

# Computer Networks

## COL 334/672

Towards building a computer network

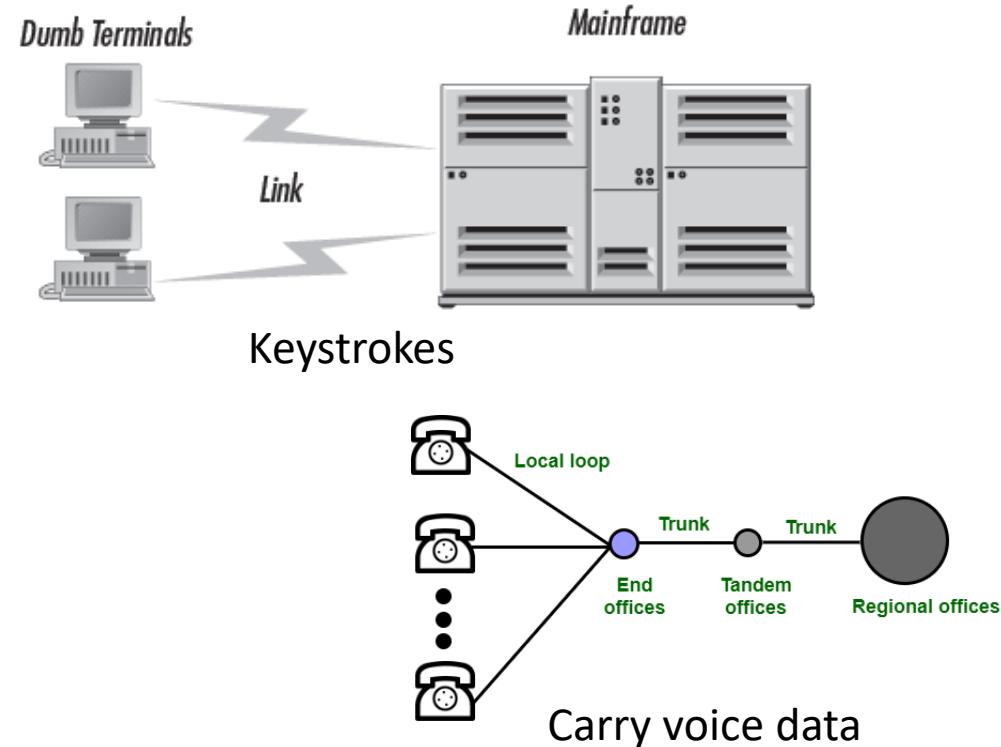
*Slides adapted from KR slides*

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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)

