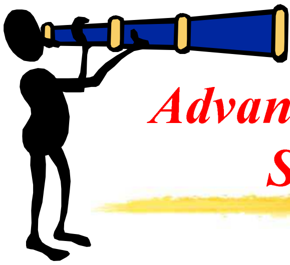

Advanced Computer Networks
Spring 2017- Set #1

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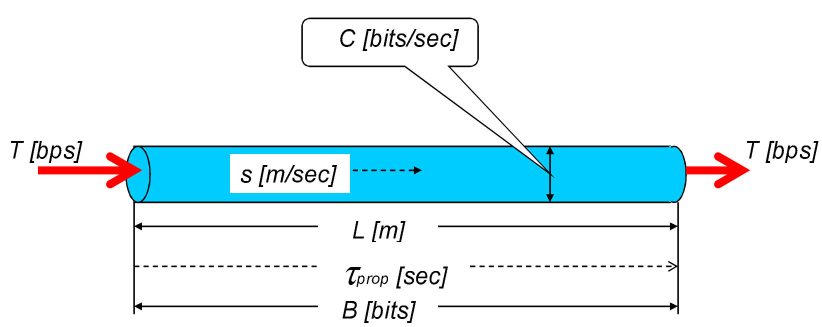
A Link as a "Communication Pipe"

⌘ A communication link/path is modeled as a conduit carrying liquid (water).



The Communication Pipe (con't)

- The *bit capacity* of the pipe, B [bits], the *propagation delay* of the pipe, τ_{prop}, and the pipe *utlization*, ρ, are given by:

$$\tau_{prop} = \frac{L}{s}; \qquad B = C \cdot \tau; \qquad \rho = \frac{T}{C}$$

- Thus a total delay of a message of size M [bits] is:

$$\tau_{total} = \tau_{prop} + \tau_{transmission} = \frac{L}{s} + \frac{M}{C}.$$

- For example, consider a link of 4,000[miles]=6,400[km] @ 2/3 the speed of light:

$$\tau_{prop} = \frac{6.4 \cdot 10^6}{1.53 \cdot 10^8} = 4.17 \cdot 10^{-2}[\sec] = 41.7[m\sec].$$

The Communication Pipe (con't)

- Now consider the case of a message of 10 [Kbytes] and
  - link capacity, C=10[Kbps]:

$$\tau_{transmission} = \frac{80 \cdot 10^3[b]}{10 \cdot 10^3[bps]} = 8[\sec];$$

$$B = 10[Kbps] \cdot 41.7[m\sec] = 417[b].$$

  - link capacity, C=100[Mbps]:

$$\tau_{transmission} = \frac{80 \cdot 10^3[b]}{100 \cdot 10^6[bps]} = 0.8[m\sec];$$

$$B = 100[Mbps] \cdot 41.7[m\sec] = 4.17[Mb].$$

The Communication Pipe (con't)

- link capacity, C=1[Gbps]:

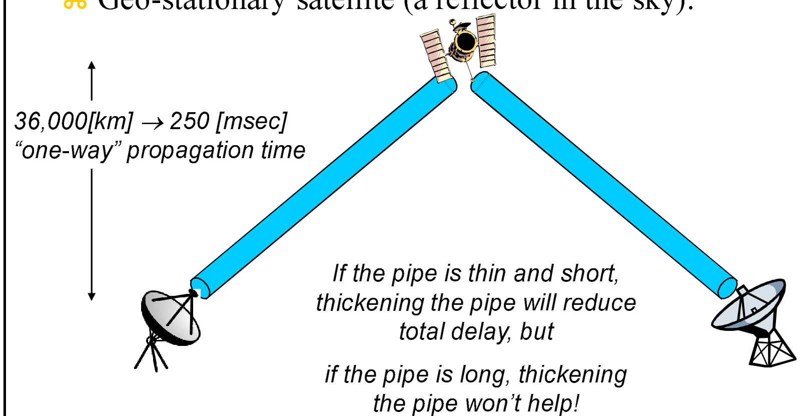
$$\tau_{transmission} = \frac{80 \cdot 10^3 [bits]}{10^9 [bps]} = 0.08\ [msec];$$
$$\mathrm{B} = 1\ [\mathrm{Gbps}] \cdot 41.7 [msec] = 41.7\ [Mb]$$

