ELEC-4120 2014-SPRING COMMUNICATION NETWORKS TUTORIAL 1

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OUTLINE

- Circuit Switching vs. Packet Switching
- Packet-switching problems and techniques
- Protocol stack
- Queuing delay

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CIRCUIT SWITCHING VS. PACKET SWITCHING

CIRCUIT SWITCHING VS. PACKET SWITCHING

Circuit Switching

- Dedicated resources for admitted user

Packet Switching

- Best effort networking for all users
- shared media, packets are routed using statistical multiplexing

COMPARISON

Circuit Switching

- Call Setup
- Reserved and dedicated end-to-end services
- Guaranteed quality of service (QoS)
- Only one user at a time
- Line is underutilized
- The sender will not know the packets received correctly or not
- Cost is high

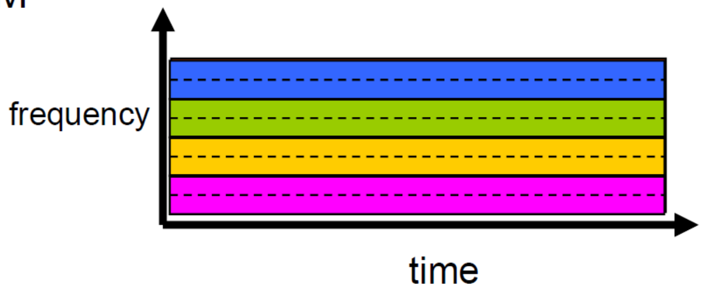
Packet Switching

- No call setup
- Media is shared
- QoS is hard to achieve
- Multiple users at the same time on the same line
- Line can be utilized to its full capacity
- There is an acknowledgment mechanism to inform the sender
- Cost is shared by users

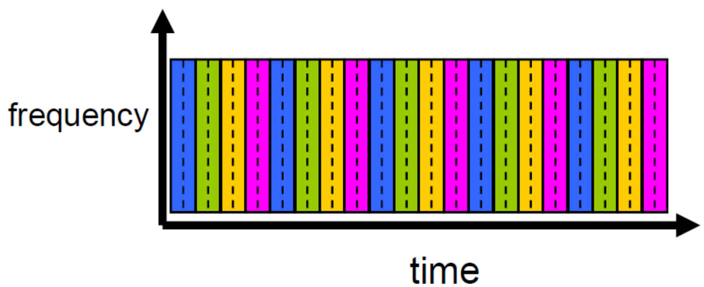
CIRCUIT SWITCHING METHODS

- Division of Network Resources
  - TDMA
  - FDMA
- Low link utilization

FDM



TDM



ADVANTAGES OF CIRCUIT SWITCHING

- What is the advantage of circuit switching over packet switching?
  - A circuit-switched network can guarantee a certain amount of end-to-end bandwidth for the duration of a call. Most packet-switched networks today (including the Internet) cannot make any end-to-end guarantees for bandwidth

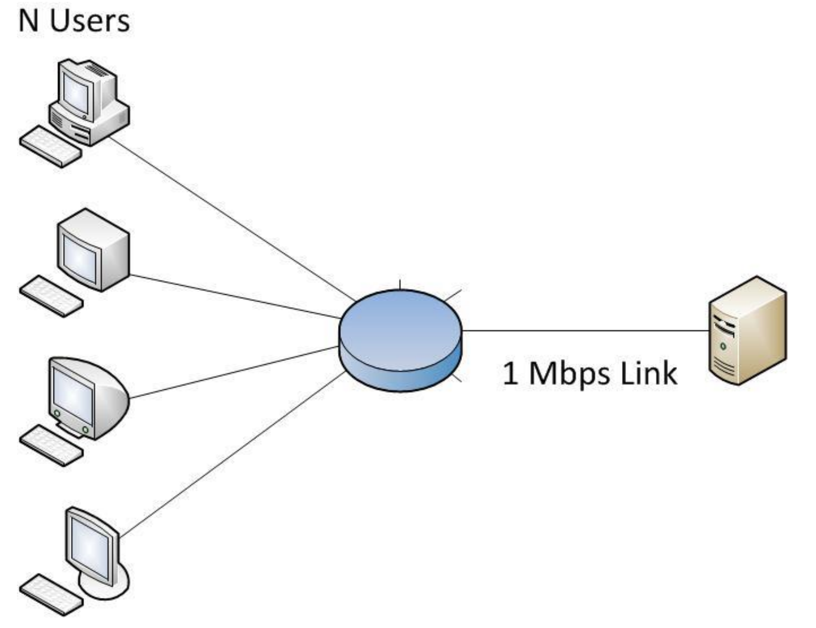
ADVANTAGES OF PACKET SWITCHING

- What is the advantage of packet switching over circuit switching?
  - Each packet uses full link bandwidth per transmission
  - Use as needed (Statistical Multiplexing)
  - Accept more calls (higher capacity). As calls may blocked and no more connection would be accepted in heavy loaded circuit

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 less than 0.0004



Packet switching allows MORE users to use network!

