Chapter 7

An Introduction to Computer Networks

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Some slides are from lectures by Nick Mckeown, Ion Stoica, Frans Kaashoek, Hari Balakrishnan, and Sam Madden

Chapter Outline

- *Introduction (slides and 7.A)*
- *Layered Architecture (slides and 7.B & 7.D)*
- *Routing (slides and 7.D)*
- *Reliable Transmission & Flow Control (slides and read 7.E)*
- *Congestion Control (slides and read 7.F)*

This Lecture

- What is a network?
- Sharing the infrastructure
  - Circuit switching
  - Packet switching
- Best Effort Service
  - Analogy: the mail system
  - Internet’s Best Effort Service

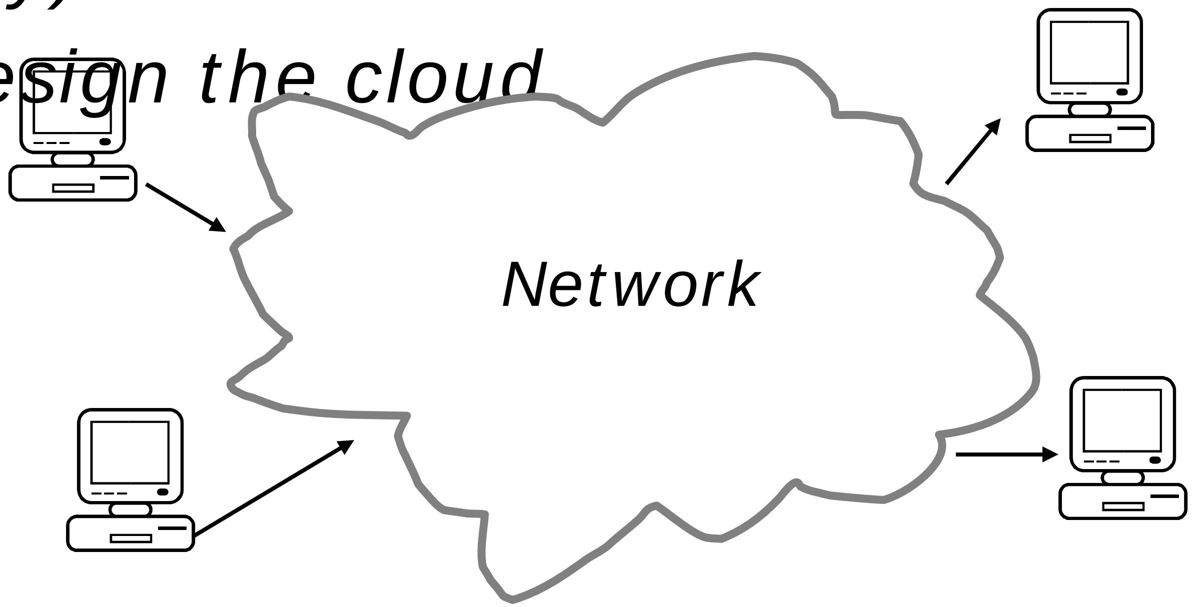
Networks

Why they are interesting?

- *Overcome geographic limits*
- *Access remote data*
- *Separate clients and server*

Goal: Universal Communication (any to any)

Design the cloud



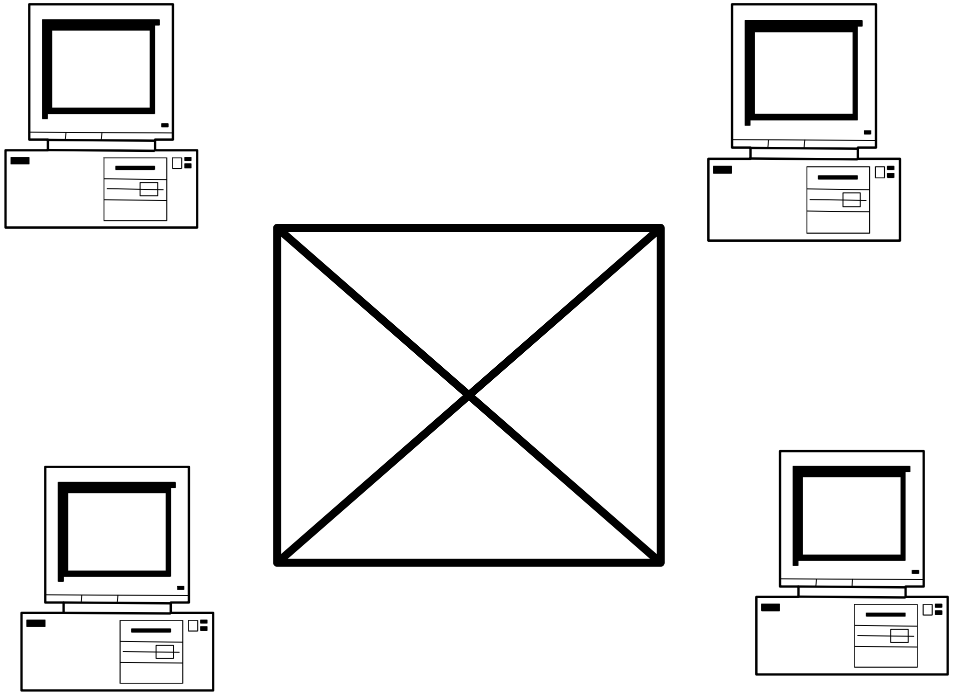
Connectivity

Link

- DSL, T1, T3, …
- Characterized by
  - Capacity or bit-rate (1.5 Mb/s, 100Mb/s, …)
  - Propagation delay (10us, 10ms, 100ms, ..)
  - Transfer time on a link = # bit/bit-rate + propagation delay

