Computer Networks
COL 334/672

To Packet Switch or Not

Slides adapted from K&R book

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Sem 1, 2024-25

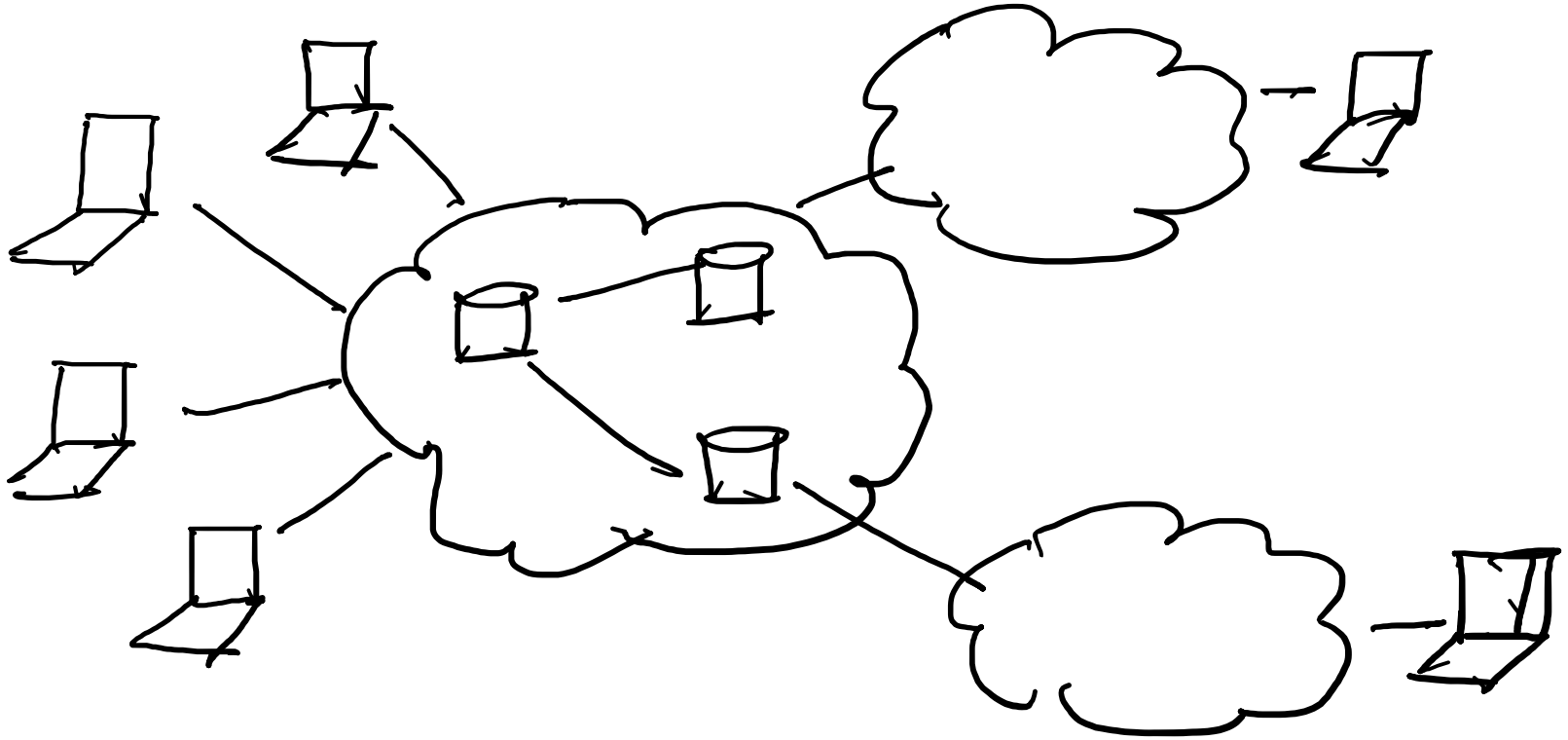
Recap

- How to send data over the Internet?
- Need protocols for distributed networks

① link data transmission

② Addressing / Routing

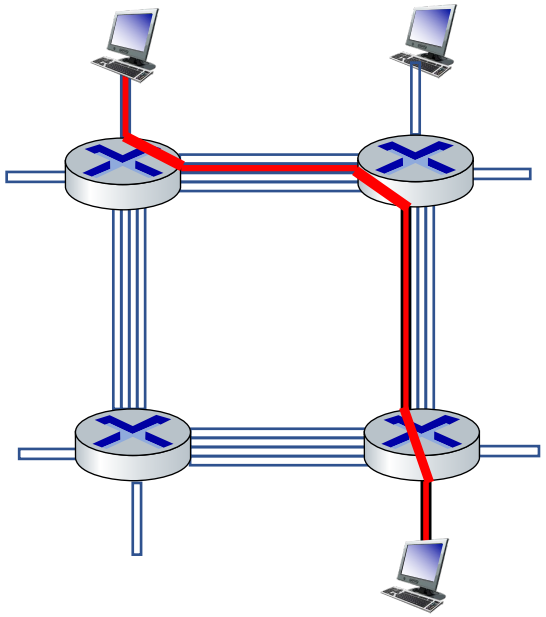
③ Multiplexing



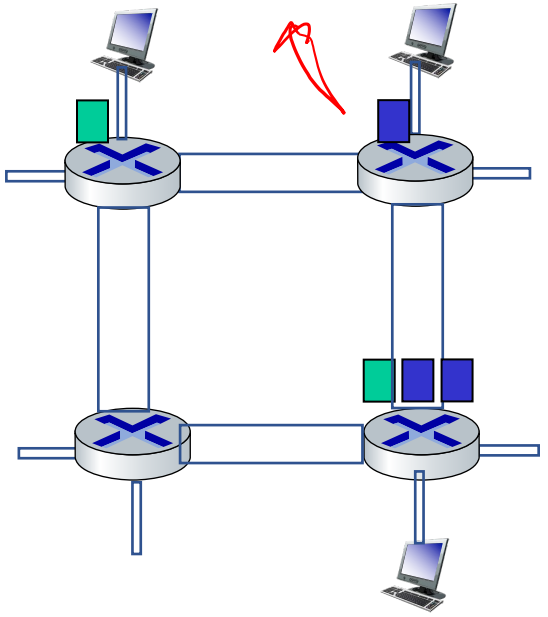
Recap

"Bursty"

- How to send data over the Internet?
- Need protocols for distributed networks
- Two communication paradigms:
  - Circuit switching – resource reservation,
  - Packet switching – on-demand → Statistical Multiplexing
- **This class**: which option did the Internet chose and more .. ~~Statistical multiplexing~~



store & forward



Packet-switching versus circuit switching

Internet uses packet switching

- Great for "bursty" data – sometimes has data to send, but at other times not
  - Efficient resource sharing (why?)
  - Simpler*, no call setup unlike circuit switching
- however, does not provide any performance guarantee, best-effort delivery
- excessive congestion possible: packet delay and loss due to buffer overflow
  - protocols needed for reliable data transfer, congestion control
  - Implication on router design

