# Data Networks

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Recap

- ATM
- Services
- Protocol Architecture
- AAL
- ATM switching

Today's lecture

- Packet switching
- Routing & congestion
- X.25
- Frame relay
- Congestion

Packet Switching

- Is a fundamental technology that did not change since 1970
- ATM and frame relay are essentially packet switching technologies

Application data

control information
(packet header)

packet

Packet-Switching
Network
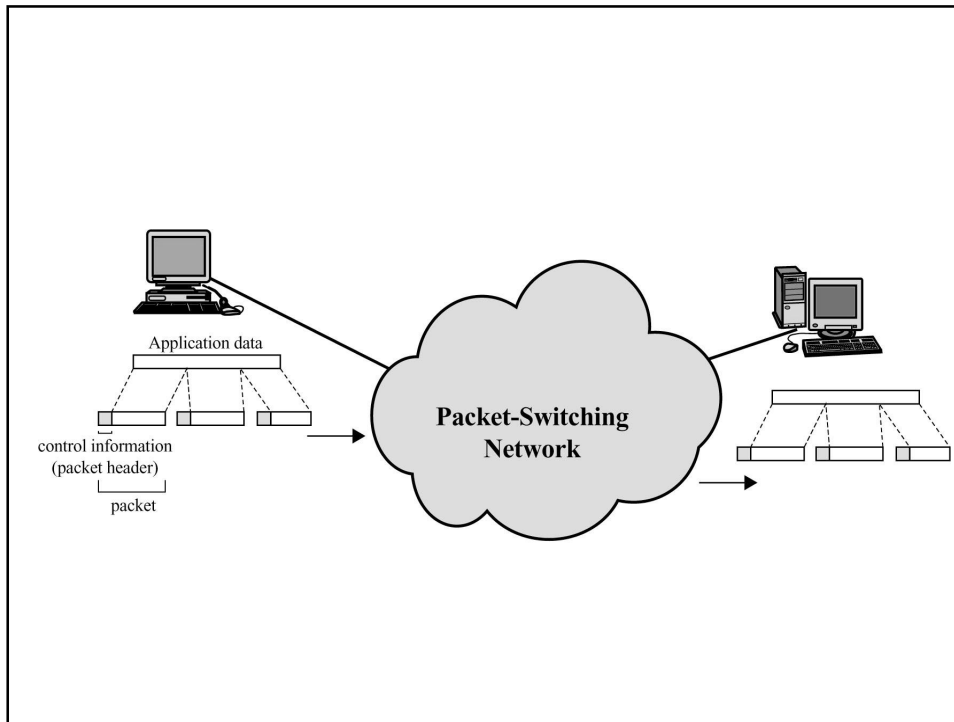
Operation

- Each packet is traveling independently of others
- Sufficient control information should be present in the packet in order to deliver the packet correctly

(a)

(b)

(c)

(d)

