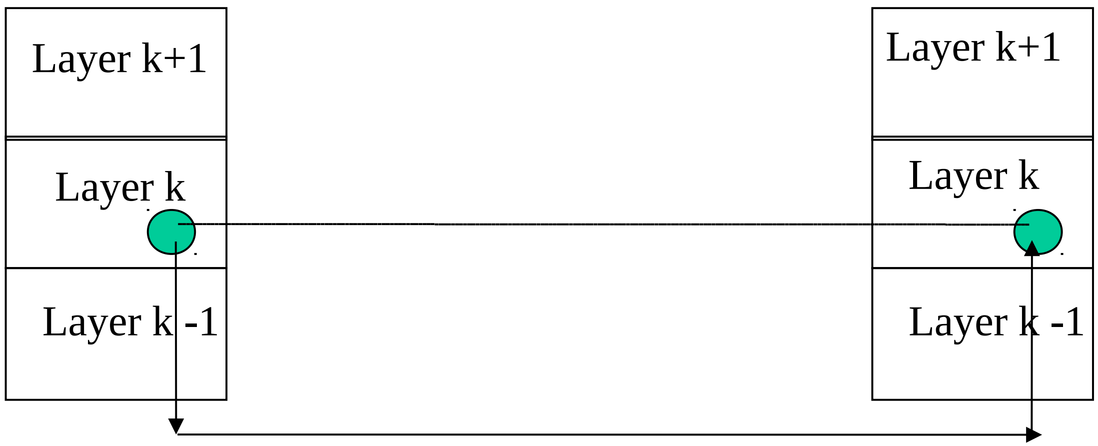
Service time evaluation for network protocols and routers

Computer Networking

Communication relies on a protocol stack with *n* layers.

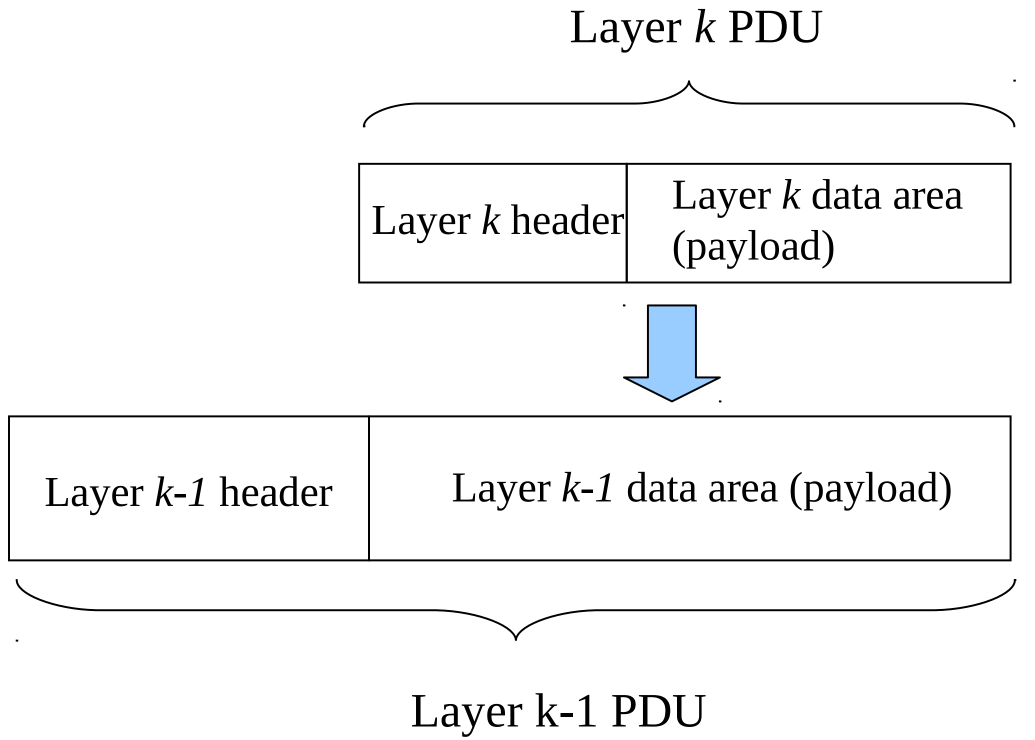
Layer *k* of an host:
- communicates with layer k of remote hosts
- exploits the service provided by layer *k-1*
- provides a service to layer *k+1*.