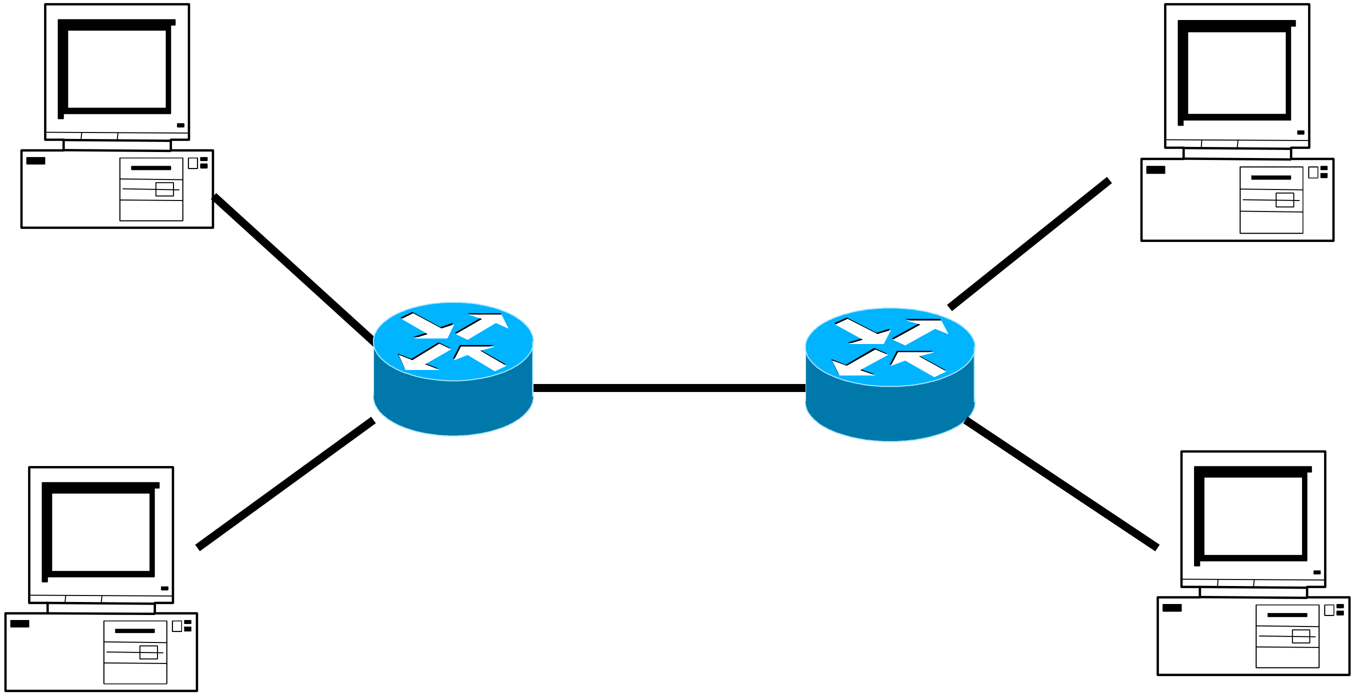
Connectivity

A mesh requires N^2 links   too costly



We Have to Share the Infrastructure

Intermediate nodes called switches or routers allow the hosts to share the infrastructure



