50.005 CSE

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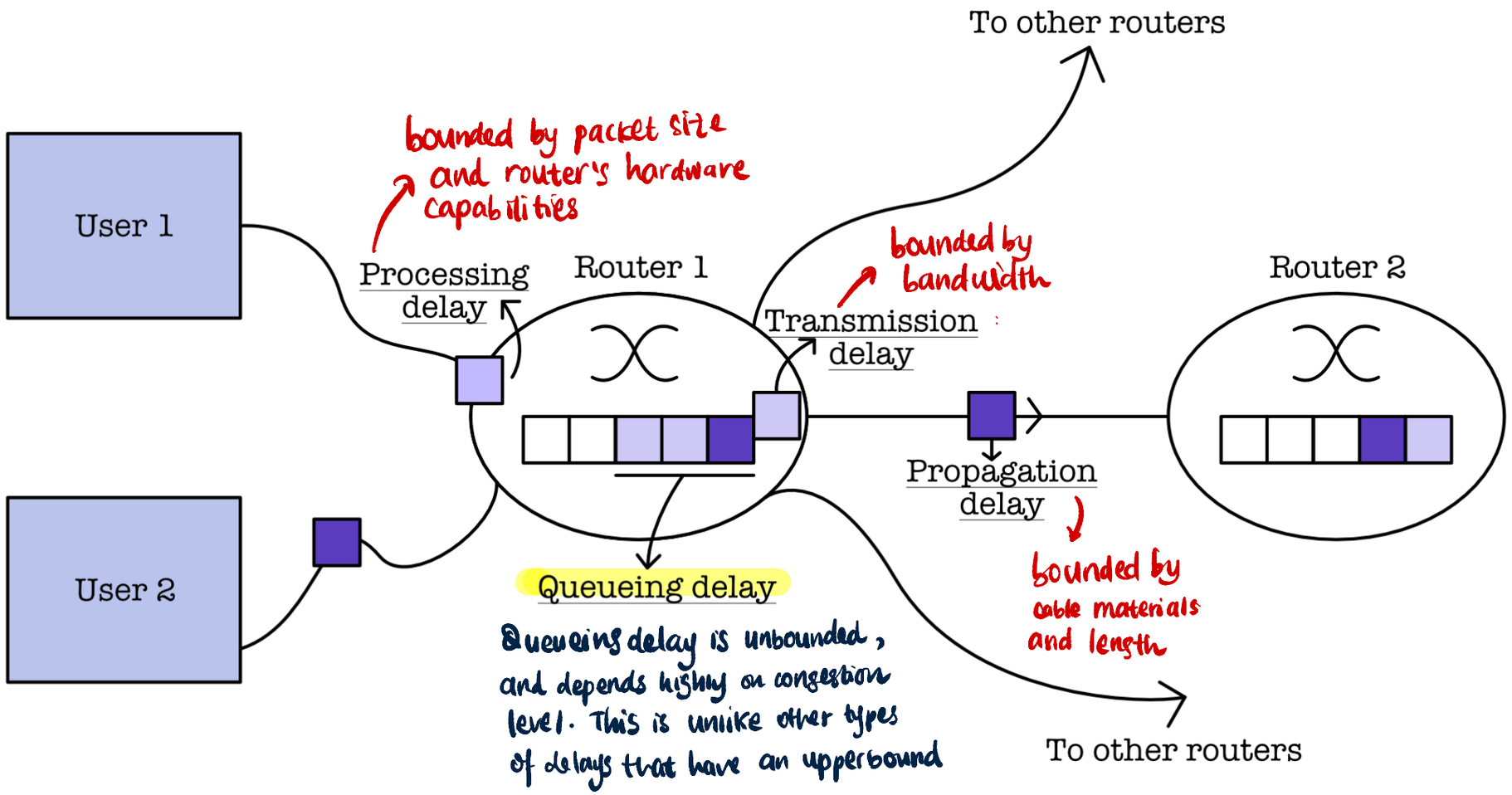
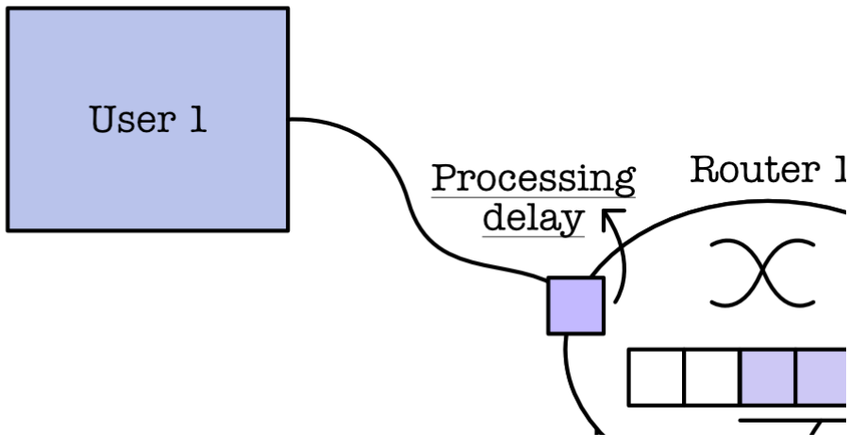
Why is there a packet queue in router buffers?



