Protocol "Layers"

Networks are complex!

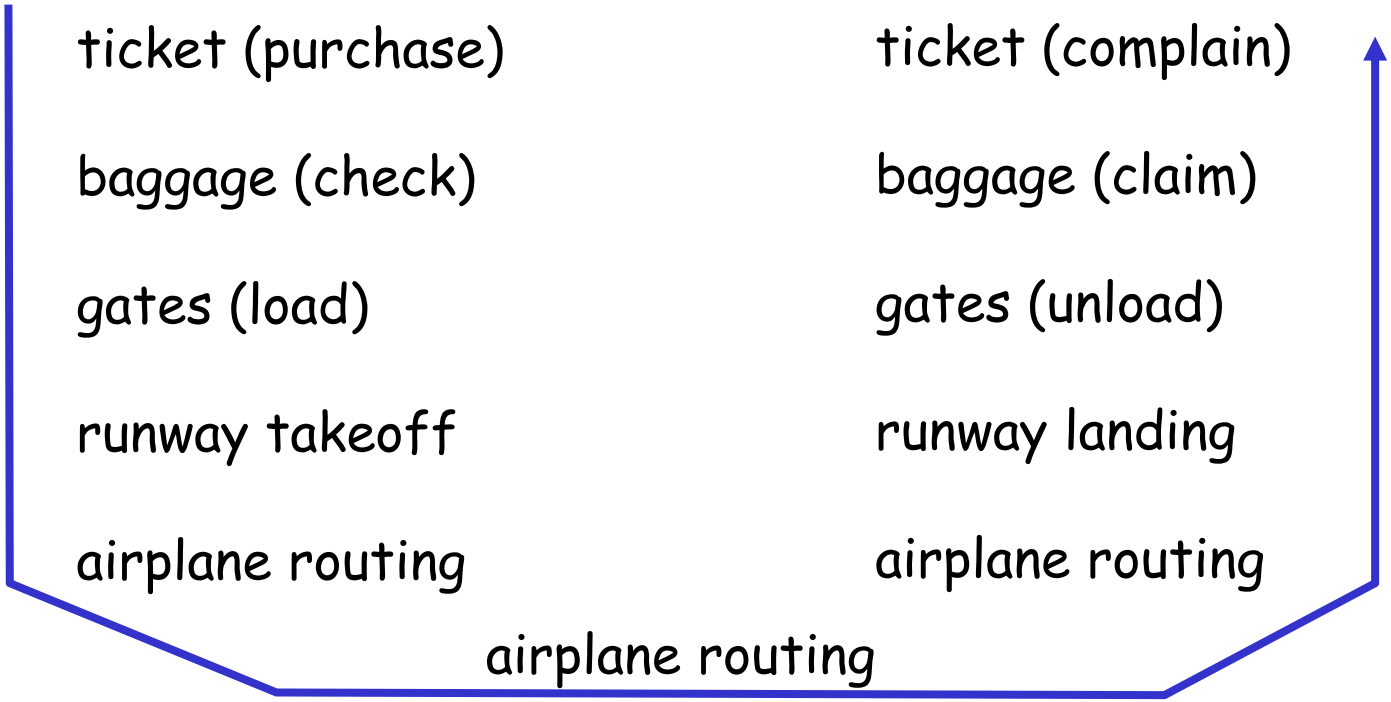
- many "pieces":
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

Question:

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

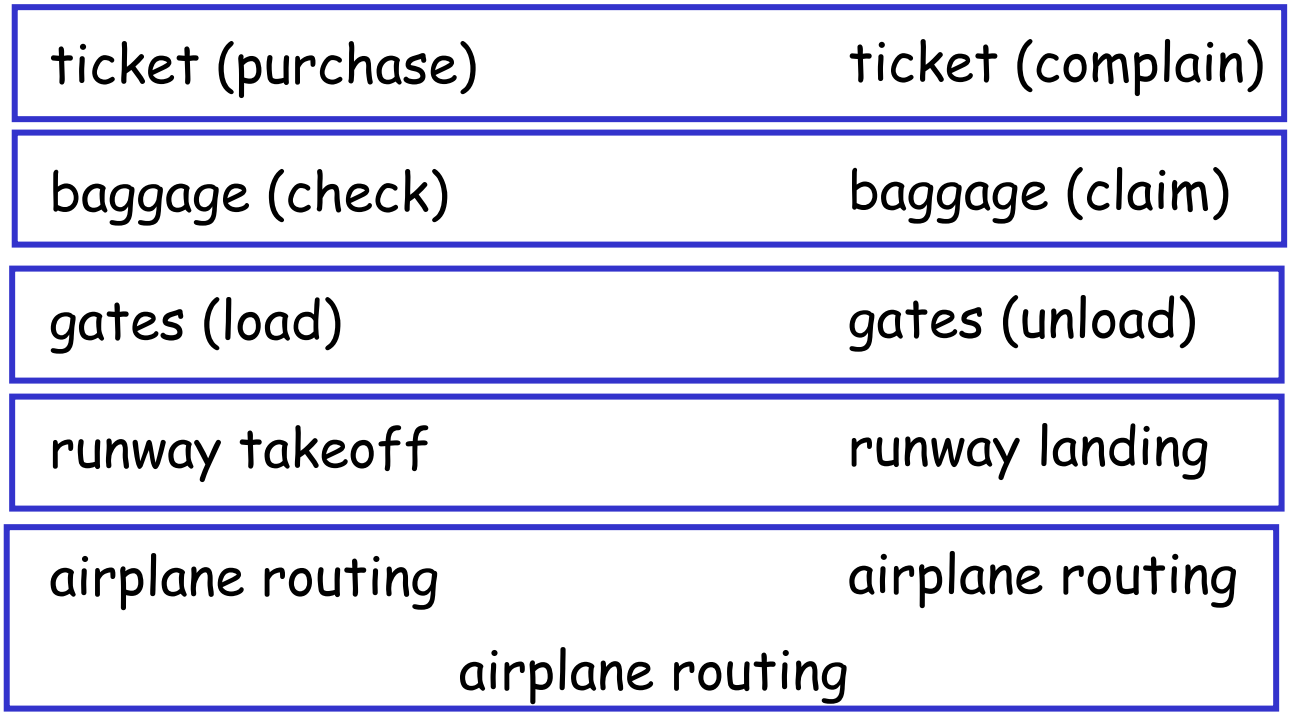
Or at least our discussion of networks?