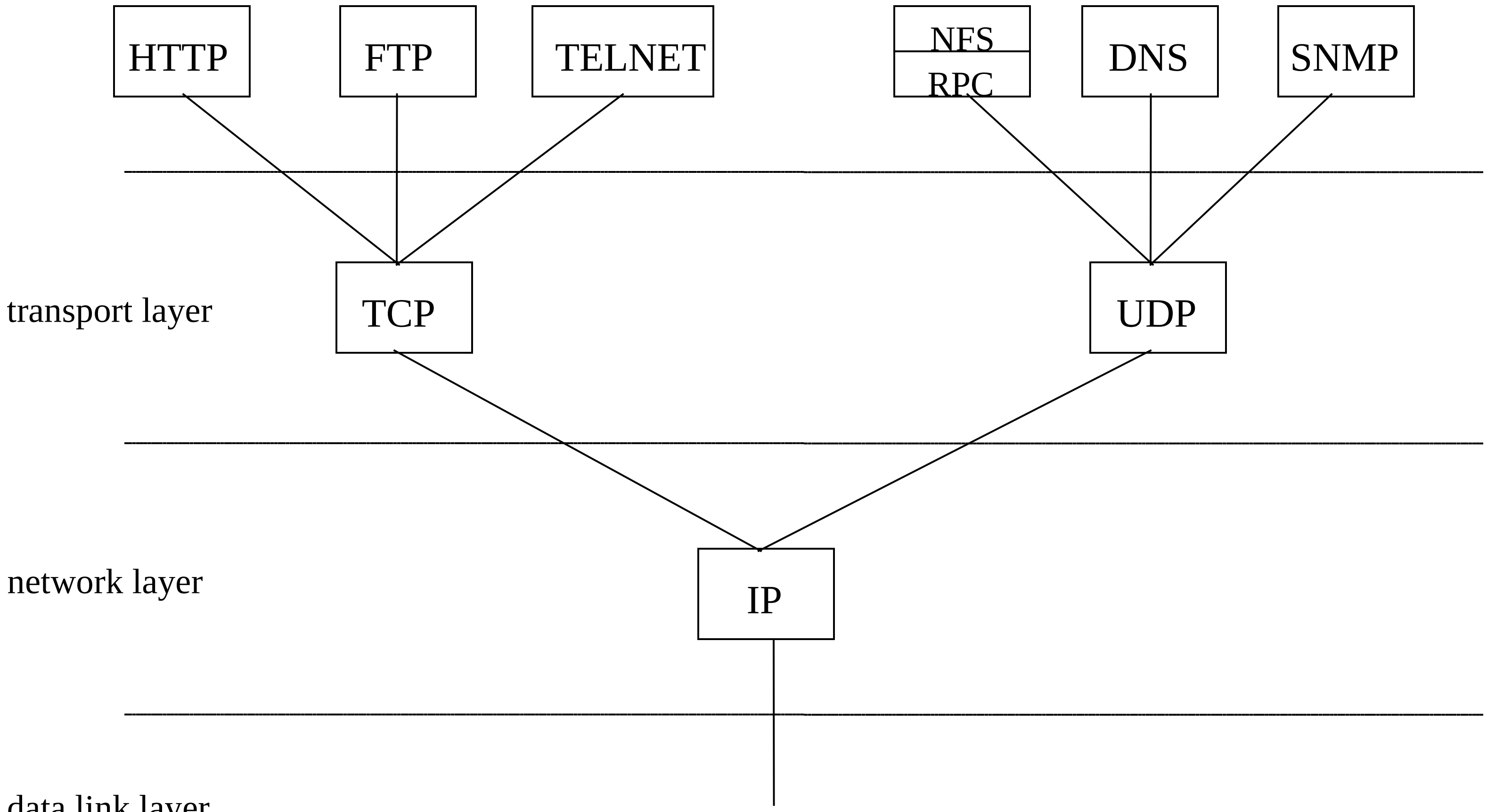
Protocol Data Units (PDUs)

A Protocol Data Unit (PDU) refers to information that is delivered as a single unit among layers.

- Layer *k-1* of sender host adds an header to data received from the layer *k*
- A PDU of Layer *k-1* becomes the payload for Layer *k*
- Layer *k* of the receiver host removes the header from data received from Layer *k-1*

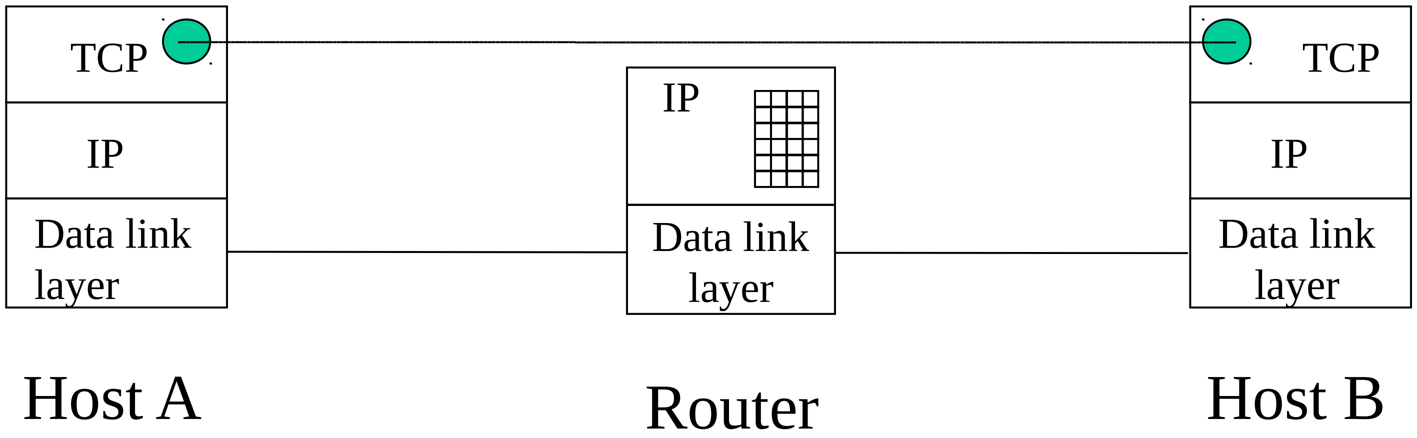


TCP/IP Protocol *Stratification*



Datagram IP Forwarding

The router holds a routing table used to find the next destination (router or host) to which the datagram is forwarded

