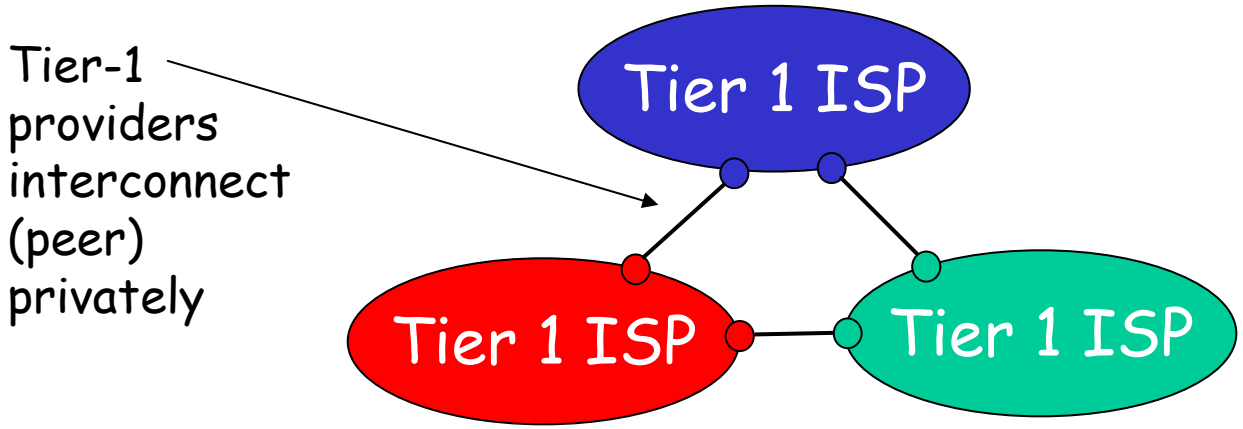
Networking

Based on the powerpoint presentation of Computer Networking: A Top Down Approach Featuring the Internet, Third Edition, J.F. Kurose and K.W. Ross, Addison-Wesley, ISBN: 0-321-22735-2.

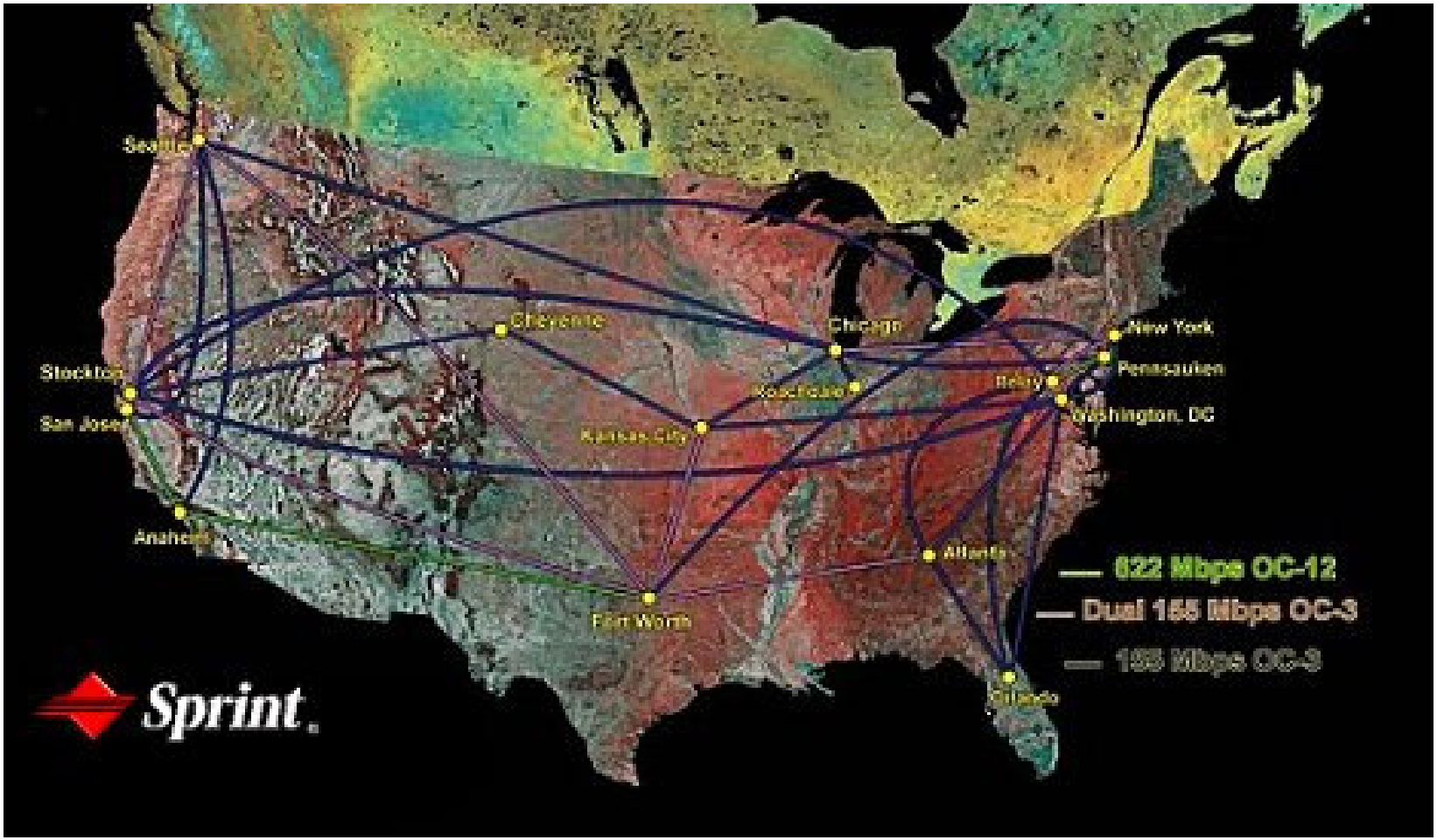
Internet structure: network of networks

- roughly hierarchical
- at center: "tier-1" ISPs (e.g., UUNet, BBN/Genuity, Sprint, AT&T), national/international coverage
  - treat each other as equals



