Computer Networks (CS F303)

BITS Pilani
Pilani Campus

Virendra Singh Shekhawat
Department of Computer Science and Information Systems

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Second Semester 2020-2021
Lecture: [1-3]

Today's Agenda

- Course Overview
- Course Administration
- What is network?
- What is Internet?
- Network Structure
  - Edge, Access Network (Physical Media), Network Core
- Circuit Switching and Packet Switching

Course Objective

- To get familiar with the principles and working of state-of-the-art of networking
  - Routing, Transport protocols, addressing, naming etc.
  - Design of network and services
- Learn how communication networks are put together
  - Mechanisms, Algorithms, Technology components
- To understand network internals in a hands-on way
  - Writing simple network applications, understanding and analyzing working principles of protocols

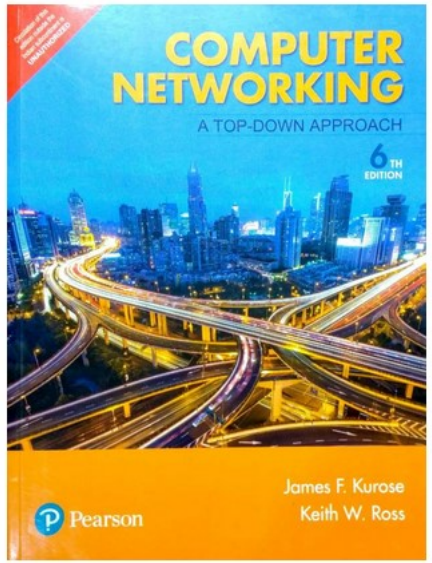
Course Overview

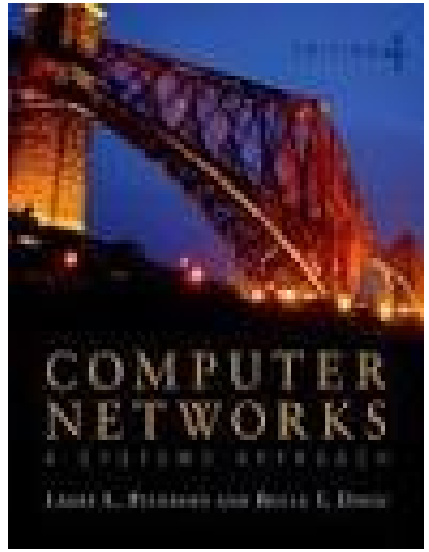
- Internet Architecture and Computer Network Primitives
- Network Applications (Application Layer)
- End to End Data Transfer (Transport Layer)
- Data Routing and Forwarding (Network Layer)
- Access Networks & LANs (Link Layer)
- Communication Channels (Physical Layer)
- Wireless and Mobile Networks

Course Administration

- Instruction delivery
  - Lecture classes
    - 12:00 – 12:50 pm [Tue, Th] and 5:00 – 5:50 PM [Fri]
  - Lab classes
    - Start from the first week of Feb (***detail will be posted on MS Teams***)
- Course page Information
  - **Lectures and course material will be available at MS Teams**
  - **For assessments NALANDA will be used (https://nalanda-aws.bits-pilani.ac.in)**
- Evaluation Plan
  - Mid Semester Test @ 30%
  - Quiz (Two) @ 20% [10% each]
  - Lab Test @ 15%
  - Comprehensive exam @35%

Text Book


COMPUTER NETWORKING
A TOP-DOWN APPROACH
6TH EDITION
James F. Kurose
Keith W. Ross
Pearson


COMPUTER NETWORKS

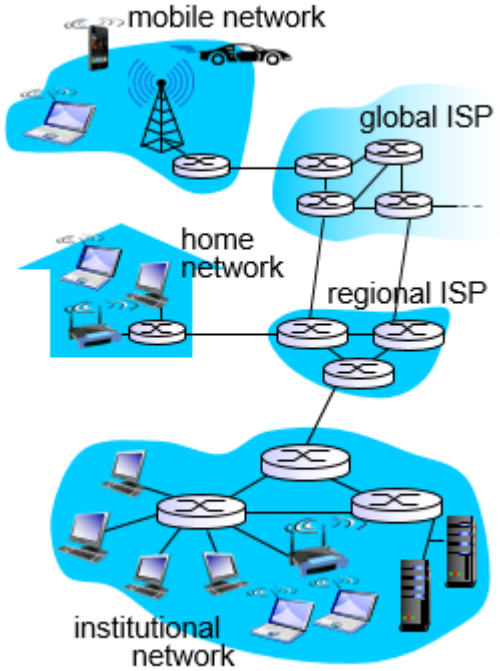
What is a Network?

- An infrastructure (shared) that allows users (distributed) to communicate with each other
  - People, devices, …
  - By means of voice, video, text, …
  - ex., Telephone n/w, Cable TV Network, Satellite network, military n/w etc. …

- Basic building blocks are
  - Nodes (Hosts and Forwarding nodes) and Links

What is Internet?

- The Internet is a Network of networks…
  - **Interconnected Networks→ Internet**



How Internet is different from other Networks?

- Enable communication between **diverse applications** on **diverse devices** over **diverse infrastructure**

Network Structure

- Network edge: applications and hosts
- Network core:

  interconnected routers
- Access networks

  The network that physically connects an host

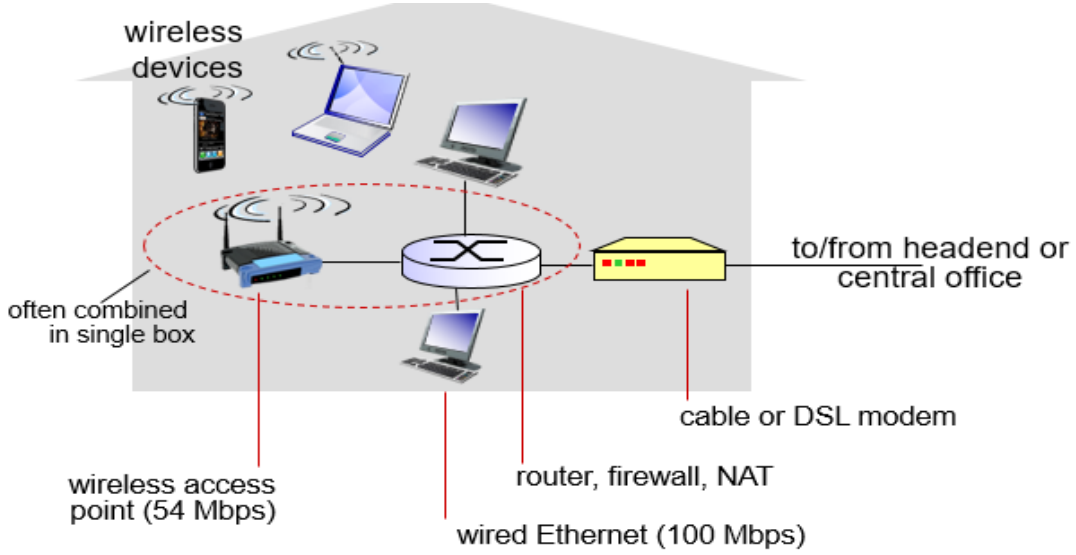
  physical media: wired, wireless communication links

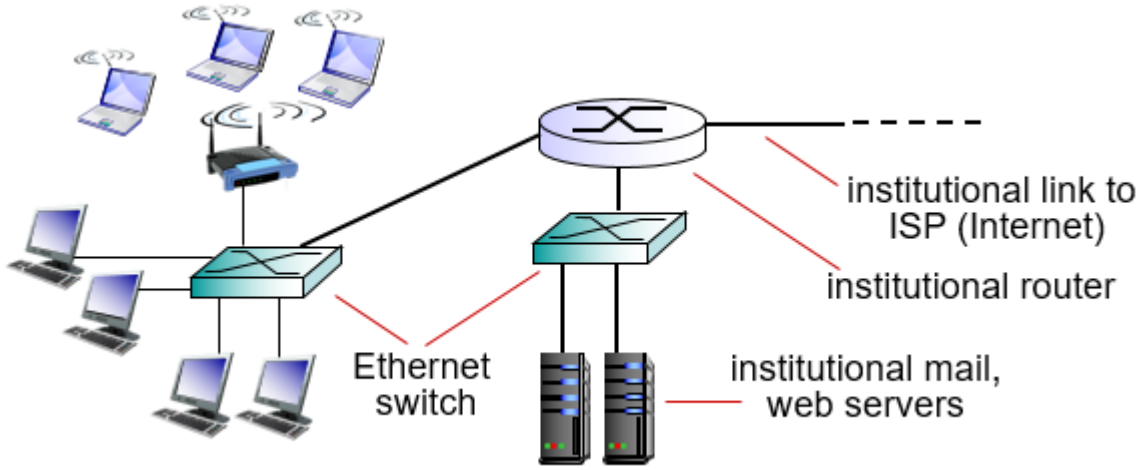
Communication Model

- Client/server model
  - client host requests, receives service from always-on server
  - e.g. Web browser/server; email client/server

