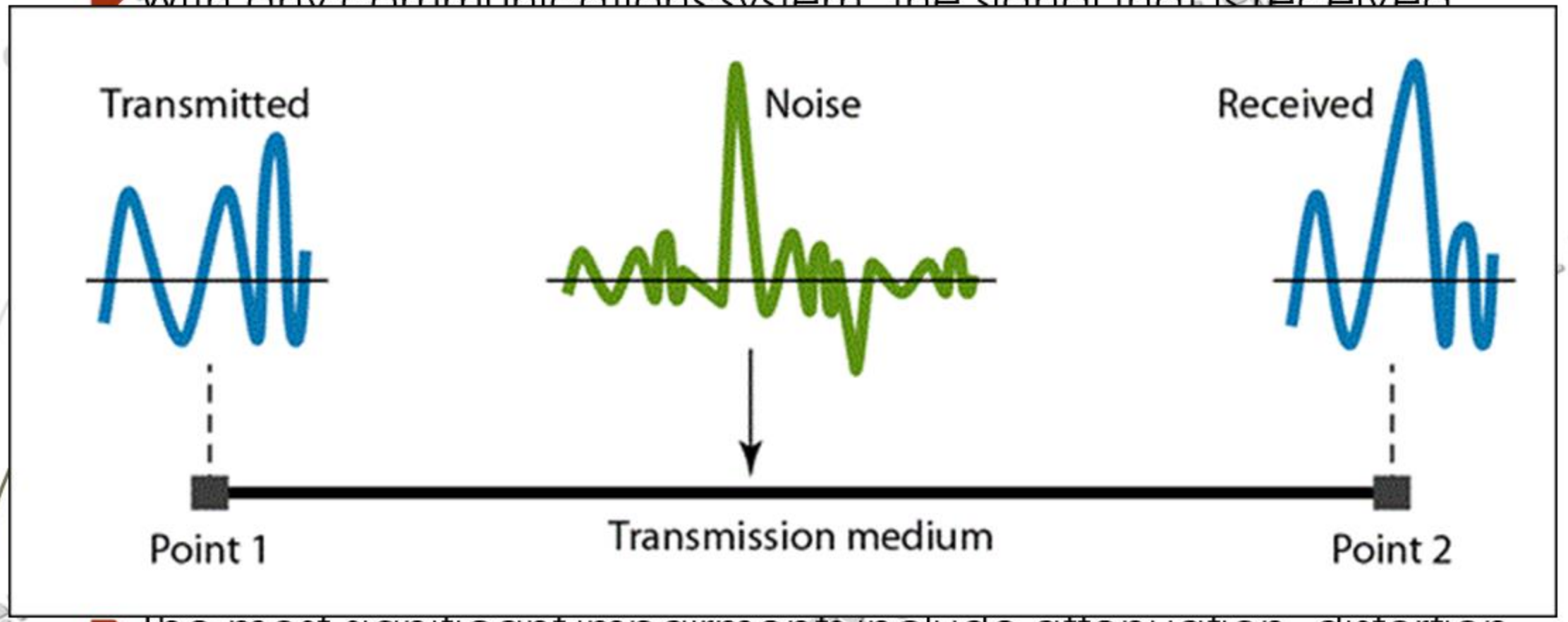
- High; 10^{-5} bits (that is, 1 in 100,000 bits) is guaranteed to have an error
- Low; with twisted-pair, 10^{-7} (that, is 1 in 10 million bits per second) will have an error, with satellite, 10^{-9} (that is, 1 in 1 billion per second) will have an error, and with fiber, 10^{-11} (that is only 1 in 10 trillion bits per second) will have an error

Transmission impairments

- With any communications system, the signal that is received may differ from the signal that is transmitted, due to various transmission impairments.
- Signals travel through transmission media, which are not perfect.
  - The imperfection causes signal impairment.
  - This means that the signal at the beginning of the medium is not the same as the signal at the end of the medium.
- Consequences are:
  - For analog signals: degradation of signal quality
  - For digital signals: bit errors
- The most significant impairments include attenuation, distortion and noise

Transmission impairments

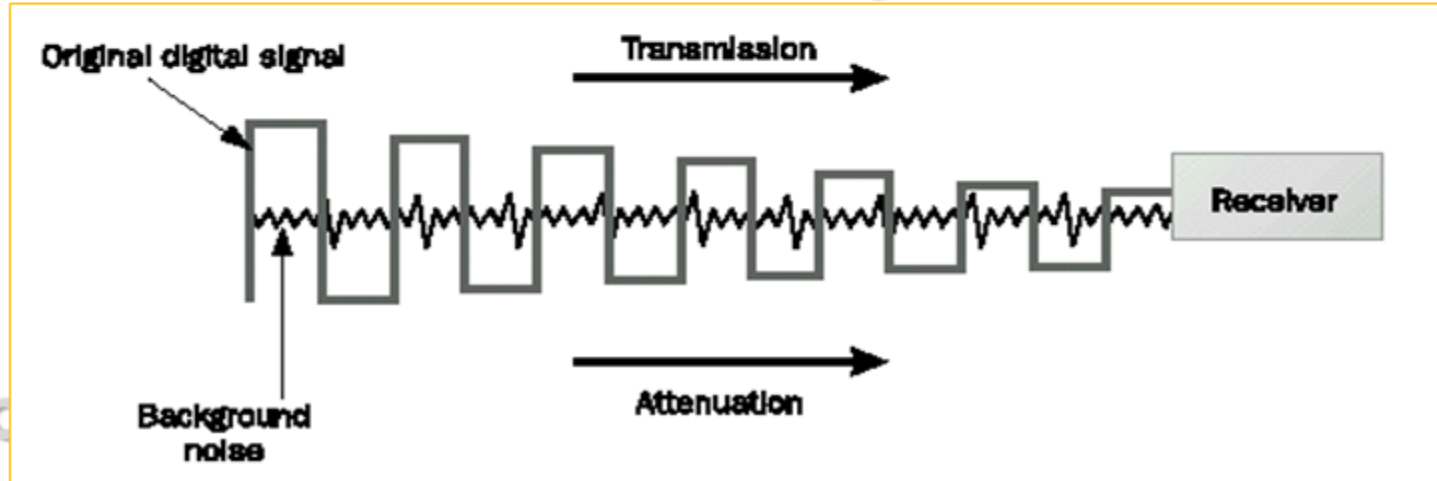
- With any communications system, the signal that is received



- The most significant impairments include attenuation, distortion and noise

Signal attenuation

- With distance, signal strength decreases
- The decrement depends on medium
  - For *guided media*, the attenuation is generally exponential and thus is typically expressed as a constant number of decibels per unit distance.
  - For *unguided media*, attenuation is a more complex function of distance and the makeup of the atmosphere.
- Subjective listening tests have shown that the preferred acoustic-to-acoustic loss in a telephone connection should be in the neighborhood of 8dB.



Signal attenuation (contd…)

Three considerations for the transmission engineer:

1. A received signal must have ***sufficient strength*** so that the electronic circuitry in the receiver can detect the signal.
2. The signal must maintain a level ***sufficiently higher than noise*** to be received without error.

