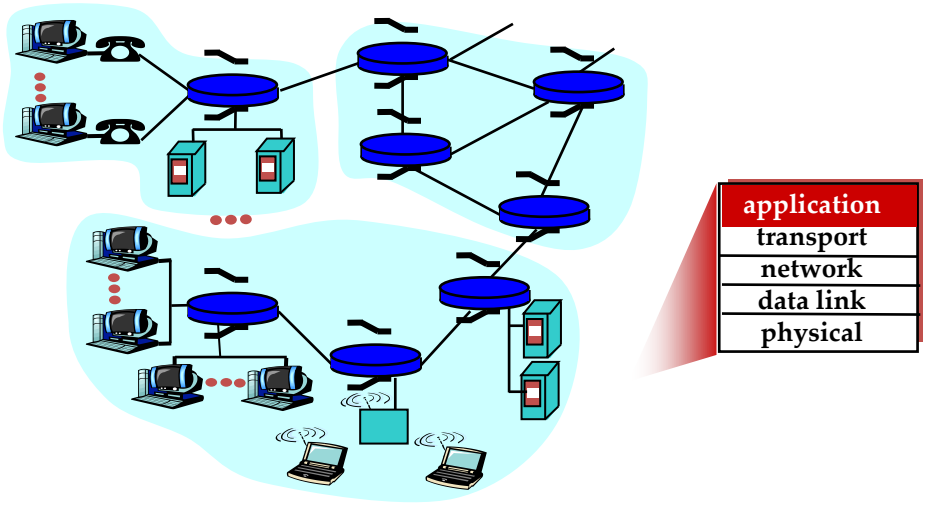
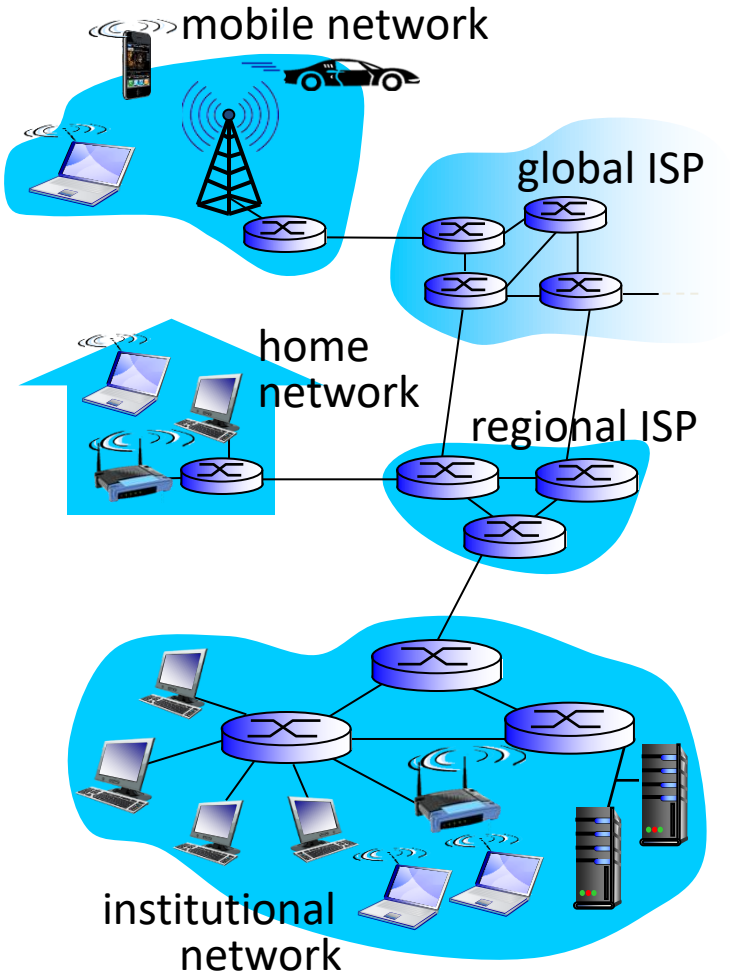
CS 4390
Computer Networks



The Internet – Network Structure

A Closer Look at Network Structure:

- *network edge:*
  - hosts: clients and servers
  - servers often in data centers
- *network core:*
  - interconnected routers
  - network of networks



- *edge: access networks*
  - Wired or wireless
- *core: core networks*
  - Routers and data communication links

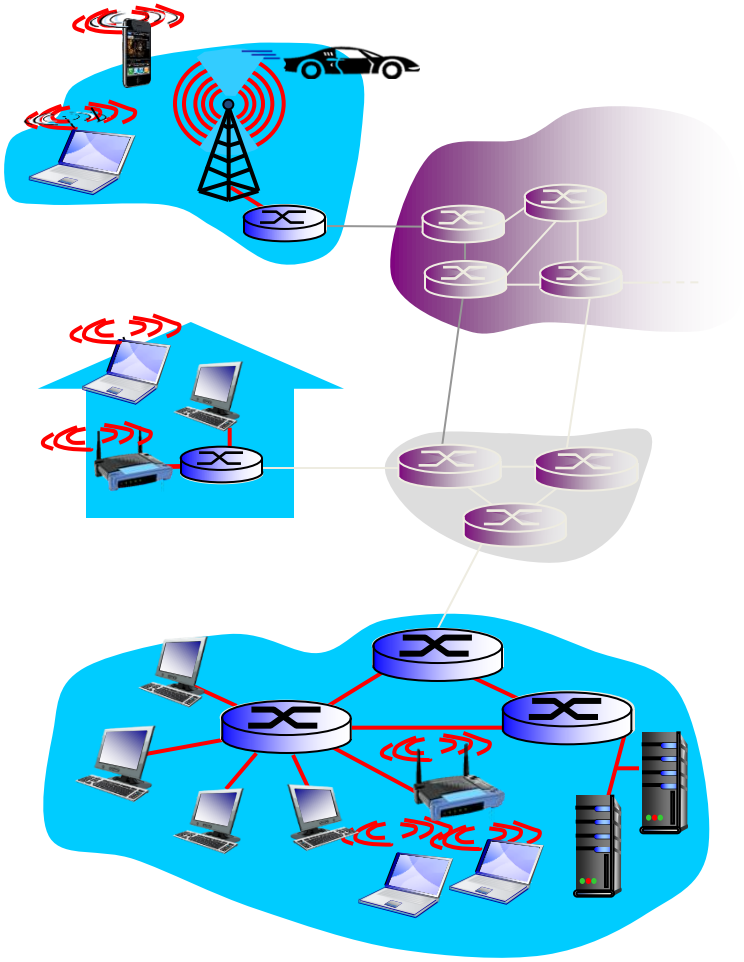
Access Networks

Q: How to connect end systems to edge router?