- Peer-Peer model:
  - minimal (or no) use of dedicated servers
  - e.g. Skype, BitTorrent

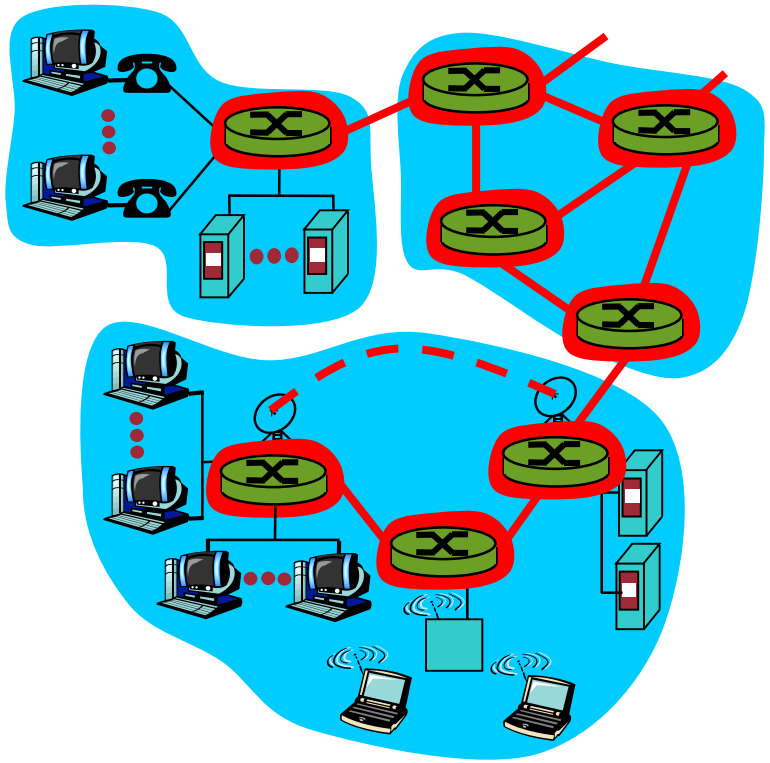
Access Networks Example





The Network Core

- Mesh of interconnected routers
- *The* fundamental question?
- How is data transferred through net or how to build the core?
  - Circuit switching: Dedicated circuit per call ex: telephone net
  - Packet-switching: Data Sent through net in discrete "chunks" ex: Internet

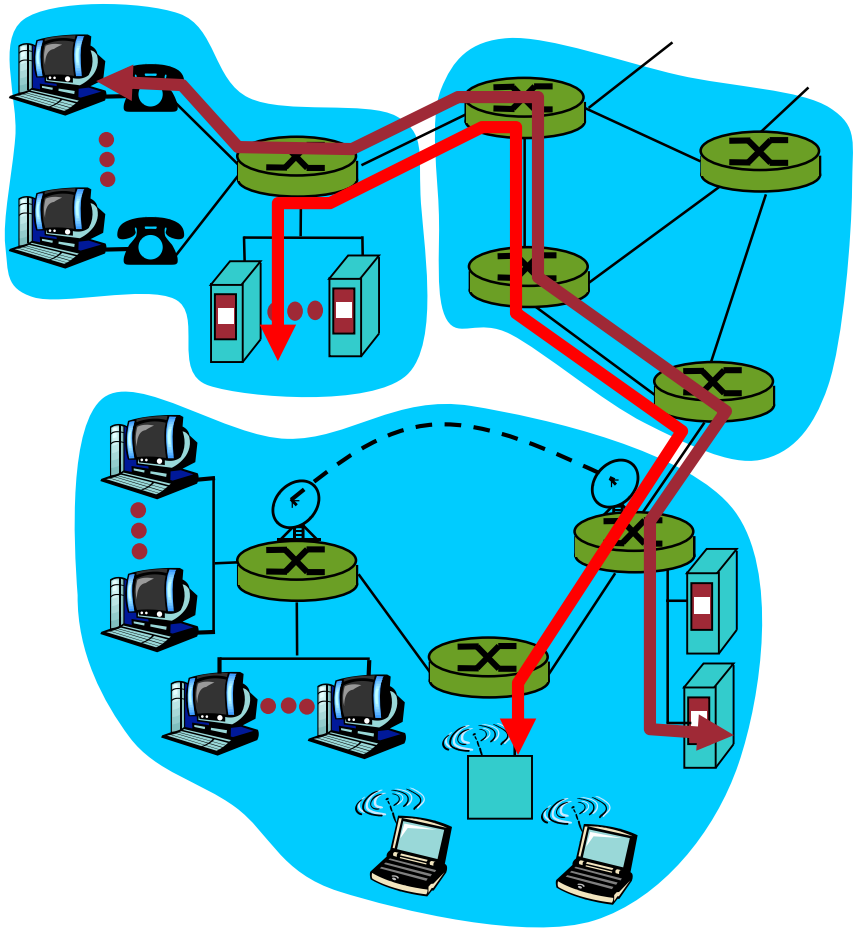


Network Core: Circuit Switching

End to end resources reserved

for “call”

- Dedicated resources: no sharing
- Circuit-like (guaranteed) performance
- Call setup required
- Link bandwidth is to be divided into “pieces”
  - Frequency division
  - Time division

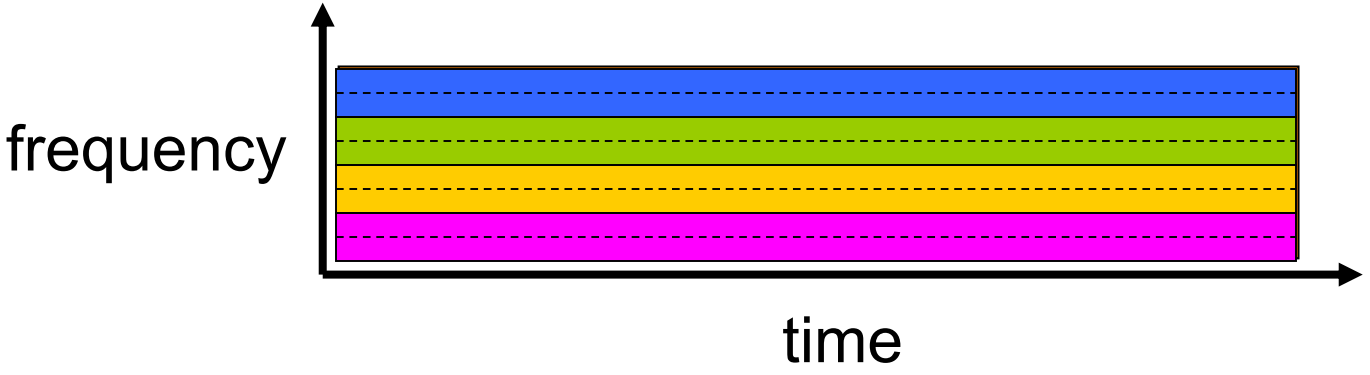


Circuit Switching: FDM and TDM

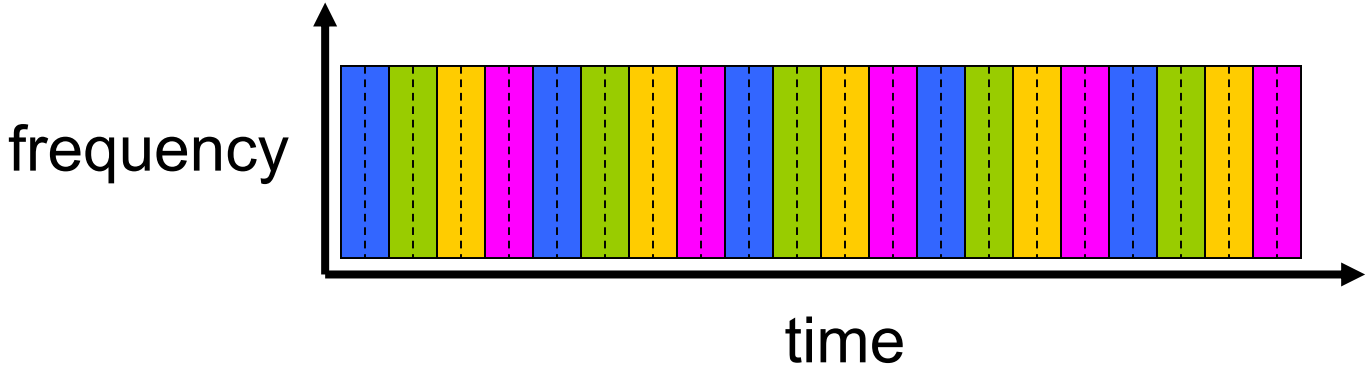
Example:

4 users

FDM



TDM



Circuit Switch: Numerical example

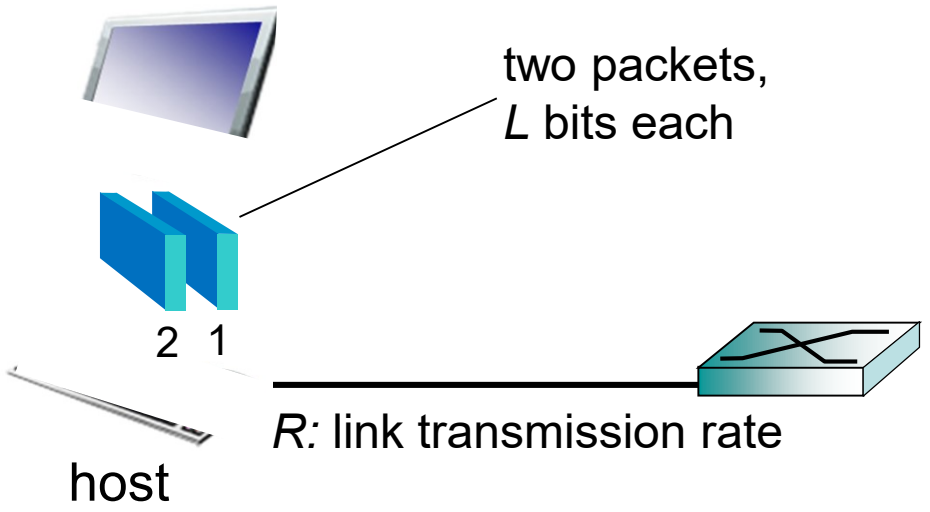
- How long does it take to send a file of 640,000 bits from host A to host B over a circuit-switched network?
  - All links are 1.536 Mbps
  - Each link uses TDM with 24 slots/sec
  - 500 msec to establish end-to-end circuit

Network Core: Packet Switching

Host sending function:

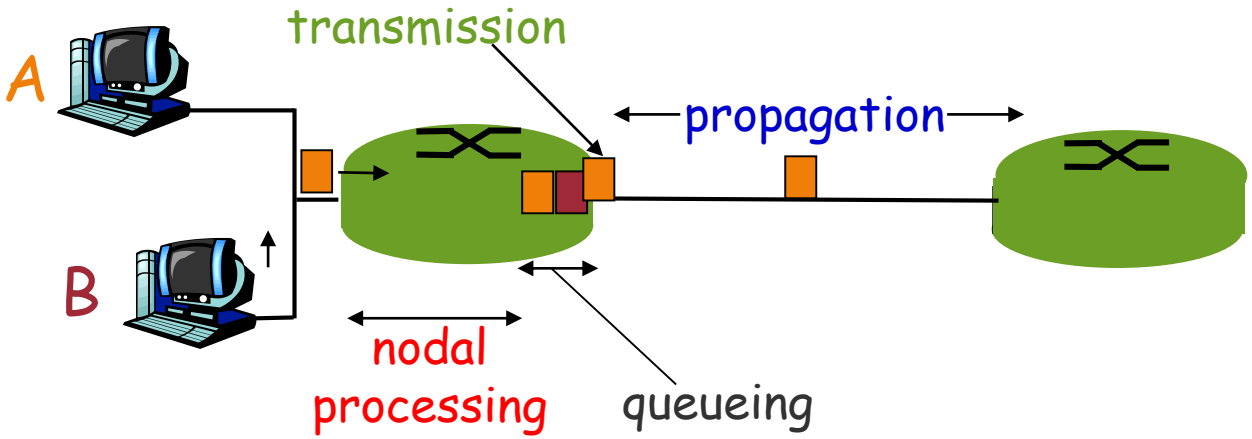
- Takes application message
- Breaks into smaller chunks, known as ***packets***, of length *L* bits
- Transmits packet into access network at ***transmission rate R* (aka Bandwidth)**

- **Store and forward**

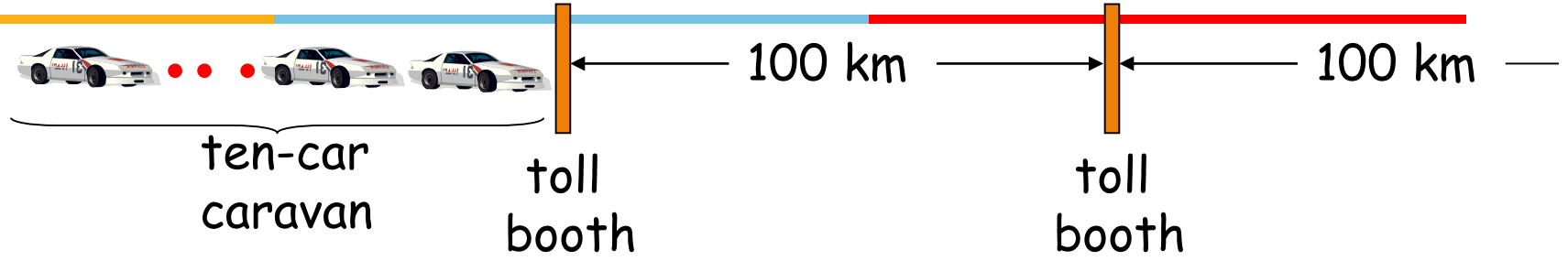


$$\text{Transmission Delay} = \frac{L\ (\text{bits})}{R\ (\text{bits/sec})}$$

Four sources of packet delay

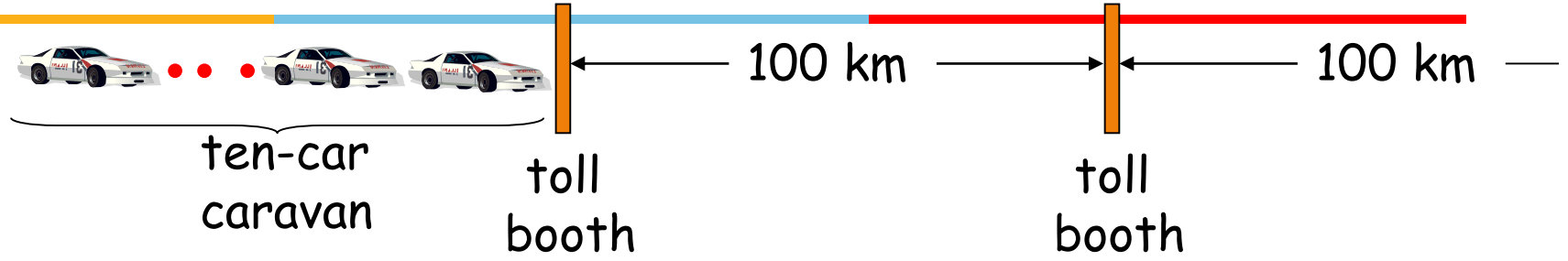


Caravan Analogy [.1]



- Cars “propagate” at 100 km/hr
- Toll booth takes 12 sec to service a car (car transmission time)
- Car is analogous to **bit**; caravan is analogous to **packet**
- Question:
  - How long until caravan is lined up before 2nd toll booth?

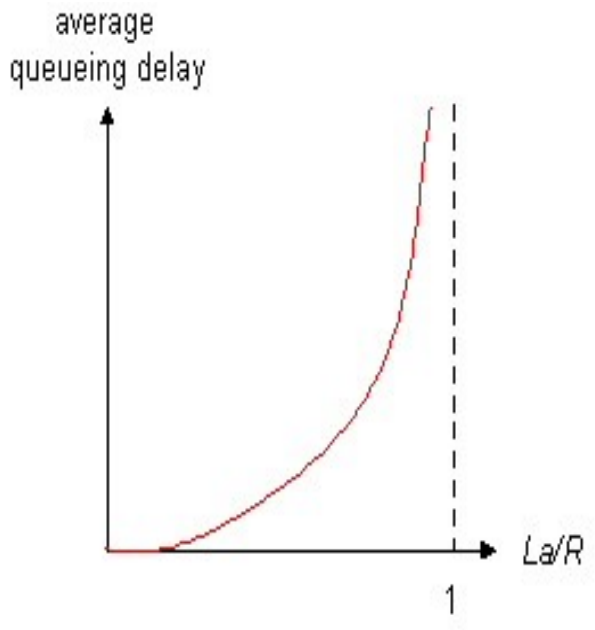
Caravan analogy [..2]



- Cars now “propagate” at 1000 km/hr
- Toll booth now takes 1 min to service a car

Queuing delay

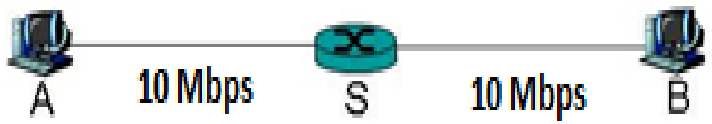
- R=link bandwidth (bps)
- L=packet length (bits)
- a=average packet arrival rate



traffic intensity = La/R

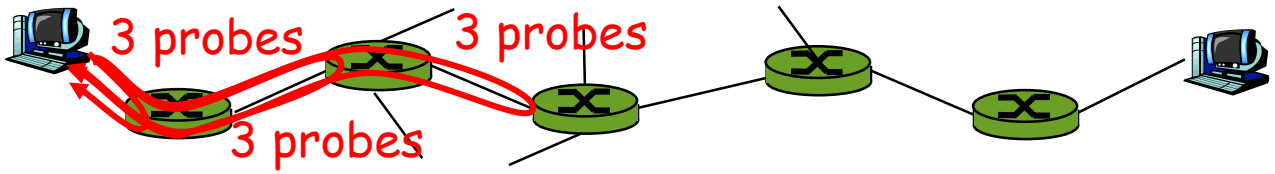
- La/R ~ 0: average queueing delay small
- La/R <= 1: delays become large
- La/R > 1: more “work” arriving than can be serviced, average delay infinite!

