

Computer Networks

COL 334/672

Towards building a computer network

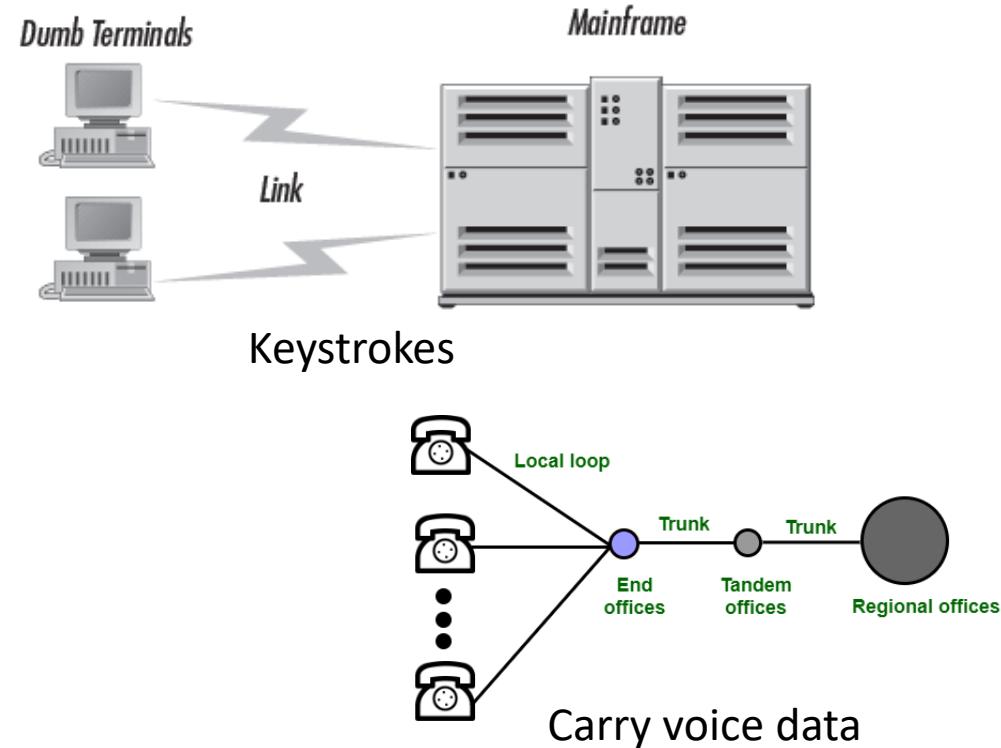
Slides adapted from KR slides

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Sem 1, 2024-25

What is a Computer Network?

- **Computer Network:** A set of interconnected computers that can communicate with each other
- **Traditional Networks**
 - Serial lines connecting dumb terminals to mainframe
 - Other networks?
 - **Characteristics:** single-use networks with specialized data or devices
- **Key distinction:** Computer networks are built to carry different kinds of data and for general-purpose hardware



Broadcast video

The Internet: a network of networks



Billions of connected computing *devices*:

- *hosts* = end systems
- running *network apps* at Internet's "edge"

Packet switches: forward packets (chunks of data)

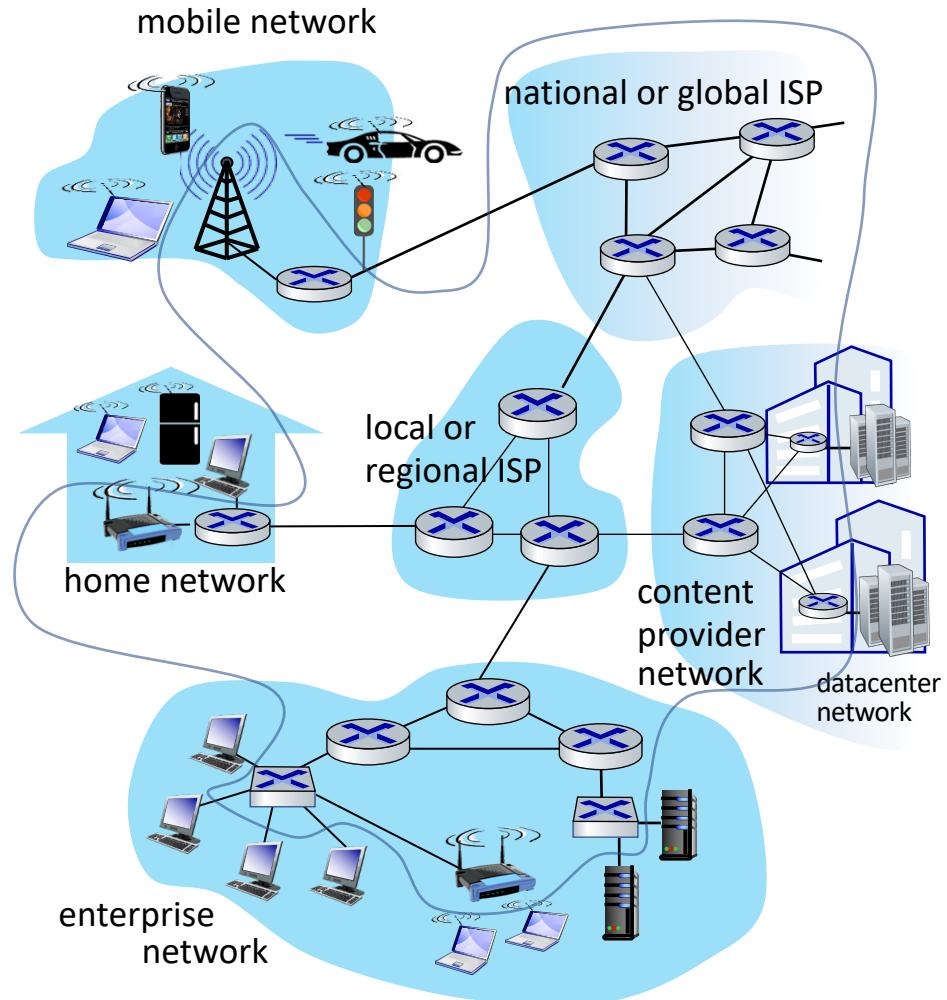
- routers, switches

Communication links

- fiber, copper, radio, satellite
- transmission rate: *bandwidth*

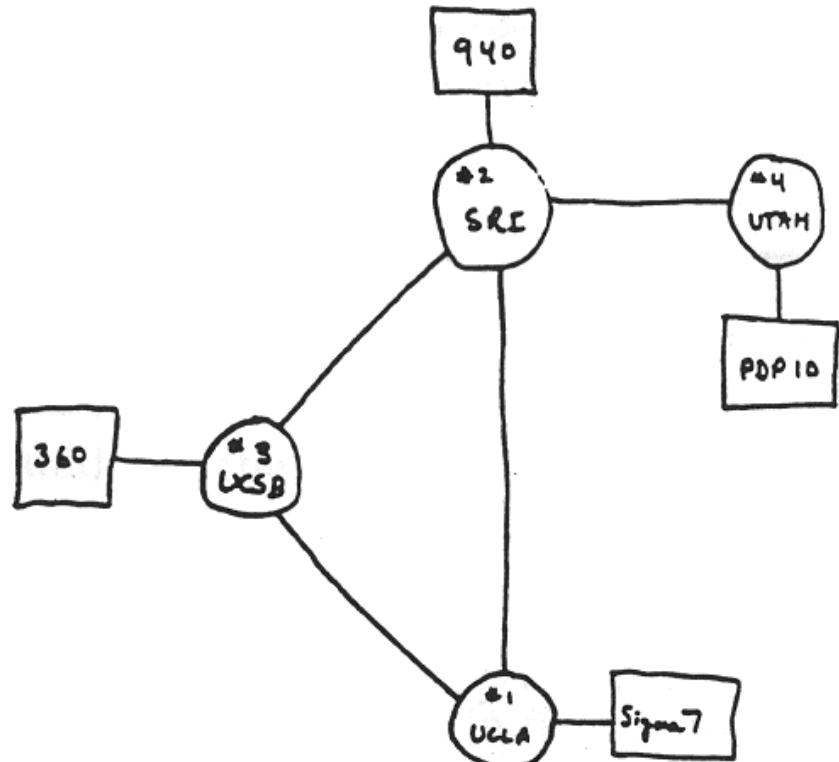
Networks

- collection of devices, routers, links: managed by an organization



Internet Evolution

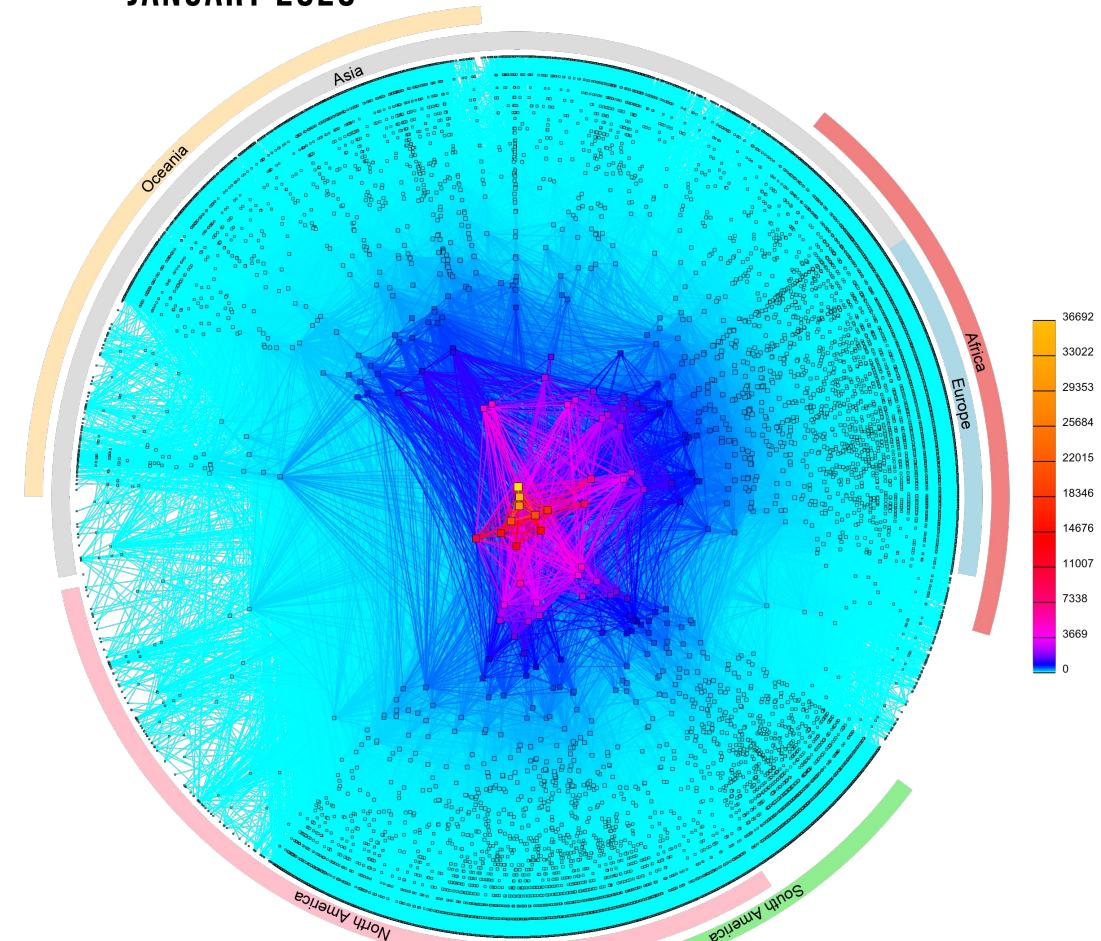
1969



THE ARPA NETWORK

This class: how/why did the Internet evolve into this kind of structure?