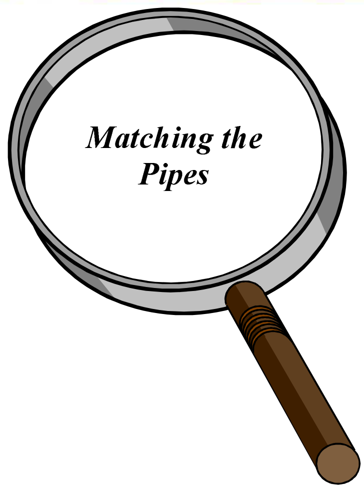
10 [Kbps] "pipe"

*1 [Gbps] "pipe" …. **bursty traffic***

Satellite Communications

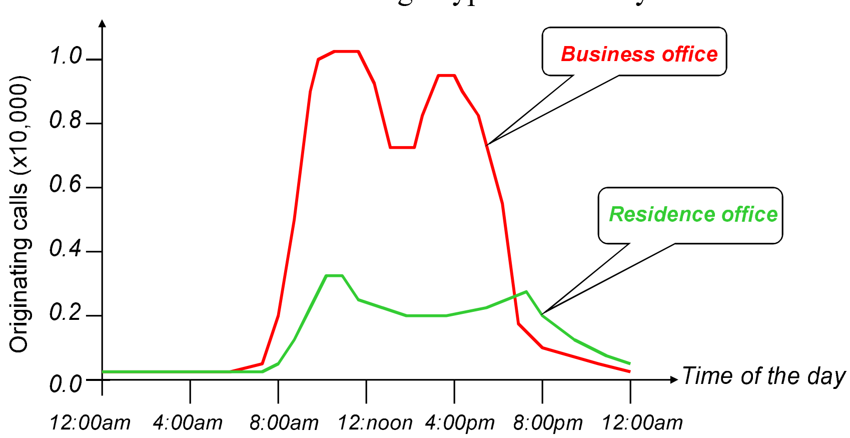
- Geo-stationary satellite (a reflector in the sky):





Variations of voice traffic demand

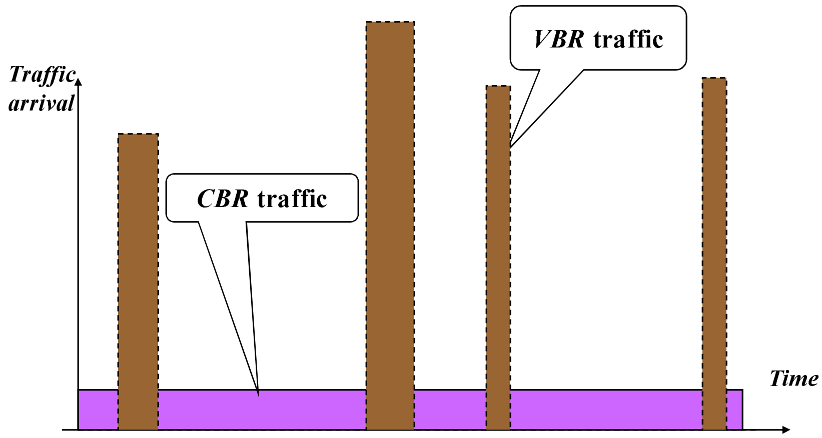
⌘ Office traffic variations during a typical weekday



Voice vs. Data

CBR = Constant Bit Rate (e.g., uncompressed voice)

VBR = Variable Bit Rate (e.g., data, compressed video)



Voice vs. Data

- Why do we need to worry about data communications?
- Why aren't voice-based systems sufficient?

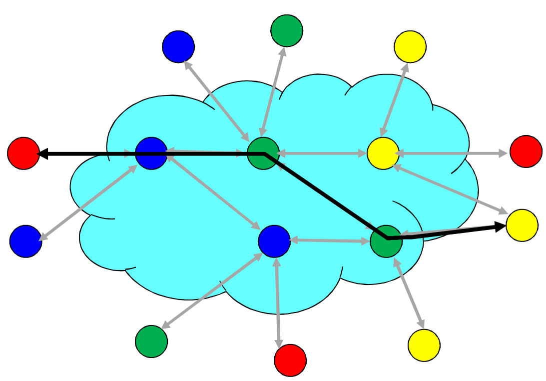
Voice	Data
Real time (low delay)	Delays are acceptable
Sensitive to jitter	Insensitive to jitter
Some errors allowable	Errorless communication
Constant bit rate	Variable bit rate ⇒ burstiness