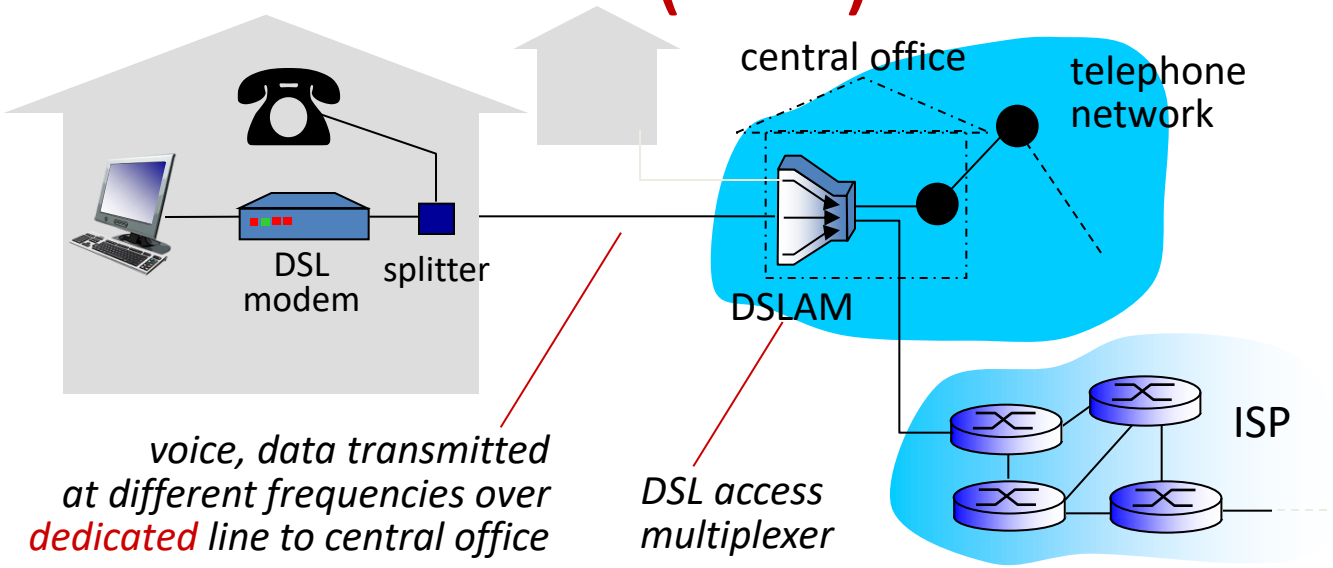
- residential access nets
- institutional access networks (school, company)
- mobile access networks

considerations:

- bandwidth (bits per second) of access network?
- shared or dedicated?

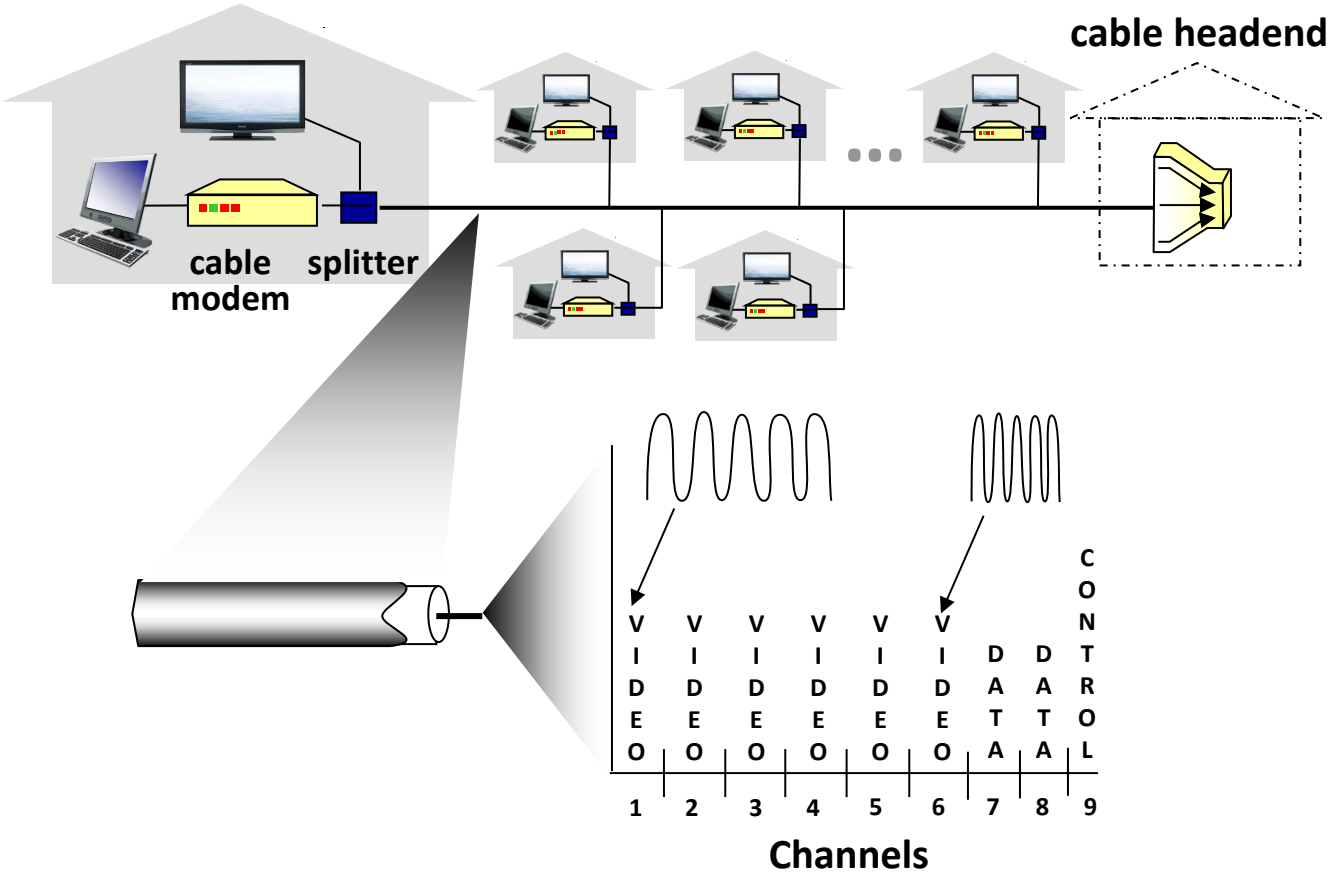


Access Net: Digital Subscriber Line (DSL)



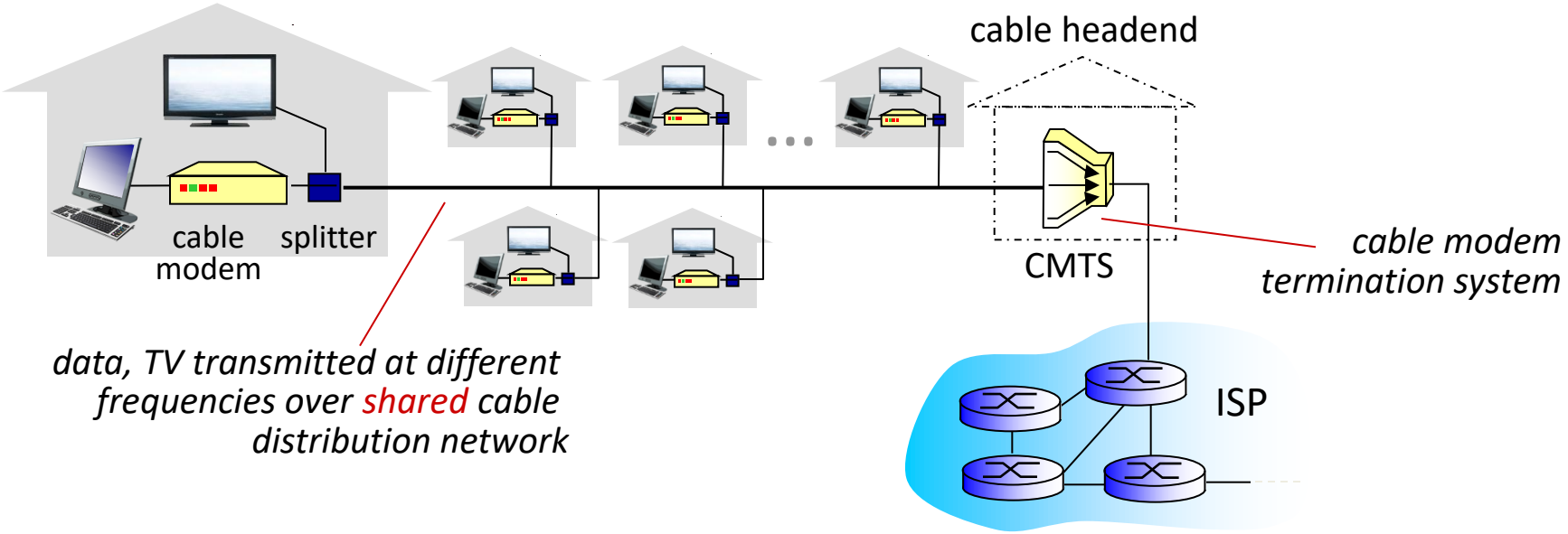
- use *existing* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
- < 24 Mbps downstream transmission rate (typically < 10 Mbps)