Sources of packet delay



1. PROCESSING DELAY

DURATION

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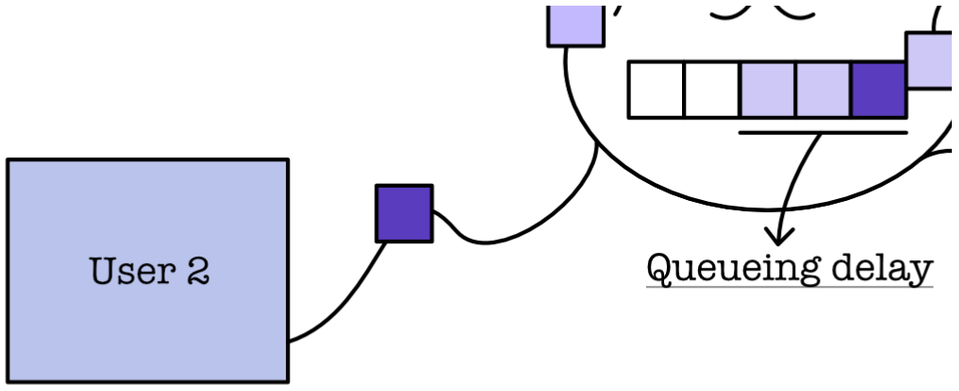
WHY

Needs time to examine **packet header for:**

1. check for bit errors (checksum),
2. determine output link by destination IP address

Sources of packet delay



2. QUEUEING DELAY

DURATION

depends on congestion level (traffic)

WHY

packet needs to wait to get to the front of the queue to reach the output link due to congestion (input rate > output rate)