Pros

Cons

→ state in routers

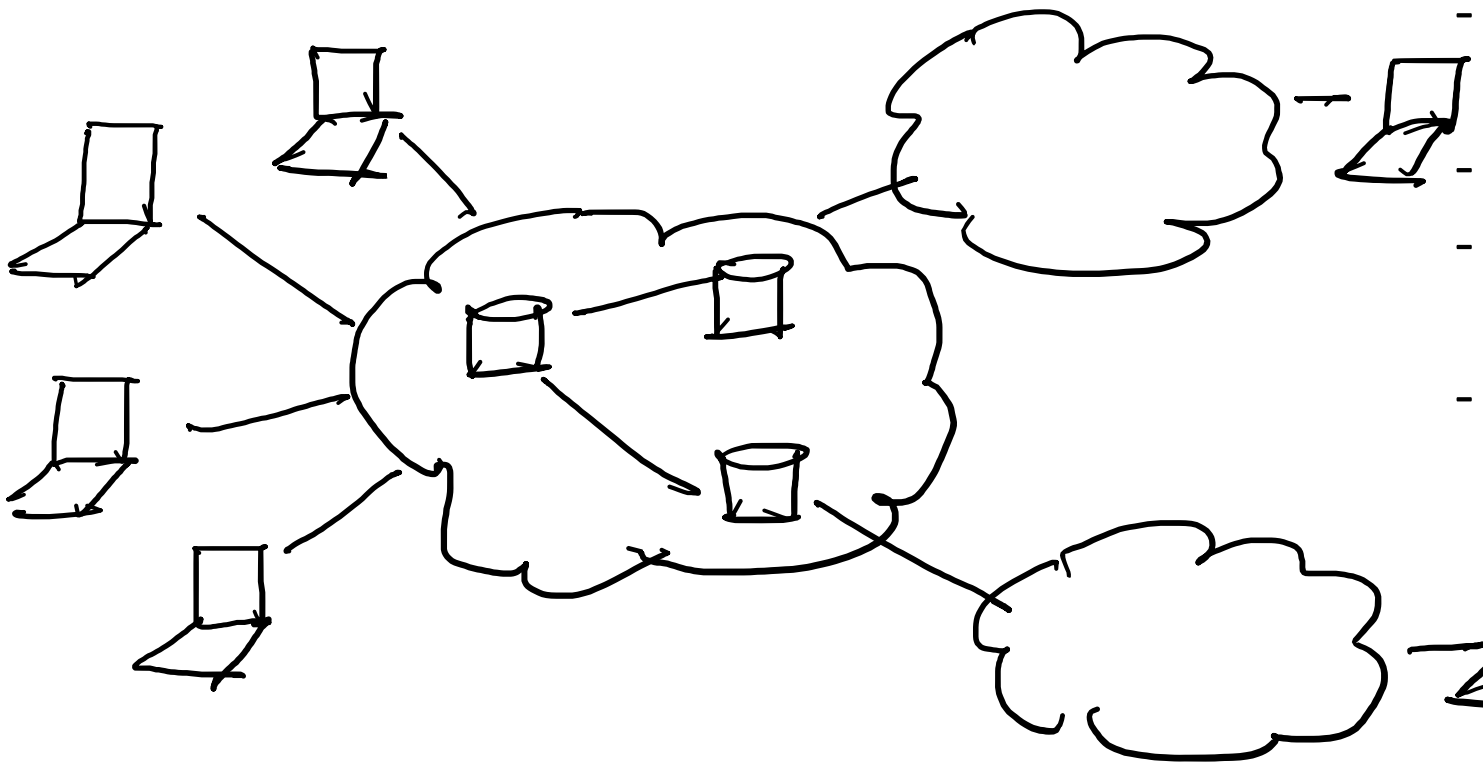
↘ what if the link goes down

store & forward → router buffer

10^9 packets per second → 10^{-9} s

10Gbps

How To Send Data over Distributed Network?



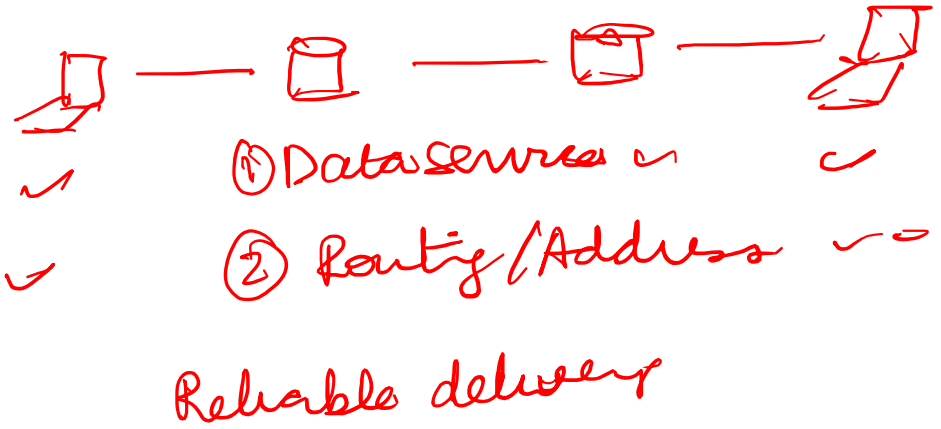
- Data transmission techniques over a link
- Addressing, routing
- Resource sharing
  - Packet switching
- Other network services

① Encryption / Authentication
② Reliability
③ Flow / congestion control

Other Network Services

① Data transmission

- Reliable delivery
- Congestion control
- In-order delivery
- Encryption
- Authentication
- …