Access Net: Cable



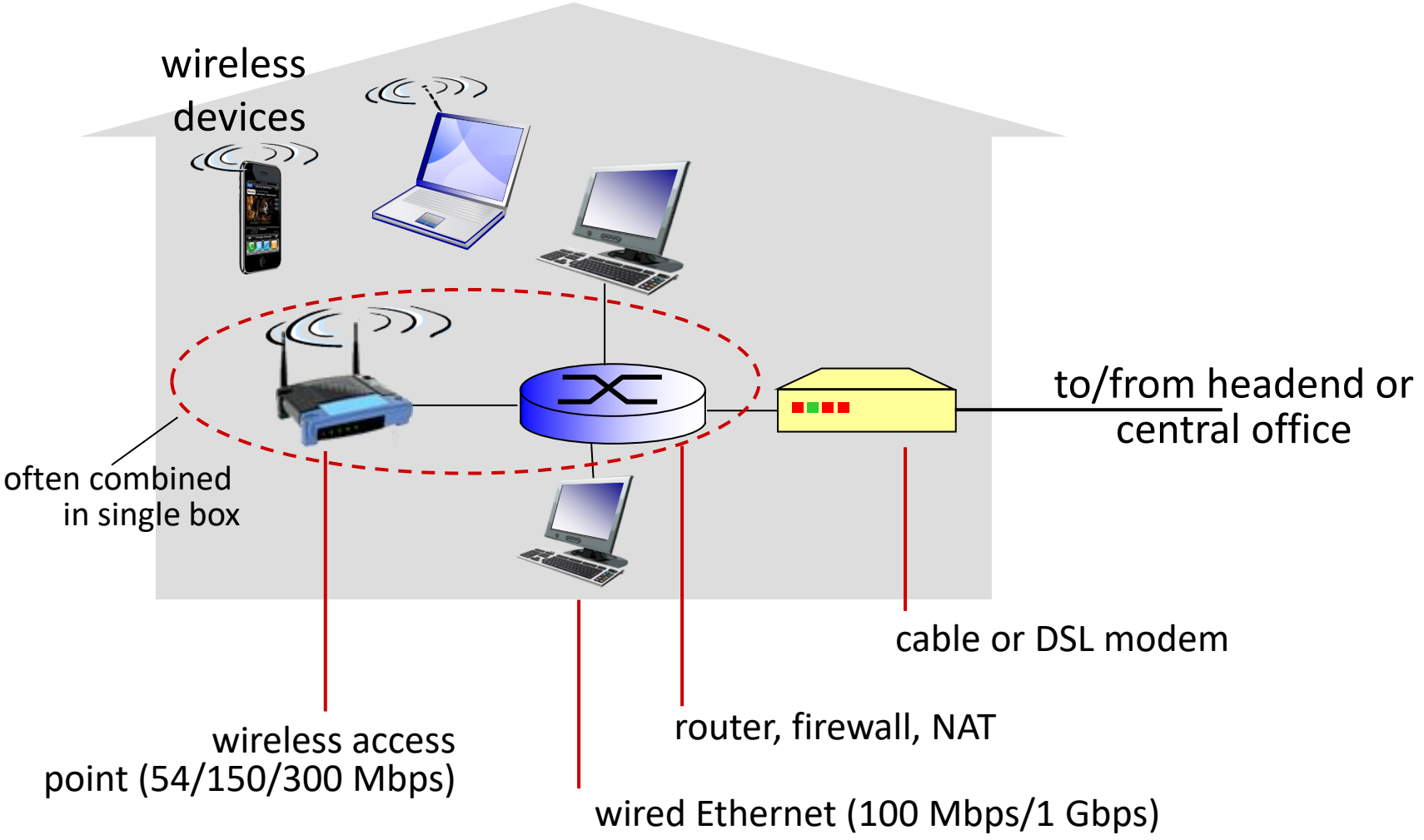
frequency division multiplexing: different channels transmitted in different frequency bands

Access Net: Cable

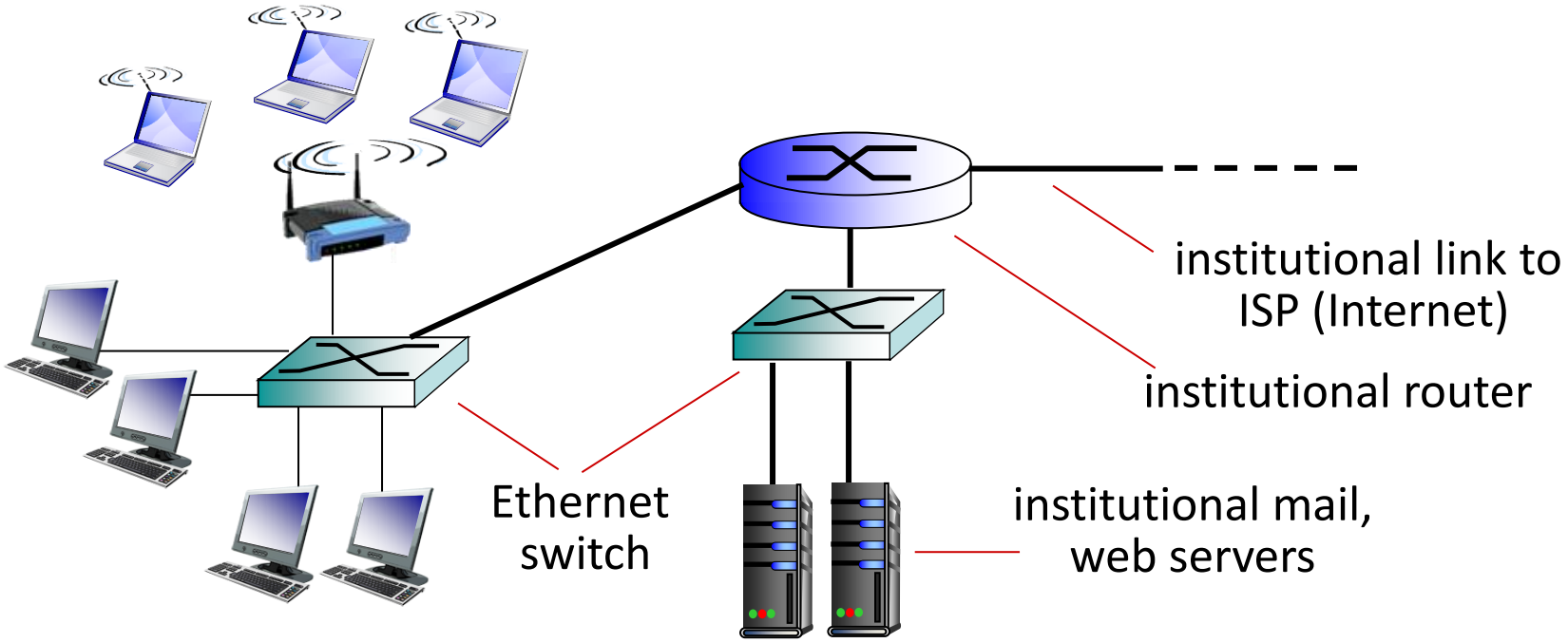


- HFC: hybrid fiber coax
  - asymmetric: up to 300 Mbps downstream transmission rate, 20 Mbps upstream transmission rate
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend
  - unlike DSL, which has dedicated access to central office

