Defining the Internet

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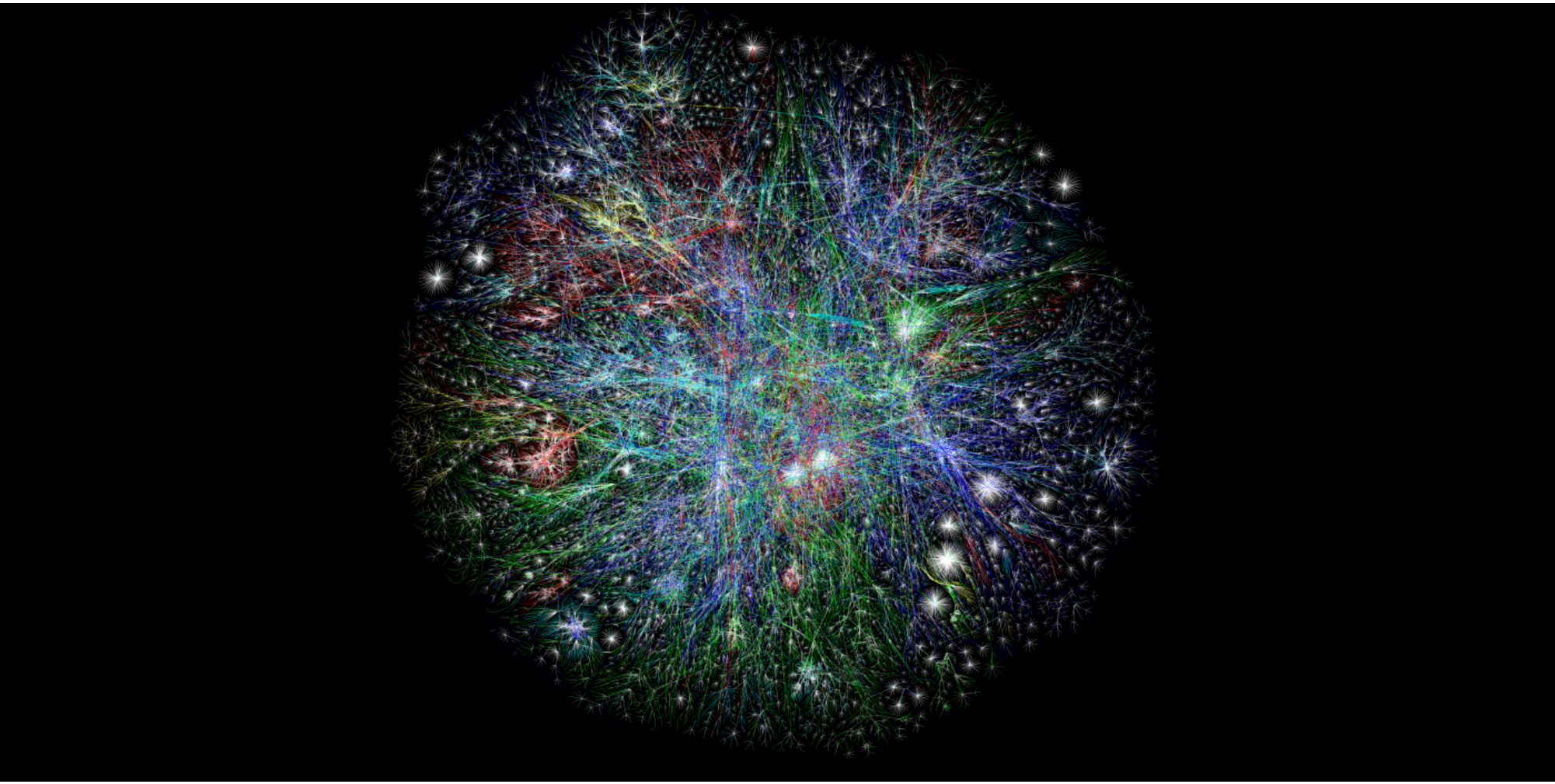
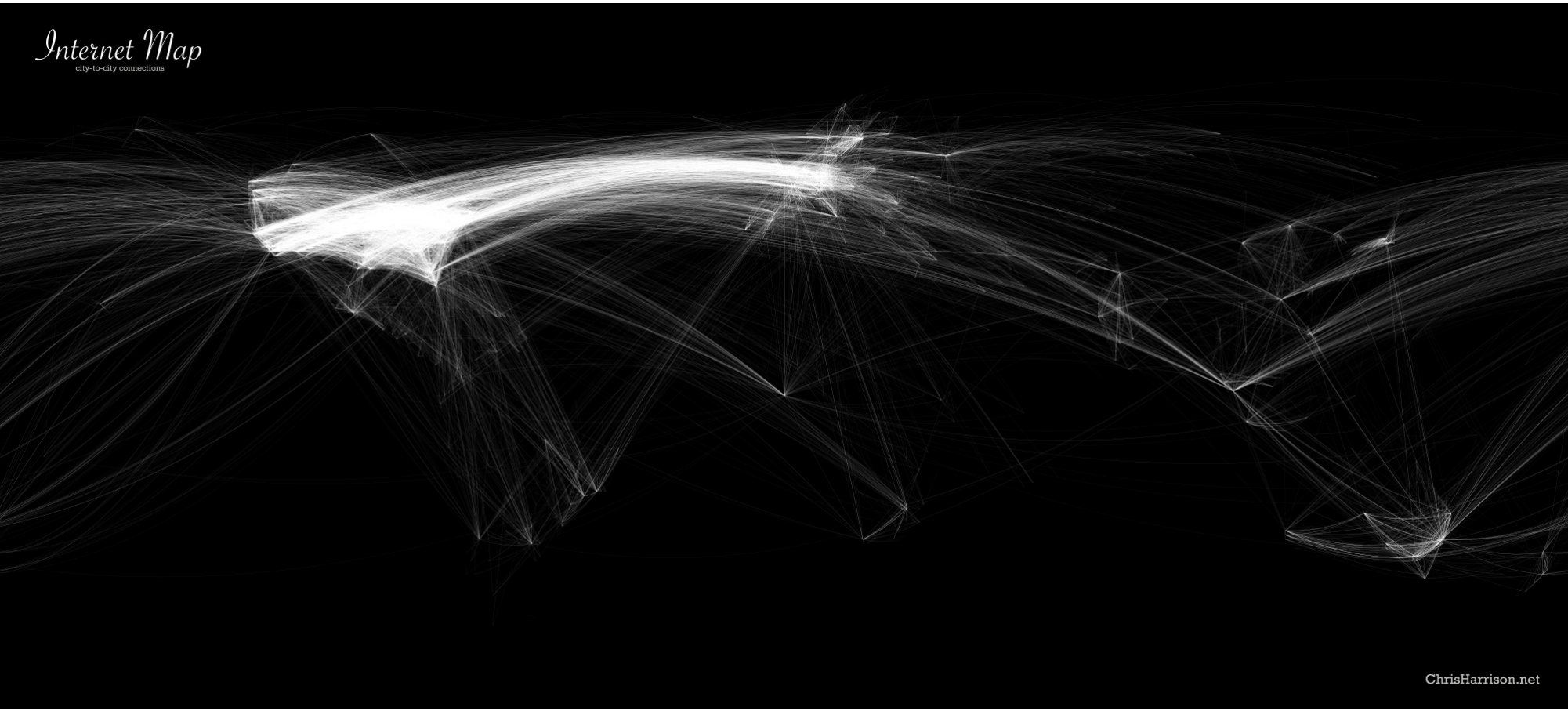
What is the Internet?