WHY?

- First, translate the problem into math and probabilities
  - active 10% of time ➔ The probability that a given user is transmitting: $p=0.1$
- Use the binomial distribution, the probability for n users to be transmitting simultaneously is:

$$\binom{35}{n} p^n (1-p)^{35-n}$$

STILL, WHY?

- The probability that there are 11 or more users transmitting simultaneously:

$$\sum_{n=11}^{35}\binom{35}{n}p^n(1-p)^{35-n}$$

- We use the central limit theorem to approximate this probability:
  - Let X_j be independent and identically distributed Bernoulli random variable, such that $P(X_j = 1) = p$

$$p\{\sum_{i=1}^{n} X_i \le x\} \approx \Phi(\frac{x-np}{\sqrt{np(1-p)}})$$

FINALLY…

$$P\left(\sum_{j=1}^{35} X_j \le 10\right) = P\left(\frac{\sum_{j=1}^{35} X_j - 35\cdot 0.1}{\sqrt{35\cdot 0.1\cdot 0.9}} \le \frac{10-3.5}{\sqrt{35\cdot 0.1\cdot 0.9}}\right)$$

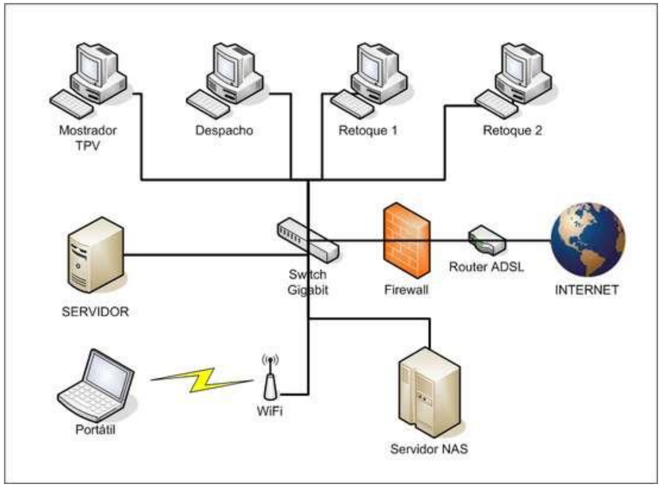
$$\approx \Phi\left(\frac{6.5}{\sqrt{3.15}}\right) = \Phi(3.662) = 0.9998$$

- So the probability is about 0.0002, less than 0.0004.

2 PROTOCOL STACK

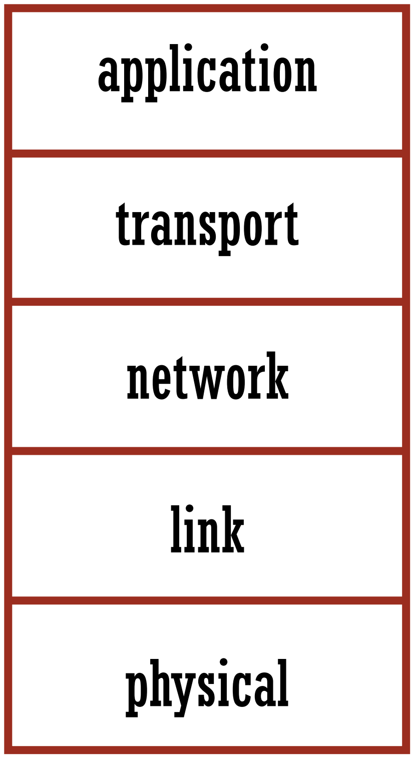
NETWORK PROTOCOL

- Definition: Machine languages used in the network, by routers, servers, workstations, mobile devices, and other network participants, to communicate with each other.