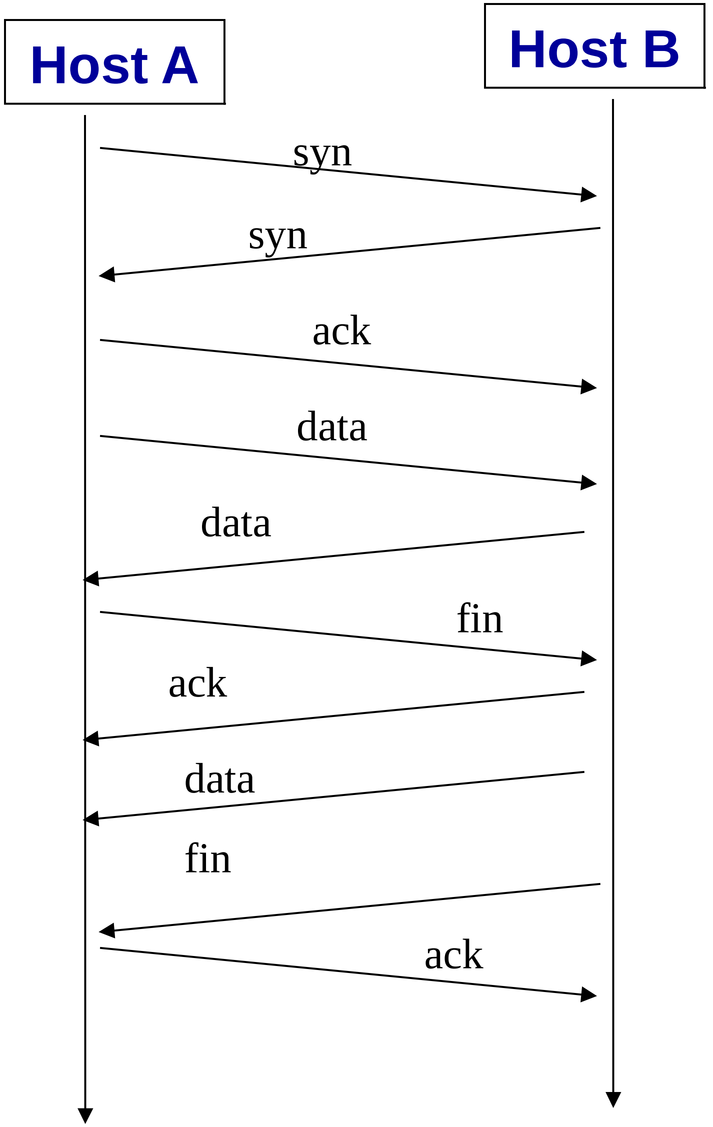


NETWORK PROTOCOLS

Protocol	PDU name	Max size	Header	Max data area
TCP	Segment	65535	20	65515
UDP	Datagram	65535	8	65527
IPv4	Datagram	65535	20	65515
IPv6	Datagram	65535	40	65495
ATM	Cell	53	5	48
Ethernet	Frame	1518	18	1500
Ieee 802.3	Frame	1518	21	1497
Ieee 802.5 TR	Frame	4472	28	4444
FDDI	Frame	4500	28	4472

TCP

- TCP provides a service: connection oriented, reliable, end-to-end, with flow control. It delivers data in the same sending order, without losses.
- TCP implements a connection reliable mechanism called *three-way handshake*
- 3 segments are required to establish a connection
- 4 segments are required to end it in both directions



IP

IP defines the format of the packets sent in Internet

Service is unreliable, datagrams can be lost

Fragmentation

- PDUs have a maximum size for the data area (Maximum Transmission Unit – MTU)
- Since the length MTUs chenges for different protocols, a router has to be able to fragment datagrams, that will be reassembled at the IP layer by the destination host.

Fragmentation disadvantages

- The router has to be able to divide PDU
- Fragments have to be reassembled by the destination host