(Solution for 1 and 2: Use of amplifiers/repeaters)

3. Attenuation is often an increasing function of frequency. This leads to ***attenuation distortion***.
   - some frequency components are attenuated more than other frequency components.

Note: Attenuation distortion is particularly noticeable for analog signals: the attenuation varies as a function of frequency, therefore the received signal is distorted, reducing intelligibility.

Distortion

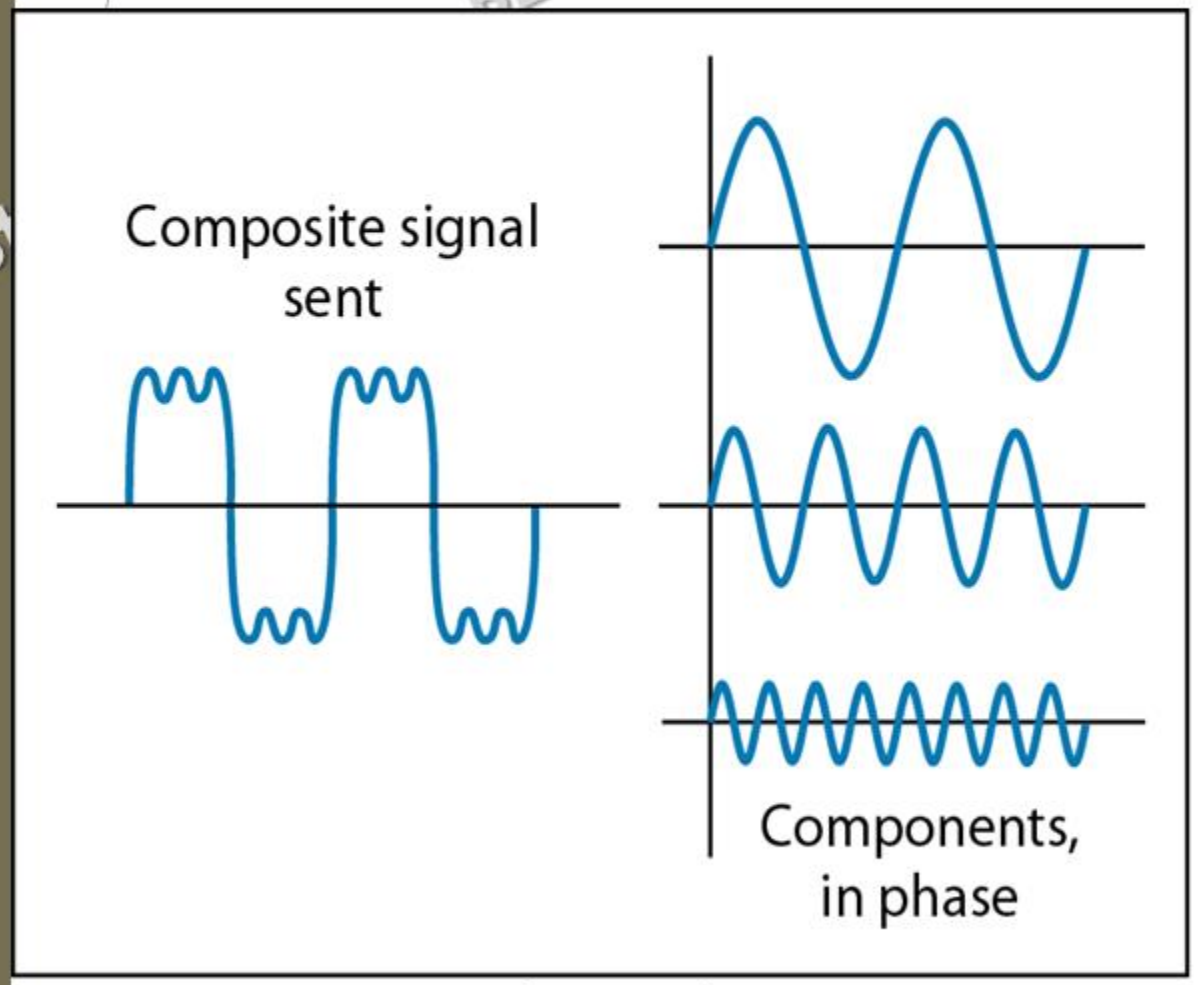
- Distortion is deterministic (in contrast to noise and interference); it is repeated every time the same signal is sent through the same path in network.
  - Thus distortions can be controlled or compensated for once the nature of the distortion is understood.
- There are many different types and sources of distortion within the telephone network.
- Some distortions arise from non-linearity in the network, such as carbon microphones, saturating voice-frequency amplifiers, and unmatched companders.
- Other distortions are linear in nature and are usually characterized in the frequency domain as either ***amplitude distortion*** or ***phase distortion***.

Distortion (contd…)

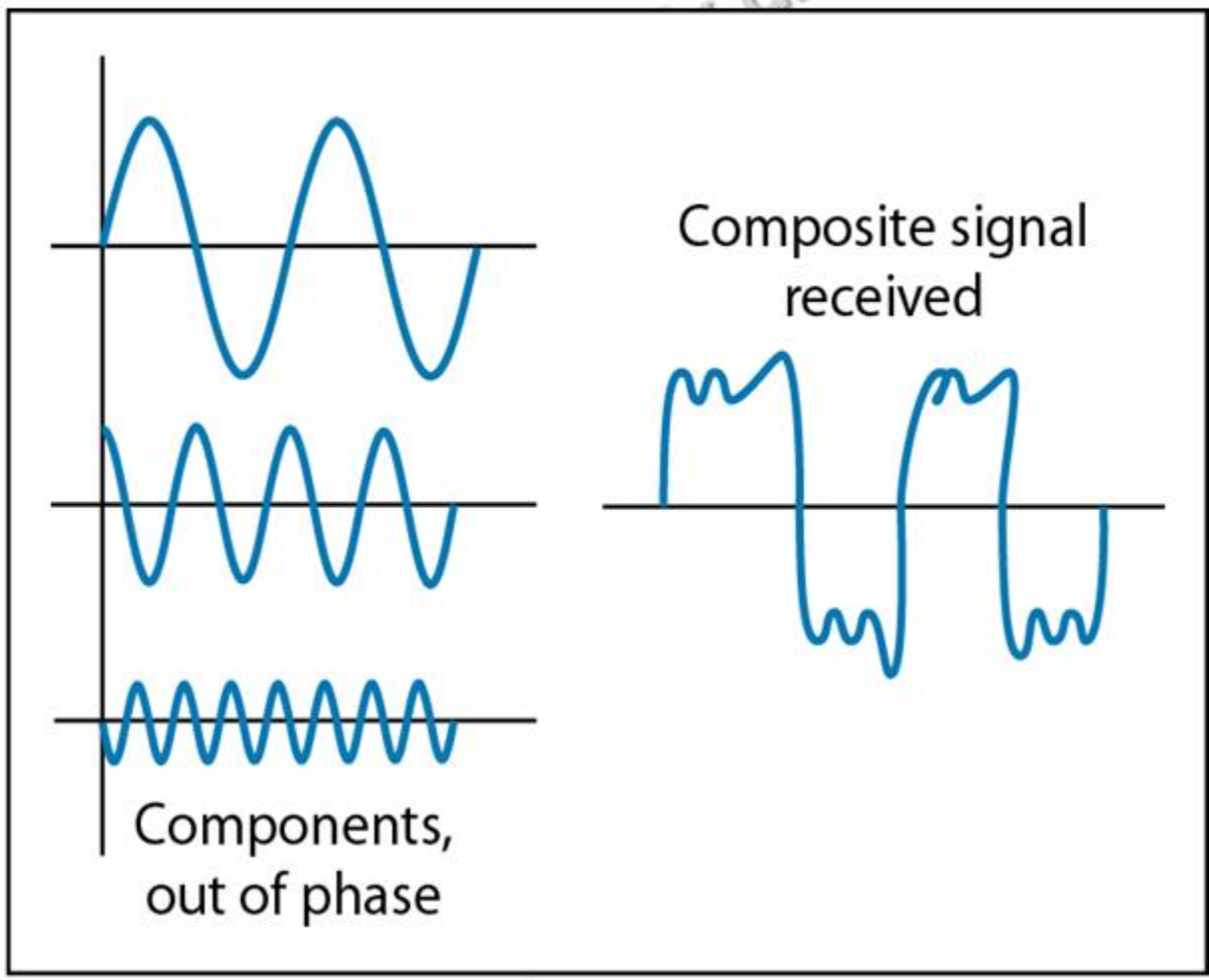
- **Amplitude distortion** refers to attenuating some frequencies in the voice spectrum more than others.

