Classification of Network and Network Topologies

Classification Criteria:
- technique
- scale / size

Technique

- ~~Broad~~ Broadcast network
- Point to point network

Broadcast

- Single communication channel shared by all machines
  (some arbitration mech should exist to ensure only 1 speaks)
- packet sent by one machine is received by all other machines in the network.
- packet is accepted or rejected based on dest address (for communicating to a single person)
  [Address is overhead - waste of bandwidth. Minimise it if possible.]

Broadcast allows

- Broadcast - default
- Multicast - multiple destination focus
- Unicast - single ~~pers~~ destination focus

different kinds of addresses for each.
Usual ~~test~~ IP address we see is unicast address.

Point to Point

- Separate comm channels between indl machines.
  n nodes, $^nC_2$ channels.
  Add 1, add n channels
- Packet sent by one machine received only by intended destination machines.

P2P also allows
- Unicasting - by design
- How? { Multicasting, Broadcasting }

Examples of Broadcast with wires: coaxial cables

*P2P = point to point

Scale / Size

- LAN
- MAN
- WAN
- PAN
- CAN - in control systems like cars with sensors, etc.
  - low data transfer
  - high criticality.

LAN

- Privately owned
- within local space (building / campus)

IEEE 802.3 802.5 802.11n

Chars:
- broadcast medium (shifting to P2P / ~~bro~~ hybrid, but based on broadcast)
- High speed
- Restricted size 2-3 km.
- low transmission time
- few errors. (low Bit Error Rate)
  Bit Error Rate → Property of all comm channel.
  high distance increases attenuation.
- Supports data

MAN

- Private or Public
- within city boundary
- IEEE 802.6
  - Distributed Queue Dual Bus.

Char
- Broadcast medium
- High speed
- " lo km
- Low transmission time.
- Supports both data and voice.

WAN

- Primarily public
- large geographic area
- Comm aspects are sep from App aspects
  - Due to scale
  - Sharing more.
  - Comm subnet
  - Host

Eg: ERNET, NKN, Internet

Chars
- Primarily P2P (P2P and serial) → How? → location
- lower speeds
- Shared resources
- High delays
- " cost of bandwidth

PAN

- Primarily wireless
Eg: bluetooth.

TOPOLOGY

Topology Geometrical arrangement of wiring scheme.

Can be diff
- Physical Topology — Describes the way actual cables are routed
- Logical Topology — Describes " " network behaves.

Bus Topology

- ~~B~~ Shared ~~Mode~~ Media
- Access to shared media done by distributed control
- Bidirectional broadcast.

- At the end of bus there is channel terminator to absorb signal. (avoid noisy channel)

Ring topology

- Shared media
- Access to shared media done by distributed control
- Unidirectional broadcast

- Signal pulled out to avoid noise.

- Physical Proximity ≠ actual proximity
  - to solve, used two rings
    - increases ~~redun~~ redundancy
    - without cost smart

Protocol: token ring

Star topology

- Media not shared
- Centralized switching.
- Inherent protection against cable failures
- Dependency on central node
- Some processing overhead

Tree

- Heirarchical
- Media not shared
- P2P links
- Small scale WANS

Each switch (junction) is terminator so works well

Mesh:

- P2P
- Media not shared.
- Peer to peer
- Multi links

- used in core backbone.

Network Design

- Stack of Layers
- Function of each different
- Each layer provides service to higher layer
- Lower layers hide details from higher.

Layers:
- reduce complexity
- standardize interfaces
- modular engineering
- accel evolution.

Allows advancement of any layer updates

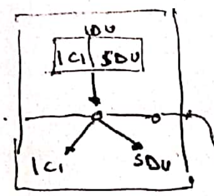
Protocols, Interface
- ~~layer~~ intra layer comm
- interlayer comm

Terms:
- Peers
- Protocol
- Interface
- Virtual communication. — eg: intralayer comm (by protocol)
- Real time " "

- Network architecture
  - Set of layers, protocols,
  - Impl. details, interface specs hidden.

- Protocol Stack,

Interface



IDU = int. data unit
ICI = ~~int~~ control info
SDU: Service data unit
SAP: service access point

- from high to lower layer each keeps adding headers (in the SDU) → also lower to higher, removed at higher layers, (ICI removed)
- ICI only for between layers, " discarded
- SDU: information keeps getting added between layers

Design Issues with Layers

- ~~Ide~~ Identify sender, receiver
  - multiple machines
  - " " process
  - Addressing

- multiple address possible (consequence of layering)

- Rules of Data transfer
  - Simplex
  - Duplex
  - no. of logical channels
  - Separate channels for separate purpose
    - data
    - control info

Same: inband signalling old of telephone)

?? IP is unreliable?