Access Net: Home Network



Enterprise Access Networks



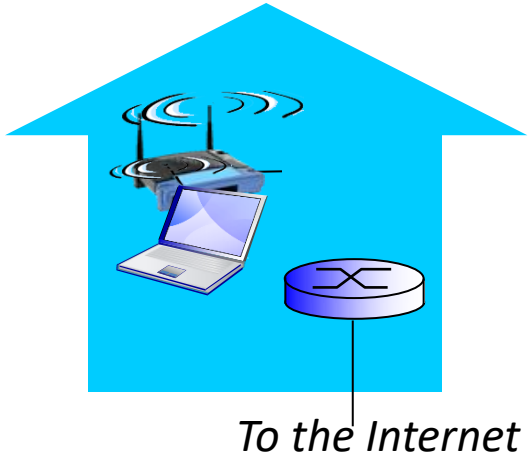
- typically used in companies, universities, etc…
  - 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
  - today, end systems typically connect into Ethernet switch

Wireless Access Networks

- shared *wireless* access network connects end system to router
  - via base station aka "access point"

wireless LANs:

- within building (100 ft)
- 802.11b/g/n (WiFi): 11, 54, up to 600 Mbps transmission rate



wide-area wireless access

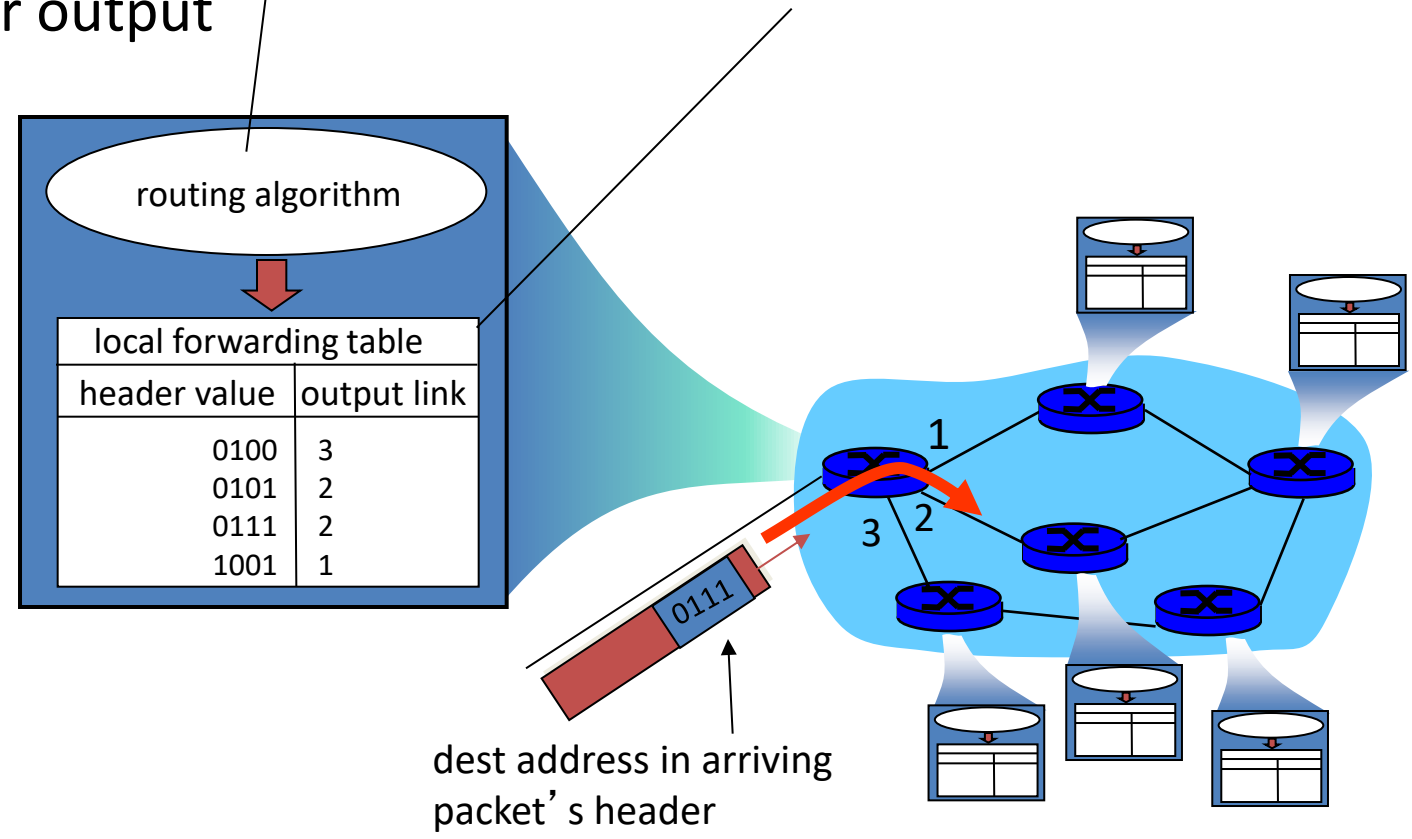
- provided by telco (cellular) operator, 10's km
- between 1 and 10 Mbps
- GPRS, 3G, 3.9G (LTE), 4G