CAIDA'S IPV4 AS CORE GRAPH
JANUARY 2020

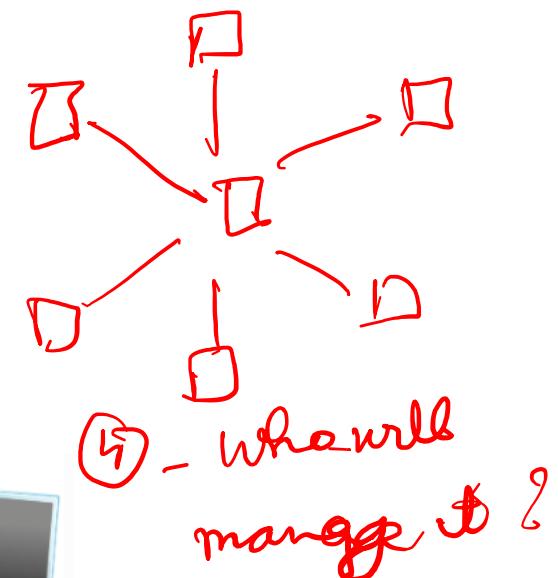
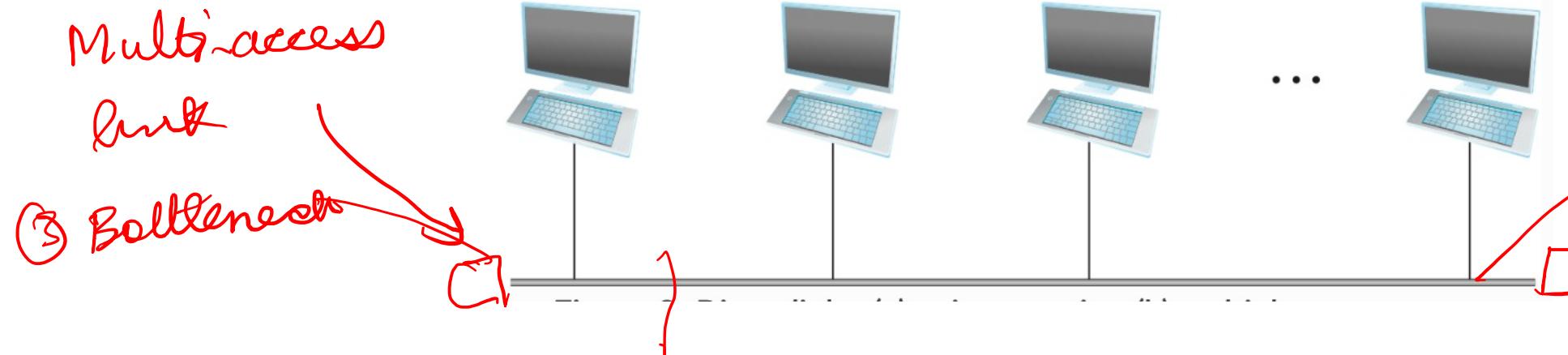


How to Build a Computer Network? From first principles..

- Let's build a network with two machines



- How do we connect n machines

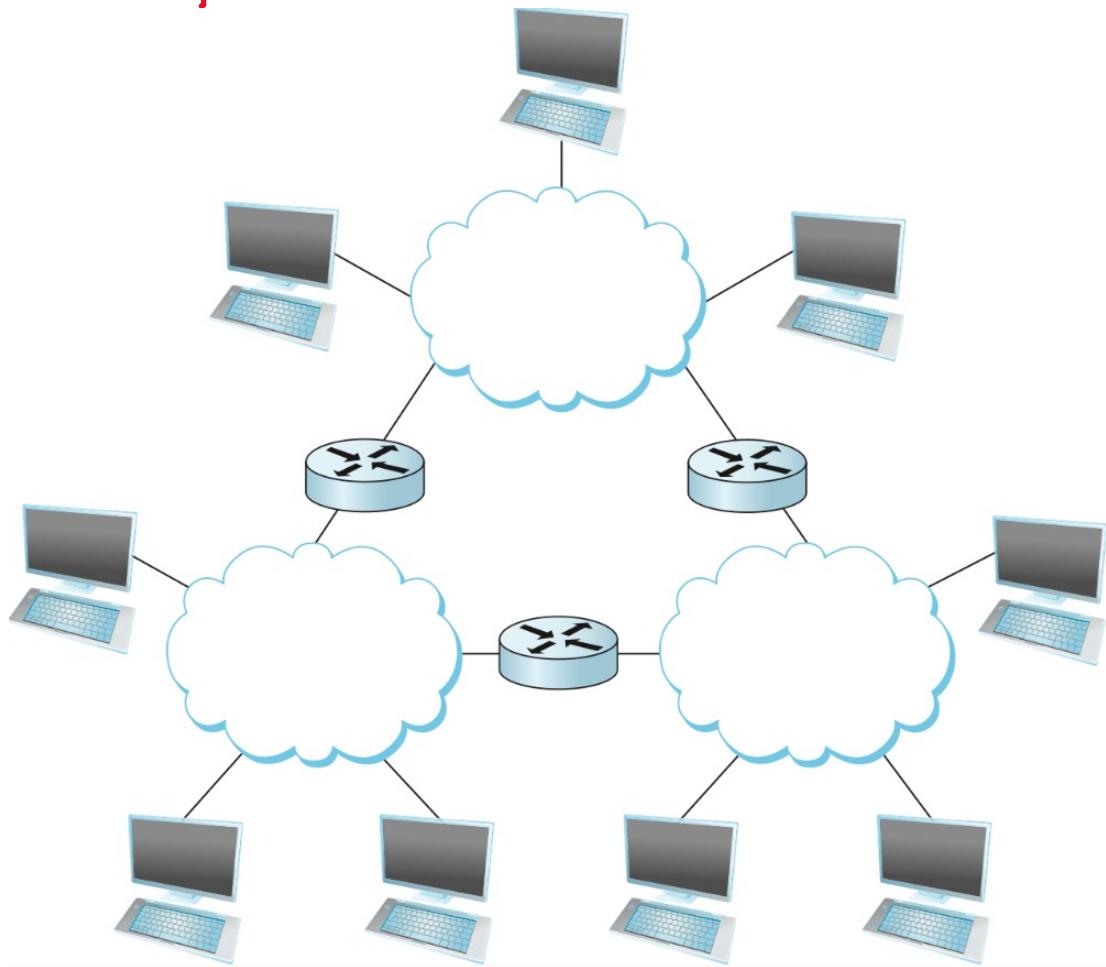
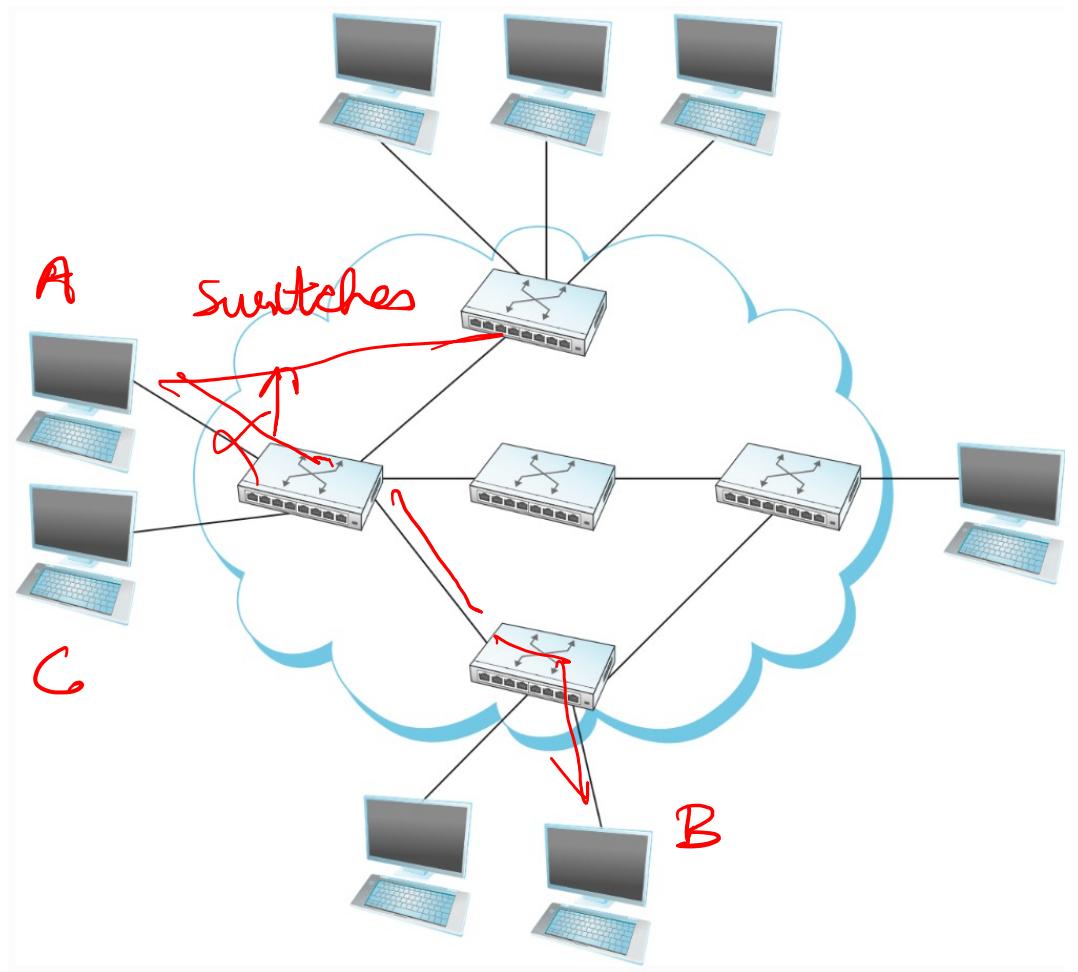


- Signal will attenuate as the length of wire grows
- Single point of failure

How to Build a Computer Network?