(e)
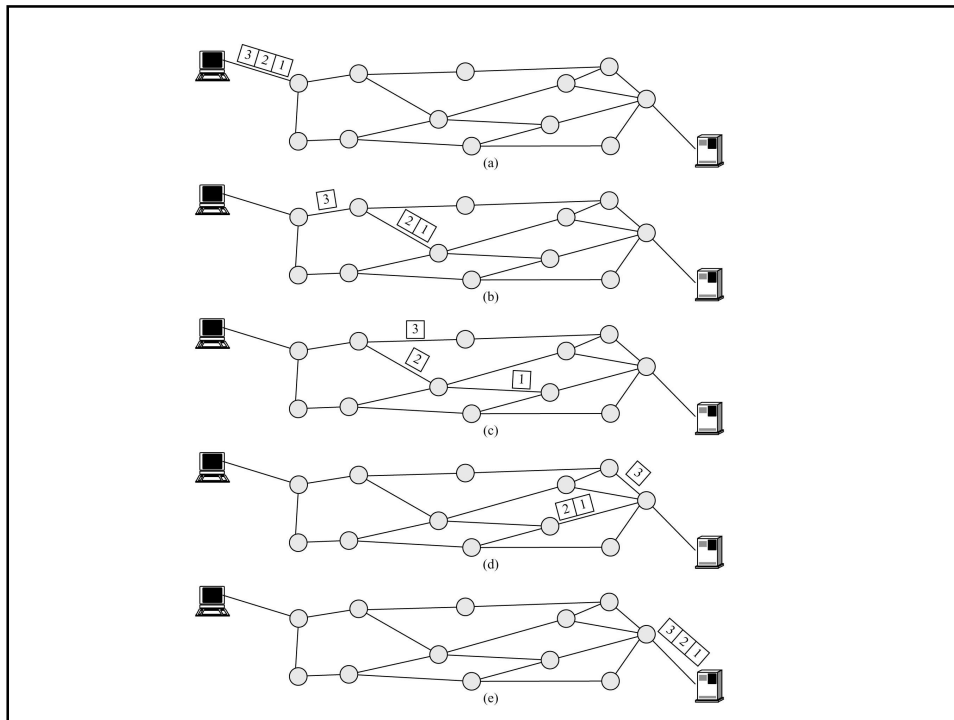
Pros & Cons

+ Line efficiency is greater
+ Data rate conversion
    - Terminal of different rates can connect
+ No blocking as in circuit switched
+ Priority can be implemented
- Processing delay and overhead
- Delay jitter
- Overhead information in packet

Can't we use circuit switching?

- Yes, if fact we call it virtual circuit (VC)
- To minimize the effects of packet switching problems, circuit switching can be utilized
- A circuit is setup before transporting the packets
- Low control/overhead is needed
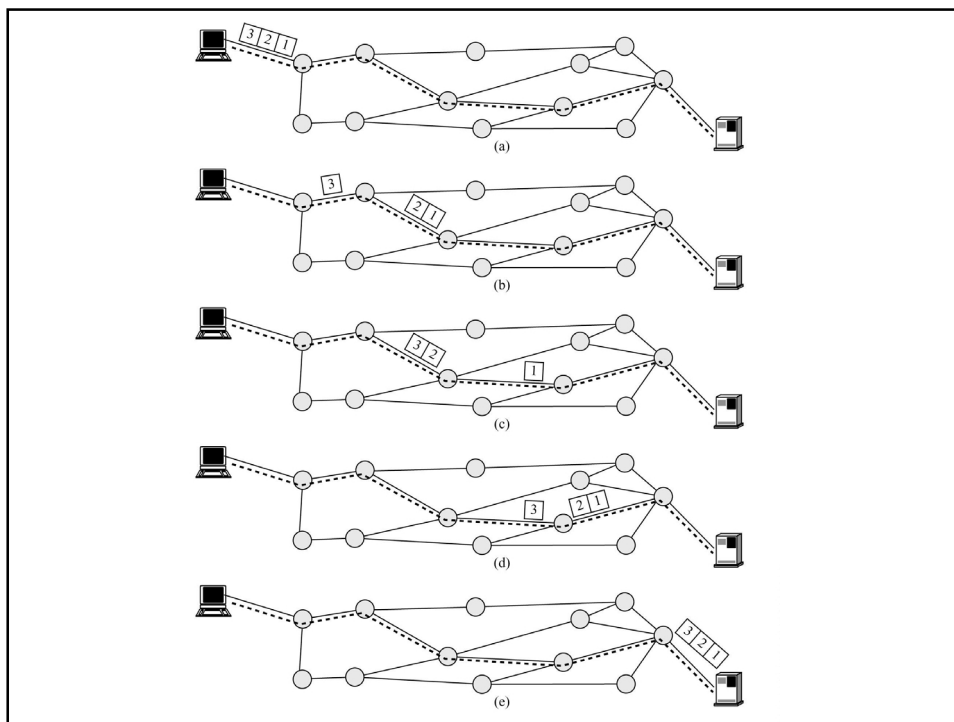
Packet switching functions

- Routing and congestion control
- Adaptive routing:
  - Routing decisions are made based on network conditions
    - Failure
    - Congestion
  - Trade of between quality of information and the amount of overhead
   - More overhead means more load on the network