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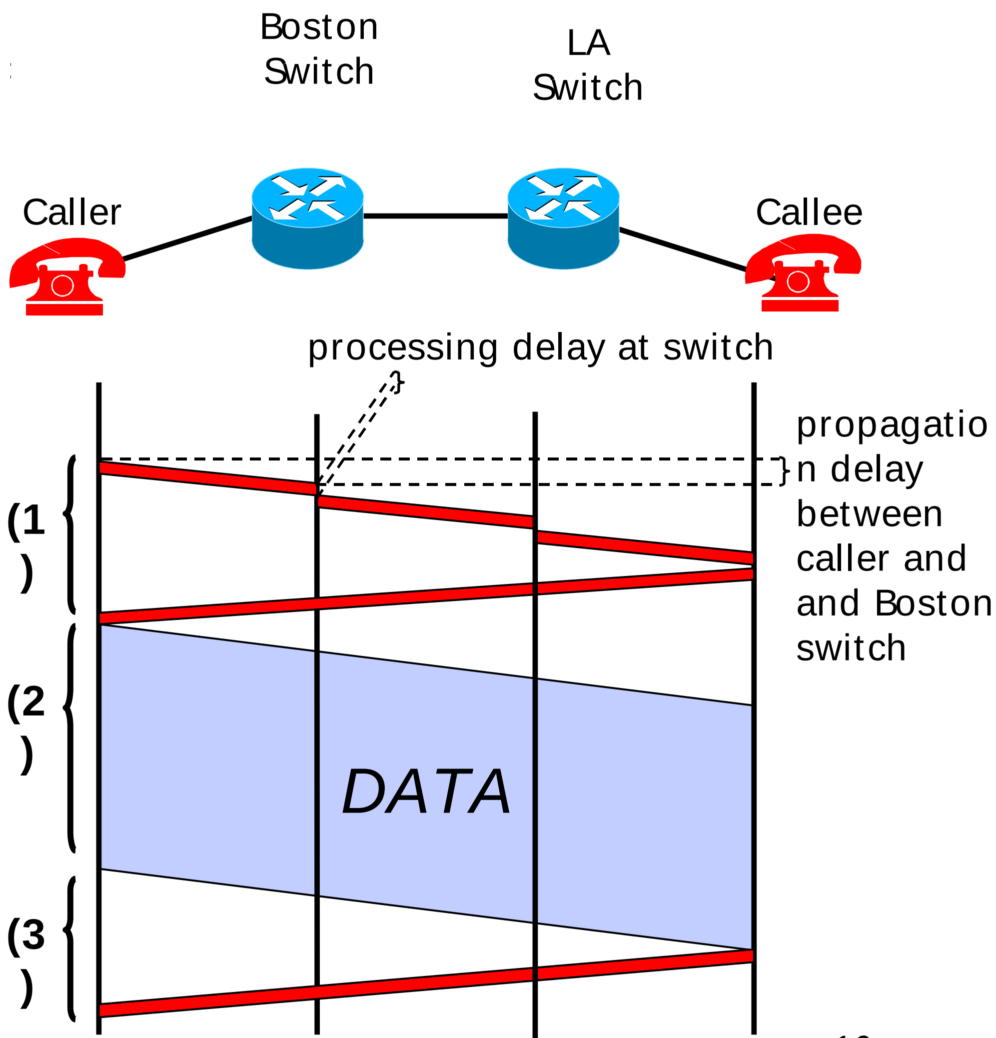
Two ways to share

Circuit switching (isochronous)

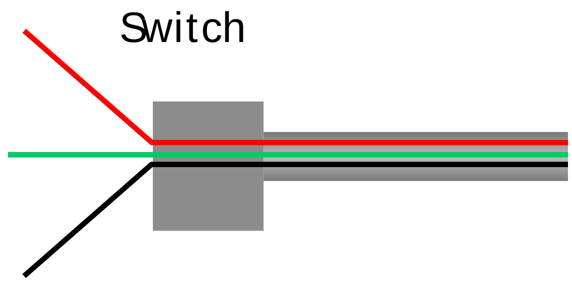
Packet switching (asynchronous)

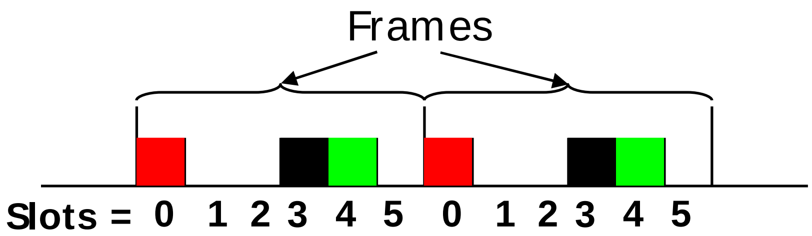
Circuit Switching

- *It's the method used by the telephone network*
- *A call has three phases:*
  1. *Establish circuit from end-to-end ("dialing"),*
  2. *Communicate,*
  3. *Close circuit ("tear down").*
- *If circuit not available: "busy signal"*



Circuit Switching: Multiplexing/Demultiplexing





One way for sharing a circuit is TDM:

- *Time divided into frames and frames divided into slots*
- *Relative slot position inside a frame determines which conversation the data belongs to*
  - *E.g., slot 0 belongs to the red conversation*
- *Need synchronization between sender and receiver*