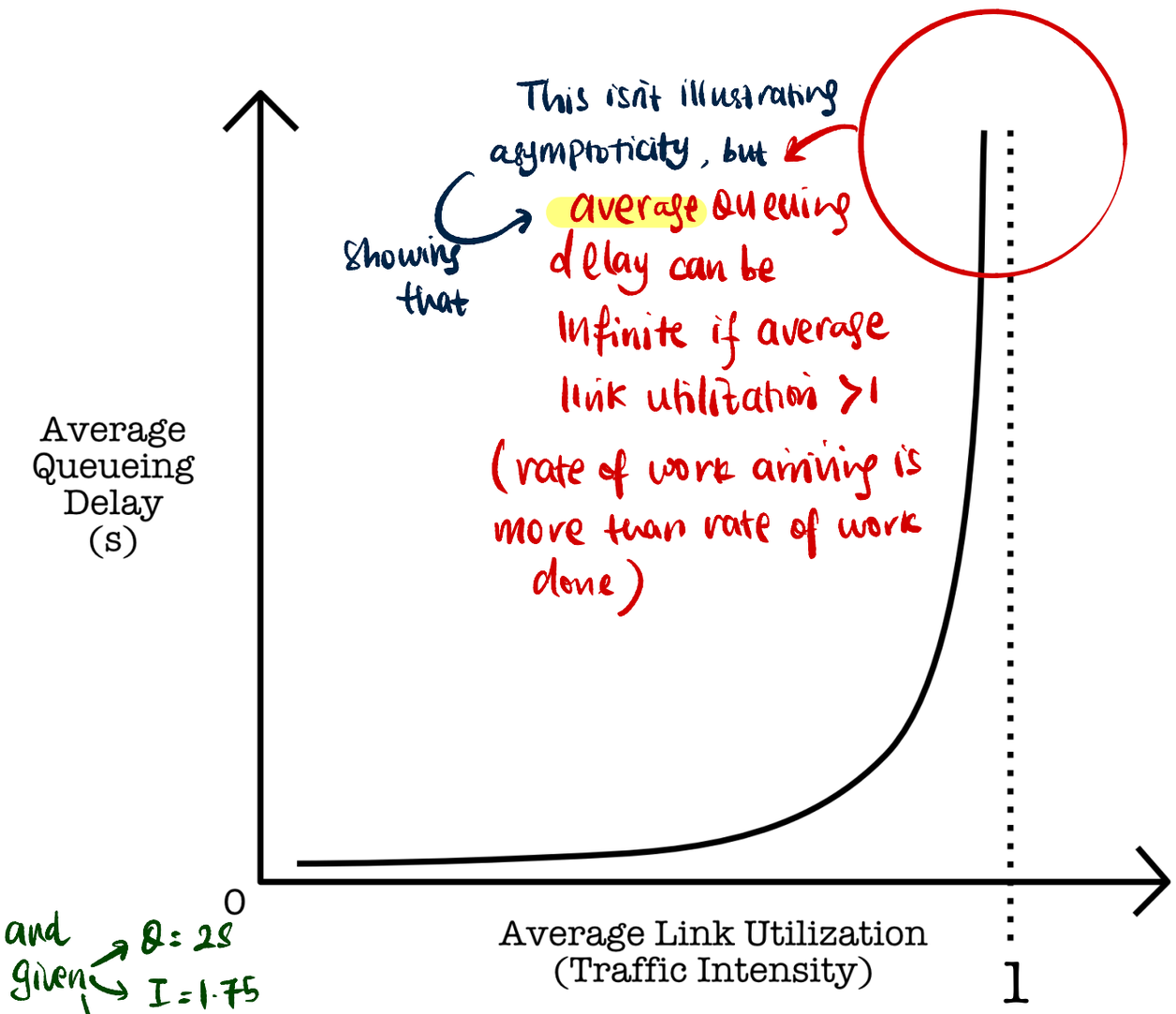
AVERAGE LINK UTILIZATION

$$\frac{La}{R}$$

L = packet length (bits)

a = average packet arrival rate

R = link bandwidth (bits/s)



Eg: given that → $\bar{Q} = 0.01$ s when $I = 0.7$
→ $P_{active} = 0.3$
→ 20 users, each sends 10 packets/s, 1kb/packet when active

① what is R to keep $\bar{Q} = 0.01$s on average?

$\therefore I = \frac{La}{R}$ → solve for R

$0.7 = \frac{1000 \times 10 \times 20 \times 0.3}{R}$

② what is R to keep Q under 0.01s at ALL times? (i.e: max Q is 0.01s)

worst case = everybody is active

$0.7 = \frac{1000 \times 10 \times 20}{R}$ → solve for R

③ and given → $Q = 2$s
→ $I = 1.75$
→ $R = 512$ b/s

what is the probability that the above is happening?

solve for n

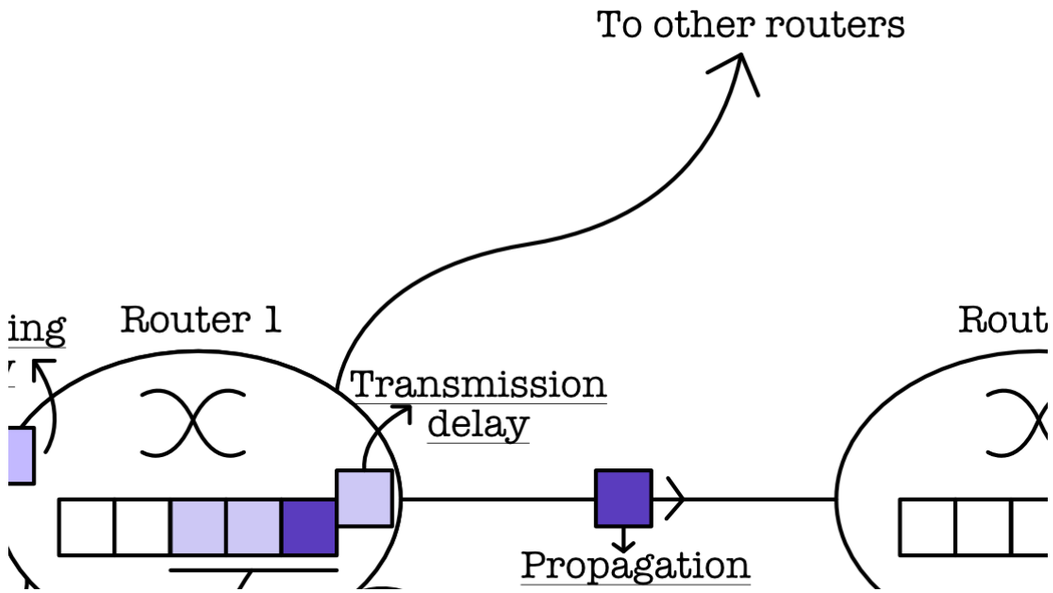
$1.75 = \frac{1000 \times 20 \times n}{512}$

then find:

$P_a = \text{any } n = {}^{20}C_n \, 0.3^n \, 0.7^{(20-n)}$

this is the probability that you queue for 2s when using the internet.