- **Phase distortion** is related to the delay characteristics of the transmission medium.
  - Ideally a transmission system should delay all frequency components in a signal uniformly, so the proper phase relationship exist at the receiving terminal.
  - If individual frequency components experience differing delays, the time-domain representation at the output becomes distorted because superposition of the frequency terms is altered at the output.

Distortion (contd…)



At the sender



At the receiver

Noise

- Noise is the insertion of unwanted signals onto the transmission signal.
- Its effect is to distort the signal during transmission
- It particularly affects digital signals.
  - The greater the noise the greater the bit error rate.

Noise

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  transmission signa
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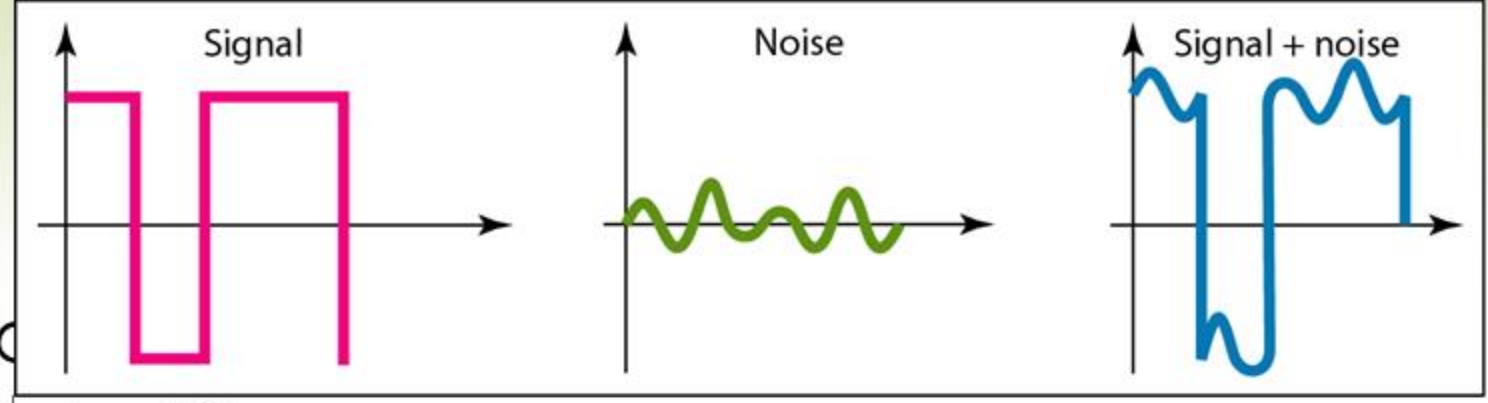
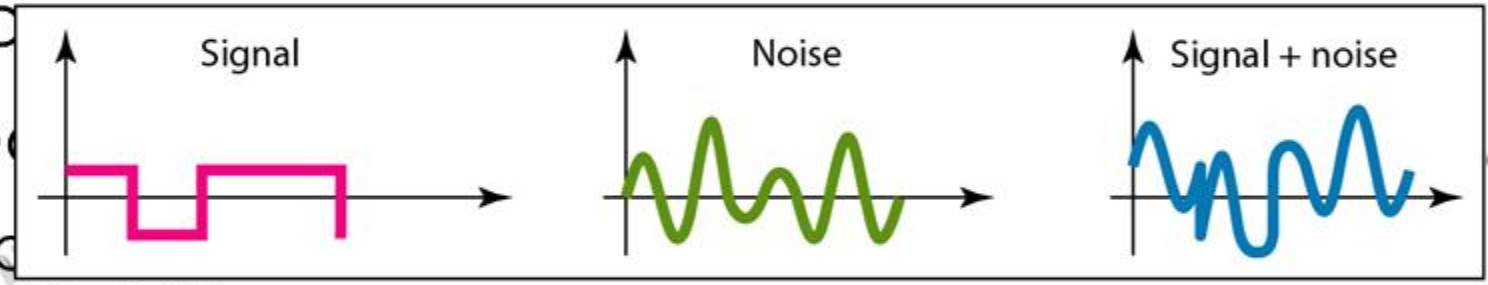
  - The greater the no
- Basic noise categories include
  1. Thermal Noise
  2. Intermodulation noise
  3. Impulse noise etc



a. Large SNR

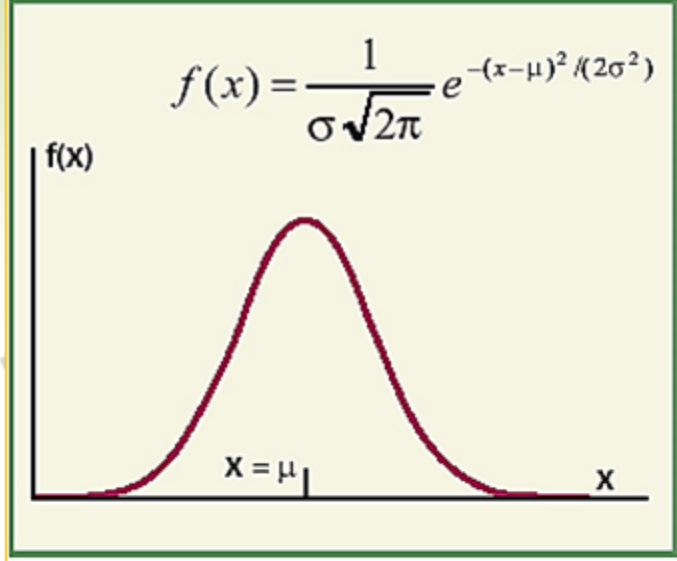


b. Small SNR

Noise (contd…)

1 **Thermal noise** (or **white noise**)

- Due to thermal agitation of electrons
- white noise with Gaussian distribution of amplitude values.
- It is present in all electronic devices and transmission media, and is a function of temperature.
  - Battery systems used to power customer loops are also a source of this type of noise
- Cannot be eliminated, and therefore places an upper bound on communications system performance.