Voice vs. Data (con't)

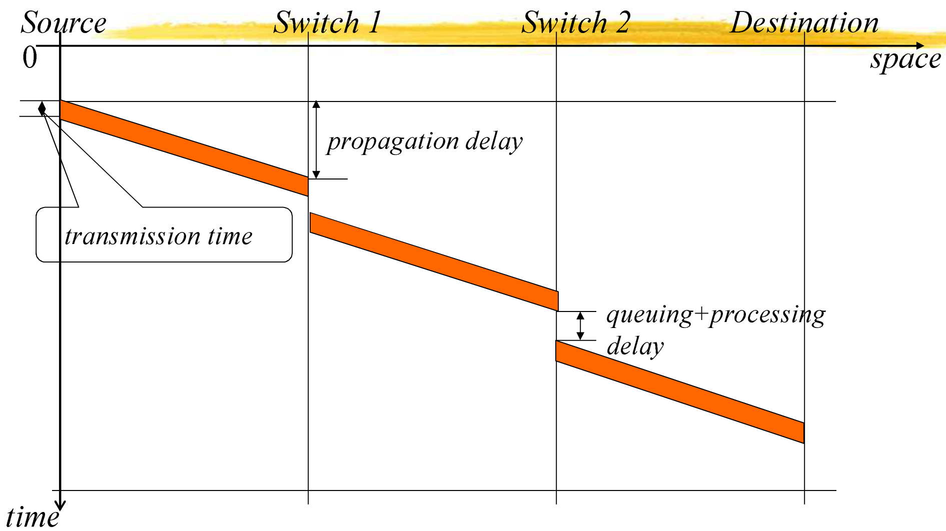
- Circuit switching was traditionally used to switch voice communication.
- Circuit switching involves a set up procedure, during which a resource dedication is performed. Once a circuit is establish, data can flow "freely" without any delay.

Switching Techniques

- Circuit Switching:



Time-Space Diagram



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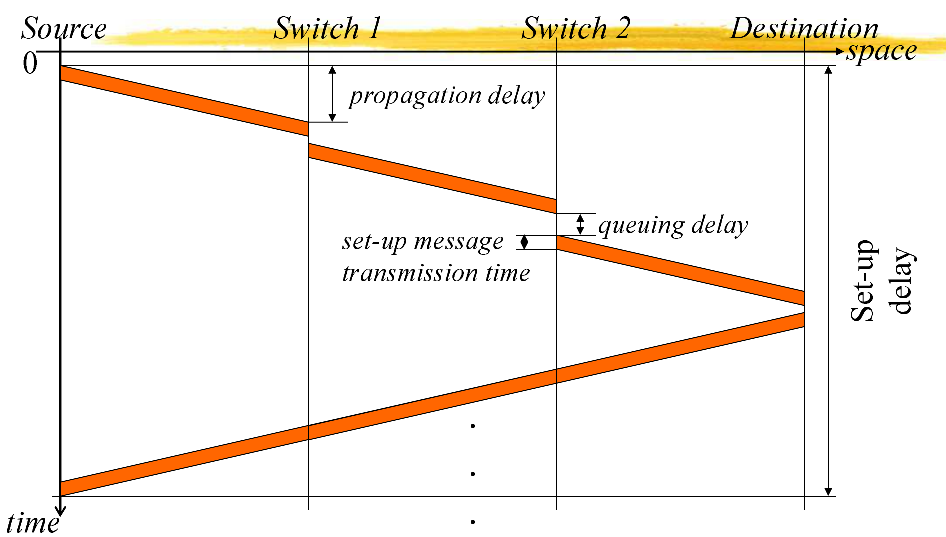
Circuit Switching (set-up phase)