Lecture notes use the word "frame" for slot

Circuit Switching

Assume link capacity is C bits/sec

Each communication requires R bits/sec

 # slots = C/R

Maximum number of concurrent communications is C/R

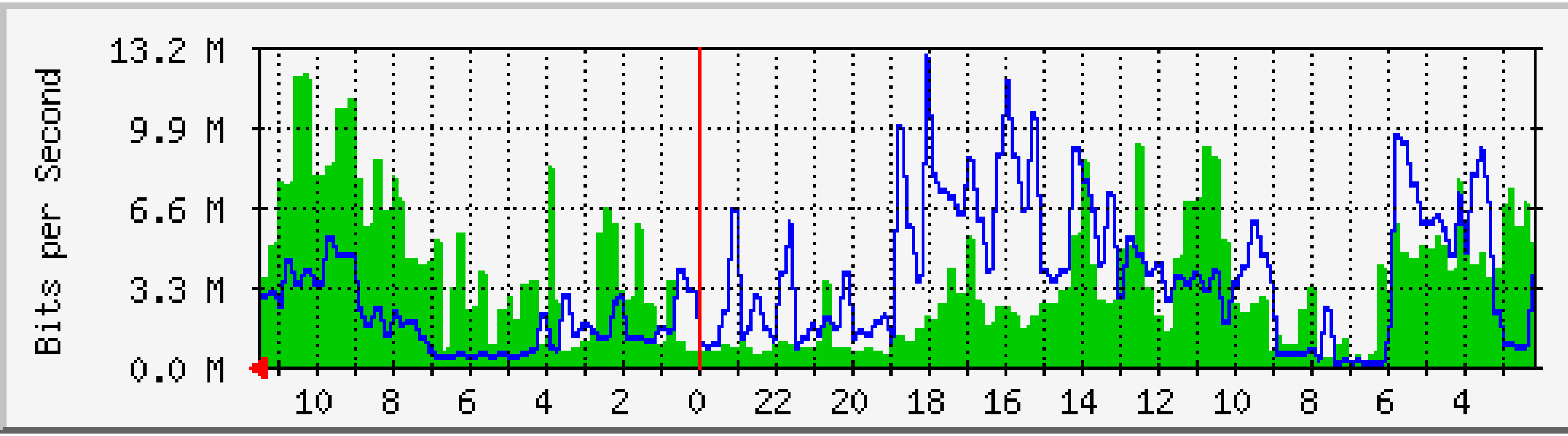
What happens if we have more than C/R communications?

What happens if the a communication sends less/more than R bits/sec?

Design is unsuitable for computer networks where transfers have variable rate (bursty)

Internet Traffic Is Bursty

Daily traffic at an MIT-CSAIL router



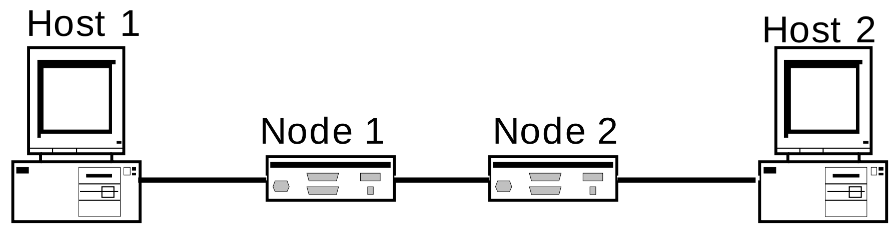
Max In: 12.2Mb/s   Avg. In: 2.5Mb/s

Max Out: 12.8Mb/s   Avg. Out: 3.4 Mb/s

Packet Switching

Used in the Internet

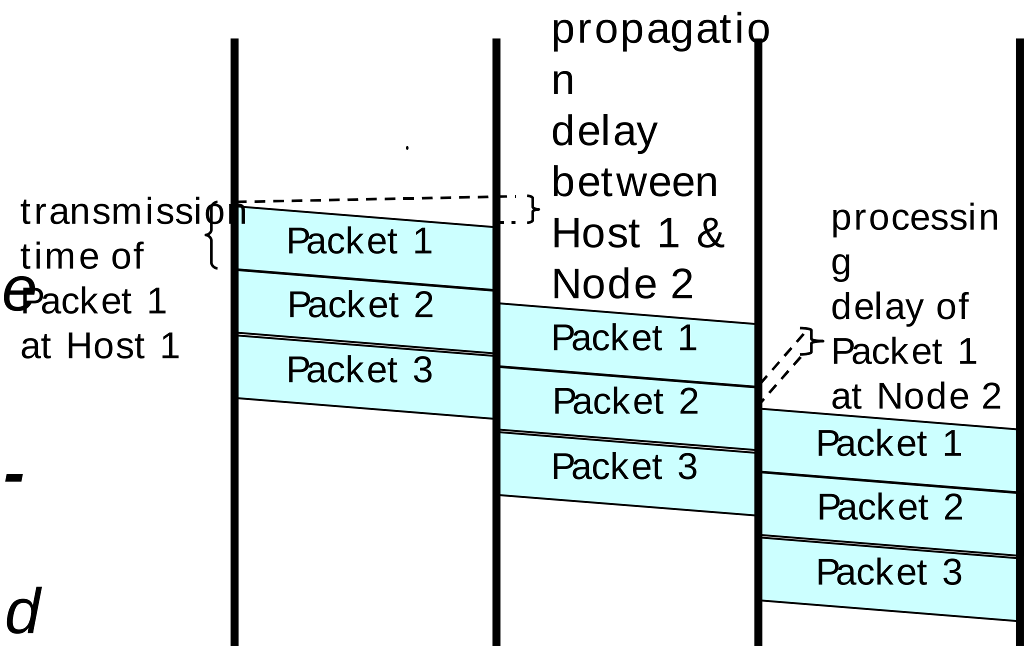
*Data is sent in **Packets** (header contains control info, e.g., source and destination addresses)*