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

Counter-to-counter delivery of person+bags

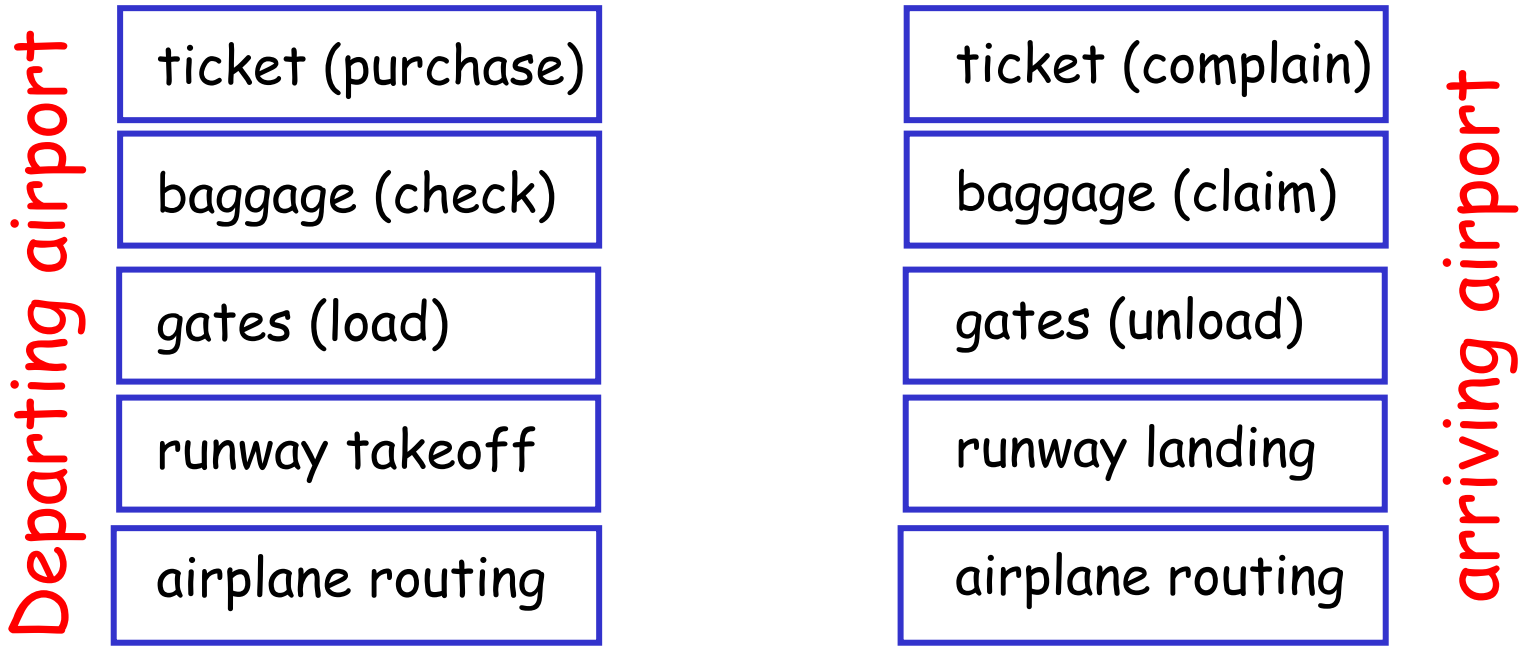
baggage-claim-to-baggage-claim delivery

people transfer: loading gate to arrival gate

runway-to-runway delivery of plane

airplane routing from source to destination

Distributed implementation of layer functionality



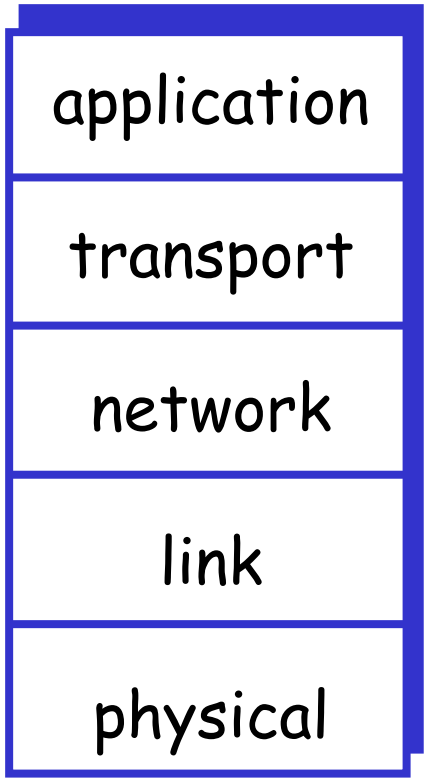
Why layering?

Dealing with complex systems:

- explicit structure allows identification, relationship of complex system's pieces
  - layered reference model for discussion
- modularization eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system
  - e.g., change in gate procedure doesn't affect rest of system
- layering considered harmful?

Internet protocol stack

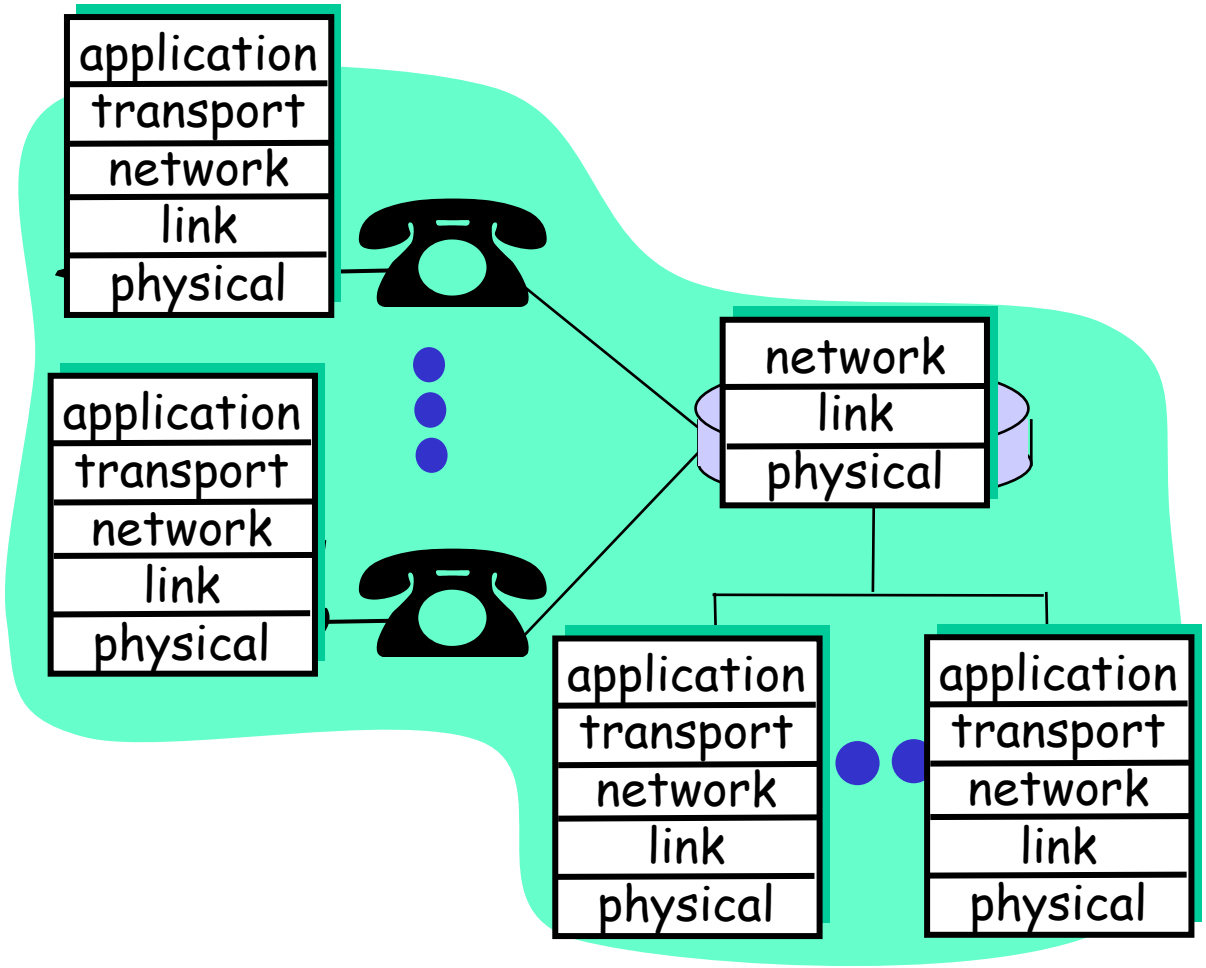
- application: supporting network applications
  - ftp, smtp, http
- transport: host-host data transfer
  - tcp, udp
- network: routing of datagrams from source to destination
  - ip, routing protocols
- link: data transfer between neighboring network elements
  - ppp, ethernet
- physical: bits "on the wire"



Layering: logical communication

Each layer:

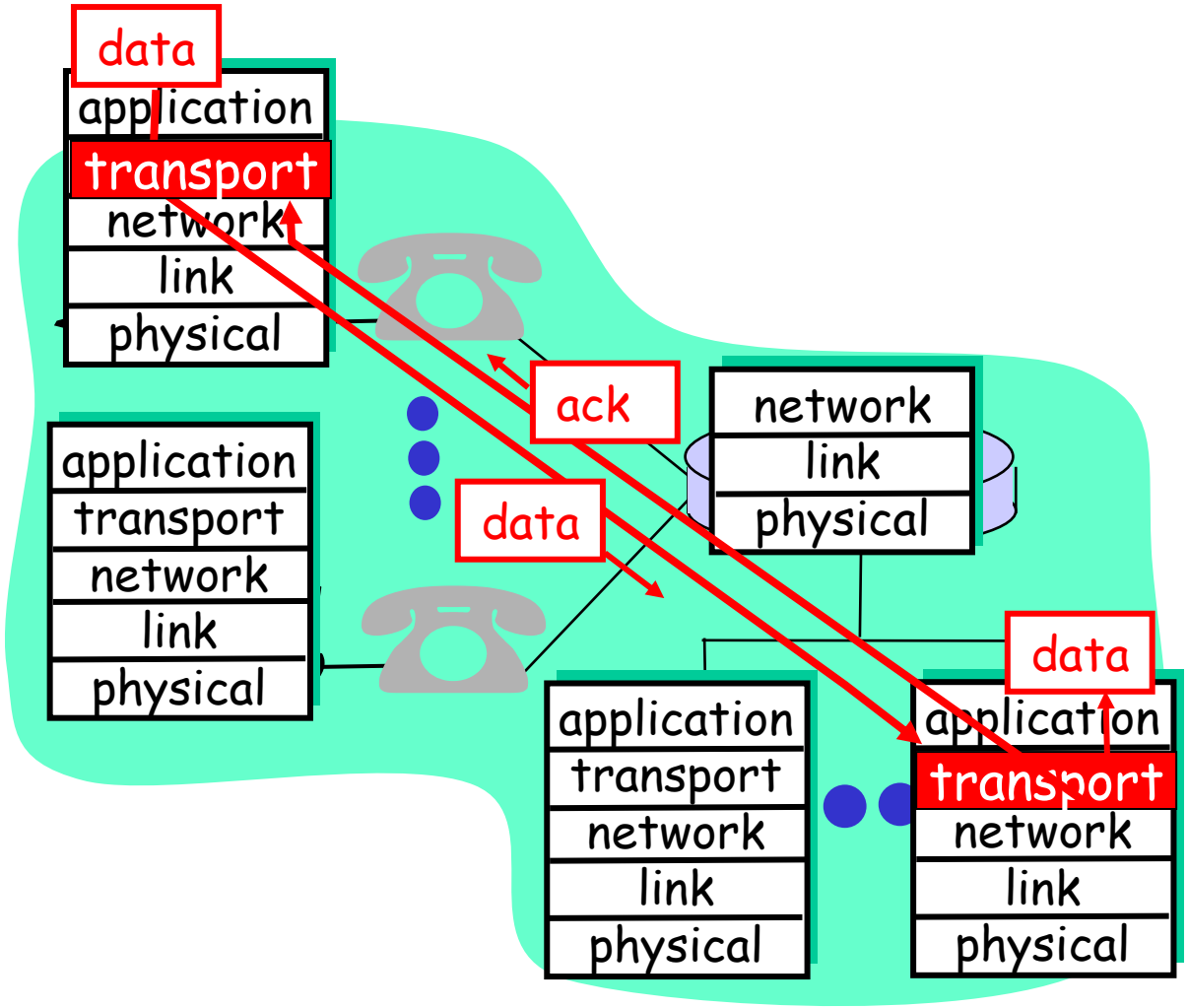
- distributed
- "entities" implement layer functions at each node
- entities perform actions, exchange messages with peers