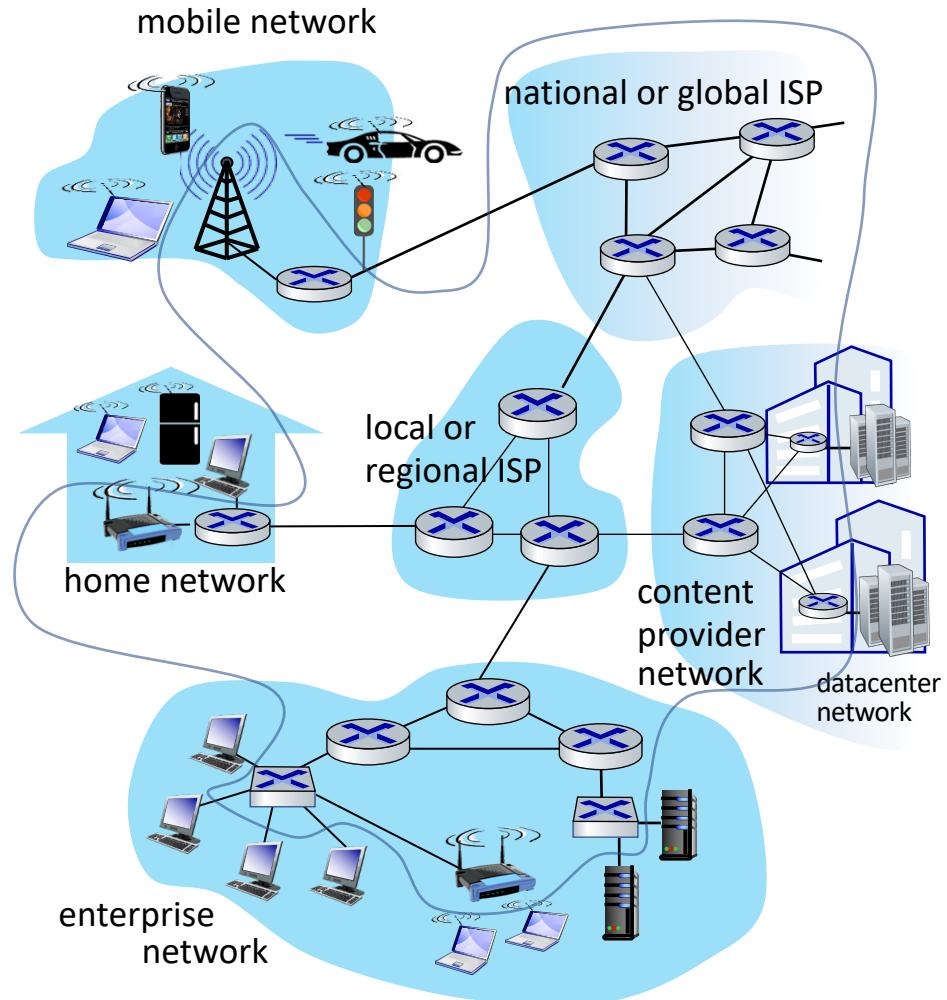
- routers, switches

*Communication links*

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

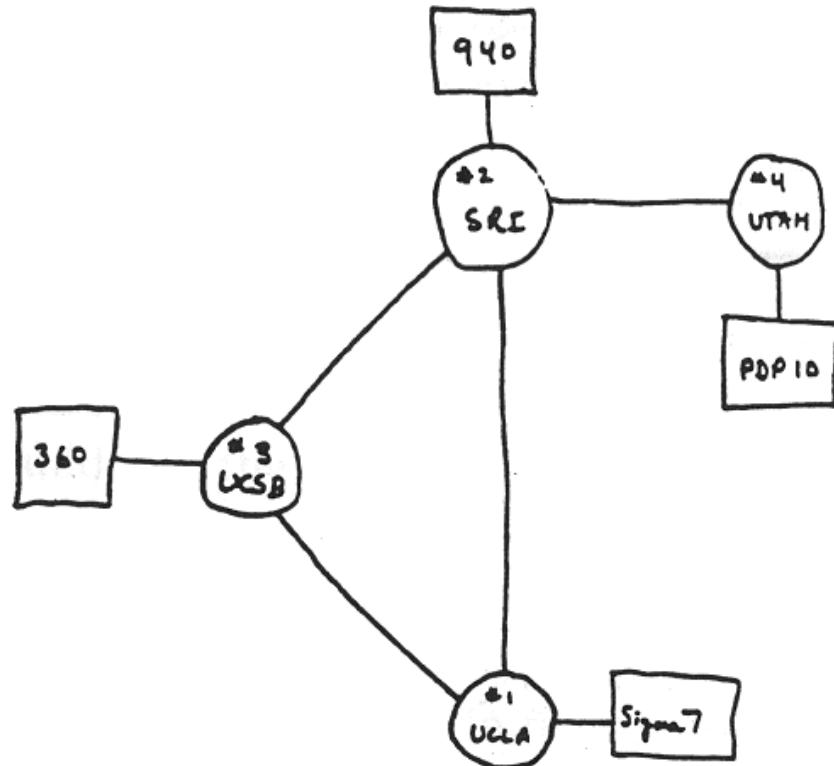
*Networks*

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



# Internet Evolution

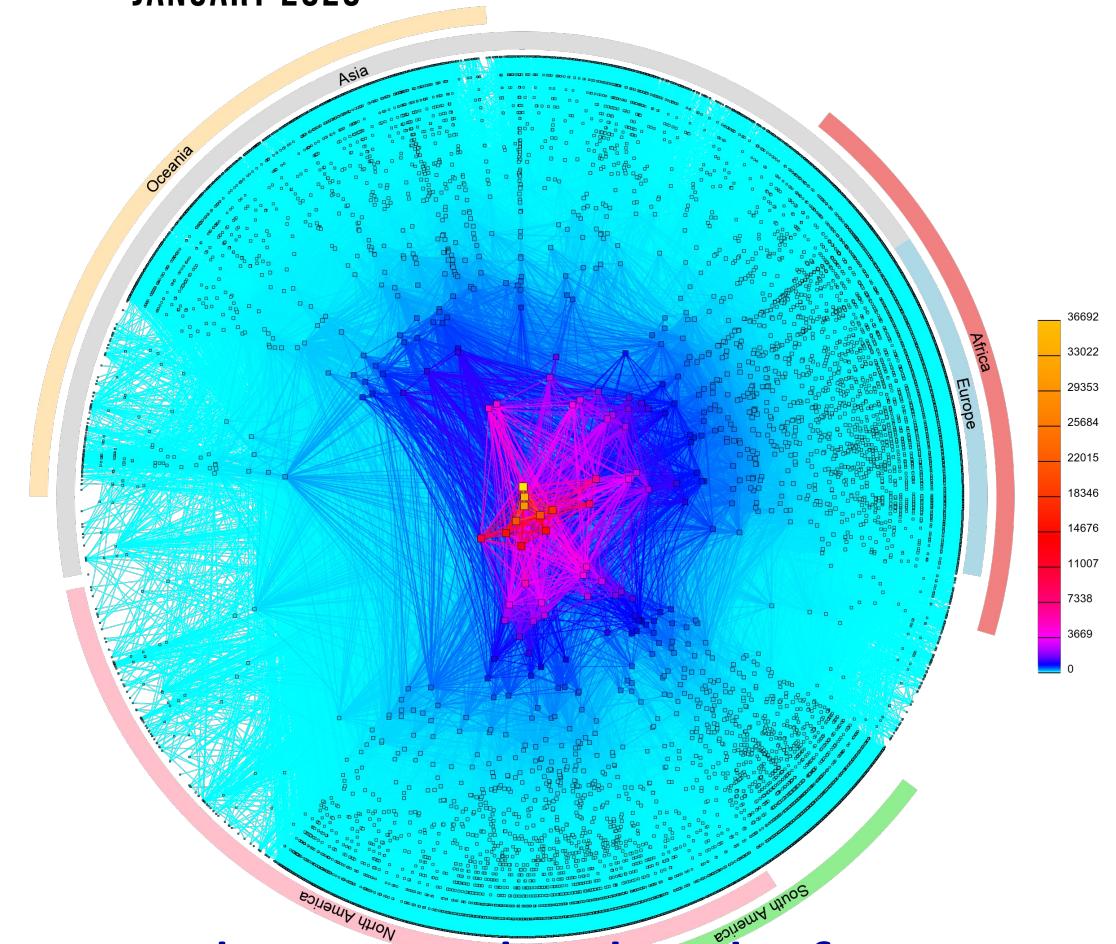
1969



THE ARPA NETWORK

2022

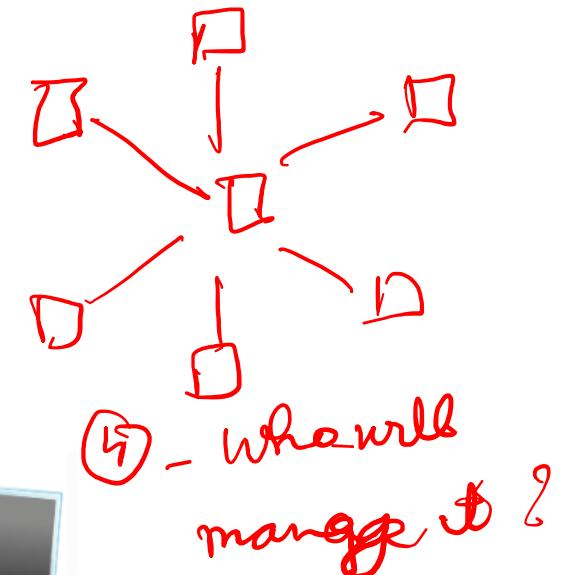
CAIDA'S IPV4 AS CORE GRAPH  
JANUARY 2020



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

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

- Let's build a network with two machines

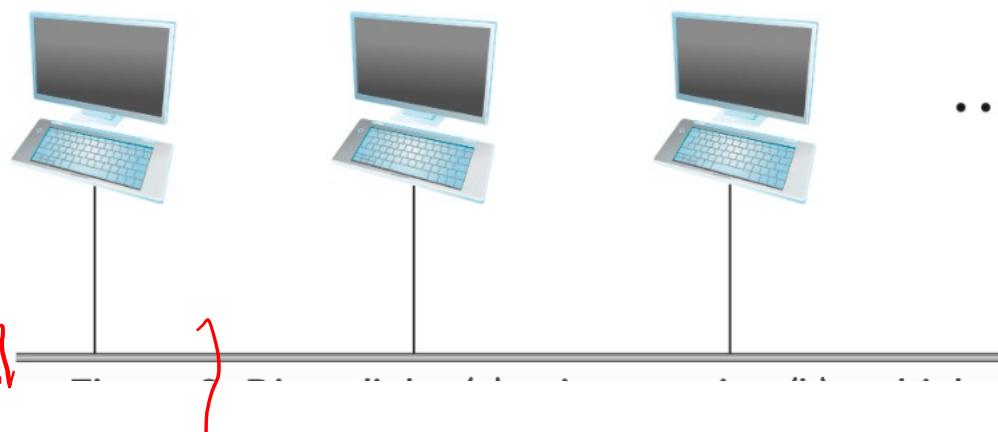


- How do we connect  $n$  machines

Mult-access

link

③ Bottleneck



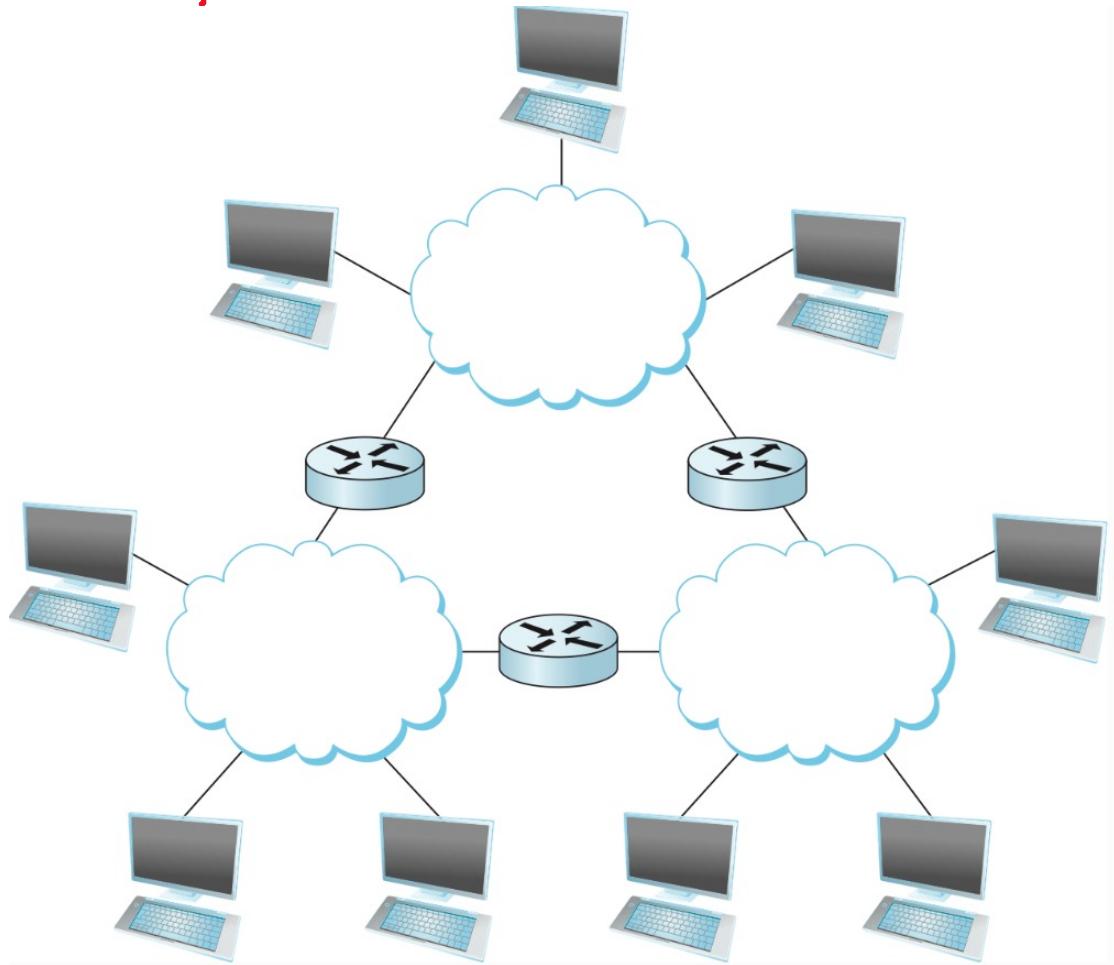
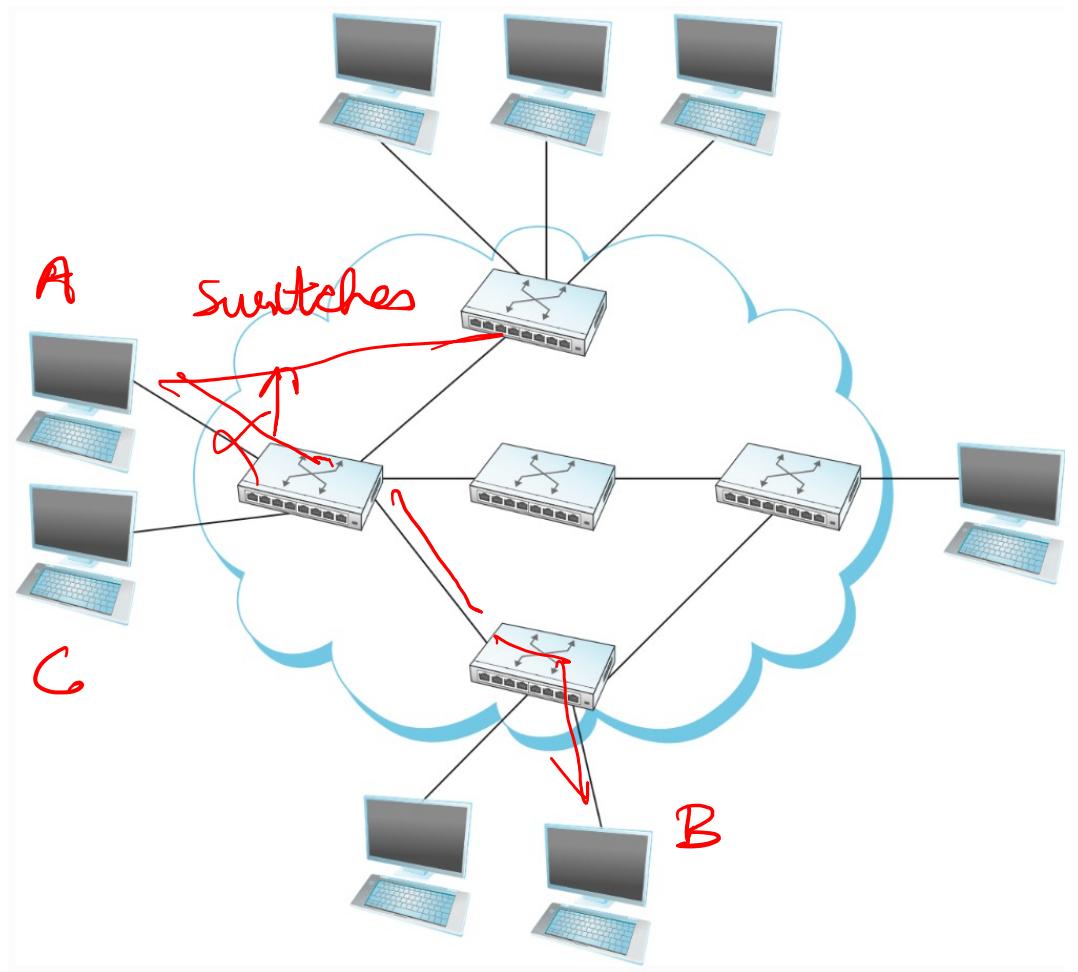
① Signal will attenuate as the length of wire grows