Sources of packet delay



3. TRANSMISSION DELAY

DURATION: depends on link bandwidth (technology)

$$d_{trans} = \frac{L}{R},\ L\text{= packet length (bits), } R\text{ = link bandwidth (bits/s)}$$

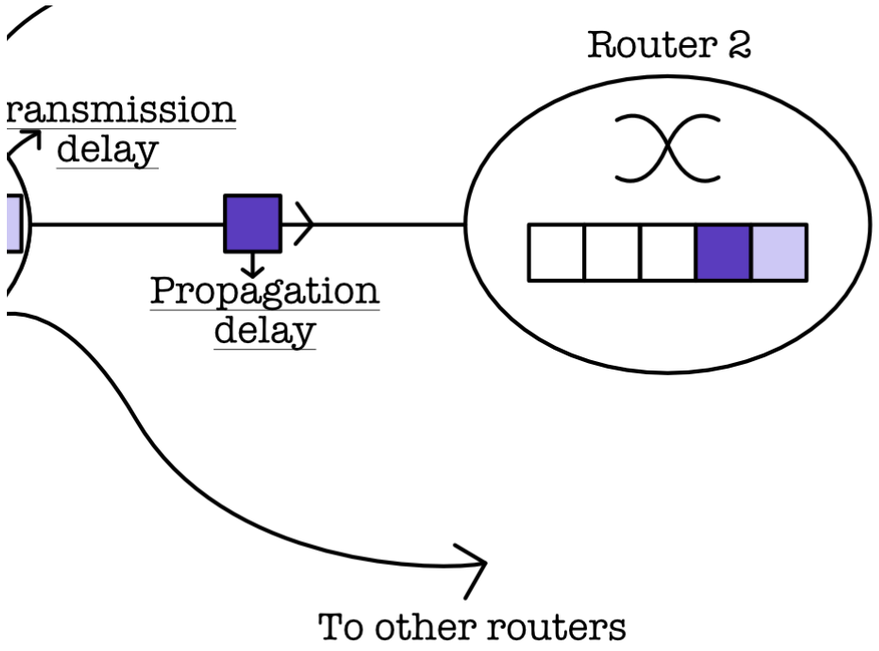
WHY

We need time to push the whole packet bits from the router end to the link (cable).

↓

pushing for example all 512 bits of packet data doesn't happen instantly.

