Pw| Damu → H3510

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03.10.2018

Communication Networks

Teacher's Sign / Remarks

- Jochen.Seitz@tu-ilmenau.de
  [H 3505]

LoRa → long range communication

Communication - process of conveying info from a sender to a receiver with the use of medium in which it is understood by both sender & receiver

* understanding
  → common language
  → synchronization
  → problem of noise/disturbance
  → contents

Comm requires that all parties understand common language that is exchanged.

Major dimensions
* content
* source
* form [digital / Binary]
* medium / channel
* destination

* purpose/pragmatic aspect

Addresses
IP address
MAC [Media Access Control]
[Message Authentication Control]
GTP [GPRS Tunneling Protocol] Tunnel ID
E-mail address
Phone Number / Fax

House Address

URL - Uniform Resource Locator

URI, URC, URN
- identifier
- characterization
- Name

URI
- URL
- URN

Hierarchy → to obtain URL

Telecommunication
- → "far" - Tele.
- assisted transmission of signal over a distance for the purpose of communication

earlier times:
smoke, drums, semaphores, flags, heliographs

Modern times:

Transmission System:

[Tx] —— Tx Medium —— [Rx]

Service Interface
→ format, size, speed etc

Service Access Point
→ address

Telecommunication Network
* Telecommunication links
* Nodes
  - → end nodes
  - → intermediate nodes

Task

forward info from one node to another (over multiple links and intermediate nodes)

Examples

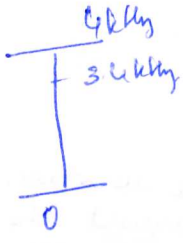
Local computer N/w, public telefone N/w, Internet

Classes of Telecommunication Networks

1. Wired v/s Wireless - Physical Medium
2. Public v/s Private - Provider
3. local v/s Global → Size

BAN [LAN] [WAN, MAN] [GAN]
PAN
CAN

4. reused v/s Open
5. Analog v/s Digital - Transported Information
   [FM]
6. Infrastructure N/w [LTE] v/s Ad-hoc N/w [BT] → Organization & Management
7. Main Application
   telephony / voice
   automation
   multimedia
   data



$f_s = 8000 \text{ samples} \rightarrow \frac{8 \text{ bit}}{\text{sample}} = 64 \text{ kbps}$

Seminar

11/10/18

Mathias Aumüller [H 2517]
- Mathias.Aumueller@tu-ilmenau.de
  google / Qxzbxh

Fundamentals

1. Explain the model of transmission system

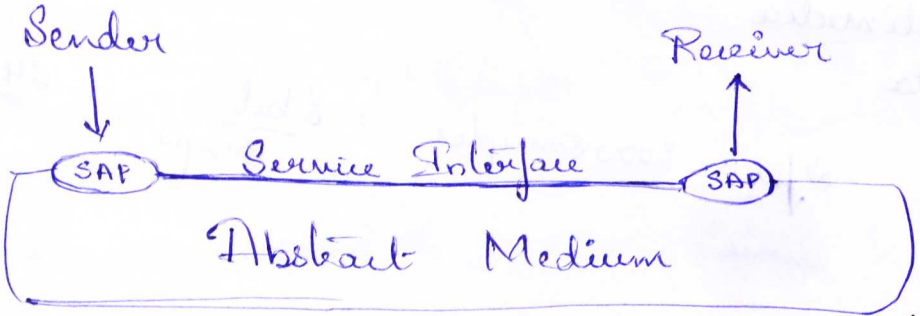
Transmitter/ Source → Transmission Medium / Physical medium → Receiver / Destination

Transmitter/ Source → Source Encoder [Remove redundancy] [Compression] → Channel Encoder → Transmission medium Physical medium

Receiver/ Destination ← Source Decoder ← channel decoder ← Physical medium

Source encoder : eg : Huffmann coding
Channel encoder : add redundancy ie parity codes

2. Explain the model of a communication system and define the terms "service interface" and "service access point"

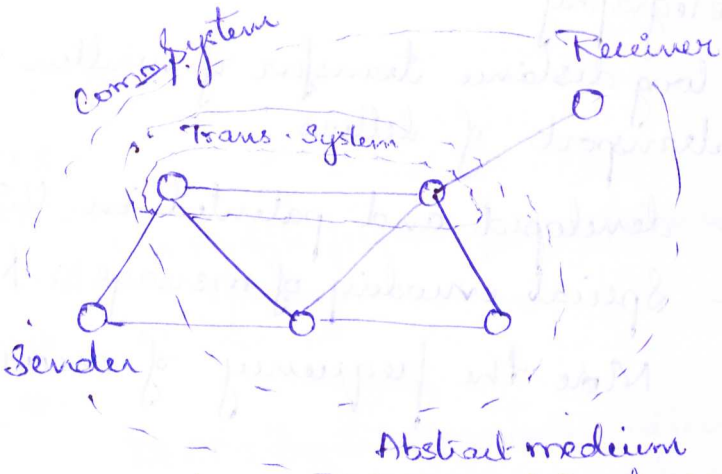


SAP :- It is a conceptual location at which one OSI layer can request the service of another OSI layer.

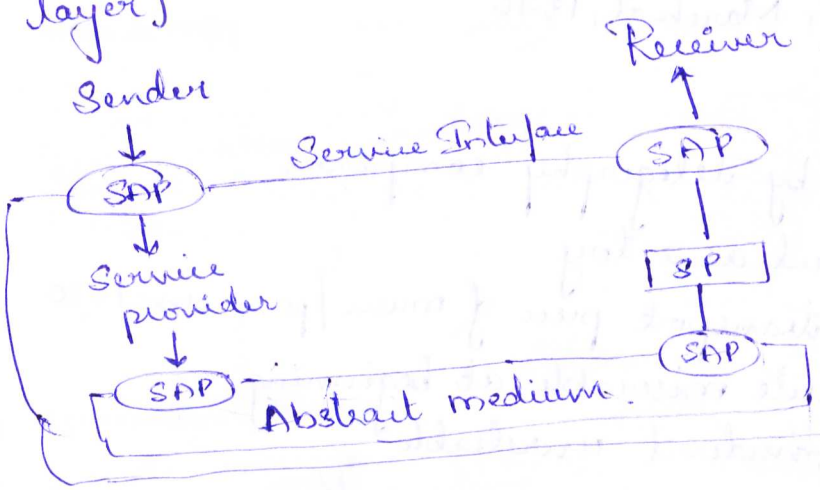
3. Difference b/w both the models

Communication Network
SAP
i) How can you access the service ? How is the service request sent ? which information needs to be exchanged and how is it coded / formatted
ii) who is my service provider ?
[There can be more than one service provider]

12 a.
- Telecommunication links
- Nodes
  * Intermediate nodes
  * End nodes



11.c. The model of a transmission system is a pipelined model which describes the communication between two parties over a physical channel.
The model of a communication system is a layered model which describes the interaction between many parties in a network
[The transmission system would be on the lowermost layer]



12.b. For the service user (ie sender) everything below the service source Interface looks like a Medium / Channel he is using.
- In practice, there can be more abstraction layers ie a protocol which serves this SAP using another SAP of a different protocol instance.
- One layer does not need to know how the layer below works, it only needs to know the services (and its interface) which is provided by this layer

12.10.2018

1. Telegraphy
- long distance transfer of written messages without physical transport of letters
- developed and patented in US in 1837 by Sammuel F. B. Morse
- Special encoding of message : Morse code.
  More the frequency of occurance of a letter → shorter the code

2. Telephony

Philip Reis (1834 - 1874)
- presented first working telephone in 1860/61
- first public demonstration of the telephone on Oct. 26, 1861

Alexander Graham Bell (1847 - 1922)
- Patent issued on March 7, 1876

Success of Telephony:
→ telephony disliked by telegraphy companies
→ telephony : considered as a toy
  * first service → transport piece of music / poem in 1880
→ speech quality quite miserable at beginning
→ Communication considered unreliable

Wireless Communication

Guglielmo Marconi [1874 - 1937]
- "father" of mobile comm

Heinrich Hertz
→ demonstrated EM waves

Desiré Edouard.

First Generation
A, B, C Network

2nd Generation - GSM, GPRS, EDGE

3rd Generation - CDMA | UMTS

3.9 Generation - LTE IMT 2000 → mobile frequency, 4th of development spectrum.

4th Generation - LTE Advanced.

5th Generation - IMT 2020.

DECT : Digital European Cordless Telephony.
↳ changed to Enhanced.
(part of IMT 2000)

Hypertext Transfer Protocol

ftp → used before

hypertext → documents interlinked

http → link

TIMES

- ~~Technology~~
- Telecommunication
- Information Technology
- Media
- Entertainment
- Security

Mobile Communication

* world wide coverage.
* Anybody, anywhere, anytime

ISM band

→ Unlicensed

→ * wifi, Zigbee etc

* All kinds of communication
  → data
  → speech
  → multimedia

Improvement of CDMA

→ HSUPA
- HSDPS → High speed uplink/downlink packet access

Mobility and Globalization

1) i-Mode - business model, platform for different services
2) WAP - wireless application protocol
3) Voice over IP
   → RTP
   → SIP
4) internet in vehicles
   - CA
5) navigation
6) PLMN → public LAN mobile N/w
   [GSM, GPRS, EDGE, UMTS, IMT 2000, 3G, HSDPA, LTE, LTE+, 4G, 5G]
7) digital broadcast
   [DAB, DAB+, DVB-C/S/T]
   location based service

1G:
Analog Telephone Systems
2G: Digital Telephone Systems

2G → 3G
higher BW and throughput
2G: circuit switching
3G: packet switching

8) wireless multimedia
9) global village
10) ubiquitous computing [everywhere]
11) m-commerce
12) quality of service
13) location based service

14. Wireless personal Area Nlw [Bluetooth, Zigbee]
15. Wireless local Area Nlw [IEEE 802.11, HIPERLAN]
worldwide standardization
Anybody, anywhere.

Technical Communication
earlier : humans involved in communication
future : machines communicate to each other
ex: remote controlled factories, Industry 4.0 [autonomous & flexible]
Vehicular communication [C2C, C2X, V2X, ..]
home automation (smart home)

Ubiquitous Computing
* IT beyond PC
tablets / smartphones
wearable devices
* Enhanced environments
Sensor Nlw
smart homes.
* Ubiquitous
independent of user
non perceptible → pervasive computing
self-acting

15.10.18

Eras of Computing
* Mainframe Eras → 1 P, many users
* PC Era - 1 P, 1 user
* Ubicomp Era - 1 User, many P

Converging Networks
* Speech comm
* Tech comm
* Internet
* Entertainment
→ Mobile & wireline comm infrastructure

X.25 [DATEX-P] - Data exchange → Packet switching

Telephony
→ latency [low, < 150 ms]
→ no jitter
→ 64 kbps fixed bandwidth

Internet
- reliability

Automation
→ low latency

Com

Chapter 2:

Communication Network : Fundamentals

Optimal path
→ reliable
→ low latency
→ fastest
→ low traffic

Components of NW :-
* Terminal equipment [End nodes]
* Switching equipment [Intermediate nodes]
* Physical Media [Radio links | coaxial | OFC]

⇒ Need for International Standards

Tele, Bearer Services
Auxiliary Services → caller ID etc
value added Service → paid service ex: hotline

Main Task
Tx of info from 1 terminal equipment to another.

Fully Meshed Network
each node connected to every other node
for n nodes $\frac{1}{2}(n(n-1))$ links required

Ex:- 7 nodes → 21 links

Partially Meshed Network

Standardization Bodies (1)
ISO - International Organization for Standardization
ITU - Intl Telecommunication Union
IEEE Institute of Electrical & Electronics Engg.

Regional
ETSI, ANSI, BNI

Std. Bodies (11) → for Internet
IETF - Internet Engineering Task Force

Special Interest Groups
* Bluetooth - SIG
* Ecma Intl
* The Open Group (former OSF and X/open)
* ZigBee alliance

Communication Association

Requirements
* Address of VM/user
* Fulfillment of user/app requirements

Entities
* Man-to-Man
* Man-to-Machine
* Machine-to-Machine

Communication links

* Serial → USB, DVD
* Parallel → printers (Centronix)

Direction

Simplex → 1 way
- Radio / TV broadcast
- Fire Detector
- Sensors node.

Duplex → 2 way
- Telephony
- Internet
- Video Game

Half duplex → 2 way, one way at a time
- Citizens Band
- Walkie-Talkie

Order of Delivery

* FIFO
* FIFO + priorities
* Random delivery order

Quality of Service

* throughput
* cost
* security
* latency
* reliability
* usability

Performance
- Signal runtime
- Response Time
- Throughput

Cost
- Investment
- Operating

Reliability
- Transmission Errors
- Comm. Breakdown
- Service Reliability

Security
- Information integrity
- Confidentiality
- Authentiität
- Non-repudiability

* Scalability
- Complexity
- Scalability
- Usability

Layered Approach

Seminar II

18.10.18

13a) - Possibility to use different application on the same Network (POTS ↔ network)
- Interoperability of Hardware and Software of different manufacturers
- Structured implementation of protocol mechanisms on the end system and the network.
- Implementations of layers can be exchanged [Ethernet / FDDI or HTTP/SMTP]
- Split of challenges [ie End to End or device to device]

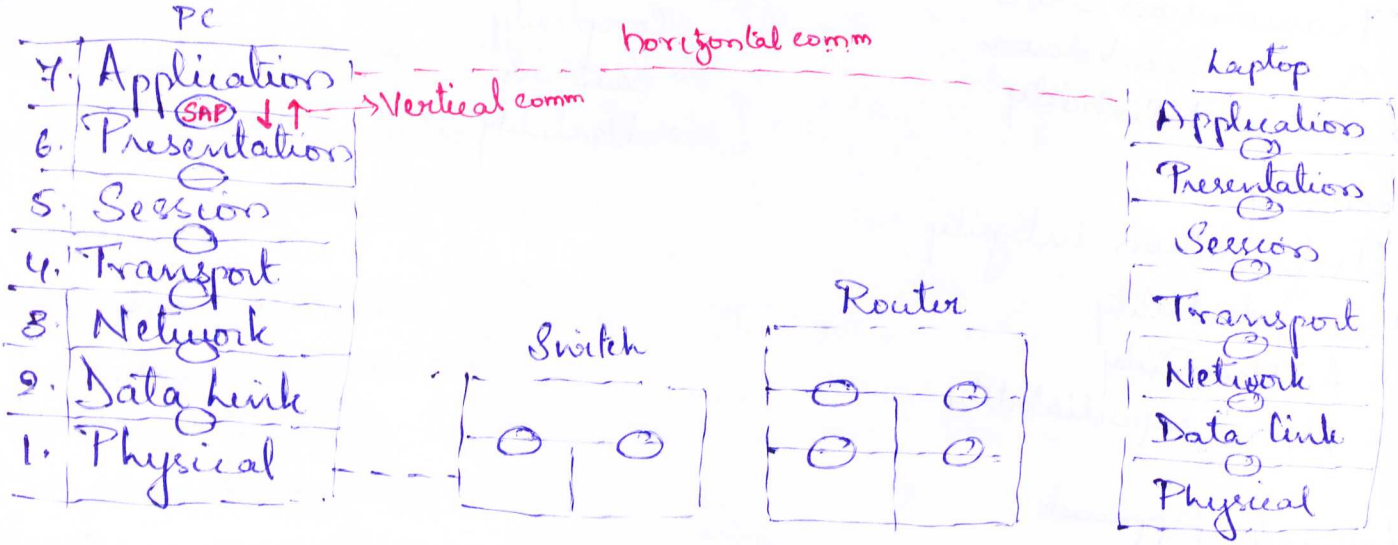
b.) 7, 4/5 layers (have more adv)

More layers
+ function of each layer can be defined more precisely and more finely.
- every layer adds some overhead

⇒ Different approaches with different number of layers (OSI ISO, TCP/IP, DOD)

ISO OSI

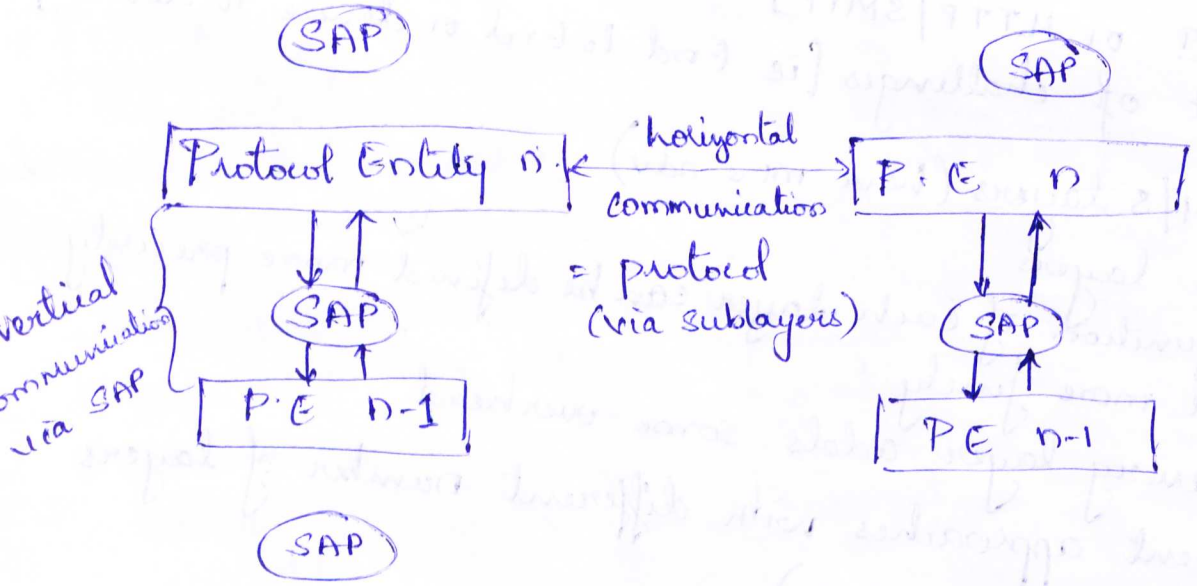
ISO/OSI



Vertical communication : b/w 2 different layers
horizontal communication : b/w 2 same layers

c. Horizontal communication → Communication between two protocol instances from the same layer (protocol)

Vertical communication → Communications between a protocol instance of a layer n with a protocol instance of layer n-1 via the SAP



d. The communication service is realized as a protocol which is spoken between two protocol instances
- the protocol and the instances provide the service to an upper layer

2. Protocol Mechanisms :-

2.1a. Layer 2 | Data link layer : Device to device, errors on physical medium.
Layer 3 | Network : End to End ie IPV4 Header checksum (not IPV6)
Layer 4 | Transport : End to End Error control (resend of lost packets (reordering))

b. - Receiver must be able to recognise transmission errors
- Redundant information must be added (ie send everything twice, parity bits, checksum)
- Receiver must be able to inform transmitter of error
Acknowledgement of validate frames or re-request of erroneous frames.
- Identification of frames
  - Identification number, alternating bit
- OR. FEC [Forward error correction]

c. All bits are X-ORed at the sender, the result is the parity bits.
- The parity bits is sent with the data
- The receiver is also X-ORing the received bits. The result has to be 0 if it is not, there was an error. Otherwise the transmission might be error free, but it could also have 2 or another number of even errors

1

1	0	1	1	1
0	0	0	0	1
1	0	0	1	0
1	1	1	0	1
1	0	0	0	

needs to be changed to '1'

Cross parity check

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Communication Architecture

Communication layers
* Interface to the physical medium
* Interface to the application
* Several communication entities

Increase in no. of layers → more the overhead, layers have more responsibility and not complex.

Service and Protocol
* Peer entities * Service

Telephony service
→ Dial Tone is obtained only when channel is free and it is possible to make a call

Dialing → number of interrupts [old telephones] in the closed circuit denotes number dialed

At the Rx
Voltage makes the phone ring

→ Hanging up releases the channel

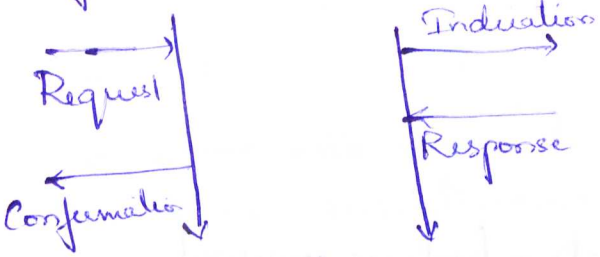
Service
= Set of functions in one layer
* offered at SAP

* delivered by co-operating entities
* defined by set of Service Primitives (SP)

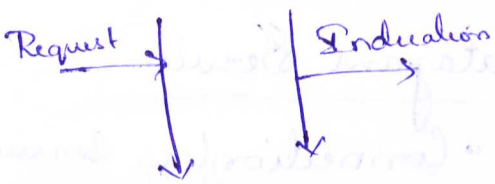
SP: - * Request
- * Indication
- * Response
- * Confirmation

Different Kinds of Service

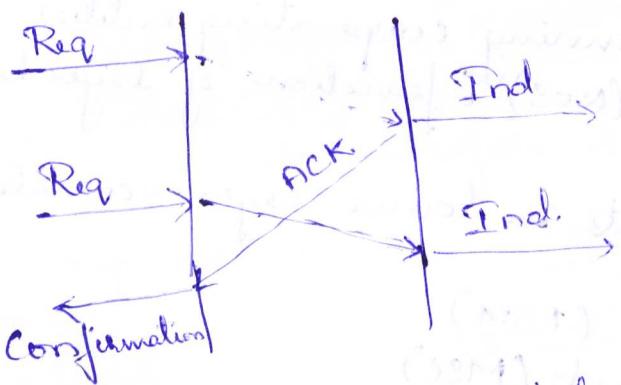
1 Confirmed service



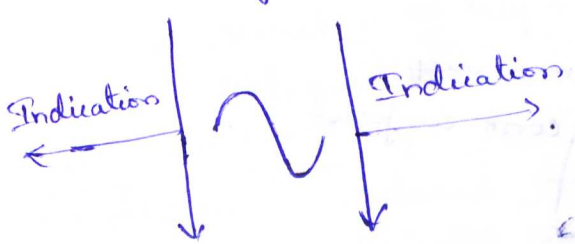
2a Unconfirmed Service



Confirmation ≠ Acknowledgment [not the same]
Ack → inside the protocol → mechanism of a protocol



2b. Initiated by the service provider



Connection Oriented Service

3 phases
* connection establishment [confirmed service]
* data transmission [unconfirmed service]
* Connection release [confirmed / unconfirmed service]

for Telephony → connection release is unconfirmed service

for TCP port number is the connection end point.

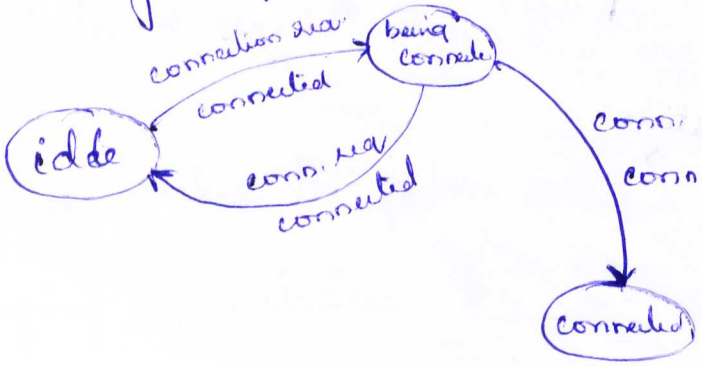
Datagram Service

- Connectionless Service
  * ghost
  * no phases for connection setup / release required
  * unconfirmed service

→ IP is a datagram [data + (tele)gram] service

Idea behind Protocols

* Rules for concurrently running cooperating entities
* Enhancement of Quality (QoS) of services of layer below
* Distributed Algorithm
* Imp prob: failures / faults in lower layer → considered
* Specification of protocols
  → Finite State Machine (FSM)
  → Message Sequence Chart (MSC)



Protocol functions

* Elementary atomic function

→ Encapsulation

(→ priorities, address set is a part of this along with the data

→ Segmentation & reassembly

Size limitations

* to have fair medium access (by multiple users)
  [too lengthy packets take more time]
* to avoid error lower bit error probability inside the packet

Connection Management

* Connection establishment
* Connection - maintenance → resource allocation
* Connection release
* Handling the connection breakdown
* Handling of "orphaned" connection
* Further
  * addressing
  * Address mapping [Name and address]

Routing

→ optimal path to interface & next node

path depends on

* speed
* load
* latency
* cost
* number of hops
* reliability

Data Transfer:

→ desired : ordered data transfer
: different priorities for different data

Load Control:

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"Load control"

"Error detection and correction

- Redundancy
  - * Parity
  - * Checksum
- Acknowledgements
  - * Stop & wait → wait for Ack before sending next packet
  - * Credit-Based

Stop & wait → long latency

- Time out - wait for certain amount of time to receive ACK
- Numbering of packets
  - * Sequence control

Error Correction

- Redundancy
  - * Forward error correction

Hamming distance

- Symbols (sequence of bits)

min. amount of different bits

1 1 1 Hamming distance = 3

0 0 0

# of bit errors to detect : 2 [Hamming distance - 1]

0 1 1

# of bits/errors to correct : 1

1 1 1

- Retransmission
  - * Selectively
  - * Go-back-N
- Reset
- Abort

Multiplexing and Bundling :-

Multiplex
- One entity serves several entities in the layer above

Bundling
- One entity utilizes it

Shared medium access

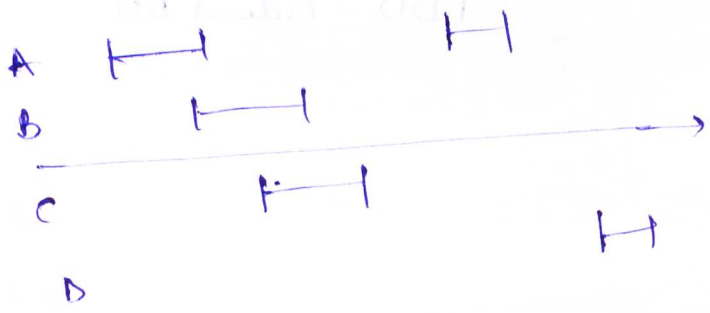
Controlled medium access

- Alternatives
  - * centrally controlled
  - * without the central control (eg. token based)

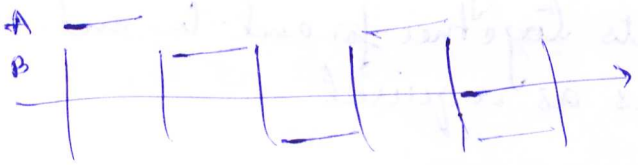
* No collision
* Problem: Part of BW might be unused.