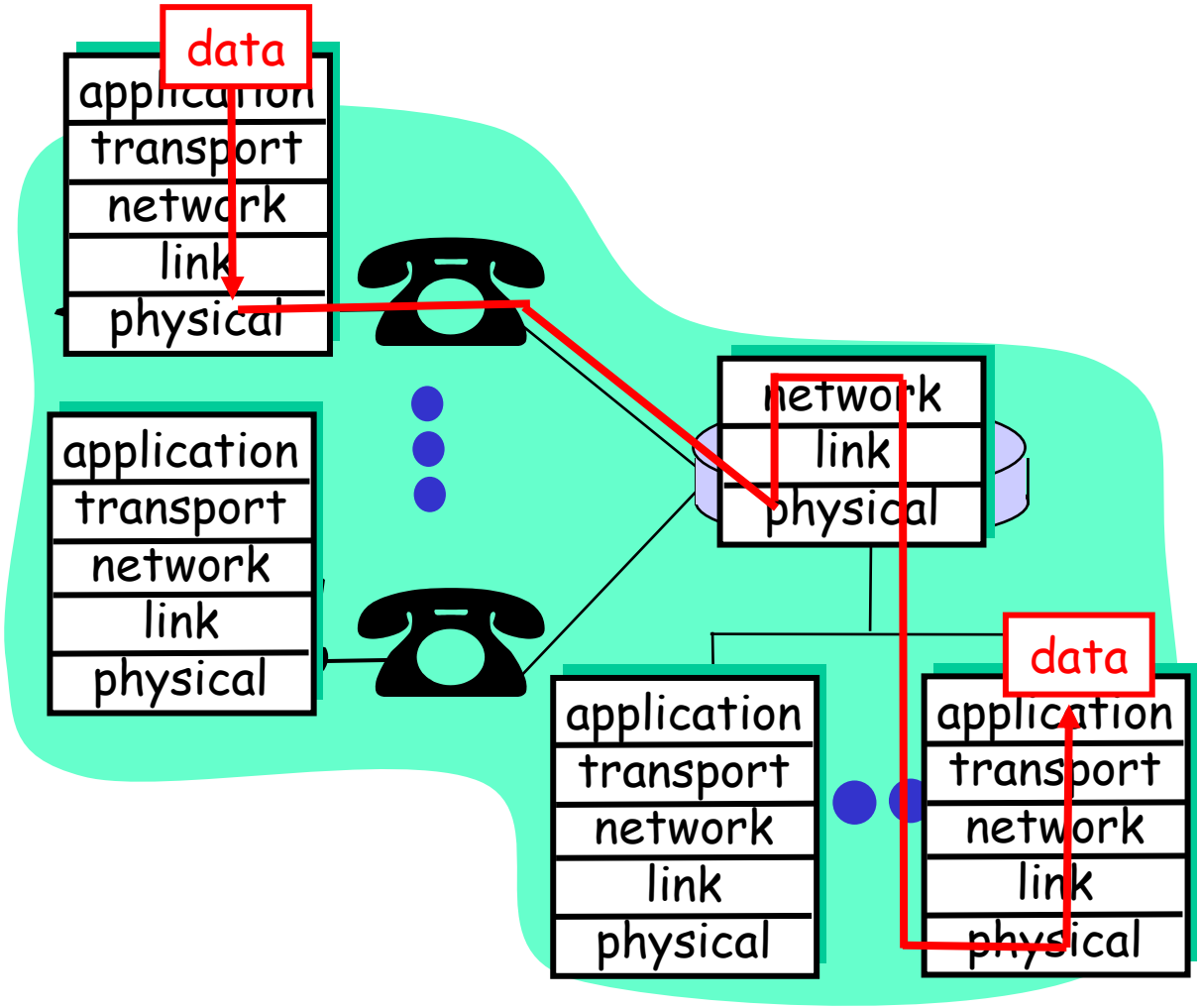
Layering: *logical* communication

E.g.: transport

- take data from app
- add addressing, reliability check info to form "datagram"
- send datagram to peer
- wait for peer to ack receipt
- analogy: post office