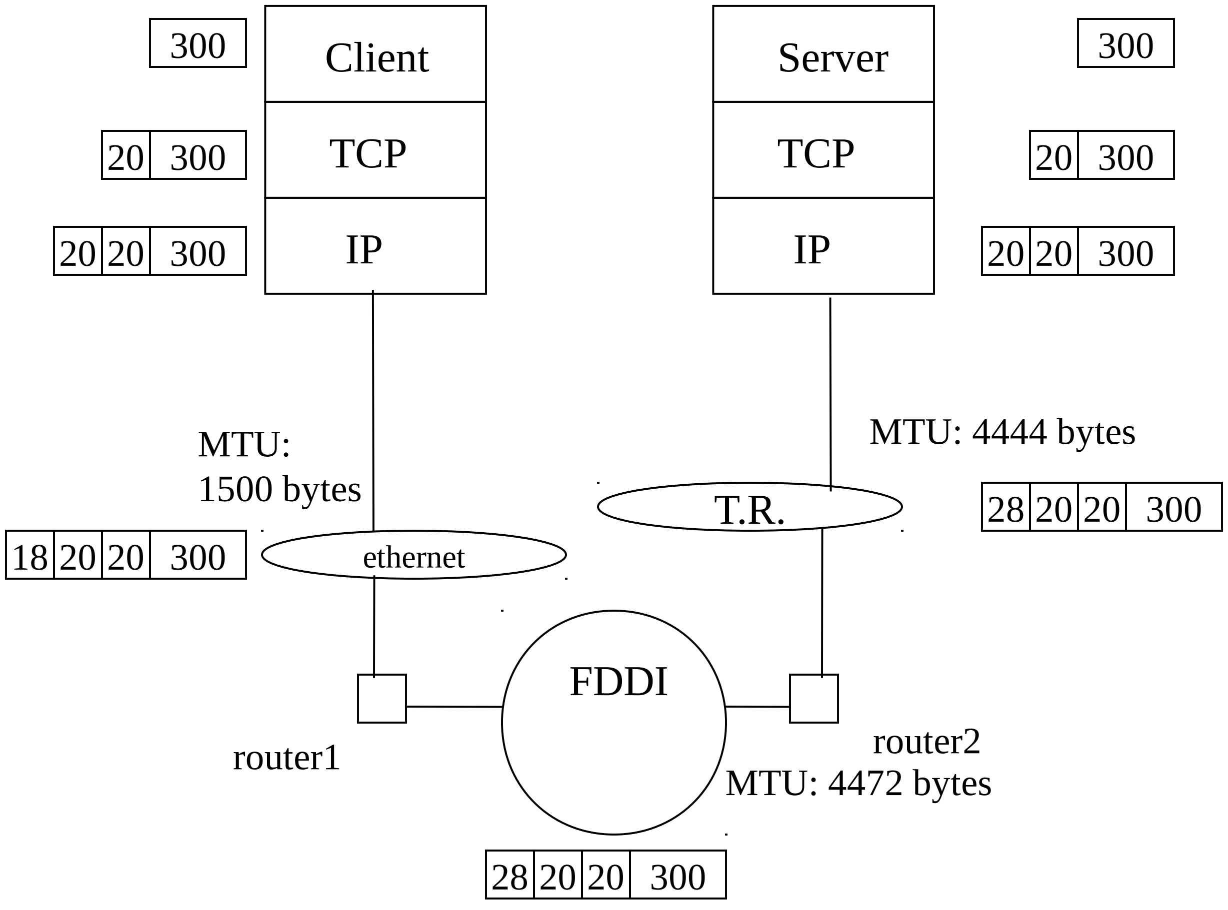
- NOTE: IP standard establishes that a datagram has to be fragmented by the sender host

Service times

$$\text{Service Time of a message} = \text{Time to transmit the message over the network} = \frac{\text{\# of bytes of message}}{\text{bandwidth}}$$

Example WITHOUT fragmentation

300 byte message sent from a Client to a Server



Bandwidth

Eth: 10.000.000 bps
FDDI: 100.000.000 bps
T.R.: 16.000.000 bps

LAN service time

300 byte message sent from a Client to a Server

$$\text{Service Time Eth} = \frac{\boxed{18\,|\,20\,|\,20\,|\;300} \times 8}{10.000.000} = \frac{358 \times 8}{10.000.000} = 0.000286 \text{ sec.}$$