Monitoring system generates token when one node is has released but data is lost. To avoid wastage

Aloha - Hawaii → to interconnect all the islands over radio; transmit whatever you have, if successful ACK is obtained else NO ACK.



Slotted Aloha → used by GSM for setting up connection need to synchronize



Controlled Access

Arbitrary Medium Access

No central control

Each node decides whether it may send

Random Back-off Algorithm - 802.11

CSMA/CA

- Combination : Hybrid Medium Access
  - → in Satellites
    - 2 phases : 1 phase has time slots (small)
      - 2 phase → no collision

"Synchronization"

- Different content
  - * Signal level
    - → Clock, sensing
  - * Medium Access

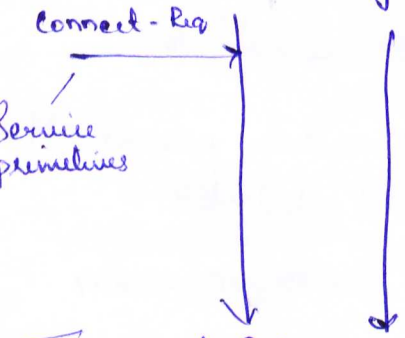
ISO/OSI Basic Reference Model

N-IDU → Interface Data Unit

ICI → Interface Control Information

PCI - Protocol Control Information (Header)

PDU - Protocol DU



Transport Oriented

Physical

Datalink → comm b/w 2 neighbouring nodes

Network → takes links & puts together for end-to-end comm

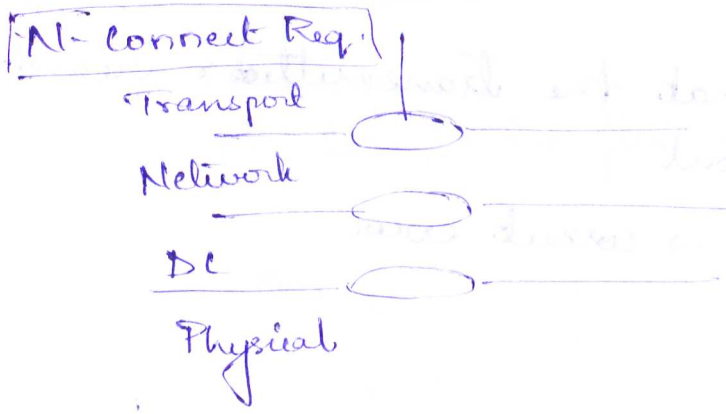
Transport → different services as required

Session → virtual pinapk

Presentation → 2 peer entities understanding each other

Application → Application protocols HTTP, SMTP etc

Network layer → connection request (Sends to Data link layer)



25.10.18

Cy

2.1.

Cyclic Redundancy Check

Seminar-3

2.1.d $x^4 + x^3 \quad 1 \Rightarrow$ $x^4 x^3 x^2 x^1 x^0$ → Generator polynomial of degree 4

$1\ 1\ 0\ 0\ 1$

Sender

$1\ 1\ 0\ 0\ 1\ 1$ → 4 zeros are added to this

$1\ 1\ 0\ 0\ 1\ 1\ 0\ 0\ 0\ 0$

$1\ 1\ 0\ 0\ 1 \;\big|\; 1\ 1\ 0\ 0\ 1\ 1\ 0\ 0\ 0\ 0$

$1\ 1\ 0\ 0\ 1$

$0\ 0\ 0\ 0\ 1\ 0\ 0\ 0\ 0$

$1\ 1\ 0\ 0\ 1$

$0\ 1\ 0\ 0\ 1$ → The remainder is the FCS [Frame Check Sequence]

$1\ 1\ 0\ 0\ 1\ 1\ 1\ 0\ 0\ 1$ → is transmitted

~~2+d~~

Receiver

$1\ 1\ 0\ 0\ 1 \;\big|\; 1\ 1\ 0\ 0\ 1\ 1\ 1\ 0\ 0\ 1$ [~~÷ 11001~~]

$1\ 1\ 0\ 0\ 1$

$0\ 0\ 0\ 0\ 0\ 1\ 1\ 0\ 0\ 1$

$1\ 1\ 0\ 0\ 1$

$0\ 0\ 0\ 0\ 0$

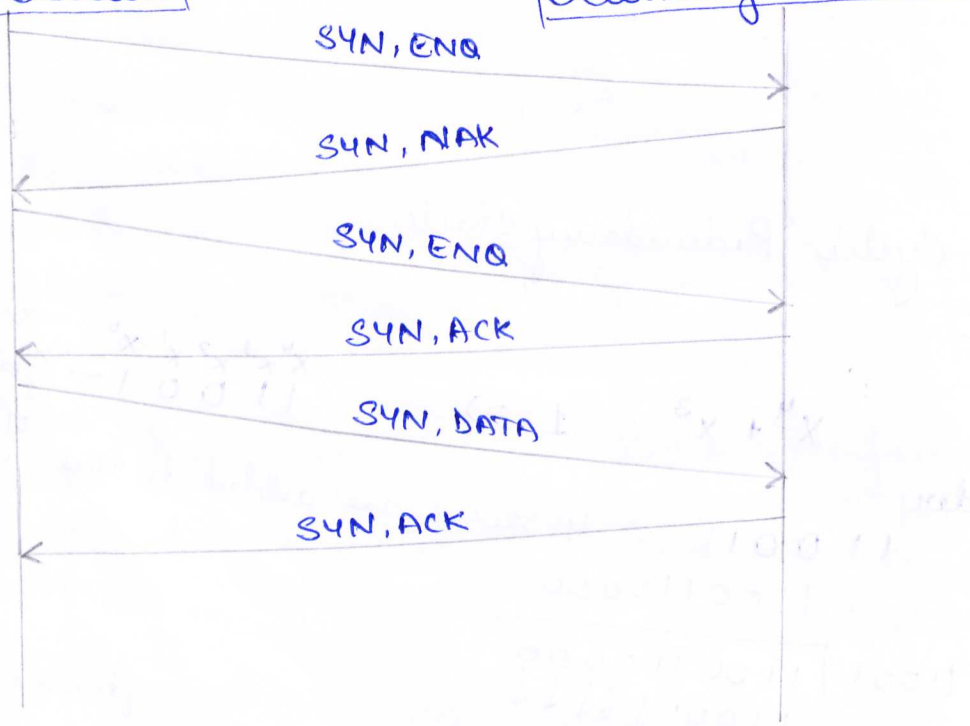
if the remainder at the receiver is non-zero value, then was an error

if it is zero there was no error ~~for~~ an error in the form of a multiple of the polynomial.

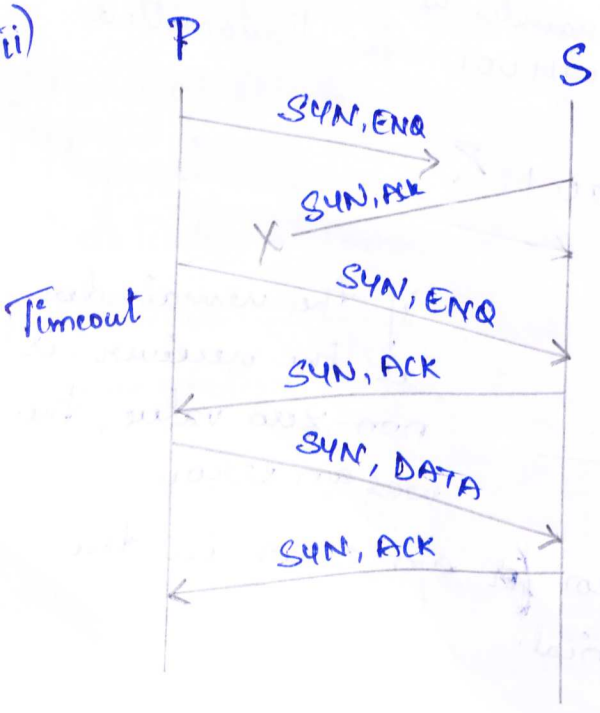
e) A negative acknowledgement is sent to the transmitter ⇒
⇒ retransmit if there is an error detected

- No ACK. is sent, so that the transmitter resends the frame after a timeout
- If enough information → correct error

i)

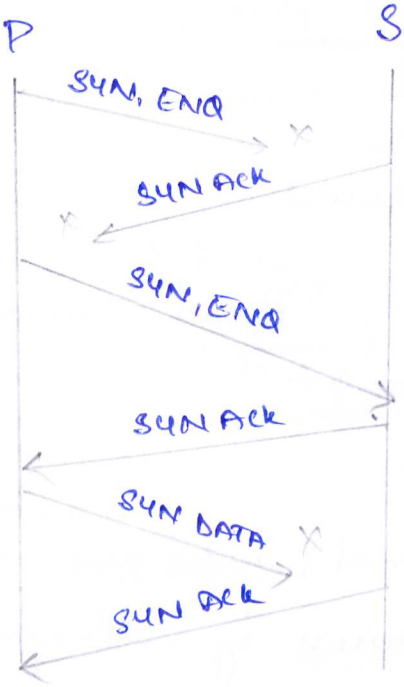


ii)

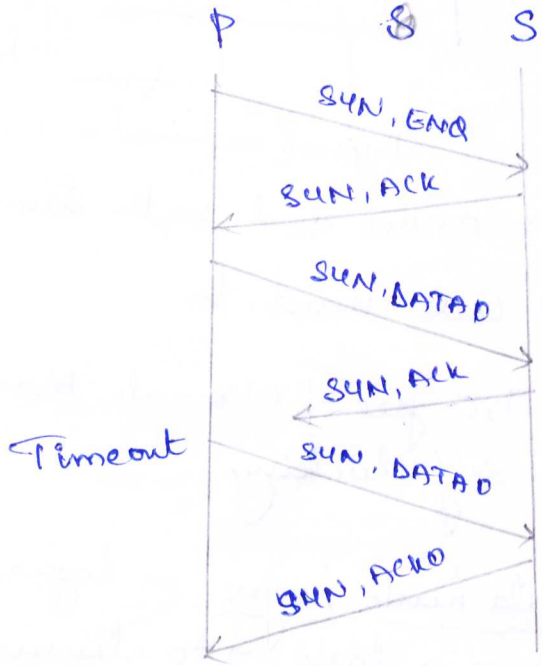


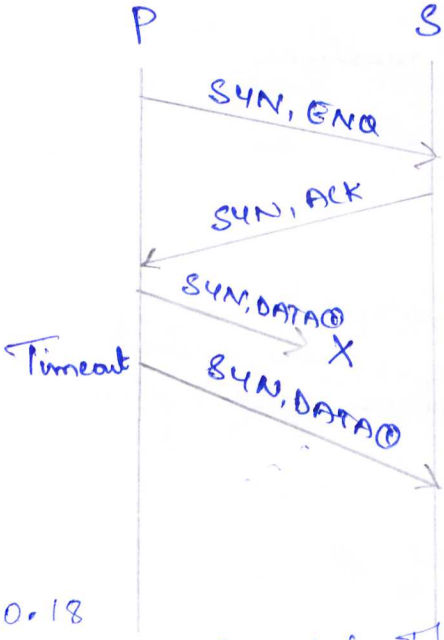
iii) - count timeouts, increase waiting time inform upper layer and interrupt transmission

iv) Test with checksum
send NACK like in the first example



v)





→ Alternative ~~BIT~~ sequence number

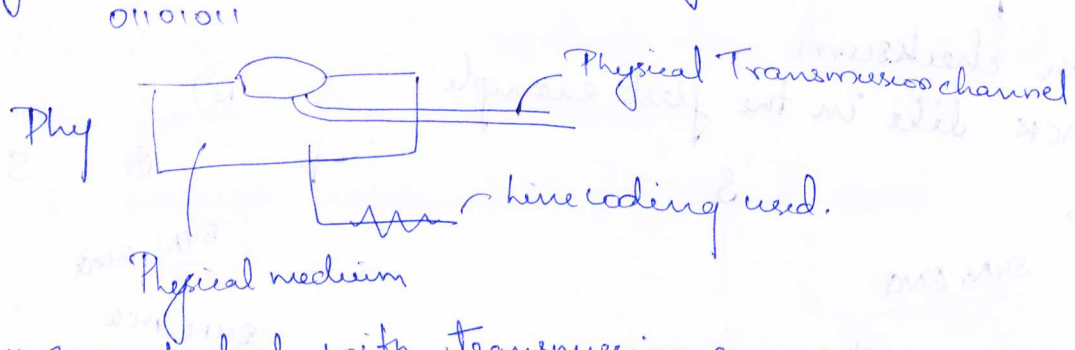
26.10.18

* Please Do Not Throw Salami Pizza Away → (Network) OSI Layers

Transport-oriented layers
* only deal with bit sequence egal of the data txd
- Transport - Data link
- Network - Physical

Physical layer

- glue b/w medium & Comm system



* cannot deal with transmission errors

The code must be.

Baud → Samples / sec

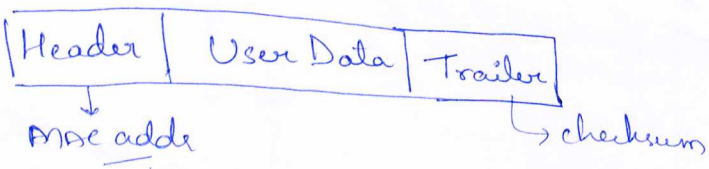
1. DC-free [Alternate Mark Inversion code etc]
2. self clocking

Data link layer → logical link control & media access control

* main task → to eliminate bit errors by adding redundancy
  CRC, parity bits
* has addressing info
* Several mechanisms to correct errors
* Medium Access Control (MAC) for shared medium

LLC

Frame



* communicate with neighbours and other intermediate end systems like bridges etc.

Network layer

* used to send data end to end.
* responsible for finding optimal path through the network & forward the info
* should control network load
* works connection oriented / connectionless
* based on world wide unique address (telephone no, IP Addr)

Doubt

Only MAC addr is not used as the size is too large. Small routing tables decide faster to send the packet towards the destination

Transport layer:-

* data transfer b/w different pairs of application on end systems
* Adds QoS to service provided
* works connection oriented / connectionless (TDP)

Application-oriented layers:-

* depends on application & semantics
* aware of kinds of info txd

Layers → Application
→ Presentation
→ Session

Session layer:-

* Allows organising & synchronizing dialogue b/w 2 applications
* allows to reset the connection anytime
* confirms source release
* controls exchange of info

Presentation layer:-

* provides coding of the info => so that Rx understands the syntax & semantics of Txd bits
* overcome abiguity

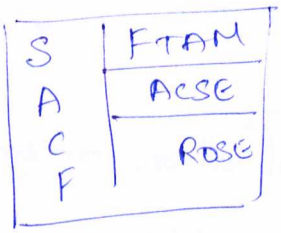
ASCII, EBCDIC

Application layer:-

* provides a set of diff. services

File transfer, access & management
MHS, ISO/OSI E-mail
Remote Operation (ROSE)
Association control Service element (ACSE)

* contains several Appliation Service Elements (SASE)
  * Single Association Control function (SACF)



LLC → 2b

Three layered Architecture

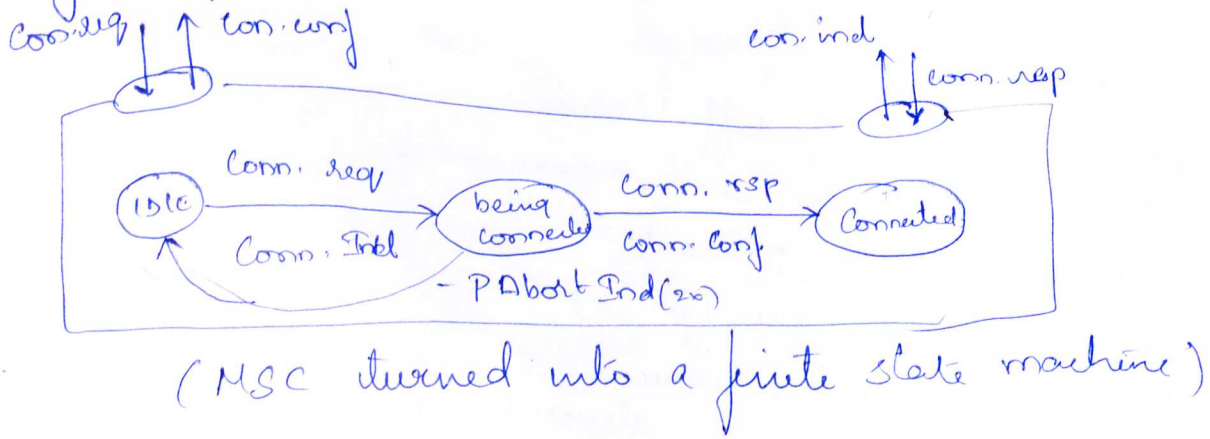
Application Oriented	OSI layers 5 →
Transport Oriented	OSI Layers 2b - 4
Network Access	OSI layer 1 - 2a

→ less processing overhead
prevents redundant functions
high performance

Chapter 3: Protocol Specification

Message Sequence Chart (MSC)
Finite State Machines (FSM)
Special Comm Scenario

Message Sequence Charts



(MSC turned into a finite state machine)

* Provider abort Indication

Seminar IV

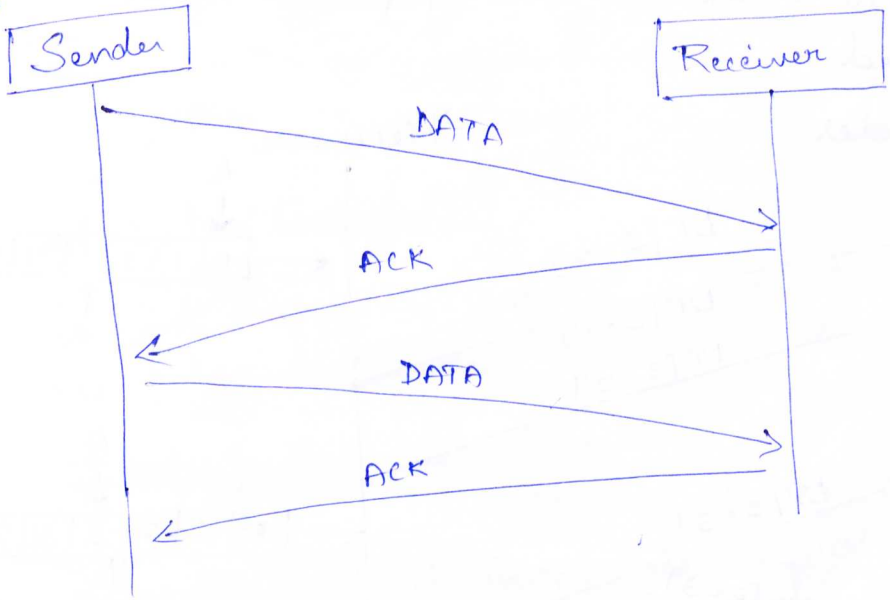
29.10.2018

Flow Control

→ One of the technique is "Stop & Wait"

Stop & Wait

23 a) Stop & wait



b) Sender stops transmitting data
- Resends data after timeout if ACK is not received

c) No, for each packet full round trip time is added

d) Credit based mechanism: The sender gets a credit of n-packets which are allowed to be sent without an acknowledgement.
→ Receiver acknowledges multiple packets at once by requesting the next expected packet.

e i) Throughput is higher and delay is lower, because the sender doesn't need to wait for the ACK each time. (in full duplex environments the ACK can be sent while the sender is transmitting

ii) In error prone environments the packets size can be reduced without impacting the throughput and delay as much as in the stop & wait case.

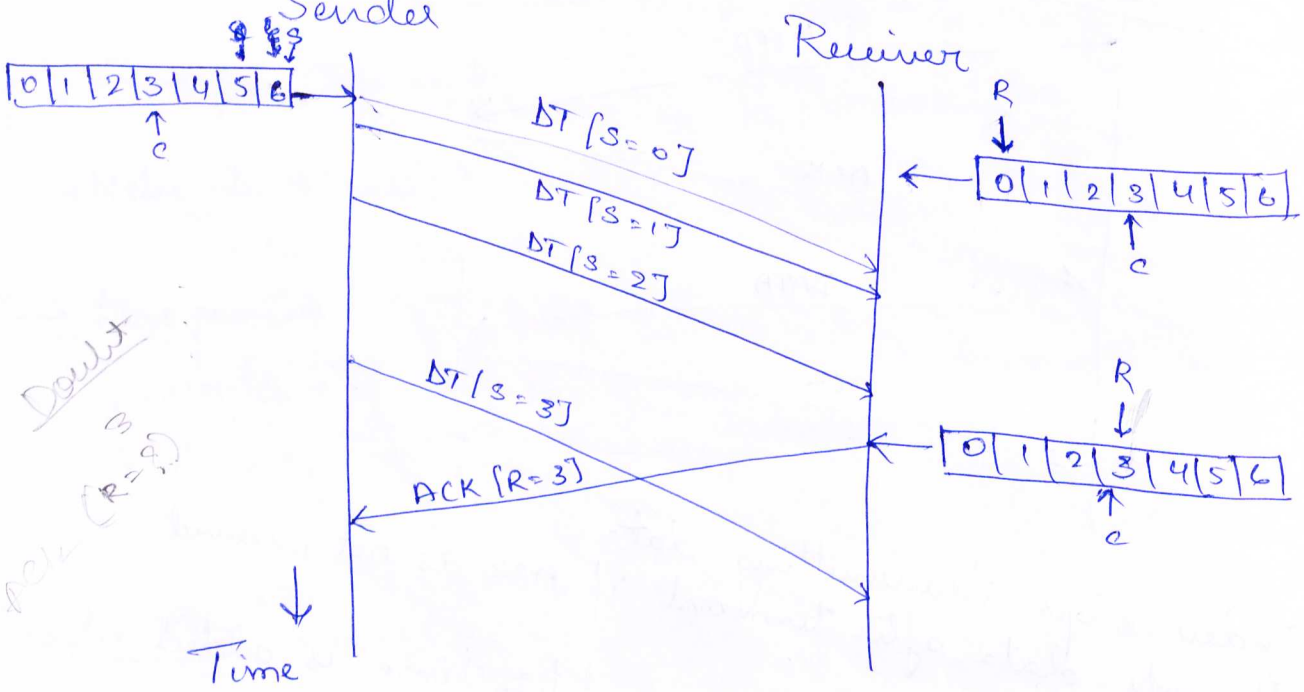
f.) Given:

Max window size is 4

'S' is the sequence number

'R' is the Next packet to be received

'C' is the Max number of packet that could be received

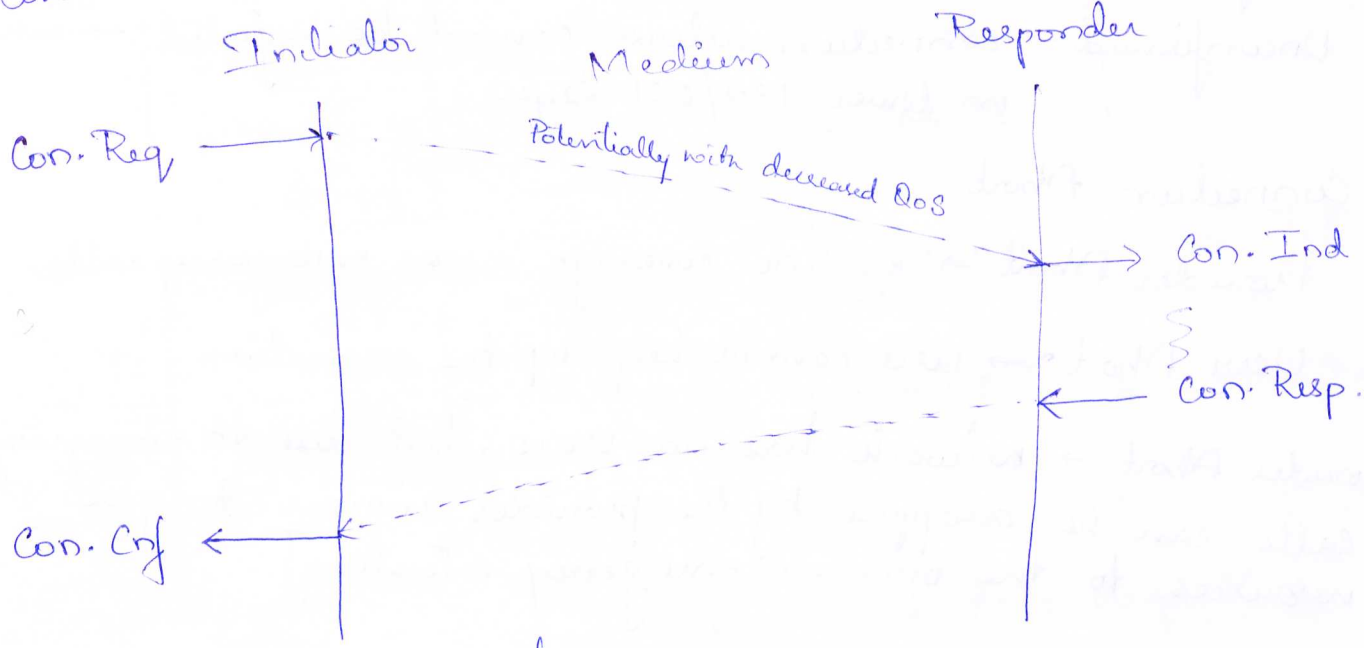


1.11.2018

Finite State Machine

Connection Oriented

Connection establishment



Unconfirmed Data Transfer:

→ Unconfirmed has only request & indication only DT PDU & ACK PDU helps the sender know that the data is transmitted

ACK → of not for the last data sent.

if ACK not rcvd, internally sends the data packet again after timeout [without any data request from responder]

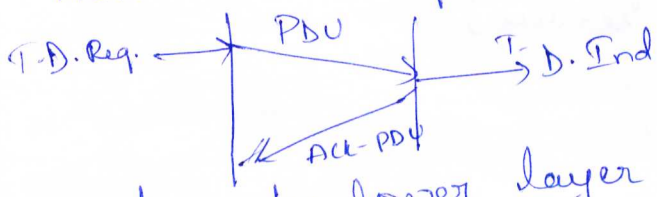
- expedited data transfer } Types of data tx
- normal data transfer

expedited → high priority

Confirmed v/s ACK

Confirmed → all 4 present

ACK → Data req & Indication



rely on the lower layer that it functions correctly.