- Error Control
  - detection codes
  - correction codes
  - notification of error
- which channel to use for notification.
- decision on each
- coordinating detection/correction amongst layers

- Order of messages
  - in sequence
  - out of "
  - numbering
  - reassembly.

ATM: all data is 20-30 bytes, may be fit in a single packet (DONT NEED THIS ISSUE)

- topologies have redundancy built in.
- receiver may receive ~~message~~ packets out of sequence.
- decisions need to be made on viability.

- Flow control.
  - protect slow receiver from fast sender
  - predecided transmission rate.
  - Receiver feedback.
  - Situation analysis by sender.

- leaky bucket algorithm
- How does feedback work in connectionless system

- Size of message.
  - Destruction/loading
  - Disassembly + reassembly
  - Impact of overheads

- ~~frag~~ fragmentation = further splitting past packet *
- with higher bandwidth, more control info (overhead) can be transferred

- Multiplexing
  - De-multiplexing
  - utilizing common resources
  - Physical layer multiplexing
  - Logical channel "
    - tunnels

- Path selection
  - multiple
  - routing
  - cost of path
  - quality of path
  - security concerns

- most cases backbone decides path
- Sender may want to decide path in some way, but autonomy to backbone.

- each indi packet may do same path or multiple.

Same:
- predecide path for all
- ~~takes~~ takes initial setup time,
- indi packet transfer is fast

Diff:
- each packet header looked at, decision made.
- slower each packet?
- more flexibility

NETWORK REFERENCE MODELS

- Many, focus on 2.

Layered Models
- OSI ~ heavily influenced by IBM SNA
- TCP/IP
- IBM SNA } prior to standardization
- DECNet ~ first

OSI Ref Model (Open Systems Interconnect)
- 7 layers [why? coz IBM SNA]
- Just model, no specification of working protocol.

Basis for Layers (Specific to OSI)
- Abstraction
- performs well defined function
- Minimise info flow across interface.
- large to divide function among layers
- small to manage.

Layers:

Physical	Layer
Data Link	"
Network	"
Transport	"
Session	"
Presentation	"
Application	"

Physical, Data Link, Network, Transport } Focus

Session, Presentation, Application } - realm of OS

Physical Layer
- Define comm channel. (wire, wireless, cable, etc).
- Raw bits (no DS, nothing but 0,1)
- Voltage, Current Levels — some systems use voltage for bits, some use direction of current
- Signal duration.
- Comm mode (simplex, duplex, etc)
- Connector type
- Definition of pins

Eg: RS-232 (V.24)
- Serial
- Replaced by the USB

Data Link Layer
- Transform raw transmission channel into error free channel for higher layers [raw data is converted to data frames]
- Error handling
  - Acknowledgement or not.
- Flow control.
- Control access to shared media
  - Medium Access Control (MAC) sublayer.

eg: Ethernet

Network Layer

So far, the physical/data link layers were ~~...~~ procedure- connection based, ~~...~~ concerned with physical details of communication.
[needs some knowledge of topology]]

- Controls subnet
- Routing of packets
  - Fixed
  - Dynamic — critical as we're going toward procedural communication
- Addressing
- Packet Size [missing shows up at all layers other than physical]
- Congestion Control — to ensure transfer
- Quality of Servis
  - Delay [time from source to dest] !?
  - Jitter [variation in delay]
    - in connection oriented, delay predictable, less jitter
    - more of an issue ~~...~~ for less common real-time data transmission streams?
    - TISTEC: ... protocol ... with ... delay ... communication ...
- Interconnection of heterogeneous networks.

Transport Layer

eg: IPv4

- Segment user data
- Ensure delivery of data
- Isolate upper layer from changes in hardware techs.
  - lower 3 layers are more telecom / network backbone infra ~~...~~ structure, transport isolates higher application level layers.
- Define type of service for session layer. [just interface]
- Order of delivery. = ~~...~~ ... (information? ... application ...)

eg: TCP : in order
UDP : out of order.

- Idea of E2E communication.
- Connection establishment
- Connection control.

Session Layer:

} end system application part.

- Session establishment
- Dialog control.
- Sync at user data level.
  - recovery after crash.