Network Core: Two Key Functions

routing: determines source-destination route taken by packets

- *routing algorithms*

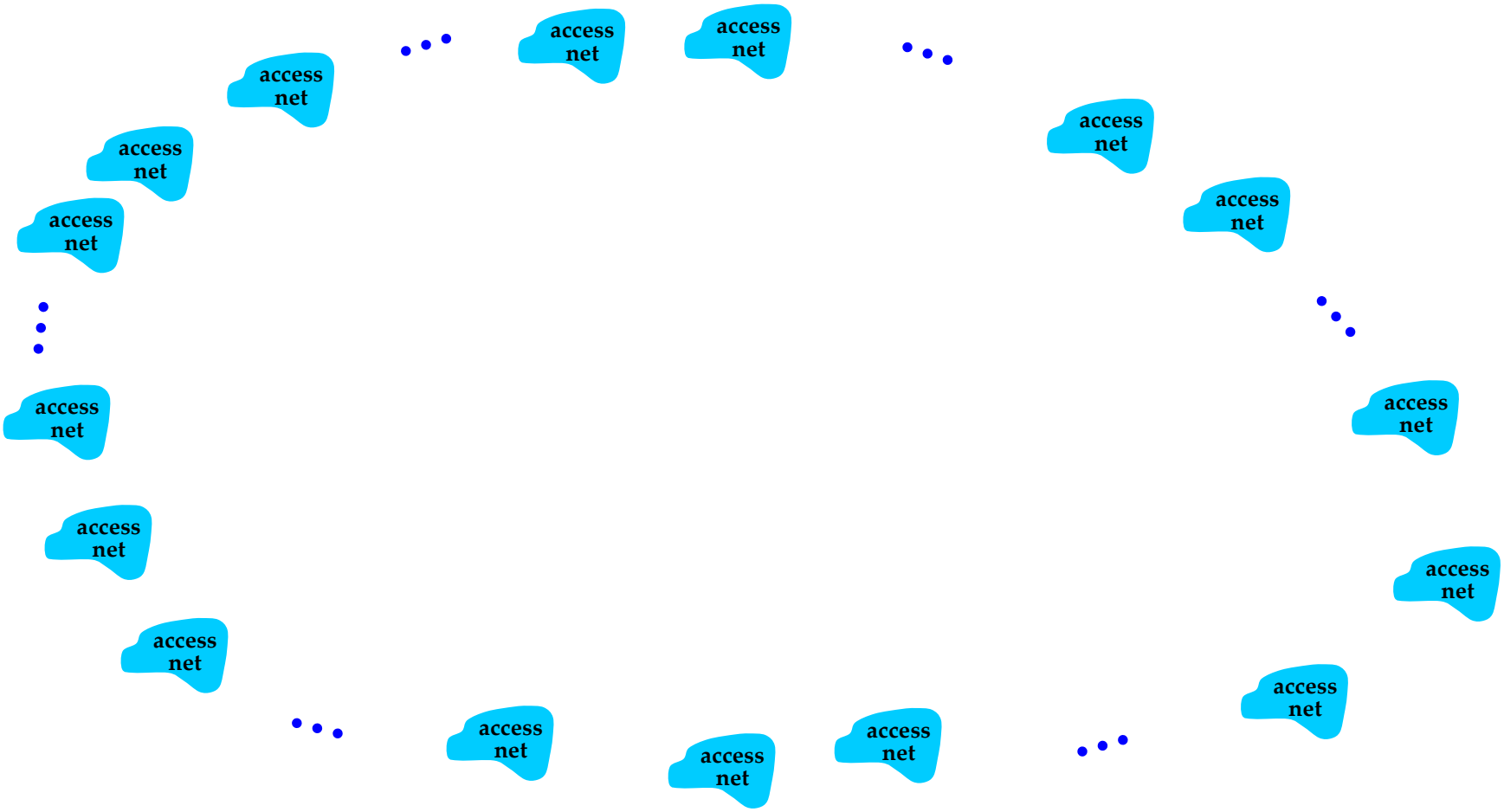
forwarding: move packets from router's input to appropriate router output



Internet Structure: Network of Networks

- End systems connect to Internet via access ISPs (Internet Service Providers)
  - Residential, company and university ISPs
- Access ISPs in turn must be interconnected
  - So that any two hosts can send packets to each other
- Resulting network of networks is very complex
  - Evolution was driven by *economics* and *national policies*
- Let's take a *stepwise* approach to describe current Internet structure