Connection Release

Confirmed → comm partner confirms release / rejects [higher layers]

Unconfirmed → connection release cannot be rejected → used on lower ISO/OSI layers.

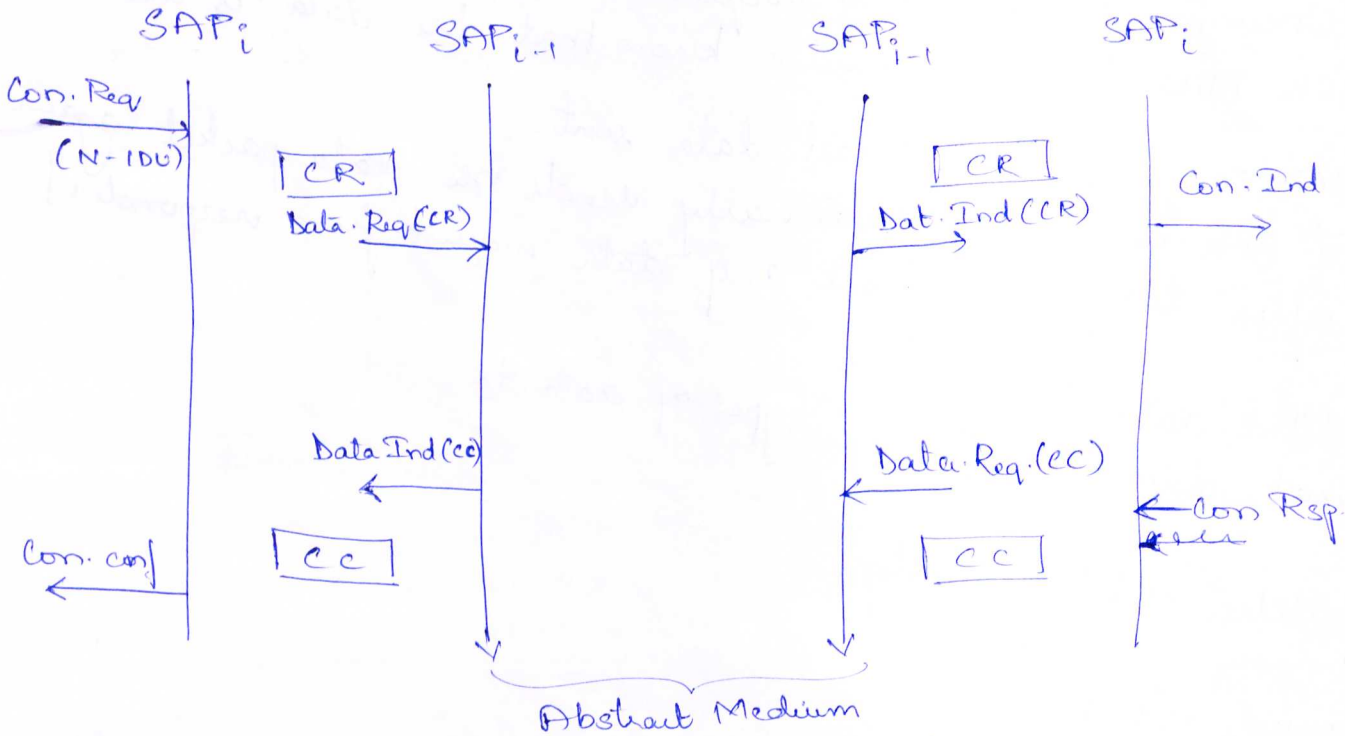
Connection Abort

Provider Abort → ex: no coverage , ex: emergency calls.

User Abort → user cannot keep up the association

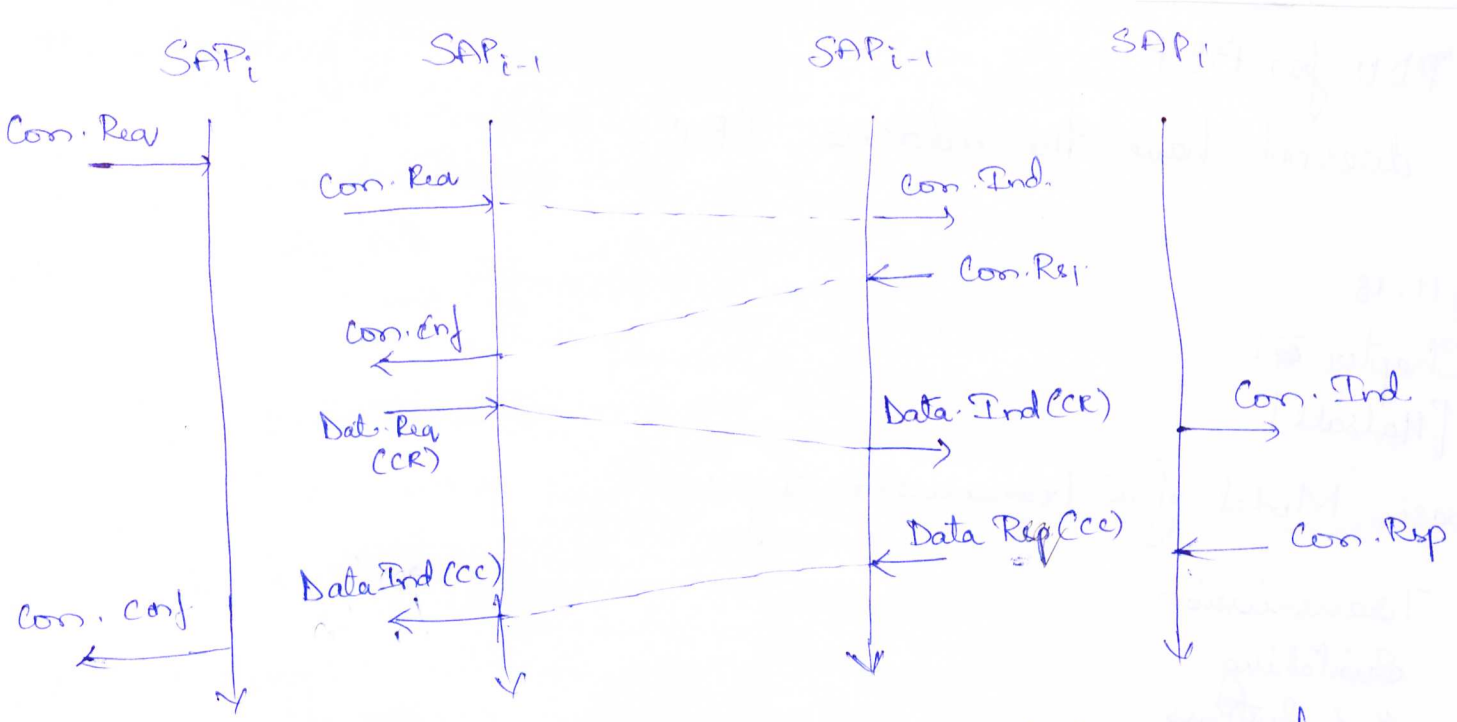
[Provider Abort → network has no issue , but due to emergency calls can be dropped by the provider inorder to give resources to the ones in emergency situation]

Telecommunication Protocol



CR-PDU is sent to the other side through the lower layers by using service primitives / requesting the lower layers to process the data further → Data Request is the service primitive used. [connection less service]

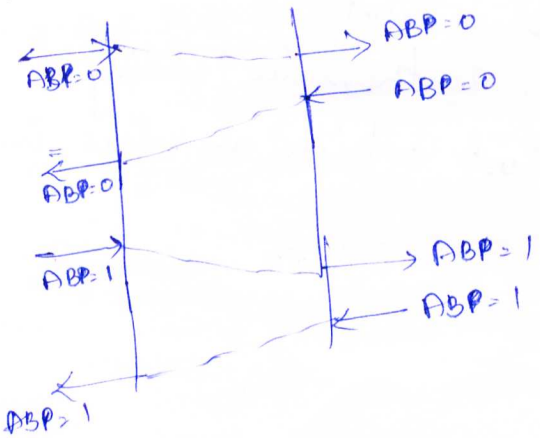
for a connection oriented service,



first setup the connection & then send data request.

PDU format
* length of PDU
* fields in the PCI (header) acc. to protocol functions implemented
* → address, number of & ACKs
  → length, info for flow / load control
  → checksum

Alternating Bit Protocol (ABP)
confirmed data transfer → upper layers
unconfirmed data transfer → lower layers
→ alternating ACK number (0 and 1) to distinguish b/w message loss & ACK loss.



PDU for ABP
does not have the address, CRC,

21.11.18
Chapter 4
[Halsall]

Basic Model of a Transmission System

Transmission
Switching
End Systems

Source coding → reduce redundancy by highest amount
further in the next block redundancy is added inorder to check & correct errors

Telephone → 300 - 3400 Hz.
Sampling frequency at 8,000 Hz.
8 bits per sample
→ 64 000 bits per second.
constant bit rate → 64kbps

Digital Signal → Source coding → compression of files
Source coding
lossless compression → no info is lost
ex: Huffmann encoding, arithematic coding
lossy compression → info is lost which are less important
received ≠ original info
ex MP3 for audio files
jpeg for image files

Channel coding:

Error detection

- Adding redundancy
  - * Parity bits
  - * Check sums

Forward Error Correction

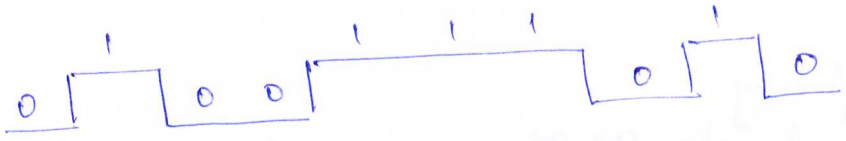
Add redundancy

→ block, hamming code.

Line Coding:

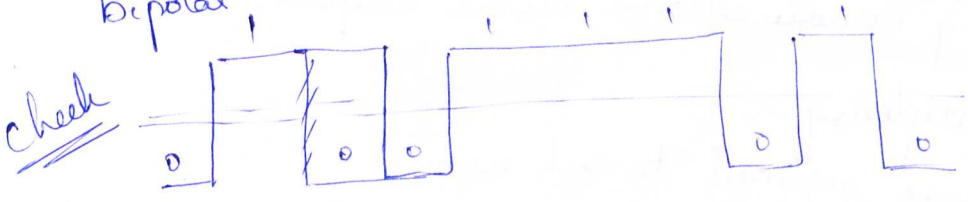
- * eliminate DC component
- * facilitate bit sync.
- * Minimize Spectral content
- * Ease error detection & correction

→ Non Return to Zero

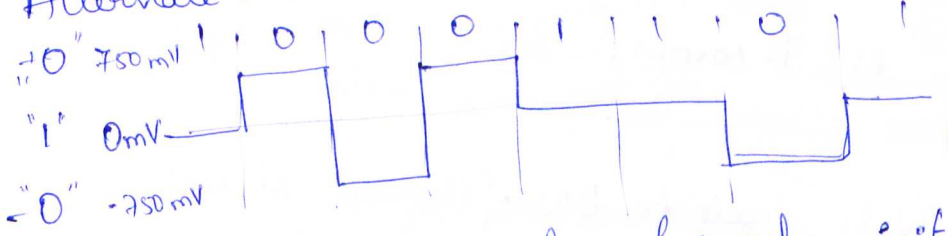


NRZ unipolar

NRZ - inverted bipolar



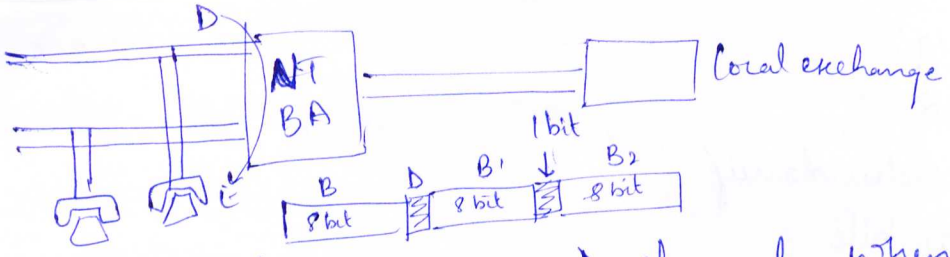
Alternate Mark Inversion



each interval DC free

(→ modified, used for ISDN)

long sequences → loss of synchronicity at receiver end.



when a call is made we allocs a D-channel. when it is successful, a B-channel is assigned. & both allocs the same D-channel. & An echo-channel is created on the other side copying the D-channel contents

Manchester Code

'1' → A⁺ to A⁻ } transition
'0' → A⁻ to A⁺ }

→ DC free (½ + & ½ -)
Synchronised

Multiplexing (MA)

Space division multiplexing
→ space partitioned into "areas"
→ each assigned an area.
→ no interference possible
ex: analog telephony, radio cells in mobile telephony

Frequency Division Multiplexing
→ separate freq. range assigned to each user
ex: fm radio, television, OFDM, & GSM.

→ can be used for both A & D comm.

Time Division
→ each user → complete access to BW of channel, at certain time periods
ex: ISDN, GSM, Digi Audio/Video broadcast
→ only Digital comm is possible

Code [Tanenbaum]
streams occupy same spectrum
→ different codes for different streams
→ ex: UMTS, CDMA

⇒ Source → Modulation → Mux → channel → Demux → Demod → Sink

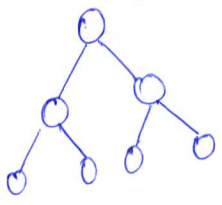
Q.
$\frac{1}{8k}$ = 125 μs → sampling time [refer telephone sampling rate]
→ allows us to multiplex 32 different calls.

→ more data rate, use less chip length and vice versa.
small code words → less combination, serves a less number of people
[need to be orthogonal]
[Proakis, Salehi → Fundamental of Comm. 8/e]

05.11.18
Chapter 5
Interconnection of Networks
Layer I : Repeater, Hub
II : Switch, Bridge
III : Router
⊗ :
Layer ≥ III : Gateway

Hub:
decouples device if faulty, shuts the link and does not disturb the other.

Spanning Tree Algorithm
→ avoid looping of bridges



* Root bridge → has smallest ID
* each bridge calculates shortest path to root bridge

"TRILL"

optimal path for unicast

hop-count to avoid infinite looping packets

Router

→ Segmentation done at end systems

Tunneling

→ process of sending an IPV6 packet in the N/w which has both IPv4 & IPv6.

→ Forwarding Decision

* Datagram Routing
* Session Routing

:→ [connection oriented]

:→ routing decision during connection establishment

:→ all packets ∈ same connection take same path

Components of Router

* Network layer protocol
  → for forwarding data packets
* Routing protocol
  → for exchanging routing info
* Routing algorithm
* Routing Table

Gateways

* Proxy server
* Firewall → shared security, access control

N/w Admin → everything that is not allowed is forbidden

User → everything that is not forbidden is allowed.

Chapter 6 : Switching Technology.

Switching
* provides temporary comm path through N/w
* involves both end systems
* connection oriented / conn less

Signaling
* control messages.
* BW is less
* has info for switching
* implemented on seperate protocol stack

MPLS → multiprotocol layer switching
→ for traffic management etc in bigger N/w
→ works b/w layers 3 and 2.

Circuit Switching (Line Switching)
→ for PSTN initially
→ also used in GSM
→ channel reserved for 2 users [others cannot access the source when a connection is established]
→ no buffers
→ Delivery is ordered
→ No. of parallel connections are limited

7.8.18

Seminar

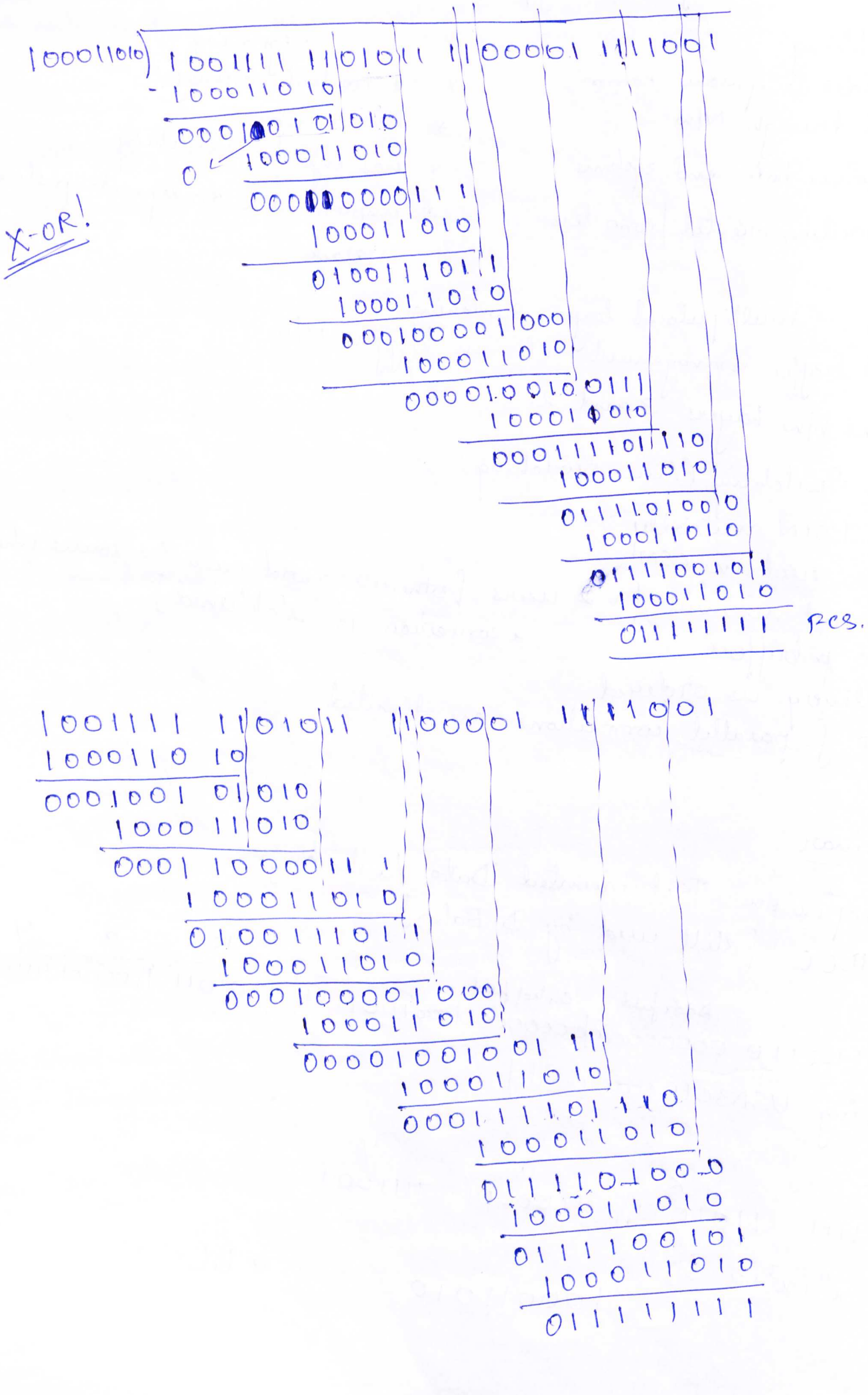
2.4 Complex ex: Bit oriented Data link layer
HDLC [still used by D. Bahn]

a) Addr field | Control field | O | K | a | Y
01111110 00000000 00000000 1001111 1101011 1100001 1111001

[using USASCII code chart]

O K a Y
1001111 1101011 1100001 1111001

$x^8 + x^4 + x^3 + x \Rightarrow$ 100011010 → 9 bits


X-OR!
100011010
1001111 11010 11 111000 01 11 1001
- 100011010
0001001 01010
100011010
0 0000000111
100011010
01001110111
100011010
000100001000
100011010
00001001 0111
100011010
00011110 1110
100011010
01111010 00
100011010
01111001 01
100011010
01111111 1
Res.