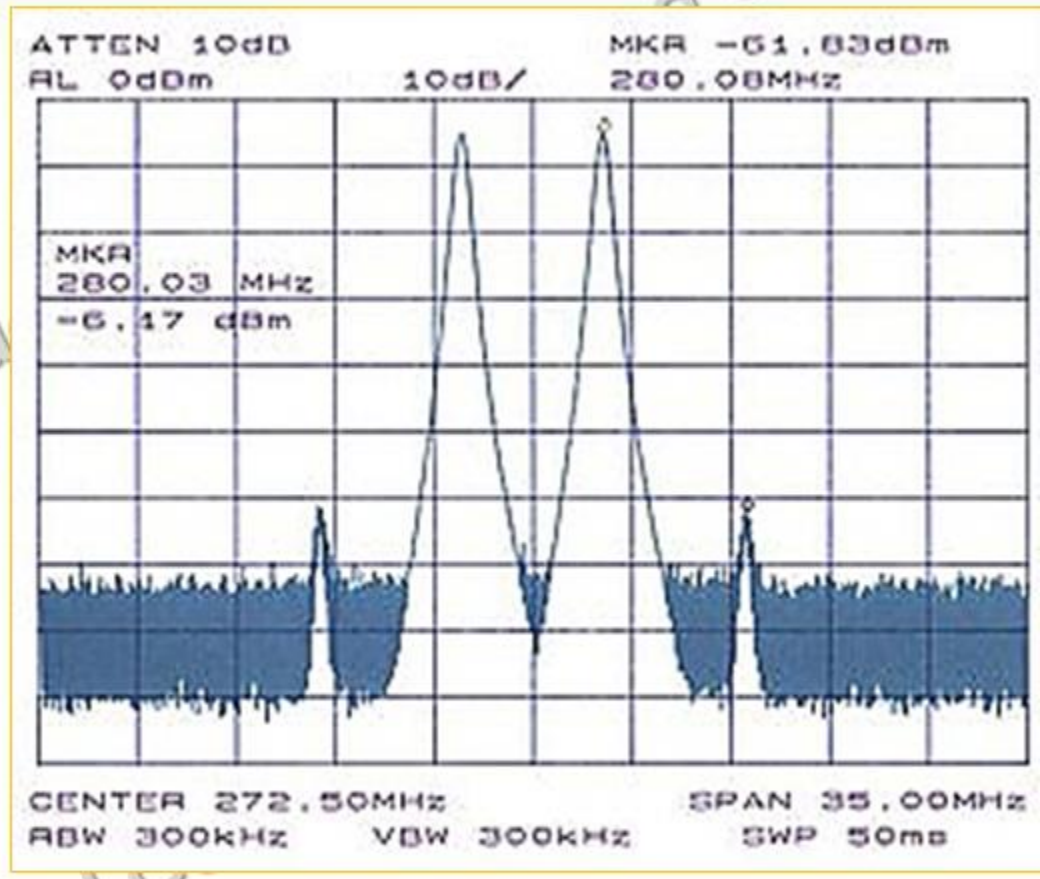


1. Gaussian noise can be represented by a distribution of fluctuations about a mean.

Noise (contd…)

2 Intermodulation noise

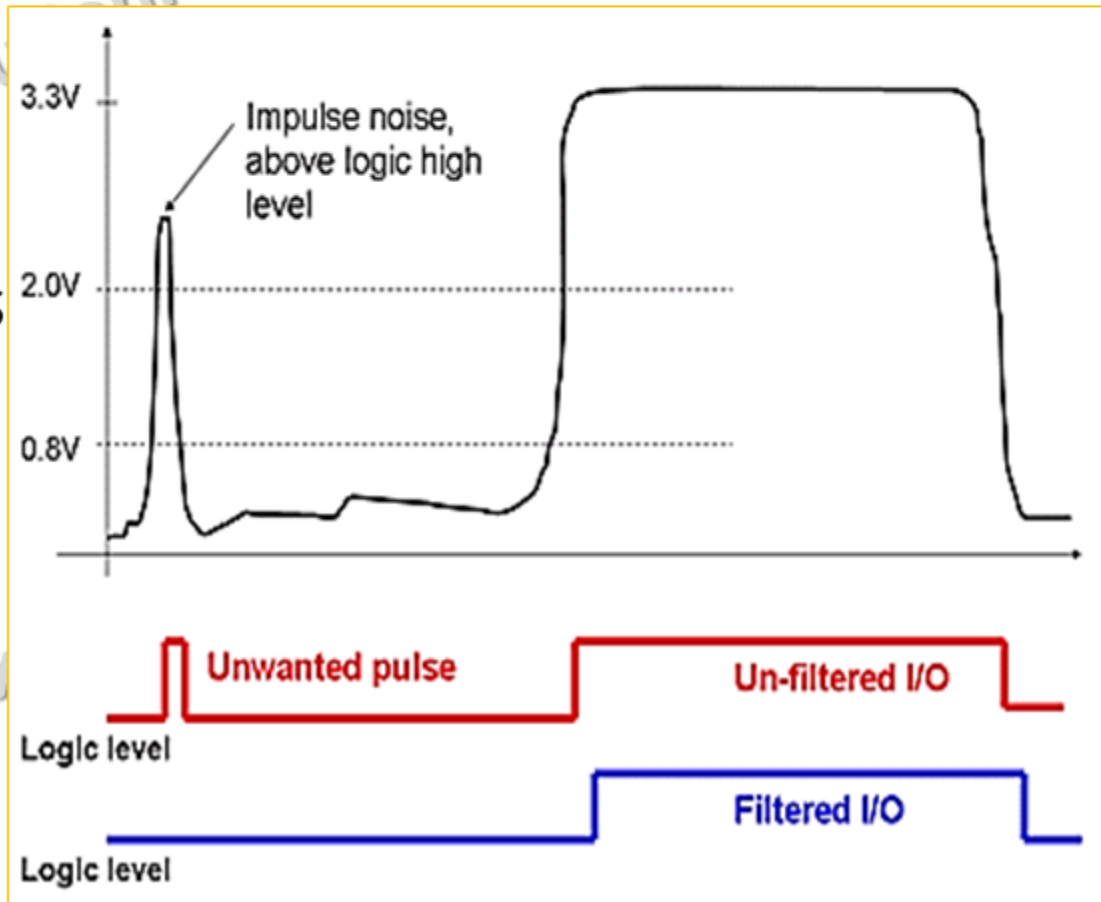
- When signals at different frequencies share the same transmission medium, the result may be intermodulation noise.
- Signals at a frequency that is the sum or difference of original frequencies or multiples of those frequencies will be produced.