Example



“Real” Internet delays and routes

- What do “real” Internet delay & loss look like?
- **Traceroute** program: provides delay measurement from source to router along end-to-end Internet path towards destination. For all *i:*
  - Sends three packets that will reach router *i* on path towards destination
  - Router *i* will return packets to sender
  - Sender times interval between transmission and reply.
  - Read RFC 1393 for more detail !!!
- http://traceroute.org

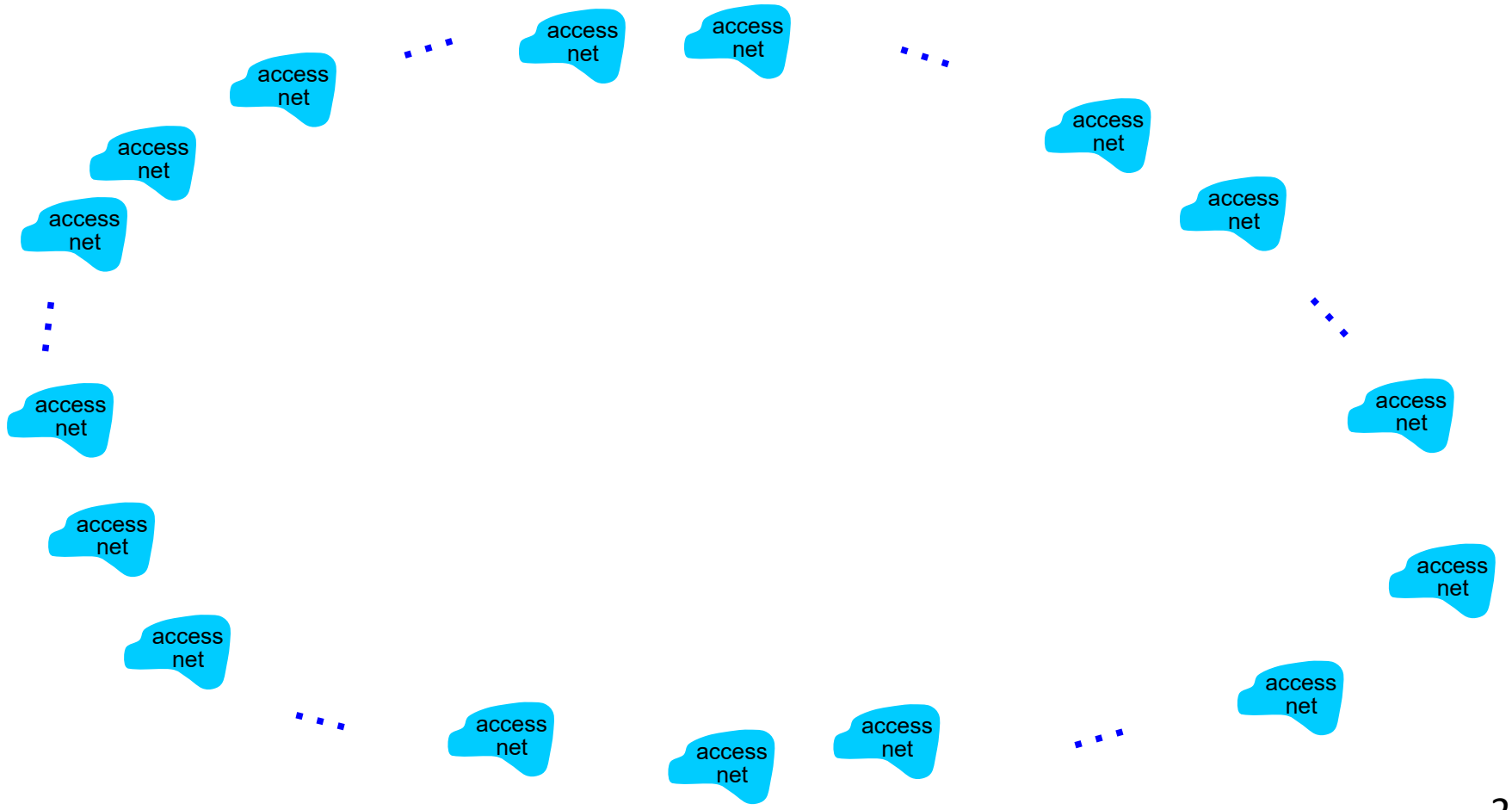


Performance Measure Parameters of Networks

- Delay
- Packet Loss
- Throughput
  - Amount of bits transferred in a unit time
    - Instantaneous throughput
      - e.g., P2P file sharing applications displays instantons throughput during downloads
    - Average throughput

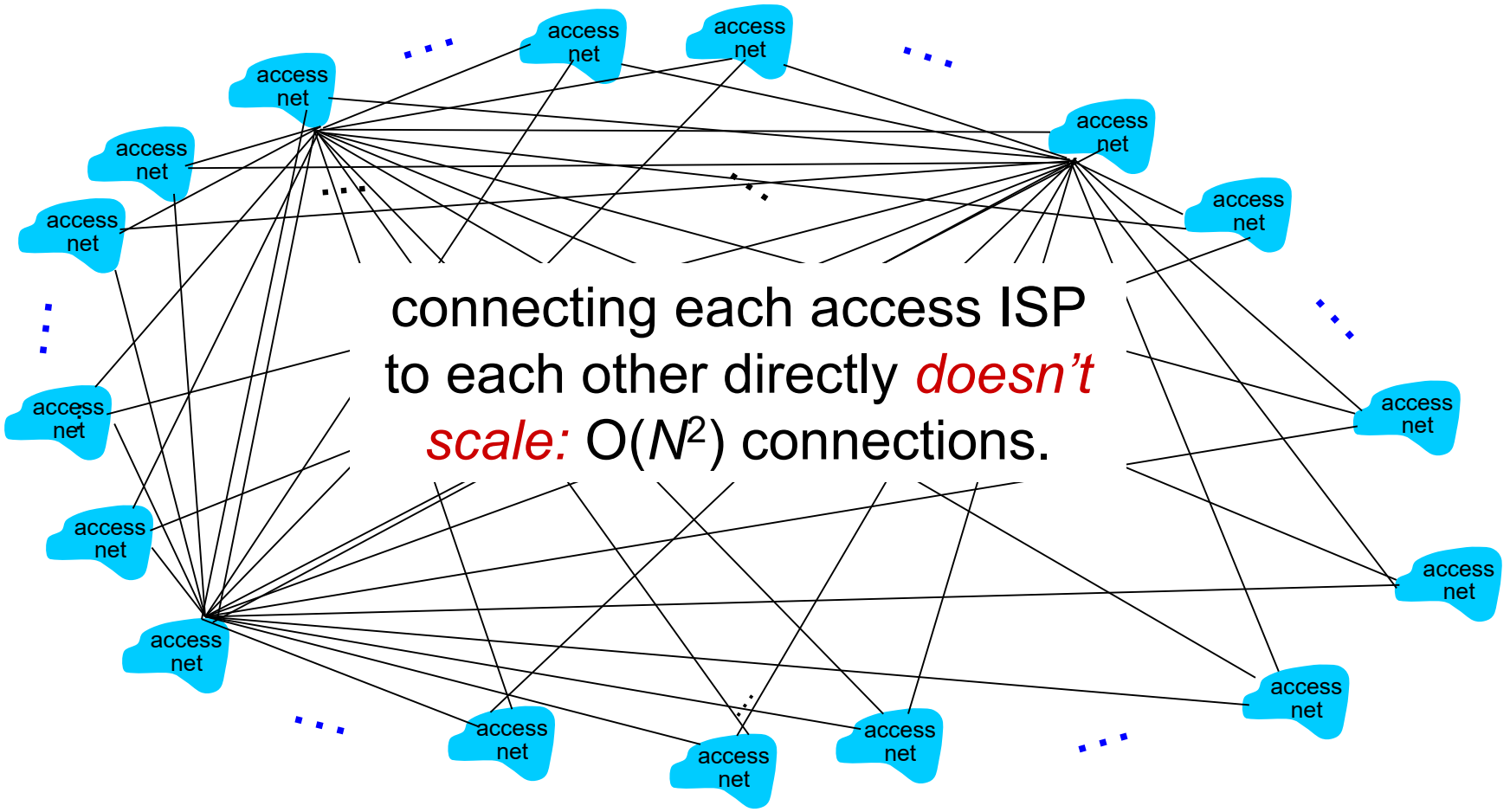
Internet structure: network of networks

Question: given *millions* of access ISPs, how to connect them together?