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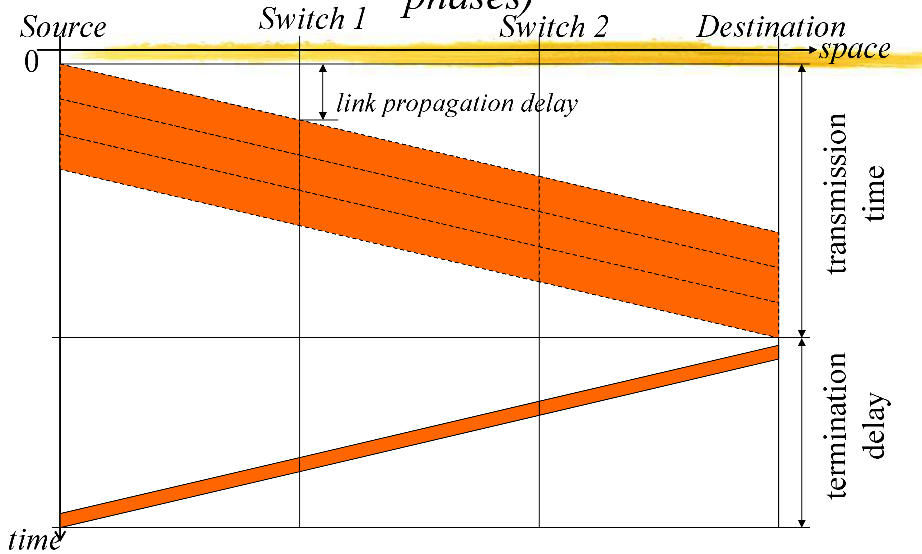
Circuit Switching (transmission & termination phases)



Voice vs. Data (con't)

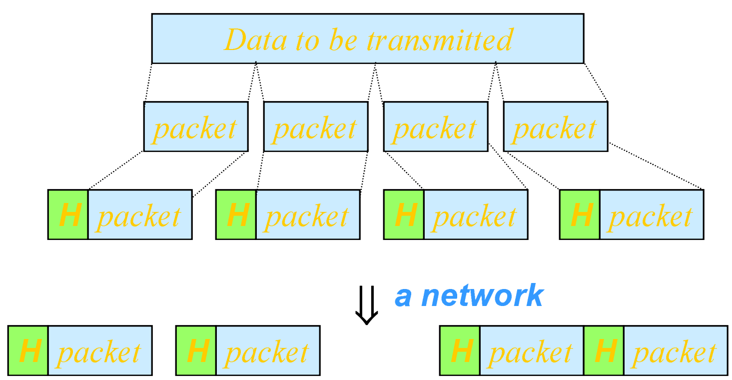
- But circuit switching assumes constant traffic patterns. Data communications, and especially computer communication, is very *bursty.*
- Such burstiness leads to inefficient use of network resources (e.g., a line is reserved, but is unused for the duration of long periods). … The pipe remains empty most of the time!!!
- This is where *packet switching (or message switching)* was invented.

Voice vs. Data (con't)

- The idea behind packet switching is simple - use statistical (time) multiplexing of the resources.
- The main problem: as the demand for resources can be highly variable in time (i.e., large degree of burstiness) and unpredictable, some data may not find the resources needed.
- An idea: since delay is not critical for data $\Rightarrow$ buffer the excess demand.
- But buffering may introduces unfairness in resource usage and large delay variations (jitter).Furthermore, some traffic may be lost due to congestion.

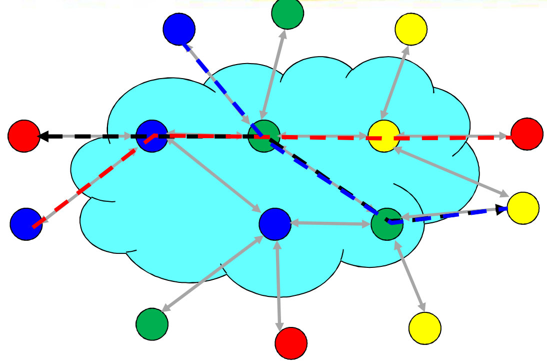
Packet Switching

- The *packet switching* has been born!
- Segment the data into small units, *packets.*



Switching Techniques

- Packet Switching:



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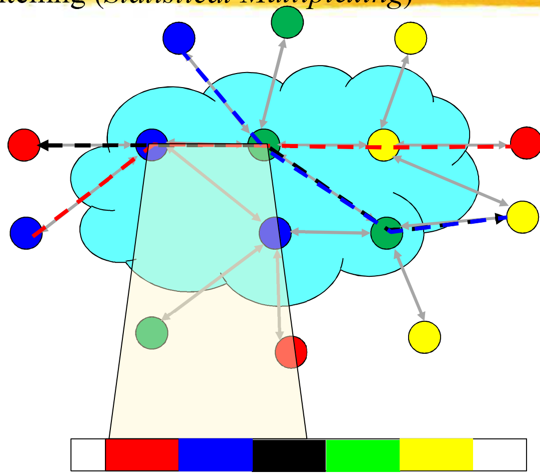
Switching Techniques