From first principles..

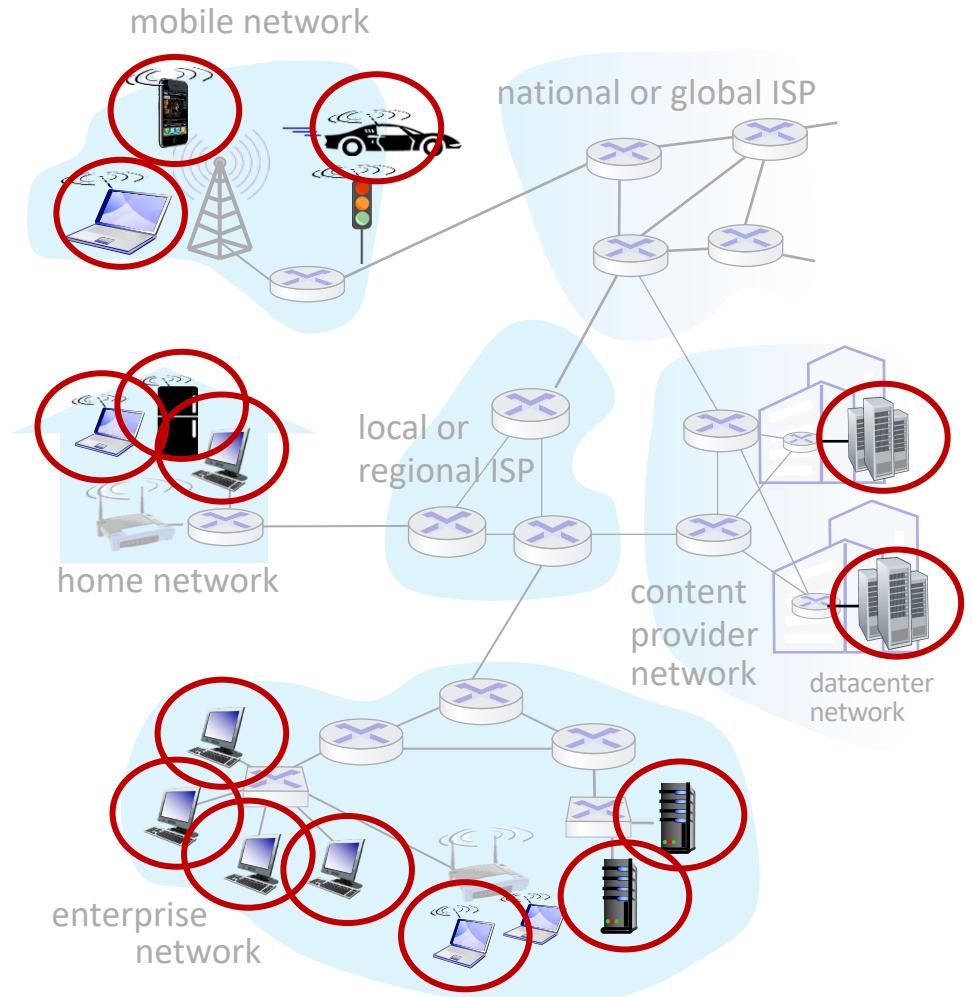
internet / Internet



A closer look at Internet structure

Network edge:

- hosts: clients and servers
- servers often in data centers



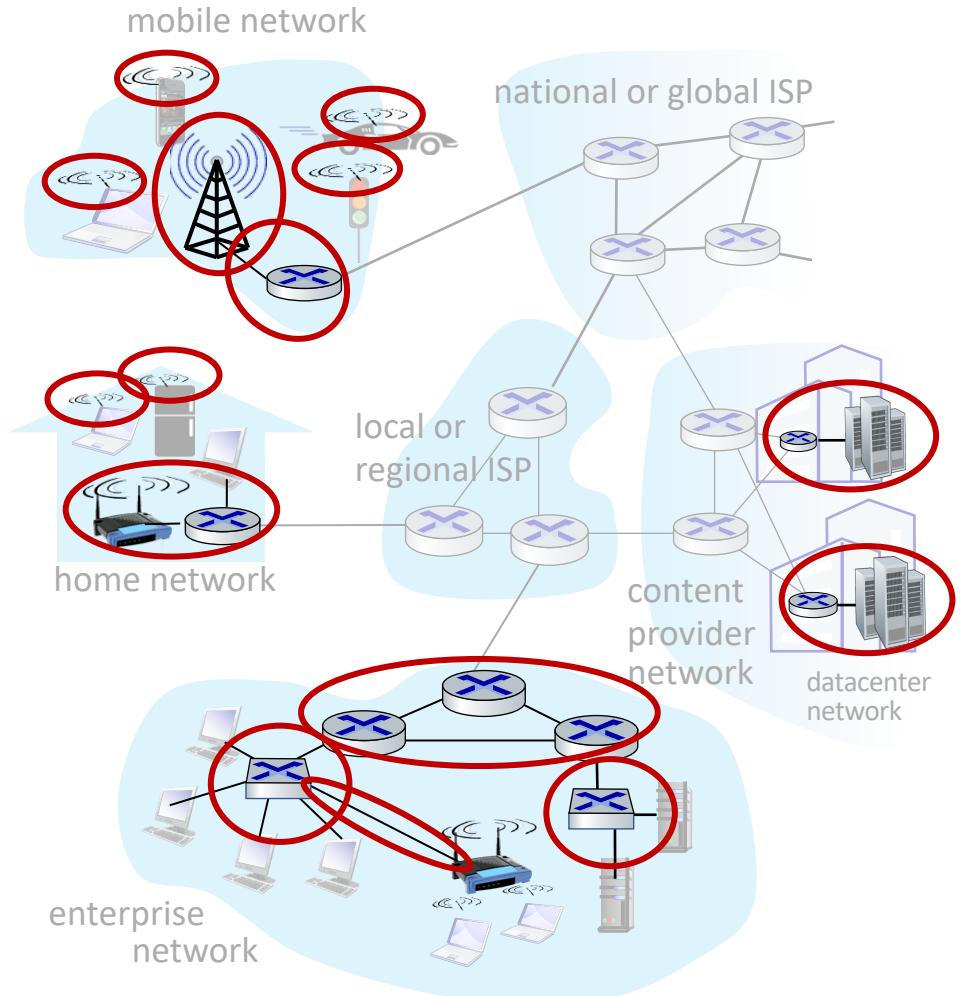
A closer look at Internet structure

Network edge:

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Access networks, physical media:

- wired, wireless communication links



A closer look at Internet structure

Network edge:

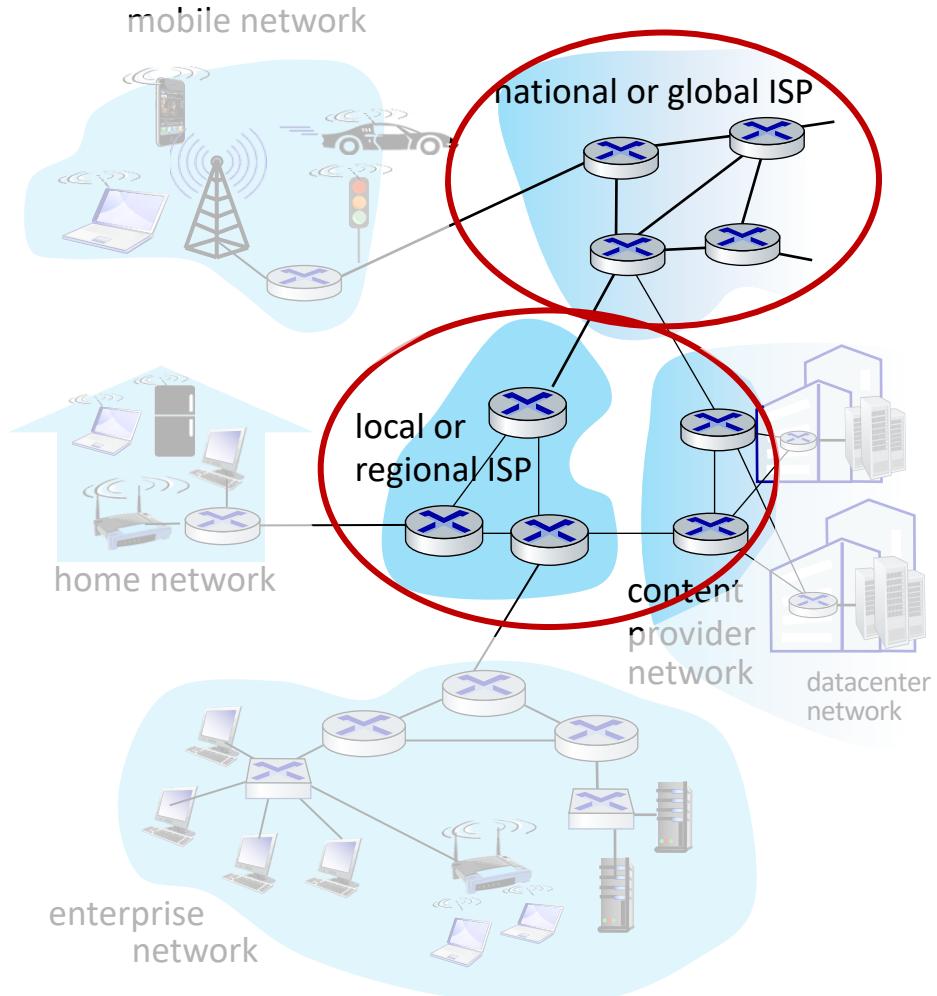
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Network core:

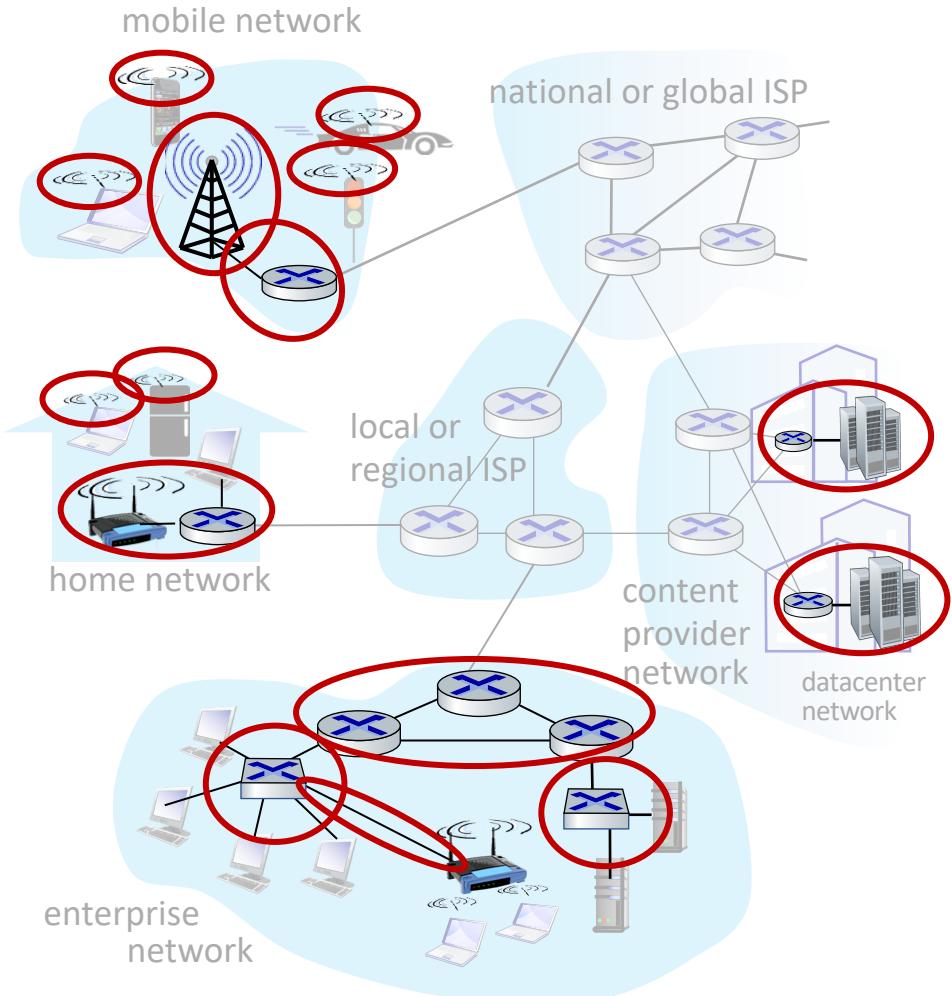
- interconnected routers
- network of networks



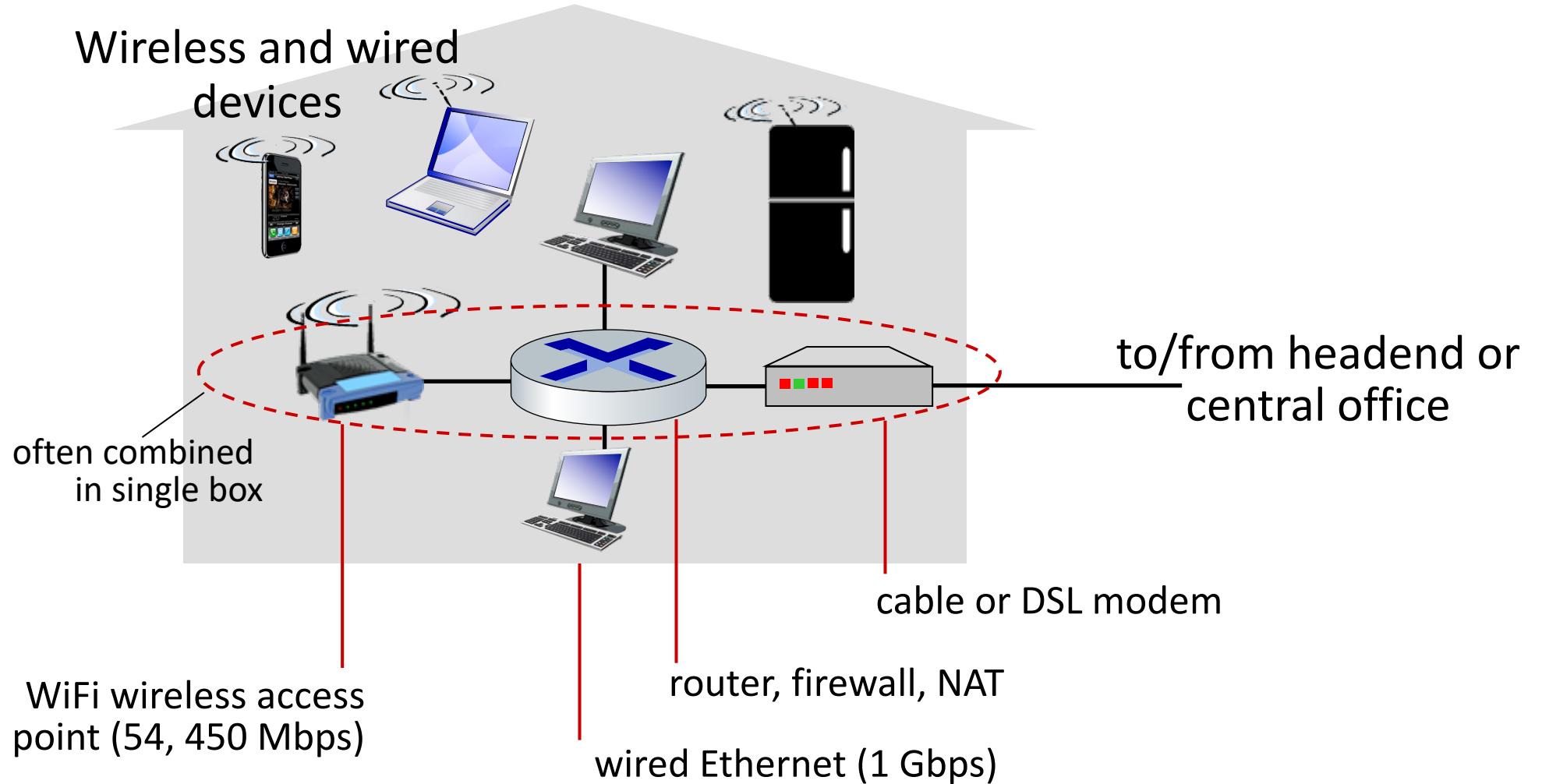
Access networks

*Q: How to connect end systems
to edge router?*

- residential access nets
- institutional access networks (school, company)
- mobile access networks (WiFi, 4G/5G)



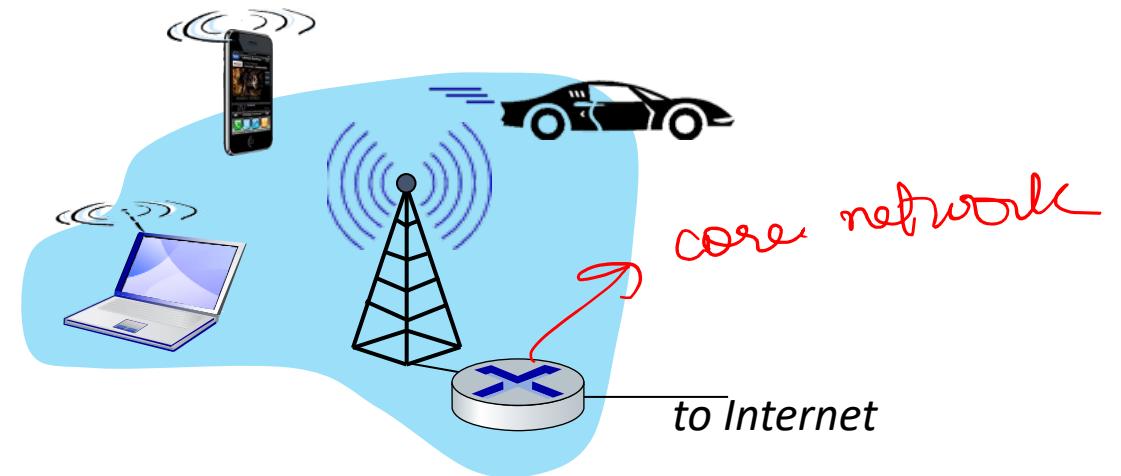
Access networks: home networks



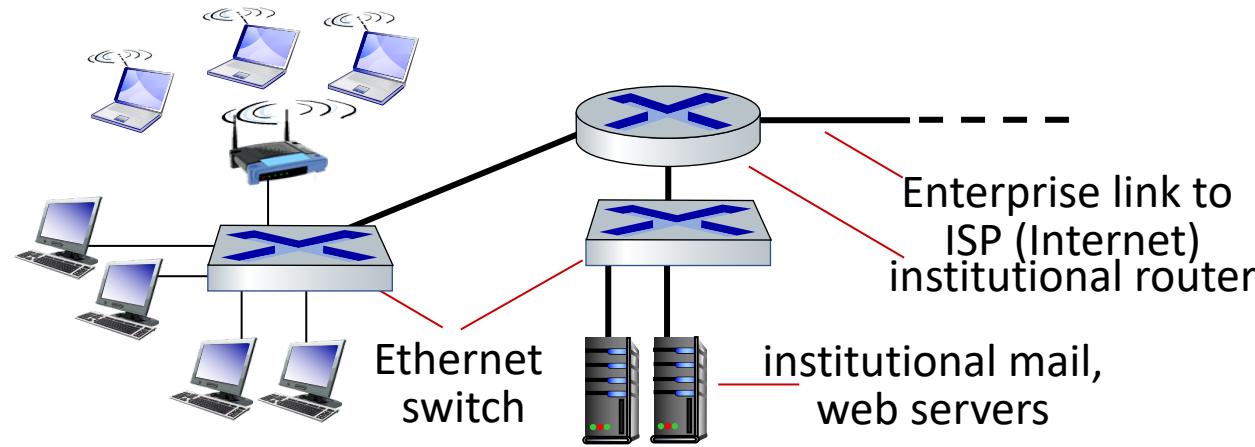
Cellular access networks

Shared *wireless* access network connects end system to base station

- provided by mobile, cellular network operator (10's km)
- 10's Mbps
- 4G/5G cellular networks