1001111 11010 11 111000 01 11 1001
1000110 10
0001001 01010
1000 11010
000 10000111
100011010
01001110111
100011010
000100000 1000
100011010
00001001 0011
100011010
00011110 1110
100011010
01111010 00
100011010
01111001 01
100011010
01111111 1

c) Bit stuffing

b.a) 10110010 01111110
FCS EOF

c. Bit stuffing
'0' after every 5 1's

1001111110101111000111111001
1001111101010111100011111001
↑ ↑

(escape sequence length)

Sem
Service and protocol specification

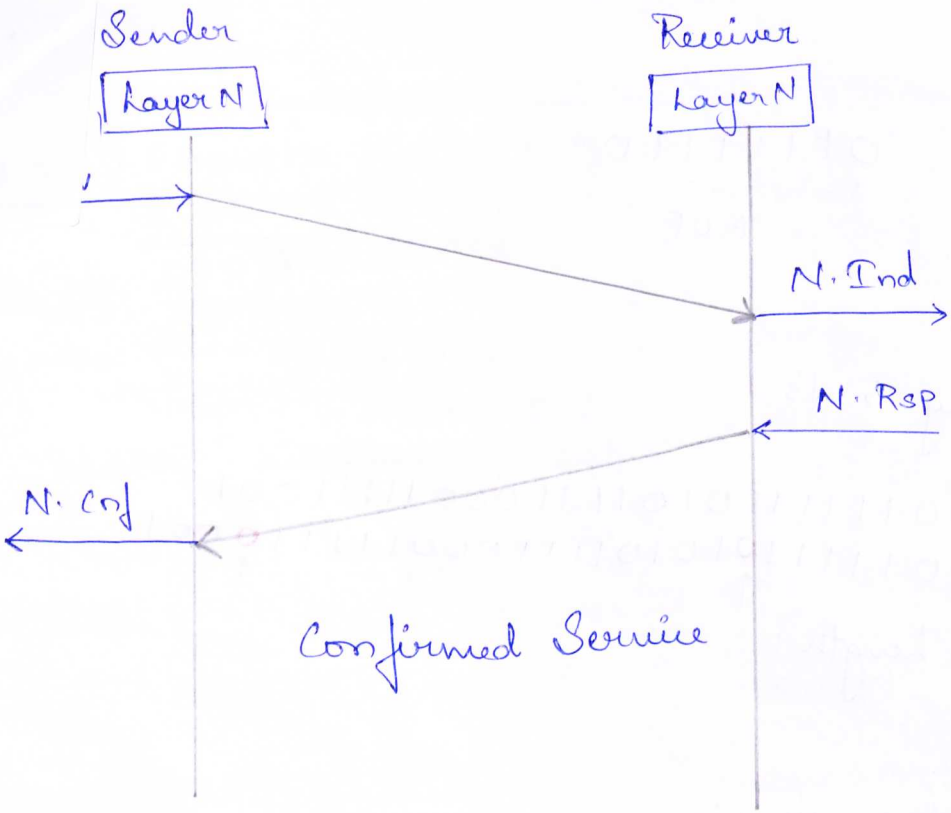
3.1
a) - Instance of defined Interface
- Is responsible for the communication between a service user and service provider
- Addressed by SAPI (SAP identifier) → multiple users
- [Communication] via communicate via service primitives which are divided into 4 groups

REQ Request
IND Indication
RESP Response
CONF confirmation

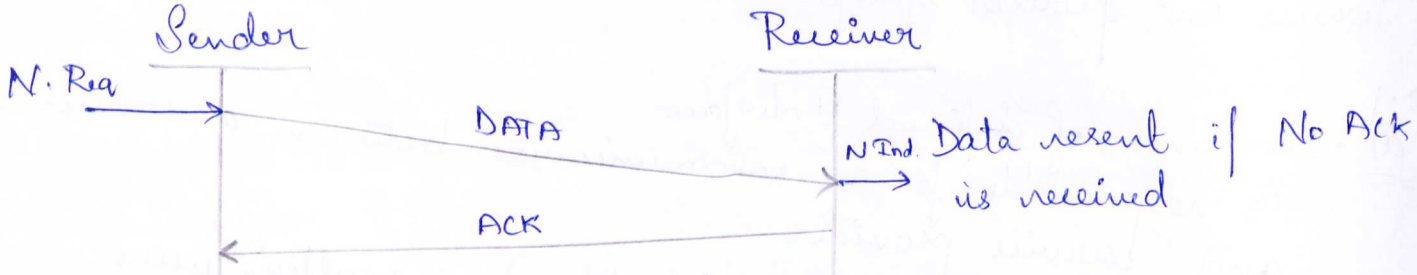
b) a) : Telephone N/w
TEI Terminal End Identifier (Address of device/phone)
ISDN SAPI (6 bit)

b) Internet:
IP address (32/128 bit) and Port (16 bit)

3.2
a) Message sequence chart



Confirmed Service



Transmission mechanism of acknowledgement

b). Confirmed → vertical communication
mechanism of ACK → horizontal communication

- One is a protocol mechanism between two network nodes (horizontal communication) the other is a mechanism between two entities in a layered architecture (vertical communication)
- The confirmed service is used to inform the Service User about an abort or success of a service request (ie connecting to a host | or opening a file)

- The mechanism of acknowledgements is used for error detection

Horizontal → only data is sent [non confirmed service]

8.11.18

Circuit Switching [echo cancellation]

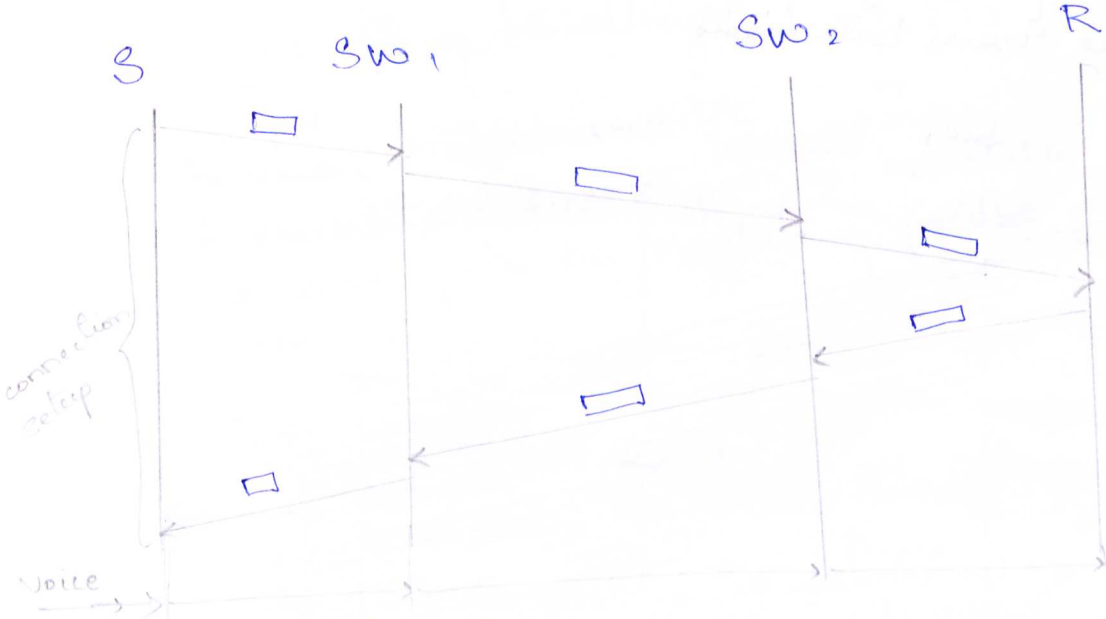
→ based on SDMA.

Crosspoints → used for connection establishment → Analog

Lines → incoming → m
→ outgoing → n

→ based on TDMA
→ digital
"Scheduler"

→ TDM II



digi. telephone → PSwitching

→ physical layer!.

CS → low and constant delay → good for voice (transmission) call
→ QOS → dedicated resource, constant throughput (no congestion)
↓ only defined for voice communication
→ ordered delivery. no sample can overtake another
→ error correction, detection not possible. [increases delay in resending the erroneous packet]

Store and Forward

→ info first stored in buffer
→ data → waits in buffer for long [if traffic] → or lost
→ priority → can lead to longer waiting time

Adv

→ single link shared
→ no occupied links
→ packet-priority systems

Dis Adv

→ variable, unforeseable delay

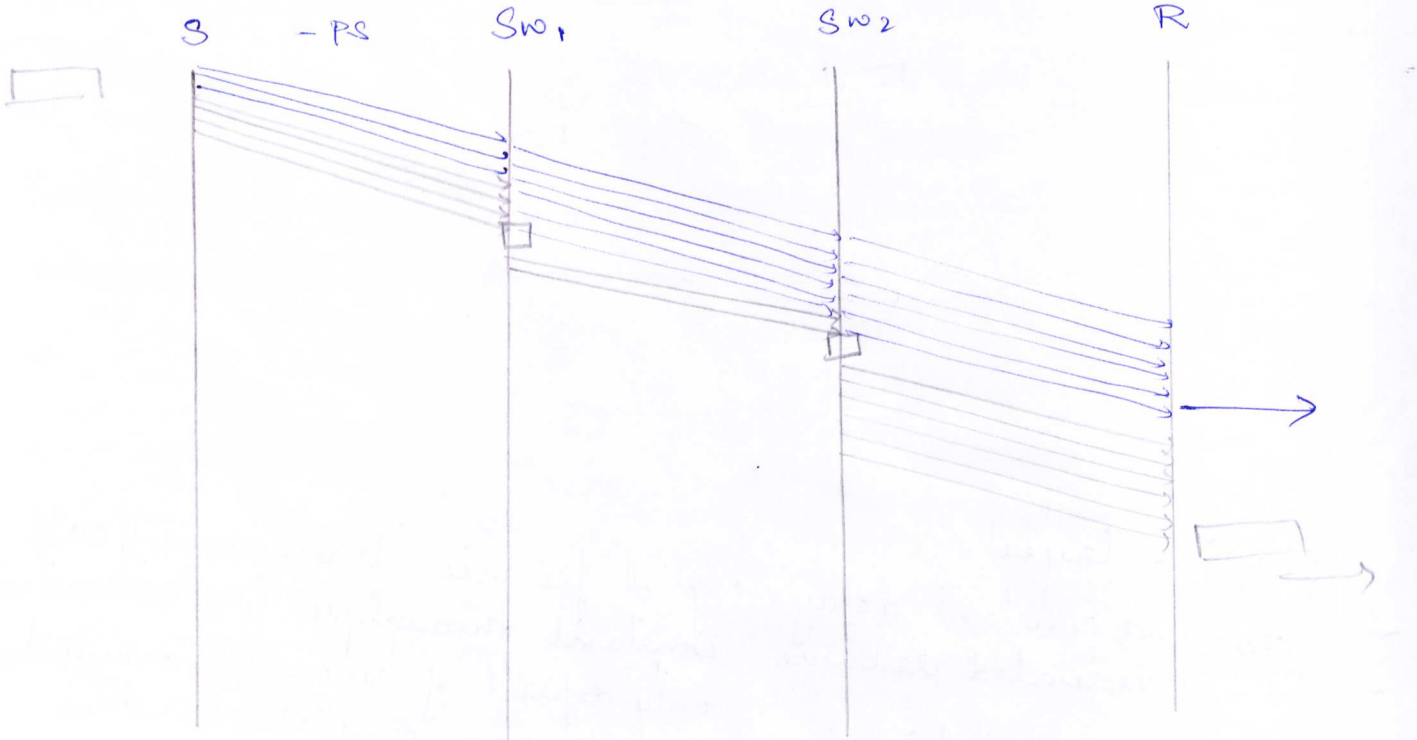
Message Switching

"Message" → self contained object of communication
* variable length [4 bytes, 4GB etc → a pic, text]

Segmenting messages

→ partitioning message (layer 3) into several data frames (layer 2)

Segmenting over Several Data links



msg → reassembled before tx to next
complete msg is received

Message Switching Principle
→ completely received & reassembled before txd over next data link

Message Switching
→ connectionless → when only 1 message needs to be sent
is usually

Packet Switching
Layer 3 deals with packets of
* max length
* might be of fixed length.

Packets are received, buffered & forwarded to next node
— in prev diagram → Packet Switching

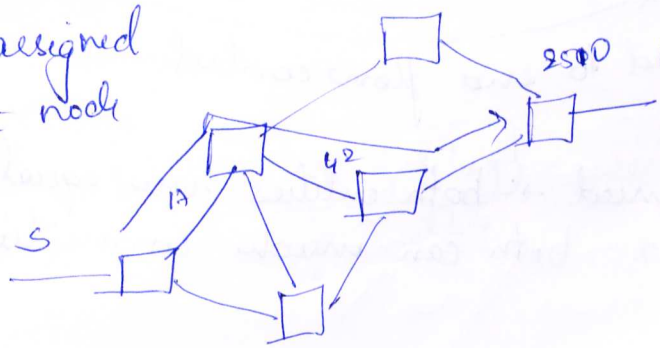
IPV6 → no intermediate nodes to segment packets
info is delivered much earlier than message switching
packets forwarded independent of each other

Packet forwarding (Stallings)

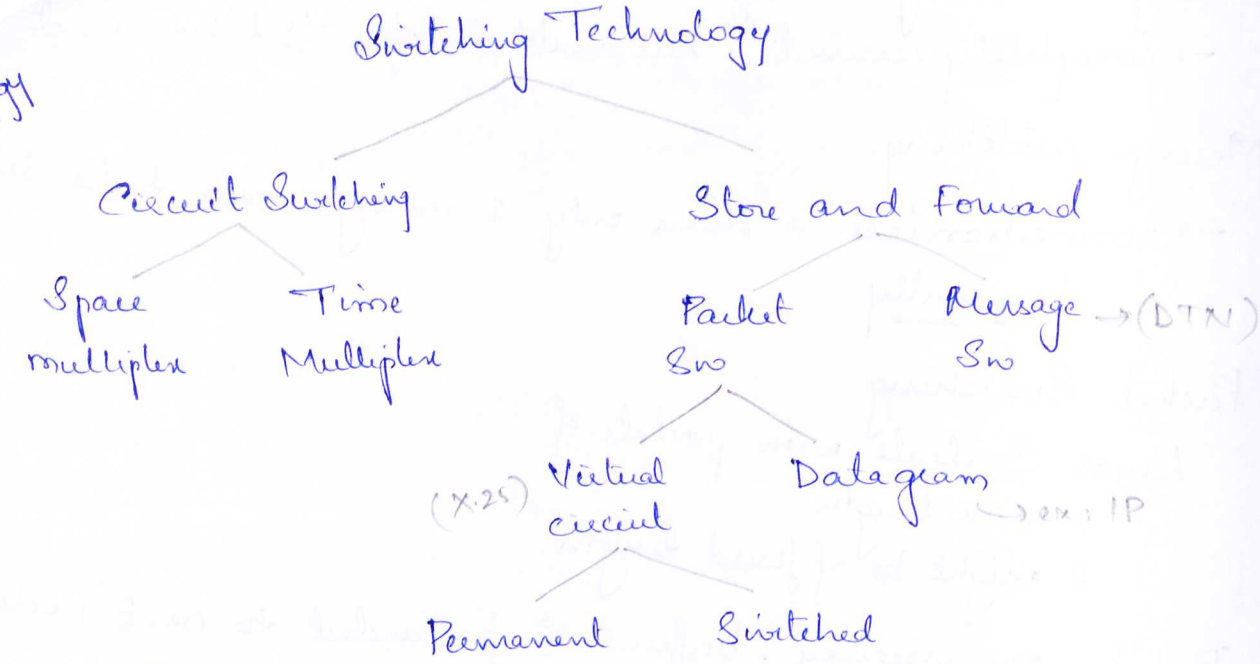
On connection establishment,
→ it means a dedicated path is available → packets follow the same path. no overtaking possible, transmitted in order

Connection-oriented
Virtual connection/circuit
PVC, SVC
permanent → switched (ex: telephone)

Connectionless
* Datagram Switching
At each node diff ID is assigned
VC ID → only for the next node



Exam Ques based on Nlw Technology



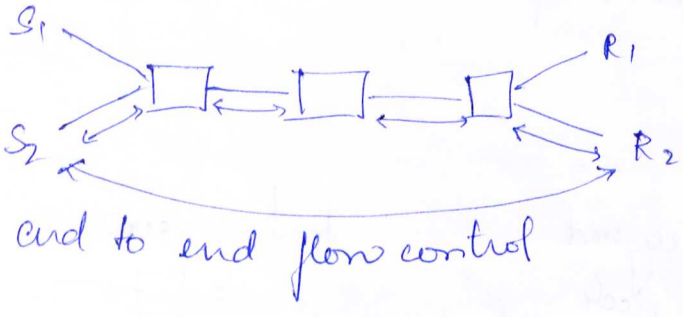
Message switching
→ variable delay
→ variable throughput
→ error detection & correction → possible
→ not ordered delivery

Chapter-7: Connection Oriented Packet Switching

Packet switching → for data
Circuit → for voice.

RSVP → resource reservation protocol for Internet
→ a virtual path setup for IP packets to take the path

X.25



end to end flow control

Balanced → both entities have equal rights
ex: both can invoke connection

Unbalanced → entities have different rights
ex: Master - slave
Master initiates connection

12.11.18

ITU-T X.25

X.25 - Physical layer
→ interface b/w station node link

X-21
↳ covers first 3 layer of OSI
* circuit switching
* error detection & correction

X.25 - Data link layer
Link Access Protocol Balanced

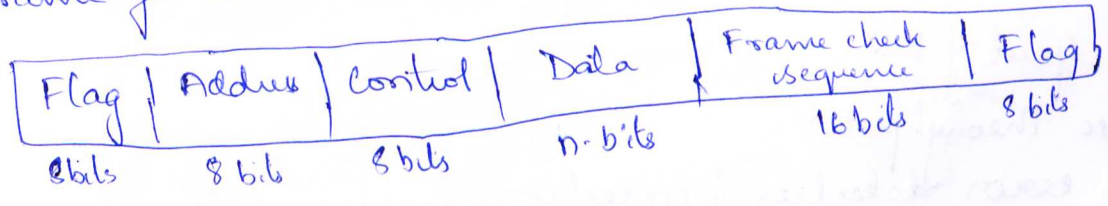
High level Data Link Control (GDLC)
- Bit oriented, code transparent Data link Protocol

bit oriented - arbitrary number of bits
code transparent - any sequence of bits

HDLC
→ half & full duplex mode
→ Point-2-point/multipoint config
→ bit oriented, code transparent DL Protocol
→ piggy backing for ACK [sent in a frame]
→ flow control based on "sliding window"

Operating modes
Normal response Mode (NRM)
Asynchronous response Mode (ARM)
Asynchronous Balanced Mode (ABM)

Frame format



When secondary station sends a response, its own address is put in the HDLC frame as the connection is P-2-P
ie only 1 primary station is there to receive.

Control field

I - frame → information
S - frame → Supervisory

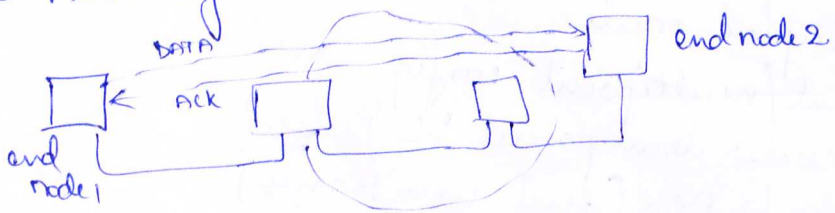
[Flow control → to slow down the rate of transmission,
S - frame can be used]

U - frame → Unnumbered

U - frame used → when we set some operation mode & for connection, it has no number, but the other node has to respond by sending ACK, hence it sends
U - ACK (U-A)

HDLC : MSC

X-25
→ has ACK again → end to end ACK.



Error correction
→ node to node

Address need not be sent each time. It is sent only once while connection is established → point-to-point comm

To increase speed of X-25
→ increase throughput
→ avoid error detection & correction in upper layers

Frame Relay : Frame

FECN / BECN → used when there is congestion in N/w, the sender is told to stop ⇒ slow down or receiver to wait for the incoming packets

→ no ACK and sequence number in Frame relay.
no retransmission

Seminar

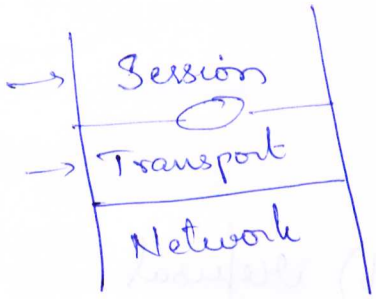
15.11.18

Lesson 3.3 T-Layer connection establishment

a) Transport layer is service provider for session layer

Session layer is service user of T-Layer

(T-Layer is service user of the network layer but not for the connection service)



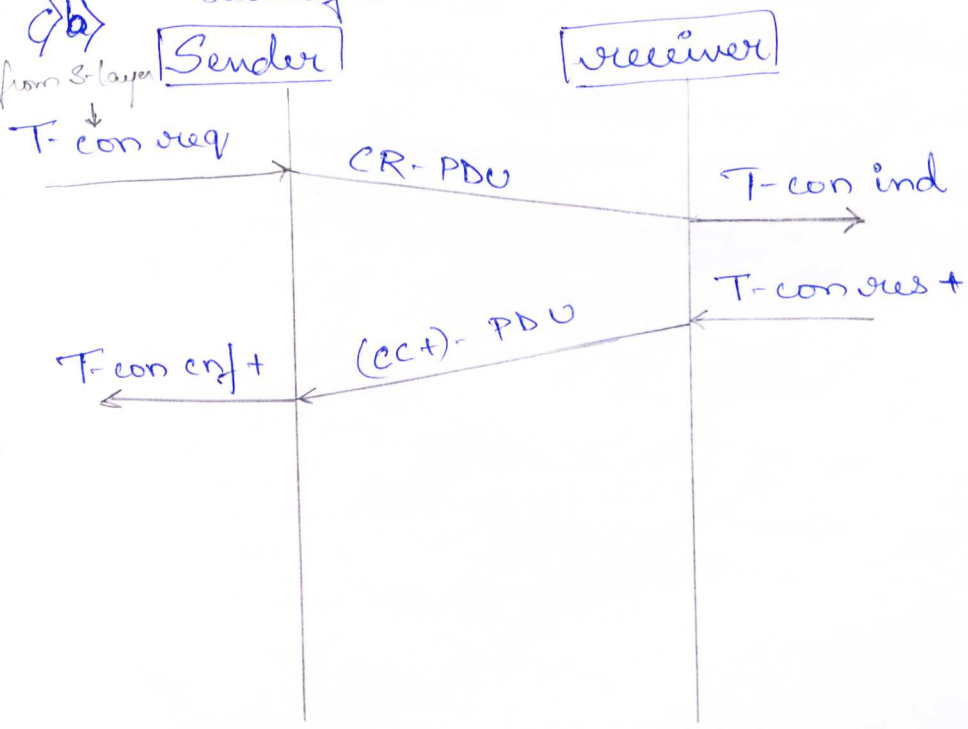
b) Request (req), Indication (ind), Response (res +/-), Confirmation (cnf +/-) → 4 Primitives

Services : Connection (con) Data (data)
Disconnect (dis) Provider | User-Abort (PAbo/UAbo)

CR → conn. request PDU

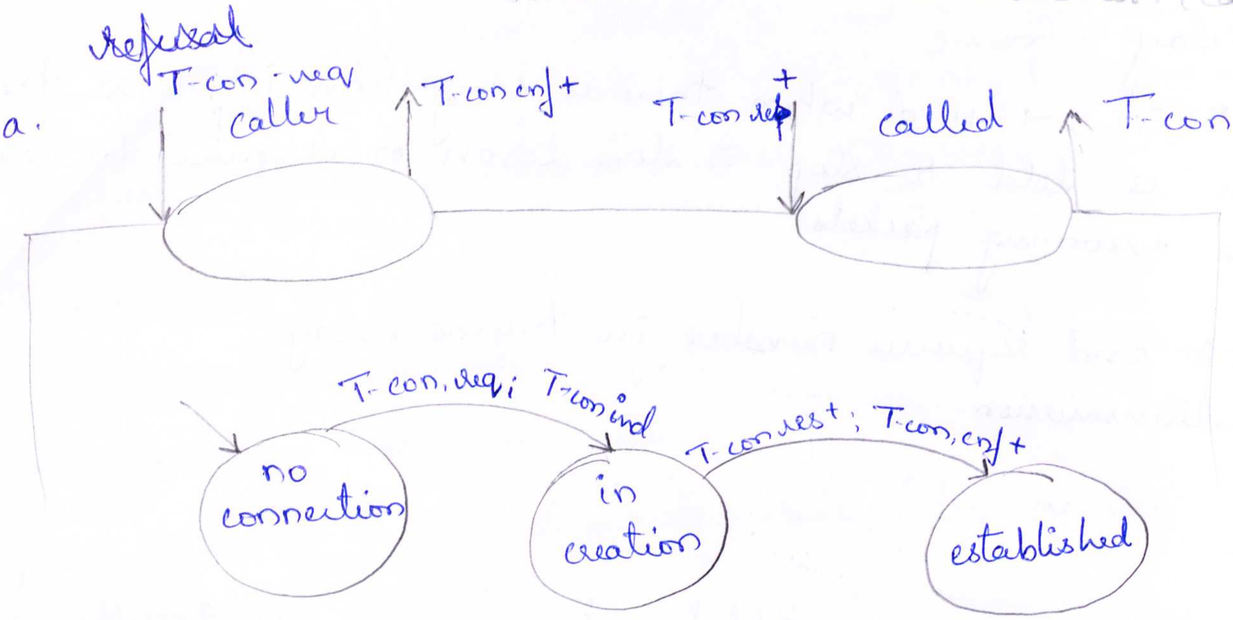
Successful connection establishment

(b)

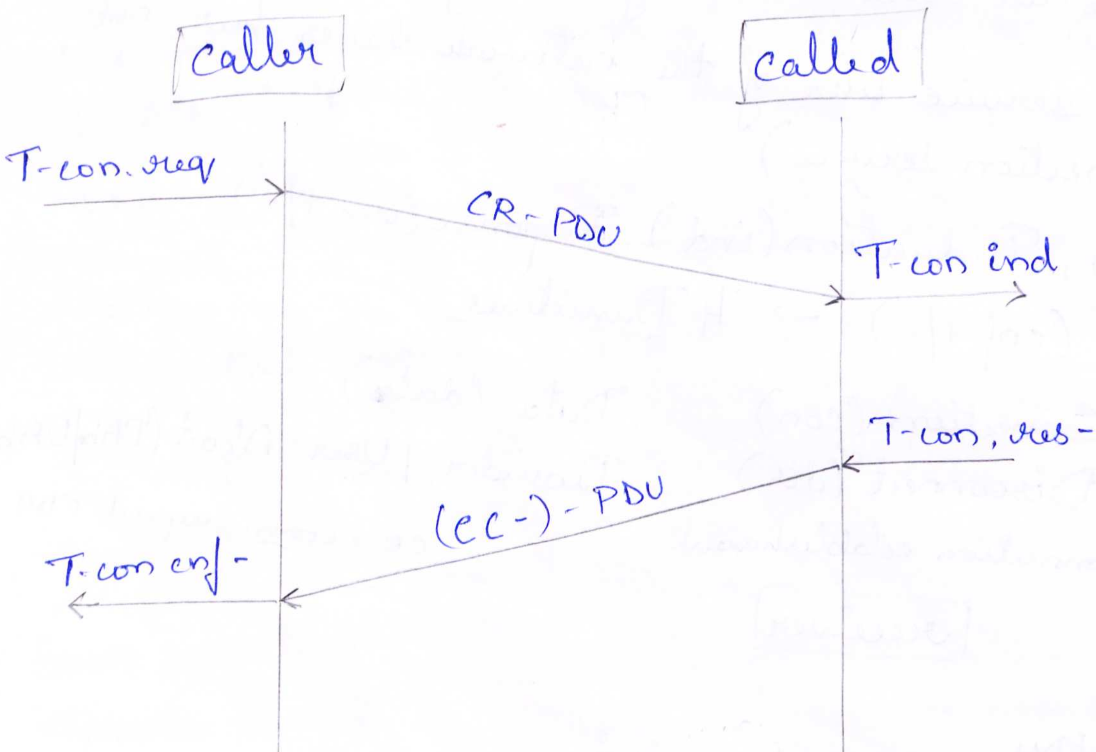


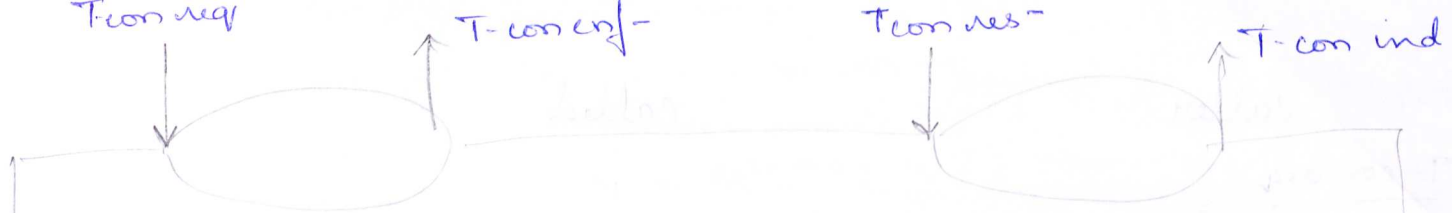
Abstract Medium sends indication (called side)

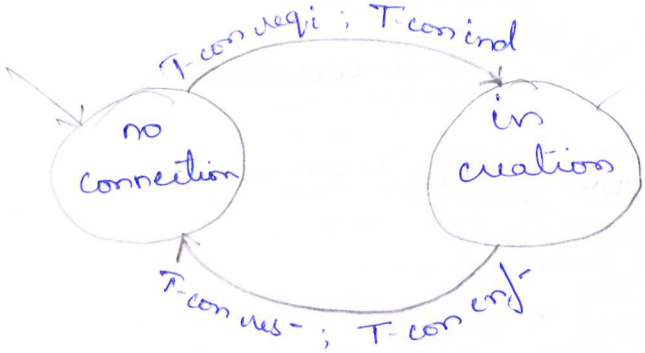
c) a.