Noise (contd…)

3 Impulse noise

- Impulse noise is non-continuous, consisting of irregular pulses or noise spikes of short duration and of relatively high amplitude.
- It is generated from a variety of cause, e.g., external electromagnetic disturbances such as lightning.
- It is generally only a minor annoyance for analog data.
- But it is the primary source of error in digital data communication.



Interference

- Noise and interference both characterized as unwanted electrical energy fluctuating in an unpredictable manner.
- Interference is usually more structured than noise since it arises as unwanted coupling from just a few signals in the network.
  - anything which alters, modifies, or disrupts a message as it travels along a channel
- Various categories of Interference:
  - **Electromagnetic interference** (EMI), disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from an external source

Interference

- **Common mode interference** (CMI), Interference that appears on both signal leads (signal and circuit return), or the terminals of a measuring circuit, and ground.
  - A form of coherent interference that affects two or more elements of a network in a similar manner (*i.e.* highly coupled) as distinct from locally generated noise or interference that is statistically independent between pairs of network elements.

Interference

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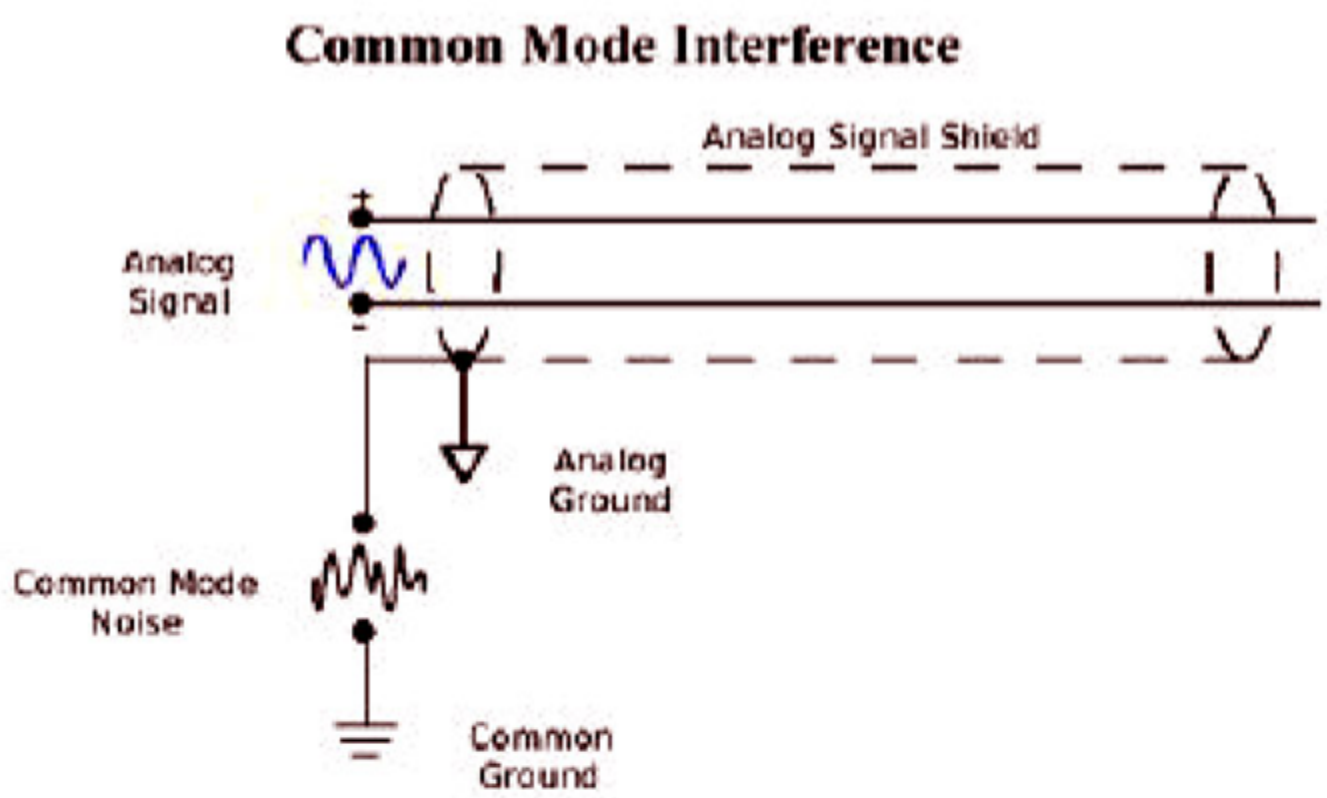

- **Adjacent-channel interference** (ACI), interference caused by extraneous power from a signal in an adjacent channel
  - ACI may be caused by inadequate filtering (such as incomplete filtering of unwanted modulation products in FM systems), improper tuning or poor frequency control (in the reference channel, the interfering channel or both).

Interference

- **Co-channel interference** (CCI), also known as crosstalk
- **Inter-symbol interference** (ISI), distortion of a signal in which one symbol interferes with subsequent symbols
  - This is an unwanted phenomenon as the previous symbols have similar effect as noise, thus making the communication less reliable.
  - ISI is usually caused by multipath propagation or the inherent non-linear frequency response of a channel causing successive symbols to "blur" together.
- **Inter-carrier interference** (ICI), caused by Doppler shift in OFDM modulation

Interference

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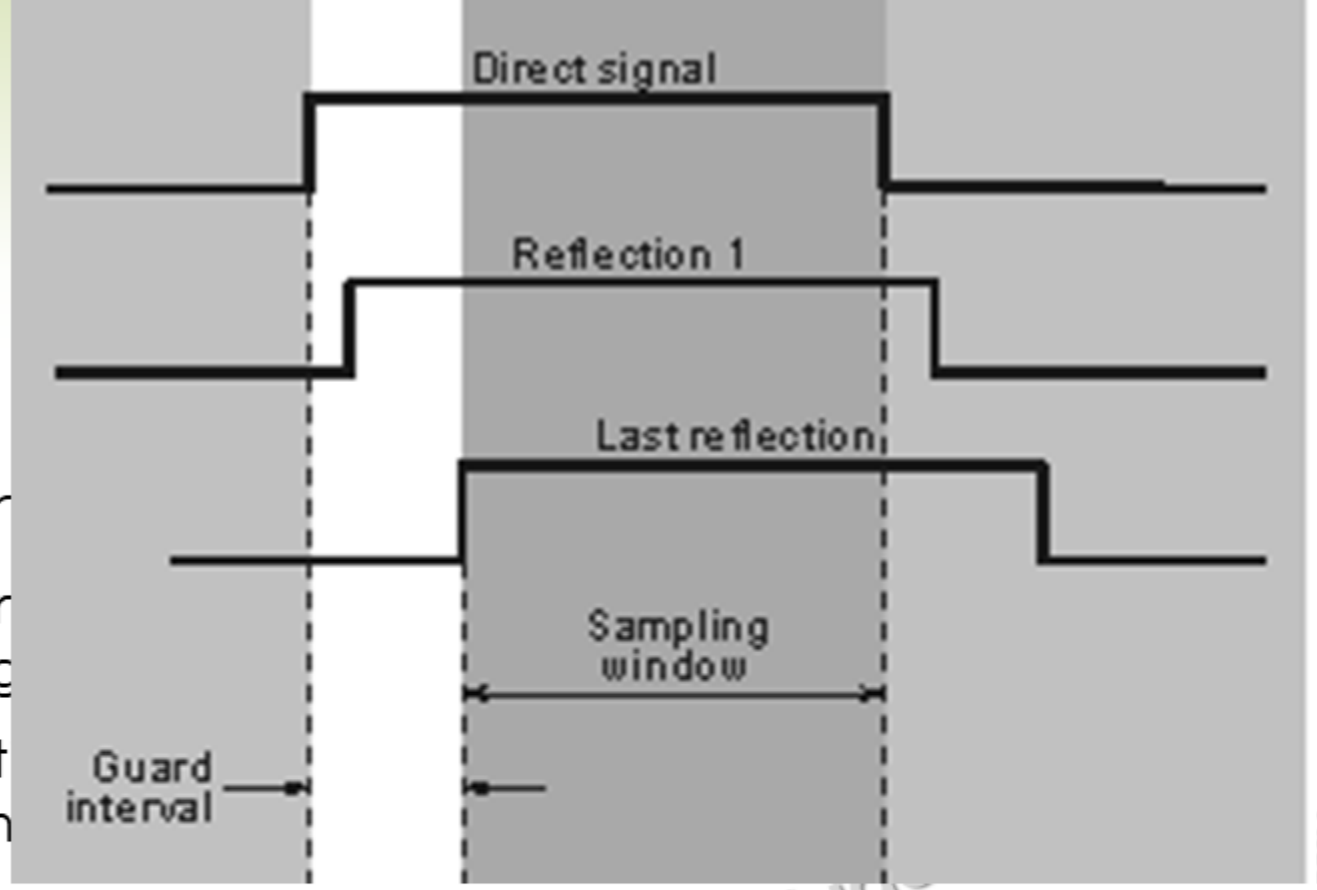