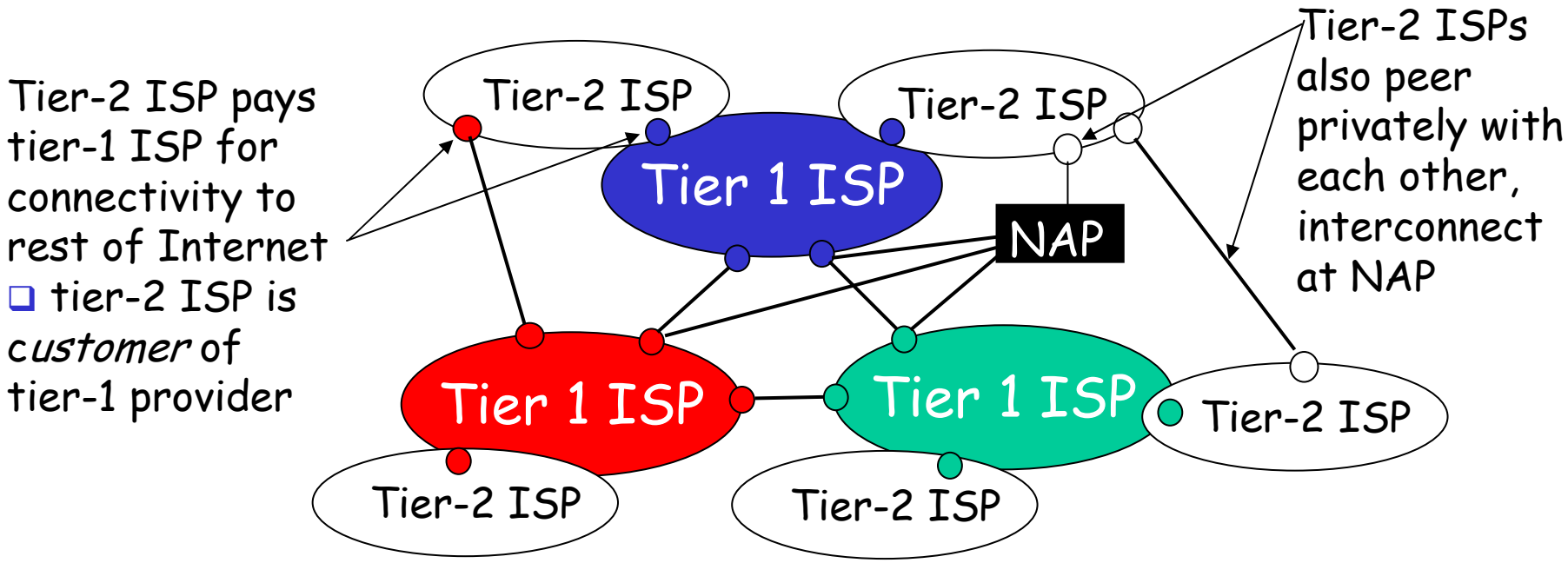
Tier-1 ISP: e.g., Sprint

Sprint US backbone network

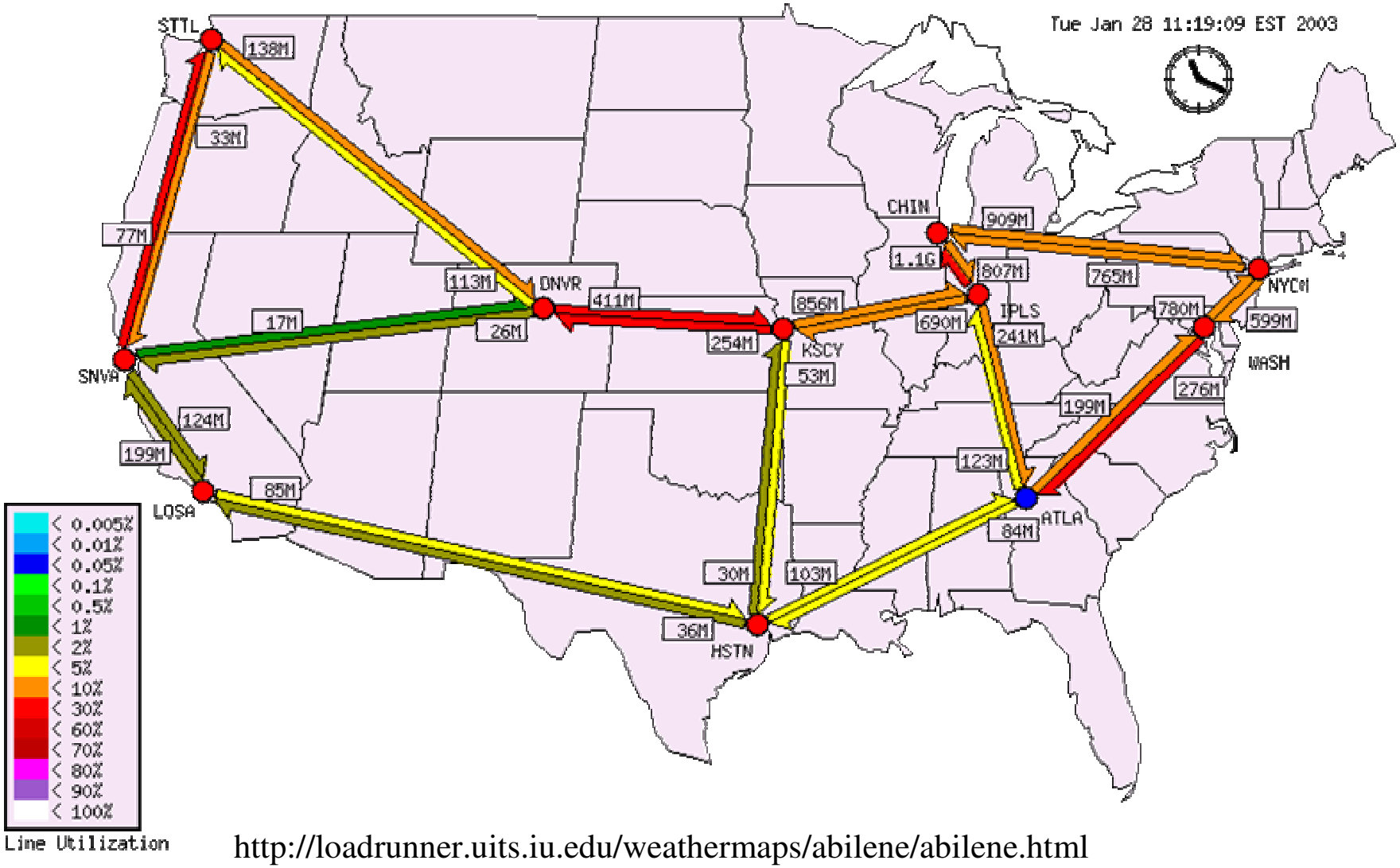


Internet structure: network of networks

- "Tier-2" ISPs: smaller (often regional) ISPs
  - Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs