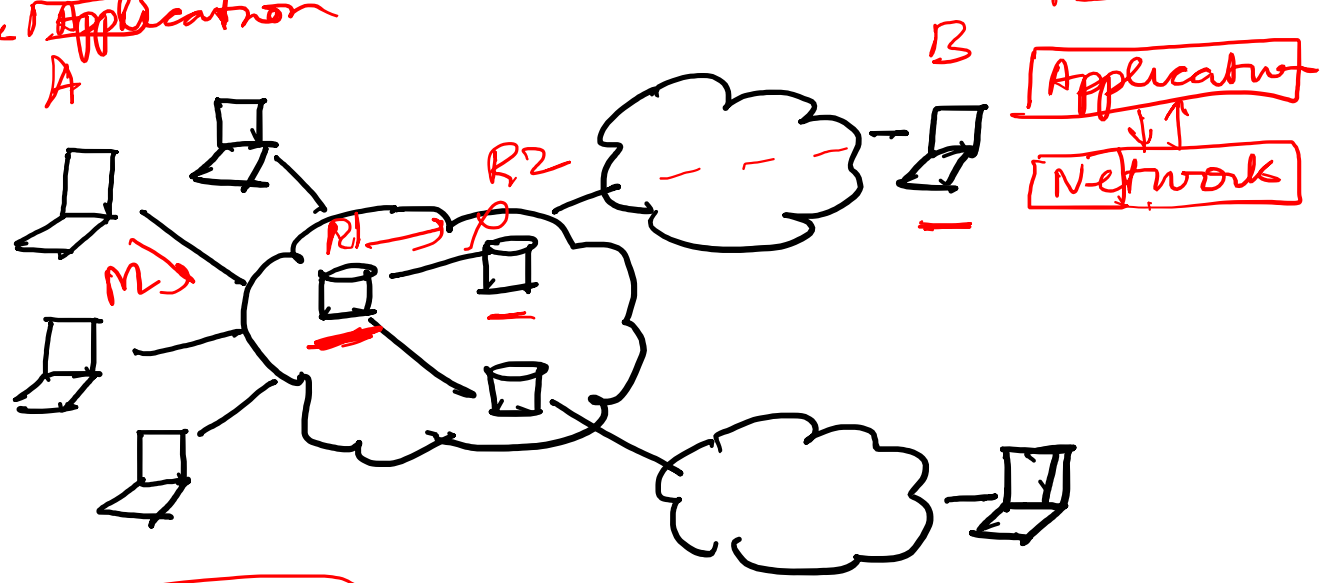


How to implement them?

→ Where to implement them?

Where to implement reliability?

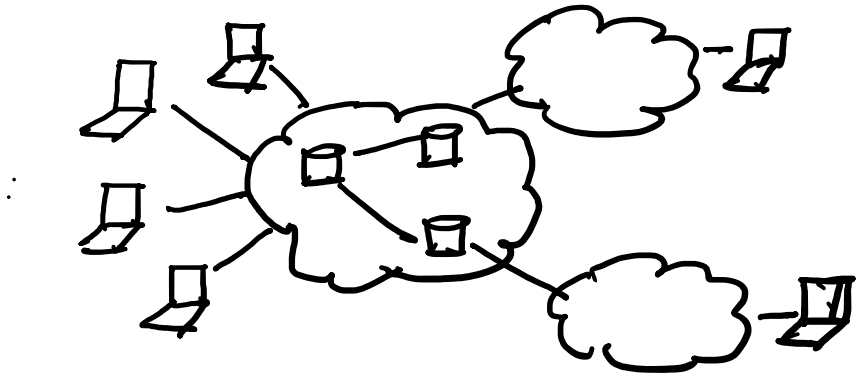
Why do we need to implement reliability?



In-network support	End-host support only
▪ Routers cache the packet and resend if it is not acknowledged ▪ Needs extra memory and compute in routers	▪ End-host send acknowledgement ▪ Reduced performance*

Where to Implement Network Services?

Two different paradigms



In-network support

- Network with rich functionality that covers most requirements
- Network with multiple "lanes"?
  - CISC-like
  - Modular network

cons → good level of infrastructure for everyone to maintain, not scalable.

End-system support only

- As little functionality as possible in the network
- Most functionality at the end points
- Also called end-to-end principle
  - Dumb network, intelligent end-points
  - Saltzer, Reed, Clark (1981)

Which option did the Internet designers chose? End-to-end principle

Why End-to-End Principle?

- Need end-to-end correctness anyways

- Not everyone needs it
  - Diminishing returns from in-network functionality
  - Cost-effective

- Not everyone has it
  - All networks are not capable of providing functionalities

- Flexibility of implementation ★ ???

Are there exceptions?

Any limitations?

why . . . . . ?

→ cost effective, always works

Summary

- How to send data across distributed networks?

- Requirement 1: Cost-effective resource sharing
  - Use packet switching
  - Implications on other network services and network equipment design

- Requirement 2: Common network services
  - Where to implement those?
  - End-to-end design principle

- Next: How does Internet architecture look like?