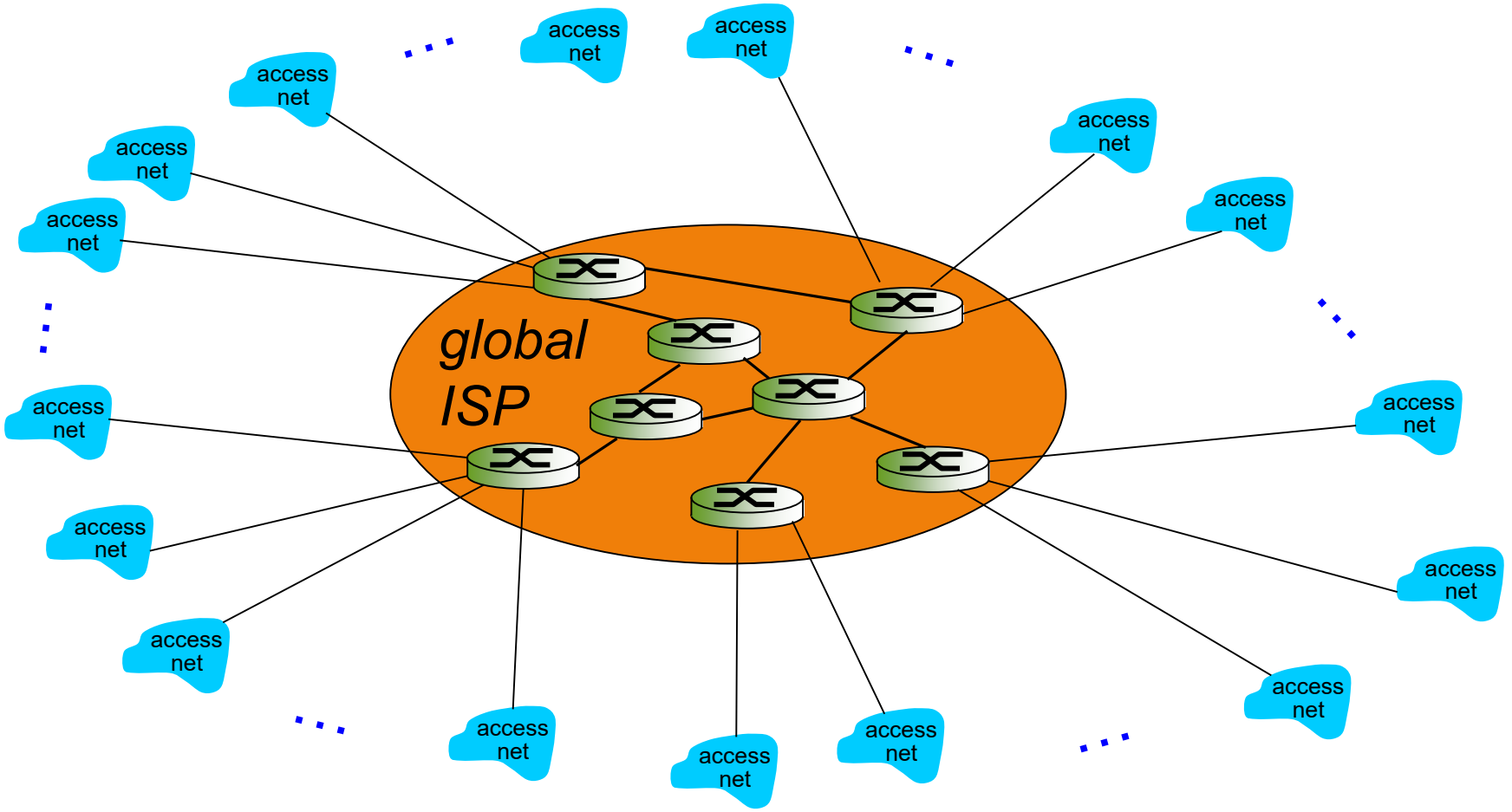
Internet structure: network of networks

Option: connect each access ISP to every other access ISP?



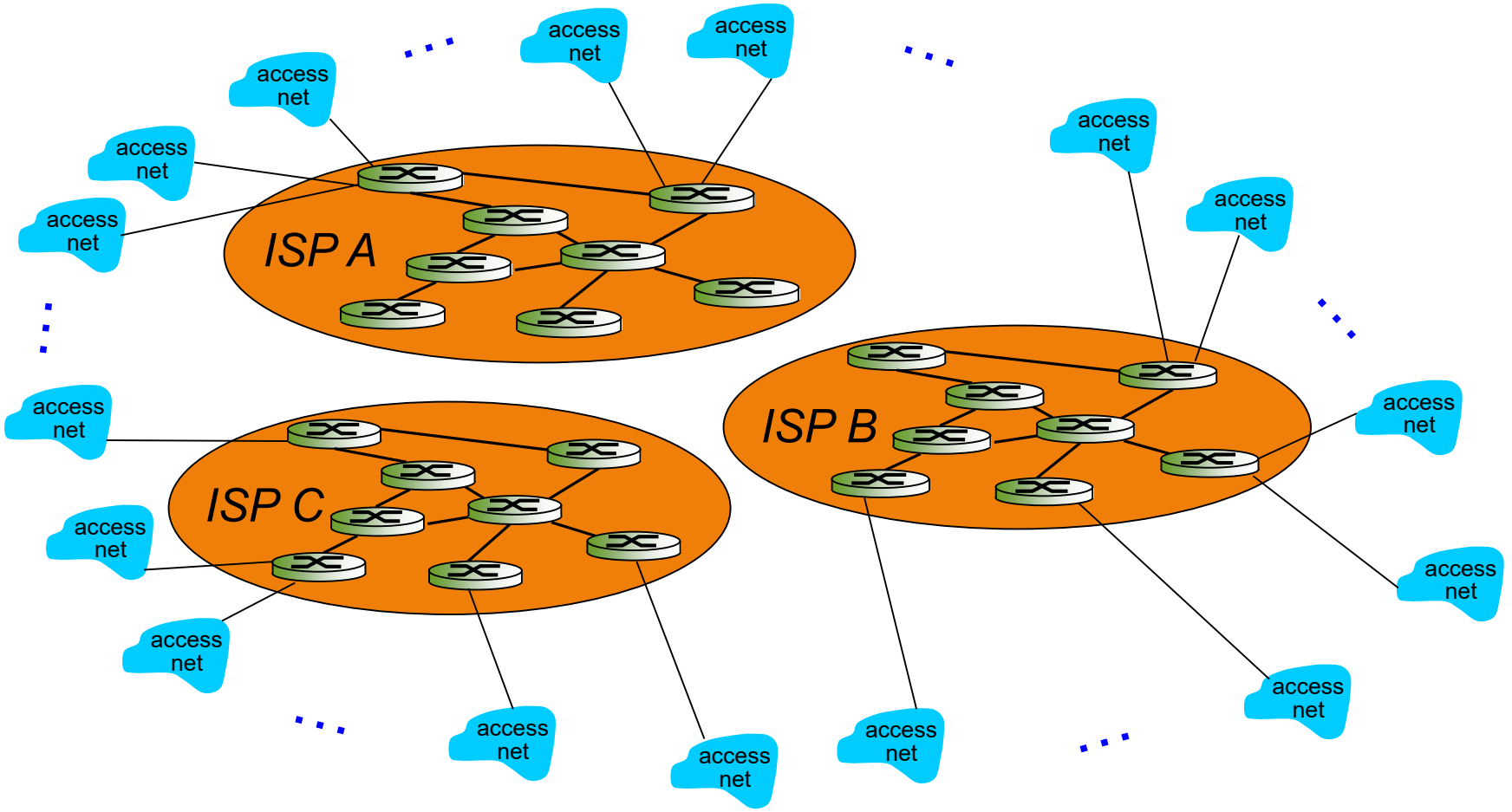
Internet structure: network of networks

Option: connect each access ISP to a global transit ISP? Customer and provider ISPs have economic agreement.