Access networks: enterprise networks



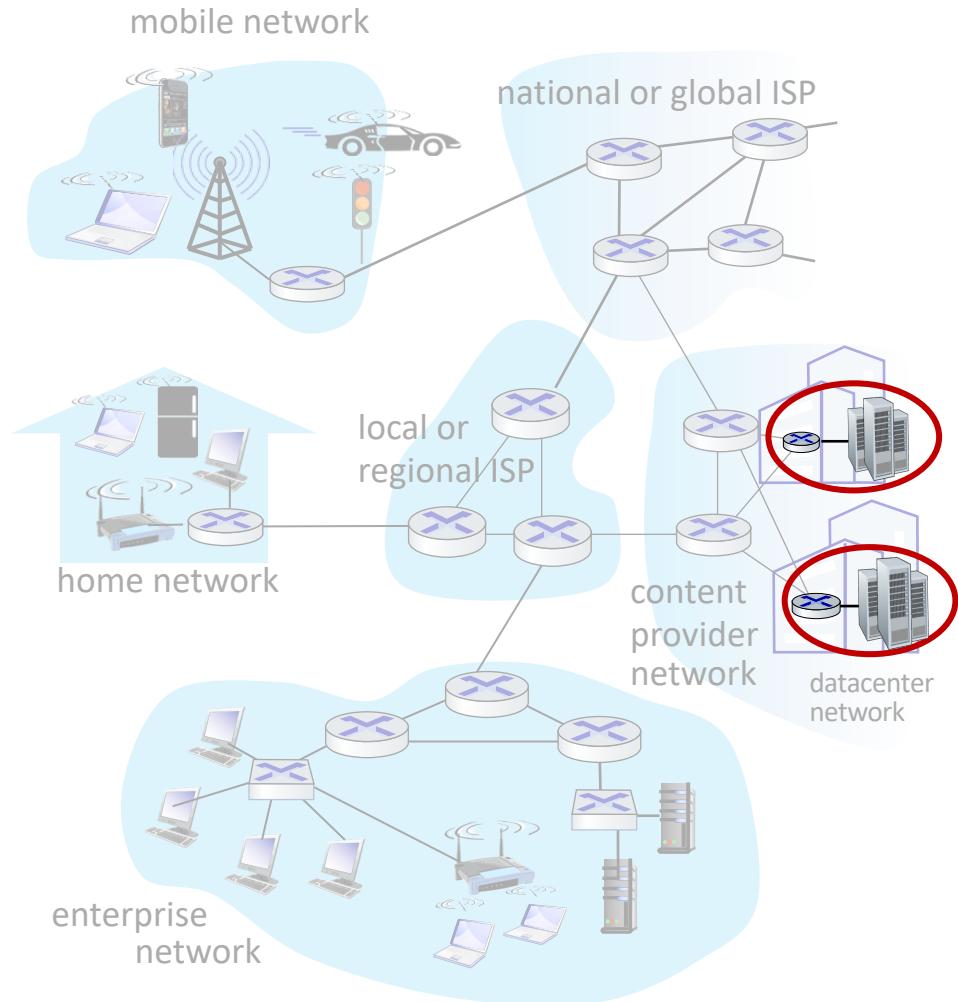
- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
 - Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
 - WiFi: wireless access points at 11, 54, 450 Mbps
- IITD network infrastructure

Access networks: data center networks

- high-bandwidth links (10s to 100s Gbps) connect hundreds to thousands of servers together, and to Internet

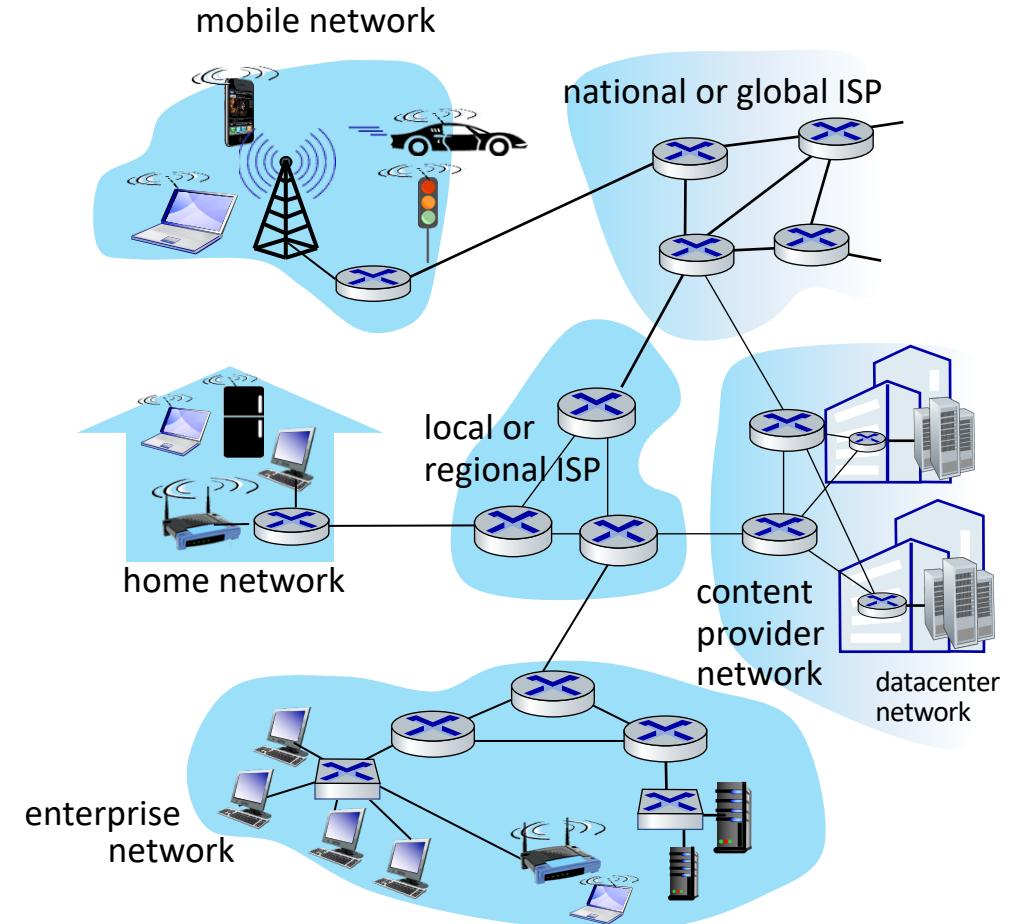


Courtesy: Massachusetts Green High Performance Computing Center (mghpcc.org)



Internet structure: a “network of networks”

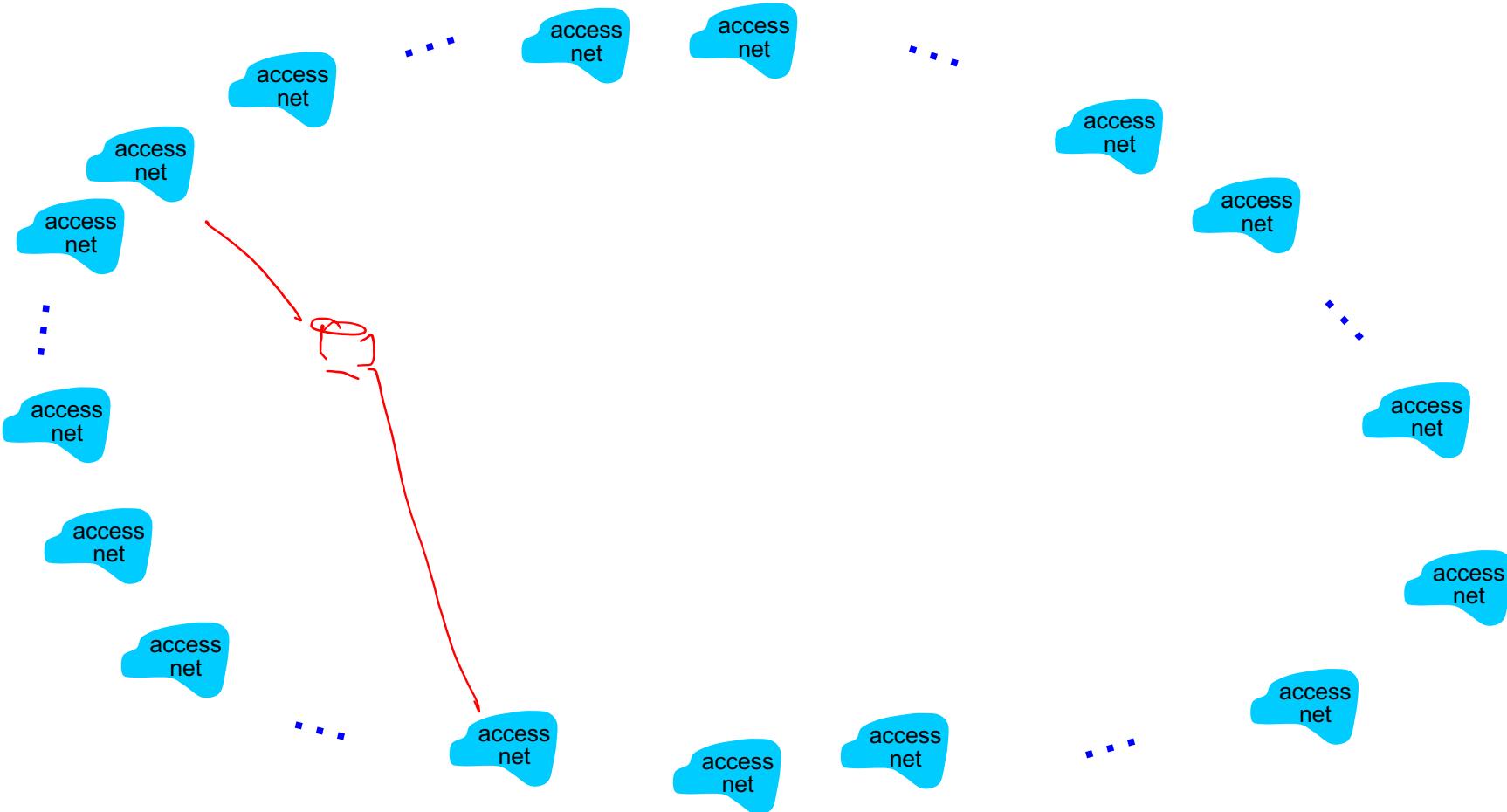
- hosts connect to Internet via **access** Internet Service Providers (ISPs)
- access ISPs in turn must be interconnected
 - so that *any* two hosts (*anywhere!*) can send packets to each other
- resulting network of networks is very complex
 - evolution driven by **economics, national policies**