Sources of packet delay



4. PROPAGATION DELAY

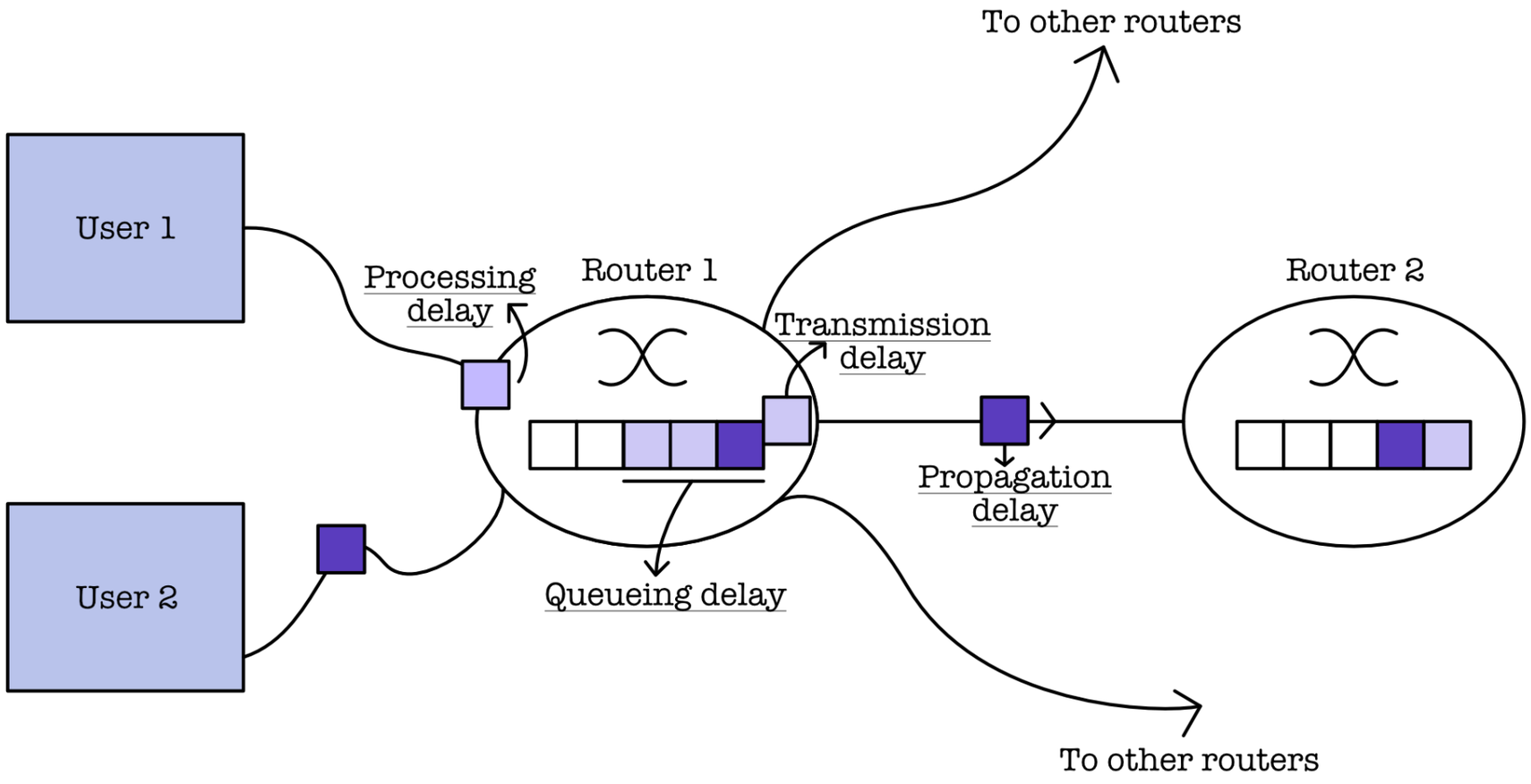
DURATION: depends on link length

$d_{prop} = \frac{d}{S}$, d= link length (m), S = propagation speed of bits on wire $\approx 2 \times 10^8 (m/s)$

WHY

Well, we need time for the bits to propagate from the output end of Router 1 to the input end of Router 2

TOTAL (NODAL) DELAY



$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

between router to router

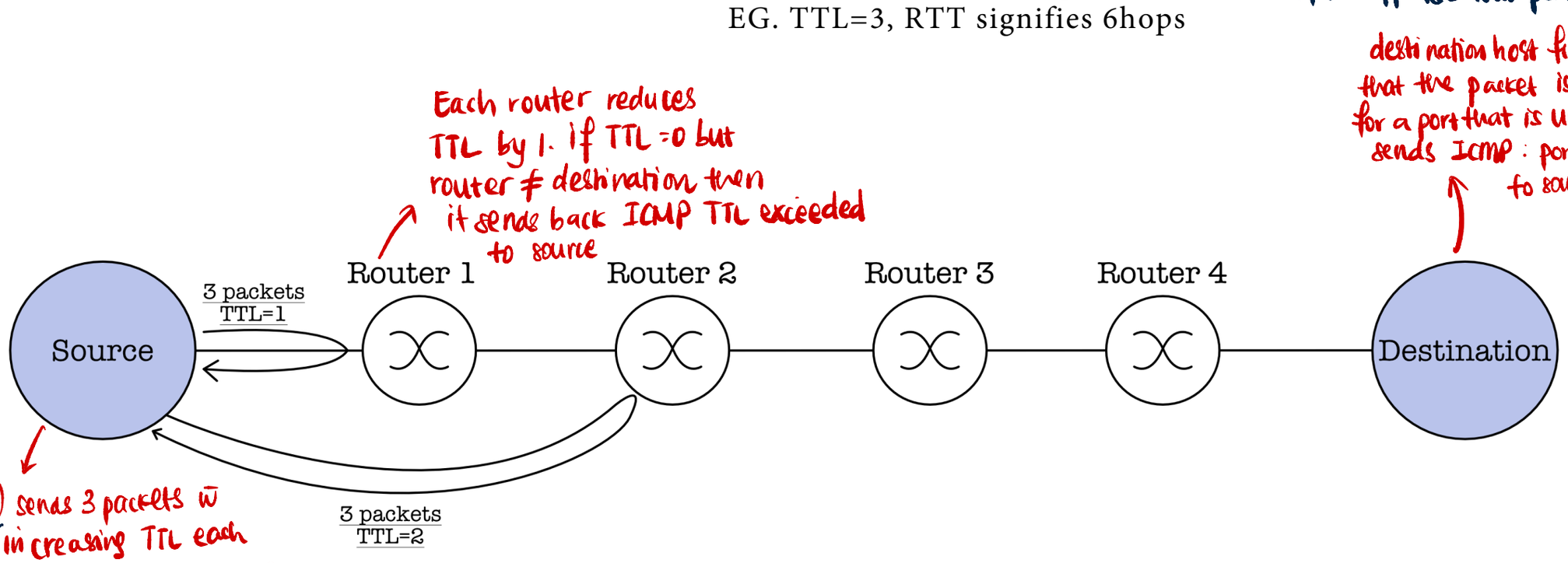
Icmp: Internet control message Protocol
↓
to send error messages and operational information (standard messages)

TRACEROUTE

Finding internet packet delay and packet routes in real life

What is port #?
↓
16 bits logical representation of a service or app in the host system.
upon receiving a packet, the OS will try sending it to the port # identified in the packet or send ICMP port unreachable message if no app has that port #.