Presentation Layer

- Syntax, Semantics of information
  HTML?
- OS
- Encoding
- Data compression, cryptography

Application Layer

- User Applications.
  - HTTP
  - SMTP
  - Telnet

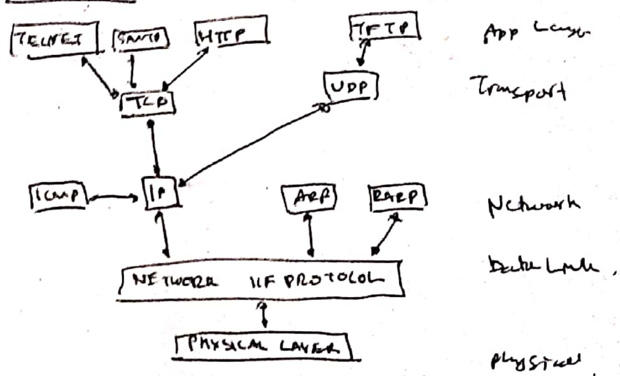
The OSI model is less common in systems.
- bad timing (too early, too detailed)
- bad implementation (lack of understanding)
- Company Politics [IT companies ~~...~~ US based, OSI Europe]

TCP/IP model

- Developed by Universities
  - engineer volunteers {no royalty}
  - no standards body
- Free
- Adopted by DoD, IETF, ~~...~~ corps.

Layers — predefined.
- Network ~~...~~ Interface < Physical, Data Link.
- Internet
- Transport
- Application < ~~...~~ Session, Pres, App

Protocol stack



Data units at diff layers

Bits	Frames	Packets	Segment/Datagram	Message
Physical	Data Link.	IP	TCP / UDP	Application

Standards

De facto
- not implementation became popular

De Jure
- Developed by standard body.

ITU
V.24, V.21, V.35

ISO ANSI IEEE
802.3
802.11

IETF — IETF
RFCs
request for comments
less competing

EIA/TIA
CAT-3
CAT-5
CAT-6

Task:

Visit websites of standard bodies.
Look for
- objectives
- operations
- members
- popular standards

Scanned by CamScanner

Communication Media

Types
- Guided
  - wires/cables
- Unguided
  - Wireless

Problems
- Attenuation.
  - loss of signal strength
- Delay Distortion
  - due to diff speed for diff freq
  - peculiar to guided media
- Noise
  - thermal, crosstalk, impulse

internal — external

Characteristics
- Bandwidth
- Delay
- Immunity from noise
- Lifespan
- Cost
- Ease of installation and maintenance

Spectrum for telecom
- Few hertz to 10^{15} hertz
- diff freq for diff media
- Bandwidth depends on carrier frequency

Guided Media

Magnetic media (technically...) [CDs etc]
Twisted Pair
Coaxial cable
Optical fiber cable

Magnetic Media

- Magnetic tapes
- other removable media.
  - CDs, Flash Disks
- high bandwidth
- High delay.
- bulk data transfer

Twisted Pair

Coaxial cable

Chars.
- Good shielding
  - better than TP
- less attenuation
- longer distances
- high bandwidth 1GHz
  - depends on cable quality.
- Skin effect = look at

Types of coax cables
- 50 ohm
  - digital transmission
- 75 ohm
  - analog "

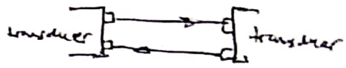
} imp – termination has to be in accordance with impedance.

- others

Usage:
- Ethernet (not anymore)
- Cable TV
- Wireless setup
- MAN.

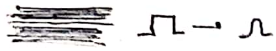
Optical Fiber cable

- Glass core surrounded by glass cladding of lower index, covered by thin plastic jacket, protected by sheath.
- Uses total internal reflection
- One or more light rays may travel in same fiber
- Due to construction, there is minimal
  crosstalk
  inter cable noise
  external
- At transmitter end
  electric signal to optical

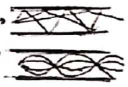


- At receiver.
  optical signal to electrical

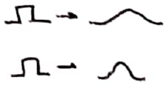
Types
- Multi mode fiber → usually uses LEDs
  - Multiple rays in 1 fiber
  - Higher attenuation short haul
- Single mode fiber → using Laser
  - Works like waveguide
  - only 1 ray in 1 fiber
  - Low attenuation long haul



- Stepped index →
- graded index →



multi mode



Chars
- Very high bandwidths
- Immune to external noise
- Long distance
- High cost
- Difficult installation
- More secure, difficult to tap
- Unidirectional
- Lightweight

Types of OFC packaging
- Single core
- Multi core → typical
- Multiple single core

Connector types
SC, ST, LC

Limitations of Guided Media

- Fixed positions, lack of mobility
- High installation time
- Difficult to install in some terrains
- freq cable faults
- Difficult maintenance.