Let's take a stepwise approach to describe current Internet structure

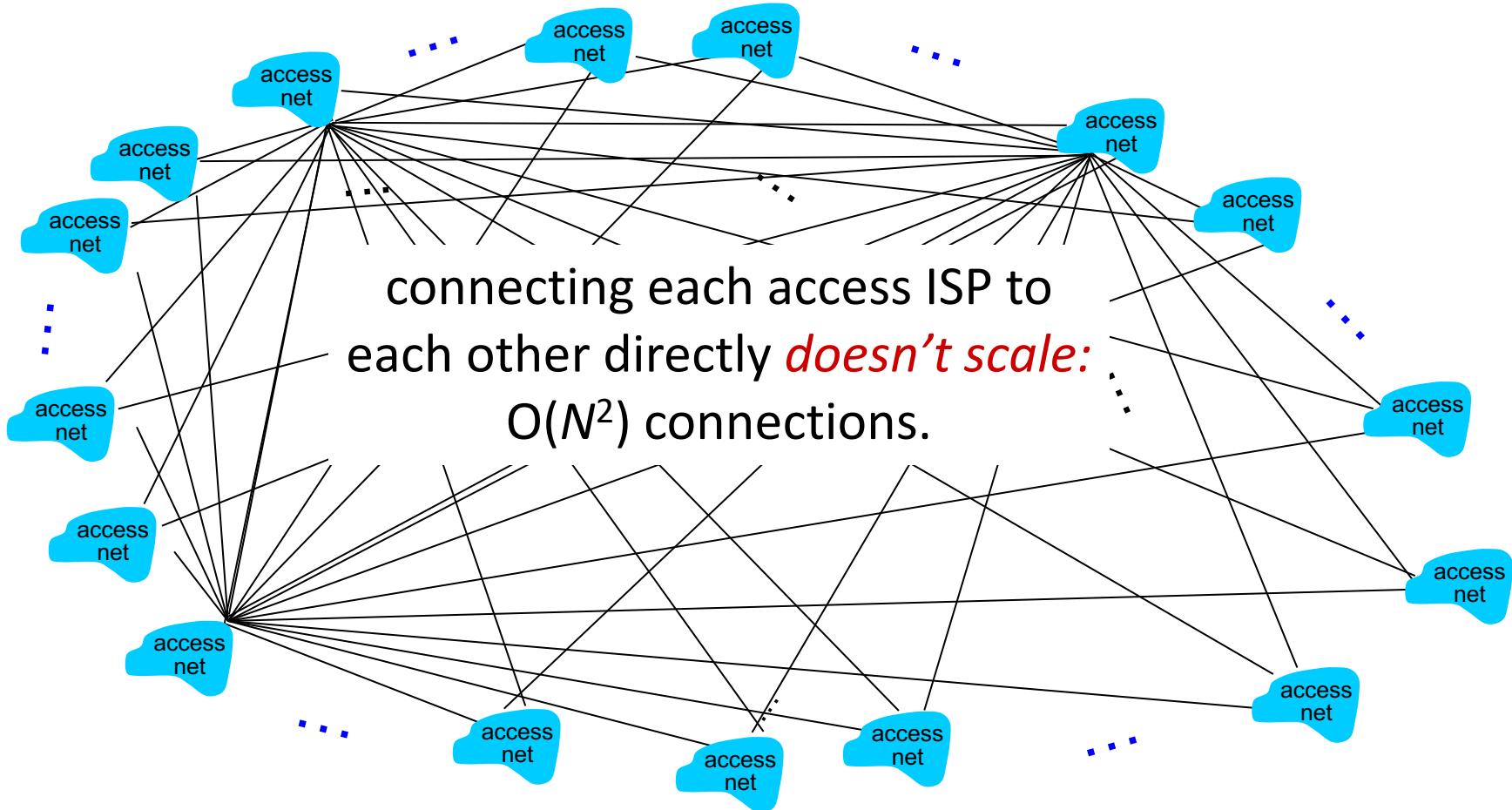
Internet structure: a “network of networks”

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



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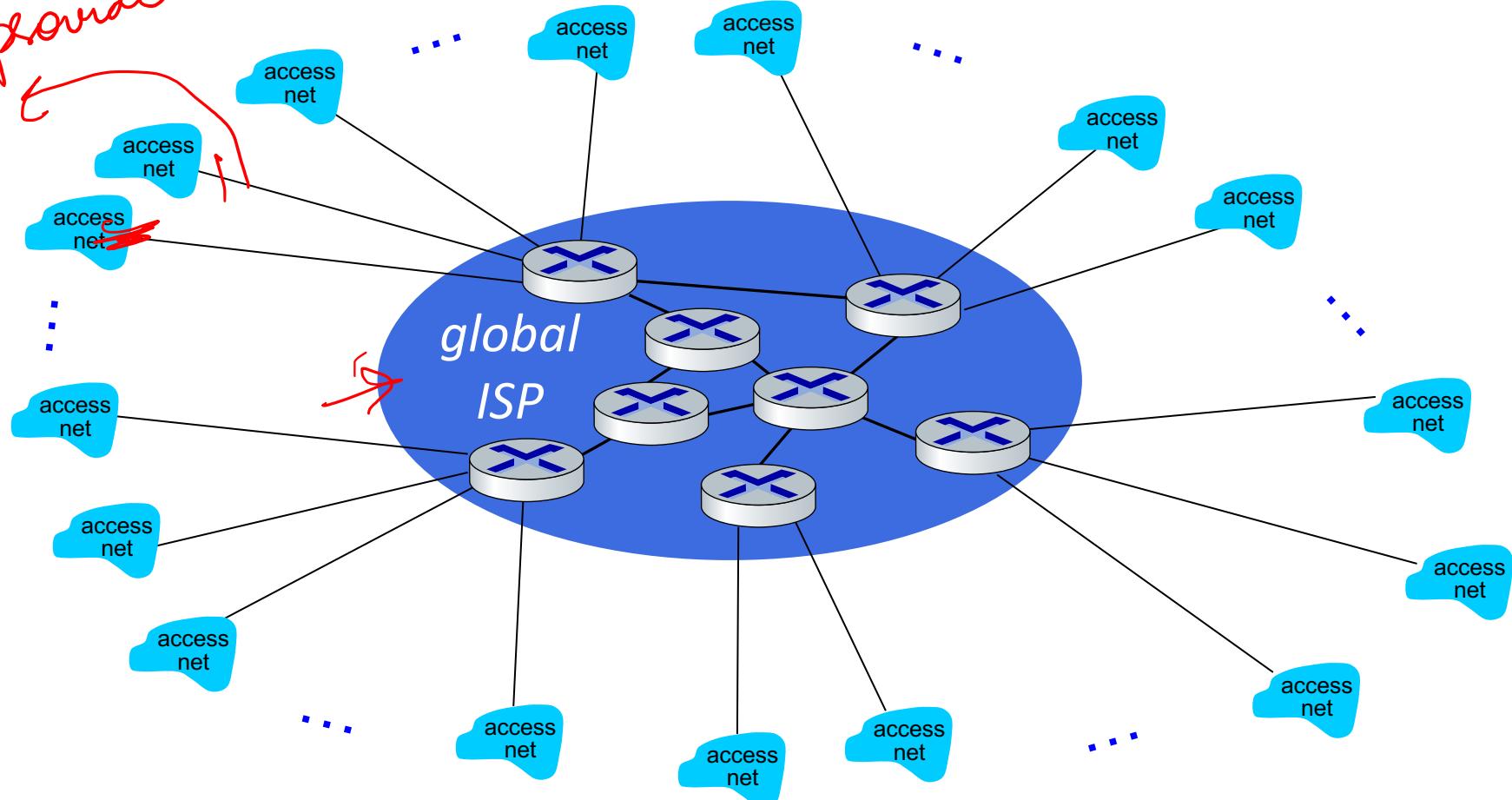


Internet structure: a “network of networks”

① SPF / Centralized
Option: connect each access ISP to one global transit ISP?

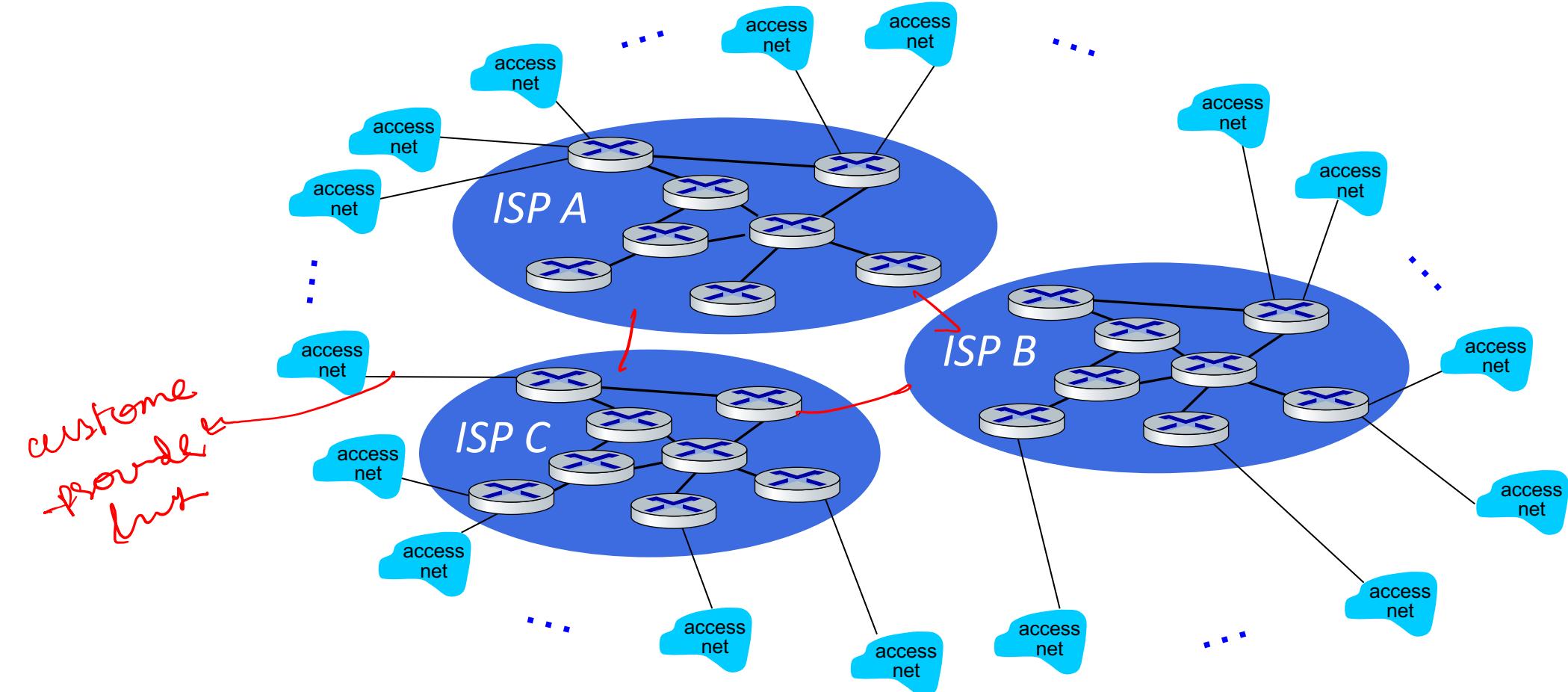
② Monopoly
Customer and provider ISPs have economic agreement.