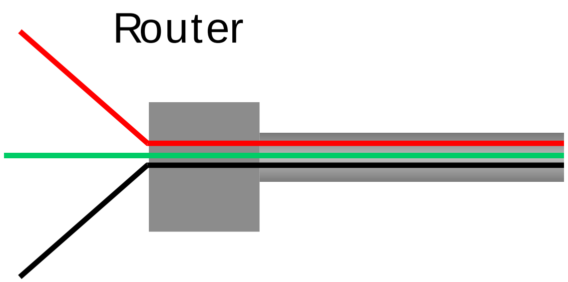
Per-packet routing

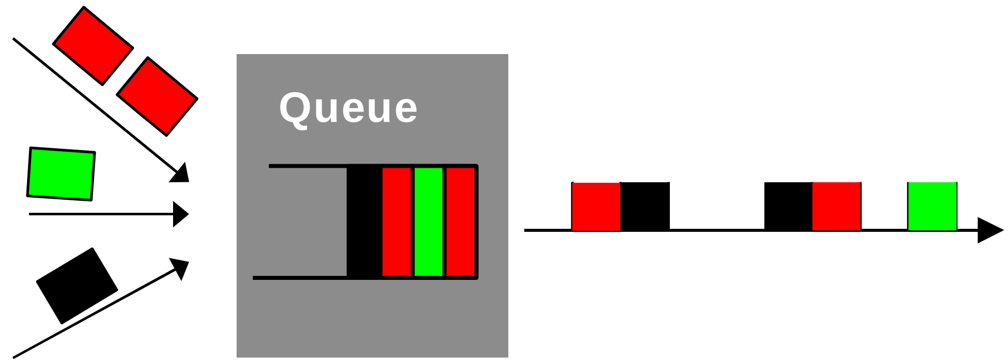
*At each node the entire packet is received, stored, and then forwarded (**store-and-forward networks**)*

No capacity is allocated



Packet Switching: Multiplexing/Demultiplexing





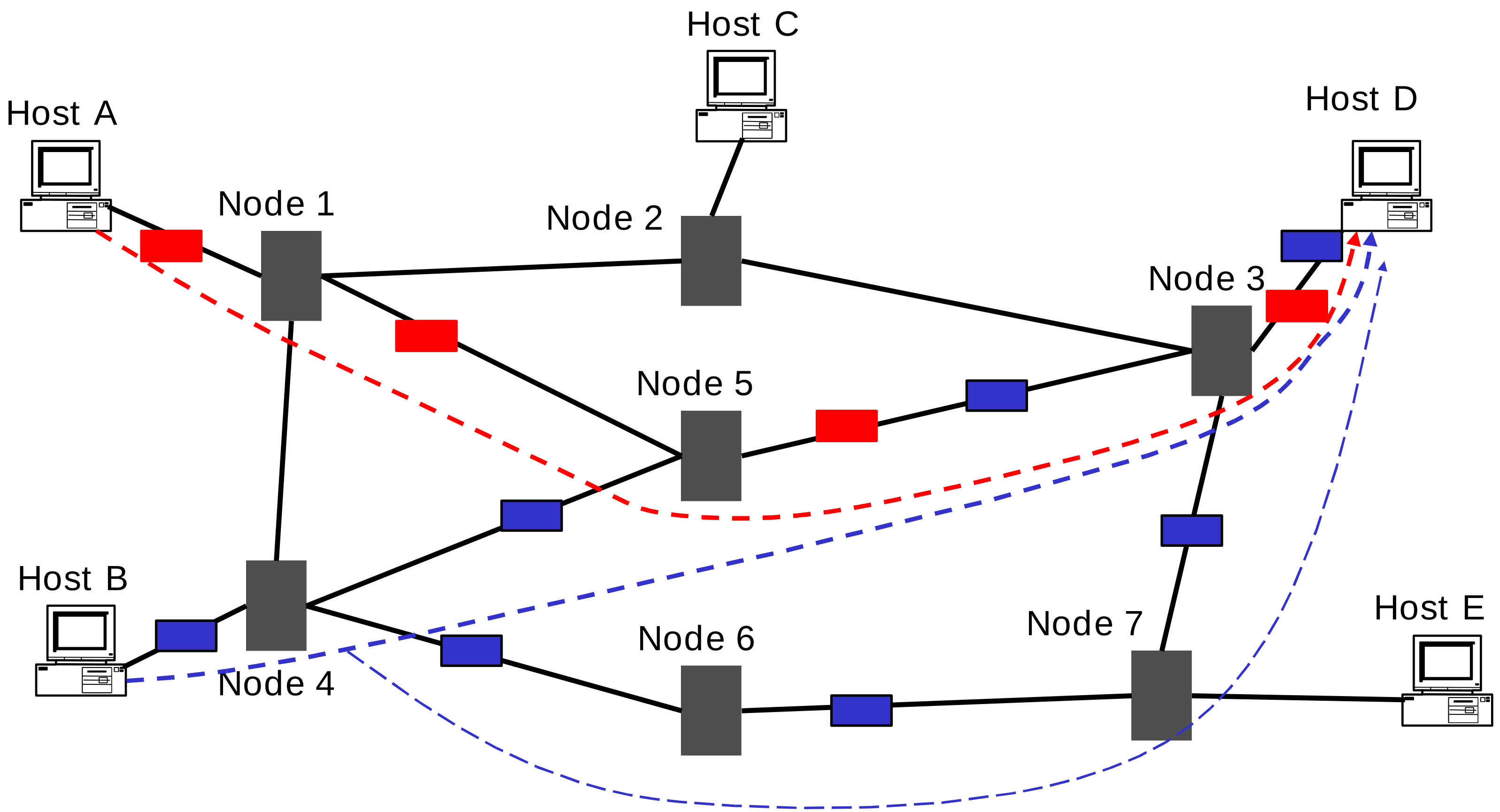
- Multiplex using a queue
  - Routers need memory/buffer
- Demultiplex using information in packet header
  - Header has destination
  - Router has a routing table that contains information about which link to use to reach a destination