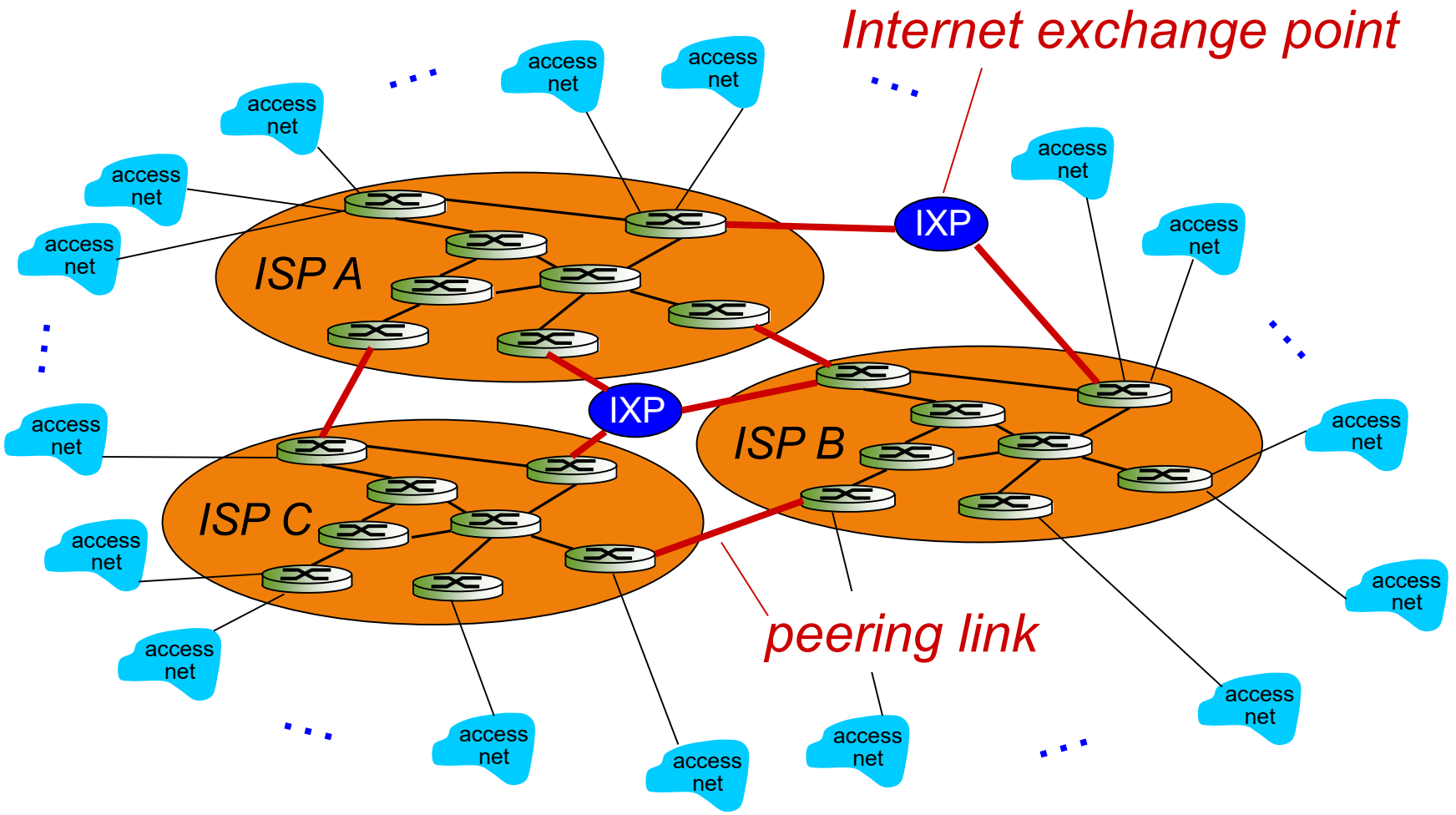
Internet structure: network of networks

Single global ISP does not scale, there are multiple global ISPs ….