customer provider



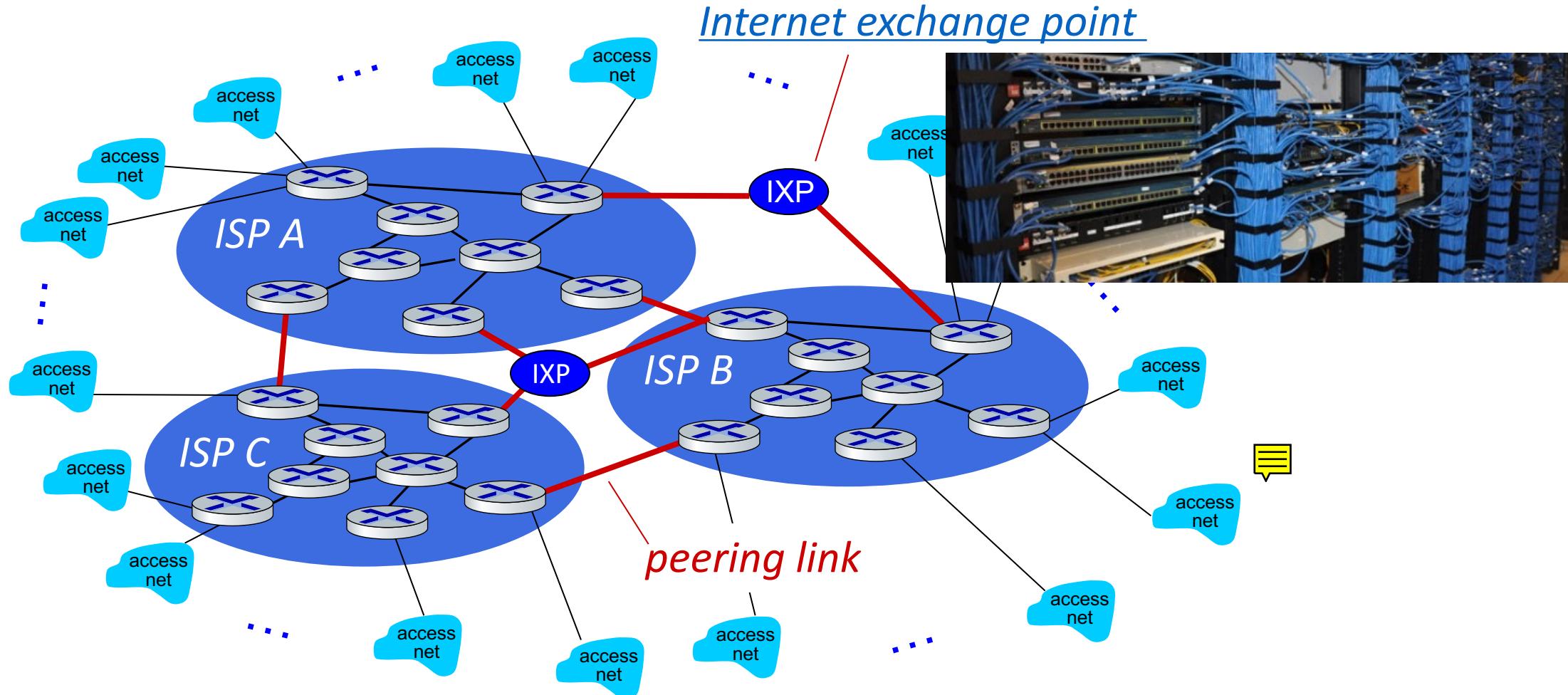
Internet structure: a “network of networks”

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



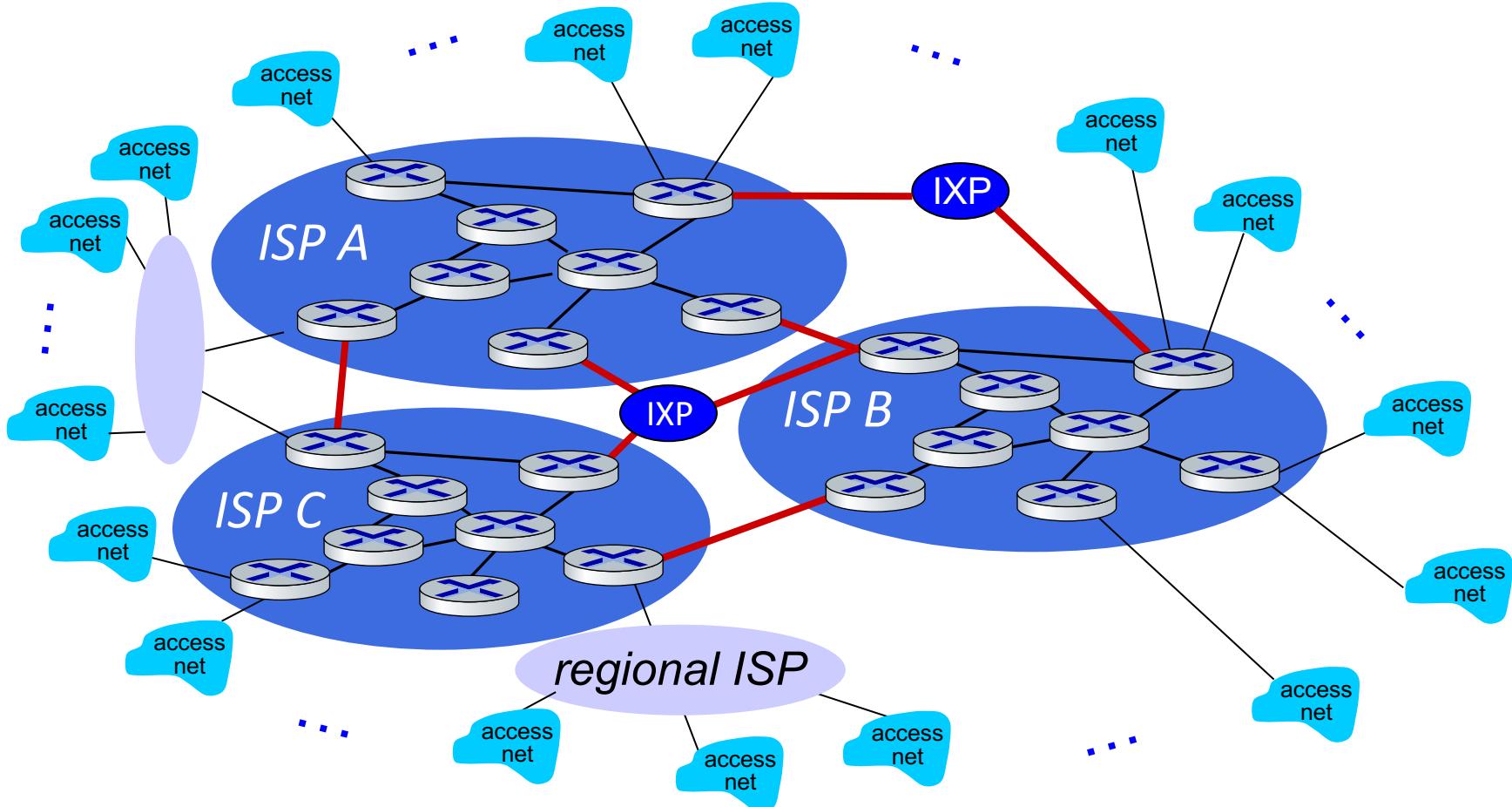
Internet structure: a “network of networks”

But if one global ISP is viable business, there will be competitors who will want to be connected