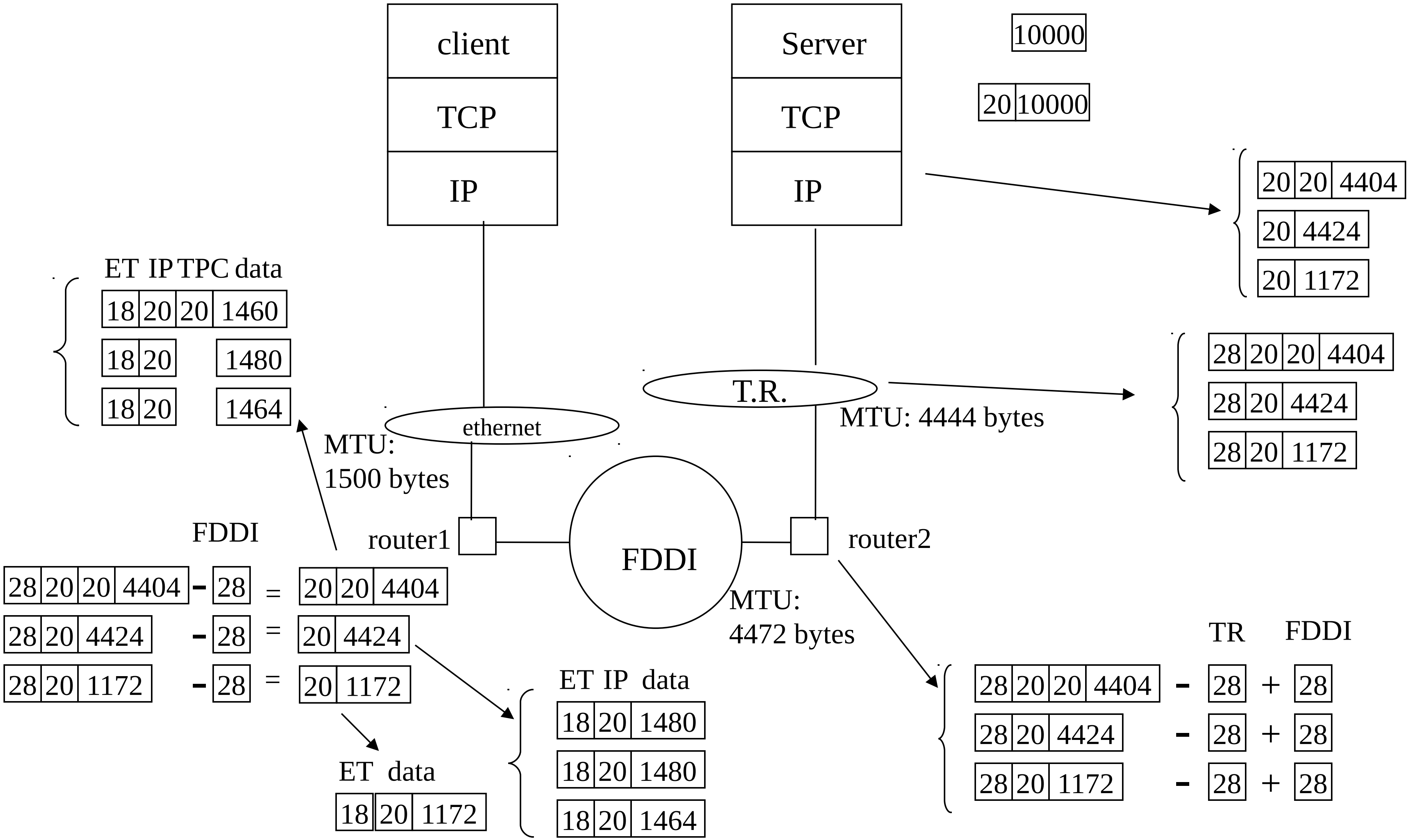
$$\text{Service Time FDDI} = \frac{\boxed{28\,|\,20\,|\,20\,|\;300} \times 8}{100.000.000} = \frac{368 \times 8}{100.000.000} = 0.00002944 \text{ sec.}$$

$$\text{Service Time TR} = \frac{\boxed{28\,|\,20\,|\,20\,|\;300} \times 8}{16.000.000} = \frac{368 \times 8}{16.000.000} = 0.000184 \text{ sec.}$$

Example WITH fragmentation

The Server sends a 10.000 byte reply to Client

*Hypothesis: TCP **does not know** the local network MTU*



LAN Service Time

The Server sends a 10.000 byte reply to Client

Hypothesis: TCP ***<u>does not know</u>*** *the local network MTU*

Case of Token Ring:

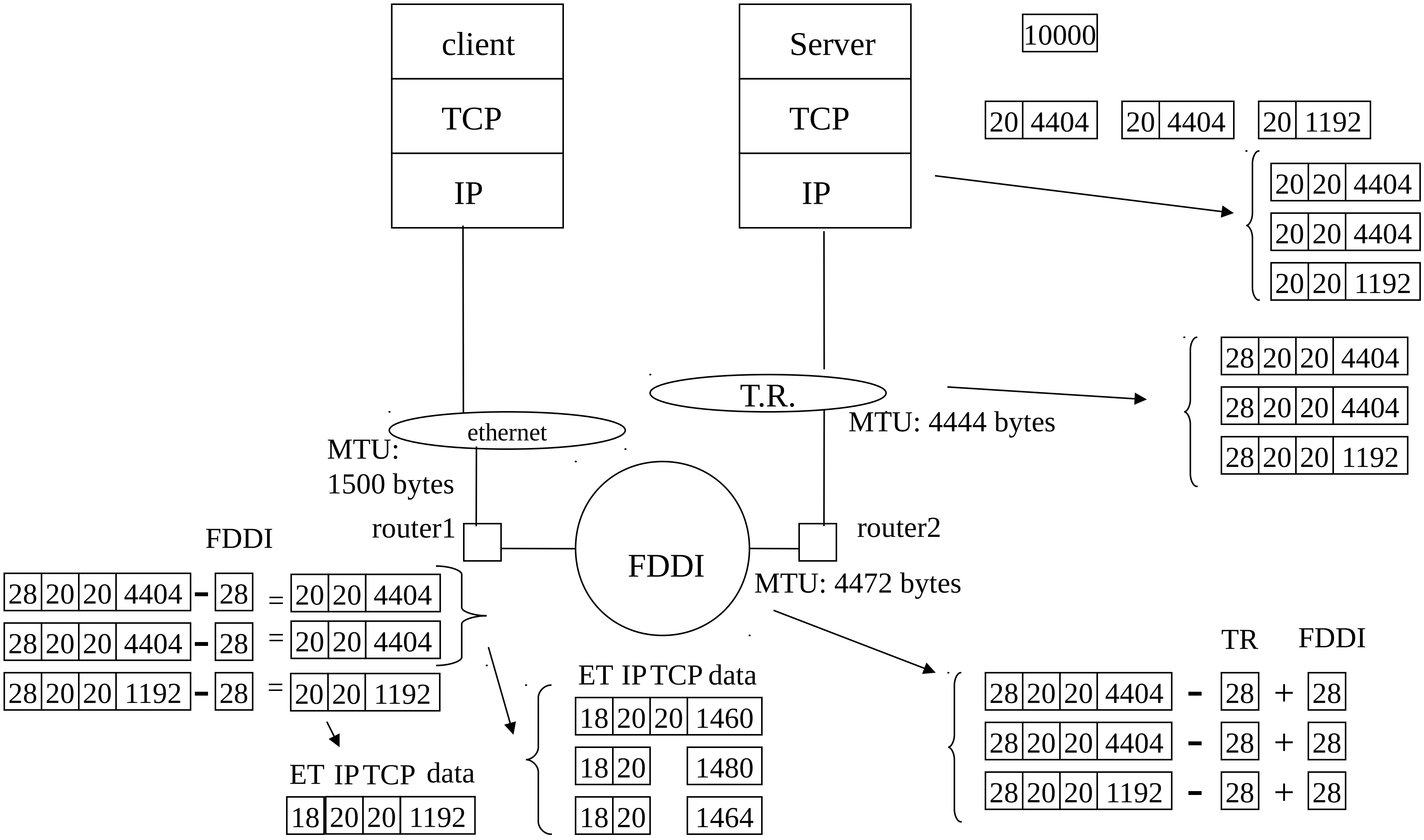
$$\text{Service Time} = \frac{\left(\boxed{28 \mid 20 \mid 20 \mid 4404} + \boxed{28 \mid 20 \mid 4424} + \boxed{28 \mid 20 \mid 1172} \right) \times 8}{16.000.000}$$

$$\text{Service Time} = \frac{(4472+4472+1220) \times 8}{16.000.000} = 0.005082 \text{ sec.}$$

Example WITH fragmentation

The Server sends a 10.000 byte reply to Client

*Hypothesis: TCP **knows** the local network MTU*



LAN Service Time

The Server sends a 10.000 byte reply to Client

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Case of Token Ring:

$$\text{Service Time} = \frac{\left(\boxed{28 \,|\, 20 \,|\, 20 \,|\, 4404} + \boxed{28 \,|\, 20 \,|\, 20 \,|\, 4404} + \boxed{28 \,|\, 20 \,|\, 20 \,|\, 1192} \right) \times 8}{16.000.000}$$

$$\text{Service Time} = \frac{(4472+4472+\mathbf{1260}) \times 8}{16.000.000} = 0.005102 \text{ sec.}$$

$$\left.\begin{array}{l} 0.005102 \text{ sec.} \\ 0.005082 \text{ sec.} \end{array}\right\} \quad \textbf{20 } \boldsymbol{\mu}\textbf{sec different}$$

Average service time

Evaluation without fragmentation

Let's specify:

MTU_n: network n MTU (byte)

XOvhd: X protocol overhead (byte)

$FrameOvhd_n$: network n overhead (byte)

$Overhead_n$: network n total overhead (TCP+IP+frame) (byte)

$Bandwidth_n$: network n bandwidth (Mbps)

Ndatagrams: number of IP datagrams required

Nsegments: number of TCP segments required (< or = Ndatagrams)

N: number of networks

Average service time

Without fragmentation

TCP does not know LAN MTU

$$NSegments = \frac{MessageSize}{65515}$$

TCP knows LAN MTU

$$NSegments = NDatagrams$$

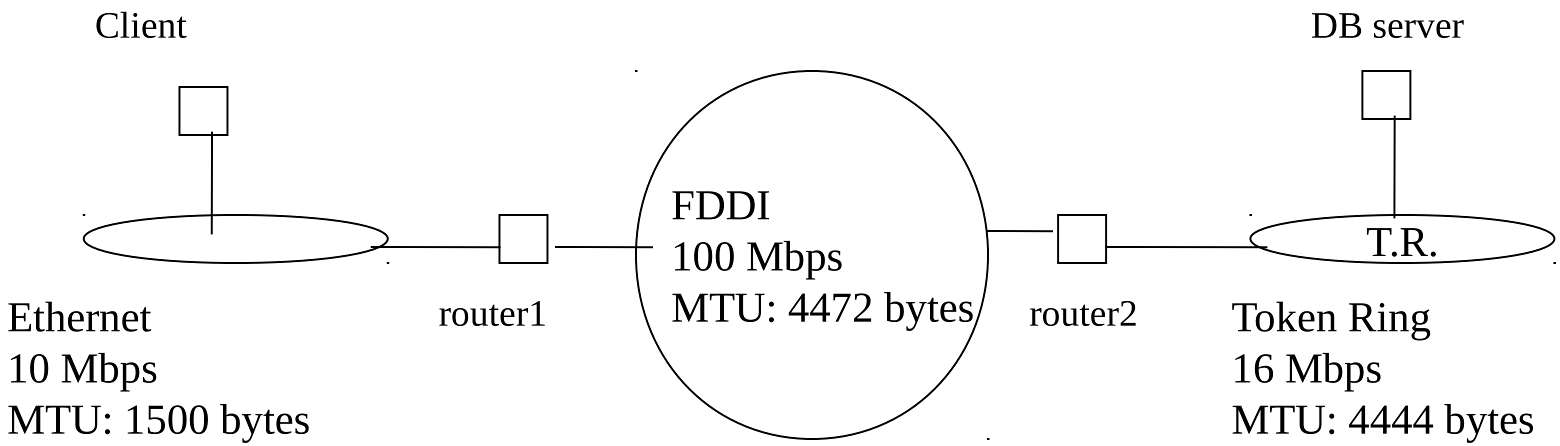
$$NDatagrams = \frac{MessageSize + NSegments \times TCPOvhd}{\min_n MTU_n - IPOvhd}$$