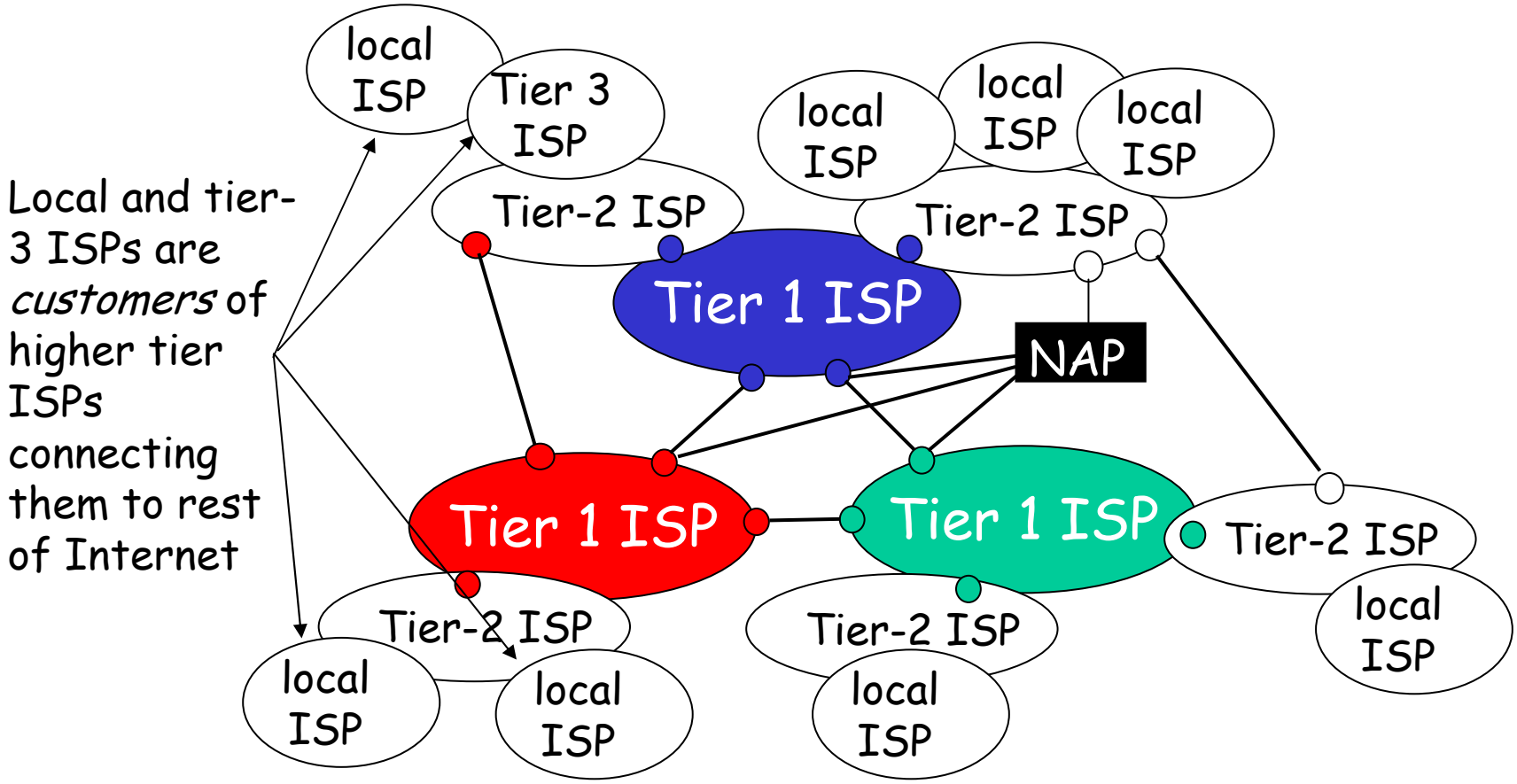
Tier-2 ISP: e.g., Abilene (Internet2)



http://loadrunner.uits.iu.edu/weathermaps/abilene/abilene.html

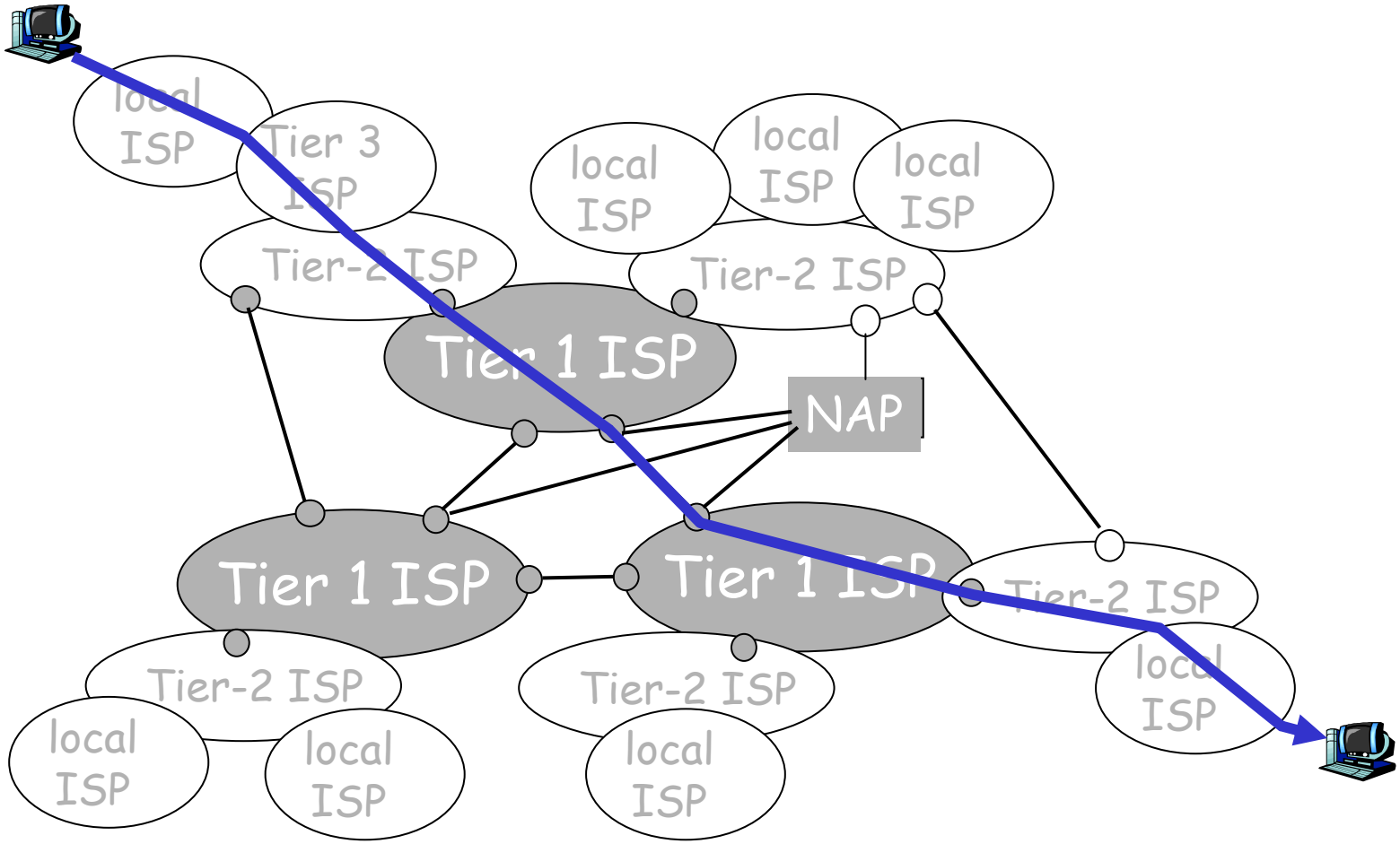
Internet structure: network of networks

- "Tier-3" ISPs and local ISPs
  - last hop ("access") network (closest to end systems)