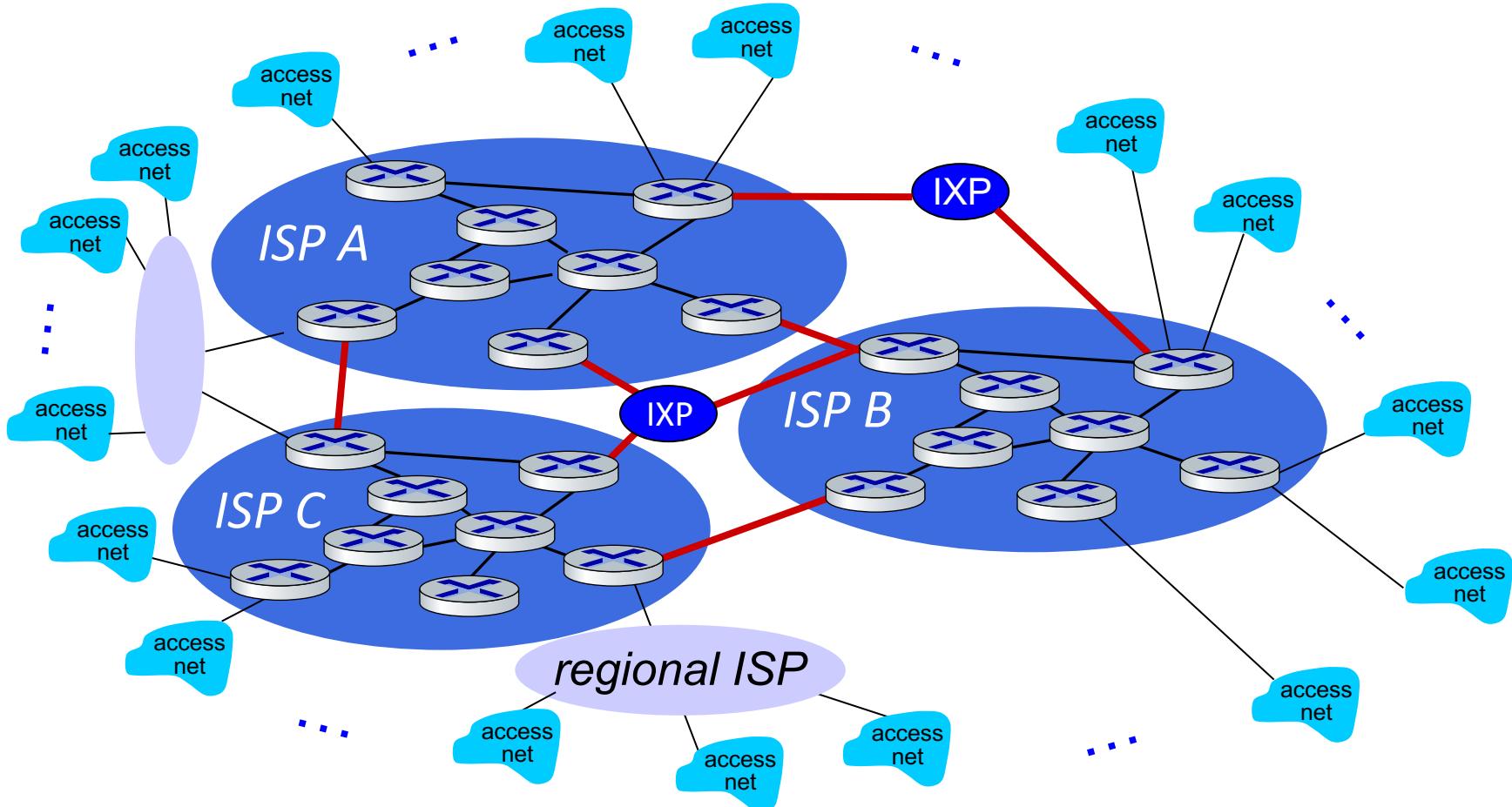
Internet structure: a “network of networks”

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



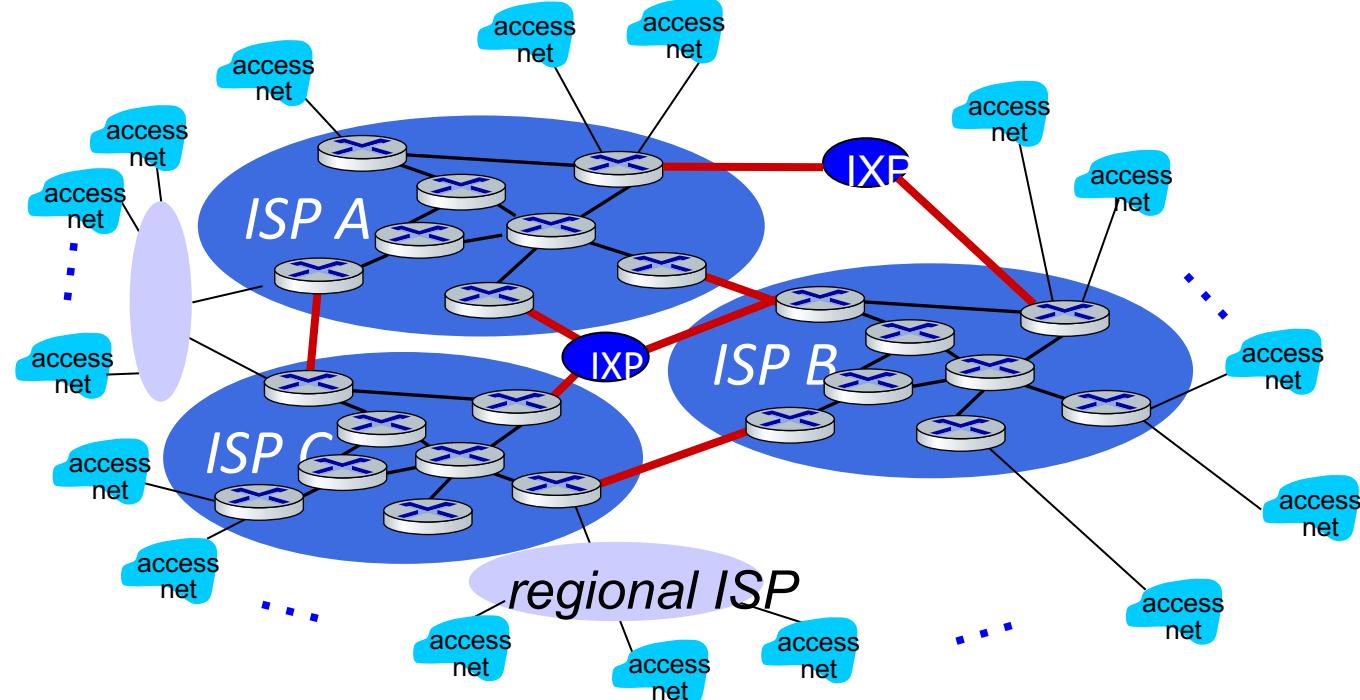
Internet structure: a “network of networks”

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3-tier Internet Architecture

- Tier-1 ISP
 - Global reach
 - Don't pay for transit
 - E.g., TATA Communications, AT&T
- Tier-2 ISP
 - Customer for some networks
 - Providers or peers for others
 - E.g., ? *Rel/Arstel*
- Tier-3 ISP
 - Only act as customers
 - E.g., ? *IFTD*



Is it that neat?

Internet structure: a “network of networks”

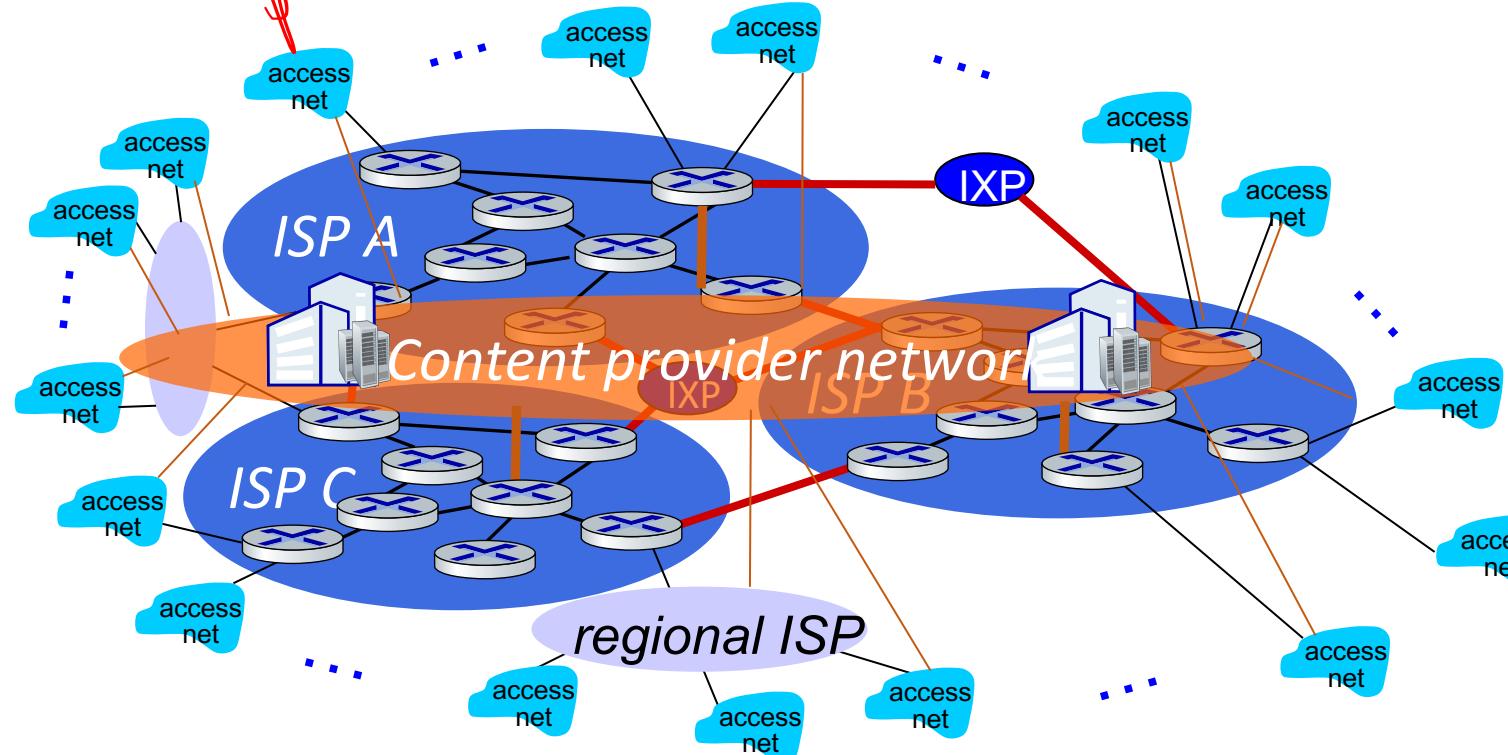
Content provider networks (e.g., Google, Microsoft, Akamai) may run their own network..

But why?

Moreover, tier-1 ISPs are also hosting content

..to bring ~~Content Distribution Network~~ content close to end users

This has led to flattening of the Internet



Google: Lord of Peering!

- Google has been peering directly with access networks
- [Open peering policy](#)
- Explains Google loads so fast!
- Is it a win-win for both the access network and Google?
 - Economic for access network
 - Performance for customers
 - Greater control over traffic

Peering is the direct interconnection between Google's network and another network to support the exchange of traffic. Networks peer to gain some combination of economic, performance and traffic control benefits.

[Submit your peering request](#)

Google has an open peering policy, subject to certain technical, commercial and legal requirements.

We're able to peer at the internet exchanges (IXPs) and private facilities listed in our [PeeringDB entry](#). Note that some interconnect locations may not be available for all networks.

Summary

- Explored the structure of the Internet, network of networks
- Distributed networks (scalability, manageability, economic reasons)
 - Implications on other aspects of Internet design
- 3-tiered architecture: tier-1, tier-2, and tier-3 service providers
- Recent times, flattening of Internet due to:
 - Tier-1 hosting content
 - Content providers running large networks
- Next class: how do you send data over distributed networks?