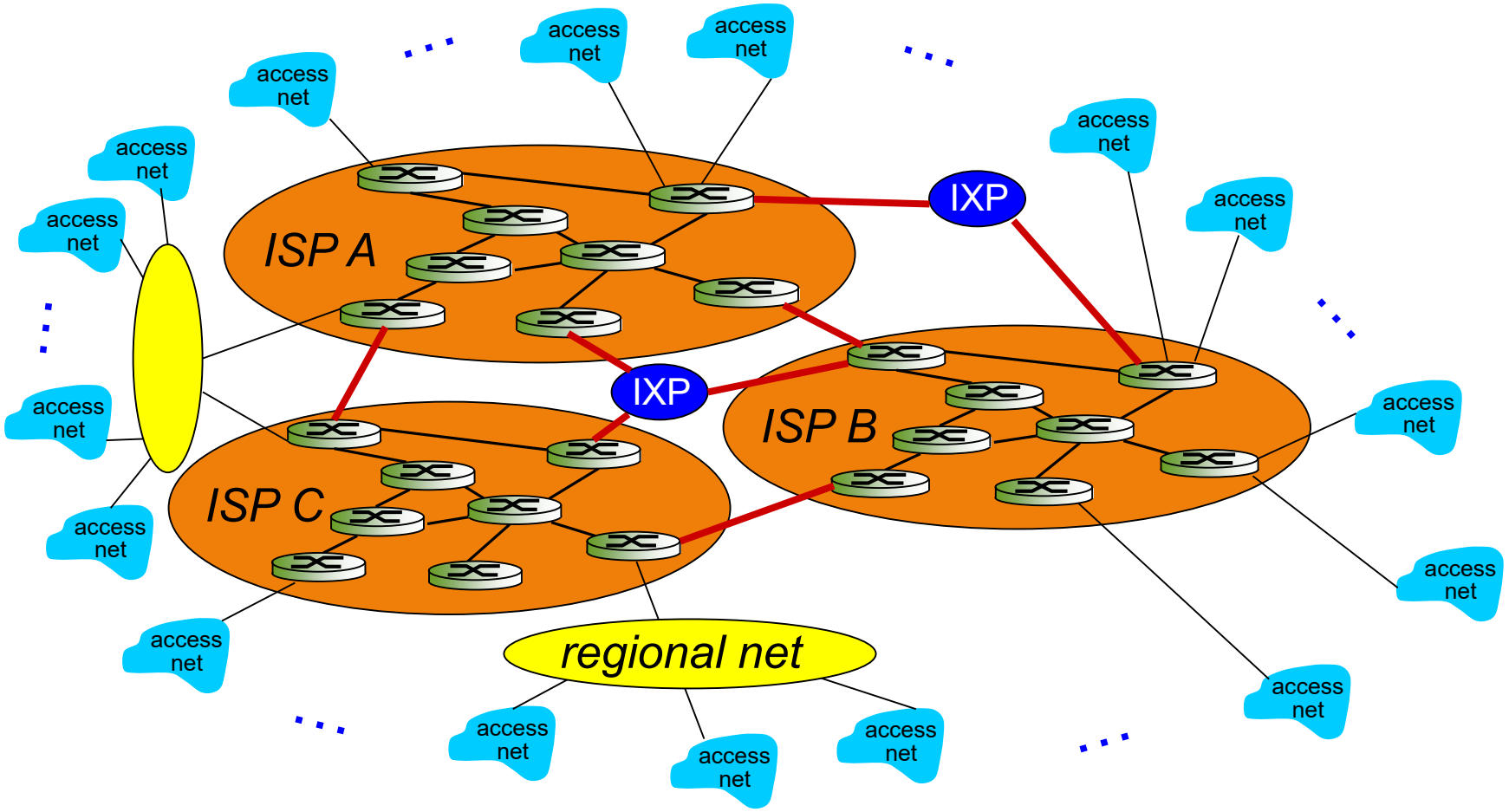
Internet structure: network of networks

Multiple global ISPs must be interconnected



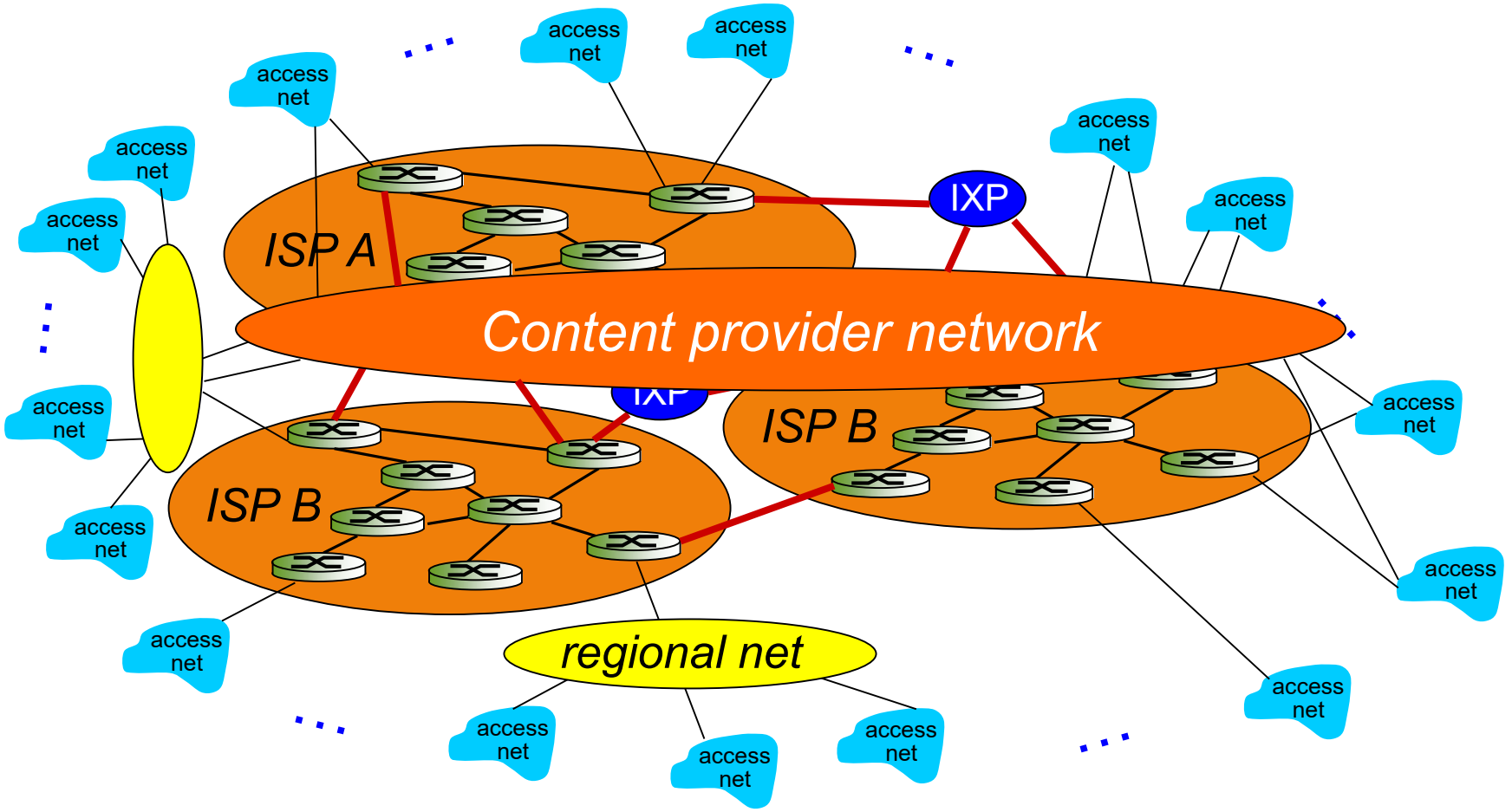
Internet structure: network of networks

… and regional networks may arise to connect access nets to ISPs



Internet structure: network of networks

… and content provider networks (e.g., Google, Microsoft, Akamai) may run their own network, to bring services, content close to end users



Goals for the DARPA Internet Architecture

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0. Connect existing networks

Initially ARPANET and ARPA packet radio network

1. Survivability
2. Support multiple types of services

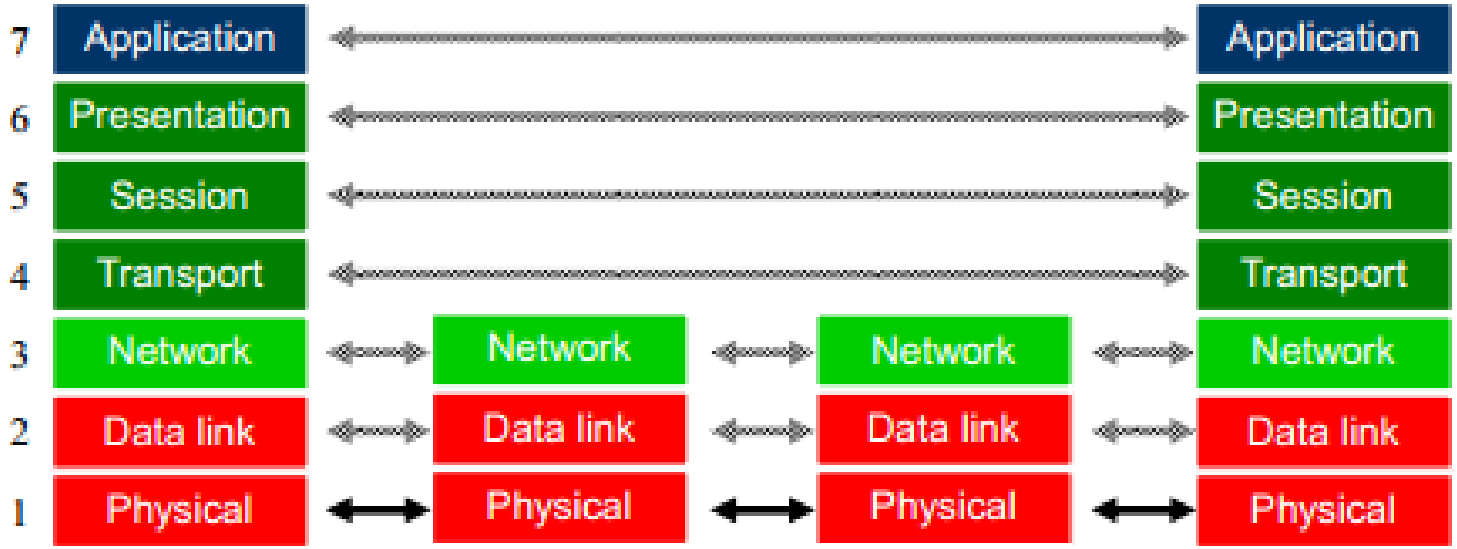
Differ in Speed, Latency and Reliability

3. Must accommodate a variety of networks
4. Allow distributed management
5. Allow host attachment with a low level of effort
6. Be cost effective
7. Allow resource accountability

How to deal with the Complexity of a system?

- Go for modular design
  - Break up the Internet “system” in a set of modules with well-defined interfaces
    - Each module performs specific functions
    - Implementation of module can change
    - Can build a large complex system from modules implemented by many parties

Layered Network Model (OSI)



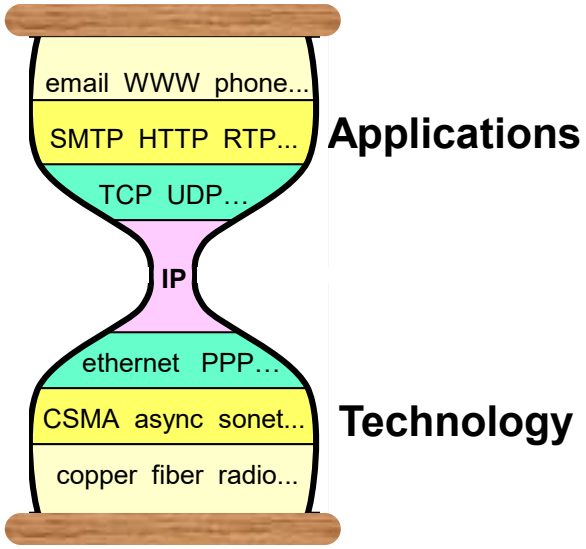
Presentation: allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
Session: synchronization, check pointing, recovery of data exchange