Internet structure: network of networks

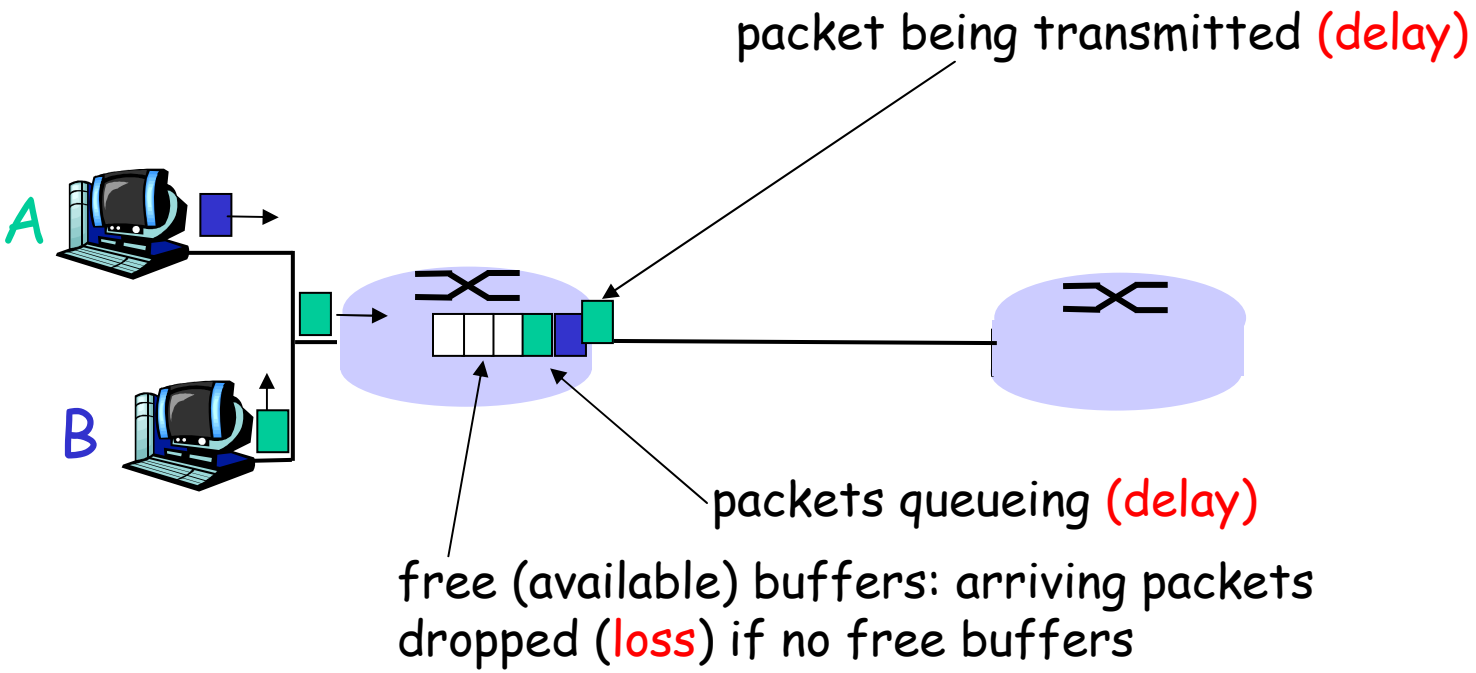
- a packet passes through many networks!



How do loss and delay occur?

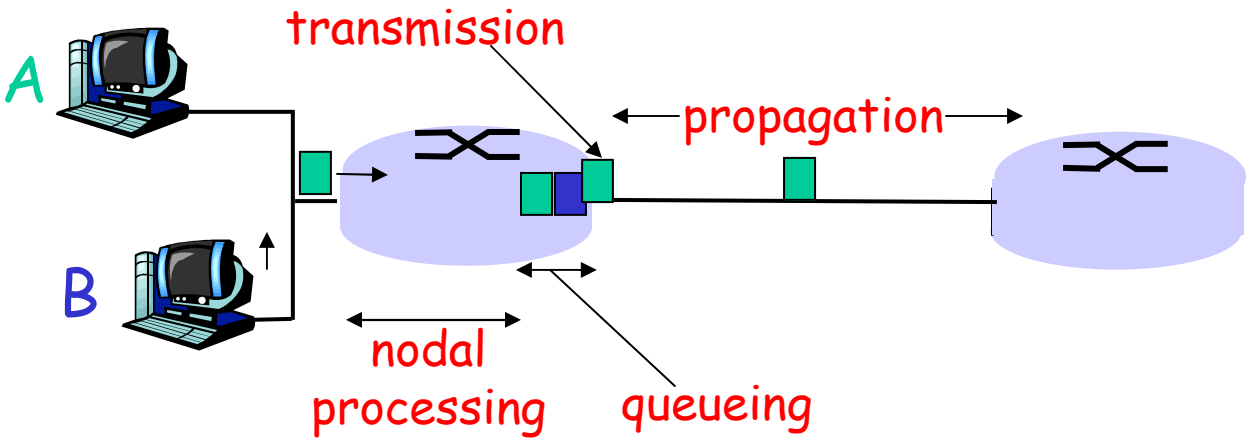
packets *queue* in router buffers

- packet arrival rate to link exceeds output link capacity
- packets queue, wait for turn



Four sources of packet delay

- 1. nodal processing:
  - determine output link
- 2. queueing
  - time waiting at output link for transmission
  - depends on congestion level of router



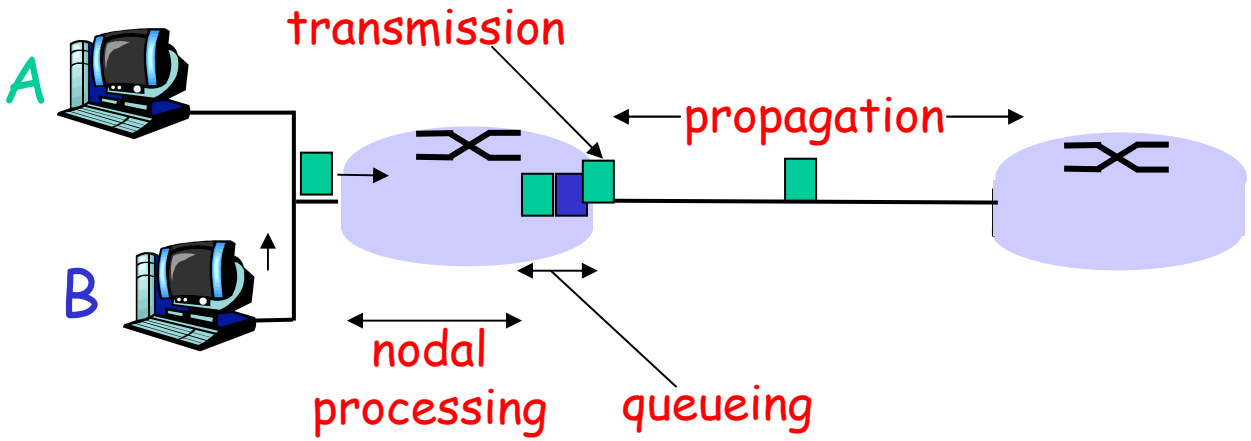
Delay in packet-switched networks

3. Transmission delay:

- time to send bits into link = L/R

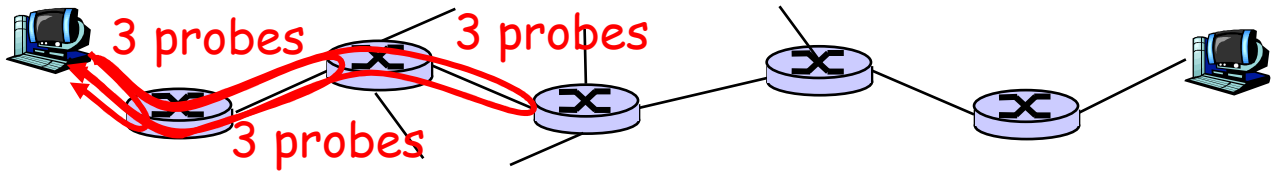
4. Propagation delay:

- time to travel down link



"Real" Internet delays and routes

- What do "real" Internet delay & loss look like?
- **Traceroute program:** provides delay measurement from source to router along end-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.



Packet loss

- queue (aka buffer) preceding link in buffer has finite capacity
- when packet arrives to full queue, packet is dropped (aka lost)
- lost packet may be retransmitted by previous node, by source end system, or not retransmitted at all

Protocol "Layers"

Networks are complex!