TTL decides #hops
EG. TTL=3, RTT signifies 6hops



Each router reduces TTL by 1. If TTL =0 but router ≠ destination then it sends back ICMP TTL exceeded to source

destination host finds out that the packet is intended for a port that is unusable, sends ICMP: port unreachable to source

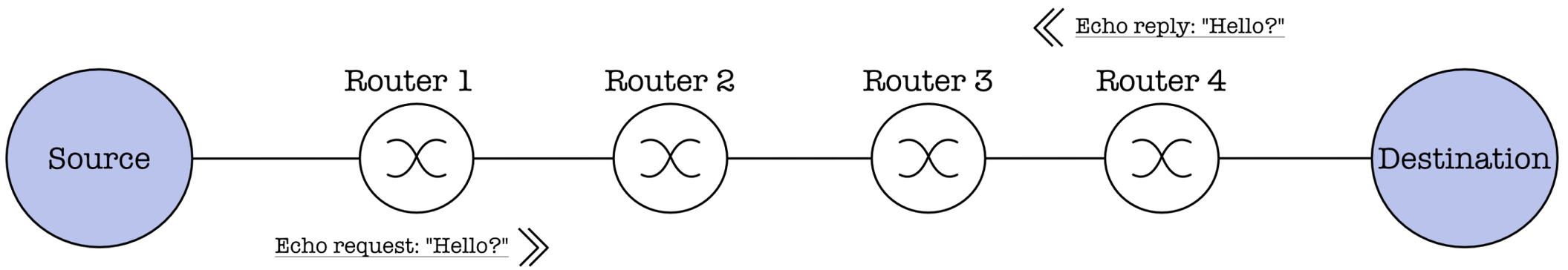
① sends 3 packets w increasing TTL each time it receives icmp TTL exceeded, and record the RTT (round trip time)
↓
to a likely unusable port in the destination

② stops sending once it receives icmp: port unreachable
(or when too many *** timeout has occurred).

FYI: PING

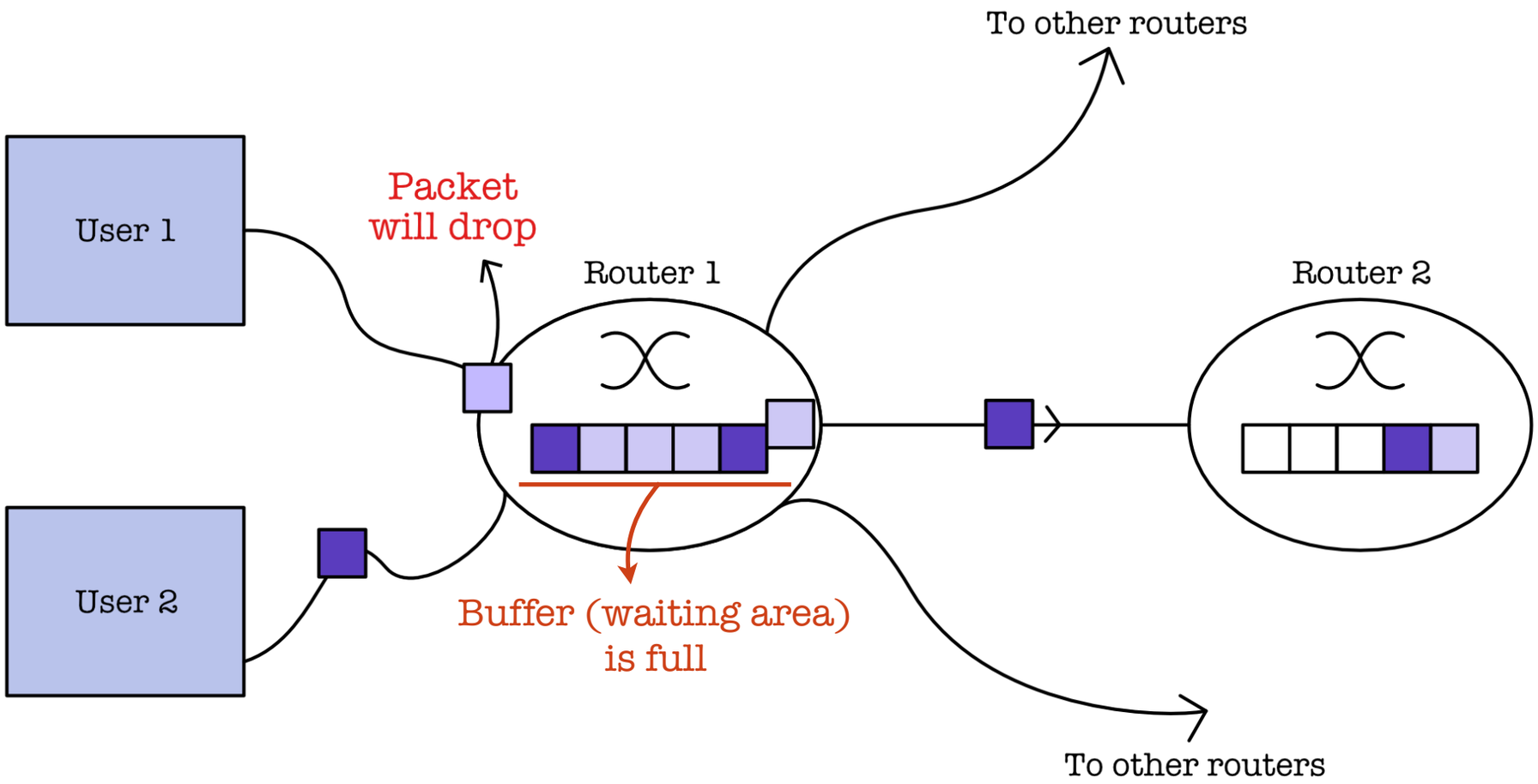
a program that sends ICMP echo request
some hosts block ICMP echo request for security / performance reason