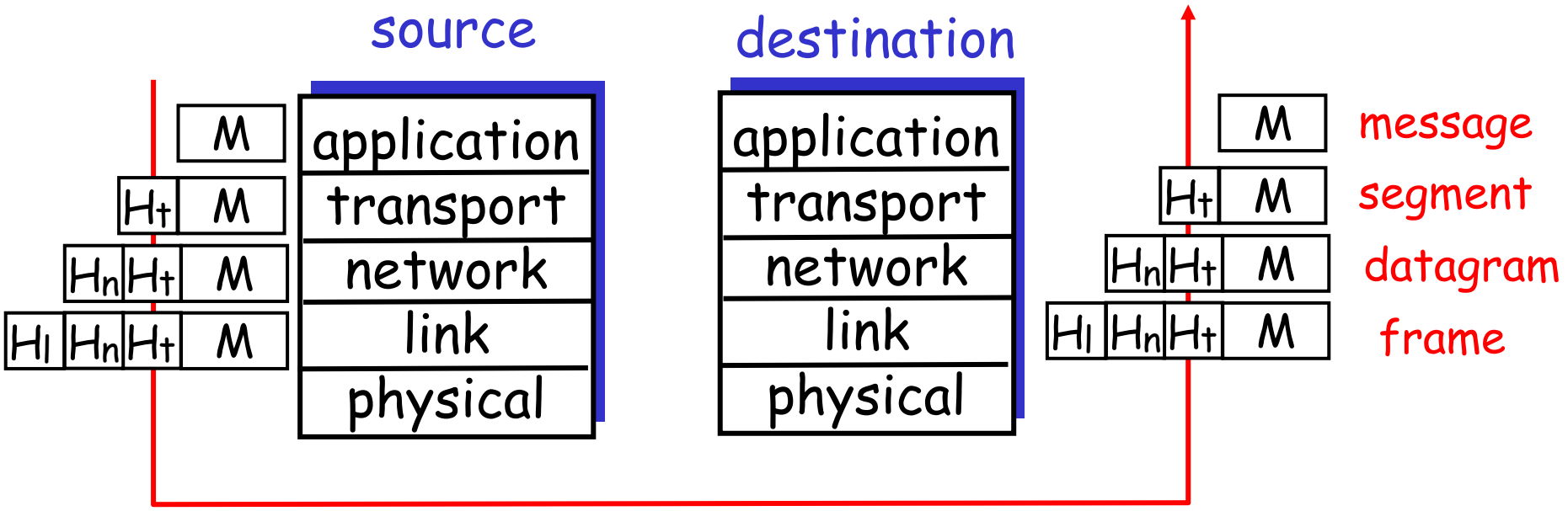
Layering: physical communication



Protocol layering and data

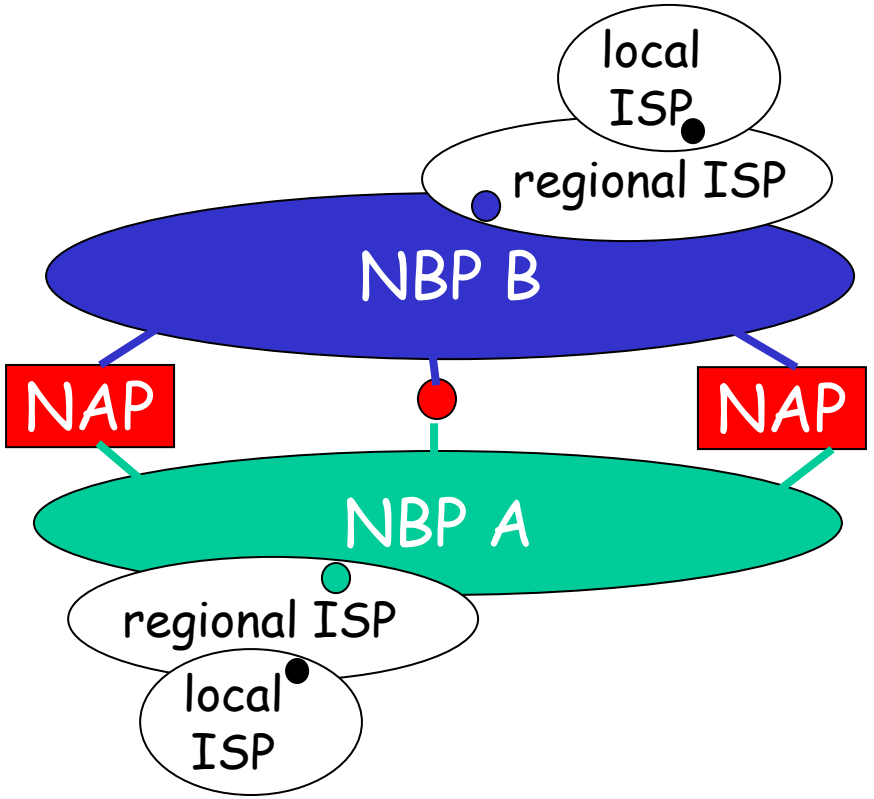
Each layer takes data from above

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



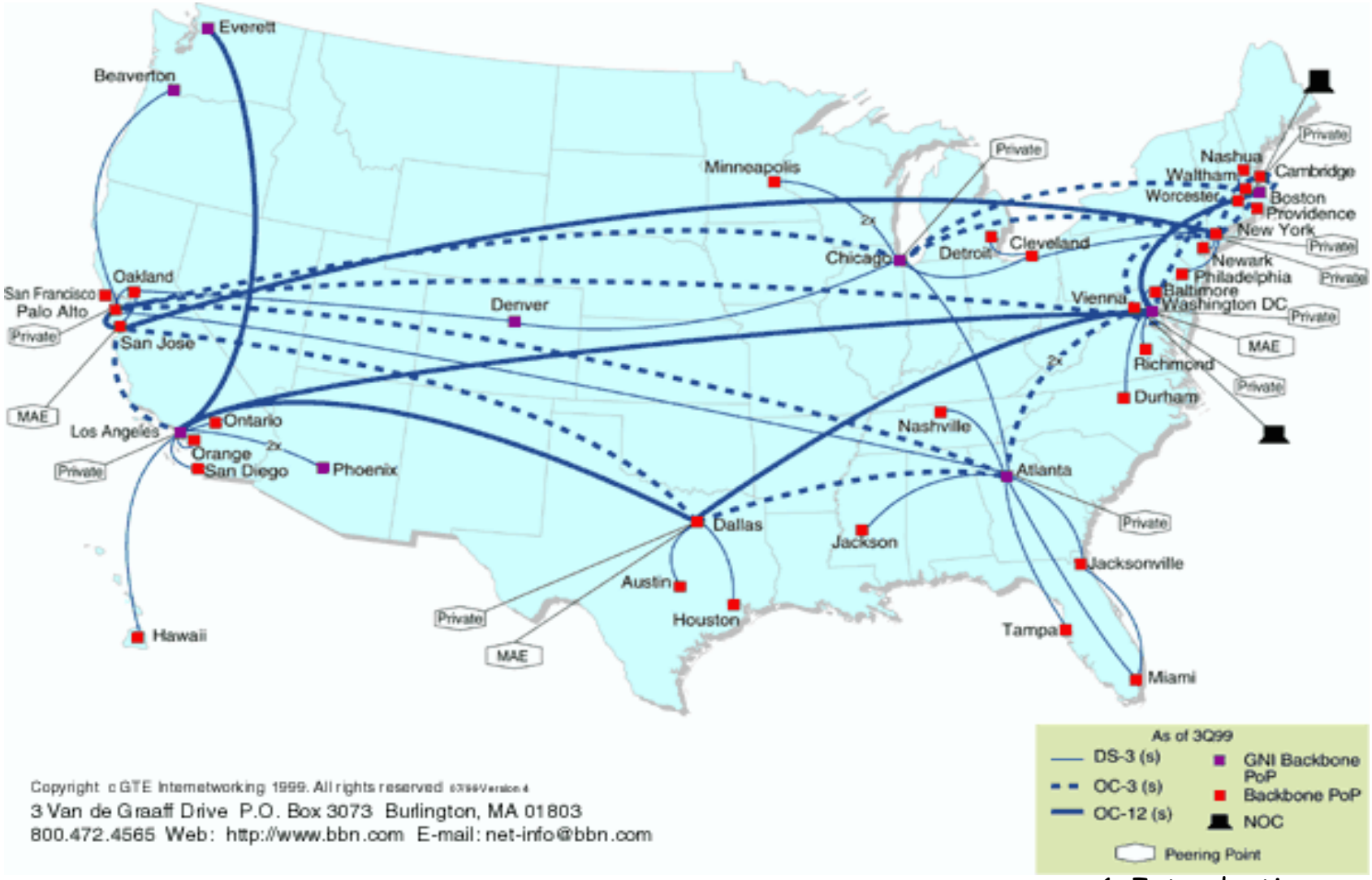
Internet structure: network of networks

- roughly hierarchical
- national/international backbone providers (NBPs)
  - e.g. BBN/GTE, Sprint, AT&T, IBM, UUNet
  - interconnect (peer) with each other privately, or at public Network Access Point (NAPs)
- regional ISPs
  - connect into NBPs
- local ISP, company
  - connect into regional ISPs