Interference - Crosstalk

- Co-channel interference or CCI is crosstalk from two different radio transmitters using the same frequency.
- phenomenon by which a signal transmitted on one circuit or channel of a transmission system creates an undesired effect in another circuit or channel.
  - usually caused by undesired capacitive, inductive, or conductive coupling from one circuit, part of a circuit, or channel, to another.
- Sources include coupling between wire pairs in a cable, inadequate filtering or carrier offsets in older FDM equipment, effects of non-linear components on FDM signal and inter symbol interference in time division multiplexing (TDM).

Crosstalk (contd…)

- Crosstalk is one of the most disturbing and undesirable imperfections that can occur in a telephone network.
  - In analog systems, is particularly difficult to control since voice signal power levels vary considerably (i.e. across a dynamic range of 40dB).
  - The absolute level of crosstalk energy from a high level signal must be small compared to a desired low-level signal. In fact, crosstalk is more noticeable during speech pause, when the power level of the desired signal is zero.
- Two basic forms of crosstalk of concern to telecommunication engineers are near-end crosstalk (NEXT) and far-end crosstalk (FEXT).
- **Near-end crosstalk** refers to coupling from a transmitter into a receiver at a common location.
  - Often this form of crosstalk is most troublesome because of a large difference in power levels between the transmitted and received signals.
- **Far-end crosstalk** refer to unwanted coupling into received signal from a transmitter at a distant location.

Crosstalk (contd...)

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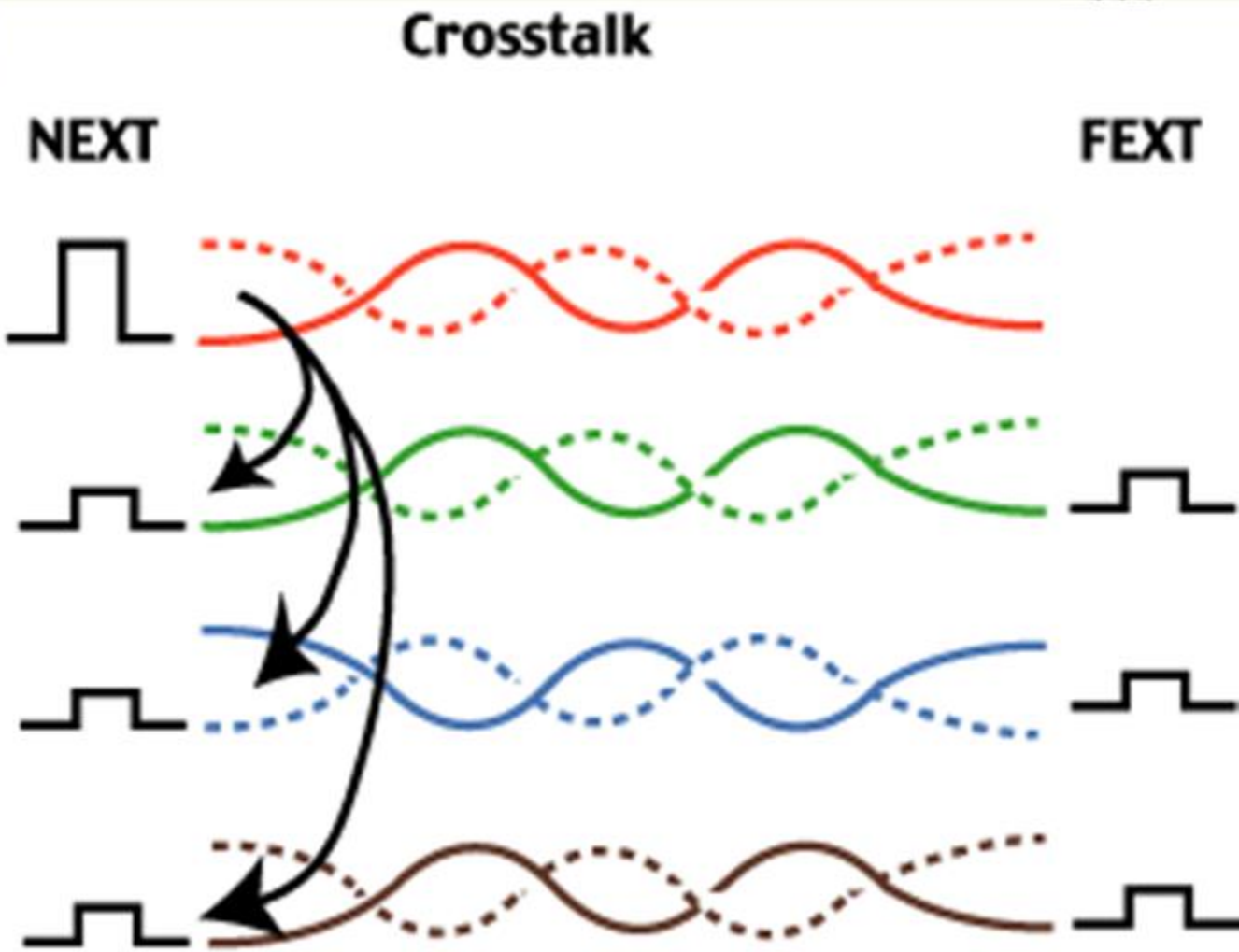
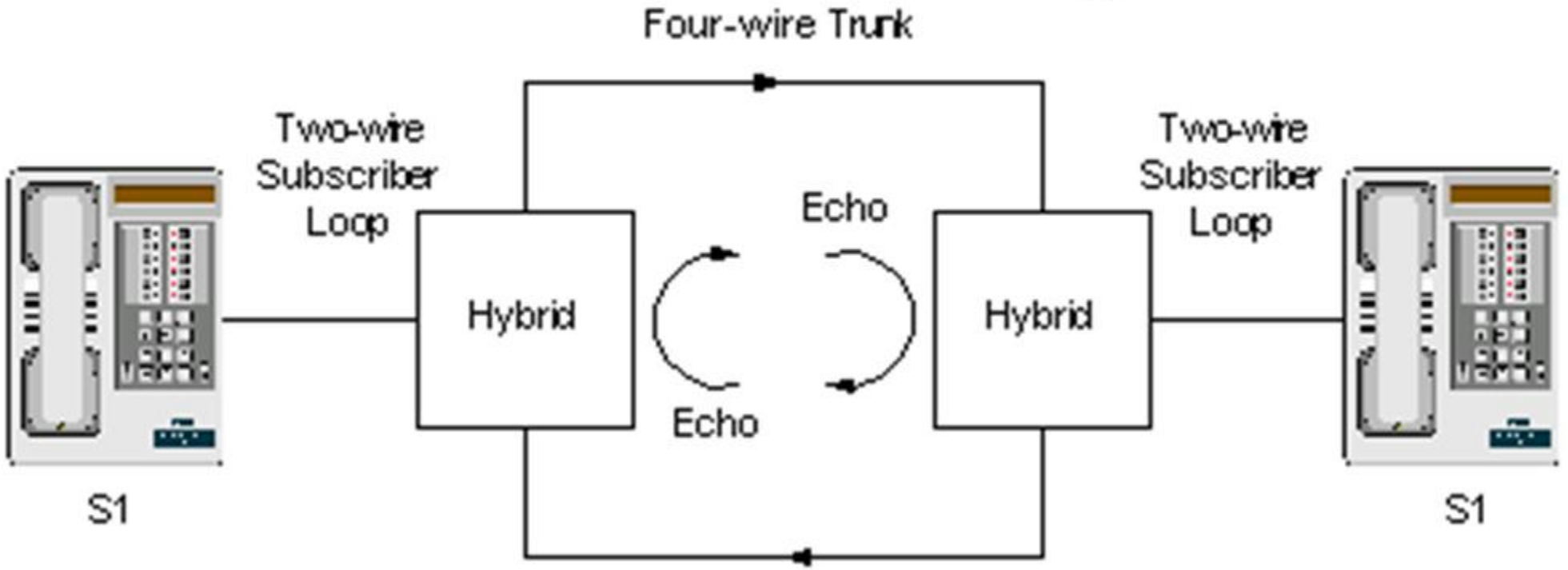