② Single point of failure

# How to Build a Computer Network?

## From first principles..

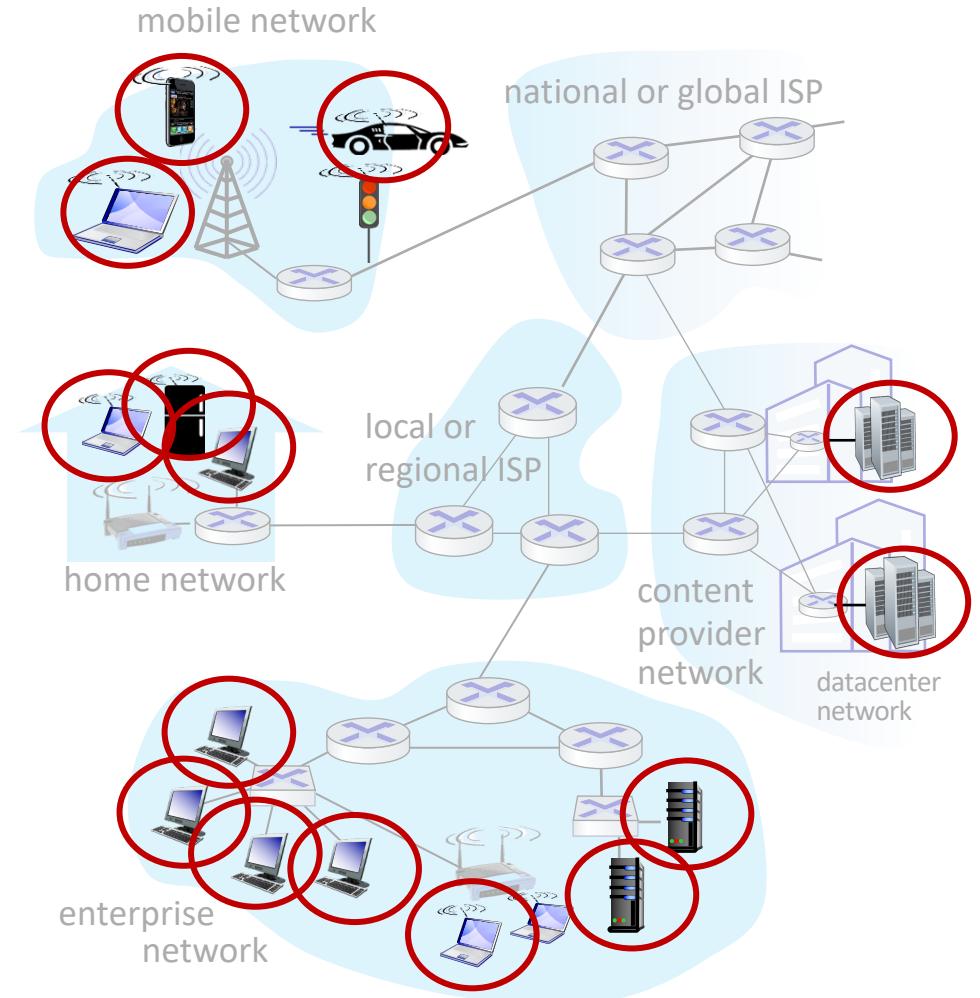
internet / Internet



# A closer look at Internet structure

## Network edge:

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



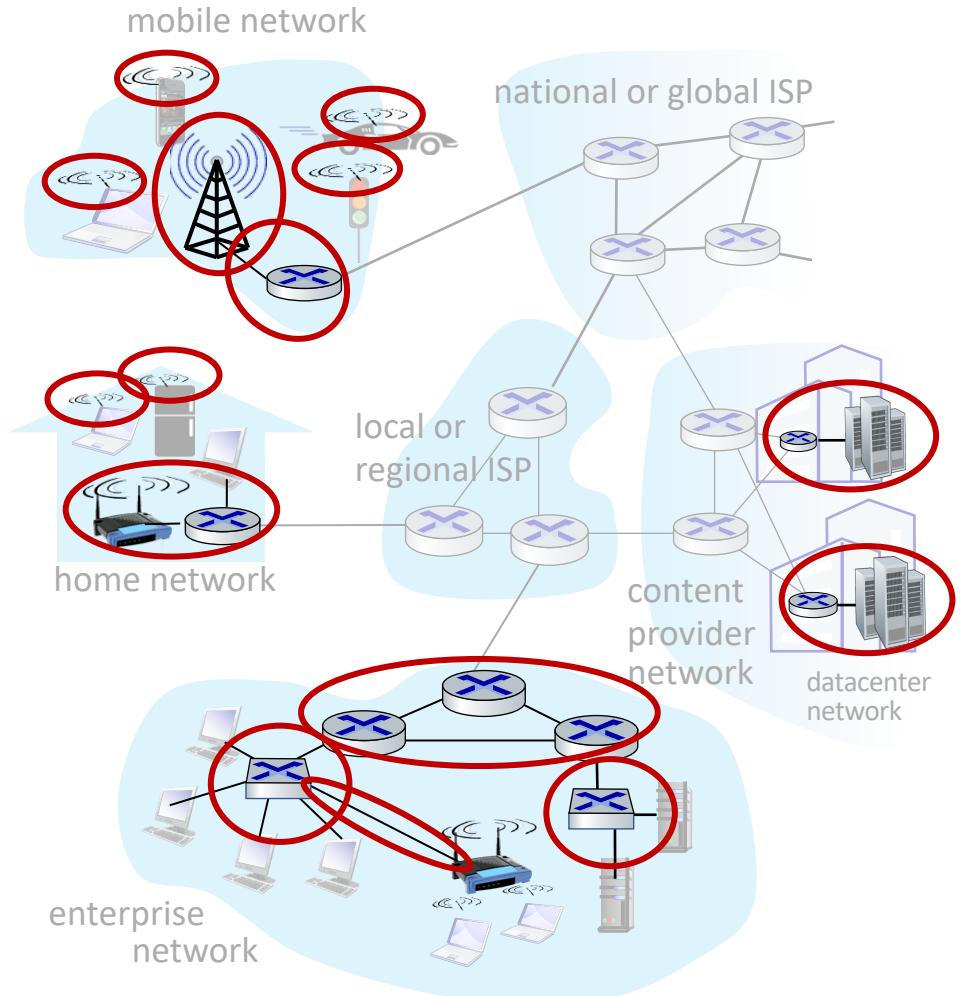
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## Access networks, physical media:

- wired, wireless communication links



# A closer look at Internet structure

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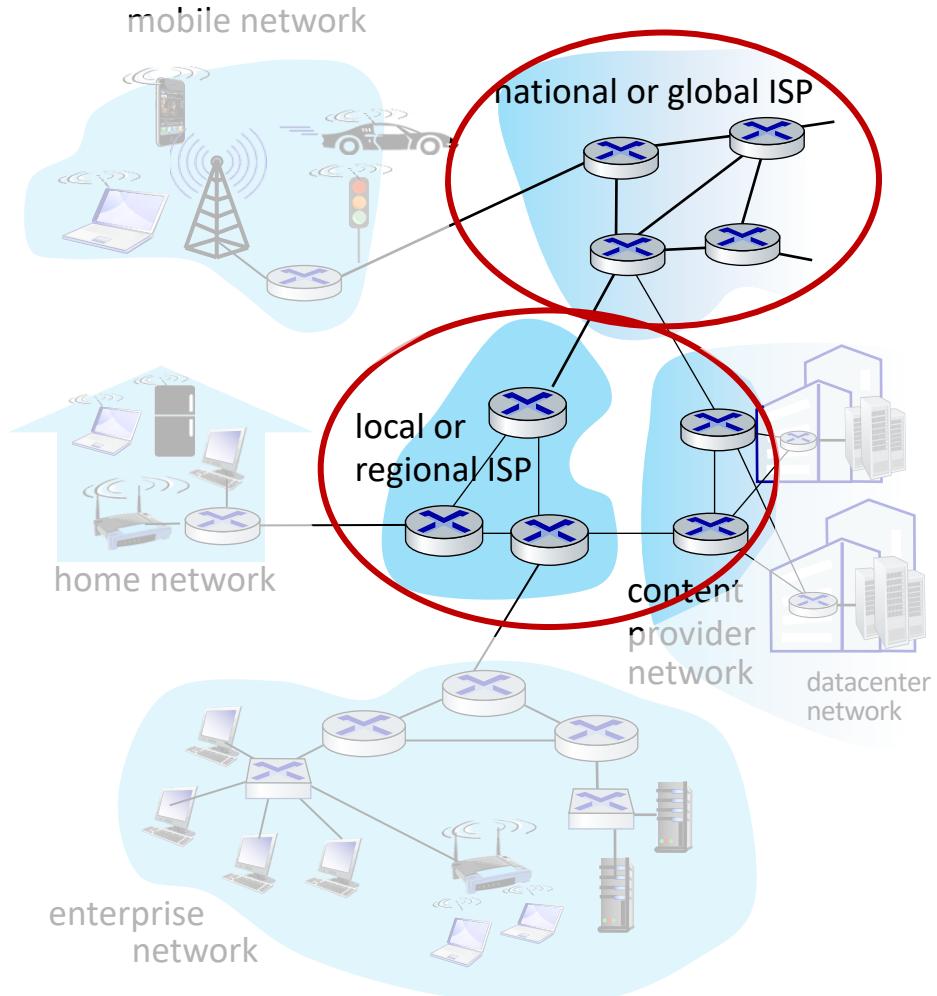
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## Access networks, physical media:

- wired, wireless communication links

## Network core:

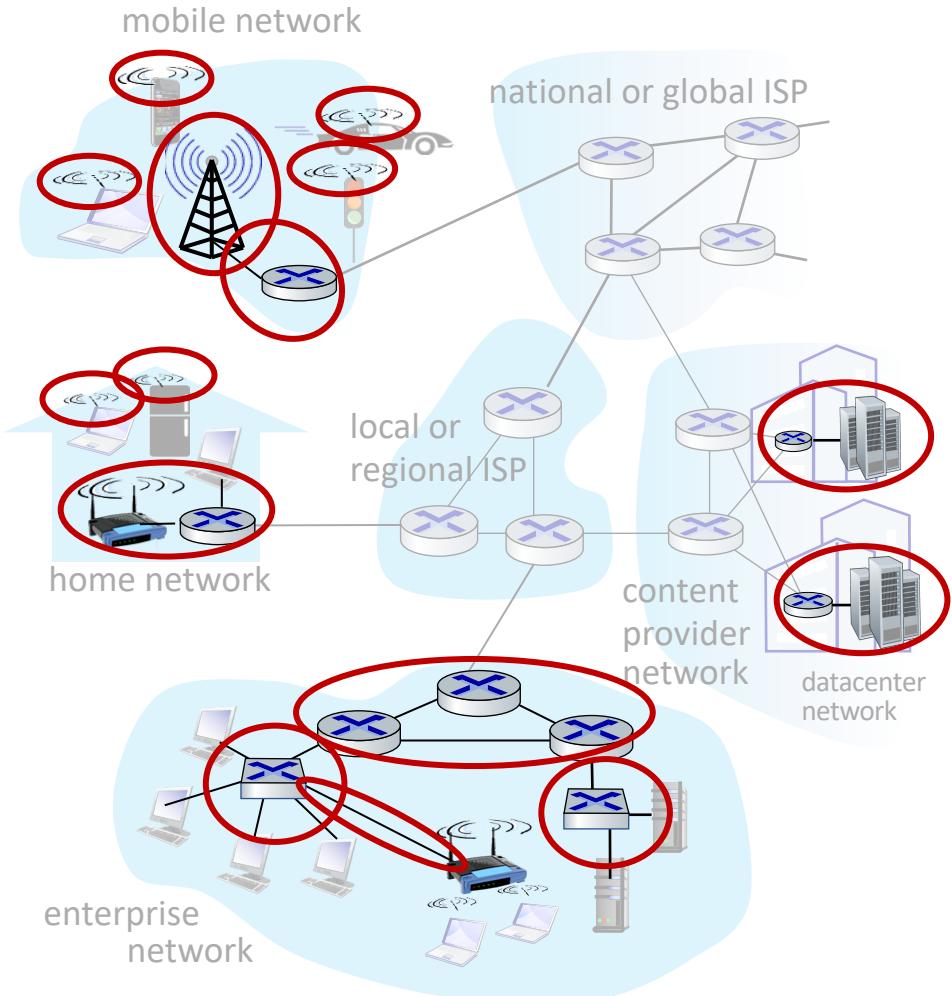
- interconnected routers
- network of networks