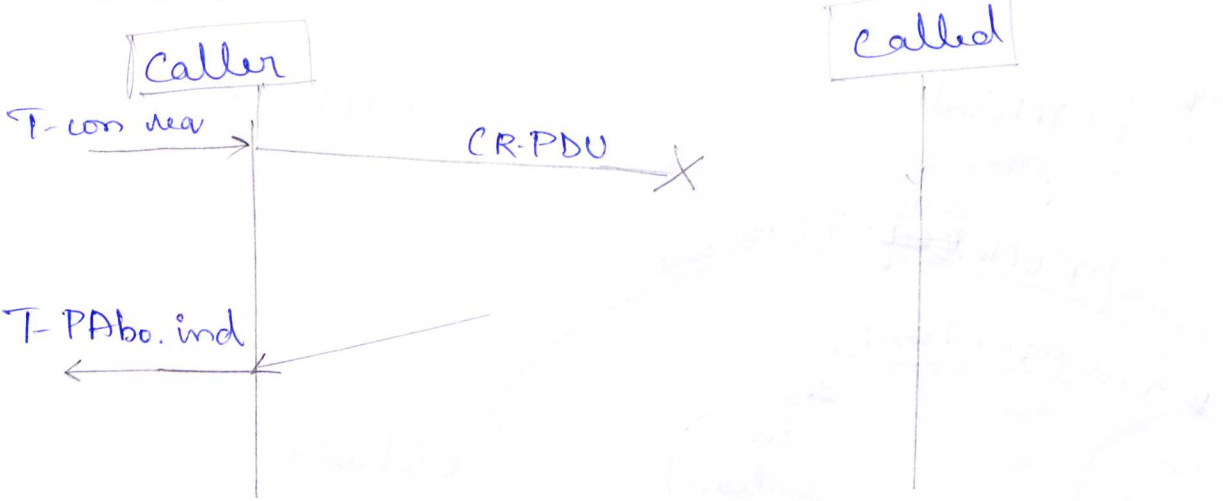
c)b) refusal

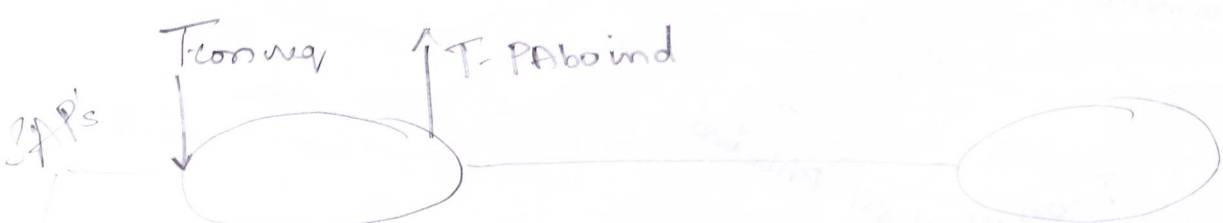


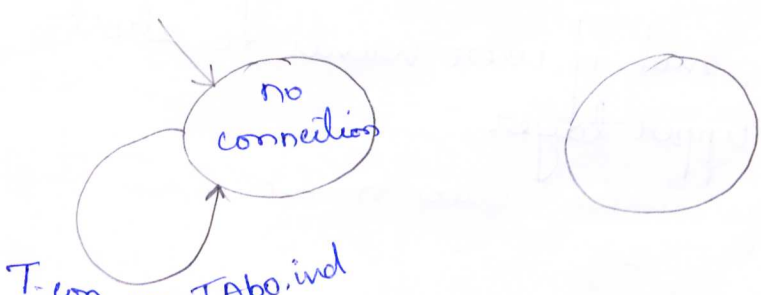

T-con req
T-con cnf-
T-con res-
T-con ind

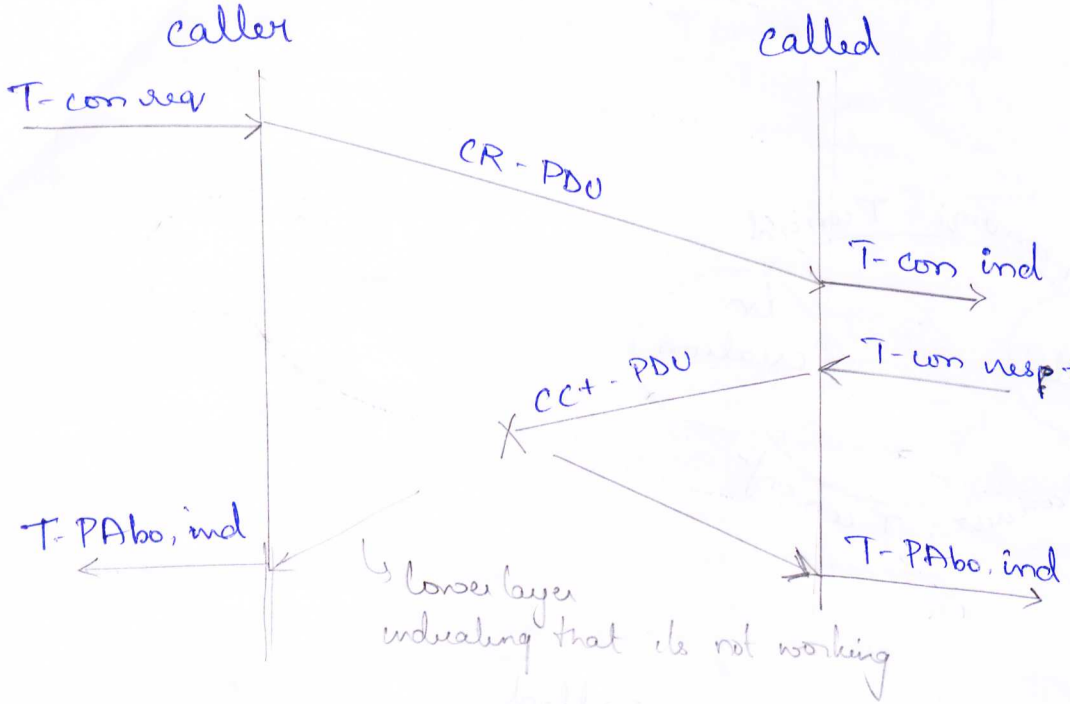

T-con req; T-con ind
no connection
in creation
T-con res-; T-con cnf-

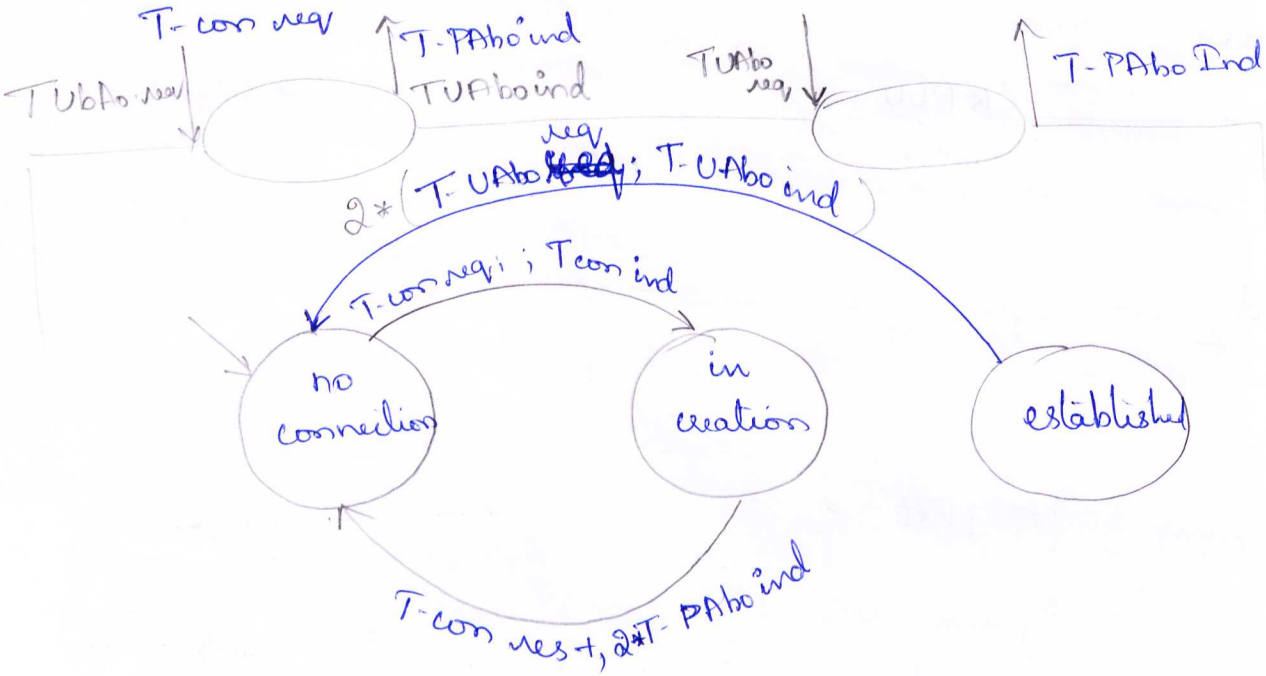
Abort


Caller
called
T-con req
CR-PDU
T-PAbo. ind


T-con req
T-PAbo ind
3 PDUs


no connection
T-con req, TAbo. ind





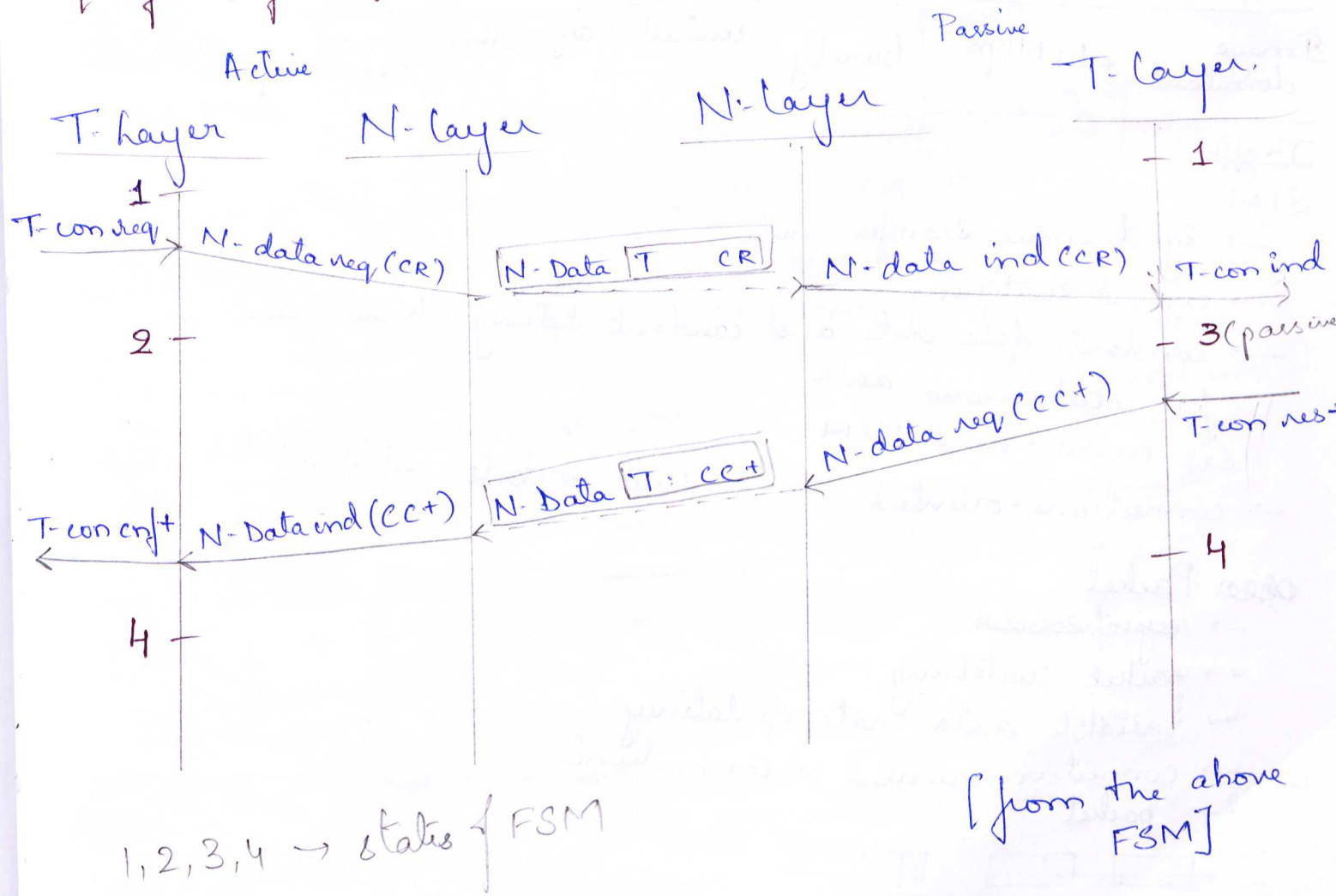
When it is established, and if user wants to abort T-UAbo req is sent from upper layer

UAbo req can be sent by Session layer on both sides ie caller & called → can be sent by both.

[refer successful establishment] → ##### blue

[refer refusal] (black)

MSC to FSM!



1, 2, 3, 4 → states of FSM

[from the above FSM]

16. CI - 18

Broadband Applications According to ITU-T

Network Requirements

gaming, videoconferencing, Network connections, Online TV/ video streaming, Image download traffic → depends on codec

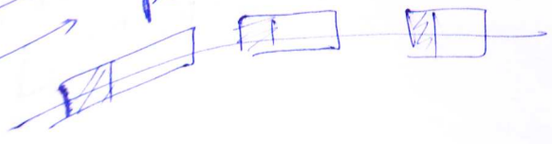
	data rate	traffic char	relation sender/ receiver	Symmetry of traffic	Connection
gaming	< 10 Mbps	bursty	multi-peer	asymmetric bidirectional	Yes
Video conferencing	< 10 Mbps	constant variable	multi-peer	sym/asym bidirectional	Yes
Network connections	> 100 Mbps	bursty	multi-peer	variable symmetry	not necessary
Online TV	10 - 100 Mbps per user	variable	multi-cast	unicast	not necessary
video streaming	10 - 100 Mbps per user	bursty	many unicast streams	unicast with small control channel	connections (for accounting)
Image download	< 10 Mbps	bursty	unicast	asymmetric	not necessary

Traffic:

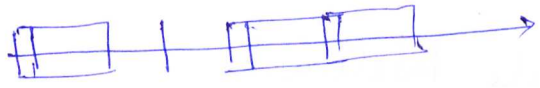
ST → Synchronous transfer mode
→ circuit switching
→ constant data rate and constant latency, hence used for isochronous data
→ narrow band ISDN
→ connections-oriented

unit → bits

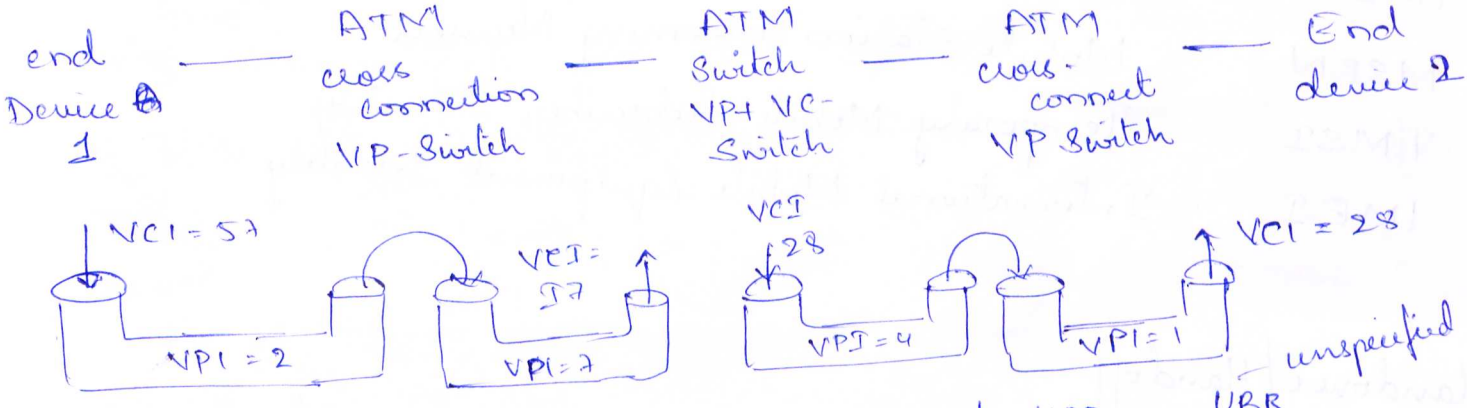
→ Packet
→ packet switching
→ variable data rate & latency
→ connection oriented or connectionless packet



ATM
→ asynchronous
→ packet switching (to have variable but foreseeable data rates)
→ Variable data rates (guarantees possible)
→ limited latency (if required
unit → cell (fixed size and small)
sent
→ connection oriented
cell → 53 bytes



ATM : Cell Header (UNI)
→ User Network Interface
Virtual Channel and Virtual Connection



ATM and AAL

	CBR class A	VBR - RT class B	UBR-nrt, UBR class C	UBR class D
Timing	real time	real time	no real time	no real time
Bit rate	constant	variable	variable	variable
Connection	C.O	C.O	C.O	C.Less
AAL	(1)	2	3/4	

ATM → always connection oriented
upper layers can be connectionless, ↓ not much different

AAL I → isochronous traffic

AAL 5 → packet switching

BUS → broadcast unknown server

AAL
→ segmentation of the IP packets (cells of 48 bytes + 5 bytes of header)

Adaptation layer AAL

Chapter 8: Public land Mobile Networks

PLMN

19.11.18

MSISDN - Mobile Phone Number

IMSI - International Mobile Subscriber Identity

MSRN - Mobile station Roaming Number

TMSI - Temporary Mobile Subscriber Identity

IMEI - International Mobile Equipment Identity

Handover / Handoff

Change of cell / radio channel at the air interface

3 phases:

1. Diagnosis of the necessity of handover
2. Identifying & reserving the new channel
3. Switching to the new channel & releasing the old one

Types

* Hard handover
* Soft handover - new channel is set, both channels are used to send data

Forms of Handover

1. Network controlled
2. Network assisted ✓
3. Mobile assisted
4. Mobile controlled ✓

> most selected sort of H/o

Handover Decision

* Different HO procedures
  - → Horizontal HO
  - → Vertical HO

* Parameters
  - * channel characteristics [usually to be determined on both sides]
  - * QOS
  - * Parameters on provider side
  - * User preferences
  - * Multidimensional problem → multi criteria decision making

Roaming

Security Hazards

- Confidentiality of radio channel
- Authentication
- —

Simplified Reference Model for Mobile Networks

- Aspects of Mobile Communication

Signal propagation

Multipath propagation

GSM

GSM , adv. disadv

Mobile Services

E

MT → physical layer [wireless comm]

→ authorization, modulation, error detection etc

TE → application

R → adaptive

S → digital interface

19. Architecture

23.11.10

System architecture

Radio Subsystems

GSM-R → railways

Station-to-train, intra train communication

Mobile Station

SIM

→ stores &

Keys - ~~shared~~ or shared key, encryption

MSISDN / IMSI

number directory

SMS

Provider / Services

PIN / PUK

NSS → Network and Switching Subsystem

Operator Subsystem
→ enables centralized operation
AUC, EIR, OMC

GSM - TDMA | FDMA

Training → used for error detection, synchronising

every 3.5 hrs encryption key needs to be changed → during call

Logical Channels

group	channel	Directions for Comm.
Traffic Channel	TCH/F, Bm (full rate)	MS ⟷ BSS
	TCH/H, Lm (half rate) ↓ lower rate	MS ⟷ BSS both directions
Signaling Channel Dm — Broadcast	BCCH broadcast control	MS ← BSS
	FCCH freq. correction	MS ← BSS
	SCH synchronisation	MS ← BSS
Common Control (To setup connection, all MS use same channel)	RACH random access → used to reply to BSS by MS	MS → BSS
	AGCH access grant	MS ← BSS
	PCH paging channel	MS ← BSS
	NCH notification channel	MS ← BSS
Dedicated Control (channel dedicated)	SDCCH standalone dedicated	MS ⟷ BSS
	SACCH slow associated	MS ⟷ BSS
	FACCH fast associated	MS ⟷ BSS

It's last class till 10:20 at Humboldtbau

GSM Protocol layers for Signalling

MM - mobility management
CM - call management

Data is sent in time slots using circuit switching

ciphering → exchange of new keys

alerting → uses SACCH

Types of HO

a problem with physical link → BS indicates to change frequency

→ handover within the cell

HO Decision

HO Procedure

→ Mobile assisted HO

Security in GSM

GSM Authentication

SRES → sign response

RAND - random accesses

GSM - circuit switching

→ ideal for telephony

→ lacks the rate to send data

→

26.11.18

Data Services in GSM - I

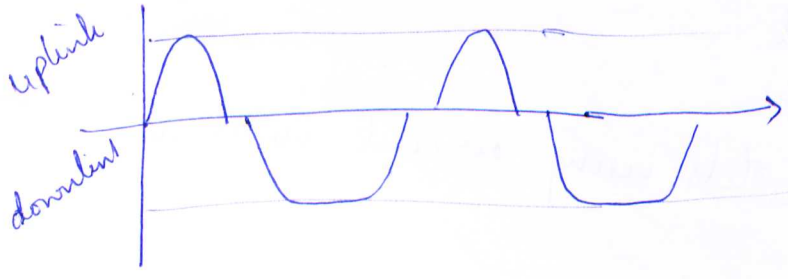
data tx → 9.6 kbps

advanced → 14.4 kbps

HSCSD

- 57.6 kbps

disadv : Channels blocked for voice transmission



Data Services in GSM II

- GPRS
  - * packet switching
- GPRS Network elements
  - GSN → allows access to public data network (internet or X.25)

GPRS : QoS
- ~~Reliability~~

class 3 → default Quality of Service

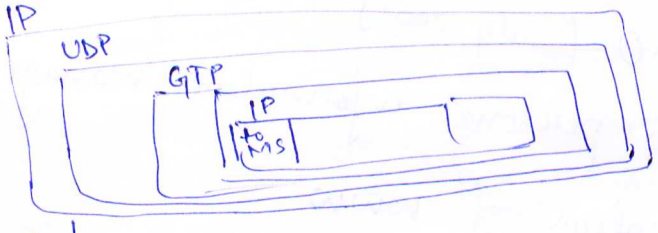
GPRS Architecture

Gn → support moving users

Protocol Architecture

GTP → GPRS Tunneling Protocol
serving link b/w GGSN & SGSN

IP is tunnelled in GTP, UDP & IP



if its IP packet → UDP is used
, X.25 packet → TCP
↳ assumes reliable data link layer

LLC → logical link Control

BSSGP → provides QoS
→ handover

RLC - radio link Control

MAC → AC for radio channel

Management

Data flow & Segmentation

Interworking with IP N/W

DHCP - Dynamic Host configuration protocol

WAP

- wireless application protocol
- Goals: internet contents & enhanced services for mobile end devices

problems with older mobile

* processor speed
* screen size
* may be black/white
* data rate → compress HTML
* no touch screen → number block
* presentation of content