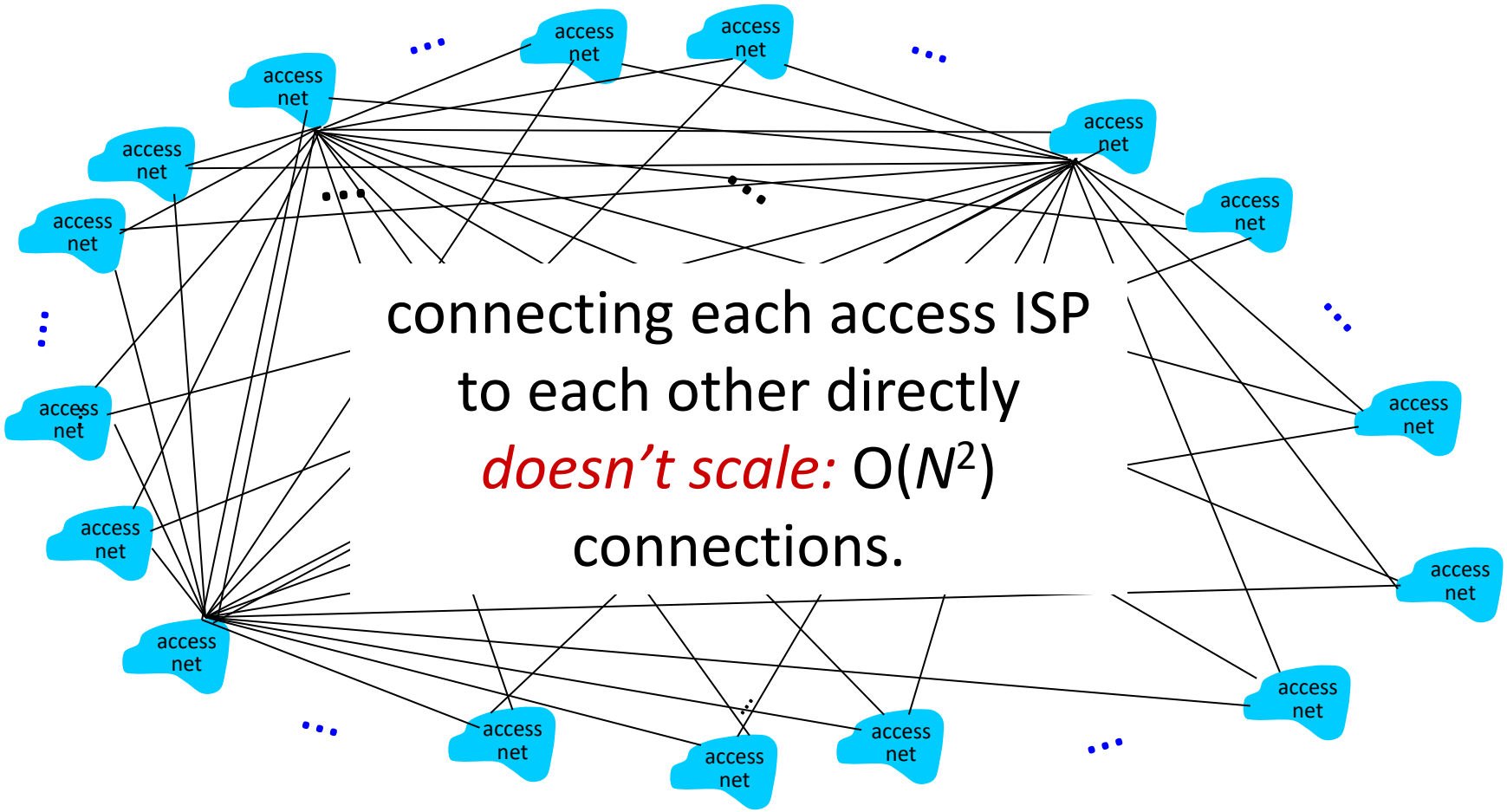
Internet Structure: Network of Networks



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

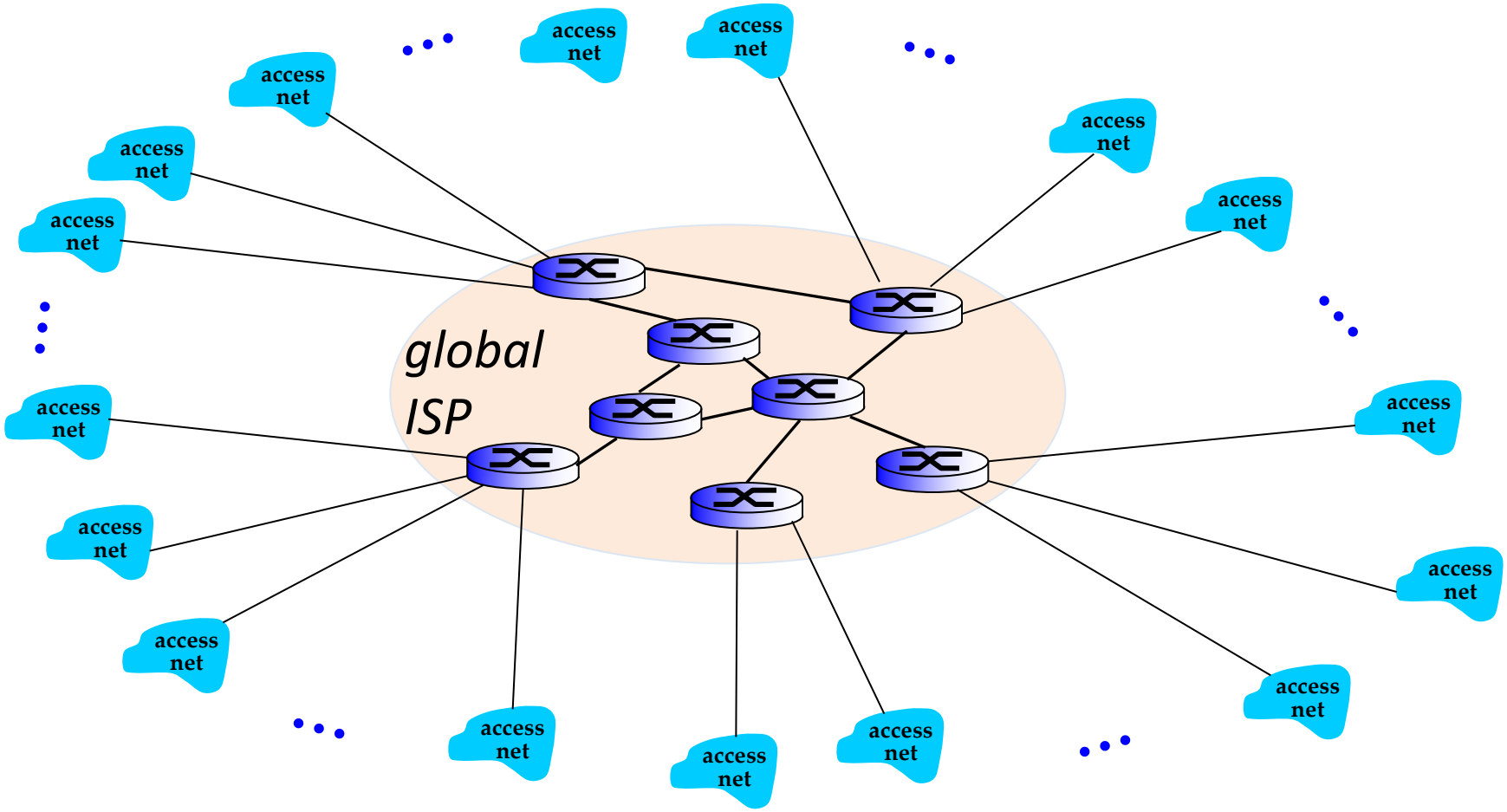
Internet Structure: Network of Networks

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



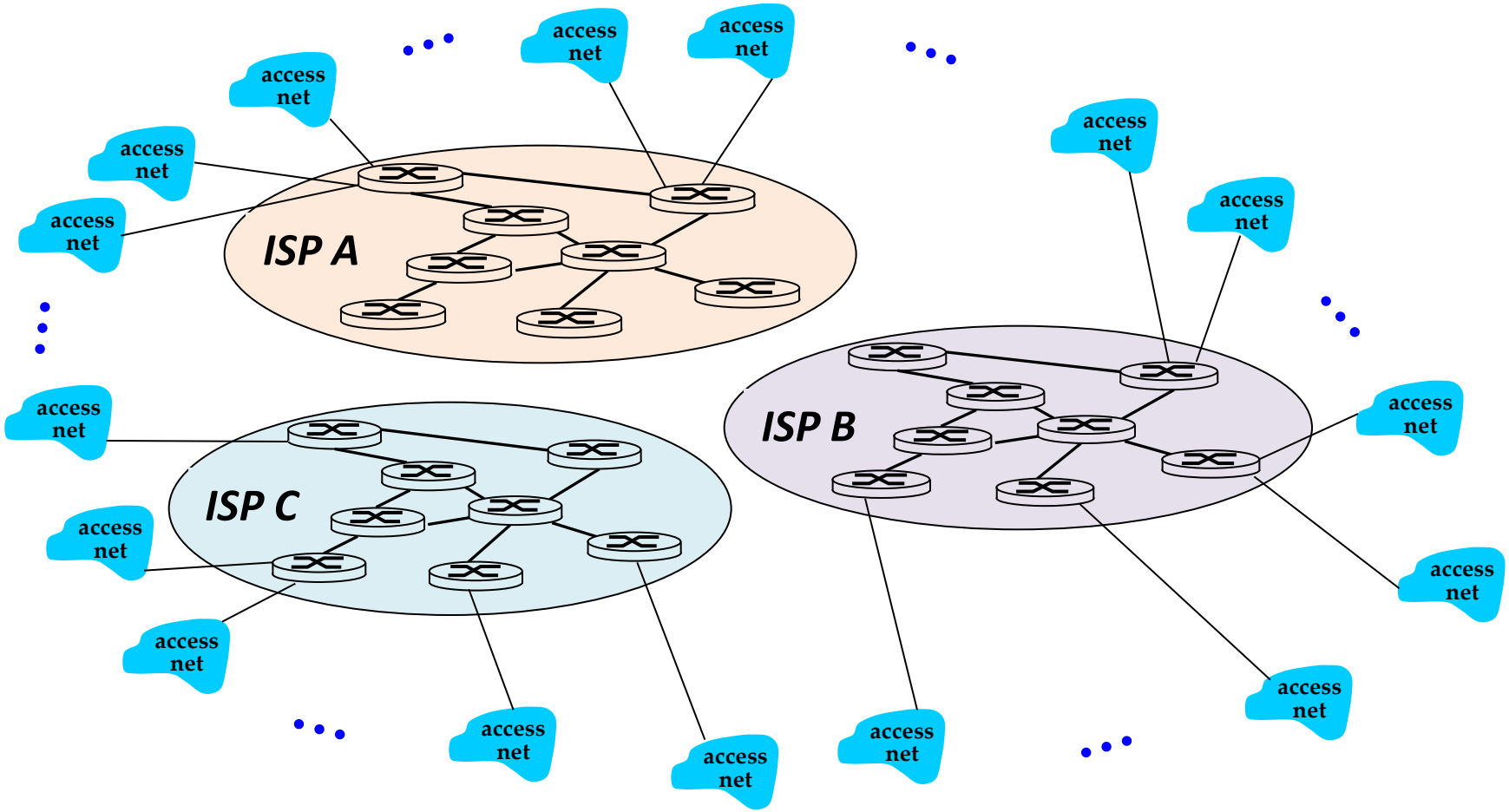
Internet Structure: Network of Networks