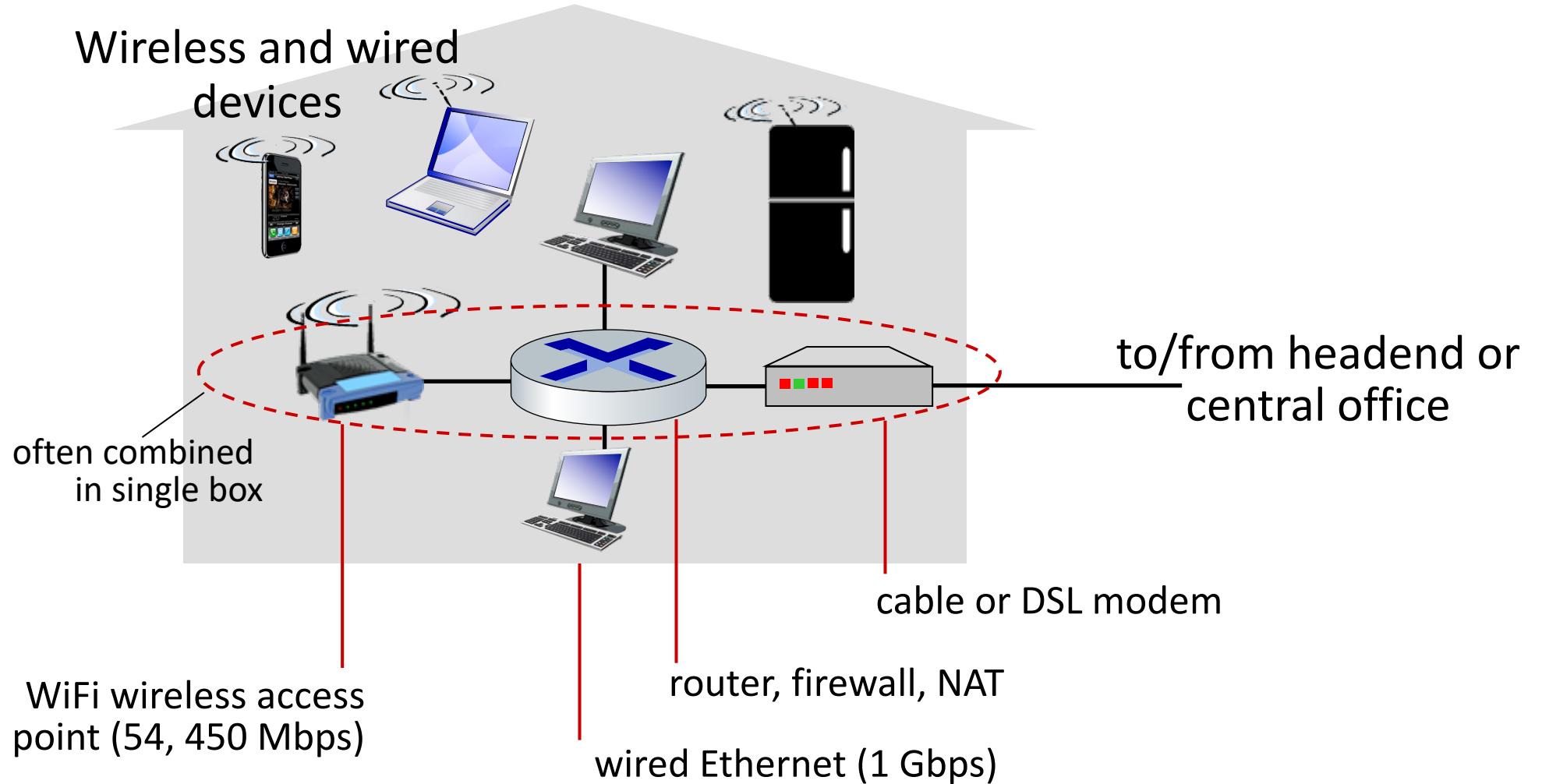
# Access networks

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

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



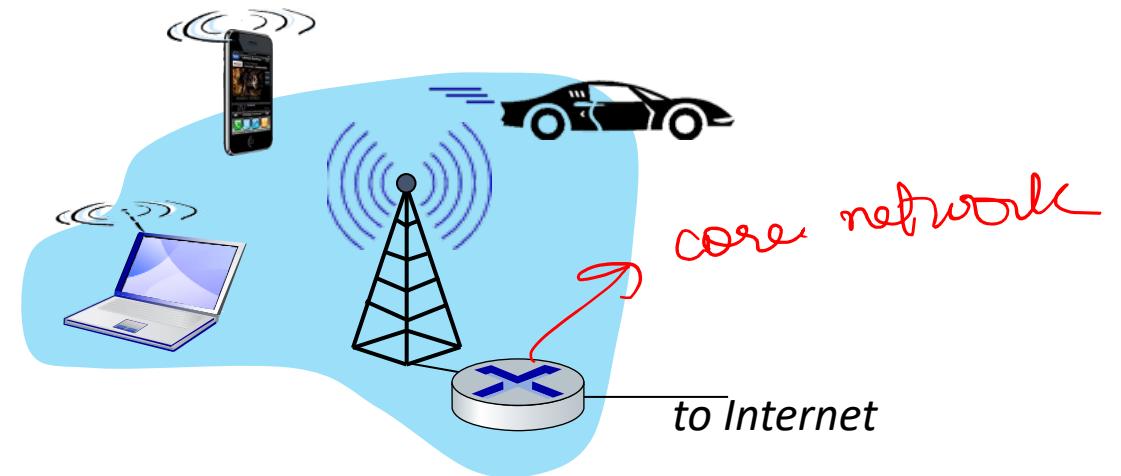
# Access networks: home networks



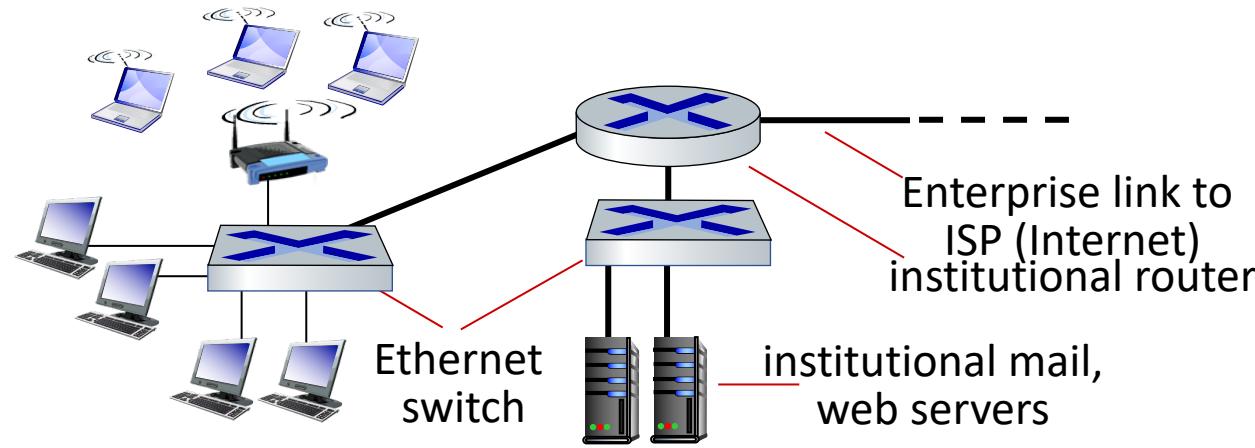
# Cellular access networks

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



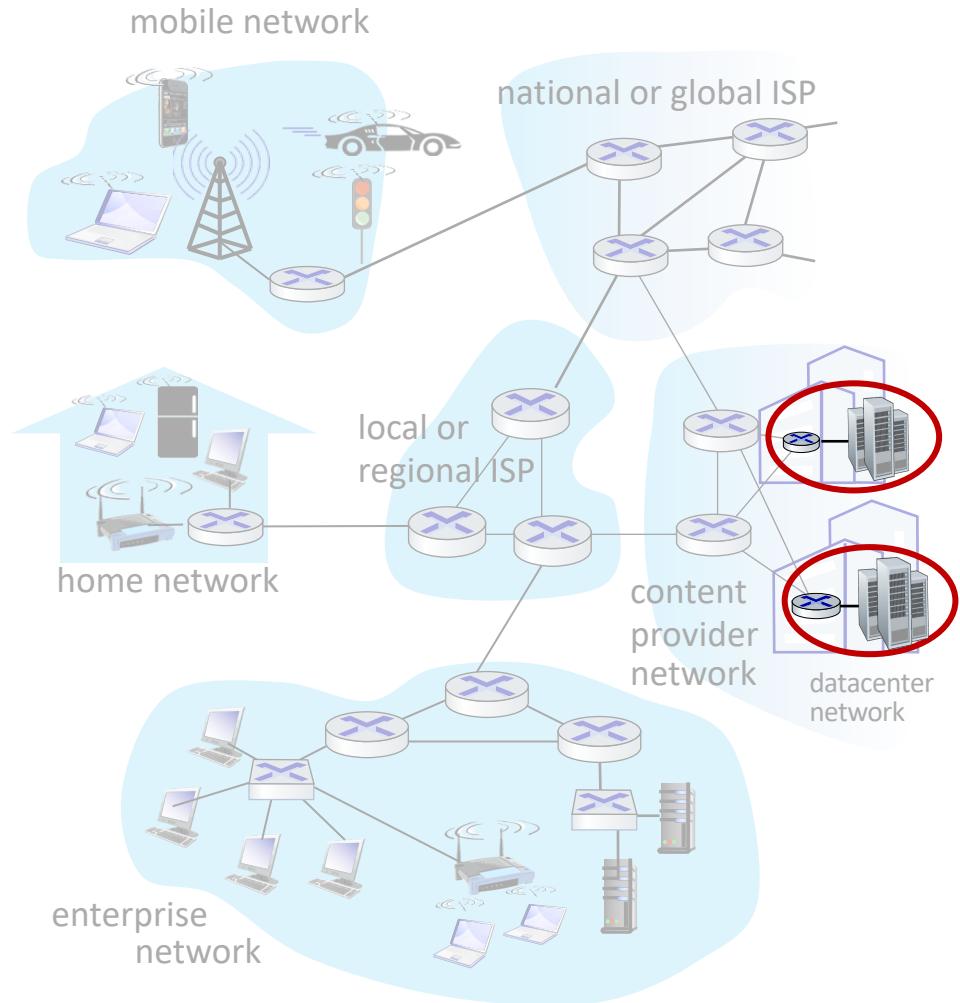
- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
  - Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
  - WiFi: wireless access points at 11, 54, 450 Mbps
- IITD network infrastructure

# Access networks: data center networks

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

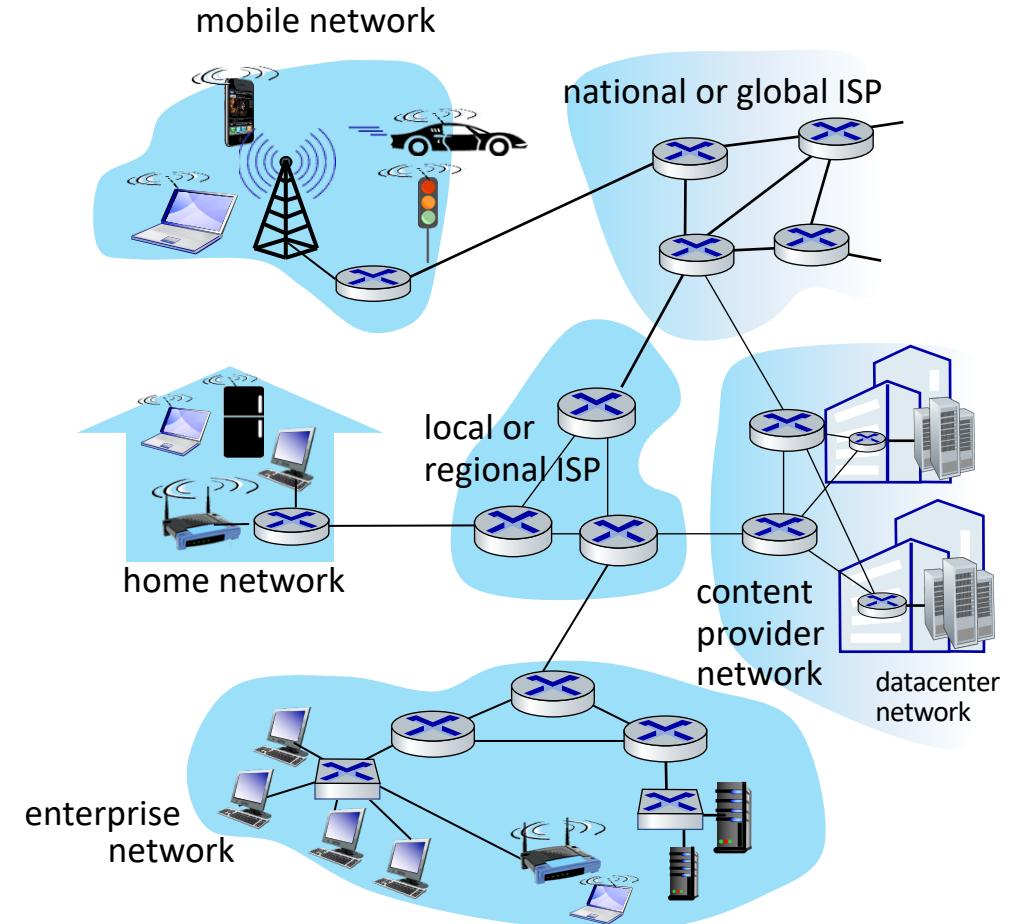


Courtesy: Massachusetts Green High Performance Computing Center ([mghpcc.org](http://mghpcc.org))



# Internet structure: a “network of networks”

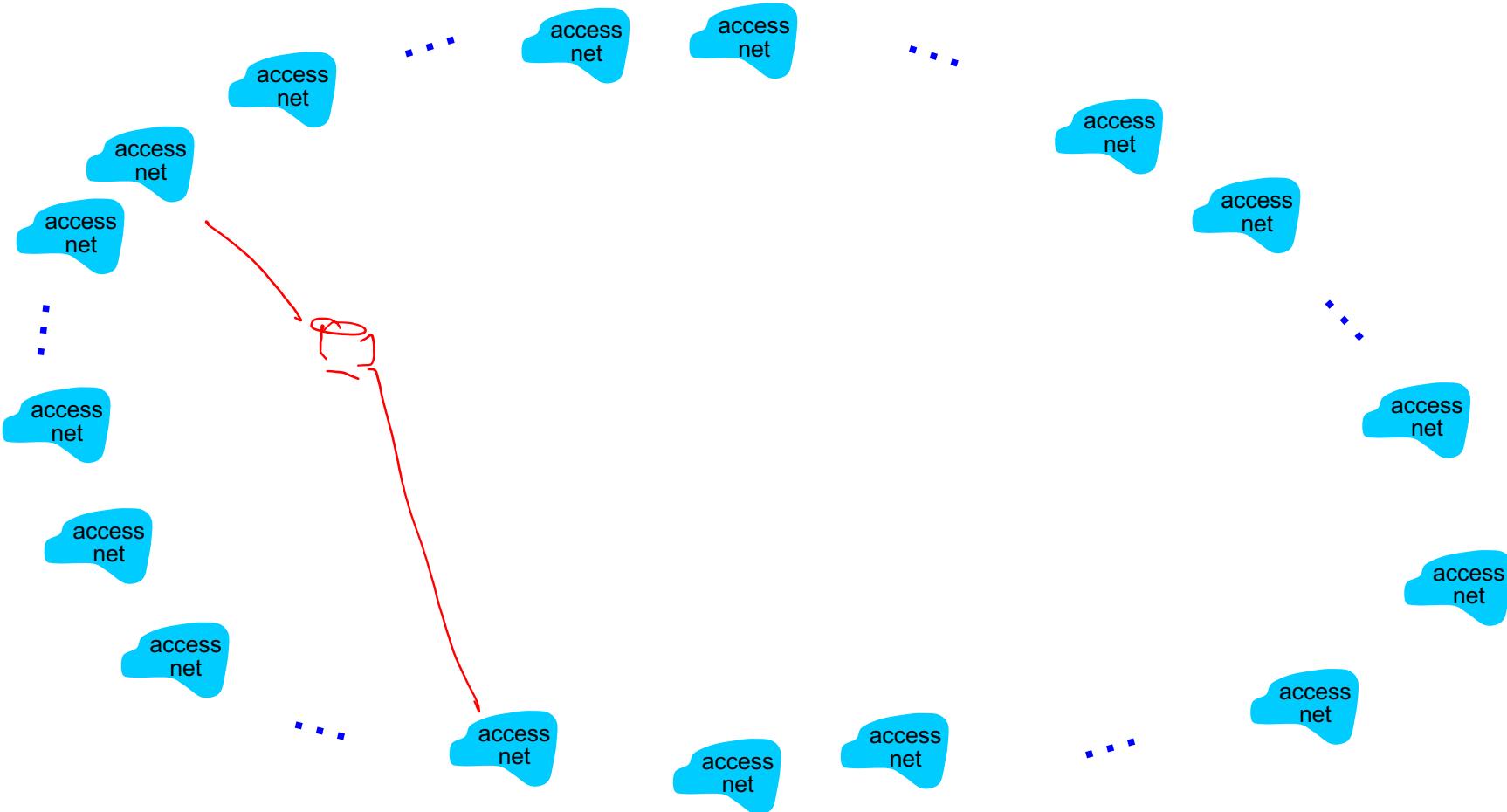
- hosts connect to Internet via **access** Internet Service Providers (ISPs)
- access ISPs in turn must be interconnected
  - so that *any* two hosts (*anywhere!*) can send packets to each other
- resulting network of networks is very complex
  - evolution driven by **economics, national policies**