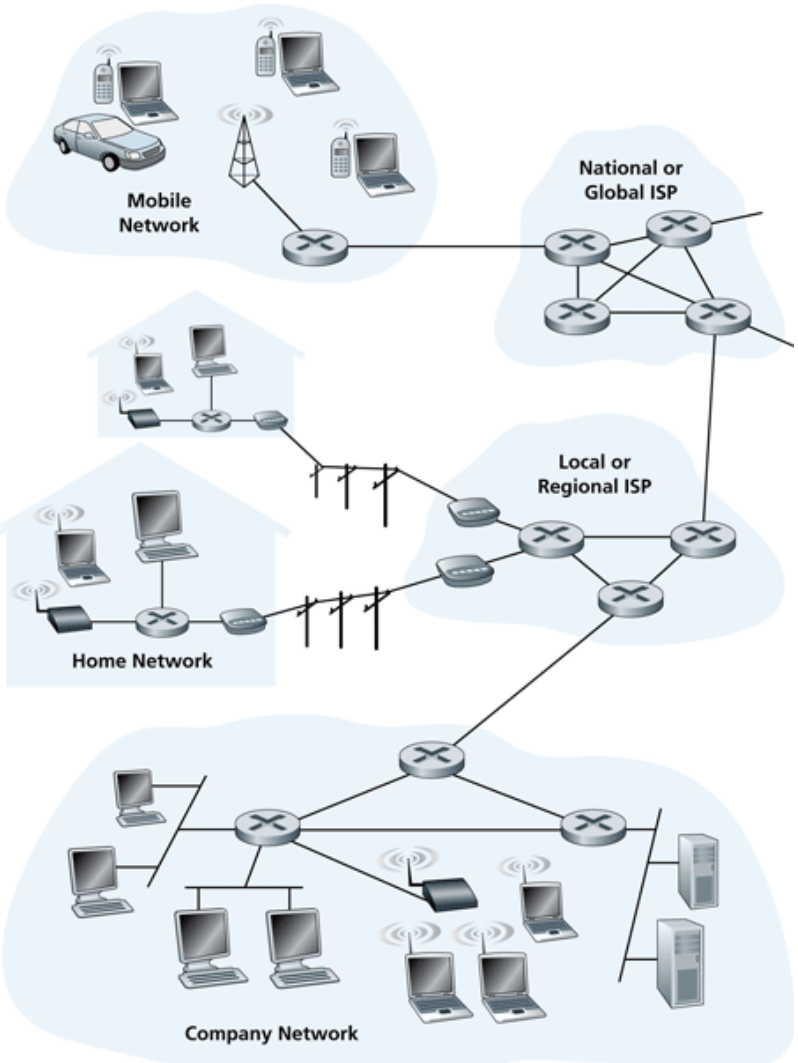
Internet Map, courtesy Barrett Lyon, 2003