Internet Stack (TCP/IP) : Layer Functionalities

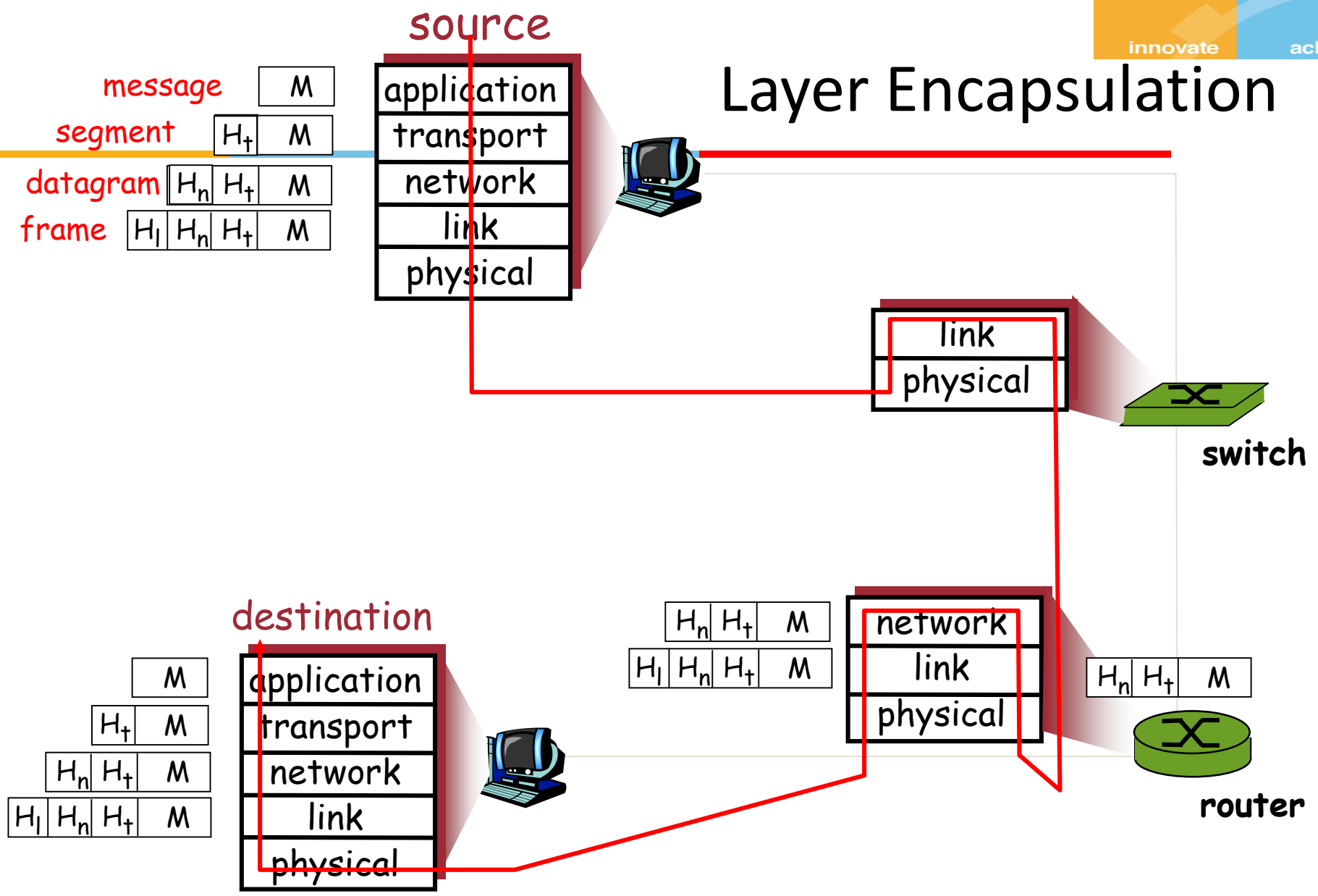
- **Physical layer** delivers bits between the two endpoints of a "link"
  - Copper, fiber, wireless, visible light, …
- **Datalink layer** delivers packets between two hosts in a local area network
  - Ethernet, WiFi, cellular, …
  - "Boxes" that connect links are called bridges or switches
- **Network layer** connects multiple networks
  - The Inter-net protocol (IP)
  - Routers forward packets
- **Transport layer**: process-process data transfer
  - TCP, UDP
- **Application Layer**: supporting network applications
  - FTP, SMTP, HTTP

IP Hourglass Architecture

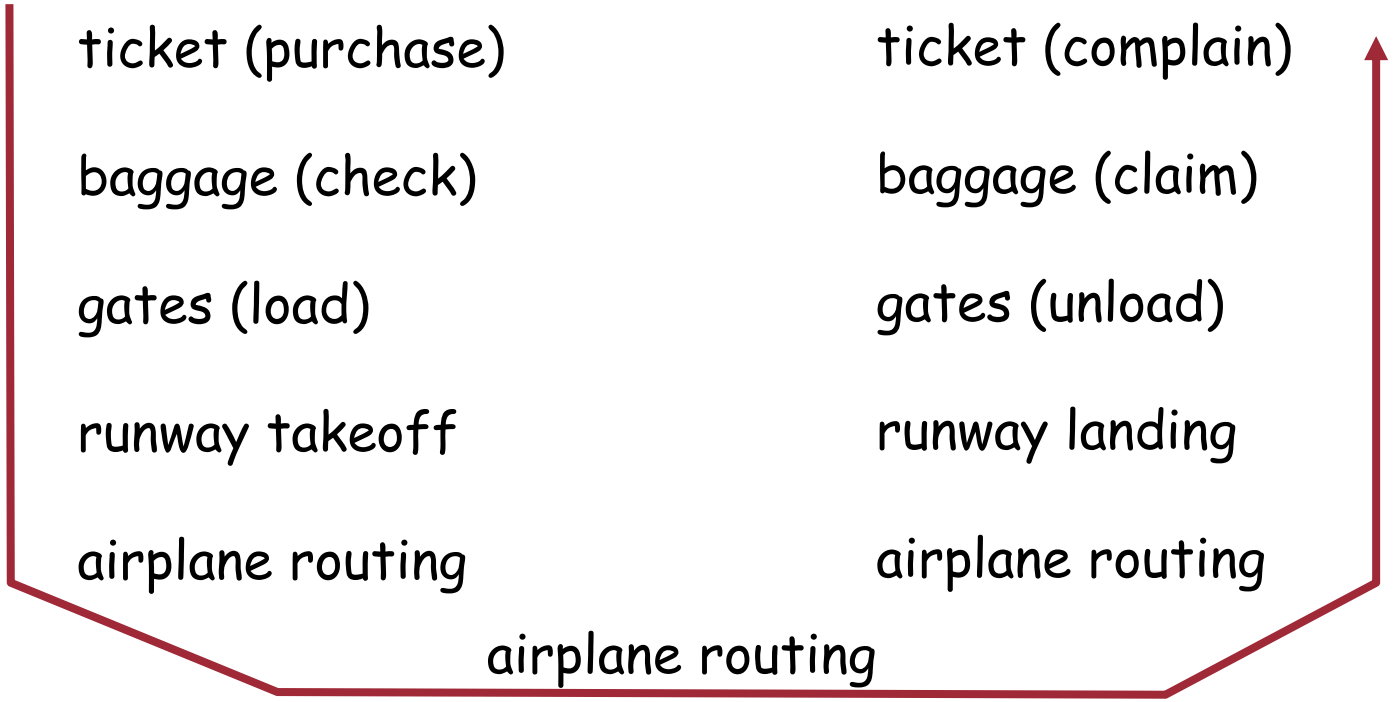
- Need to interconnect many existing networks
- Hide underlying technology from applications
- Decisions:
  - Network provides minimal functionality
  - "Narrow waist"
  - ***Best Effort Service…!***
  - Tradeoff→ No assumptions no guarantee



Layer Encapsulation

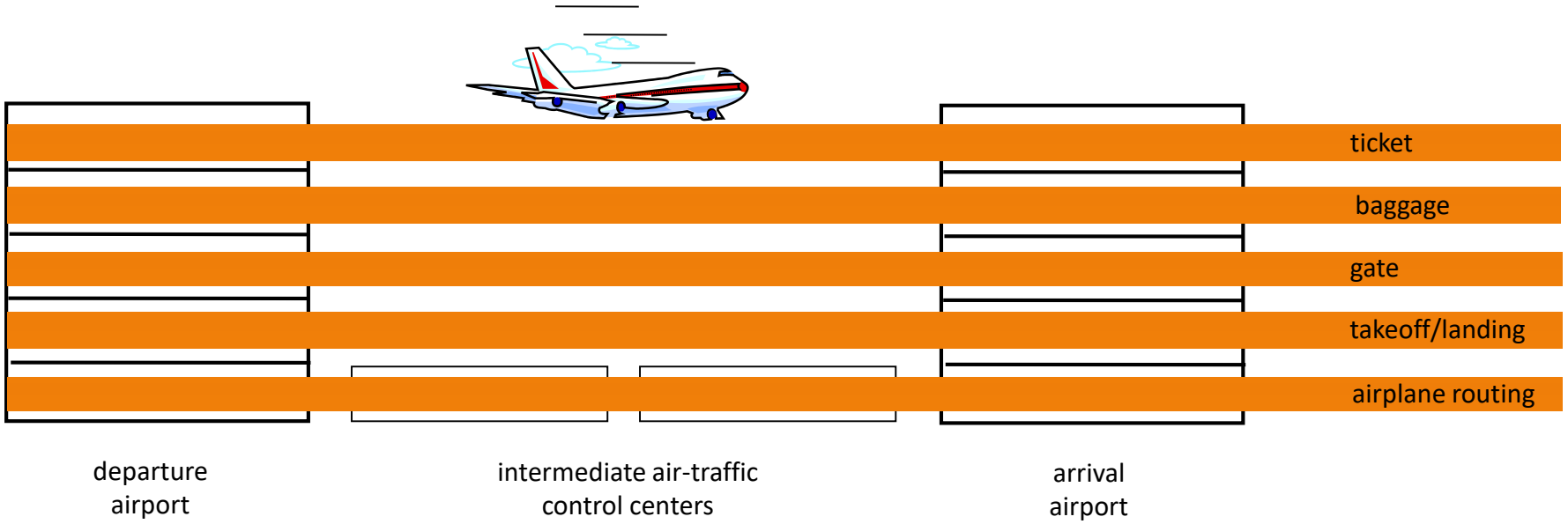


Example: Organization of air travel



- A series of steps

Layering of airline functionality



Layers: Each layer implements a service

- Via its own internal-layer actions
- Relying on services provided by layer below

Thank You!