(rough estimate)

$$Overhead_n = NSegments \times TCPOvhd + Ndatagrams \times (IPOvhd + FrameOvhd_n)$$

$$ServiceTime_n = \frac{8 \times (MessageSize + Overhead_n)}{Bandwidth}$$

Exercise



The client sends 3 transactions per minute (0.05 tps), whose average message lenght is 400 bytes. Length of 80% of replies is 8092 bytes and length of the 20% is 100.000 bytes

Assuming that no fragmentation exists and the TCP layer does not know the netwotk MTU, evaluate the average service time for requests and replies for each network.

Exercise - solution

- Using

$$\text{NDatagrams} = \frac{\text{MessageSize} + \text{Nsegment x TCPOvhd}}{\text{min}_n \ \text{MTU}_n - \text{IPOvhd}}$$

We can evaluate the numbers of Datagrams required in each case (request, short reply and long reply)

(400+1*20)/(1500-20) = 1 (request)

(8092+1*20)/(1500-20) = 6 (short reply)

(100000+2*20)/(1500-20) = 68 (long reply)

Exercise - solution

- Using

$$\text{Overhead}_n = \text{TCPOvhd} + \text{Ndatagrams} \times (\text{IPOvhd} + \text{FrameOvhd}_n)$$

We can evaluate the network overhead (case of ethernet):

$\text{Overhead}_{Eth} = 20 + 1\ (20 + 18) = 58$ (request)

$\text{Overhead}_{Eth} = 20 + 6\ (20 + 18) = 248$ (short reply)

$\text{Overhead}_{Eth} = 20 + 68\ (20 + 18) = 2604$ (long reply)

- Using

$$\text{ServiceTime}_n = \frac{8 \times (\text{MessageSize} + \text{Overhead}_n)}{\text{Bandwidth}}$$

We can evaluate the Service Time (case of ethernet):

$\text{Overhead}_{Eth} = 8 \times (400 + 58) / 10.000.000 = 0.366$ msec request

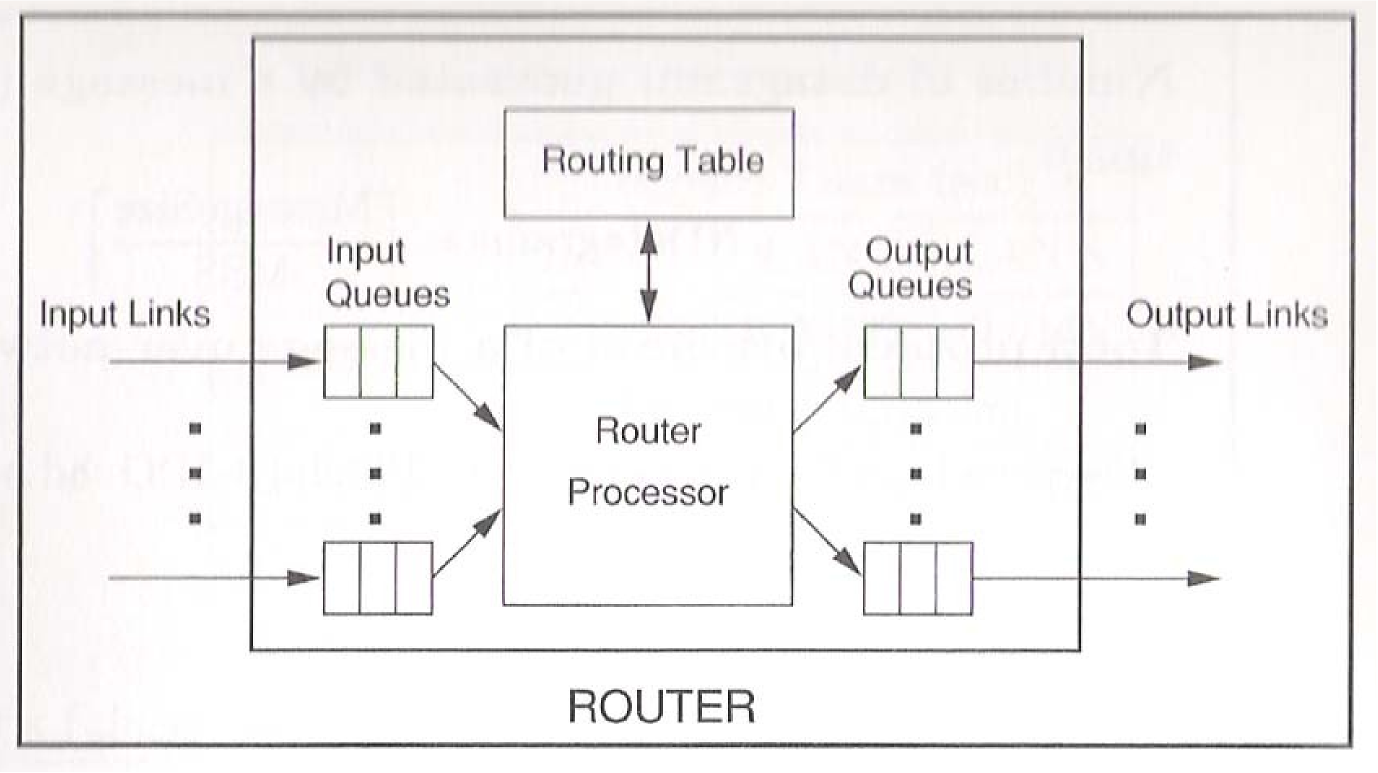
$\text{Overhead}_{Eth} = 8 \times (8092 + 248) / 10.000.000 = 6.67$ msec short reply