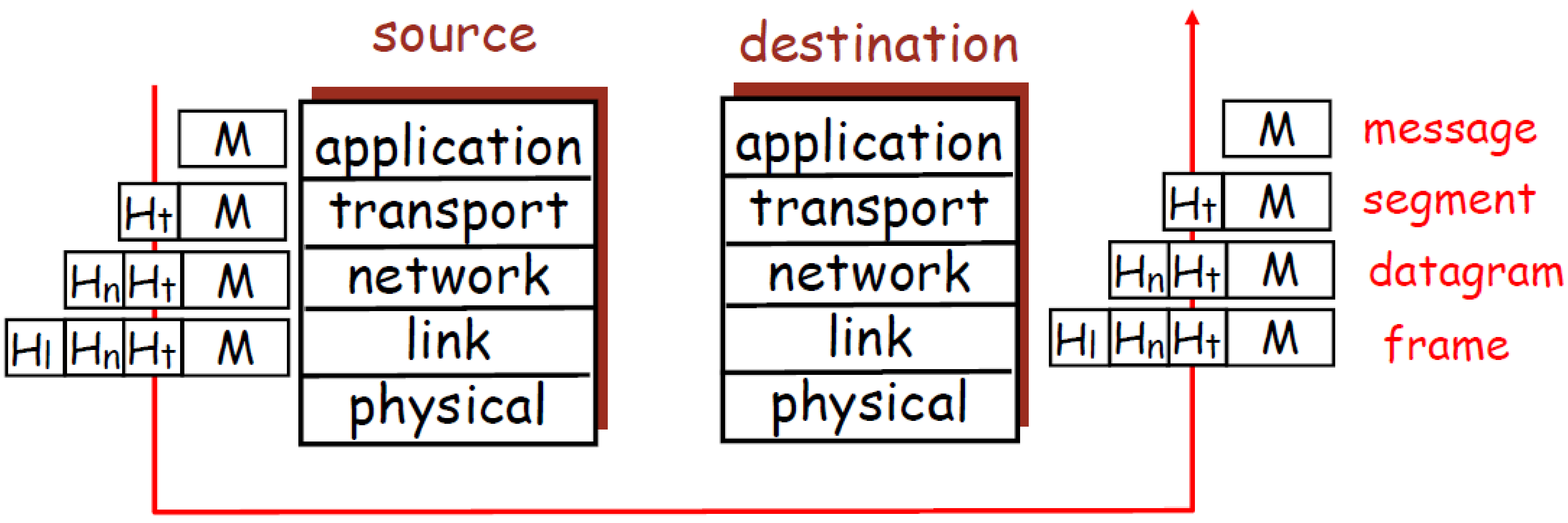


INTERNET PROTOCOL STACK

- Application: supporting network applications
  - FTP, SMTP, STTP
- Transport: host-host data transfer
  - TCP, UDP
- Network: routing of datagrams from source to destination
  - IP, routing protocols
- Link: data transfer between neighboring network elements
  - Ethernet
- Physical: bits “on the wire”



PROTOCOL STACK



3 DELAY

DELAY

- $d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$
  - d_{proc}: processing delay (a few microseconds or less).
  - d_{queue}: queuing delay (depend on congestion).
  - d_{trans}: transmission delay (L/R).
  - d_{prop}: propagation delay (a few microseconds to hundreds of milliseconds)

MORE DETAILS ON DELAY

- Router processing
  - Check errors
  - Determine output link
- Queuing
  - Time spend on waiting
  - Depends on congestion
- Transmission Delay
  - Time to send bits into link = L/R
    - L = packet length
    - R = link bandwidth
- Propagation Delay
  - Time for a bit to travel through the link = d/s
    - d = length of link
    - s = propagation speed in medium

QUEUING DELAY

- The queue length depends on traffic arrival and departure process
- Each packet can stay in the queue for a certain amount of time based on its QoS parameter. After that packet will be dropped by the router. If the packet finds a full queue it will be lost.
- Average arrival time: average time between packets arrival equals to $1/\lambda$, where λ is the average arrival rate
- Average service time: average time between packets departure denoted by $\bar{x} = \frac{1}{\mu}$, where μ is the average departure rate
- $\rho = \bar{x}\lambda = \lambda/\mu$ is called link utilization or traffic intensity

QUEUING DELAY

- Very important result that relate three basic quantities for most queuing systems
- λ= average arrival rate
- $\bar{N}$ = average number of packets in the system
- $\bar{T}$= average time each packet spends in the system
- Little's Theorem: $\bar{N} = \lambda \bar{T}$
  - true for general arrival processes and service processes.
- Example:
- Assume arrival rate is $a = 1$ packet per second and the delay of each packet is $s = 5$ seconds. What is the average number of packets in the system?

CONT'D

- average number of packets in the system $\bar{N} = \frac{\rho}{1-\rho}$
- Average waiting time $\bar{W} = \bar{T} - \bar{x}$
- Average waiting time is equal to average number of packets in the system multiply by average service time of the packets $\bar{W} = \bar{N}\bar{x}$