Computer Networks (CISC3001) Tutorial

Tutorial

- Permutation and Combination (math)
- Packet switching
- Packet delay

Permutation and Combination

Let's start with a simple example.

A student is to roll a die and flip a coin. How many possible outcomes will there be?

1H	2H	3H	4H	5H	6H
1T	2T	3T	4T	5T	6T

6*2 = 12 outcomes

12 outcomes

Permutation and Combination

For a college interview, Robert has to choose what to wear from the following: 4 slacks, 3 shirts, 2 shoes and 5 ties. How many possible outfits does he have to choose from?

4*3*2*5 = 120 outfits

Permutation and Combination

A **Permutation** is an arrangement of items in a particular order.

Notice, **ORDER MATTERS**!

To find the number of Permutations of n items, we can use the Fundamental Counting Principle or factorial notation.

$$P(n,r) = n(n-1)(n-2)...(n-r+1)$$

$$= \frac{n!}{(n-r)!}$$

Permutation and Combination

A **Combination** is an arrangement of items in which order does not matter.

ORDER DOES NOT MATTER!

Since the order does not matter in combinations, there are fewer combinations than permutations. The combinations are a "subset" of the permutations.

$$C(n,r) = \frac{n!}{r!(n-r)!}$$

Permutation and Combination

Combination

$$C(n,r)=\frac{n!}{r!(n-r)!}$$

- What if order *doesn't* matter?
- In poker, the following two hands are equivalent:
  - A♦, 5♥, 7♣, 10♠, K♠
  - K♠, 10♠, 7♣, 5♥, A♦

- How many different poker hands are there (5 cards)?

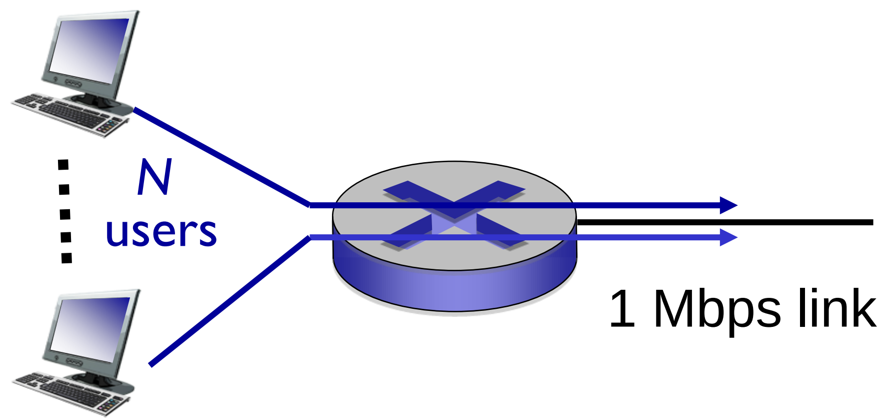
$$C(52,5)=\frac{52!}{5!(52-5)!}=\frac{52!}{5!47!}=\frac{52*51*50*49*48*47!}{5*4*3*2*1*47!}=2,598,960$$

Packet switching versus circuit switching

packet switching allows more users to use network!

example:

- 1 Mb/s link
- each user:
  - 100 kb/s when "active"
  - active 10% of time



- *circuit-switching:*
  - 10 users
- *packet switching:*
  - with 35 users, probability > 10 active at same time is less than .0004 *

Q: how did we get value 0.0004?

Solution

- Given the total number of 35 hosts served, the probability that only 1 host is actively sending its data is as follows

$$C_{35}^{1}(0.1)^{1}(0.9)^{34}$$

- Given the total number of 35 hosts served, the probability that 2 hosts actively are sending their data is as follows

$$C_{35}^{2}(0.1)^{2}(0.9)^{33}$$

- Therefore, given the total number of 35 hosts served, the probability that more than 10 hosts are actively sending their data is as follows

$$\sum_{i=11}^{35} C_{35}^{i}(0.1)^{i}(0.9)^{35-i} = 1 - \sum_{i=0}^{10} C_{35}^{i}(0.1)^{i}(0.9)^{35-i} = 0.0004$$