National Backbone Provider

e.g. BBN/GTE US backbone network



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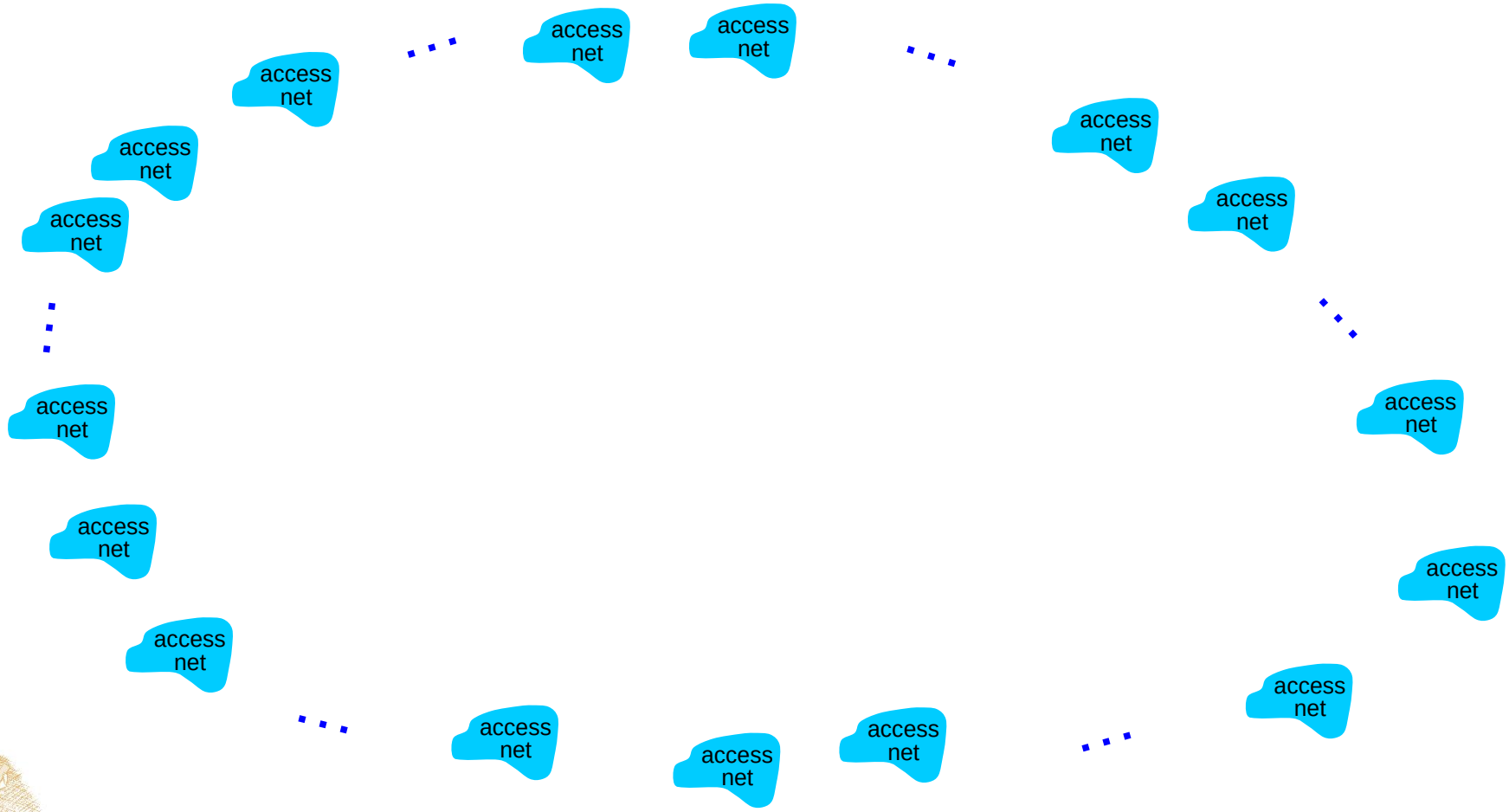
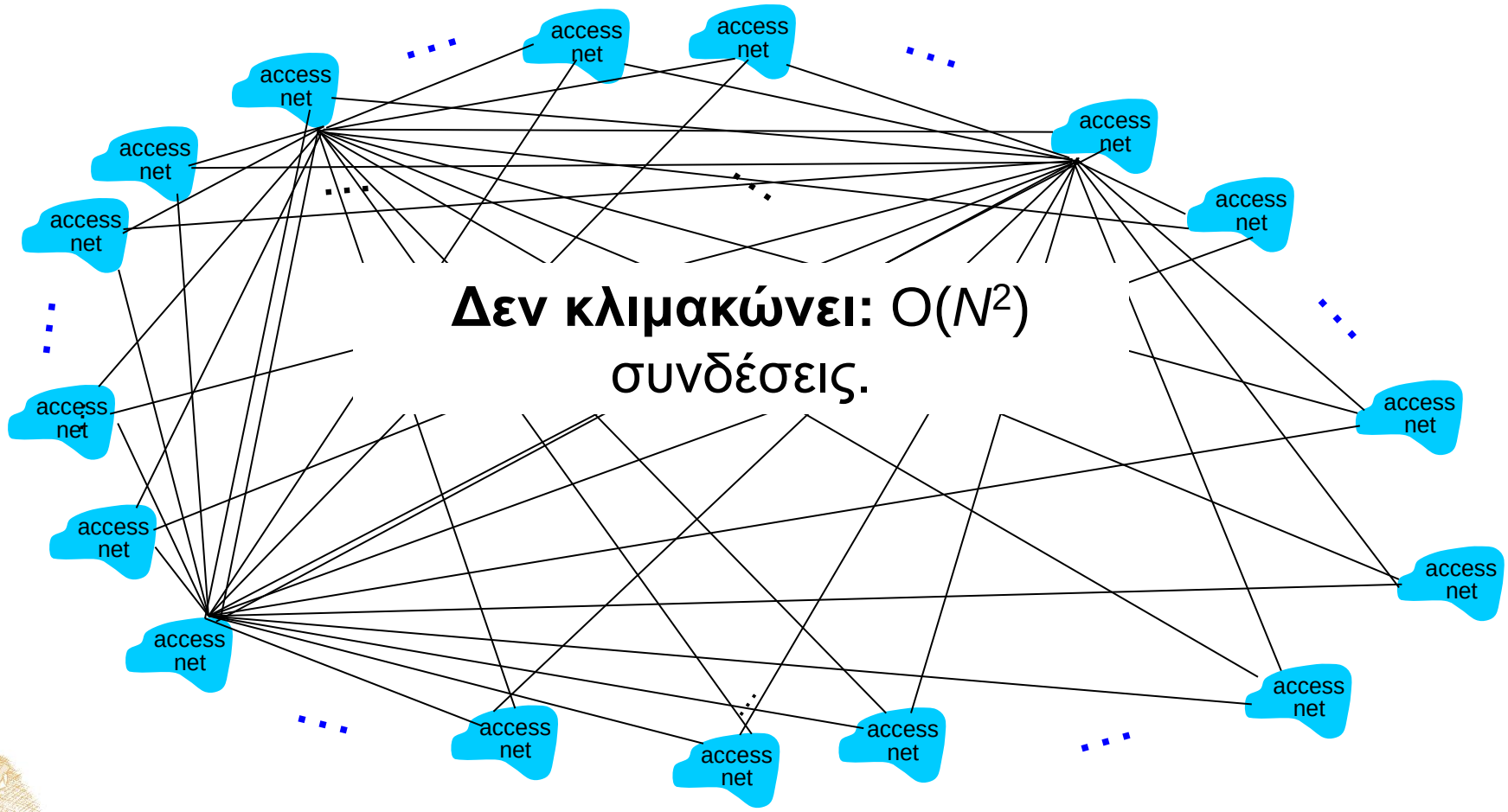
Δομή του Διαδικτύου: δίκτυο δικτύων