Congestion

- Occurs when number of packets put onto the network approaches the packet-handling capacity of the network.
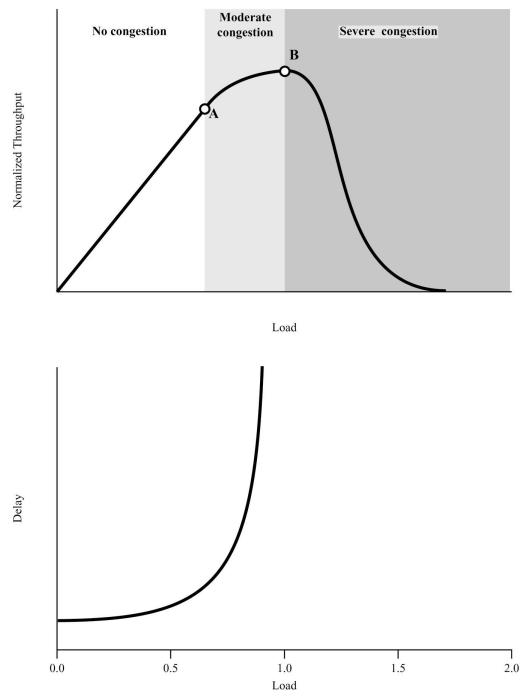- Mission: Maintain the number of packets below a red-line
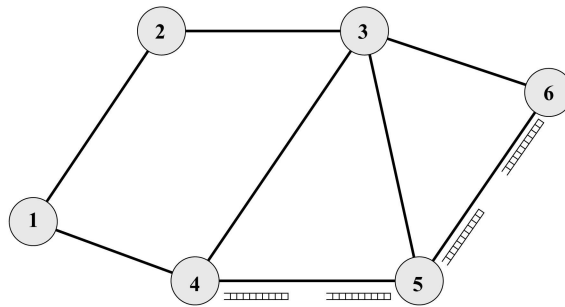
Congestion

- To see the impact of congestion of network performance, we define:
  - Throughput = delivered packets to dest
  - Offered load = transmitted pkts by src
    - We normalize to max. theoretical throughput
  - Delay
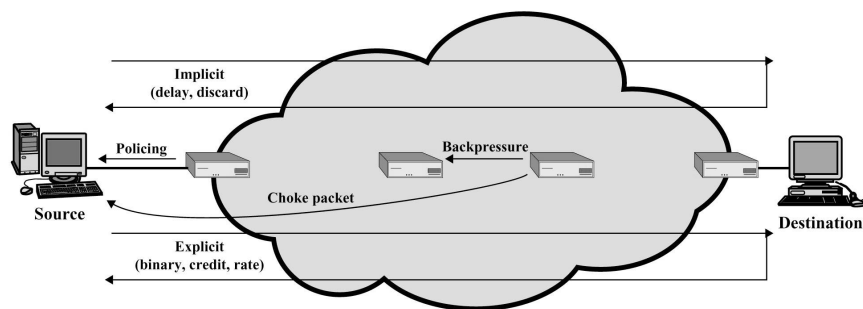 - Power = ratio of throughput to delay

Ideal case: Infinite buffers
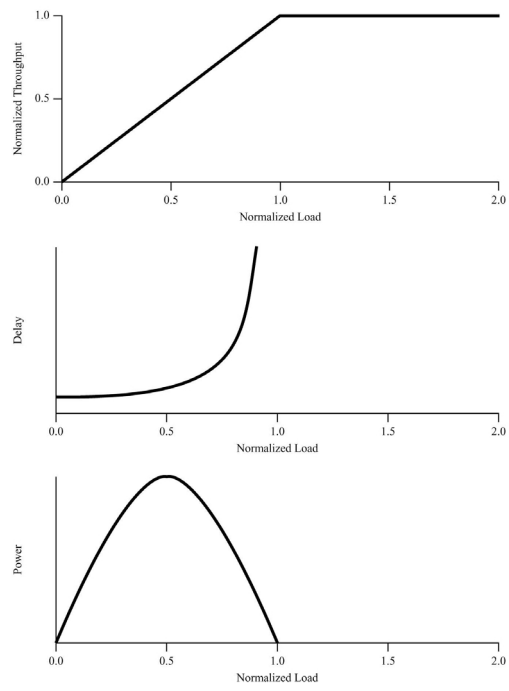
Practical case: finite buffers

Congestion Control

- Proactive vs. Reactive
  - Backpressure
  - Choke packets
  - Implicit congestion control
  - Explicit congestion control
  - Policing