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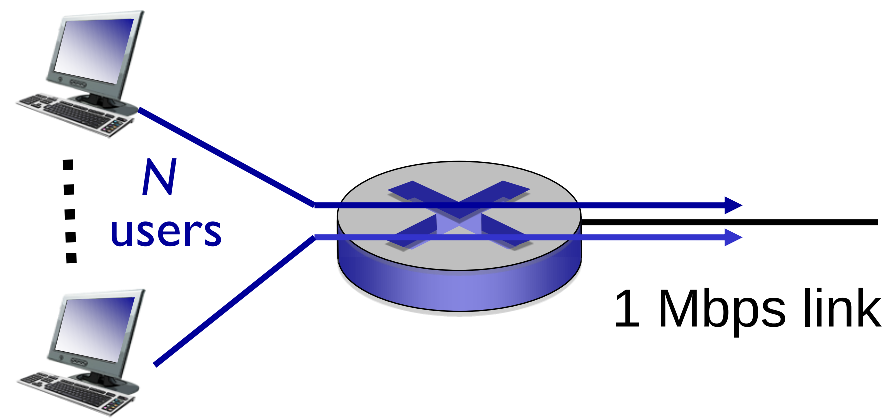


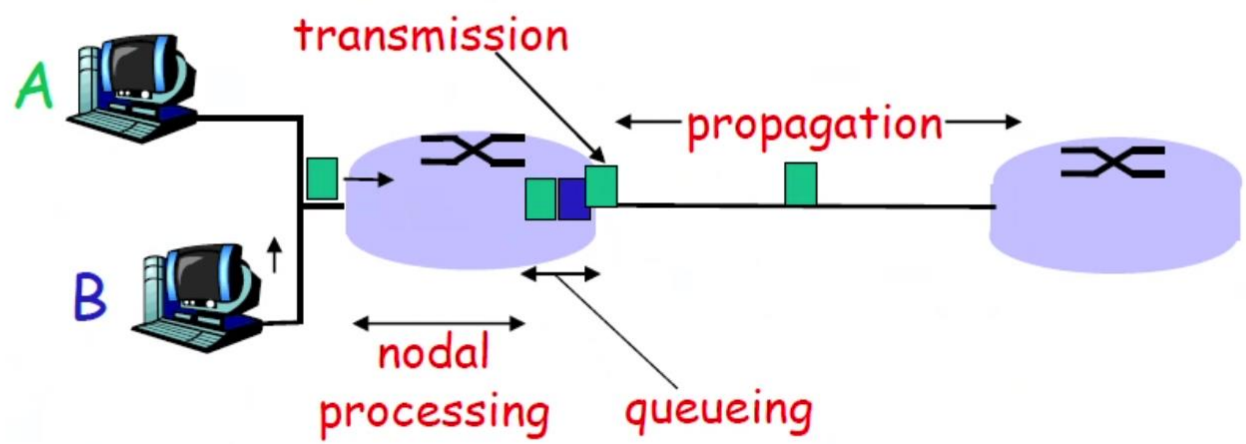
- *circuit-switching:*
  - 10 users
- *packet switching:*
  - with 35 users, probability > 10 active at same time is less than .0004 *

Q1: If the probability that more than 10 users are active at same time is less than .001, then how many users can be served by the system?

Q2: Support that 50 users are served by the system, what is the probability more than 10 users are active at same time?