E: Δεδομένου ότι έχουμε εκατομμύρια ISPs πρόσβασης, πως τους διασυνδέουμε



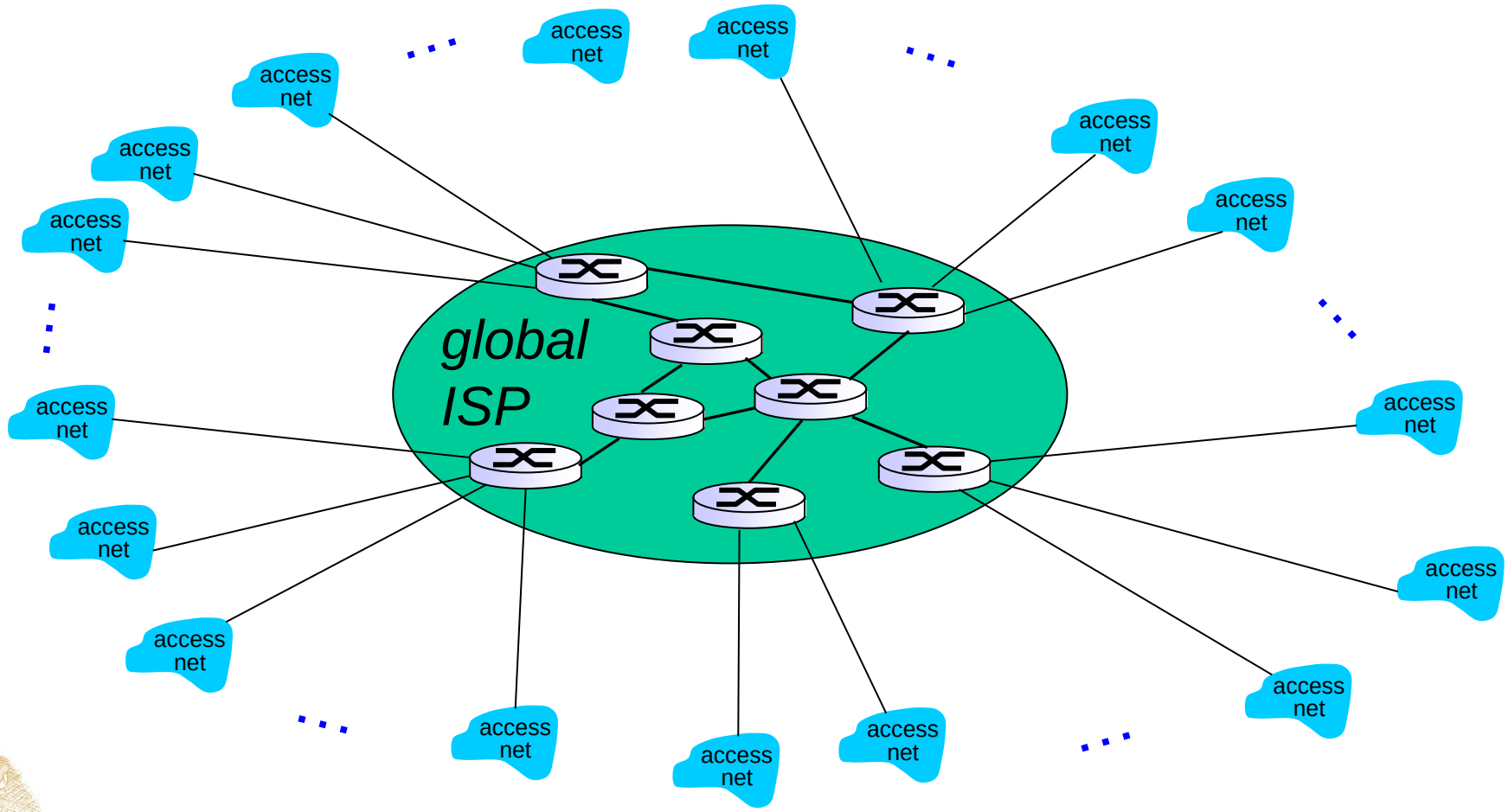
Δομή του Διαδικτύου: δίκτυο δικτύων

Επιλογή: Σύνδεσε κάθε ISP πρόσβασης με όλους τους άλλους



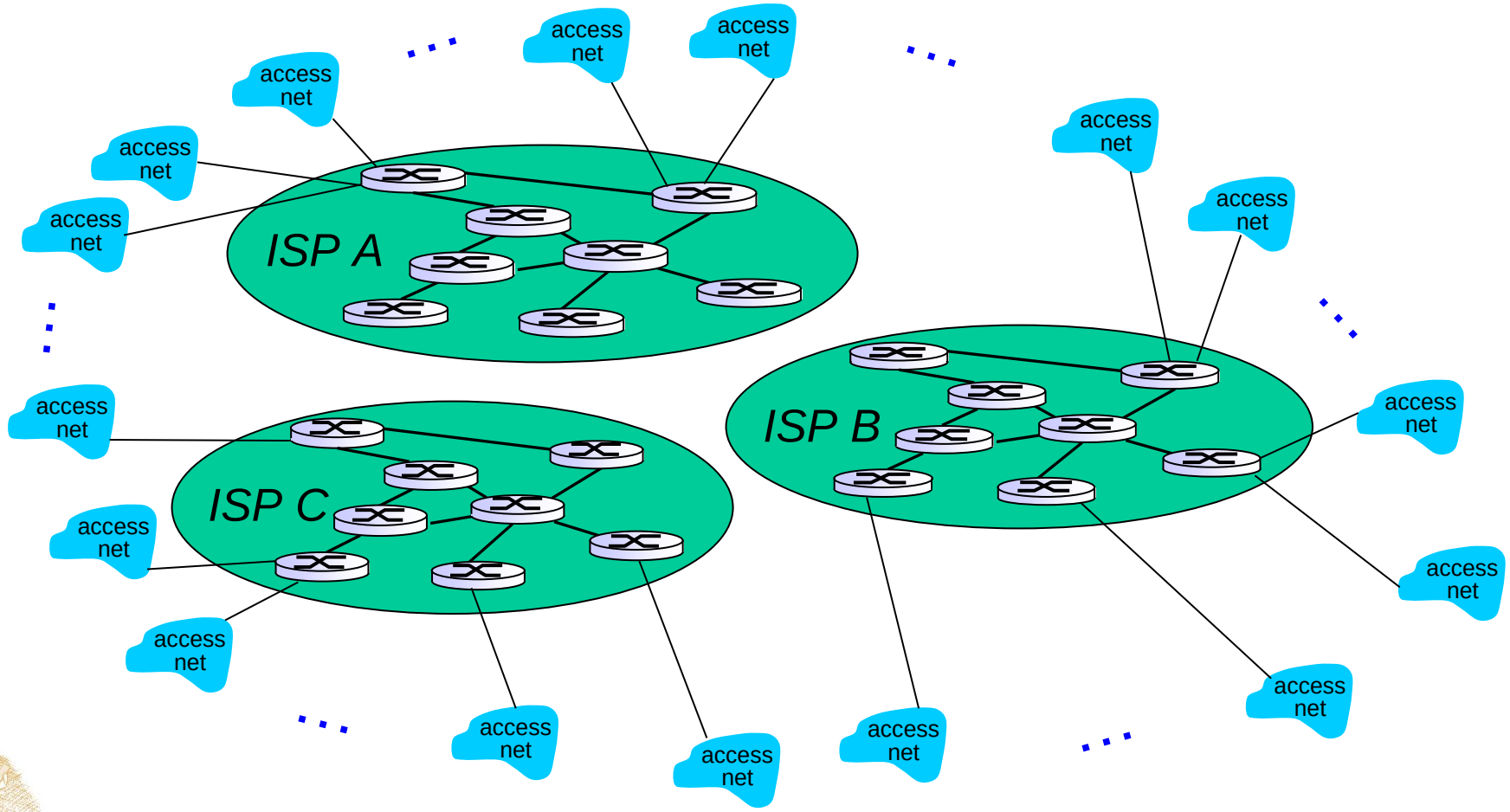
Δομή του Διαδικτύου: δίκτυο δικτύων

Επιλογή: Σύνδεσε κάθε ISP πρόσβασης με ένα παγκόσμιο ISP μεταφοράς; **Πελάτης** και **παροχέας** ISPs έχουν οικονομική συμφωνία



