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End-to-End Delay / One way Delay (OWD)
Time taken for a packet to be transmitted across a network from source to dest

Round Trip Time (RTT) – 2 paths are measured.

1)

Transmission Delay

$\frac{L}{R} = \frac{\text{Packet length}}{\text{transmission rate (Mbps)}}$

all routers have to get the packets onto the telecom transmission link.

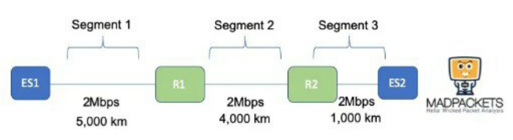
Yayılma
Propagation Delay

$\frac{D}{S} = \frac{\text{Distance between nodes}}{\text{Propagation rate (speed)}}$

Type of connection may change propagation speed.

End-to-End Delay Example

A packet length of 1,500 Bytes is sent over the following path, what is the end-to-end-delay.



Segment 1:

Transmission Delay

The end system, ES1, pushes the 1,500 Byte packet onto the wire.

$\frac{L}{R} = \frac{1500\ B}{2Mbps} = 6\ \text{ms}$ → Convert to bit

Propagation Delay

Once the packet hits the wire, the propagation delay is how long it takes the bit to be sent over the wire to R1.

$\frac{D}{S} = \frac{5000\ km}{2.5 * 10^8 ms} = 20\ \text{ms}$

Segment 2:

Transmission Delay

It's the same 6 ms since the packet size is still 1,500Bytes and the transmission rate is still 2Mbps

Propagation Delay

The distance between R1 and R2 is now 4,000 km so we'll see a decrease in propagation delay to 16 ms.

$\frac{D}{S} = \frac{4000\ km}{2.5 * 10^8 ms} = 16\ \text{ms}$

Segment 3:

Tranmission Delay

Again, no change in L or R so it's still 6 ms.

Propagation Delay

The distance from R2 to ES2 is 1,000km so again we'll see a lower propagation delay,

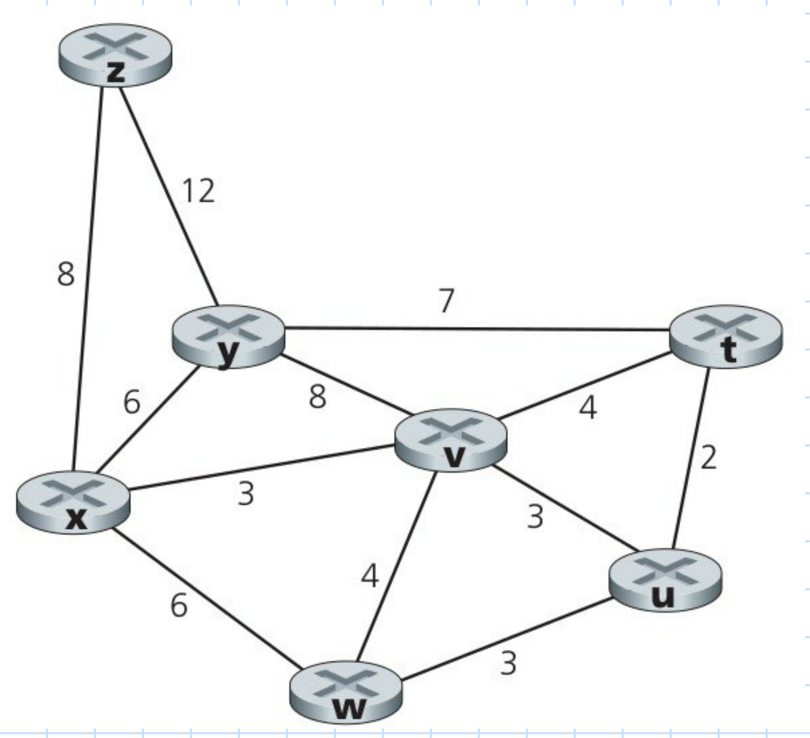
$\frac{D}{S} = \frac{1000\ km}{2.5 * 10^8 ms} = 4\ \text{ms}$

Router Processing Delay

Just for the sake of completion, let's say the router vendor told us the router processing delay is 5 ms. So any packet going through R1 or R2 will automatically incur a 5 ms delay for packet processing.