Queues introduce

- *Variable Delay*
  - *Delay = Queuing delay + propagation delay + transmission delay + processing delay*
- *Losses*
  - *When packets arrive to a full queue/buffer they are dropped*

Packet switching also show reordering

Packets in a flow may not follow the same path (depends on routing as we will see later)   packets may be reordered



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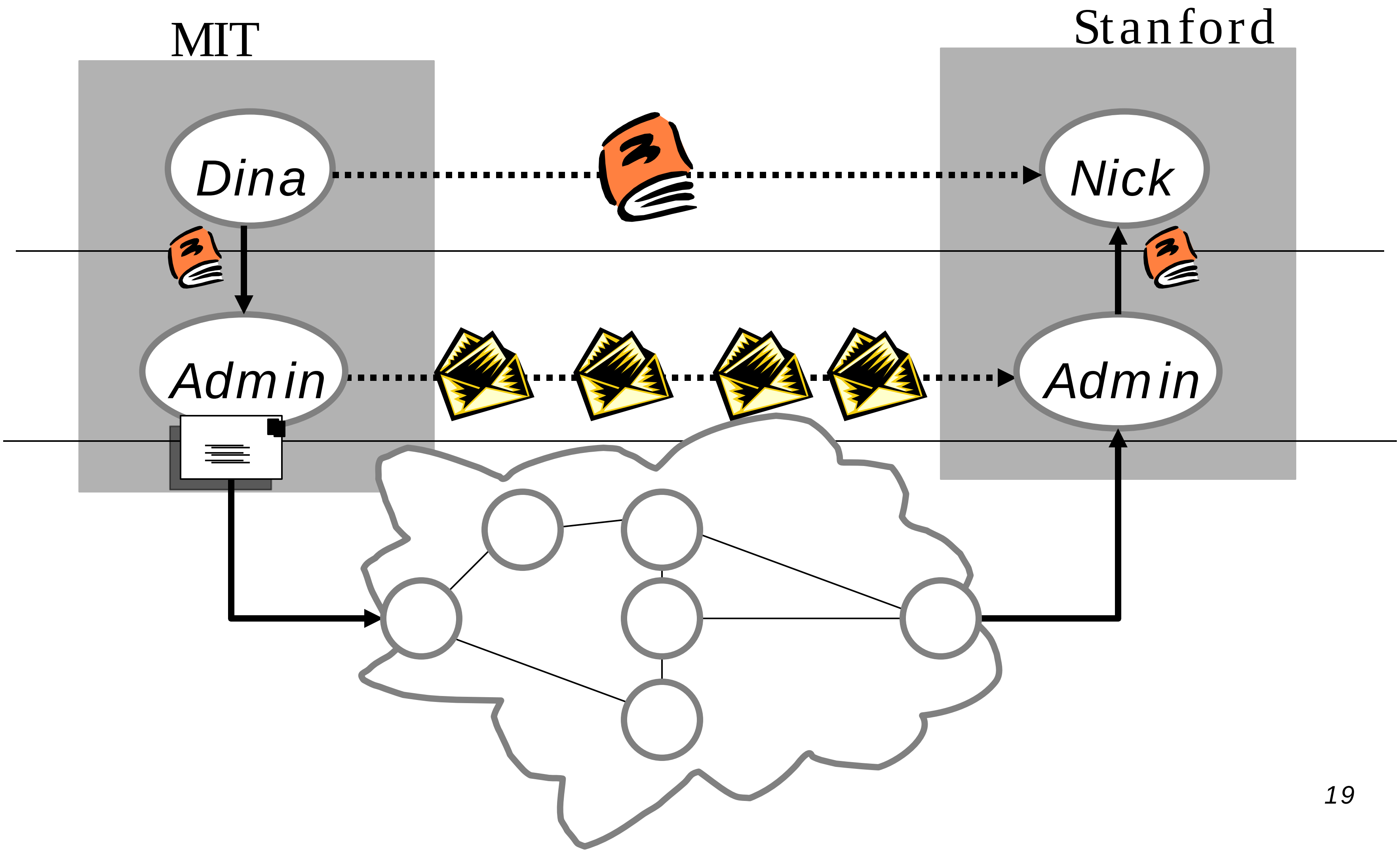
  - *Circuit switching*
  - *Packet switching*
- *Best Effort Service*
  - *Analogy: the mail system*
  - *Internet's Best Effort Service*