$\text{Overhead}_{Eth} = 8 \times (100.000 + 2604) / 10.000.000 = 82.1$ msec long reply

Service times evaluation

		Request	Short reply	Long reply
Eth	Ndatagrams	1	6	68
	Overhead (byte)	58	248	2604
	ServiceTime(msec)	0.366	6.67	82.1
FDDI	Ndatagrams	1	6	68
	Overhead (byte)	68	308	3284
	ServiceTime(msec)	0.0374	0.672	8.26
TR	Ndatagrams	1	6	68
	Overhead (byte)	68	08	3284
	ServiceTime(msec)	0.234	4.2	51.6
Router	Latency (134 usec/packet)	134	804	9.112

Network Router



Router queues

Router Service Times

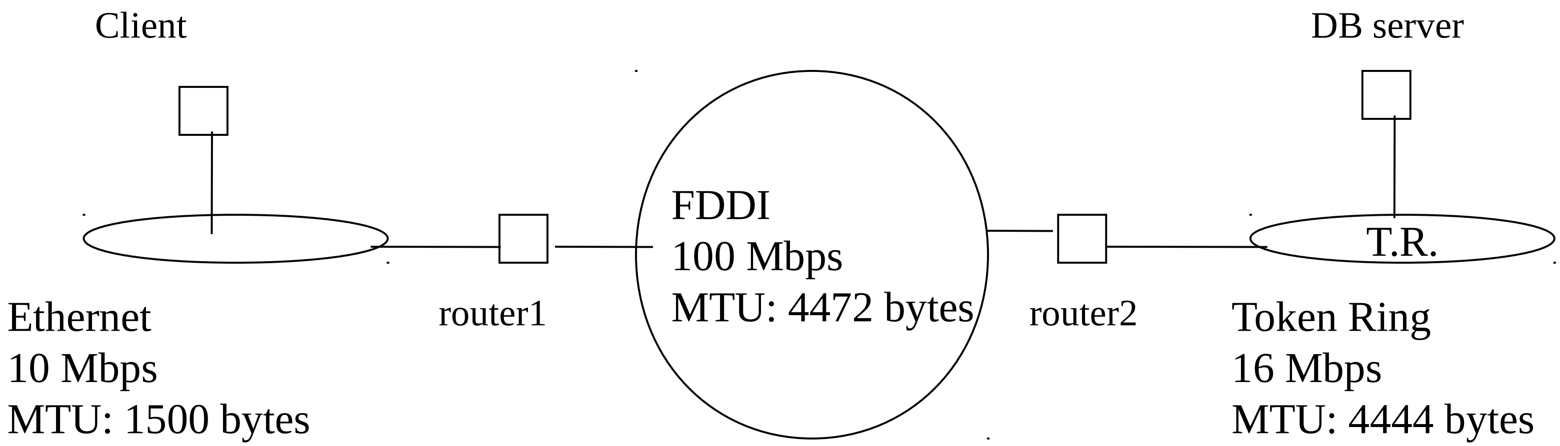
Router latency (μsec per packet): time spent by the router to process a datagram (the value is provided by the manufacturer).

RouterServiceTime: Ndatagrams * RouterLatency

Where

$$\text{NDatagrams} = \frac{\text{MessageSize} + \text{TCPOvhd}}{\min_n \text{MTU}_n - \text{IPOvhd}}$$

Exercise



- Router 1 and 2 process 400,000 packets/sec

⇒ Service time: 2.5 μsec (=1/400,000)

⇒ Service demand at router

Client Request	Short Reply	Long Reply
1 x 2.5 = 2.5 μsec	6 x 2.5 = 15 μsec	68 x 2.5 = 170 μsec