- Packet Switching (*Statistical Multiplexing*)



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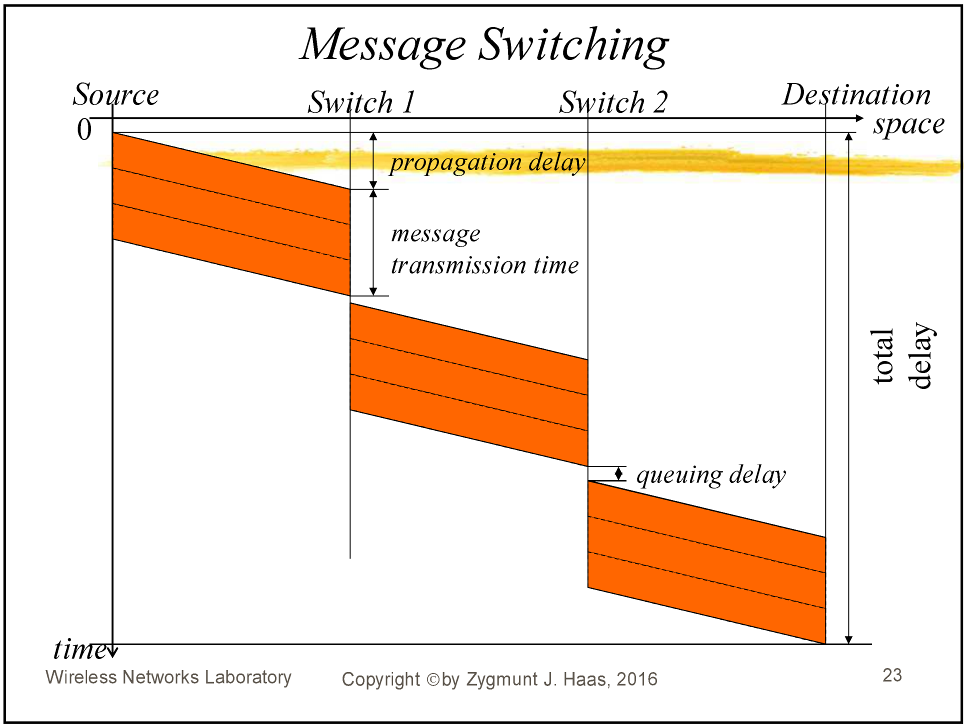
Message Switching
Source
Switch 1
Switch 2
Destination
0
space
propagation delay
message
transmission time
total
delay
queuing delay
time
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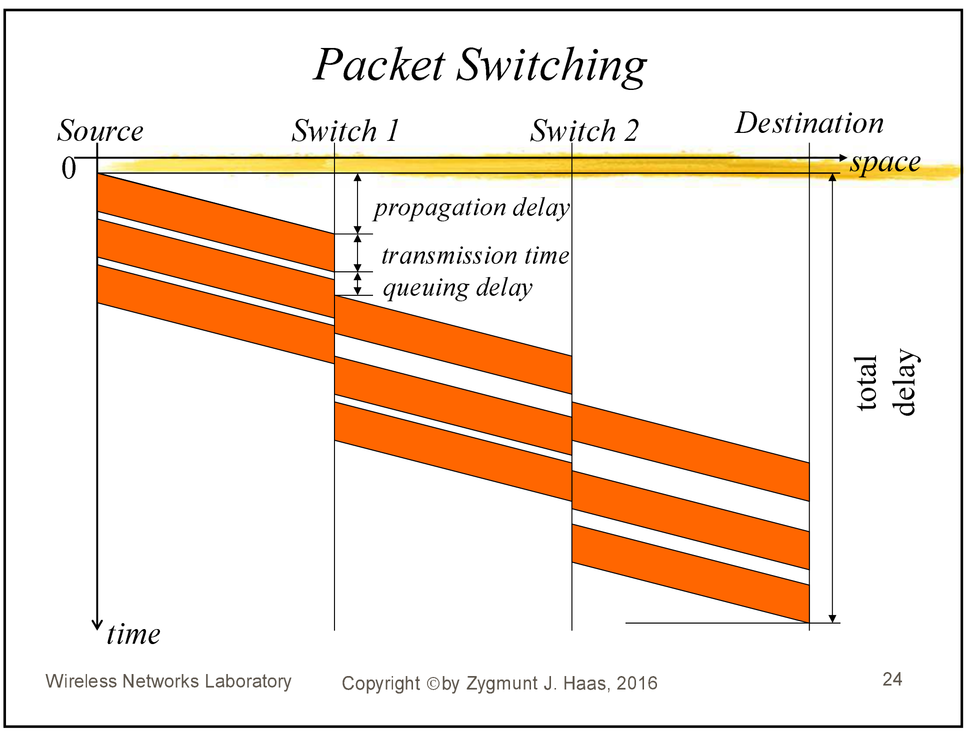
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Statistical Multiplexing Gain