The mail system



Characteristics of the mail system

Each envelope is individually routed

No time guarantee for delivery

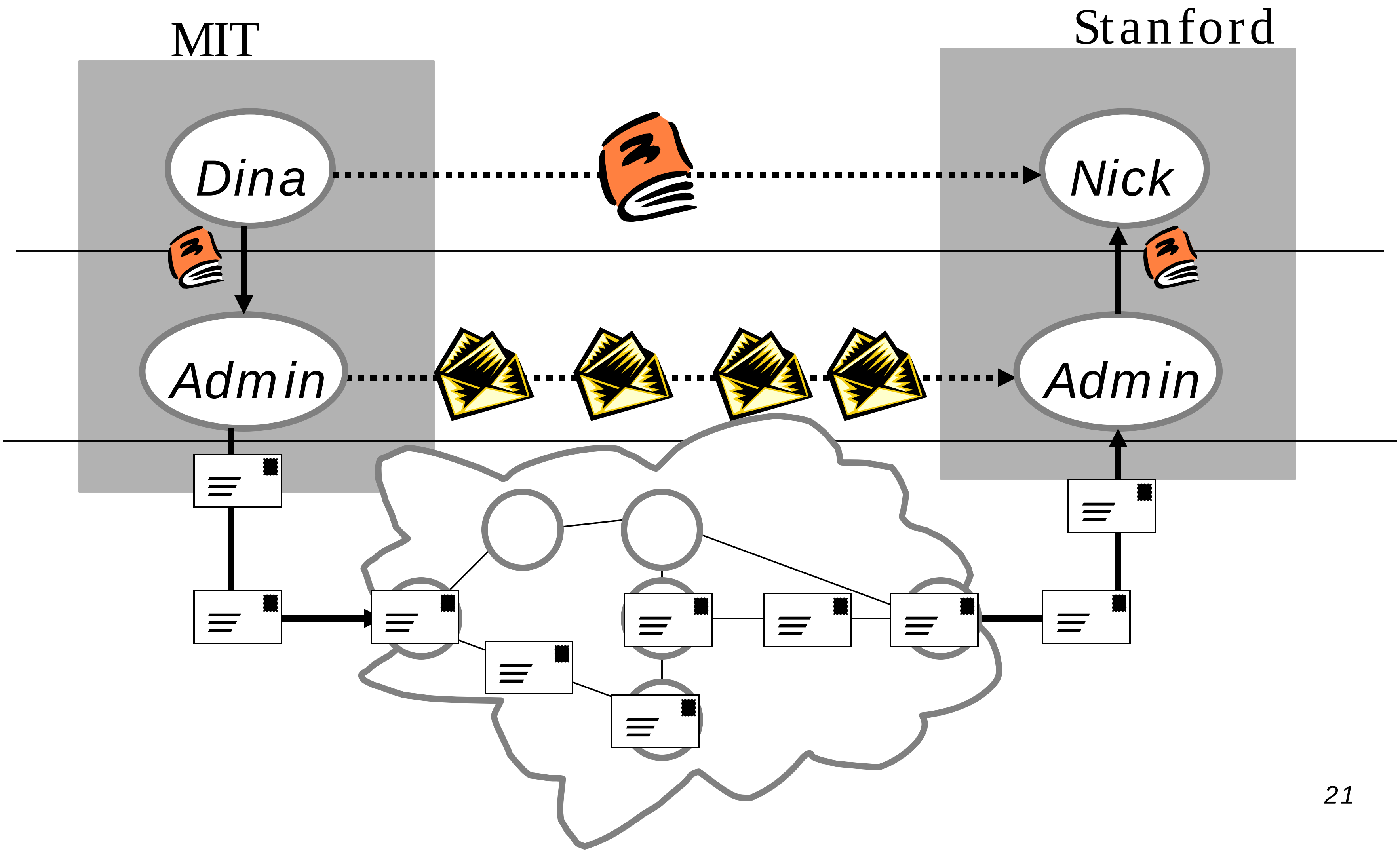
No guarantee of delivery in sequence

No guarantee of delivery at all!