Overall End-to-End Delay -> Segment 1 delay = 26 ms Segment 2 delay = 22 ms Segment 3 delay = ~~10~~ 6 ms Router Processing = 10 ms Total End-to-End Delay = ~~68~~ 64 ms

2) $c(x,y)$ ⇒ Link cost from node x to y. ($= \infty$ if not direct neighbors)



The below table is the computation of shortest path from source x to all the nodes by using Dijkstra's algorithm:

Subsets of nodes

S'	l(t),c(t)	l(u),c(u)	l(v),c(v)	l(w),c(w)	l(y),c(y)	l(z),c(z)
x	∞	∞	3,x	6,x	6,x	8,x
xv	7,v	6,v	**3,x**	6,x	6,x	8,x
xv**u**	7,v	**6,v**	3,x	6,x	6,x	8,x
xvuw	7,v	6,v	3,x	**6,x**	6,x	8,x
xvuwy	7,v	6,v	3,x	6,x	**6,x**	8,x
xvuwyt	**7,v**	6,v	3,x	6,x	6,x	8,x
xvuwytz	7,v	6,v	3,x	6,x	6,x	**8,x**

Here,
S' = subset of nodes.
c(v) = Current path of node v
l(v) = Least cost path of node v

So, the following are shortest paths from **x** along with their costs:

t: xvt = 7;

u: xvu = **6**;

v: xv = **3**;

w: xw = **6**;

y: xy = **6**;

z: xz = **8**

3) **Protocol pipelining** (Sliding window protocol)

ack = Alındı bildirimi

A technique in which multiple requests are written out to a single socket without waiting for the corresponding responses.
Improvement in protocol performance over high latency connections. Reduces waiting time.

Examples: HTTP, SMTP and FTP.

Buffering at sender or receiver.

– 2 generic forms of pipelined protocols; go-back-n, selective repeat

Go-back-N:

- Sender can have up to N unpacked packets in pipeline.
- Receiver only sends cumulative ack packet if there is a gap.
- Sender has timer for oldest unacked packet (when timer expires, retransmits all unacked packet.

Selective Repeat:

- Sender can have up to N unacked packets in pipeline.
- Sender sends individual ack for each packet
- Sender maintains timer for each unacked packet. (when timer expires, retransmit only that unpacked packet.)

Protocol:

Protocol defines format, order of messages sent and received among network entities and actions taken on message transmission receipt.

1)

a) Datagram → Connecti
Virtual circuit → Connectionful

Packet Switching methods

↳ Datagrams – Packet routing selection depends on the number of datagram (packets) waiting
↳ Might reach in different order.
↳ Better use of communication chanels.
↳ Ideal for short package transmission.
↳ Not reliable.
↳ Major disadvantage is if a packet can only be forwarded if resources (buffer, CPU) are available.
↳ No need for reserving resources to implement.

Example of datagram was Internet (TCP/IP)

Virtual Circuits – Before the packet transmission begins, the best path is selected.
↳ All packets follows this path from the start to end of the connection.
↳ Sorted receipt of packets. (without checks and delay and recomposition of message.
↳ Ensures that all packets successfully reach the destination. (No packet will be discarded due to unavoibility of resources. So highly reliable,
↳ It is used by ATM (Asyncranous Transfer Mode) Network for Telephone calls.
↳ Disadvantage; Each time new connection is set-up, resources and extra info have to be reserved at every router on path. It's problem if many clients try to reserve router's resources.

b)

TCP

- Requires an established connection
- Slow
- Can retransmit lost data packets
- Able to sequence
- HTTPS, SMTP, FTP

UDP

- No need to establish connection
- Fast, efficient
- Unable to sequence
- Video streaming, DNS, VoIP

c)

Client Server

Servers and clients are distinctive
Centralized Server
Server replies to services which are asked by client.
More stable
Can be used both small and large networks.

Peer-to-Peer

Clients and servers are not distinguished.
Every peer stores its own data.
Every node can accomplish both request and response.
Less stable
Mostly for short networks.