Unguided Media

Chars
- flexible
- fast deployment
- no cable faults
- easy maintenance
- lower costs (loaded statement)
- limited bandwidth
- interference

- At lower freqs
  - easy to generate
  - travel long dist
  - penetrate buildings
  - omnidirectional
  - interference between users
  - absorption by earth surface.

- At higher freq
  - unidirectional
  - antenna needs to be aligned
  - less interference from neighbours
  - line of sight communication
  - Reflected from buildings (multi path fading)

Data Link Layer

Media Access Control

Channel Allocation:

- How to allocate single broadcast channel to multiple users
  - Static channel allocation
  - Dynamic " "

Static Allocation

- Bandwidth divided into portions
  (does not have to be equal)
  [freq slicing / time slicing]

  FDM → usually TVs
  TDM → usually digital comm
  WANs use a hybrid approach.
  ↳ sat comms

+ Simple implementation
- Wastage of bandwidth
- Inefficient
- not suitable for bursty traffic
  ↳ usual data flow.

Dynamic Channel Allocation

- Bandwidth not bound to any one user
- No permanent allocation
  - arbitration required
    - central manager → specific types of VSAT & WANs in general.
    - Distributed " "
- Suitable for bursty traffic
- less wastage.
  ↳ primarily for bursty traffic

Access Protocols

- ALOHA
  Pure
  Slotted.
- Carrier Sense Multiple Access (CSMA)
  persistent CSMA
  non " "
  CSMA with collision detection.

Pure ALOHA

- Uncoordinated users competing for channel
- Users can transmit as they want
- Causes collisions
  - Users are always in listening mode and can find out the collision
  - Retransmission after a random

Best effort system.

- Max efficiency of protocol is 18%.
- Low delay (if free channel.

Slotted Aloha

- time in discrete intervals
- Users agree on slot boundaries

- May + Be

CSMA:

- carrier sense protocol
  - Station listens for carrier
  - Transmits when channel is free
  - Wait if channel is busy.

Non persistent CSMA:

- Listens to channel to check free.
- If busy

+ more efficient on high load.
- delays

CSMA C-CD

LAN Techs

- Arcnet
- Ethernet
- TokenRing
- FastEthernet
- FDDI
- ATM
- Gigabit ethernet
- 10 Gbit ethernet.

CSMA/CD carrier sense with Multiple Access / Collision detection.

Interframe gap.

What should be ~~ops~~ mps Gmin size at 100 MBps, 1000 MBps, 10 Gbps?

802.3 standard.

10Base2

28.1.19

Tutorial this week will be on algorithms.

IPV4 Overview

- Protocol, Addressing & ... aspect.

Functioning : TCP/IP

Layers: Application, Transport, Internet — IP, Link

Others: ICMP, ARP, RARP } control protocols, help IP function

IPV4

lookup deliberations

RFC: 791 → required to read

- 1981

Main protocol of TCP/IP

Intent: Inter networking { MAC: is local, does not move beyond your immediate network. scheme also differs }

Unreliable

- no guaranteed packet delivery
- best effort service
- Sends ICMP error message in case of certain errors before dropping packets
- Reliability provided by higher layers

- Connectionless
  - does not maintain state information of datagrams
  - Each datagram is independent, can take different routes
    - vary my decision
    - Also if more than 1 path avail.
  - Can be delivered out of order

(Allows IP to be very robust)

- Max datagram size: 64 KB } can be done in HPC / Specialised setups
- Default (practical) " : 1500 B
- datagram may be fragmented across network segments
  - Some fragment offset (sequence number) to put it back together [At destination]

IPV4 Datagram format

Bits	4	4	8	16	16	3	13	8
	VERS	HLEN	Type of service	Total length	ID	Flags	Frag. offset	TTL

Bits	8	16	32	32	320	
	Protocol	Header checksum	Source IP	Dest IP	(Options)	Data

Details in RFC

Mandatory fields : 20 Bytes

Flags can contain information like.