WAP 2.0 [July 2001]

PIM → personal information manager

integration of www

Push OTA → over the Air

→ to avoid pulling of info each time by the user

PKI - public key infrastructure

Architecture

UMTS and IMT 2000 - 3G

→ both TDM & FDM

Seminar

29.11.18

$\times \frac{\text{Bits}}{s} = 4 \cdot \frac{\text{Symbol}}{s} \times \times \frac{\text{bits}}{\text{symbol}}$

4.1a)

~~2~~ $\frac{bit}{s} = 4$

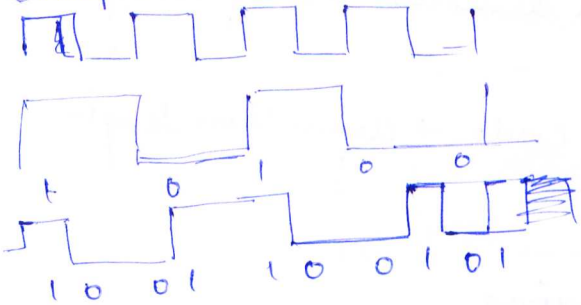
x Baudrate $\Rightarrow \frac{Symbols}{s}$

$\times \frac{bits}{s} = 4 \frac{bit}{symbol} \cdot \times$ Bd. rate $\Rightarrow \frac{Symbol}{s}$

b) If there are only 2 symbols

c) Yes, if one bit is coded with two symbol

example.



d)

0	0	1
0	1	2
1	0	3
1	1	4

$\log_2 x = \frac{\log_{10} x}{\log 2}$

To recognise the right symbol there must be a space between the symbols

4.2

$C \simeq 0.332 B$ (in dB) [Channel capacity theorem]

$C = 53 \frac{kbit}{s}$

$C = B \log_2 \left(1 + \frac{S}{N}\right)$ $\quad = a = 10^{x\left(\frac{\text{in dB}}{10}\right)}$

$C = 4kHz \cdot \log_2 (1 + 1000)$

$= 4kHz \cdot \log_2 (1001) = 53 \text{ kbits/s}$

4.3

a) 1001 1111 1111 0010

first time → refer S
if code repeats take
S2, S3 respectively

1] In the table:

Tx → n=1 (start)

S1	S1	S1	S2	S1
1001	1111	1111	0010	
+0−	++0	00−	+−0	

Sn → for 2B

1Q → 2B

2 bits at a time

b) 10 01 11 11 11 11 00 10

+3 −1 +1 +1 +1 +1 −3 +3

Bits	Q
10	+3
11	+1
01	−1
00	−3

5.1

a. Ans b, c

b. code multidivision multiplexing, time division multiplexing, space division

c. frequency division ((time) depends), code → depends on length of code & BW used

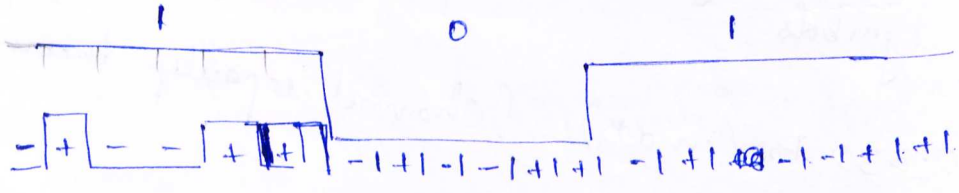
d. Space multiplexing, frequency multiplexing

5.2 CDMA

C_{SA} : − + − − + +

C_{SB} = + + − + − +

Data to be transmitted : 101



Data − + − − + + + − + + − − − + − − + +

* C_{SA} 1 0 0

Data B

C_{SB} +1+1−1+1−1+1+1−1+1−1+1+1+1−1+1−1−1

Data B + + − + − + − − + − + − − − + − + +

* C_{SB}

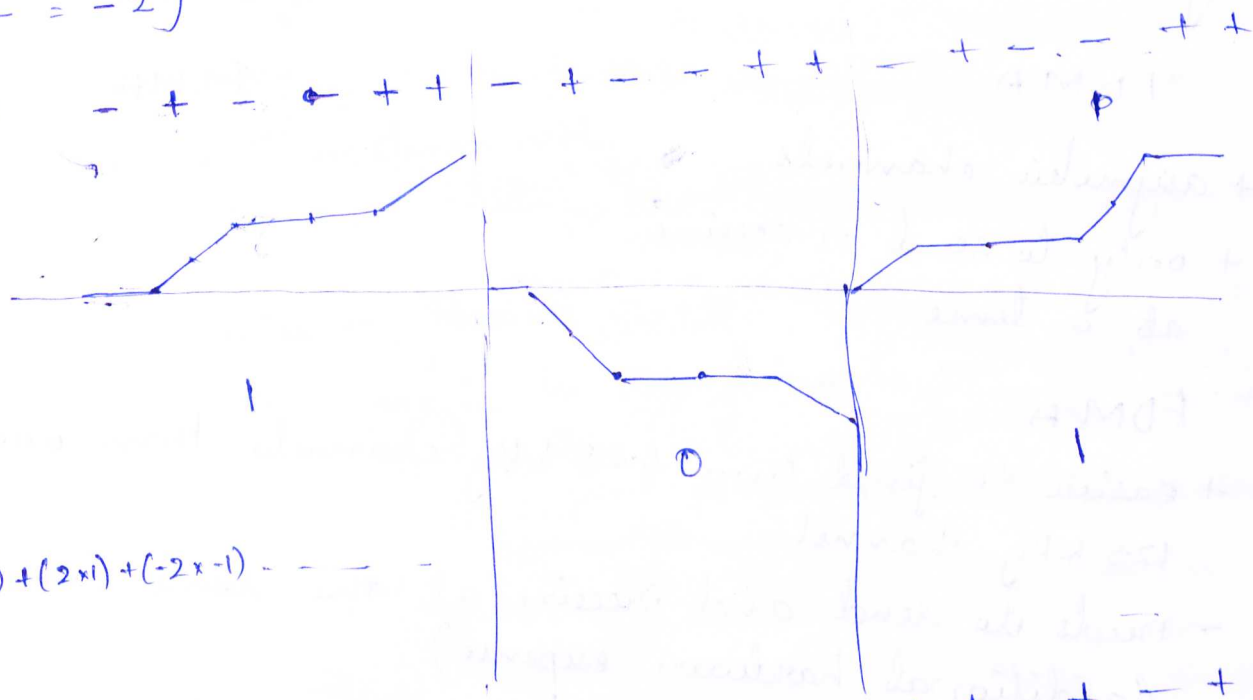
(0 = −ve) for −1 × 0 = +B

− × − = +

channel 0 0 +2 -2 0 0 +2 0 -2 +2 0 0 -2 -2 0 0 -2 +2 0

(ADD both)

[+ (+) − = 0
− (+) − = −2]



CSB : + + − + − + | + + − + − + | + + − + − +

0 +2 +2 0 0 +2 | 0 -2 -2 0 0 -2 | -2 0 0 -2 -2 0

+6 | -6 | -6

=> 1 | => 0 | => 0

5.3 TDMA vs FDMA

a) 9.8 kbits/s can be transmitted p

9.8 kbps × 2.5 ms = 24.5 bits

b) 9800 bits/s (TDMA) − 9600 bits/s (FDMA)

= 200 bits/s → difference in bit rates

$\frac{200}{24.5}$ = 8.16 $\frac{1}{s}$: => how often we can change the access method.

[9800 bps = 24.5 bits = 1176.48 bits.
8.16 /s

c) We have delay of 1176.48 + 24.85 = 1200.8 bit

= $\frac{1200.5 \text{ bit}}{9800 \text{ bps}}$ = 1225 ms 0.1225 s

No latency (mouth-to-ear delay) should be below 100ms for good quality of experience.

d) TDMA FDMA

+ asymetric channels
+ only to send or receive at a time

FDMA.

+ easier to find two 6.25 kHz channels than one 12.5 kHz channel
- needs to send and receive at the same time (additional hardware expense)

19

30.11.18
3.12.18
7.12.18

Auxillary Protocols in the Internet layer

ICMP
- Internet control message protocol

ping → ICMP message sent to node, responds if alive

ICMP: Error Messages

* Destination unreachable
  → no path to destination (link failure)
* Time exceeded
  →
* Parameter problem
  - intermediate node must process header
* Source quench
  - to decrease tx rate when overloaded

* Redirect
  - packet to be sent in a different path

ICMP : Status Request

* Echo & Echo Reply
* Timestamp & Timestamp reply
*

Delay Sender → Receiver

$T_E - T_O$ might be wrong due to not synchronized nodes

→ estimation → processing time at Rx

$$\frac{(T_1 - T_O) - (T_S - T_E)}{2}$$

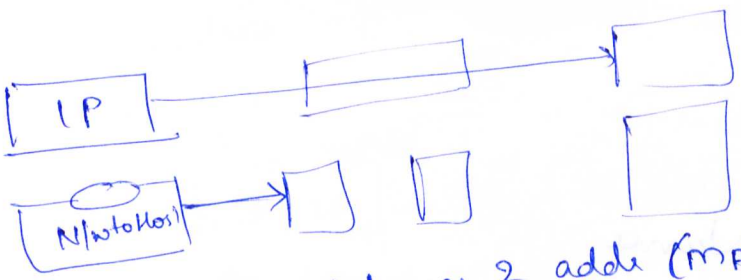
Round trip time.

ICMP : Packet format

ICMP : Trace route

ARP : Address Resolution Protocol

Task.

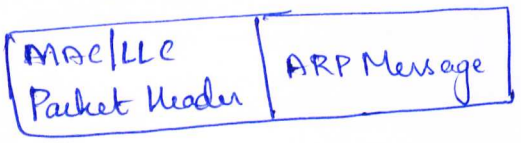


Mapping IP Addr ⇒ Layer 2 addr (MAC addr)

Modus operandi

* ARP receives IP addr for addr resolution
* ARP sends broadcast packet in LAN with IP addr
* All stations receive but only matching MAC addr replies
* reply stored in originating station
* entry deleted after sometime
  (When rebooted, may not receive from saved MAC)

ARP : Packet format



Reverse Address Resolution Protocol (RARP)

Mapping MAC addres => IP address

Internet Group Management Protocol (IGMP)

Protocol operation

→ different time slots to different groups

19

Classless InterDomain Routing (CIDR)

- 3 addres classes for IP unicast

Network Address Translation (NAT)

* unique addr (even when CIDR is used)

Dynamic Host Configuration Protocol (DHCP)

Configuration

IP addres
default Gateway
DNS server, Domain Name
Subnet mask
MTU

Point-to-point protocol

- biggest part of the network

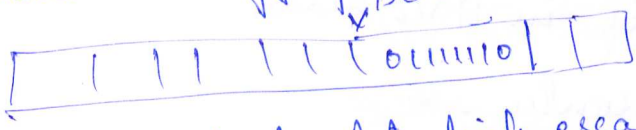
* Serial line IP (SLIP)

- no error detection
- Support of IP only
- no dynamic address management
- no authentication

Addres → 11111111
fixed as communication is from one point to another point and we donot need different addr

character oriented → therefore character stuffing
- send only bytes and not bits

character stuffing: DLE



we include data link escape character
if we have a DLE already in the sequence, we insert one more DLE, one of them are discarded later.

10.12.18

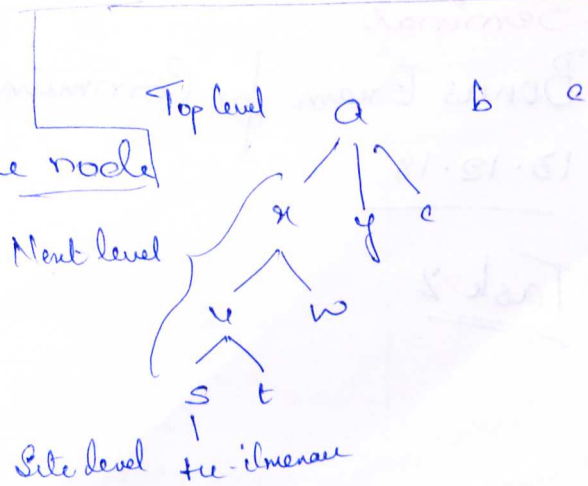
IPV4
→ not hierarchical - path of routing of packets
→ long routing table → slows routing process
→ no real security mechanism.

IPV6

Main characteristics
* huge address space

IPV4 → options field is flexible & variable, no rules for defining options
In options, we do source routing, route recording etc

Extension header → options made to appear as an extended header.
* Segmentation only end-to-end.
* QoS support
- detect 2 packets belonging to same node



Addresses
* 128 bits long, 3.4×10^{38} addresses.

Aggregatable Unicast Addr

Interface ID : like MAC addr.
→ for sending packets of IP

for security reasons, MAC addr is not a part of the frame

Segmentation 1st & then identifier in IPV6 header
→ first routing / info to router.
→ then info to end users / nodes

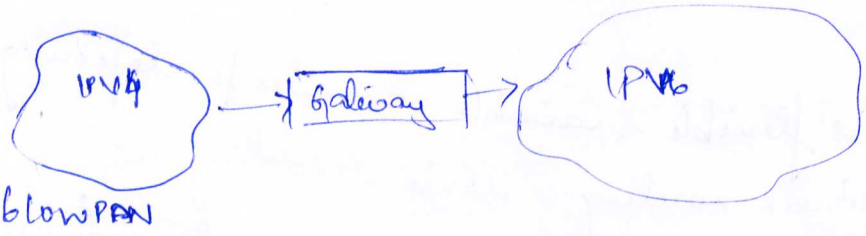
AH – allows Rx to check authenticity of packet

ICMPv6

IPV6 : Segmentation :

Security mechanism

use public key to send, private key of dest node to decrypt it.

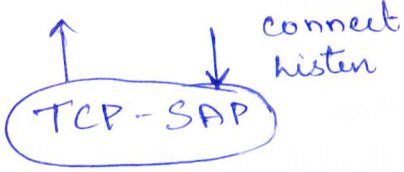


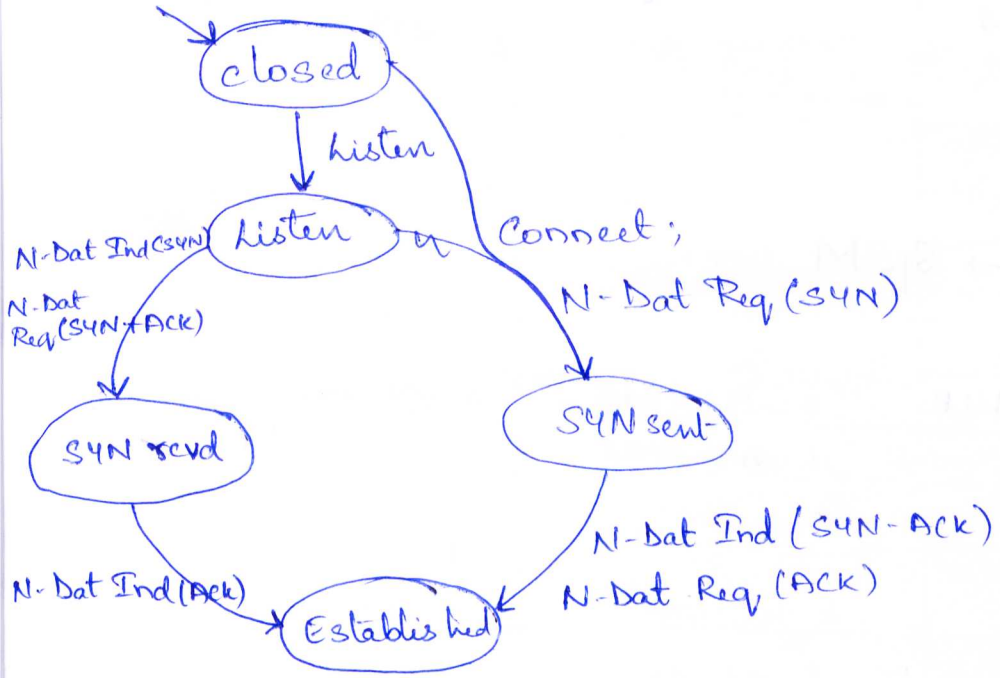
Seminar

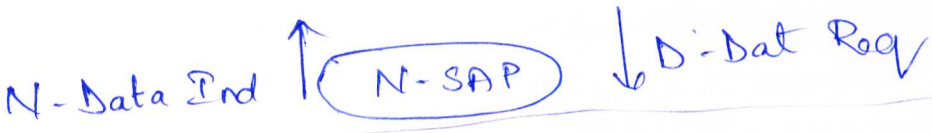
Bonus Exam for Communication Networks

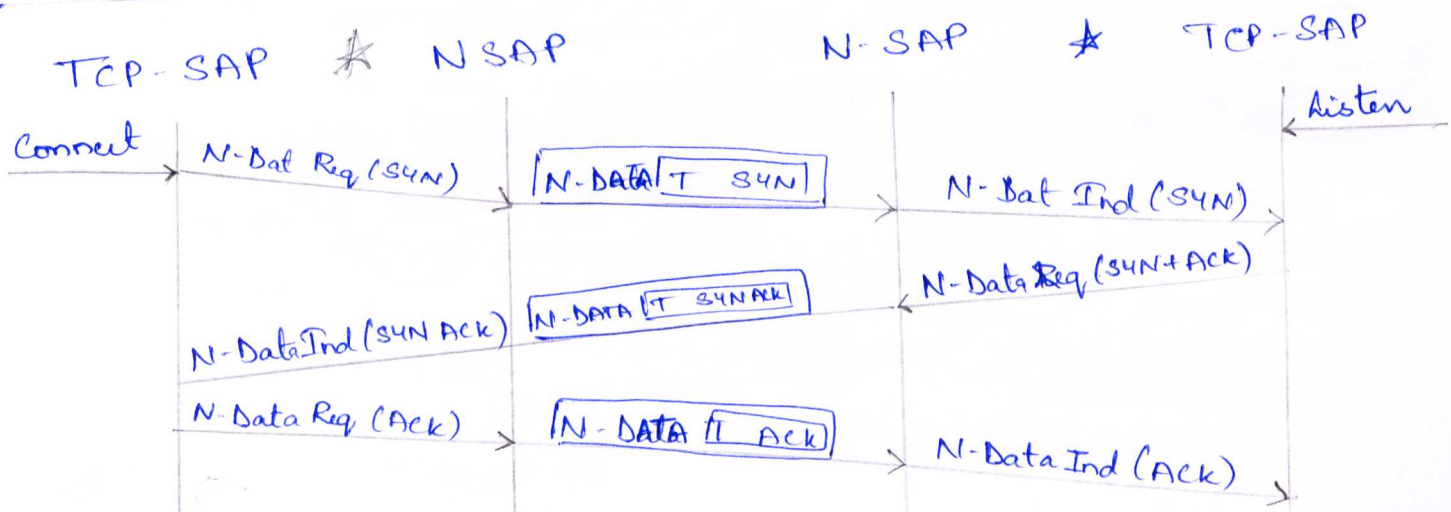
13.12.18

Task 2


connect
listen
TCP - SAP


closed
listen
Listen
N-Dat Ind(SYN)
N-Dat Req(SYN+ACK)
Connect ;
N-Dat Req (SYN)
SYN rcvd
SYN sent
N-Dat Ind (SYN-ACK)
N-Dat Req (ACK)
N-Dat Ind (Ack)
Established


N-Data Ind
N-SAP
D-Dat Req


TCP - SAP
N SAP
N - SAP
TCP - SAP
Listen
Connect
N-Dat Req (SYN)
N-DATA T SYN
N-Dat Ind (SYN)
N-Data Req (SYN+Ack)
N-Data Ind (SYN ACK)
N-DATA T SYNACK
N-Data Req (Ack)
N-DATA T ACK
N-Data Ind (ACK)

b) Timeout

Task 3

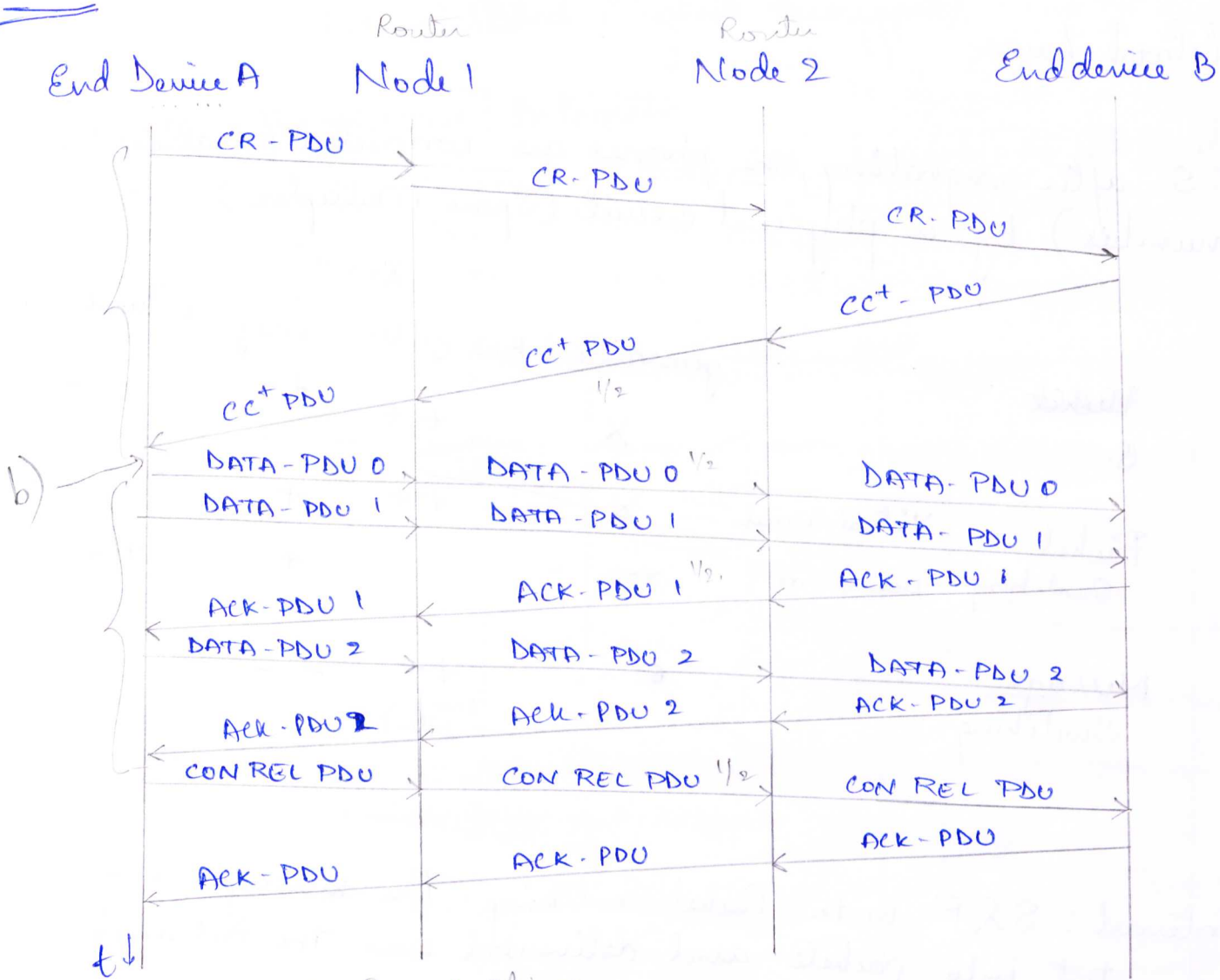
a) Limited Tx power, energy efficiency
reuse of frequencies

FDD

circuit Switching → GSM

Registers → VLR, HLR.