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



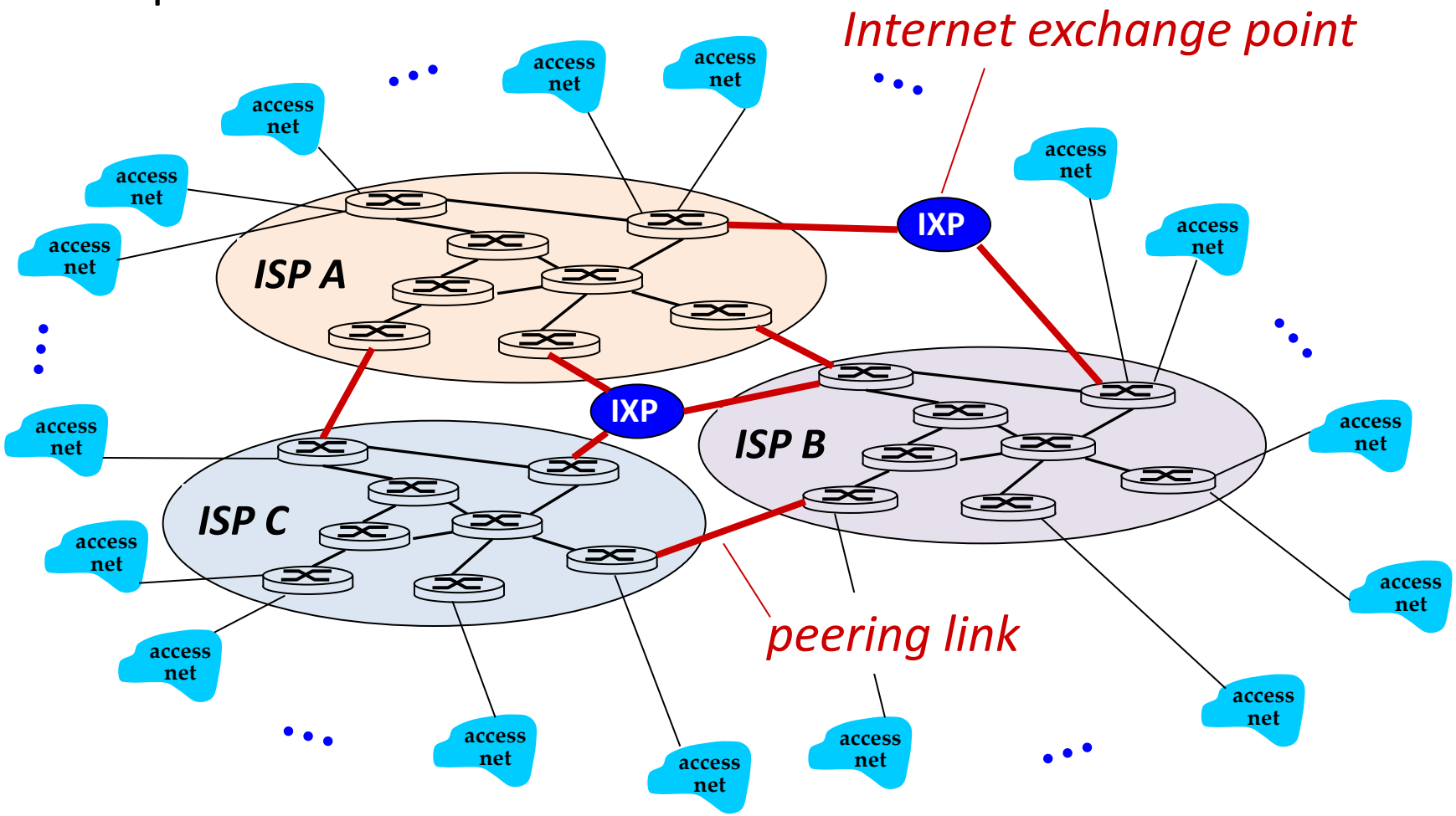
Internet Structure: Network of Networks

- But if one global ISP is viable business, there will be competitors ….



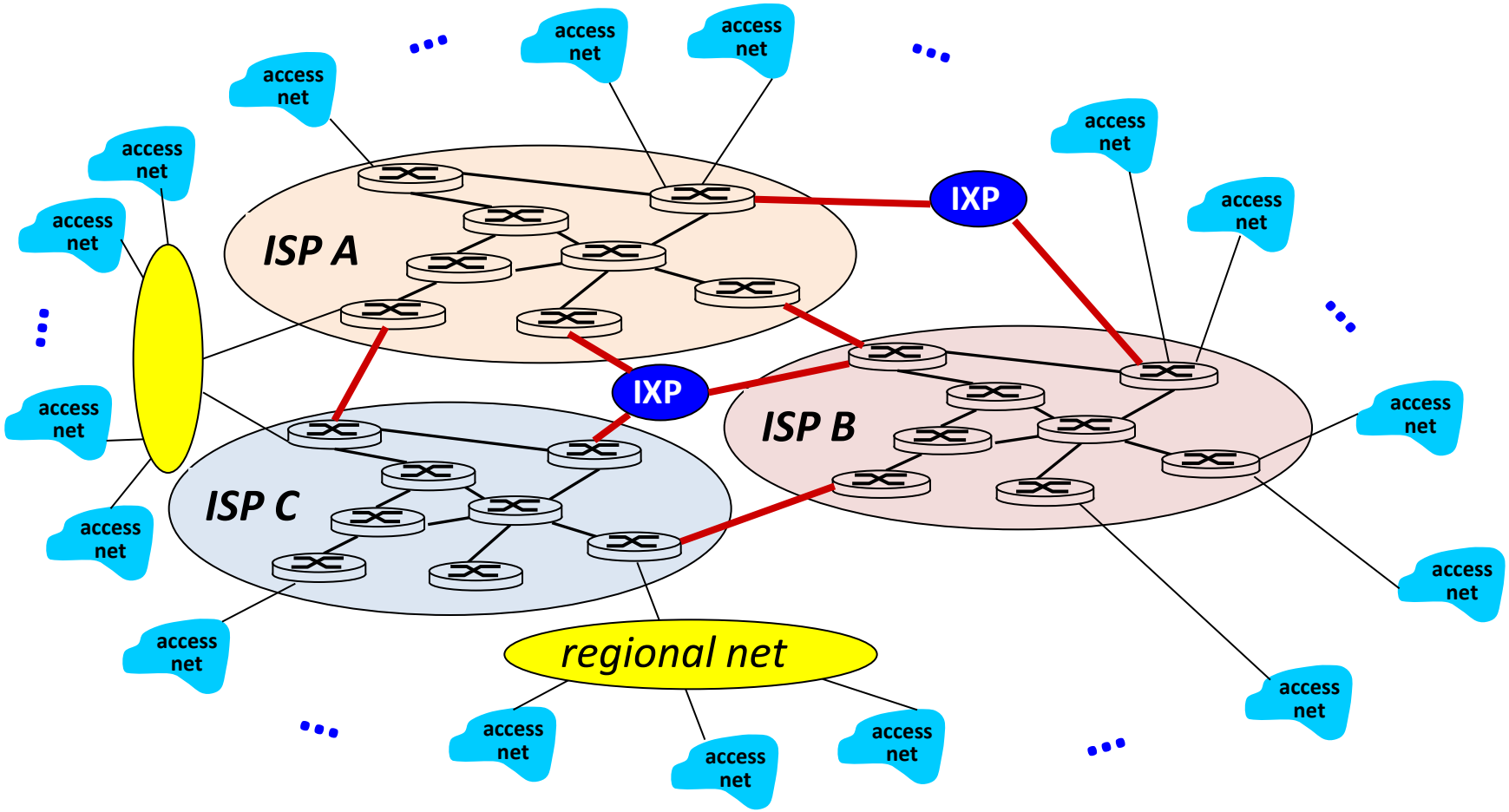
Internet Structure: Network of Networks

- But if one global ISP is viable business, there will be competitors …. which must be interconnected