What is the Internet?



▸ Internet Map, courtesy Chris Harrison, 2011

Components



- hosts
- routers
- networks
- links

Services

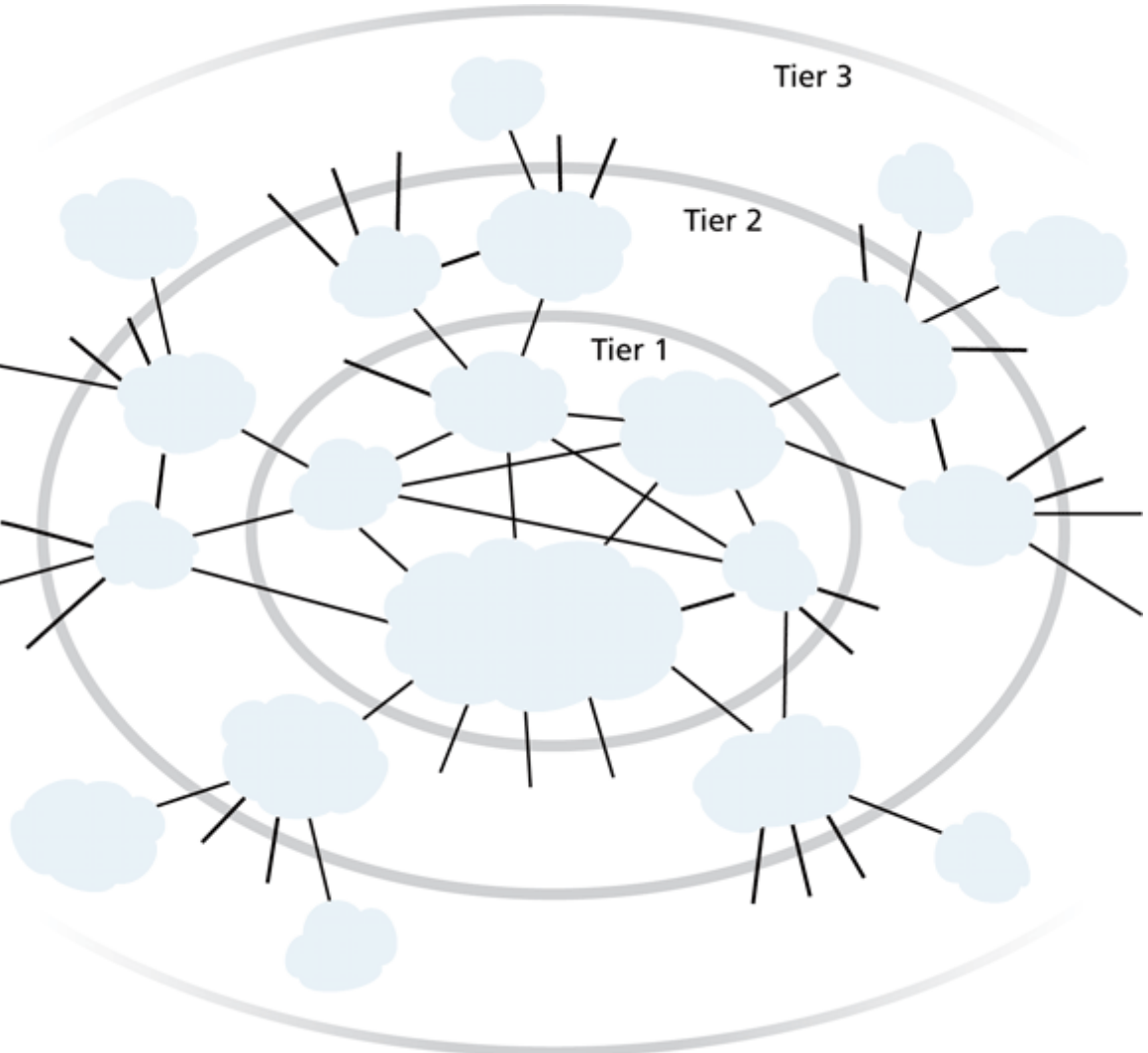
- distributed applications
  - web
  - social networking
  - email
  - games
  - commerce
  - databases
  - voting
  - file sharing
- generic services on which applications can be built
  - TCP : reliable data transfer
  - UDP : unreliable data transfer

Protocols

- Application Protocols
  - HTTP
  - FTP
  - SMTP
  - Gnutella
  - BitTorrent
- Transport Protocols
  - TCP
  - UDP
  - RTP
- Network Protocols
  - IP
  - IPv6
  - ICMP
  - DHCP
- Link Protocols
  - ARP
  - Ethernet
  - IEEE 802.11a,b,g,...
  - PPP
  - MPLS
  - ATM

Internet Structure

A Network of Networks



- roughly hierarchical
- customer-provider relationships
- Tier-1 ISPs (UUNet, BBN/Genuity, Sprint, AT&T)
  - provide national, international coverage
  - treat each other as "equals"