Task 1



No service APs & primitives
Only horizontal communication
with devices → don't need to use SAPs & primitives

6. Network layer

6.1

a) CS after signaling, the phones are connected (dialling the number) by a physical circuit (Space Multiplex)

b)

X → Yes

			guaranteed BW	jitter	delay (one)	network u
CS			X	++	++ (nearly no delay)	--
S&F	Packet Switching	Virtual Circuit	X	++	+	O(
		Datagram	~~X~~	--	+	++
	Message Switching		X	++ (no jitter)	--	-

19

b) Internet: S&F with Packet Switching. The messages are segmented into packets and delivered over the network
[when using IP in the network layer, every packet has address and can be routed on different routes between the peers ⇒ Datagram Switching]

c) public digital Telephone network (eg: ISDN)
ISDN CS TDMA physical channel

d) small mail (letter)
Letter: Packet Switching, Datagram

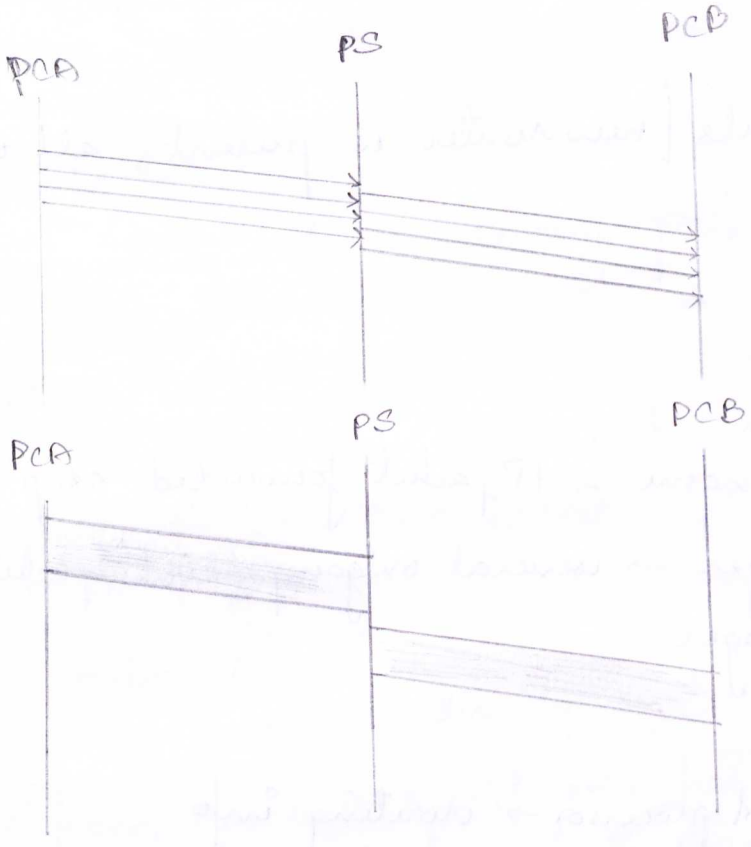
6.2

1) Video Streaming: (Packet Switching). Packet switched with connection oriented protocol and QoS (Reservations)
- Circuit Switching + small delay, no contention
→ dedicated channel
- expensive, small data rate

b) Download - Everything possible
- packet switched (highest throughput)

c - Email - Message | Datagram

d - Phone - Circuit Switched. ∴ dedicated channel, small and constant delay



14.12.18

Subfunctions of Router Task.

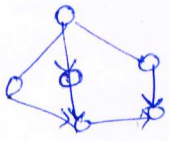
Basic forwarding

Complex forwarding

Routing Jnct

→ calculate paths & select optimum one.

* with the idea of network topology ie graph



path with shortest distance, only considering

criteria
* no. of hops
* delay
* throughput
* security
* reliability

6. Network layer

6.1

a) CS after signaling, the phones are connected (dialling the number) by a physical circuit (Space Multiplex)

X → Yes

			guaranteed BW	jitter	delay (one)	network utilization
CS			X	+ +	+ + (nearly no delay)	− −
S&F	Packet Switching	Virtual Circuit	X	+ +	+	○ (−)
		Datagram	~~X~~	− −	+	+ +
	Message Switching		X	+ + (no jitter)	− −	−

b) Internet: S&F with Packet Switching. The messages are segmented into packets and delivered over the network
[when using IP in the network layer, every packet has an address and can be routed on different routes between two peers ⇒ Datagram Switching]

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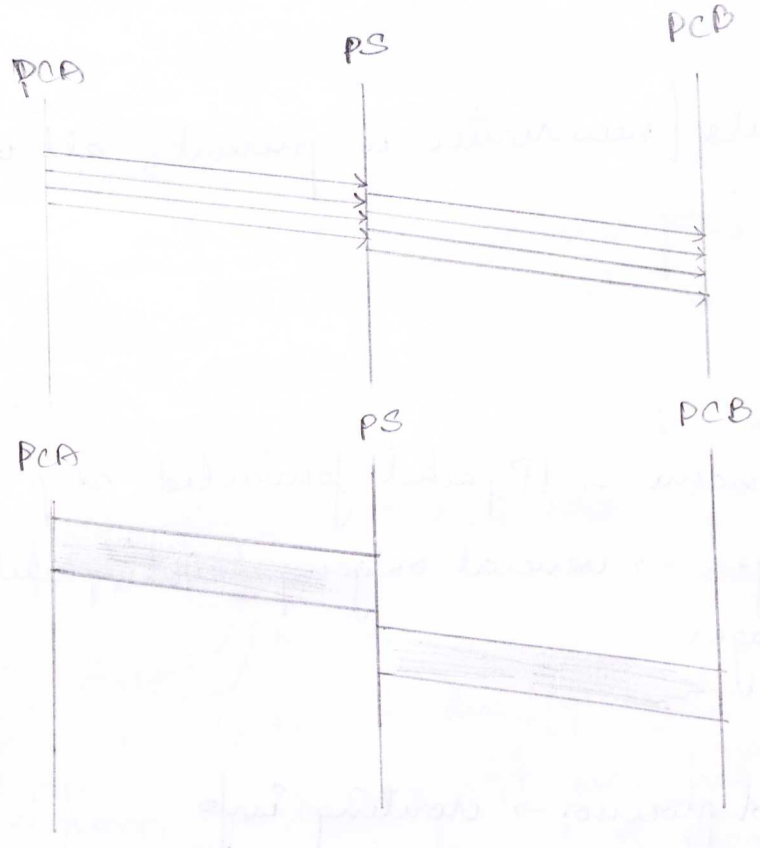
1) Video Streaming: (Packet Switching). Packet switched with connection oriented protocol and QoS (Reservations)
- Circuit Switching + small delay, no contention → dedicated channel
- expensive, small data rate

Download - Everything possible → take cheapest
- packet switched (highest throughput)

- Email = Message | Datagram

- Phone - Circuit Switched. ⇒ dedicated channel, small and constant delay



14.12.18

Subfunctions of Router Task

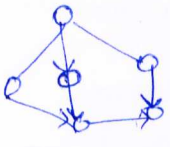
Basic forwarding

Complex forwarding

Routing Init

→ calculate paths & select optimum one

* with the idea of network topology ie graph



path with shortest distance, only considering

criteria
* no. of hops
* delay
* throughput
* security
* reliability

"Dijkstra"

Weights are assigned to each criteria & the total weight for such a s/s or link is found.

$$W = w_1 c_1 + w_2 c_2 \cdots w_n c_n$$

(w: weight)

When a link fails / new router is present, all other routers are informed

Router Components

N/w Interface

Forwarding engine → IP packet forwarded asap

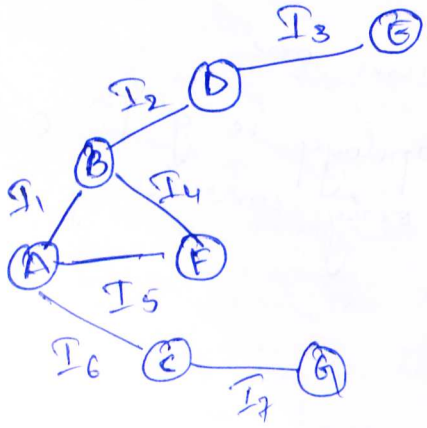
Queue manager → several outgoing (links) packets & priorities

Traffic manager

Route control process → routing info

IP forwarding Decision

Routing Table



to go from B to E we mention link I_2

A to G → I_6

" Routing Control Center"

* complete view of N/w
* routing table

Disadv:

different routing time of diff. nodes

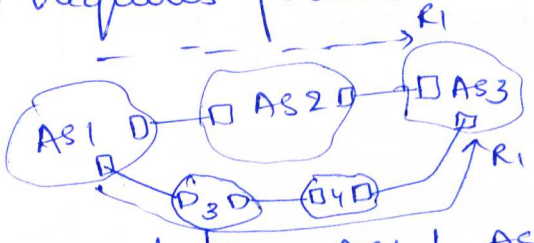
Route determination

static - fixed route

Adaptive → path changed during routing process.

Autonomous System

→ requires policies with other systems for inter-domain tx



to send from AS1 to AS2 → directly send.

if to send from AS1 to AS3, if AS1 has policy with AS2 such that AS2 acts as transit to transfer, it travels in the path R_1

if no such policy with AS2, but with only 3, 4, then the packet takes the path R_2

Intra Domain Routing

Goal: stable route

* Algorithm types

Distance Vector

- try to update knowledge of destination locally.

Routing Information Protocol

Split Horizon → ~~dead~~

to send a packet from A to C, B as intermediate node, A does not provide the info of ~~link~~ destination being C as B has to have the link to C

A - B - C - D

hops from A → 1 2 3

1 hop to A

if link b/w A - B fails, B is unaware of being part of the link.

A ↯ B (⇄) C - D ← to A

X 2 3

3 4 5

5 6 7

⋮ ⋮ ⋮

∞

17.12.18

Open Shortest Path First

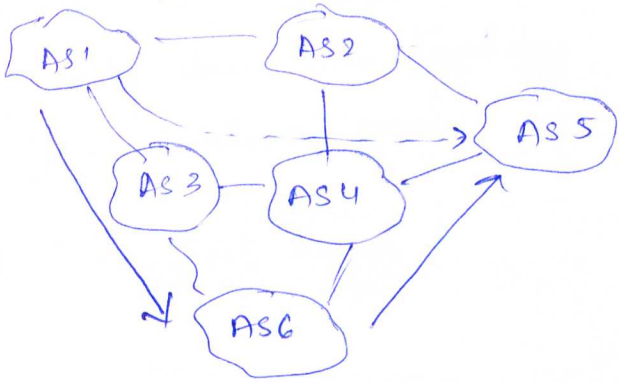
distance & quality of links considered

* Dijkstra Algorithm (Di-yak-stra)
* Control msg exchange via IP

Broader Gateway Protocol

- Application Protocol

Additional Algorithms for BGP



Cold potato
- keep packet as long as possible assuring QoS
- better for sending AS1

Hot potato
- get rid of traffic asap [just send away]
- preserve resources

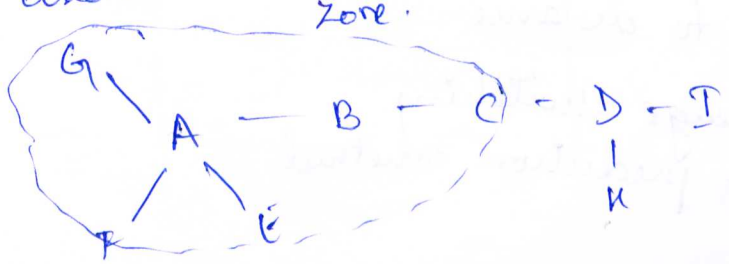
Mobile Networks

Wireless infrastructure v/s Ad-hoc N/ws

DODV

Optimized link State Protocol
- adaptive
- recalculate path often when we have mobile nodes

Hybrid Routing:
- combine protocols
  -> combo of reactive & proactive routing
  ex: Zone Routing Protocol
  - zone around a node is defined where proactive routing is used.

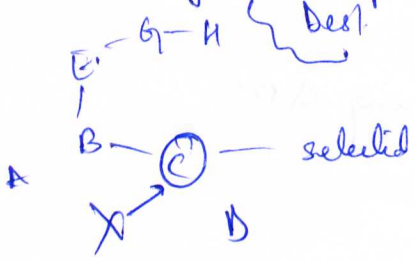


Routing for Specialised Use Cases

* Geocast
* Multicast
* Opportunistic Approaches

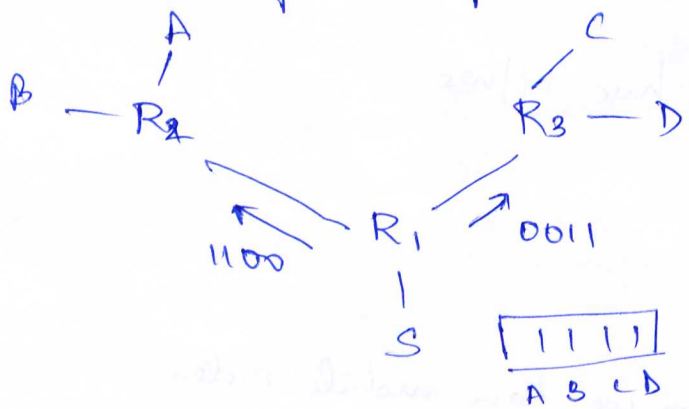
Geocast Routing

- may end up in loops



Multicast Routing

- when new node is present, all nodes are informed
- bit° identifier, adapt bit sequence accordingly



Opportunistic Routing

- msg flooded to all neighbours

* Delay Tolerant Routing

- has frequent disruptions
- interstellar comm
  → long delay due to distance
- special case of message switching
- flood / use other prediction method.

Sensor N/w challenges

* limited node resources
* Typically tree-like topology
* Different network goal

Internet Transport layer

TCP

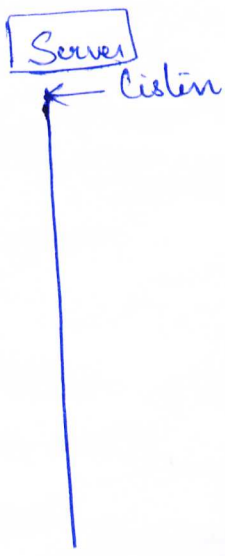
- tries to correct problems that IP cause.
* connection is established b/w 2 sockets (IP addr + port number)
* data is transferred over virtual connection
* secured connection release, wait for packets to be received before closing connection.
* full duplex data Tx, according to sequence.
- TCP does not number packets
- It number the bytes
- provides credit based flow control
- flow control using window mechanism.
- error notification

Addressing

TCP - Connection Establishment

* active

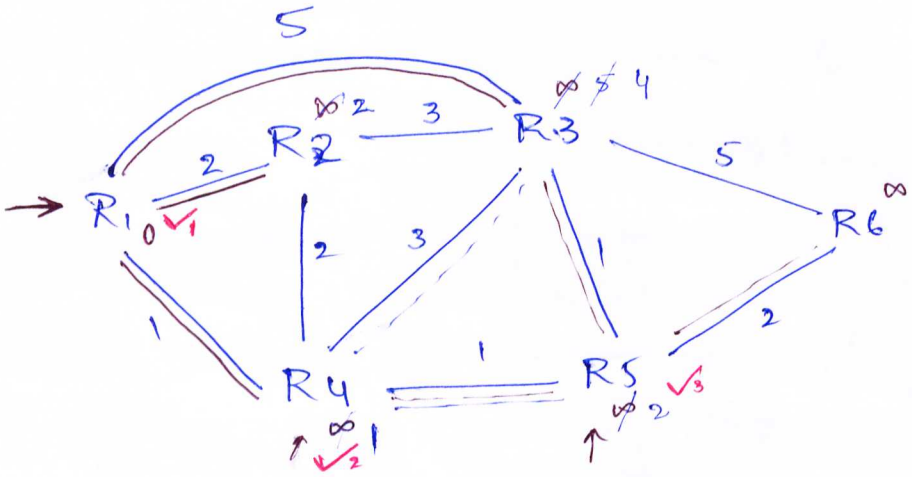
* passive



20.12.18

Seminar

6.3a.



6.3b. A lot of entities will change, because the link was highly utilized

6.3c) Initialization of all nodes with distance of "infinite";
Initialization of starting node with '0'
- Marking of the distance of the starting node as permanent
all others as temporary
- Setting of starting node active ←
- Calculation of temporary distances of all neighbour nodes of the active node by summing up its distance with the weights of edges.
- If such a calculated distance of a node is smaller than the current one, update the current node and set it as antecessor.

- Setting of the node with the minimal temporary distance as active Mark to its distance as permanent
- Repeat step 4-7 until there aren't any nodes left with a permanent distance which neighbours still have temporary distances

7. Network Layer & Data link Layer

7.1a. Data link layer → 1.5 k bytes

to be sent → 600 k bytes

600 k bytes > 1.5 k bytes

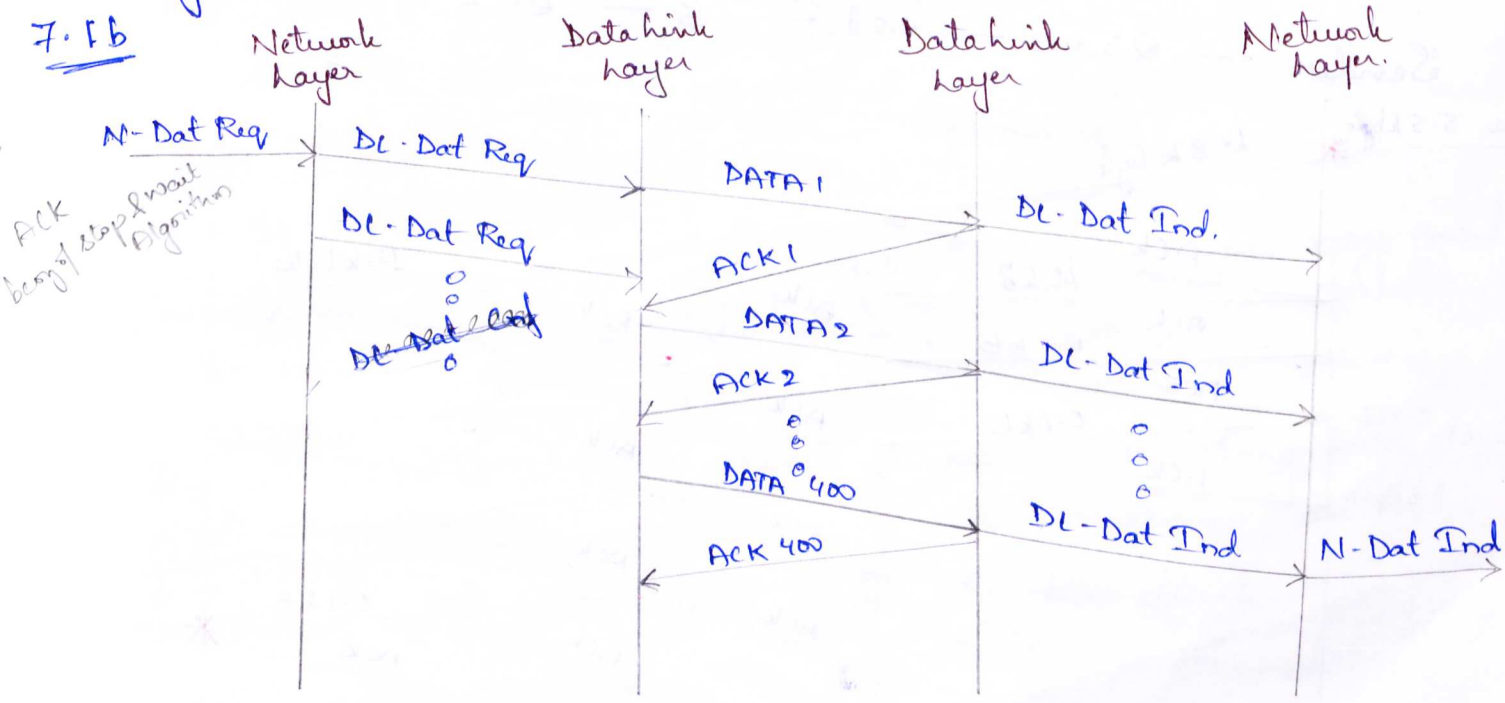
Do not fit in the frame

Hence segmentation is made.

- Segmentation and reassembly.

first, after all segments have been transmitted, the SDU can be reassembled and forwarded to the network layer.

7.1b



segment / frame size

$= \frac{600 \text{ kbytes}}{1.5 \text{ kbytes}} = 400$

400 iterations

600 kbytes of data to be transmitted in DCT 1.5 kbyte size. Hence 600 kbyte is divided into segments and sent as 1.5 kbytes in 400 frames.

7.1c

From the MSC, we wait only till 400 DATA packets are sent & 399 Acks are received to get N-DAT Ind.

600×8 → convert byte to bits

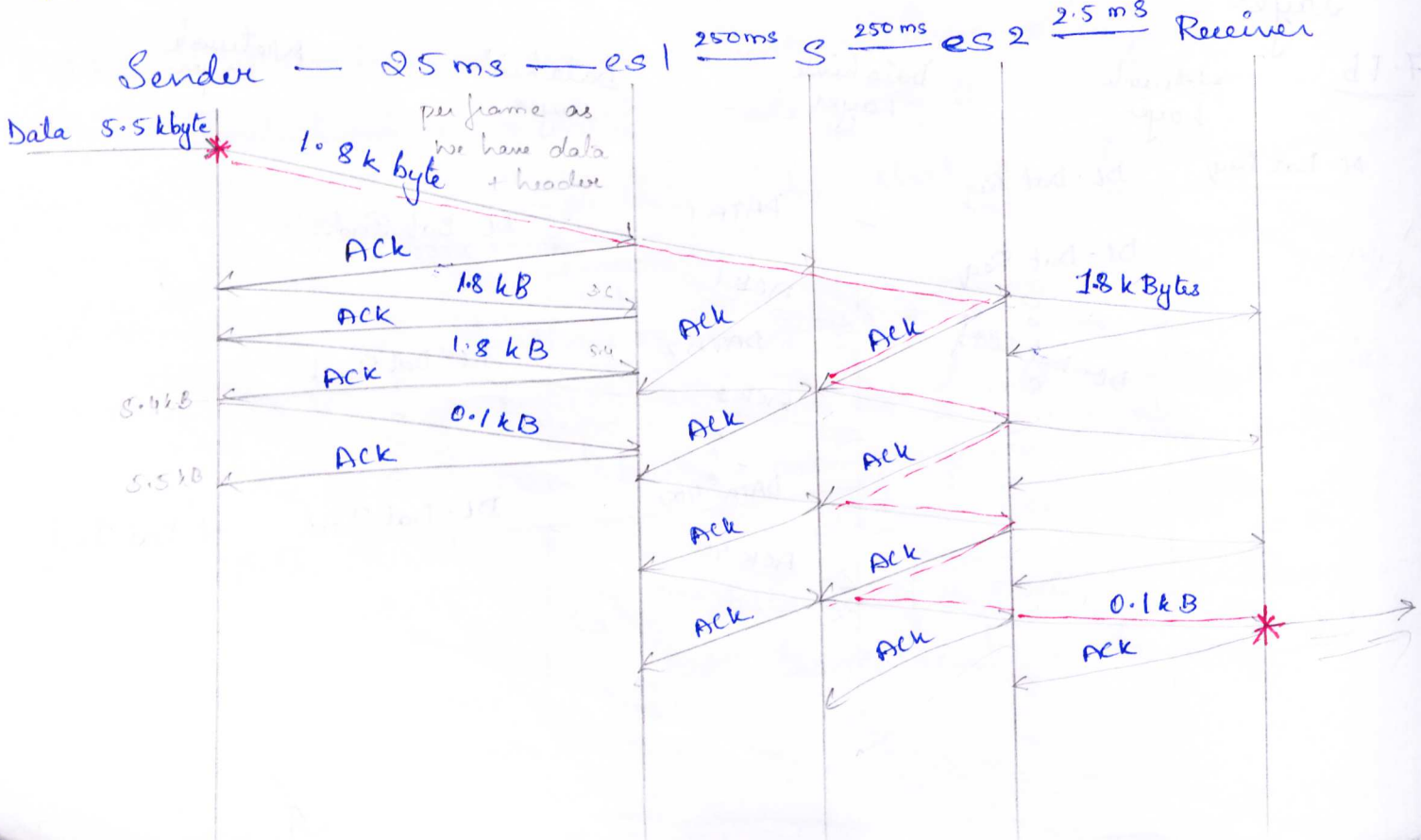
600 k byte + 399 × 1 k bit = 4800 k bits + 399 k bits

= 5199 k bits

$\frac{5199 \text{ k bit}}{4000 \text{ k bits/s}} = 1.3 \text{ s}$ to complete transfer from the delivery

$\left[\frac{\text{No. of bits}}{\text{Transmission Speed}} = \text{Time} \right]$

7.2. Satellite Communication



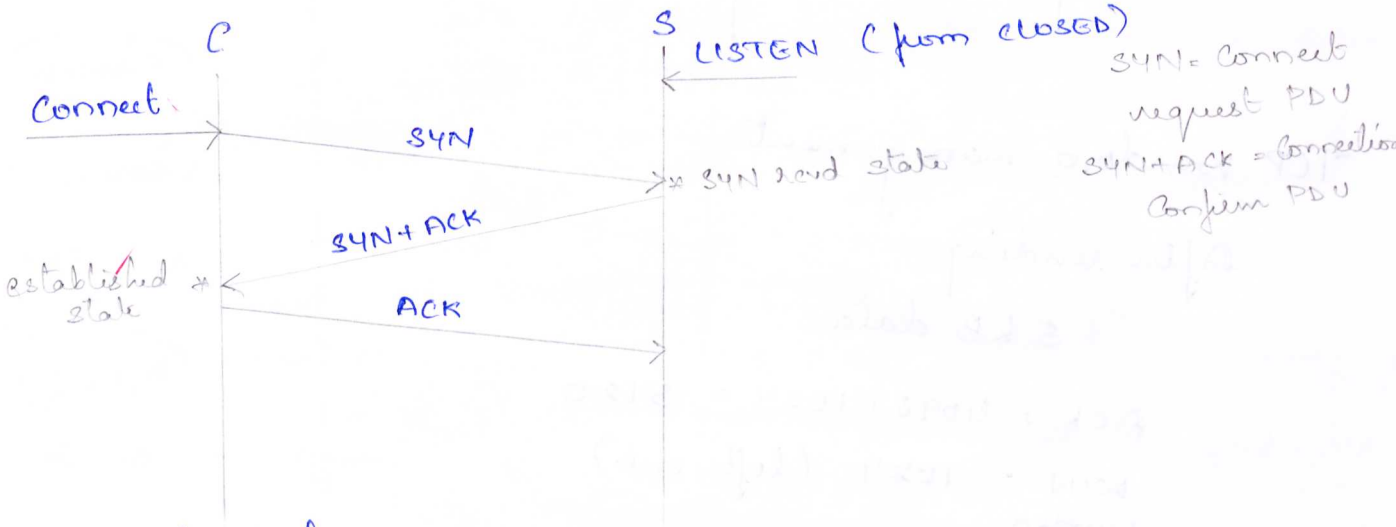
Time duration between * *

follow ⟶

25 ms + 250 ms + 250 ms x (3) + 25 ms = 2050 ms

21.12.18

TCP Connection Management



TCP Packet format

Source port addr, Destination port addr → 16 bits each.