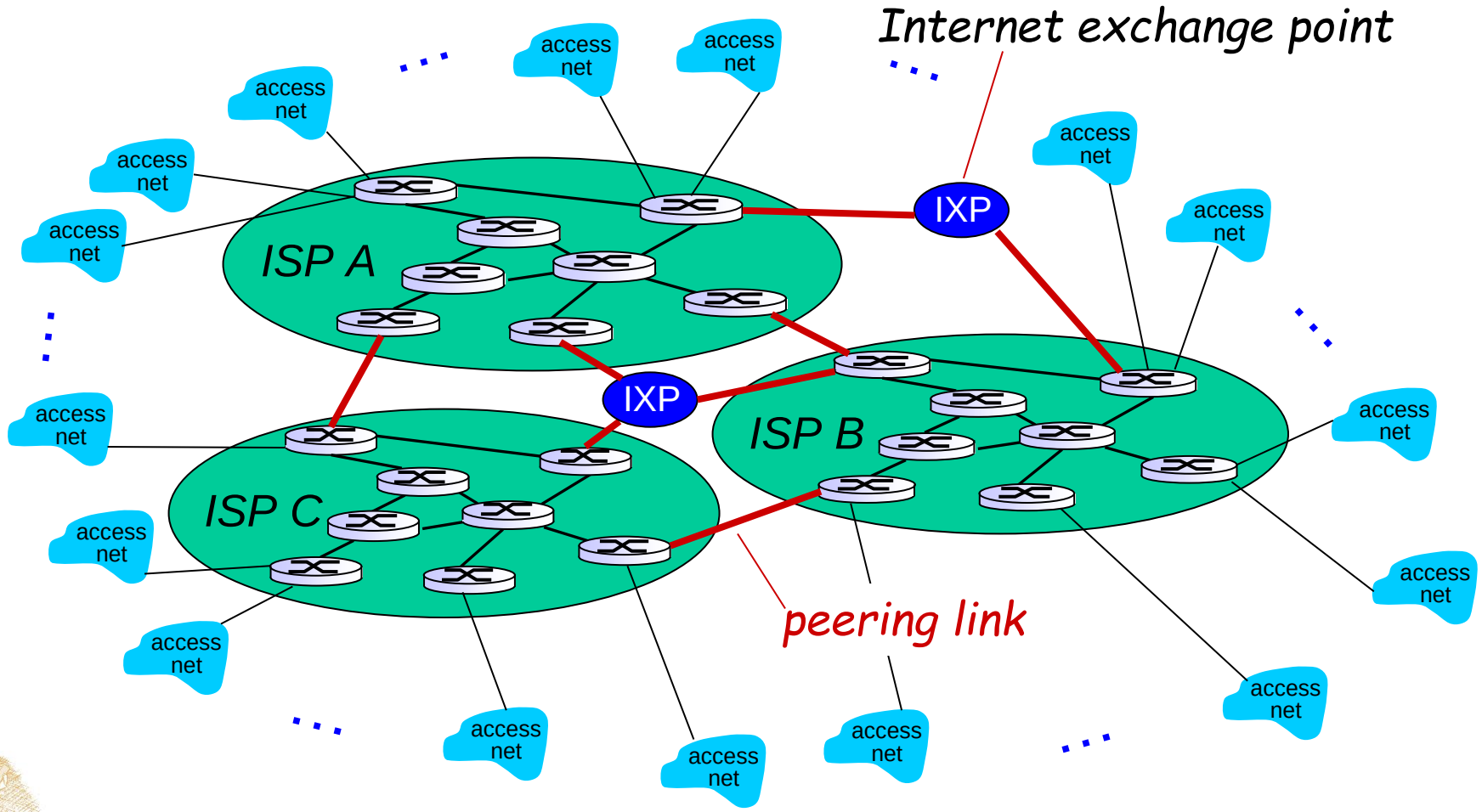
Δομή του Διαδικτύου: δίκτυο δικτύων

Αλλά αν ένας παγκόσμιος ISP είναι βιώσιμη επιχείρηση, θα υπάρξουν ανταγωνιστές…



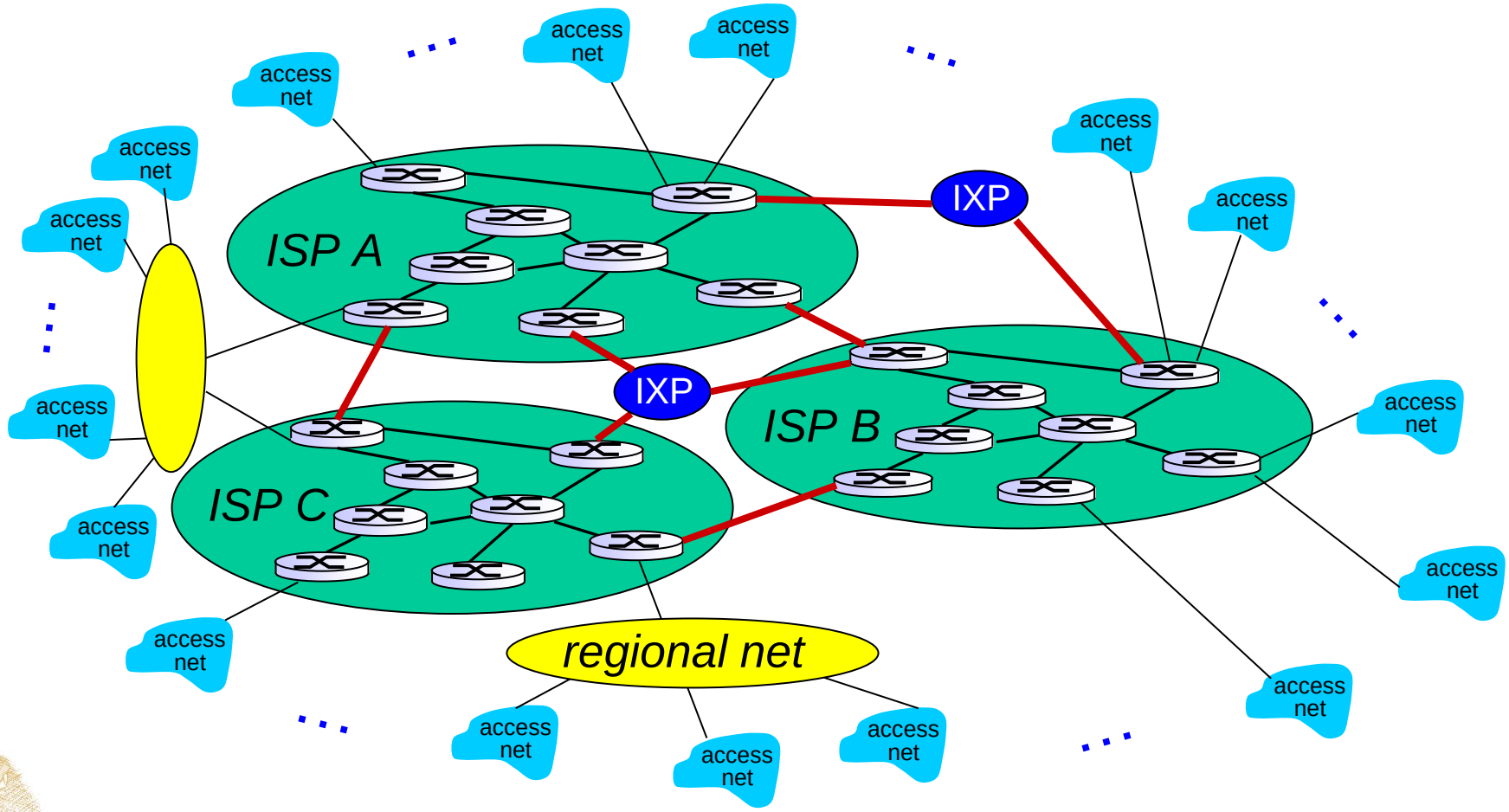
Δομή του Διαδικτύου: δίκτυο δικτύων

Αλλά αν ένας παγκόσμιος ISP είναι βιώσιμη επιχείρηση, θα υπάρξουν ανταγωνιστές…οι οποίοι θα πρέπει να διασυνδεθούν



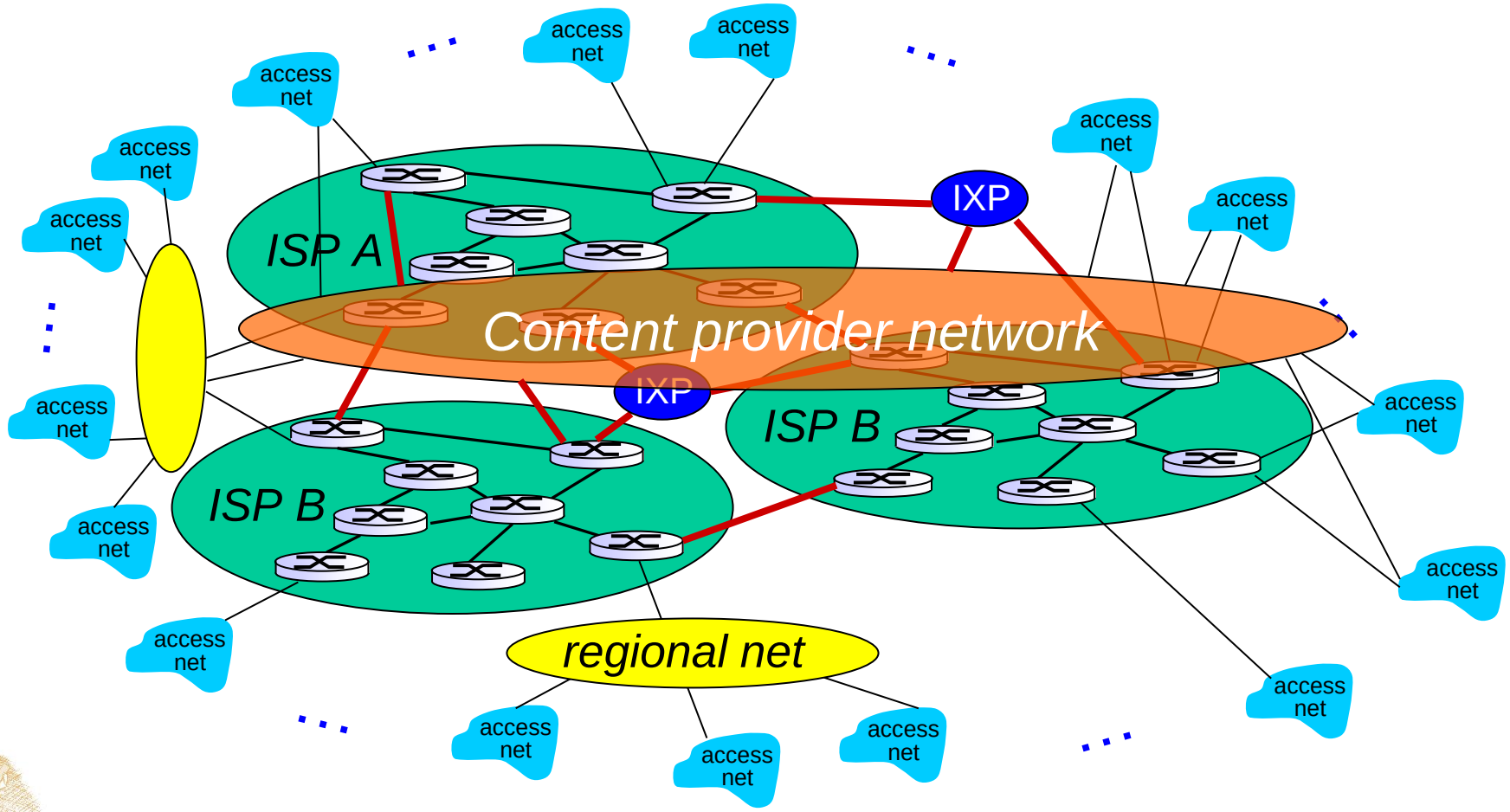
Δομή του Διαδικτύου: δίκτυο δικτύων

…και περιφερειακά δίκτυα μπορεί να αναδυθούν για την διασύνδεση των δικτύων πρόσβασης στους ISPs