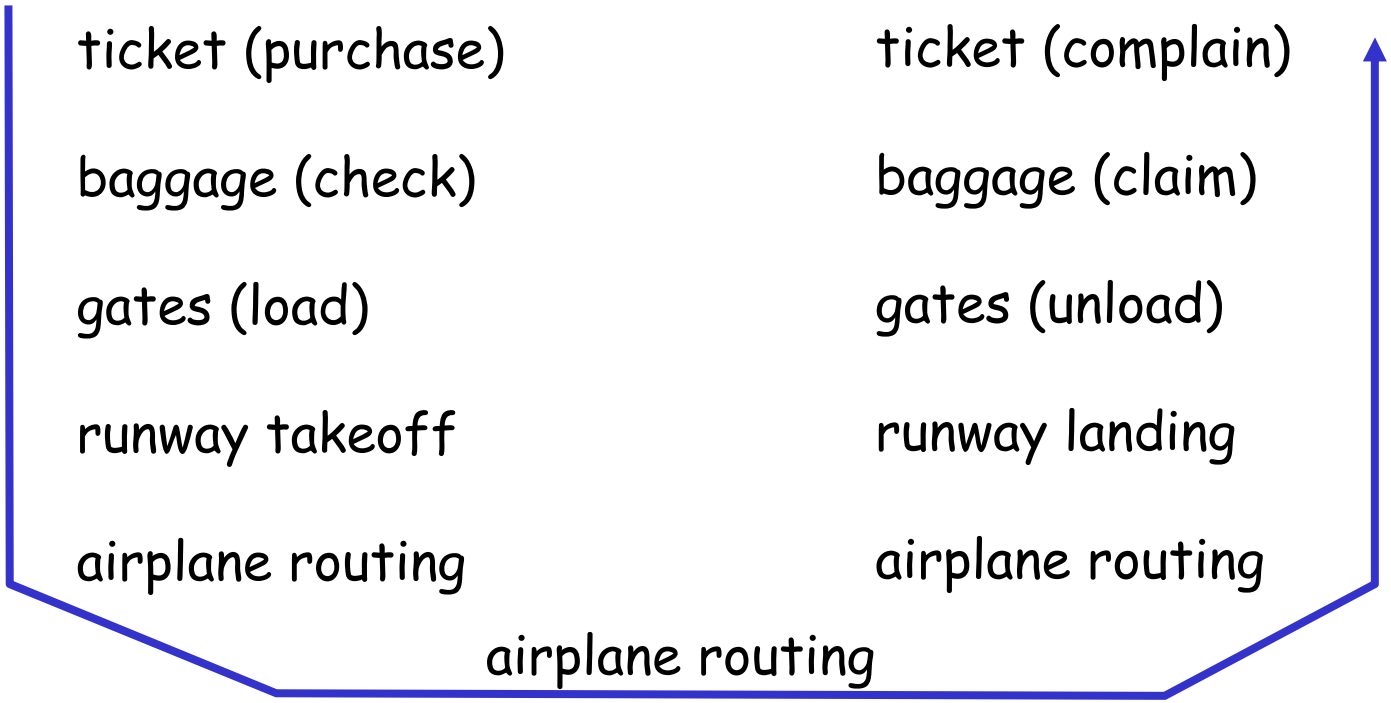
- many "pieces":
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

Question:

Is there any hope of *organizing* structure of network?

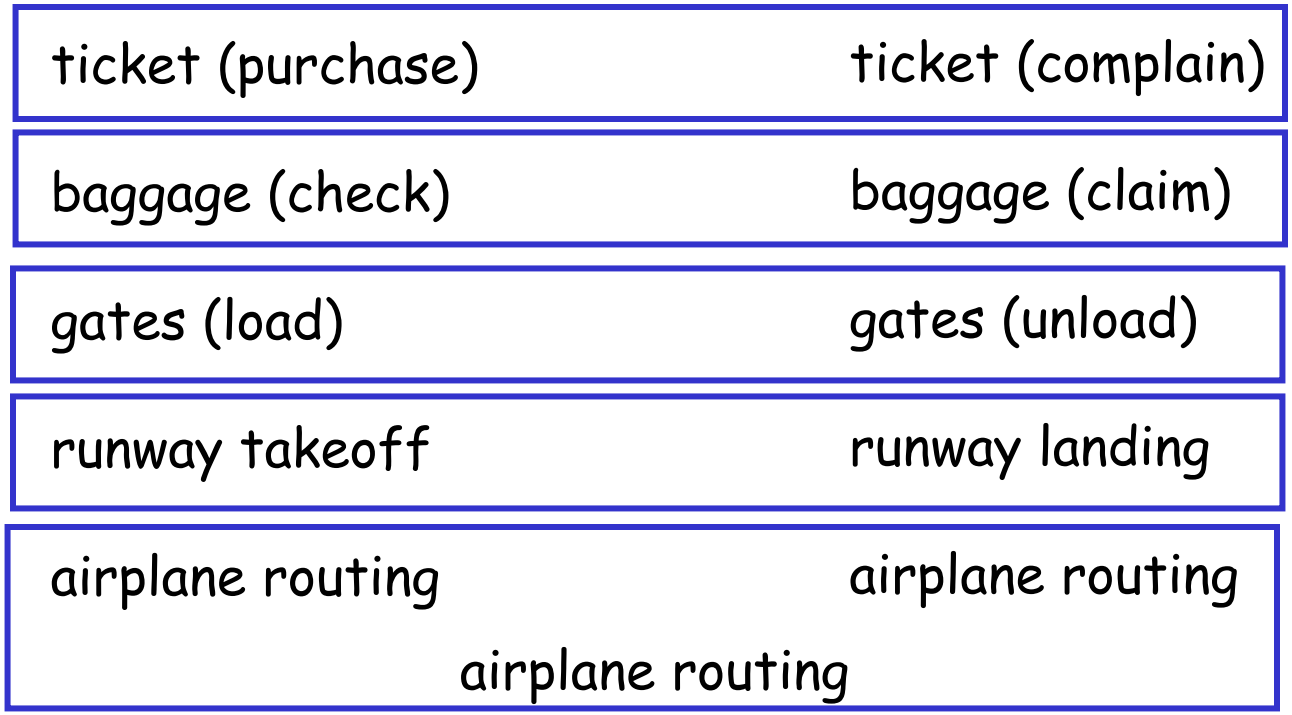
Or at least our discussion of networks?