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

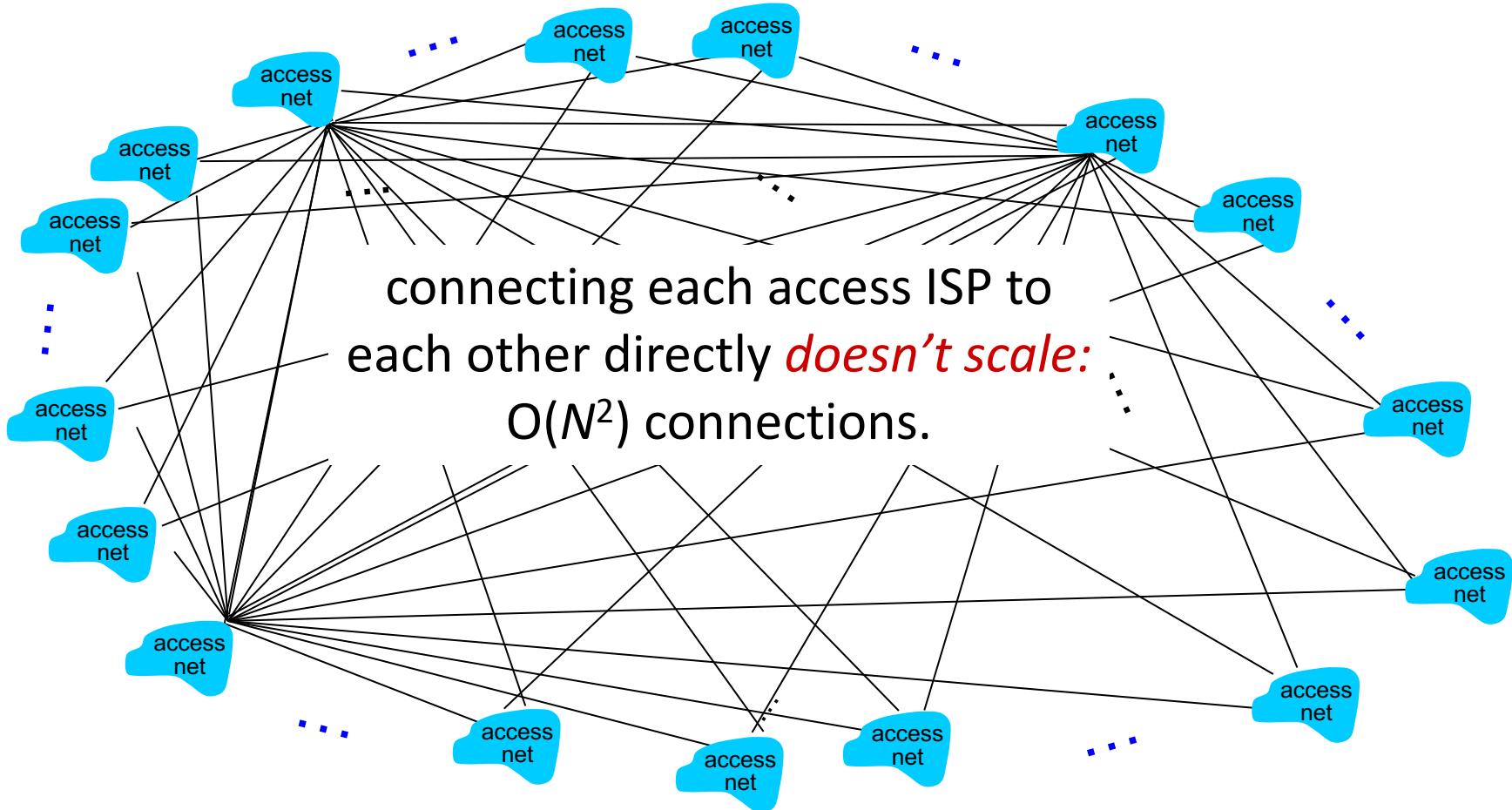
# Internet structure: a “network of networks”

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



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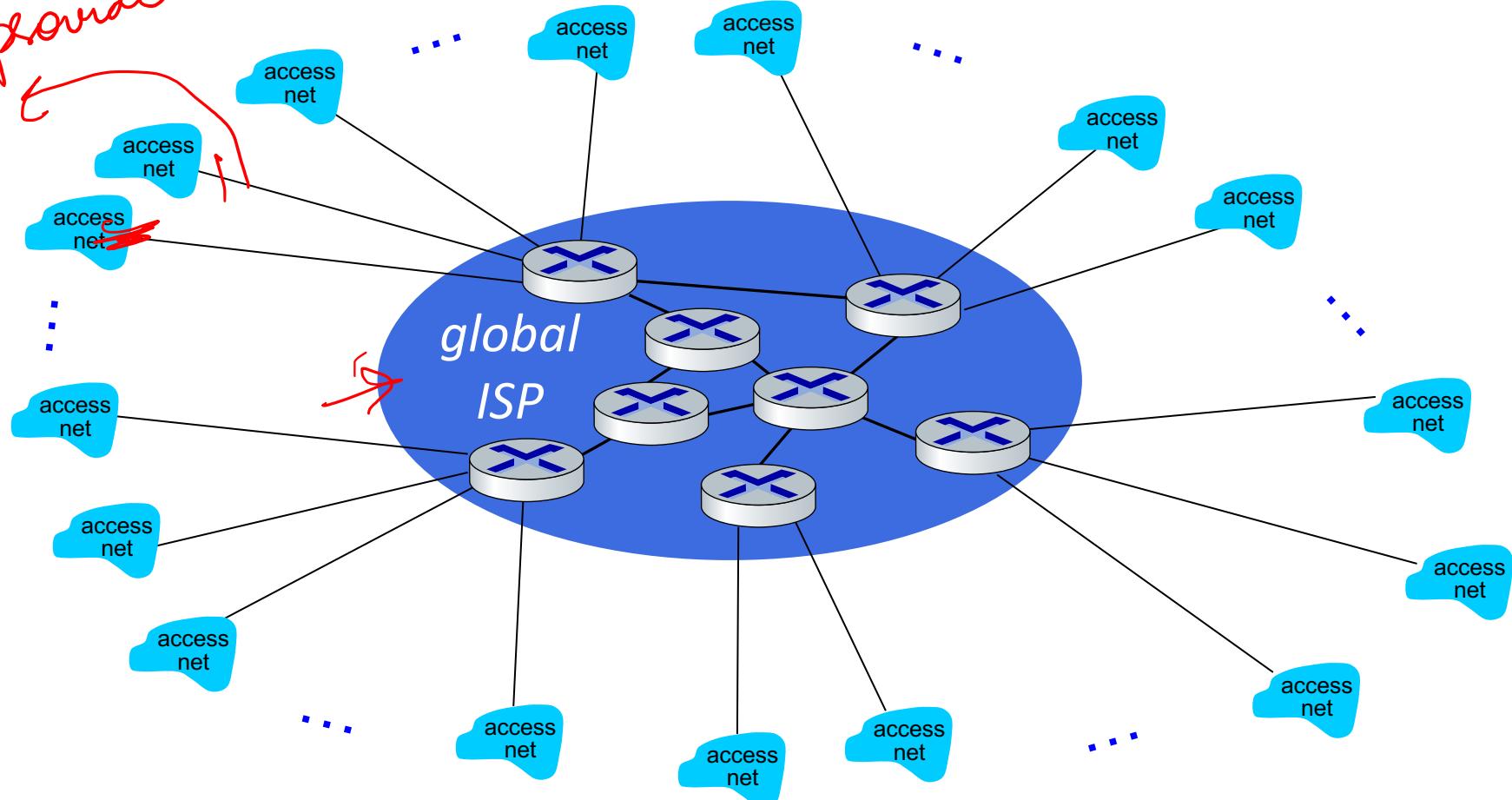