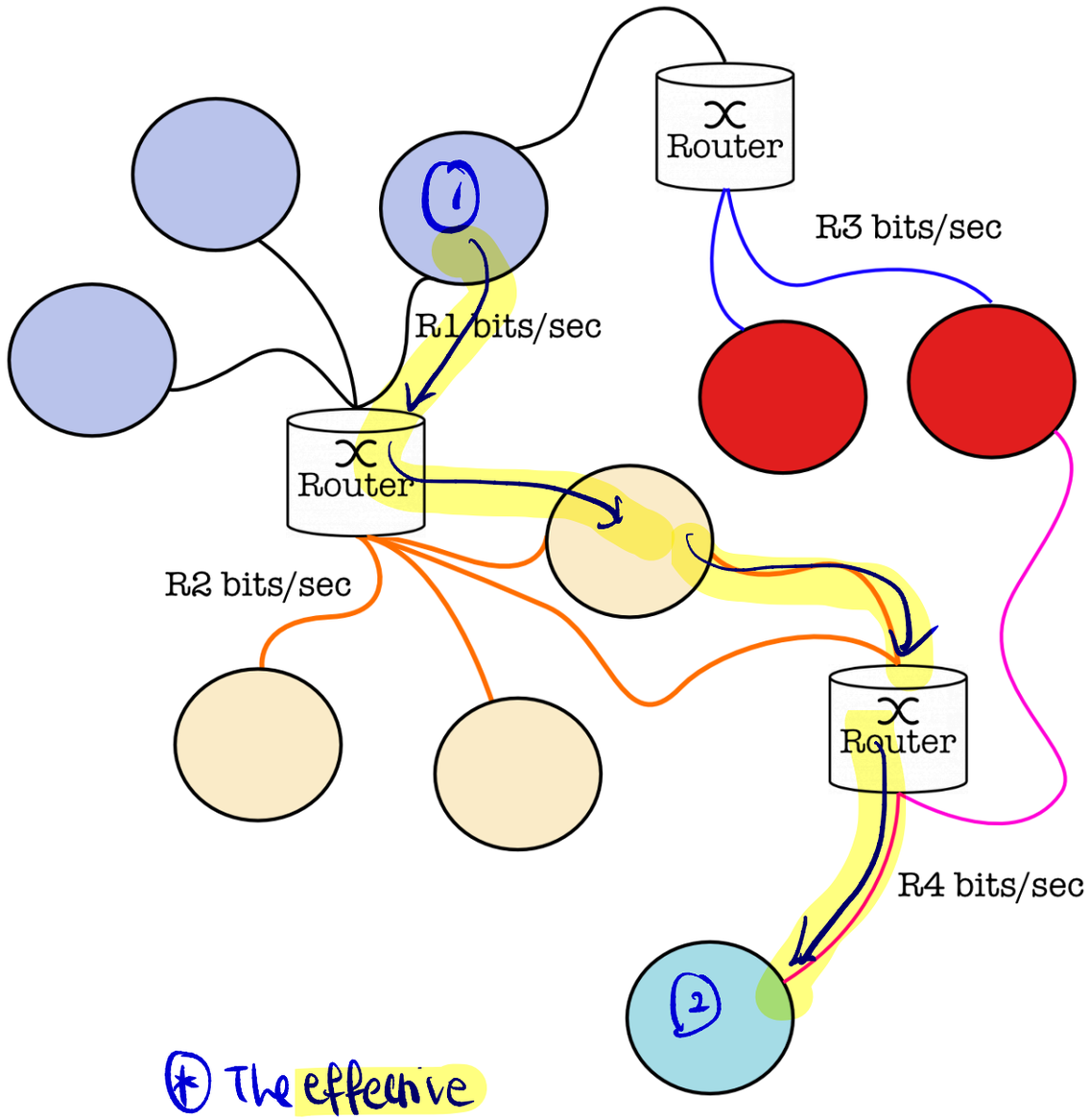
Finding out if your destination host is alive



PACKET LOSS

④ Transport layer protocol ensures delivery between end-to end host system. Hence, a packet loss may be retransmitted by the sender, depending on the protocol agreed.