Echoes and singing



Echoes and singing

- Echoes and singing both occur as a result of transmitted signals being coupled into a return path and fed back to the respective sources.
- The most common cause of the coupling is an impedance mismatch at four wire to two wire hybrid.
  - If only one reflection occurs, the situation is referred to as "talker echo".
  - If a second reflection occurs, "listener echo" results.
  - When the returning signal is repeatedly coupled back into the forward path to produce oscillations, **singing** occurs.
- Basically, singing results if the loop gain at some frequency is greater than unity.
  - If the loop gain is only slightly less than unity, a near singing condition causes damped oscillations.
- Singing and near singing conditions have a disturbing effect on both the talker and the listener.

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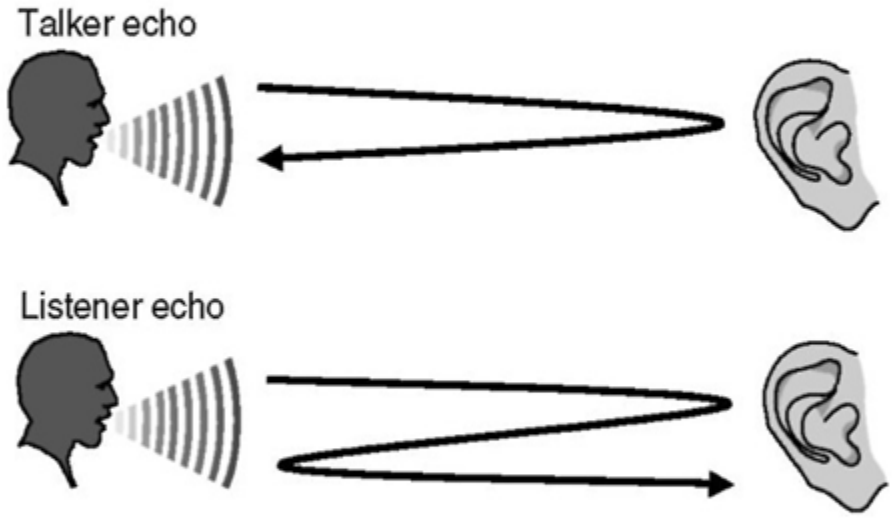
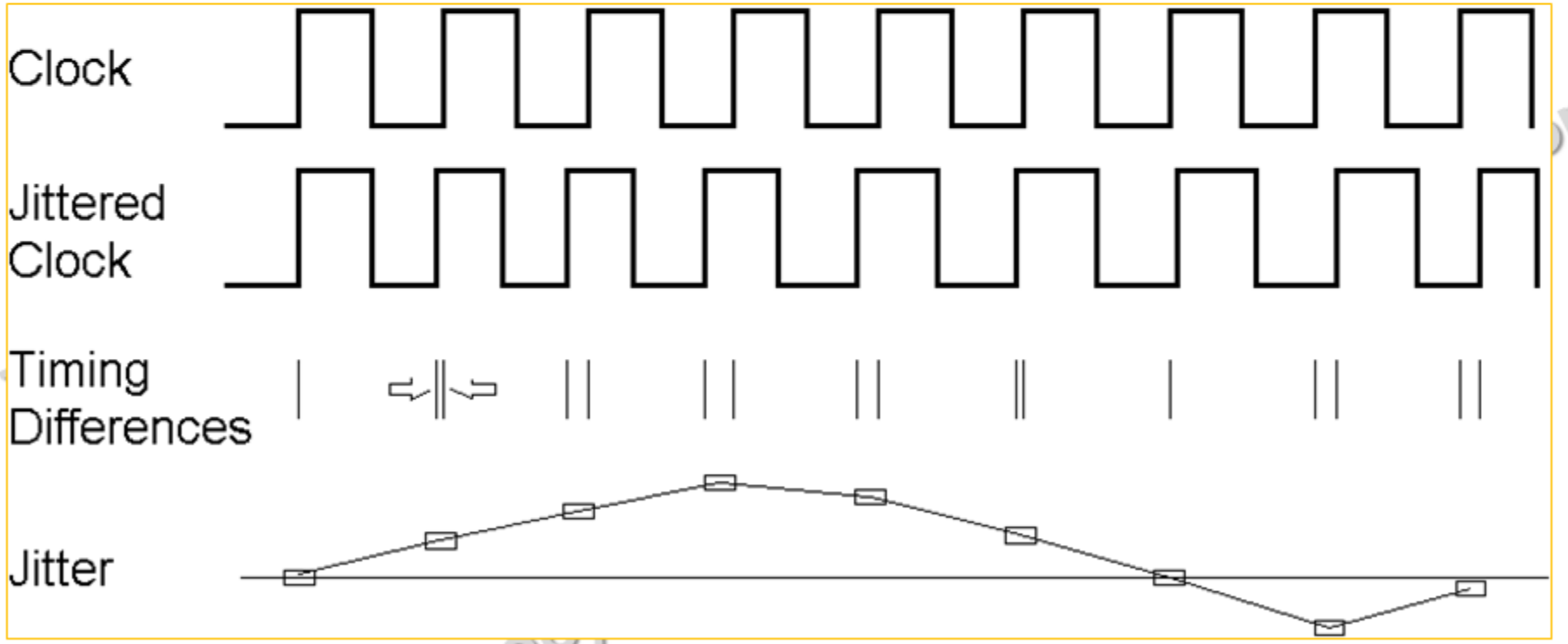