Organization of air travel



- a series of steps

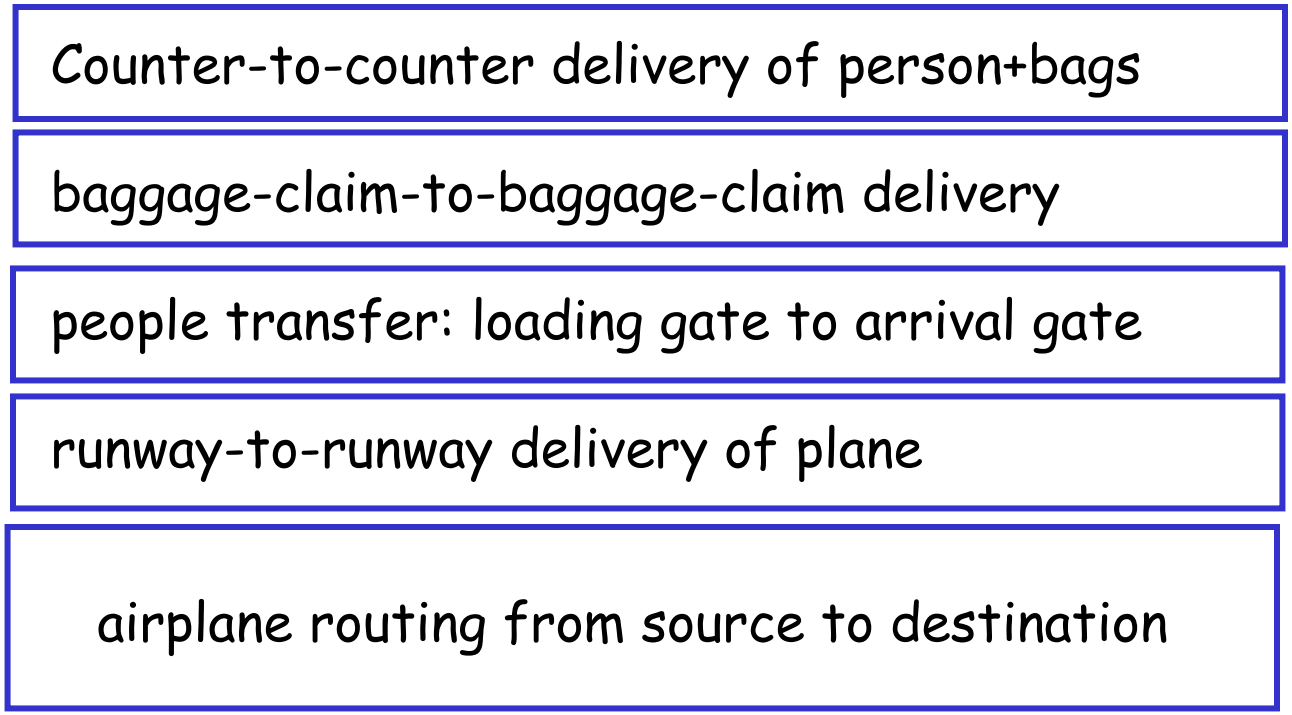
Organization of air travel: a different view



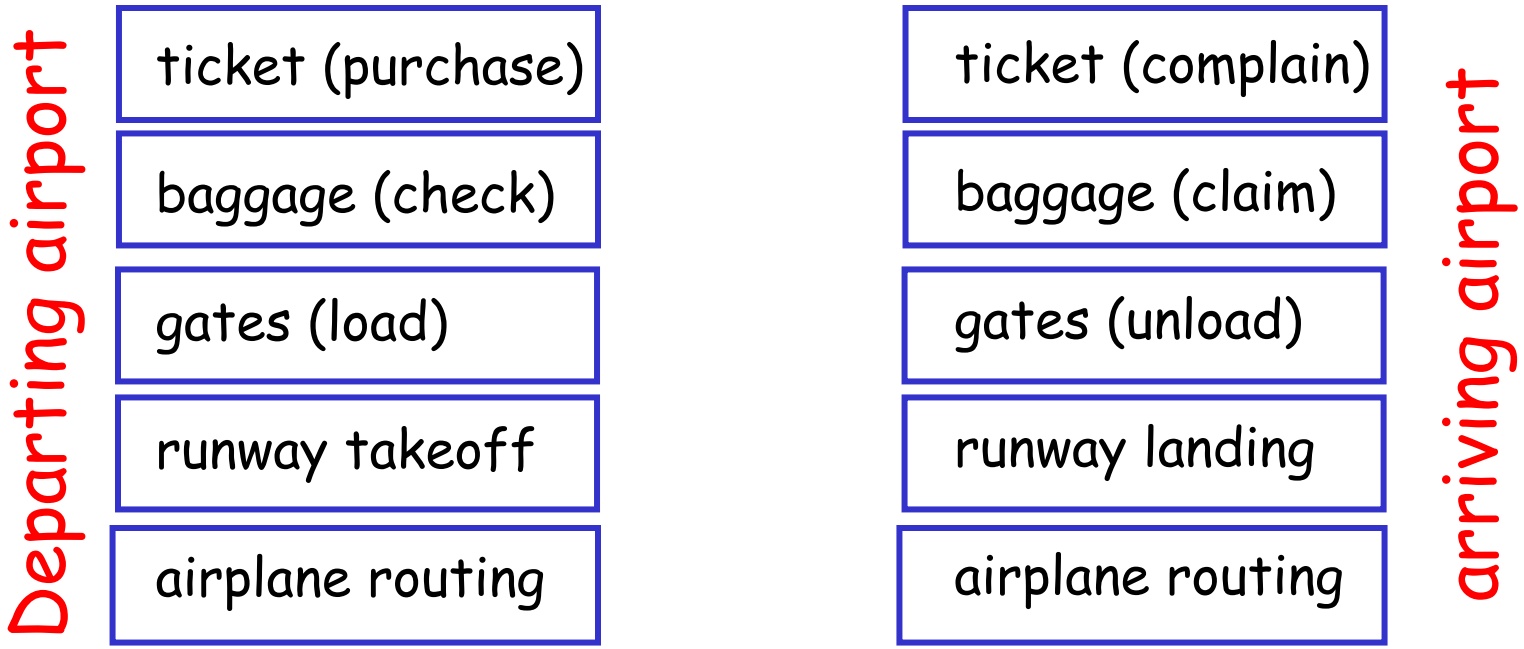
Layers: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

Layered air travel: services



Distributed implementation of layer functionality



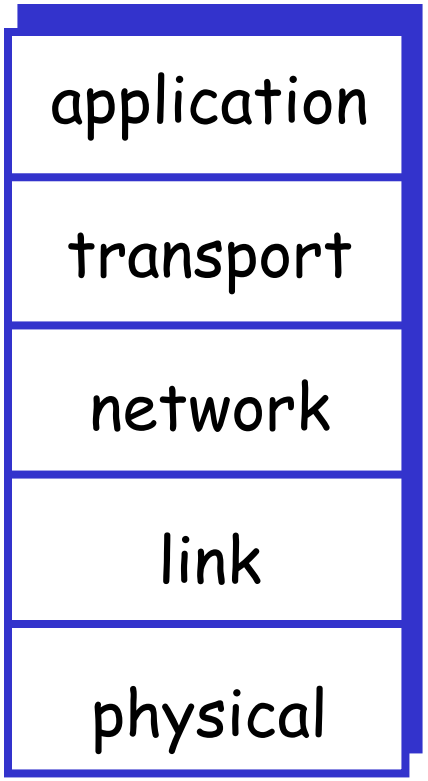
Why layering?