# Internet structure: a “network of networks”

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

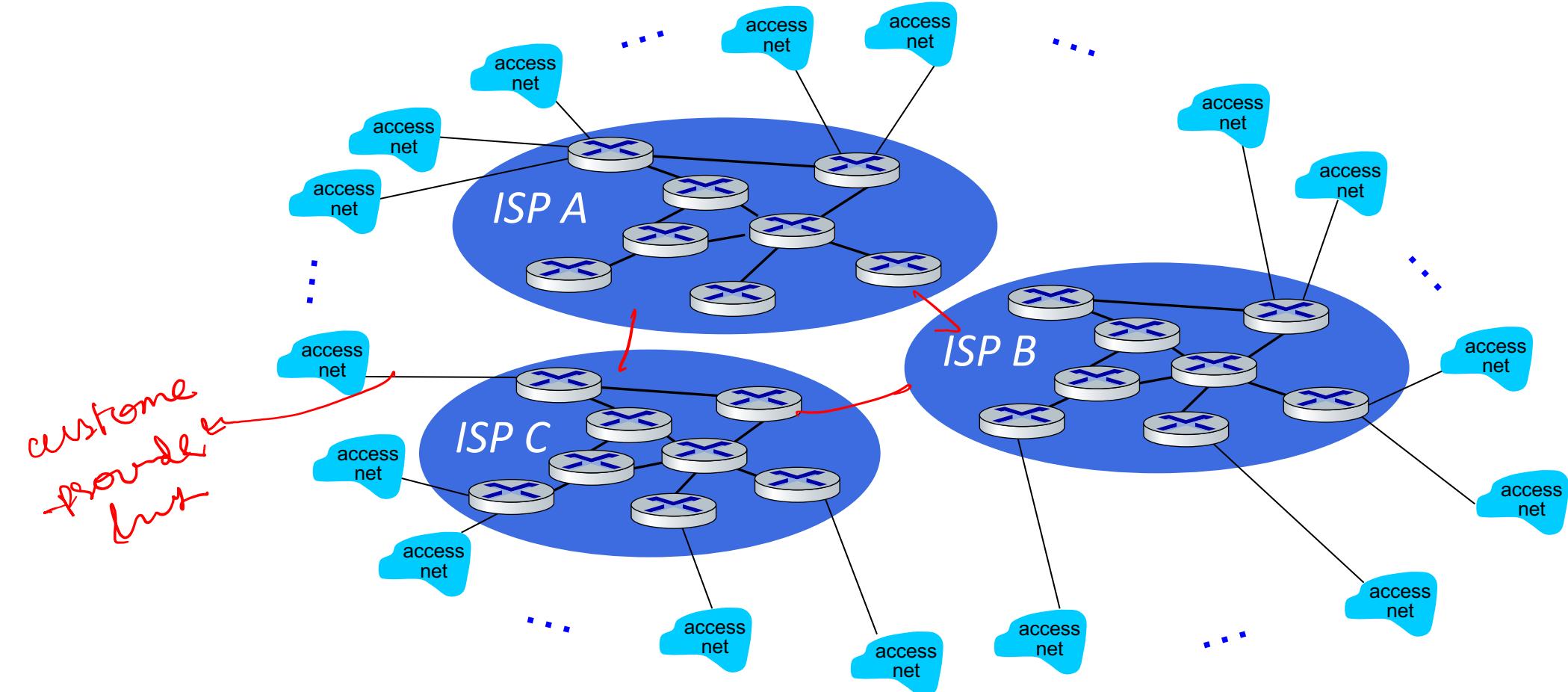
② Monopoly  
Customer and provider ISPs have economic agreement.

customer provider



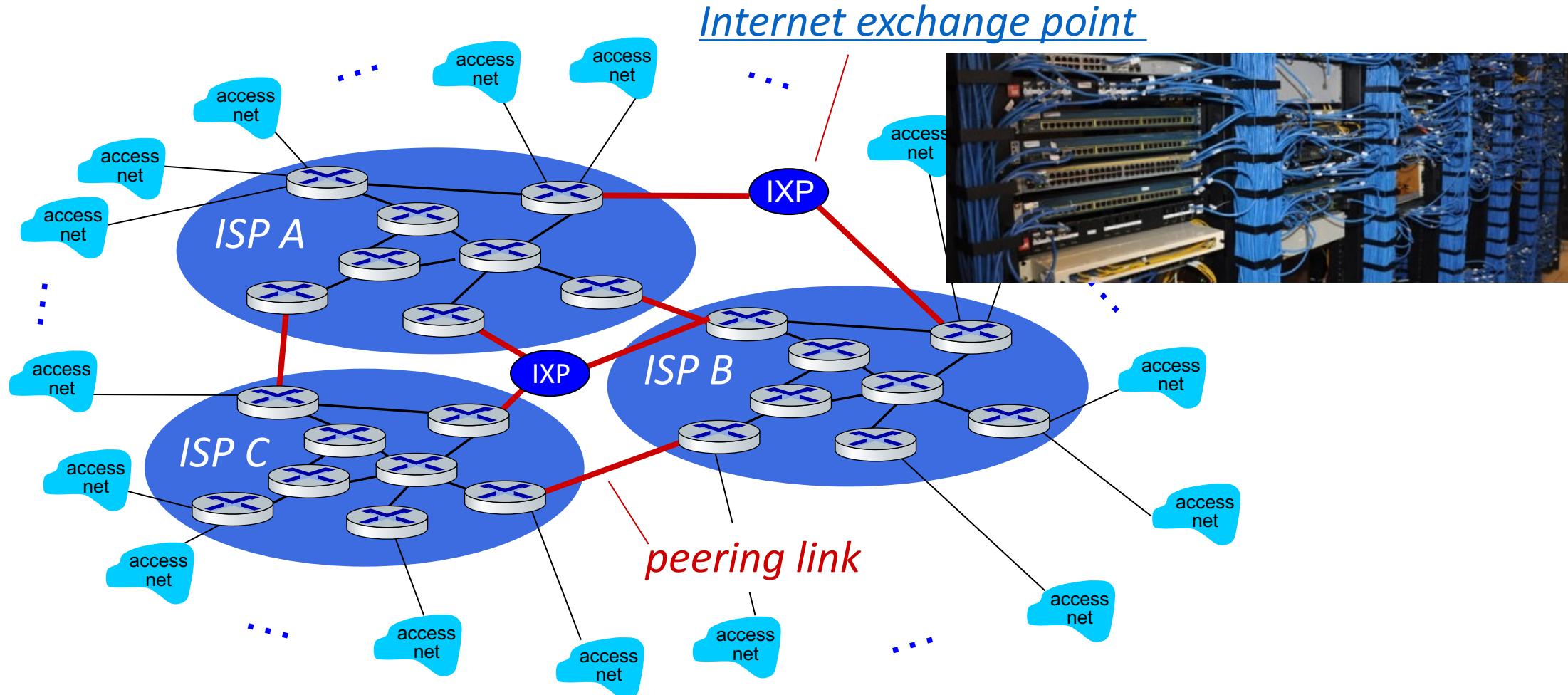
# Internet structure: a “network of networks”

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



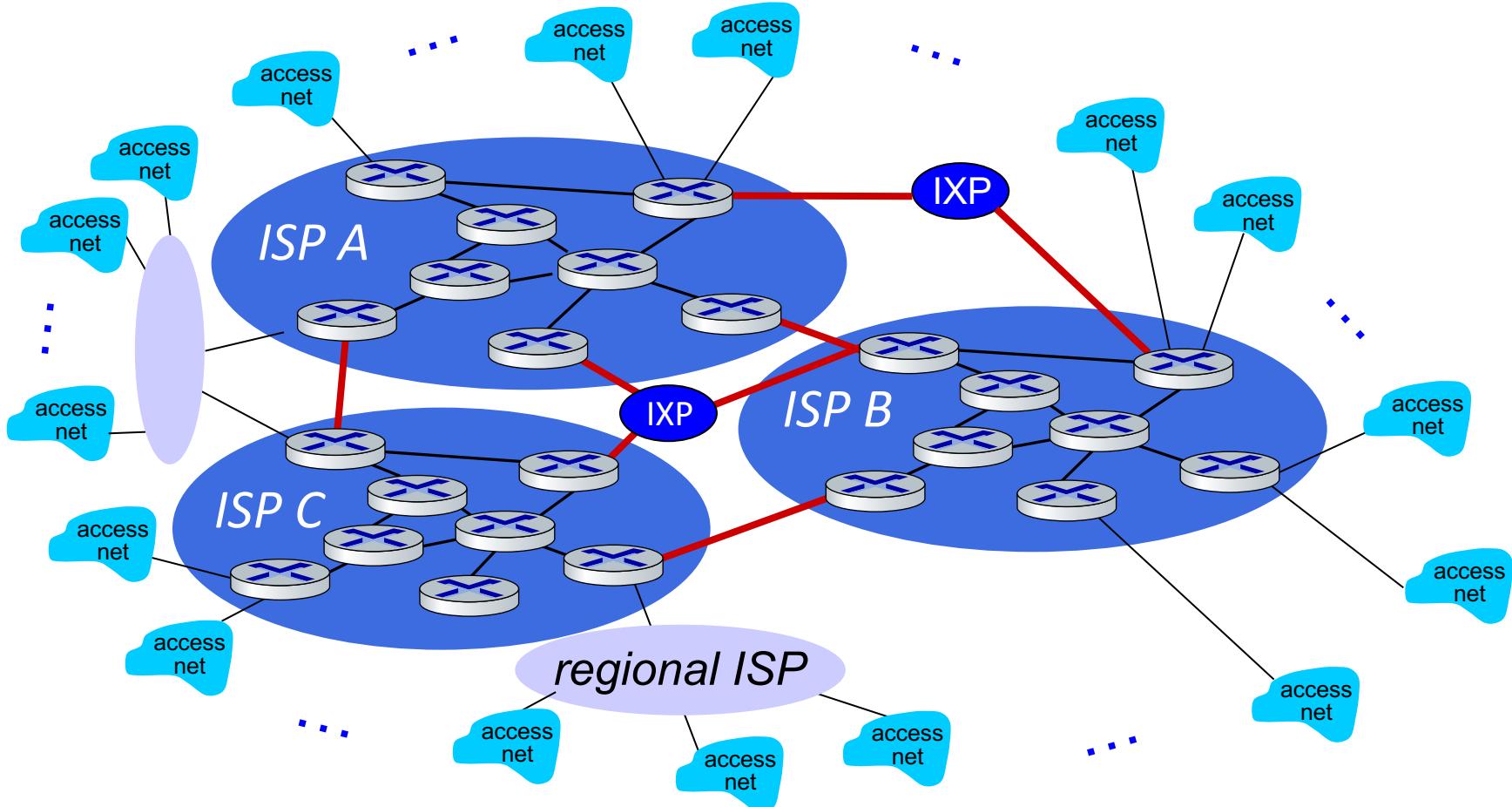
# Internet structure: a “network of networks”