- MF : more frags
- DF : don't frag.
  - ↳ if this cannot be fulfilled, packet rejected and ICMP sent to sender

header length not fixed

packet " " " (osv)

Version

IHL

indicates length of header

- Min: 5 B
- max: 60 bytes
  - ~ only upto 64

Total Length

16 bits

total length in bytes, including header

Flags

3 bits

- unused
- DF - don't frag
- MF - more frag
  - all segments except last have this enabled.

TOS 8 bits

3 bits : priority

4 TOS bits (1 set)

- min delay
- max throughput
- max reliability
- min monetary cost

Unused last bit (always 0)

mostly ignored by router

ID

helps in frag, reass

- all frags in packet have same ID (see: frag offset)

Frag offset

- 13 bits
- positioning frag
- max 8192 frag

TTL (time to live)

- 8 bits
- limits lifetime of datagram in network [no. of hops, not "time"] → hops in IP layer
- Used to eliminate routing loops
- Value set by sender (usually 32/64)
- Decremented by each en-route router.
- ICMP to sender

Protocol Field

- 8 bits
- det upper layer (TCP / UDP)

Transport	TCP 6	UDP 17
Internet	IP	

Header checksum

Only detection

- only header
- 16 bit 1's complement sum after setting checksum field to 0

every and each router has to re compute

Source
Destination Address

32 bits

Options

- security, handling restrictions
- record route, record timestamp
- loose ~~same~~ source routing
- strict source routing.

- - - - - ✂ - - - -

Internet Address

- Every node should have unique
- 32 bit.
  X.Y.Z.W

- Two components:
  - network
  - host

- routing is done with network address

- Network-Host address boundary is determined by subnet mask

Types of IP Address

- Unicast Address
- Multicast "
- Broadcast "
- Private " / Local address of not necessarily unique.
- Public " / Global address → network
  Proxy server's job
  NAT (Network Address translation)

IP Address classes

Classes of addresses

- class A
- " B
- " C
- " D
- " E
- CIDR (Classless InterDomain Routing)

A: first bit: 0
next 7 for network
last 24 for host
0.0.0.0 → 127.255.255.255 — [10.x.y.z]

B: first 2: 10
next 14 for network
last 16 for host
128.0.0.0 → 191.255.255.255.

C: first 3: 110
next 24 bits for network
last 8 for host
192.0.0.0 → 223.255.255.255

D: first 4: 1110
next 28 for group address → group
no network / host
Used as multicast address
Common IP for group
224.0.0.0 → 255.255.255.255

E:

Special: All 0's - 0.0.0.0
- Used during initial booting by BOOTP, DHCP

All 1's
- local broadcast

TCP Overview

- RFC 793
- Reliable
  - acknowledgements
  - guarantee of packet delivery
  - Reassembly of out of order data
  - discards duplicates caused by IP
  - provides end to end flow control.
  - Delayed acknowledgement — piggybacking.
    ↳ rather than sending separate acknowledgement, send it on existing outgoing dataframe.
  - .. full. buffer.

- Connection oriented
  - stateful, unlike IP
  - relationship between multiple segments
  - segments can take different routes
  - segments are delivered in order to the ~~dest~~ application layer

- Full Duplex

TCP Segment format

Scope for acknowledge

16	16	32	32	4	6	6	16	16
Source Port	Dest. Port	Seq. No.	Ack. No.	HLEN	Reserved	Code Bits	Window	Check Sum

16	0 or 32	
Urgent Pointer	Options	Data

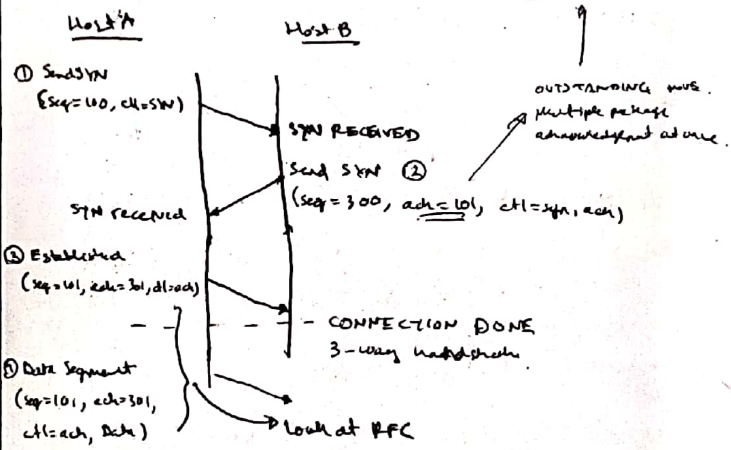
Ports

FTP	TELNET	SMTP	DNS	TFTP	SNMP
21	23	25	53	69	161
TCP			UDP		

Ephemeral Ports: ≥1024?