Packet Delay

- 1. nodal processing:
  - check bit errors
  - determine output link
- 2. queueing
  - time waiting at output link for transmission
  - depends on congestion level of router



Packet Delay

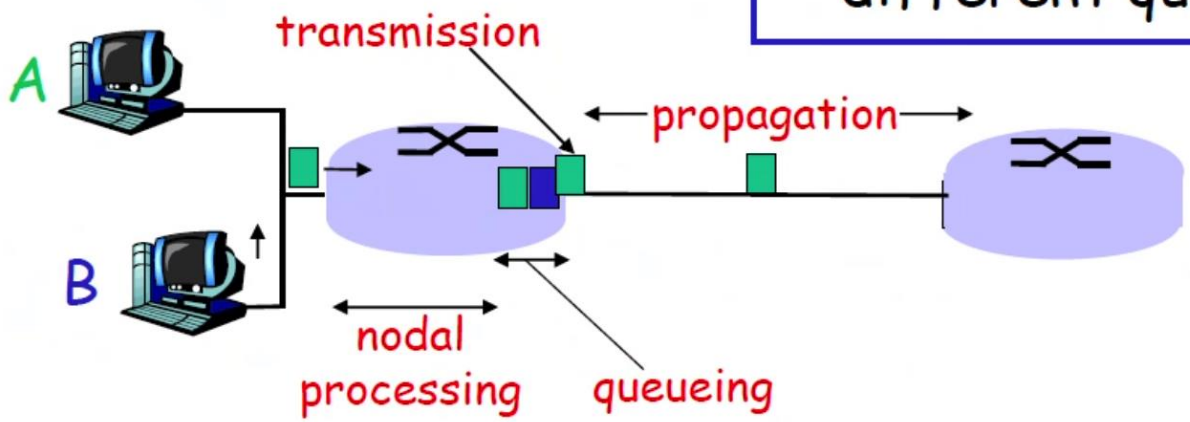
3. Transmission delay:

- R=link bandwidth (bps)
- L=packet length (bits)
- time to send bits into link = L/R

4. Propagation delay:

- d = length of physical link
- s = propagation speed in medium (~2×10^8 m/sec)
- propagation delay = d/s

Note: s and R are very different quantities!



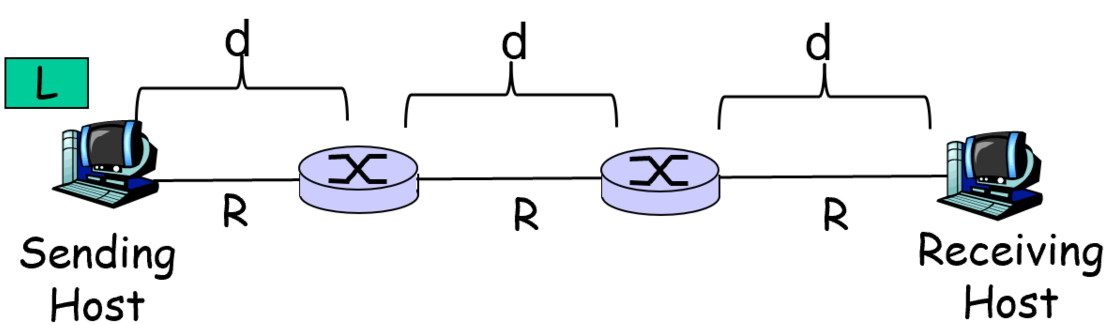
Nodal Delay

$$\boxed{d_{\text{nodal}} = d_{\text{proc}} + d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}}$$

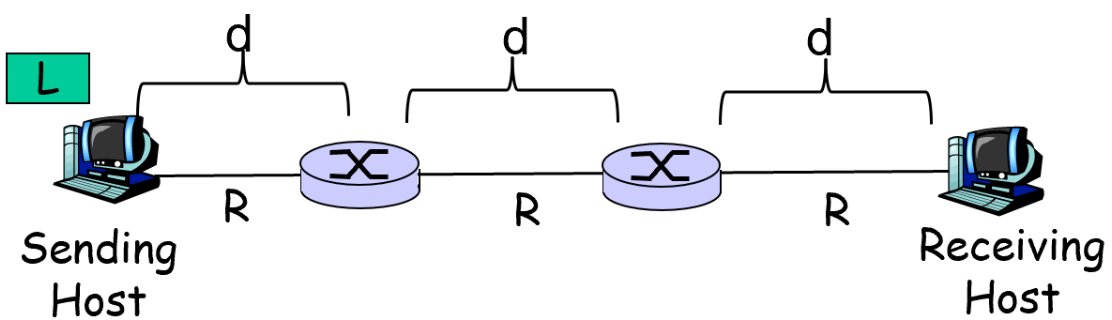
- d_{proc} = processing delay
  - typically a few microsecs or less
- d_{queue} = queuing delay
  - depends on congestion
- d_{trans} = transmission delay
  - = L/R, significant for low-speed links
- d_{prop} = propagation delay
  - a few microsecs to hundreds of msecs