Echoes and singing (contd…)

- In fact, a telephone is purposely designed to couple some speech energy (called sidetone) into the earpiece.
- For cancellation of echo,
  - Echo suppressor operates on four-wire circuits by measuring the speech power in each leg and inserting large amount of loss (35dB) typically in the opposite leg when the power level exceeds a threshold.
  - Echo canceller operates by simulating the echo path to subtract a properly delayed and attenuated copy of a transmitted signal from the receive signal to remove echo components.
  - Impedance matching of the hybrid to reduce the magnitude of the echo is another method.

Jitter



Jitter

- Jitter is undesired deviation from true periodicity of an assumed periodic signal in electronics and communication, often in relation to a reference clock.
- It is the short term variations of signal with respect to its ideal position in time.
- Excessive jitter can increase the bit error rate (BER) of communication signal by incorrectly transmitting data bit stream.
- Jitter may be caused by EMI and cross-talks with carriers of other signals.
- Jitter can cause a display monitor to flicker, affect the performance of processors in personal computers, introduce clicks or other undesired effects in audio signals, and loss of transmitted data between networks.

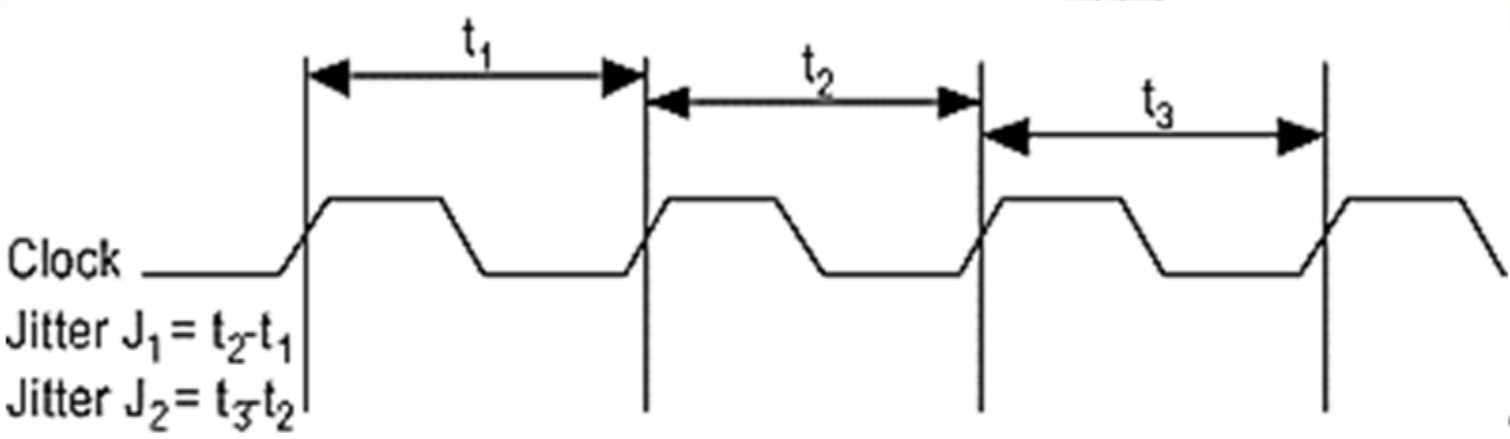
Jitter (contd…)

Types:

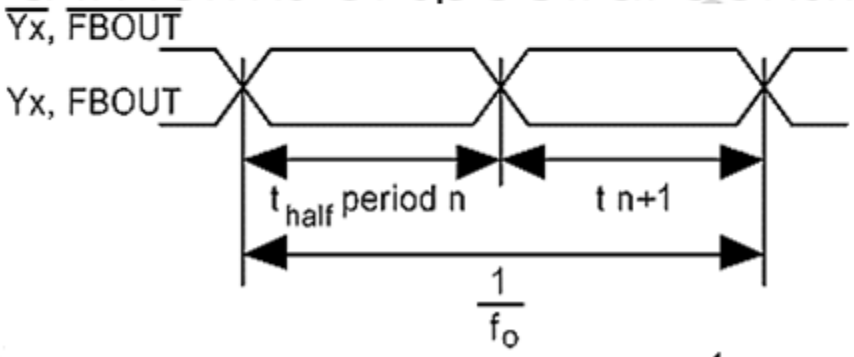
- Random jitter:
  - It is due to noise inherent in electrical circuits and typically exhibits a Gaussian distribution
  - Is due to the stochastic sources, such as substrate and power supply.
- Deterministic jitter:
  - Is a data pattern dependent jitter, attributed to unique source
  - Sources are generally related to imperfections in the behavior of a device or transmission media but may also be due to power supply noise, cross talk or signal modulation.
- Total jitter:
  - combination of random jitter and deterministic jitter

Jitter (contd…)

- Jitter Metrics:
  - Absolute jitter
  - Periodic jitter
  - Cycle to cycle jitter
  - Half period jitter



- Jitter can be quantified in same terms as all time-varying signals e.g. rms or peak to peak displacement.
- Also it can be expressed in terms of spectral density.



$$tjit(hper) = thalf\ period\ n - \frac{1}{2*f_o}$$

Bibliography

1. John C. Bellamy, "Background and terminology", in *Digital telephony*, New Delhi, Wiley India Pvt ltd, Third edition, 2000.
2. William Stallings, "Chapter3 Data Transmission", in Data and Computer communications, New Delhi, Prentice Hall of India, 7th edition, 2004.
3. Natcha Phohan, 'Network topology', *Datacom2u*, online: http://www.datacom2u.com/NetworkTopology .php (accessed: September 2015)
4. Saeed V. Vaseghi , "Noise and distortion", in Advanced Digital Signal Processing and Noise Reduction, John Wiley & Sons Ltd, second edition, 2000.
5. Engr Wasim Khan, *Transmission Impairments*, Online: http://www.engineersblogsite.com/transmission-impairment.html (accessed date: October 2014)

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