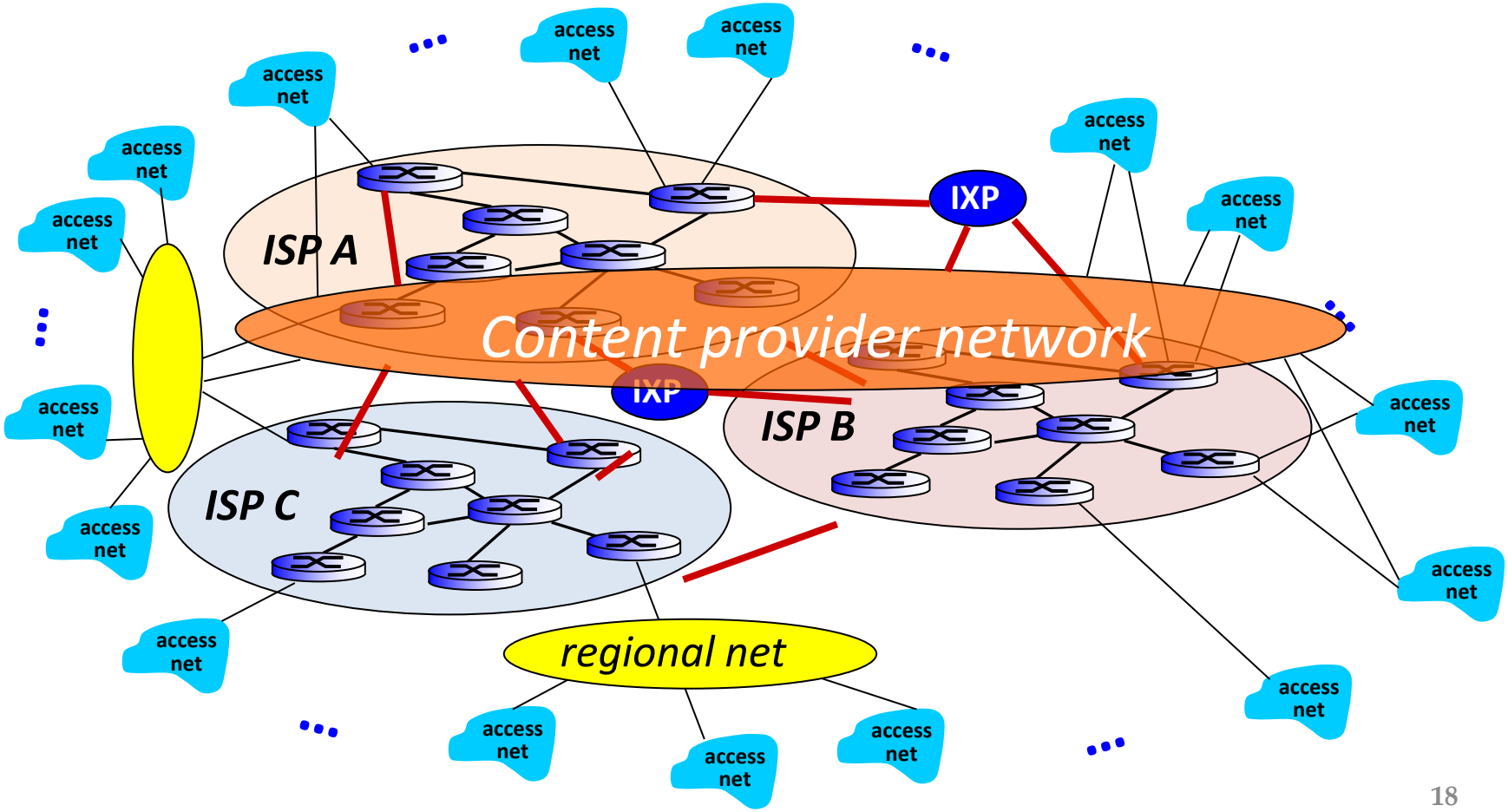
Internet Structure: Network of Networks

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

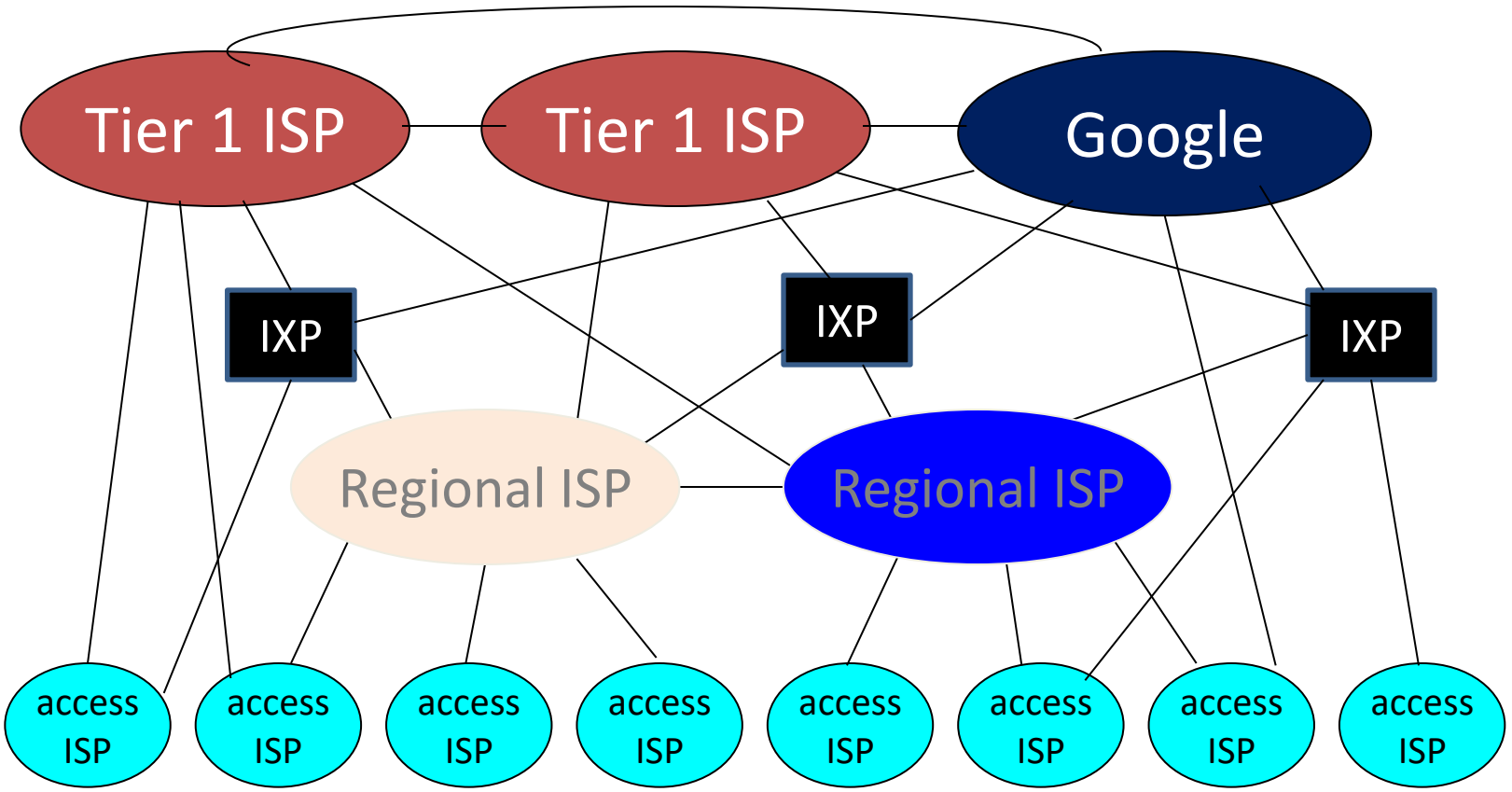


Internet structure: Network of Networks

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



Internet Structure: Network of Networks



- at center: small # of well-connected large networks
  - "tier-1" commercial ISPs (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
  - content provider network (e.g, Google): private network that connects it data centers to the Internet, often bypassing tier-1,

Tier-1 ISP: e.g. Sprint