X.25

- Specifies the interface between a host and a packet-switching network
  - Physical layer
  - Link layer: LAPB
  - Packet layer: VCs
- Control information
  - Identifying a particular VC
  - Providing sequence number

	User data	

Layer 3 header		X.25 packet

LAPB header		LAPB trailer	LAPB frame

Mainframe

C

Personal
computer

B

Personal
computer

A

Packet-Switching
Network

Server

D

Personal
computer

E

Personal
computer

F

Solid line = physical link
Dashed line = virtual circuit
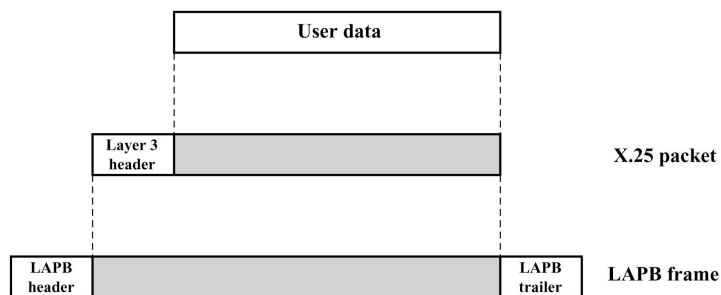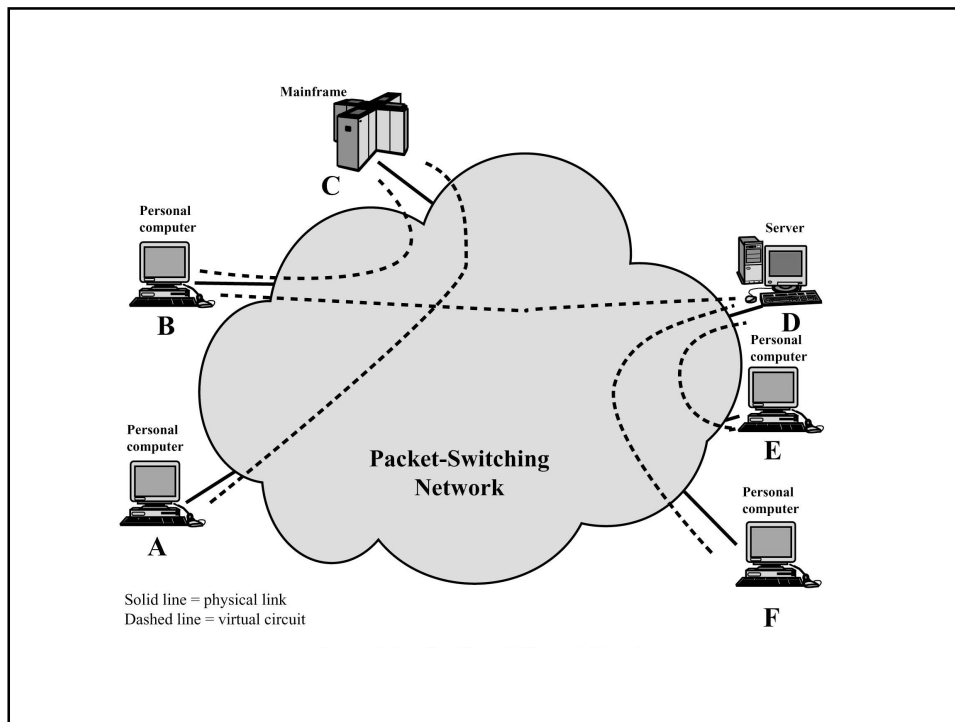
Frame Relay

- Designed to eliminate most of the overhead found in X.25
- Simpler functionalities are provided
  - End system and network have specific function
  - Dedicated VC for control

Each virtual circuit
carries control and data

LAPB pipe
carries all virtual
circuits between
subscriber and DCE

Subscriber
system

Packet-switching
node

Virtual circuits
routed separately

**Packet-switching
network**

(a) Packet switching

Each virtual connection
(with one exception)
carries only data

Multiple, independent
LAPF connections

Subscriber
system

Frame relay
node

Virtual connections
routed separately

**Frame relay
network**

One LAPF connection
used for control
signaling

(b) Frame relay