Dealing with complex systems:

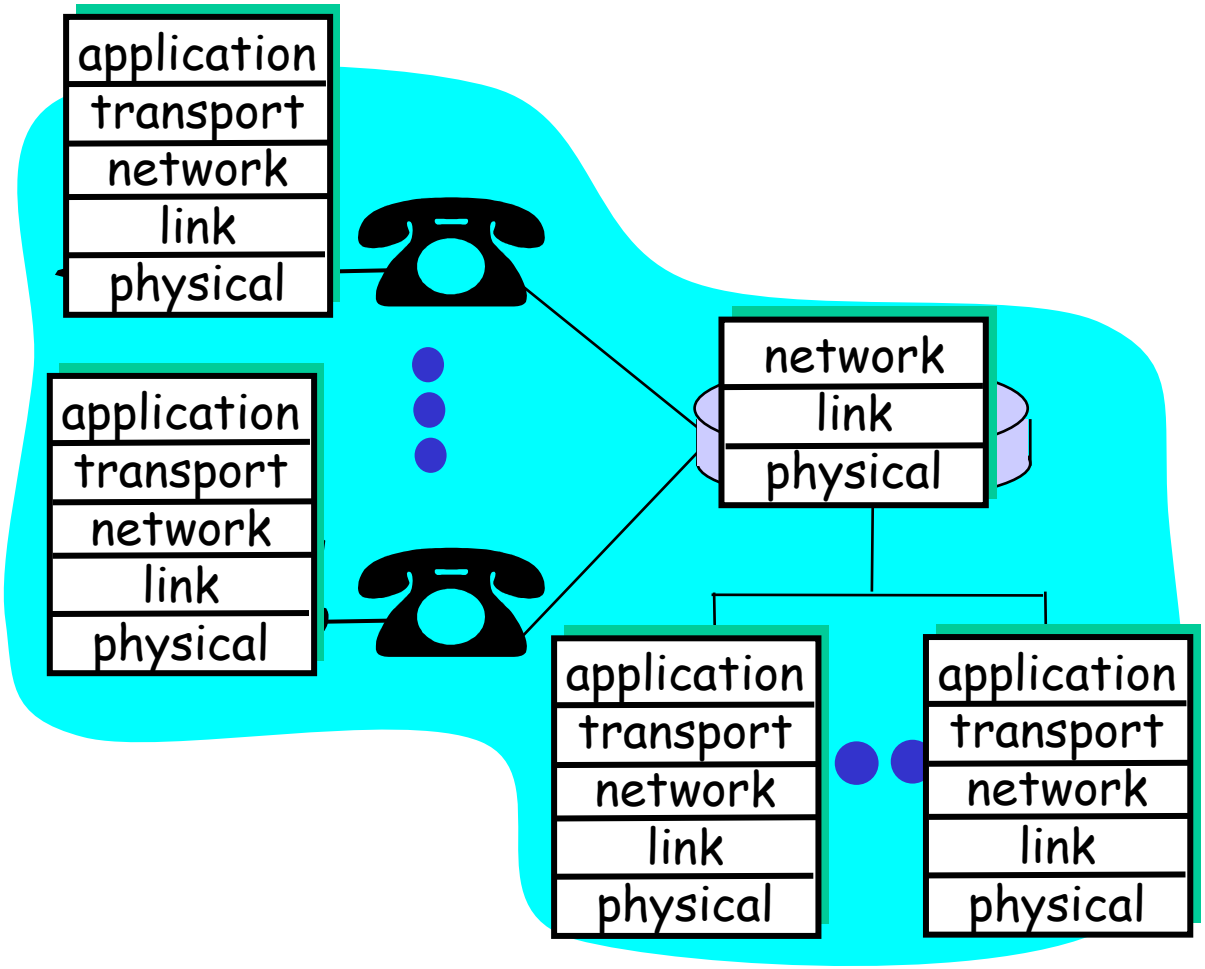
- explicit structure allows identification, relationship of complex system's pieces
- modularization eases maintenance, updating of system

Internet protocol stack

- application: supporting network applications
  - HTTP,FTP, SMTP
- transport: host-host data transfer
  - TCP, UDP
- network: routing of datagrams from source to destination
  - IP, routing protocols
- link: data transfer between neighboring network elements
  - PPP, Ethernet
- physical: bits "on the wire"