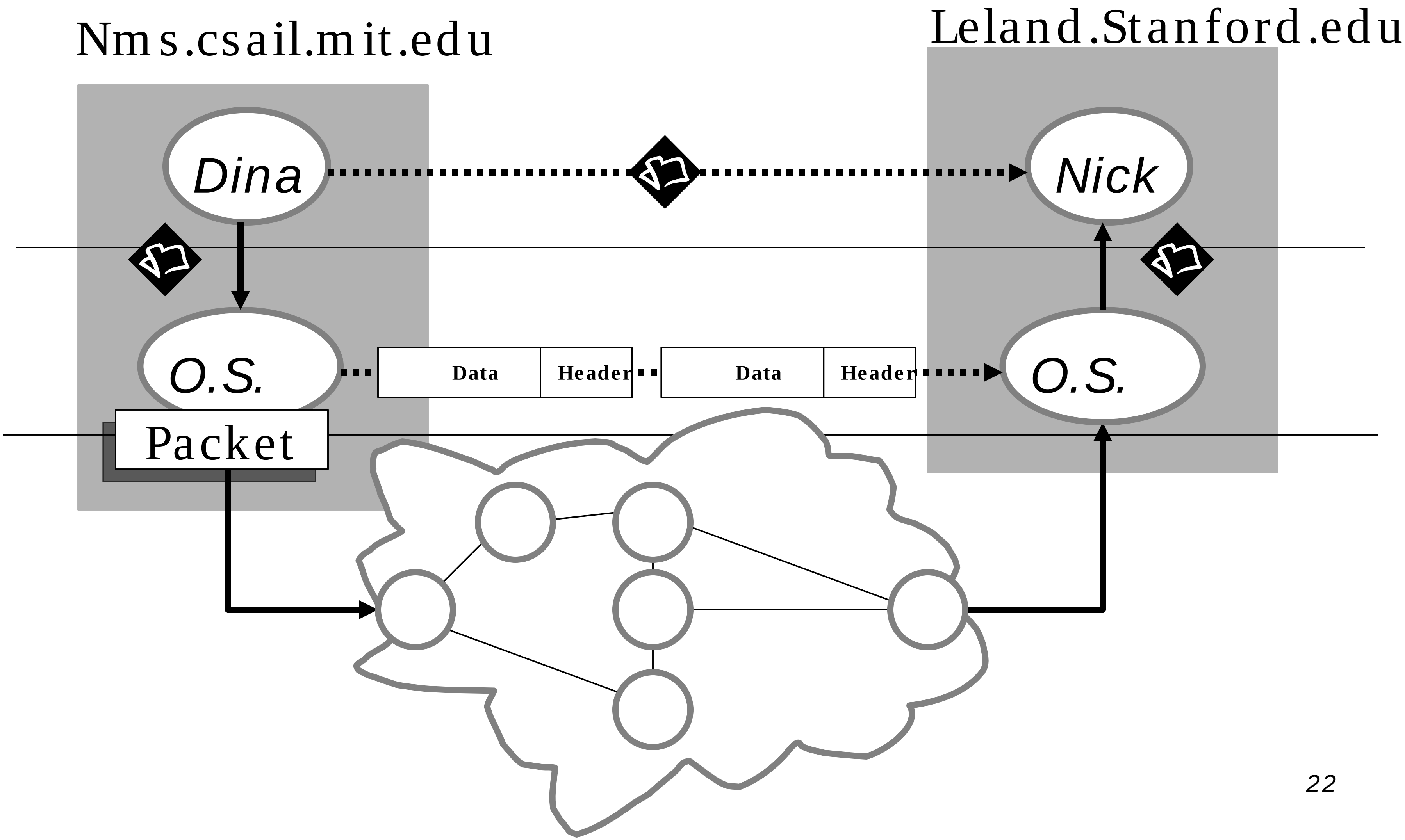
- *Things get lost*
- *How can we acknowledge delivery?*
- *Retransmission*
  - *How to determine when to retransmit? Timeout?*

If message is re-sent too soon duplicates

The mail system



The Internet



Characteristics of the Internet

- Each packet is individually routed
- No time guarantee for delivery
- No guarantee of delivery in sequence
- No guarantee of delivery at all!
  - Things get lost
  - Acknowledgements
  - Retransmission
    - How to determine when to retransmit? Timeout?
- If packet is re-transmitted too soon duplicate

Best Effort

No Guarantees:

- *Variable Delay (jitter)*
- *Variable rate*
- *Packet loss*
- *Duplicates*
- *Reordering*
- *(notes also state maximum packet length)*

Differences Between Circuit & Packet Switching

Circuit-switching	***Packet-Switching***
Guaranteed capacity	*No guarantees (best effort)*
Capacity is wasted if data is bursty	*More efficient*
Before sending data establishes a path	*Send data immediately*
All data in a single flow follow one path	*Different packets might follow different paths*
No reordering; constant delay; no pkt drops	*Packets may be reordered, delayed, or dropped*

This Lecture

We learned how to share the network infrastructure between many connections/flows

We also learned about the implications of the sharing scheme (circuit or packet switching) on the service that the traffic receives