Sequence no : no. of next byte expected

EOM - end of message - PUSH.
- PUSH up to application saying it is complete

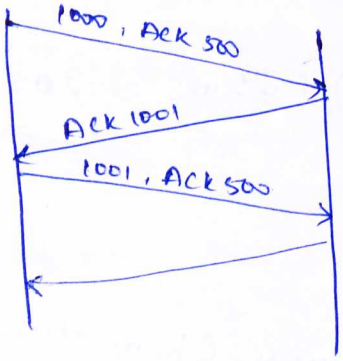
RST - reset
- reacting to a connection situation

FIN - Final
- to close connection

Window: size → max no. of bytes the other side may send.
→ amount of info. to control overflow

In the above MSC, data packet can be sent along with Ack from client to server. But only after receiving an Ack, can the server send user data to the client.

i → pckt no. of client
j → " " of server



7.

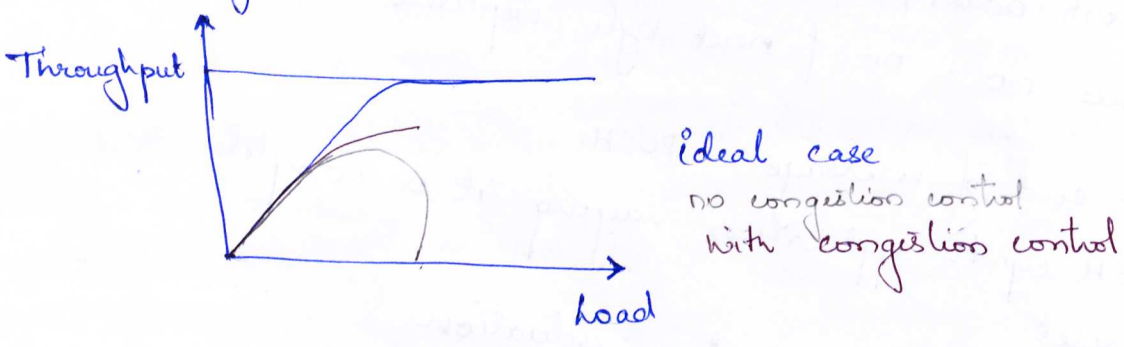
TCP window management

After sending
5 kB data

ACK : 4096 + 1024 = 5120

WIN = 1024 (left out)
window

TCP : Flow / Congestion control



overload → loss to delay & retransmission

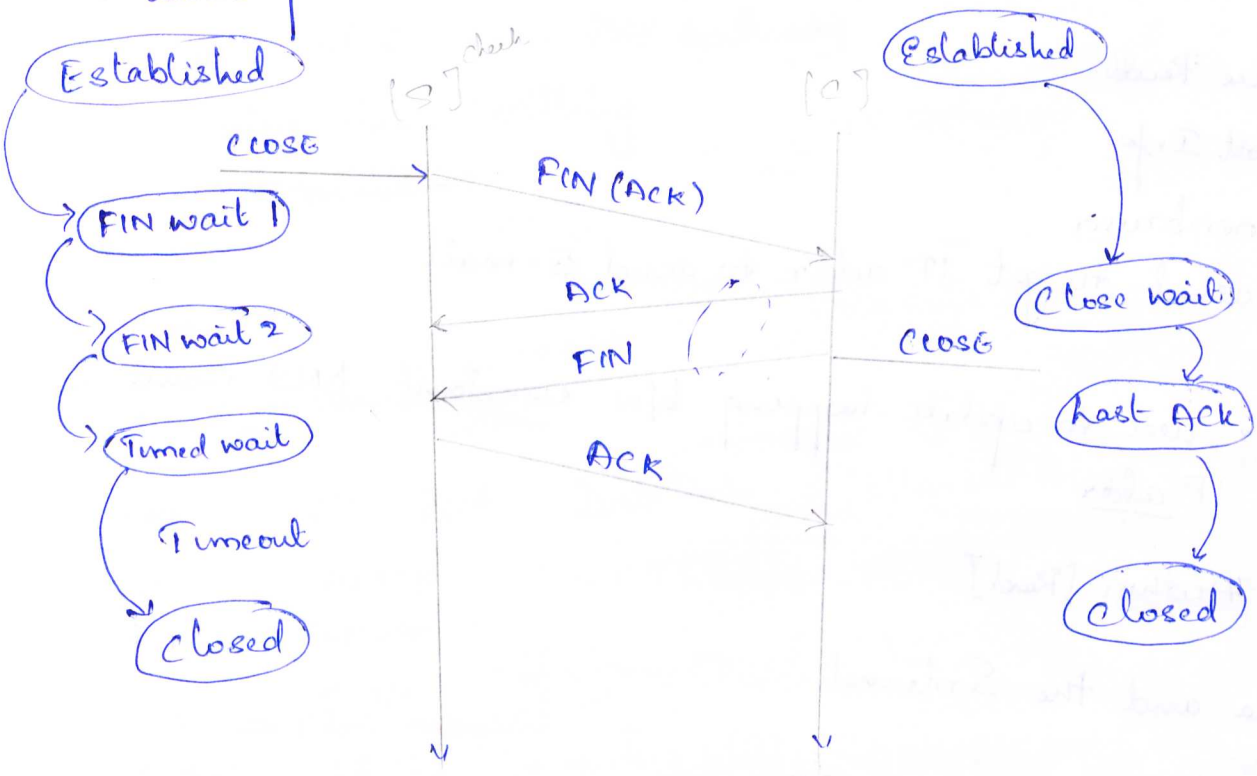
TCP → end nodes

problem in Routers → IP cannot handle, no involvement of TCP.

→ ACK is waited for.
if no ACK, expect / assume a congestion, slow down tx

TCP: Connection Release

- usually server closes the connection



- reliable data transfer in sequence
- flow and congestion control

User Datagram Protocol : UDP

* unreliable, connectionless, simpler and faster than TCP
* demultiplexing of received packets / applications according to port number (socket → port no. + packet ID)

Stream Control Transmission Protocol :

* compromise of UDP & TCP
* combine multi-streams in a message

7.01.2019

Logical Address in the Internet

DNS - Resource Record

HINFO - Host Info

DNS → Tannenbaum

MX to be asked to get IP addr to send E-mail

dyn DNS

- allows user to update mapping b/w constant DNS name & changing IP addr

Comer → Author [Read]

Multimedia and the Internet

To avoid buffer running empty

→ decrease ~~voisely~~ quality

→ reduce speed

Real Time Streaming Protocol (RTSP)

commands to control video stream → pause, play, forward, rewind position etc

RTSP - Characteristics

uses both TCP & UDP

TCP → guaranteed of receiving the command

RTP - real time protocol

RTCP - RT control protocol

VoIP

PBX - Protocol Branch Exchange

PSNT → has circuit switched

RTP sends voice samples to VoIP Gateway. TDMA is used to send voice sample to PSTN

* RTP is corrected
* SS7 is used. Map SIP to SS7

RTCP : generated near VoIP Gateway.
VoIP → also does billing
Authentication

10.01.2019

Video check

Seminar

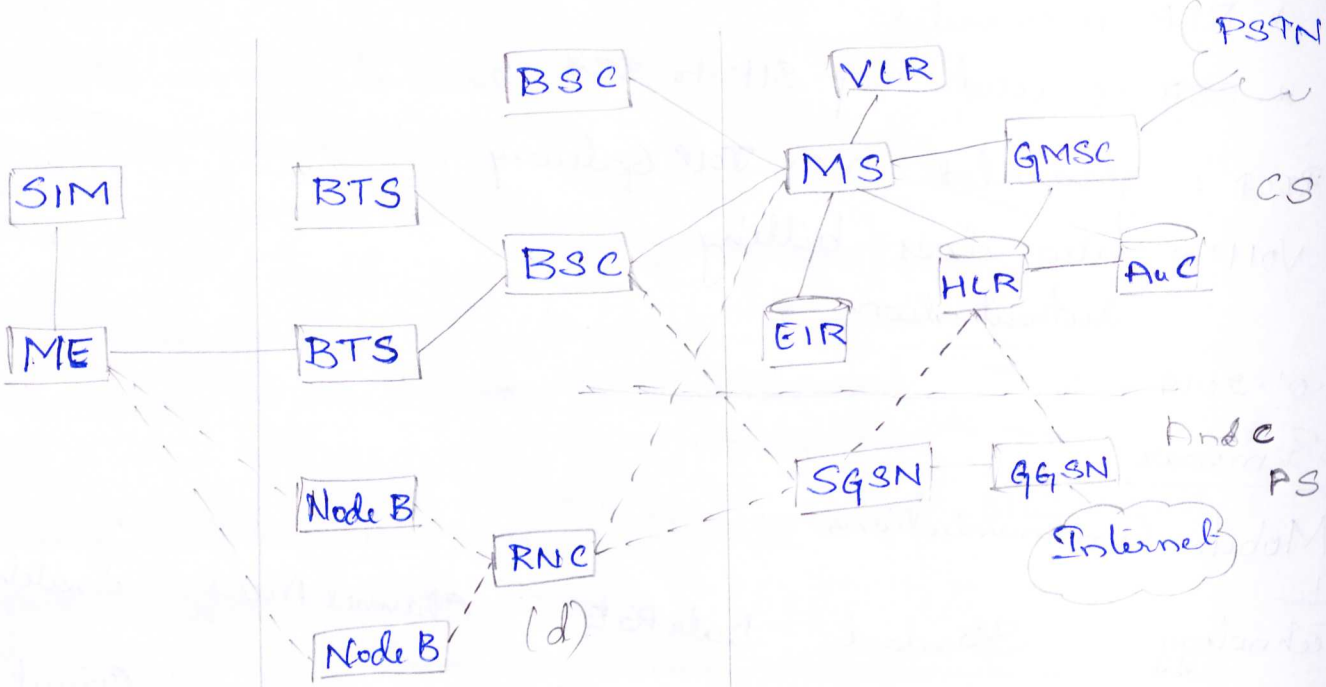
Mobile Communications

8.1

Technology	Standard	Data Rate	Channel Access	Switching
1G (1984) Analog	AMPS NMT C-450	~ 1.9 kbits/s	FDMA	Circuit Switching
2G (IS-95) (1991)	IS-95 GSM (PDC)	~ 14.4 kbits/s	CDMA TDMA	Circuit Switching Circuit Switching
2.5G (1999)	GPRS EDGE (8 slots)	384 kbits/s 473.6 kbits/s	TDMA TDMA	Packet Switching Packet Switching
3G (2002)	WCDMA/UMTS CDMA 2000	2 Mbits/s	CDMA	CS / PS
3.5G (2006)	HSDPA	10 Mbits/s	CDMA	Packet Switching
4G (2010)	LTE (A) (Pro)	0.1 ~ 1 Gbits/s	OFDMA	Packet Switching

8.2

Q.2



Mobile Station | Base Station Subsystem | Network Subsystem

b. Since HSCSD is also CS, no changes needed.

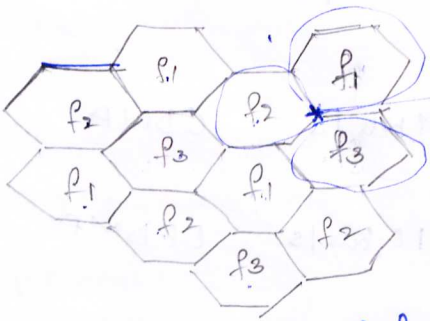
c. ---- (in NS)

d. (in BSS

Q.3

VIMP

a. 3 frequencies



more users, BS is placed here

b. - number of users : city / rural
- radiation pattern of antenna
- geographic location
- transmission power
- weather

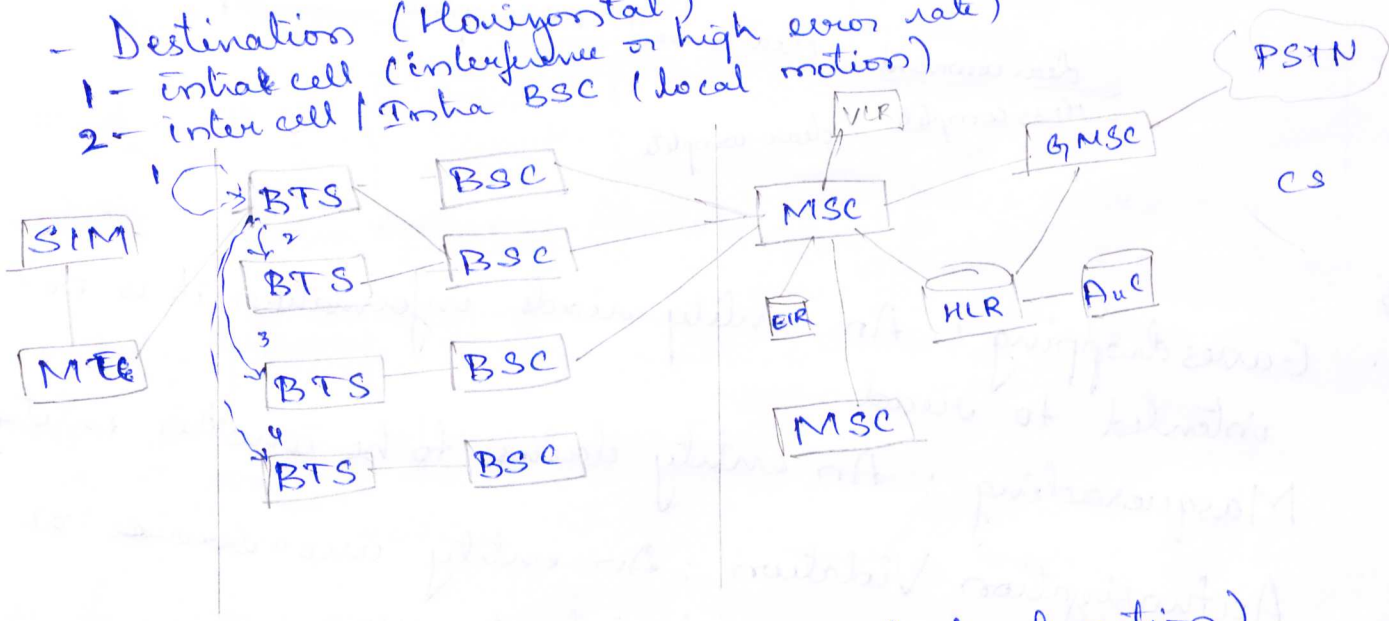
8.4

a) Maintain connection with MTS that change point of attachment
locate roaming MT

b) The procedure which is performed when a MT is changing the point of attachment

c) - Initiator
↳ Network controlled Handoff (NCHO) - network decides
↳ Mobile controlled Handoff (MCHO) - mobile decides (WiFi)
↳ Mobile - assisted Handoff (MAHO) -

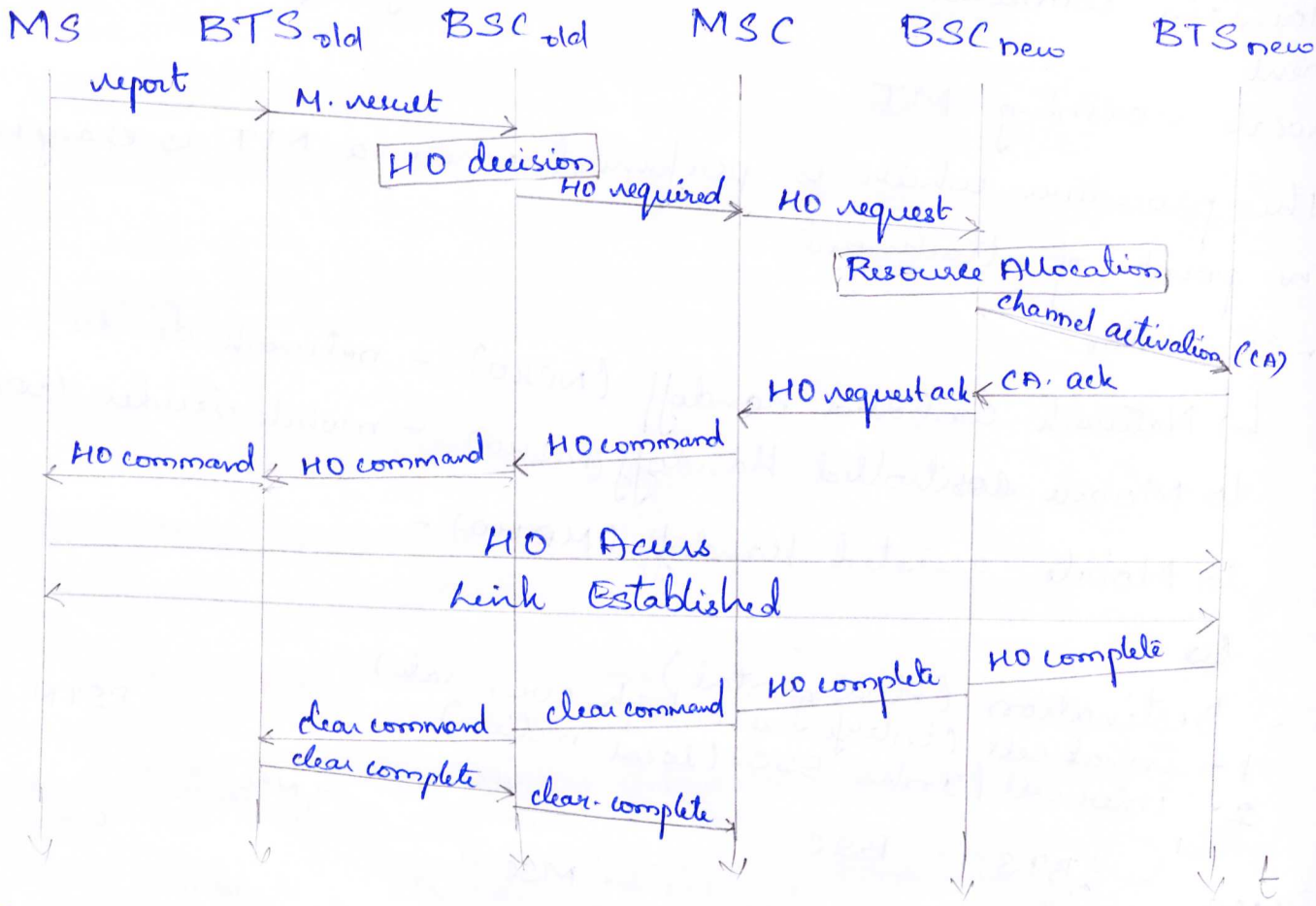
Ex:
- Destination (Horizontal)
1- initial cell (interference or high error rate)
2- inter cell / Intra BSC (local motion)



3. Inter BSC / Intra MSC (extended local motion)
4. Inter MSC (Inter city motion)

- Technology (Veritical)
- Inter-system Handover

d



8.5

a. Eavesdropping : An entity reads information it is not intended to read

Masquerading : An entity claimss to be another entity

Authorization Vidation : An entity uses a service or resource it is not intended to use

Loss or Modification of transmitted Information

11.01.2019

Voice over IP

H 323 → connects IP + port

RTP - main component for H.323 → audio & video

H.323 : Endpoints, Gateways, Gatekeepers (authentication)

B-ISDN : Broadband ISDN

G.711 → Voice codec

H-261 → Video codec 176 x 144 pixels

RAS channel - H-255 - Registration Admission Status

Call control channel - H245 → setup/teardown when we have N/w issue, changes codec, saves BW, negotiating abt coding

Call Signalling channel - Q.931 - set up/close call connection

RAS → authenticate the device & connect with the end device.

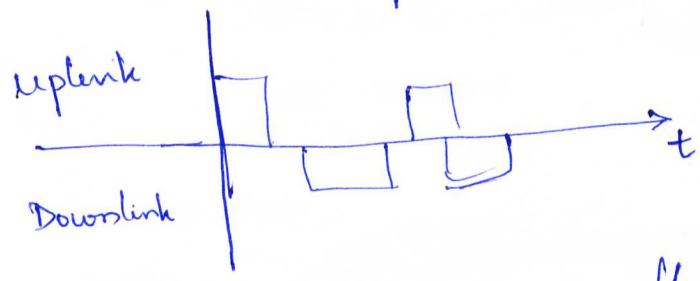
SIP
- ASCII based app protocol
- Sort of 3 way handshake
- VoIP RTP streams

VoIP send → RTP packet

Megaco → Media Gateway Control

Trunking Gateway :
Residential Gateway
Access Gateway

Role of VoIP
normal telephone call



Resource wasted, always half duplex.

VoIP → much more resource efficient

interoperability → b/w analog & VoIP such that old phones can work on both.

VoLTE → Packet Switching

9.9. Internet Applications

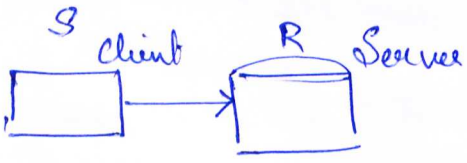
Internet Mail : SMTP

Application based multicast
- does not get ack back

<CRLF> - carriage return line field

Mail
→ guaranteed
→ Hence we use TCP

Not UDP → bcoz we do not want the mail to be sent asap (reader might read at any time)



No authentication

SMTP → not at end devices → as this the system has to function properly always.
→ not reliable

IMAP - more convenient & complex
- Superset of POP
- status stored on server
- allows group folders

POP
- status stored on end device (read | unread)

14.01.2019

SMTP

- 7 bit ASCII

uu encode → uu decode

Receiver needs to know
→ format of info (.jpeg, .mp3, .pdf)
→ coding

Header info → structure of E-mail
→ MIME Standard

Multipurpose Internet Mail Extension
* Type of message in there
* Encoding : Base 64 etc

ex: www, apps (messenger etc), ~~f~~ downloading from website

FTP

ftp phases

> authentication
> browse through the files
> download / upload file
> log out

TCP is used in Transport layer for correct reception of data without errors

World wide web

client - Servers communication based on http
exchanging Web Pages containing multimedia information
Open users to information
hyperlinks (from different servers)
- interlinked documents on different servers

Address of webpage : URL

Protocol : Server | path to destination

DNS

Address for webpage : URI : URL or URN (name)

protocol

Interface : Web Page → structure | content : html
Web browser with apps | codes

client sends request & wait for response (or error message)
→ Synchronous

Based on resources, Protocol of URL changes → ftp, http etc

LDAP – Lightweight Directory Access Protocol
- used to access directories
- used to get credentials when logged in

Uniform Resource Name (URN)

URL - location of information, changes when resource moves

URN -
bookmark info
- name remains same
- map name to location & location to IP address

host

http : // www . twilmenau.de | kw
scheme ("//") {"/" path}

<Scheme> ":" <ssp>

% 20

mail to : Seet @ ieee.org

scheme host

user "a" → user

We can have same info with different URLs.

Web v/s Internet

Internet

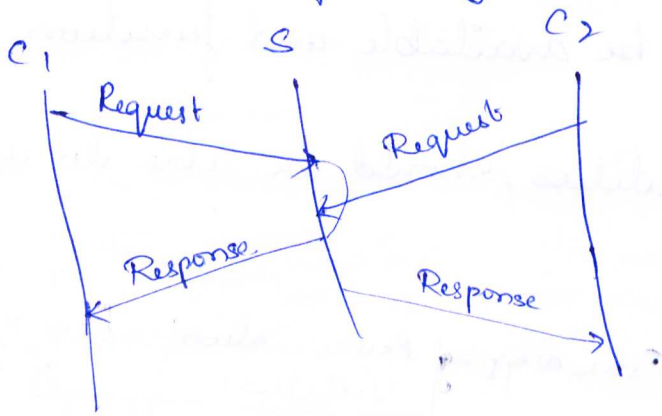
- different servers, clients etc, huge amount of protocols

HTTP Transaction

- TCP used because of reliability
- client waits until response is received
- with 2 TCP connections, make of another requests & then waits for responses

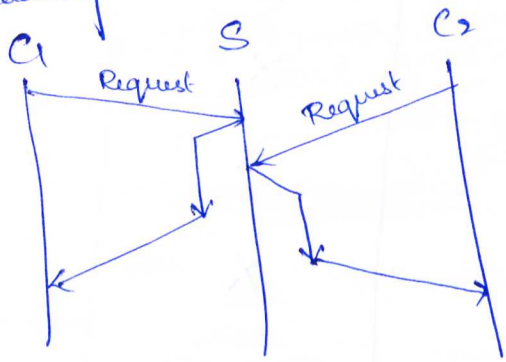
Cookie → normal string of characters

- one can be identified by this



FIFO scheme.
2nd client has to wait

multi-threading



Threads for multitasking