COMPUTING THROUGHPUT

Packets are transferred between hosts (illustrated as circles) through a series of router(s).

Throughput: rate (bits/time unit) at which bits can be transferred between sender/receiver

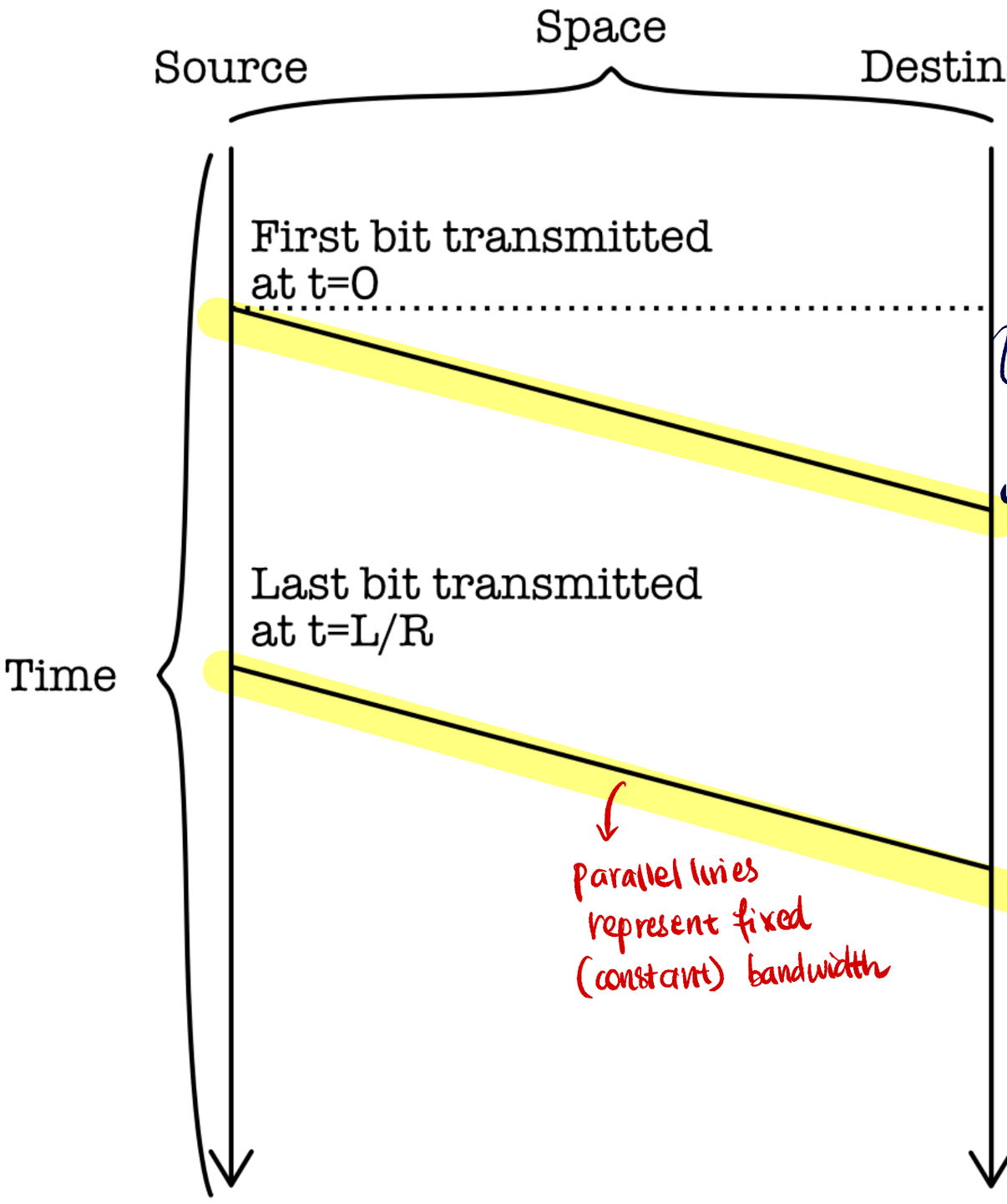
Two types of throughput:

1. **INSTANTANEOUS**
2. **AVERAGE**

It is useful to know the throughput to evaluate your network performance.

* The effective throughput between two endpoints is limited by the SLOWEST link.

Eg. if R4 : 50 b/s and R1 : 10 b/s } effective throughput b/w ① and ② is 10 b/s



NETWORK PERFORMANCE VISUALIZATION

The Space-Time diagram

Network performance is both **delay** and **throughput** limited

- **End to end delay: how flat**
- **Throughput/bandwidth speed: thickness**