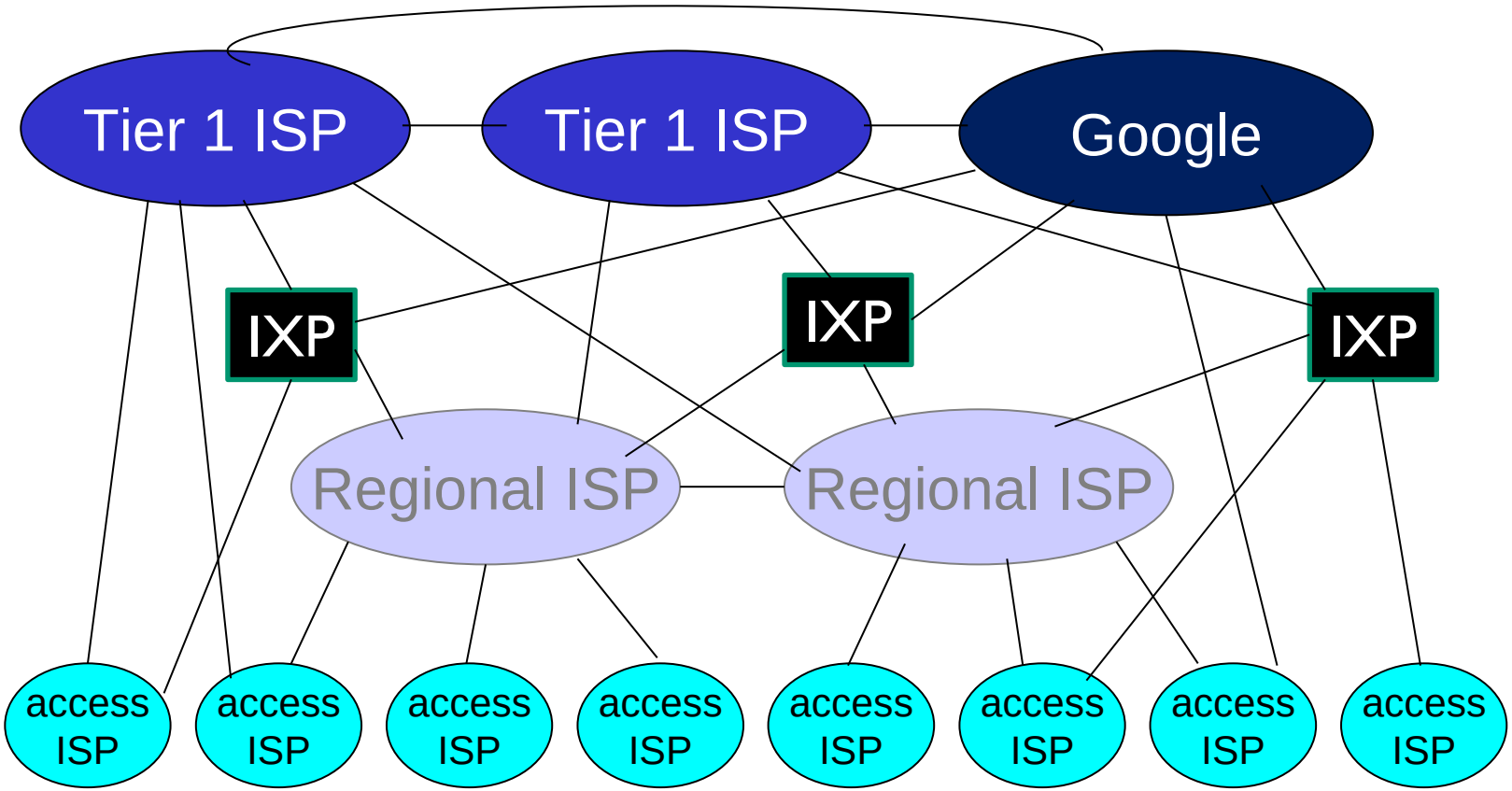


Δομή του Διαδικτύου: δίκτυο δικτύων

…και παροχείς περιεχομένου (π.χ. Google, Microsoft, Akamai) μπορεί να λειτουργήσουν τα δικά τους δίκτυα για να φέρουν υπηρεσίες και περιεχόμενο πλησιέστερα στους τελικούς χρήστες



Δομή του Διαδικτύου: δίκτυο δικτύων



- Στο κέντρο: μικρός αριθμός καλό-διασυνδεδεμένων μεγάλων δικτύων
  - **"tier-1" εμπορικοί ISPs** (π.χ., Level 3, Sprint, AT&T, NTT), εθνική και διεθνής κάλυψη
  - **Δίκτυο παροχέα περιεχομένου** (π.χ., Google): ιδιωτικό δίκτυο που συνδέει τα κέντρα δεδομένων του στο Διαδίκτυο, συχνά παρακάμπτοντας tier-1, περιφερειακούς ISPs

Internet History

1961-1972: Early packet-switching principles

- 1961: Kleinrock - queueing theory shows effectiveness of packet-switching
- 1964: Baran - packet-switching in military nets
- 1967: **ARPAnet** conceived by Advanced Reearch Projects Agency
- 1969: first ARPAnet node operational

- 1972:
  - **ARPAnet** demonstrated publicly
  - NCP (Network Control Protocol) first host-host protocol
  - first e-mail program
  - ARPAnet has 15 nodes

Internet History

1972-1980: Internetworking, new and proprietary nets

- 1970: ALOHAnet satellite network in Hawaii
- 1973: Metcalfe's PhD thesis proposes Ethernet
- 1974: Cerf and Kahn - architecture for interconnecting networks
- late70's: proprietary architectures: DECnet, SNA, XNA
- late 70's: switching fixed length packets (ATM precursor)
- 1979: ARPAnet has 200 nodes

Cerf and Kahn's internetworking principles:

- minimalism, autonomy - no internal changes required to interconnect networks
- best effort service model
- stateless routers
- decentralized control

define today's Internet architecture

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's: commercialization, the WWW

- Early 1990's: ARPAnet decomissioned
- 1991: NSF lifts restrictions on commercial use of NSFnet (decommissioned, 1995)
- early 1990s: WWW
  - hypertext [Bush 1945, Nelson 1960's]
  - HTML, http: Berners-Lee
  - 1994: Mosaic, later Netscape
  - late 1990's: commercialization of the WWW

- Late 1990's:
  - est. 50 million computers on Internet
  - est. 100 million+ users
  - backbone links runnning at 1 Gbps

ATM: Asynchronous Transfer Mode nets

Internet:

- today's *de facto* standard for global data networking

1980's:

- telco's develop ATM: competing network standard for carrying high-speed voice/data
- standards bodies:
  - ATM Forum
  - ITU

ATM principles:

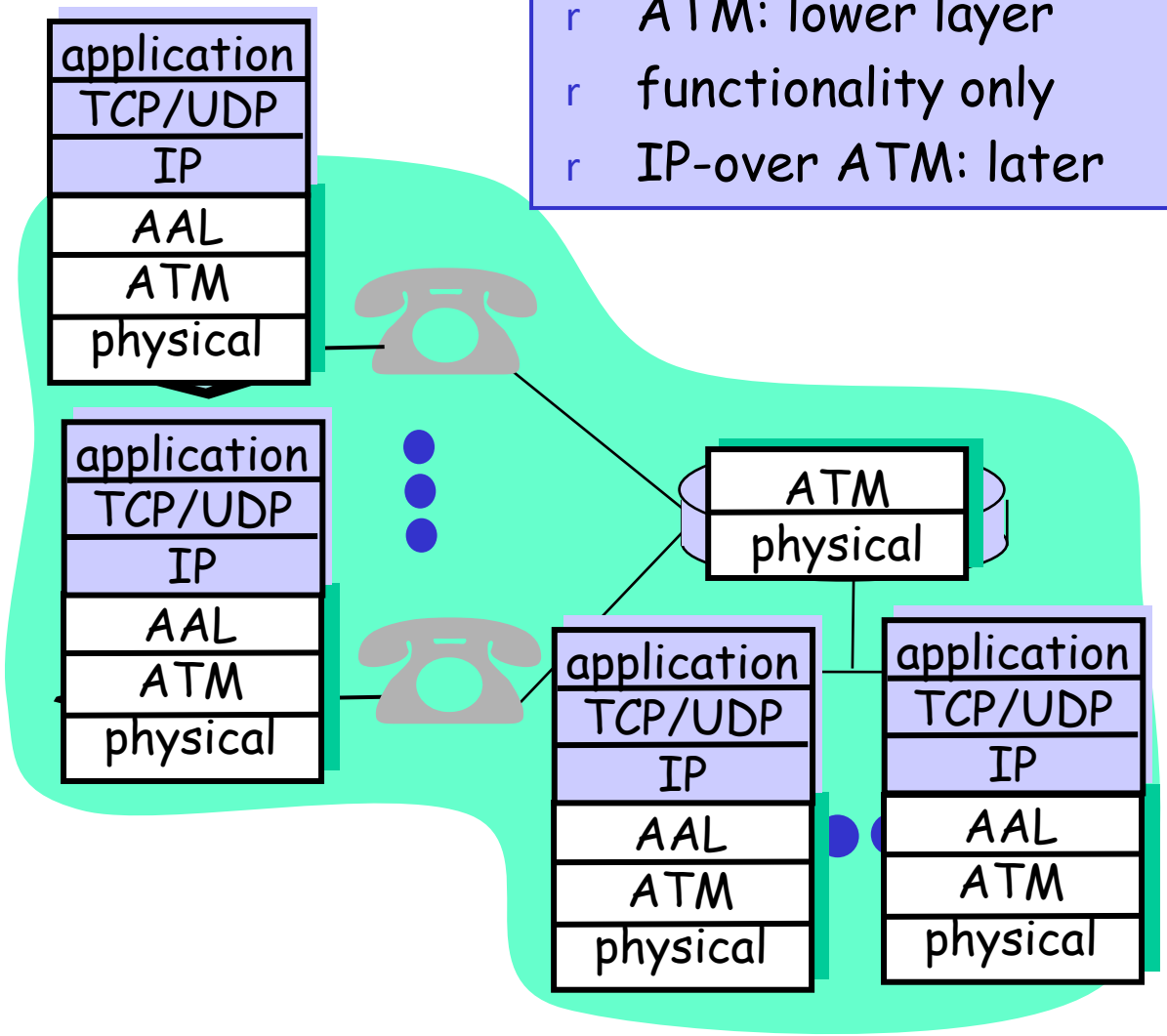
- small (48 byte payload, 5 byte header) fixed length *cells* (like packets)
  - fast switching
  - small size good for voice
- virtual-circuit network: switches maintain state for each "call"
- well-defined interface between "network" and "user" (think of telephone company)

ATM layers

- ATM Adaptation Layer (AAL): interface to upper layers
  - end-system
  - segmentation/reassembly
- ATM Layer: cell switching
- Physical

Where's the application?

- ATM: lower layer
- functionality only
- IP-over ATM: later



Chapter 1: Summary

Covered a "ton" of material!

- Internet overview
- what's a protocol?
- network edge, core, access network
- performance: loss, delay
- layering and service models
- backbones, NAPs, ISPs
- history
- ATM network

You now hopefully have:

- context, overview, "feel" of networking
- more depth, detail *later* in course