TCP Handshake

Q: out of order?
A: yes, but delay allows it.



TCP single ack

window size: 1

TCP Windowing

Window Size: part of initial connection request (@ SYN)
Receiver may disagree.
can be changed during connection

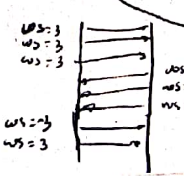


*image representative not accurate

TCP connection closure

A	B
① Send FIN	FIN received
ACK received	ACK Send 2
FIN received	Send FIN 3
④ Send ACK	ACK received

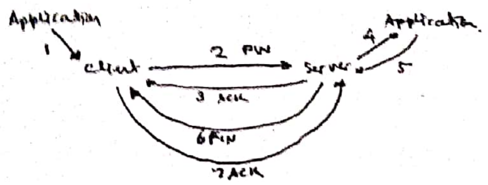
} separate so queue can be cleared.
||
Mostly not done

Since it is full duplex, both sides have to ~~set~~ independently close it.

- takes 4 segments

- Active close : Send FIN
- Passive " : Response FIN.

Sequence:



- Half close is possible
  most not done

- Timeout during connection setup.
  - When Initiator does not receive SYNACK
    1 Resend SYN
    2 First retry after 6s.
    3 Second " after 24s
    4 Stop " after 75s (Unix)
  - Times are implementation dependent

MSS Maximum Segment Size

- Exchanged with initial SYNS
- Does not appear in other packets
- If MSS not received, default = 536 bytes [old RFC rec]
- 536 + 20 IP Hdr + 20 TCP Hdr = 576B IP datagram
  → Use path discovery to optimise.
- larger MSS, better efficiency bar fragmentation
- MSS at most: = ~~up~~ (MTU − 20 − 20) B
  For ethernet: 1500−20−20 = 1460B
- If non local destination, MSS defaults to 536
- When 2 sides announce different MSS, they normally settle for the lower

Nondelivery of TCP segments

- Indicated by non receipt of ACK at sender side.
- Causes
  - Loss of packet
    - congestion
    - error in header
    - " " data.
  - Loss of ACK
  - delayed delivery by IP

- Non receipt of ACK is detected by
  - retransmission timer
  - receipt of duplicate ack → typically 3 [~~[illegible]~~ [illegible]]
- TCP assumes that nondelivery is because of congestion
  ↓
  Blind assumption → if loss because of noise or delay, ~~[illegible]~~ TCP underutilises the bandwidth available.
- Reduces window size

Types of Closure

- graceful (orderly)
  - no data loss
  - using FIN
- abortive
  - Abrupt
  - using RESET (RST)

RST

- Generated on receipt of an incorrect TCP segment
  - packet doesn't belong to the referenced connection referenced by
    - IP
    - Port no
    - Seq no.
- on receipt of connection request to nonexistent port.
- Generated by app when abort.

4.2.19

- At sender side, any queued data is thrown away

PSH

- PUSH Flag
- Indicates to receiver to send the data to the application without further delay.
- Used in interactive applications or during interactive ~~apps~~ operations
- Also used in last msg of stream

Half-open connections:

- one side abruptly terminates the session
- Causes
  - system crash
  - machine poweroff without graceful shutdown
- Server won't know, wait state.
- Dangerous, may be hijacked.
- Security apps watch out for this, may shut the conns.

Interactive Data Flow

- Repacketisation
  - sending retransmission and next segment in the same segment
- TCP protocol spoofing
  - used if Bandwidth ↑, delay ↑
  - improves wx
  - Used in VSATs

Sliding Window → TCP's approach.

- Start small.
- Ramp up (exponentially upto a point, then linear)
- Bound by upper limit of window size.
- On segment loss, reduces window loss.
- Increase again

↳ assumption that loss is because of congestion.

Congestion Avoidance

Indication of loss of packet:
- timeout
- Duplicate ACK.

Dup ACKs reduce usable window size to half
timeout. " " " " one

Fast Retransmit

When 3 or more duplicate ACK, retransmit without waiting for timeout.

READ

Congestion Avoidance
Slow Start
Fast Retransmit
Fast Recovery

Look at Ethernet Frame structure.
Understand functions on frame fields
observe variations in " struct