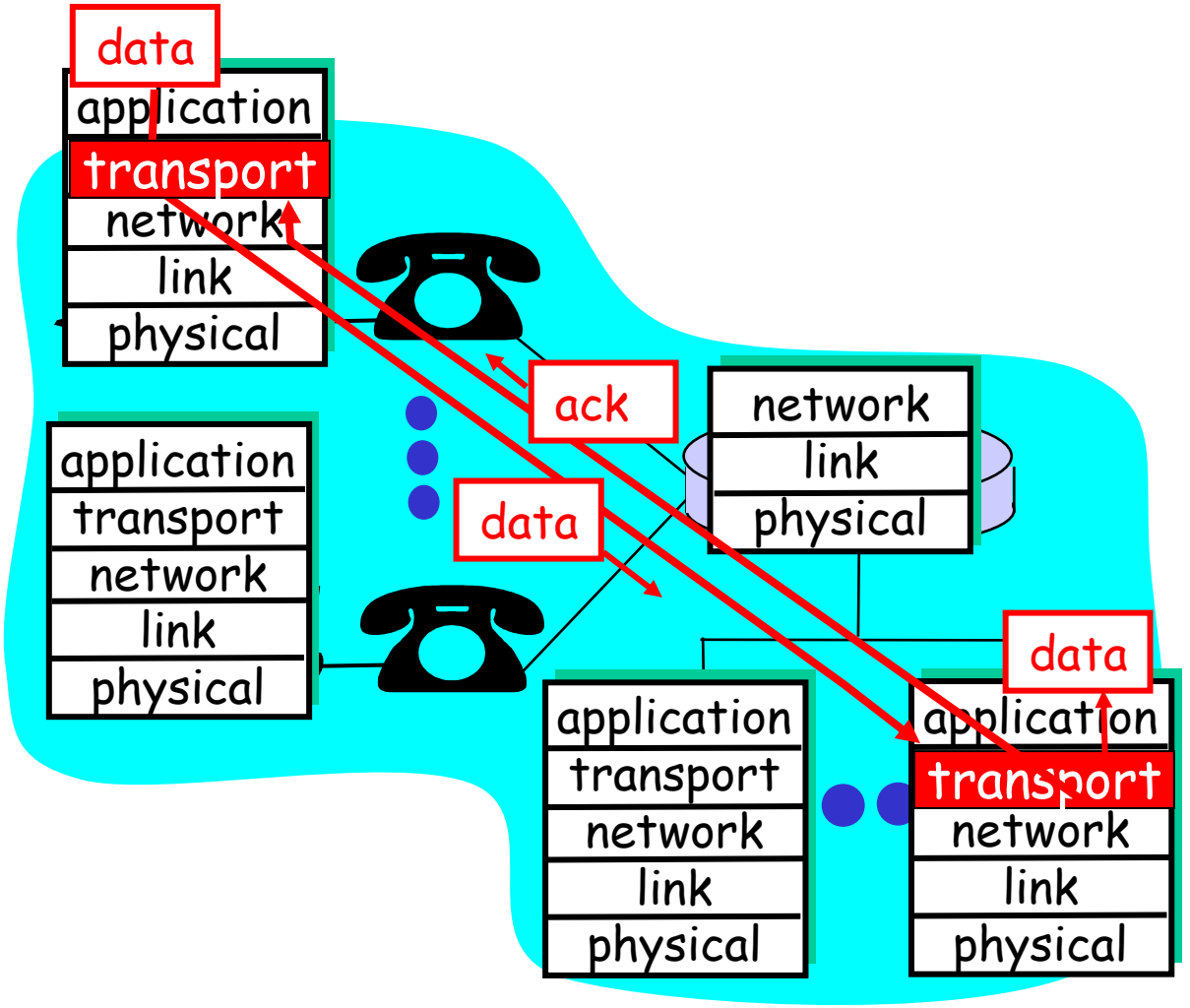
Layering: logical communication



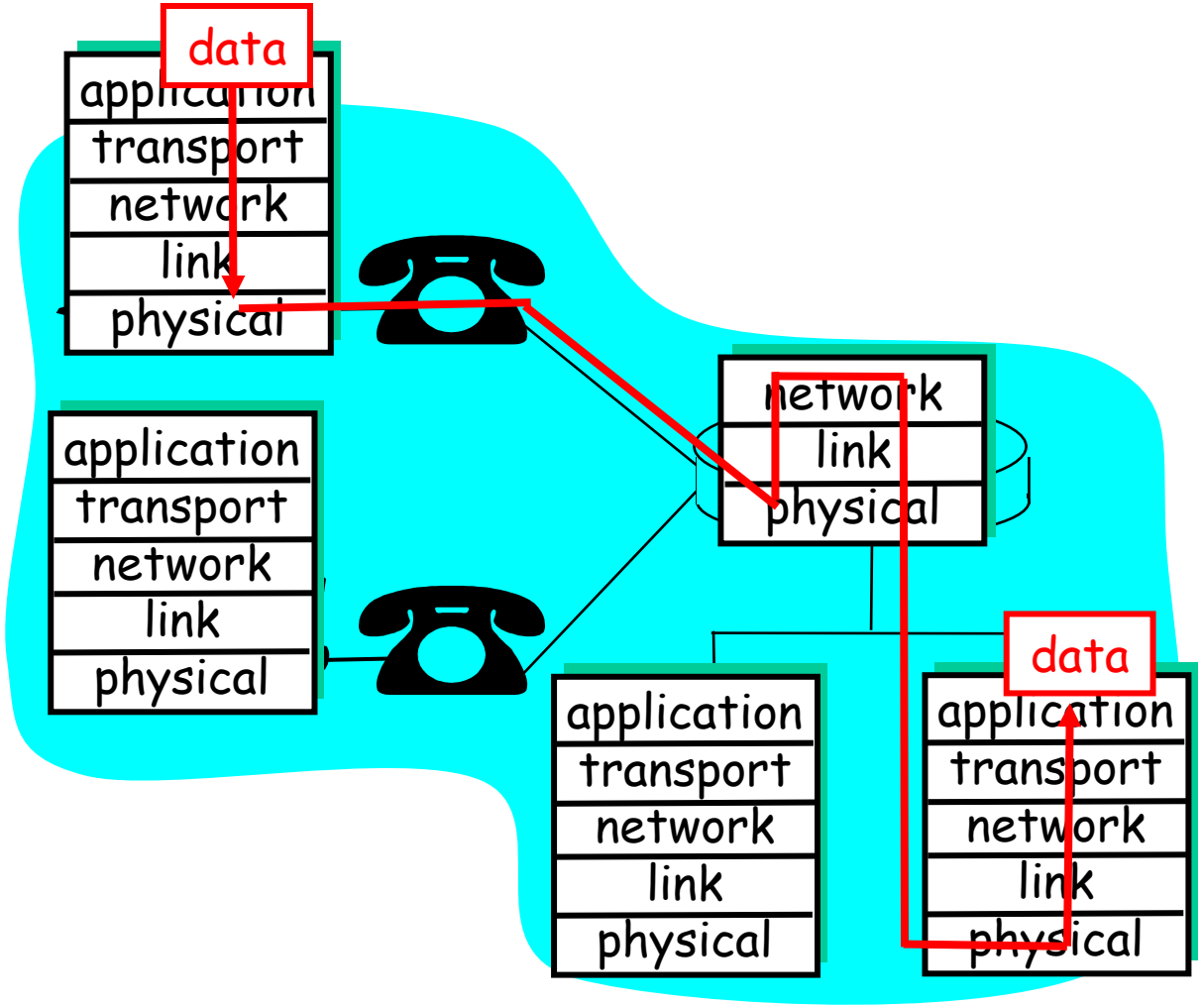
Layering: *logical* communication

E.g.: transport

- take data from app
- add addressing, and other info
- send packet to peer
- wait for peer to respond
- analogy: post office



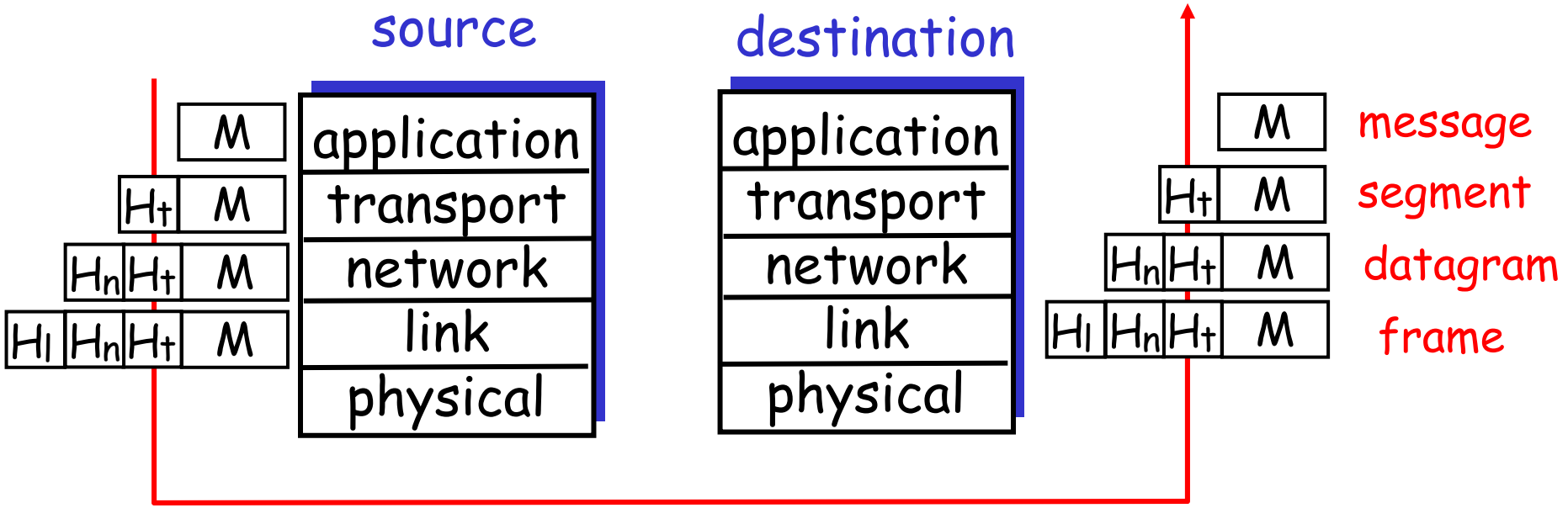
Layering: physical communication



Protocol layering and data

Each layer takes data from above

- adds header information to create new data unit
- passes new data unit to layer below



Internet History

1980-1990: new protocols, a proliferation of networks

- 1983: deployment of TCP/IP
- 1982: SMTP e-mail protocol defined
- 1983: DNS defined for name-to-IP-address translation
- 1985: FTP protocol defined
- 1988: TCP congestion control

- new national networks: Csnet, BITnet, NSFnet, Minitel
- 100,000 hosts connected to confederation of networks

Internet History

1990, 2000's: commercialization, the Web, new apps

- early 1990s: Web
  - hypertext
  - HTML, HTTP: Berners-Lee
  - 1994: Mosaic, later Netscape
  - late 1990's: commercialization of the Web

Late 1990's – 2000's:

- more killer apps: instant messaging, peer2peer file sharing (e.g., Naptser)
- network security to forefront
- est. 50 million host, 100 million+ users
- backbone links running at Gbps