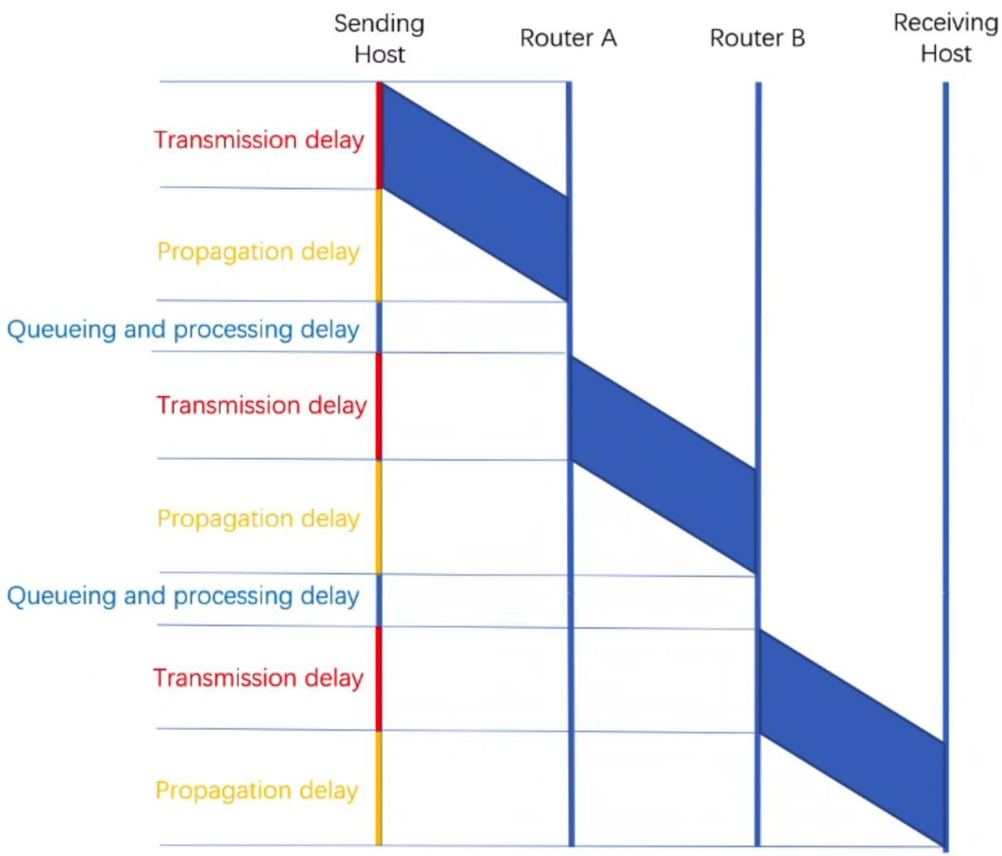
Packet Delay

- Consider a packet delivery shown in Figure 1 below. A sending-host sends a packet to a receiving-host via two routers. The packet size is of L. The distance between two different routers and the distance between host and router are denoted by d. The link bandwidth is denoted by R. The signal propagation in each link is denoted by v. For each individual router, its total node processing delay and queuing delay is denoted by T. Please calculate the overall delay for the whole packet is received by the receiving host.



Packet Delay





Total propagation delay: $3\frac{d}{v}$.

Total queueing and node processing delay: $2T$.

Total transmission delay: $3\frac{L}{R}$.

Overall delay: $3\frac{d}{v} + 3\frac{L}{R} + 2T$.