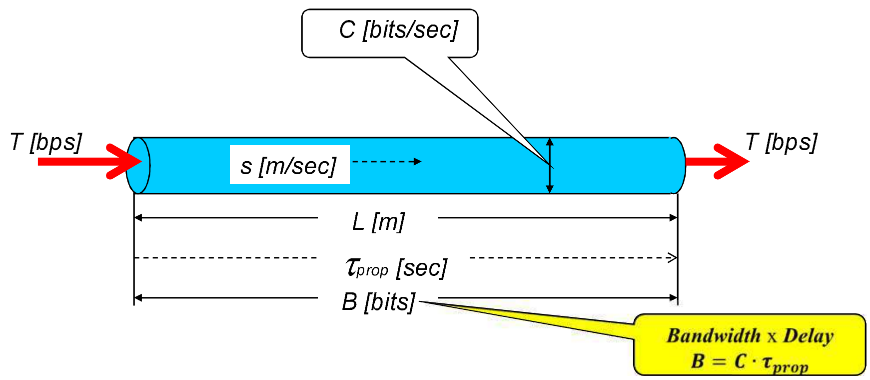
- Assume a 1[Mbps] link and individual flows of 0.1[Mbps], active 10% of the time.
- Thus, when a flow transmits alone, it uses 10% of the link capacity.
- With circuit switching, we can accommodate 10 users, and the average utilization of the link will be 10%.
- With statistical multiplexing, we can support ~30 users with probability of < 0.1% (0.001) that more than 10 flows are active at the same time.
- With statistical multiplexing, we can better fill the pipe. Why cannot we fill the pipe completely (i.e., get 100% utilization, $\rho=1$)?

Statistical Multiplexing Gain

- Conclusion, with statistical multiplexing, we can accommodate significantly large number of users with small degradation in performance … what is the performance degradation?
- But, there is no "free lunch" ….

A Link as a "Communication Pipe"

- A communication link/path is modeled as a conduit carrying liquid (water).



Packet Switching (con't)

- The advantages of *packet switching* (compared with circuit switching):
  - better utilization of resources
  - smaller overhead due to transmission errors/packet loss
  - no set up process (shorter delay for small files)
  - simple (fast) routing/switching decisions
- And the disadvantages of *packet switching* (again, there is "no free lunch"):
  - header/trailer overhead
  - routing per packet (may become a bottleneck in some cases)
  - increased delay and jitter (due to queueing)
  - more processing (segmentation/reassemble, sequencing, etc)

Comparison of switching techniques

- Circuit Switching:
  - used in telephone network
  - **dedicates resources for the duration of the connection**
  - requires (relatively long) set-up delay
  - not suitable for bursty computer traffic
- Message Switching:
  - **multiplexes messages from various sources on the same link**
  - no dedication of resources
  - no set-up phase
  - different size units (messages)
  - routing is message-based

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Comparison of switching techniques (con't)

- Packet Switching:
  - divides messages to equal-size packets
  - multiplexes packets from various sources
  - no dedication of resources
  - no set-up phase
  - one size units (packets)
  - **better multiplexing effect**
  - routing is packet-based

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Comparison of switching techniques (con't)

- <u>Advantages of Packet Switching vs. Message Switching:</u>
  - better buffer utilization
  - shorter piplining delay
  - smaller retransmission traffic (in response to errors)
  - fairness of network utilization

- <u>Disadvantages of Packet Switching vs. Message Switching:</u>
  - processing (switching, control, routing) on per-packet basis (more processing)
  - transmission overhead due to headers, trailers, etc