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



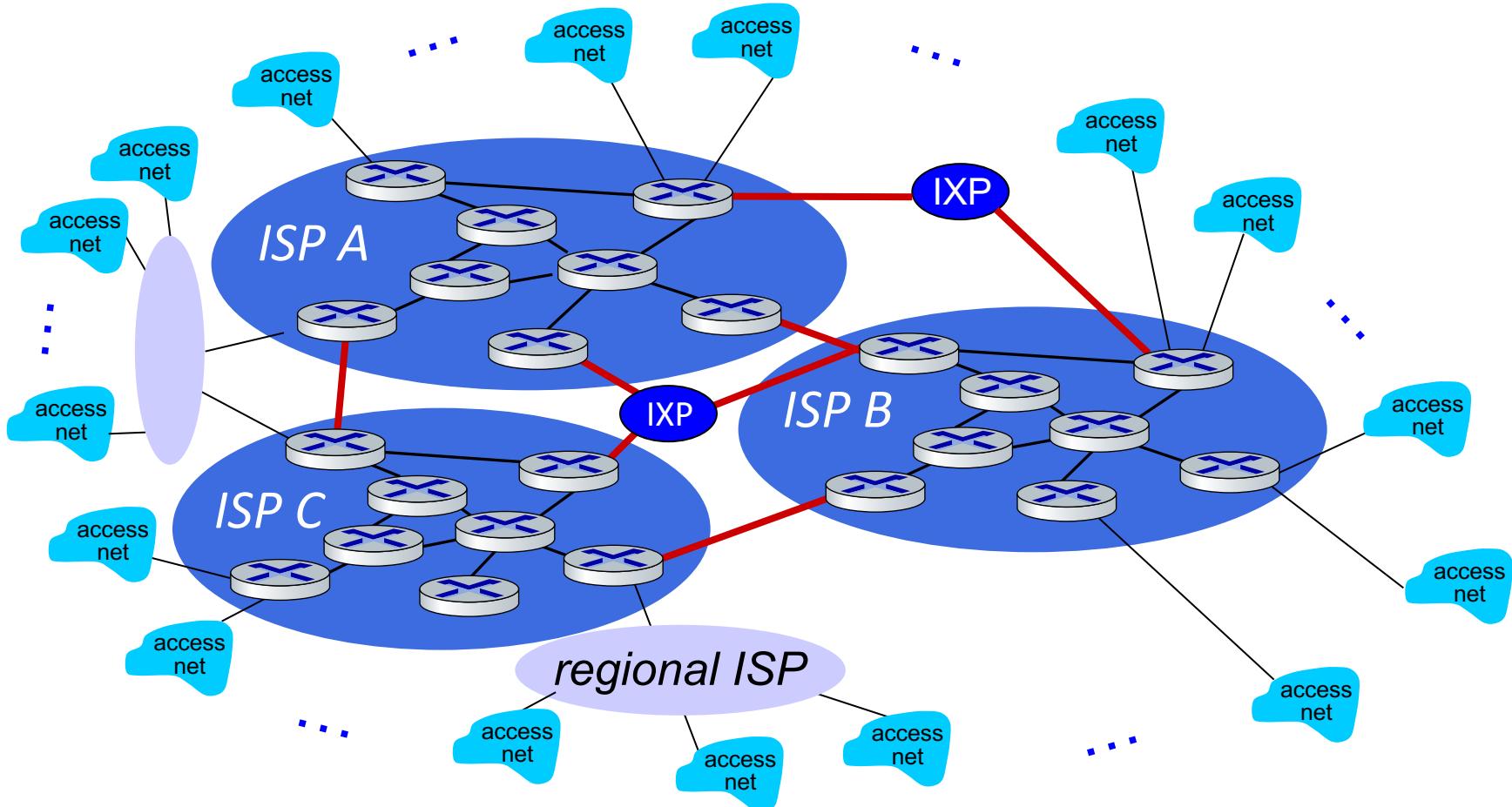
# Internet structure: a “network of networks”

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



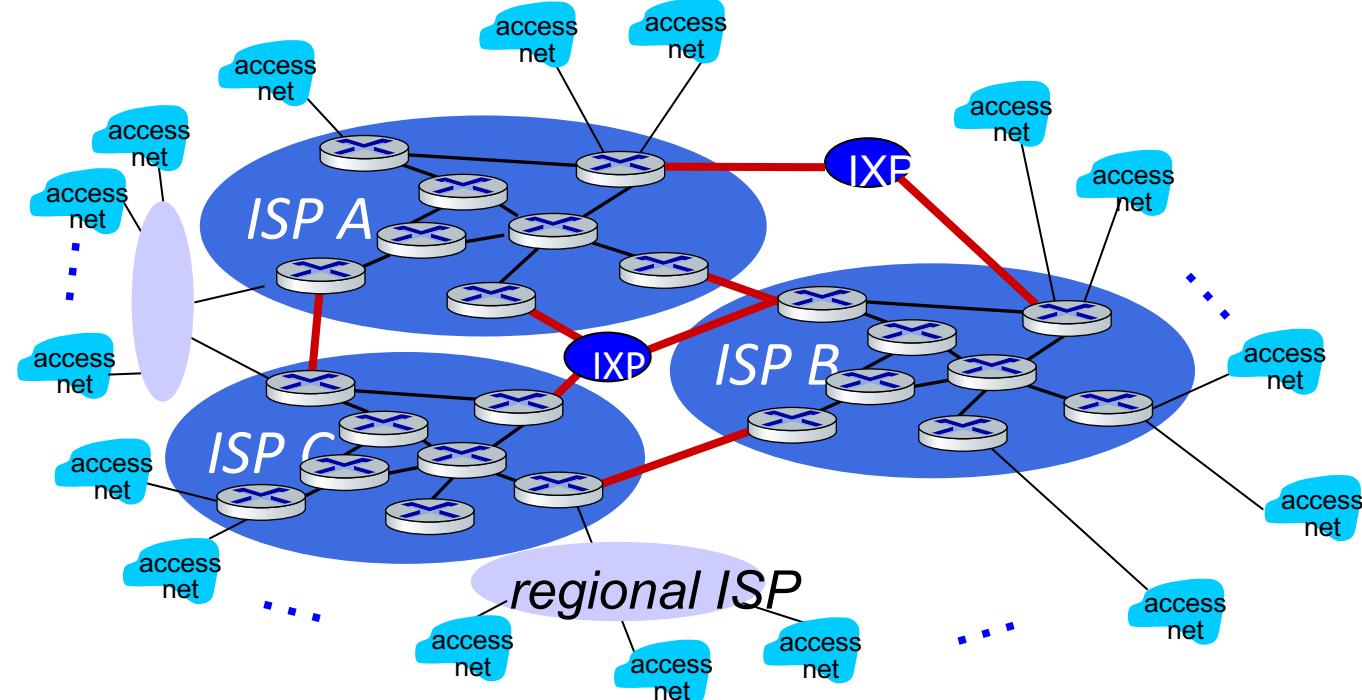
# Internet structure: a “network of networks”

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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”

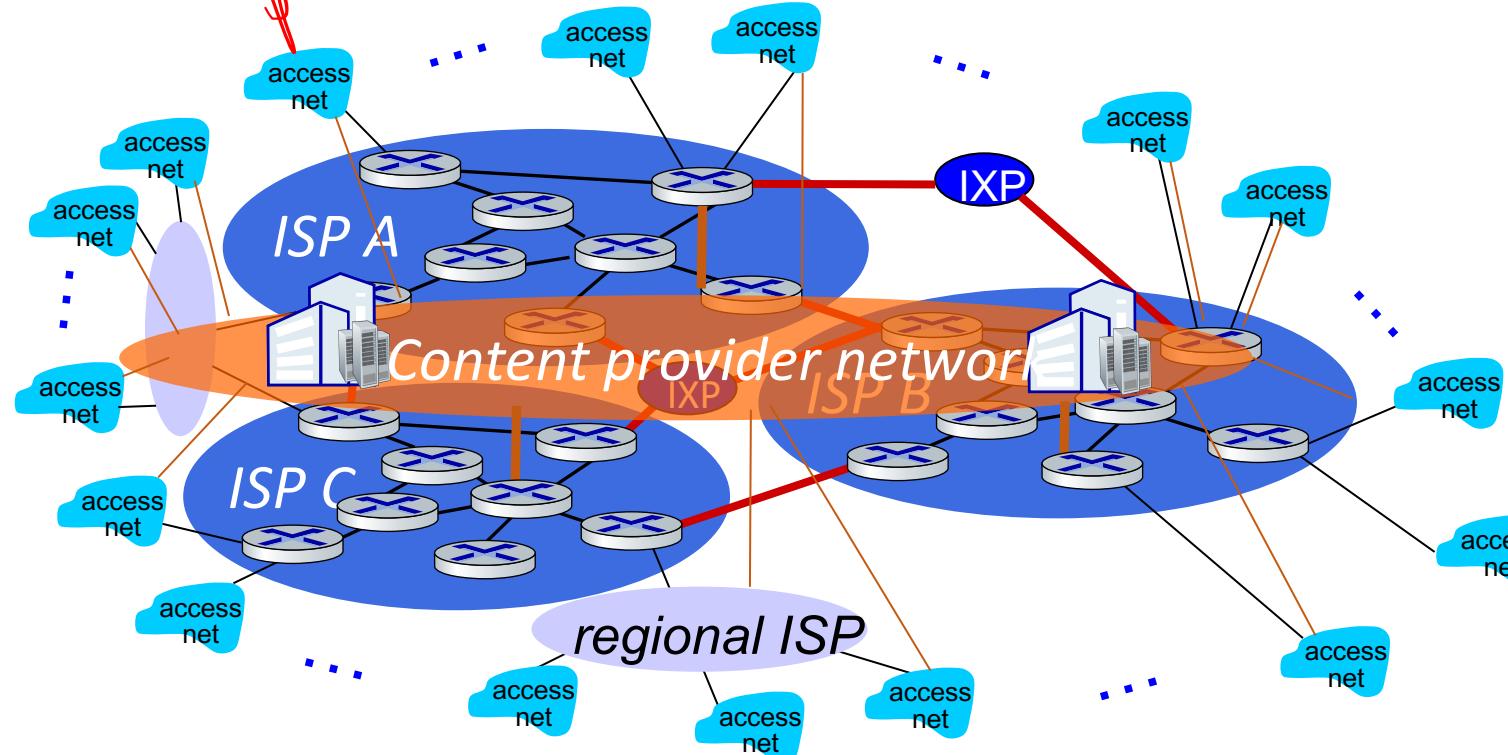
Content provider networks (e.g., Google, Microsoft, Akamai) may run their own network..

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?