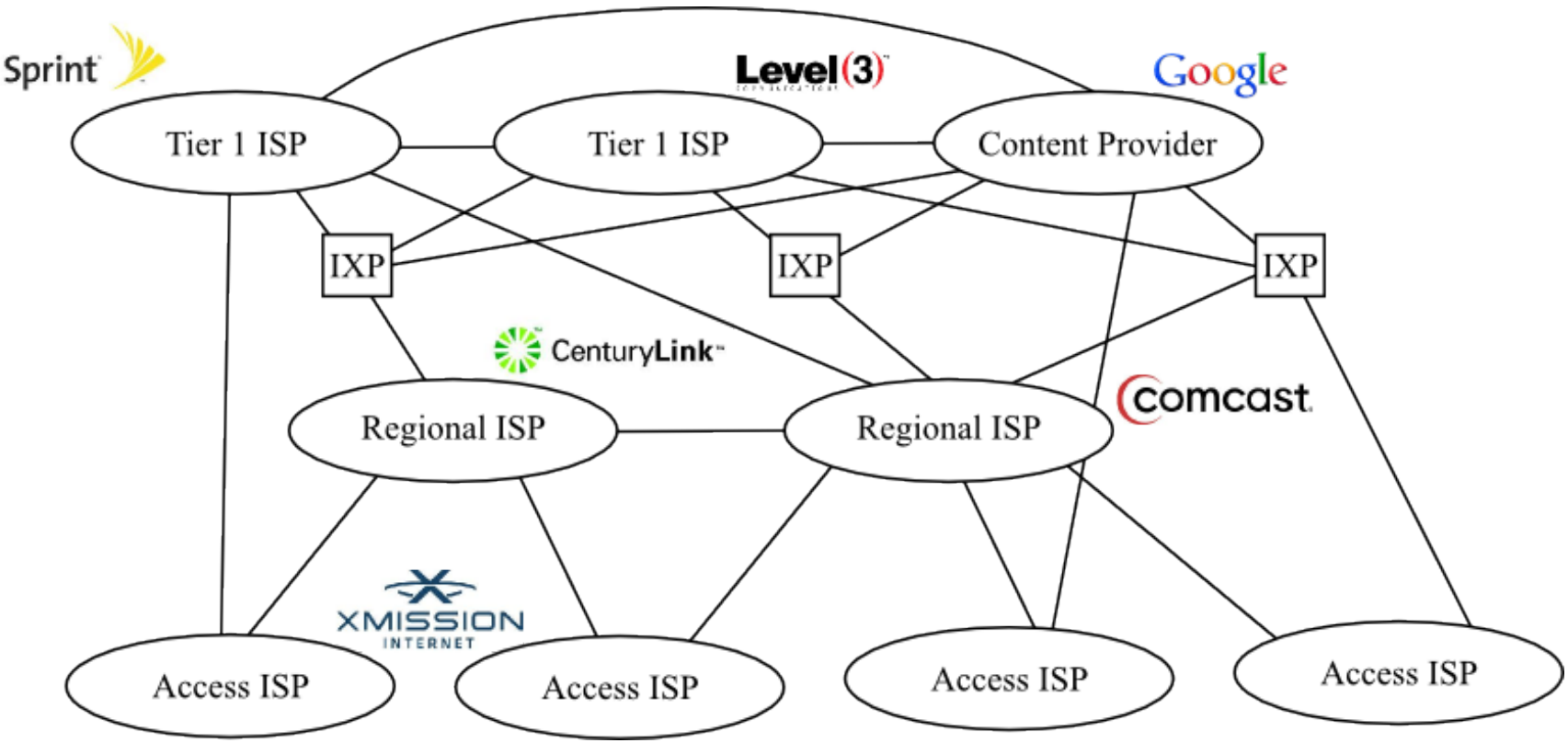
Level-3 Tier-1 Map

▸ Interactive Map

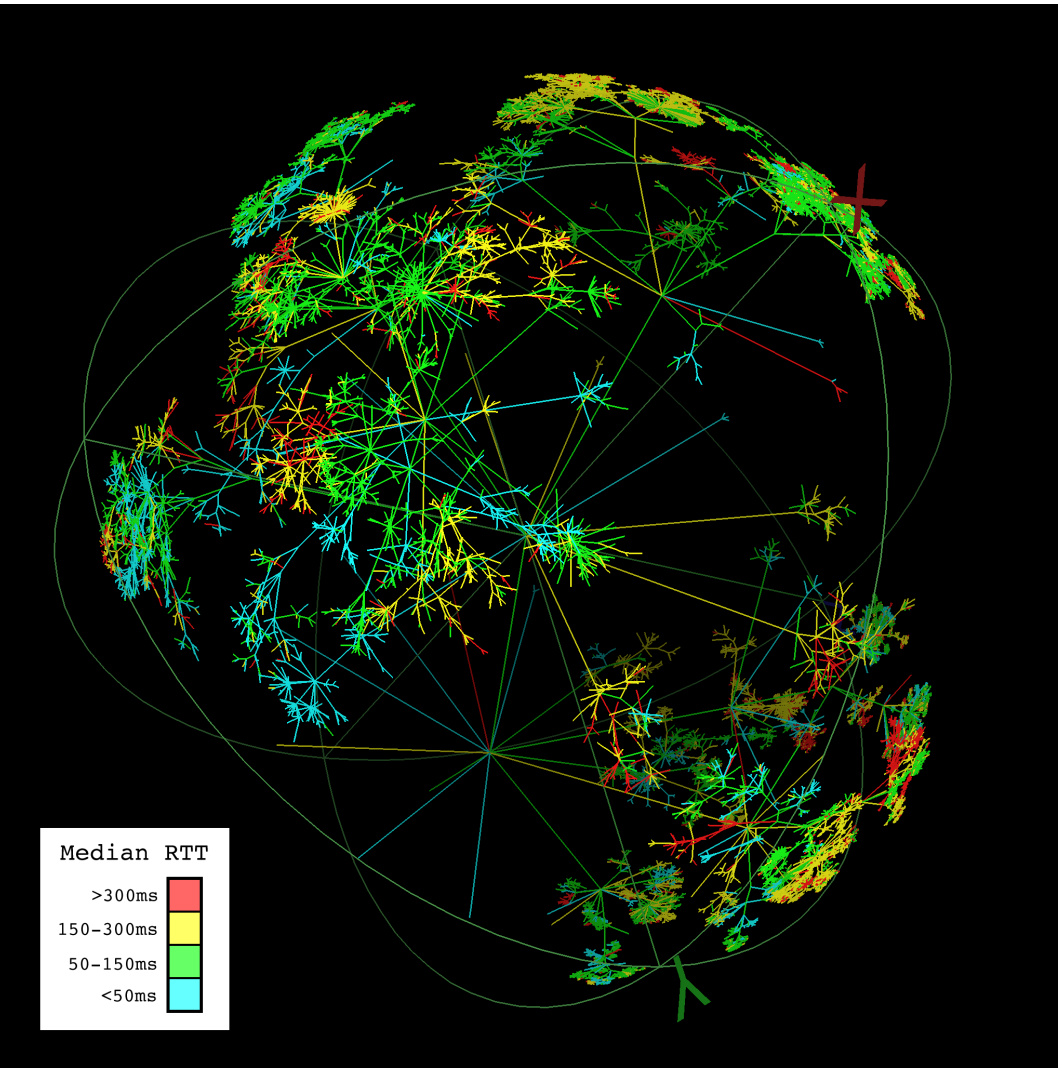
Additional Complexity

- PoP (Point of Presence)
  - router(s) in the provider's network where customer ISPs can connect
- multi-homing
  - customer ISPs may connect to more than one provider, for fault tolerance
- peering
  - connect directly to another ISP at the same level, instead of going through a provider, usually without any cost
- IXP
  - third-party location where ISPs can peer with each other
- content provider networks
  - large content providers (e.g. Google) have large networks, connect directly to lower-level ISPs and IXPs

Internet Structure



The Unique Role of the Internet



- Each network is independent
- Interoperability requires using Internet standards: IP, TCP
  - the Internet is global and must run these standards
  - your private intranet can do whatever you want it to do

Network Edge vs Core

- edge
  - desktops
  - laptops
  - cell phones
  - PDAs
  - digital picture frames
  - thermostats
  - sensors - buildings, the environment
- core
  - mesh of routers that connect end systems

Access Networks

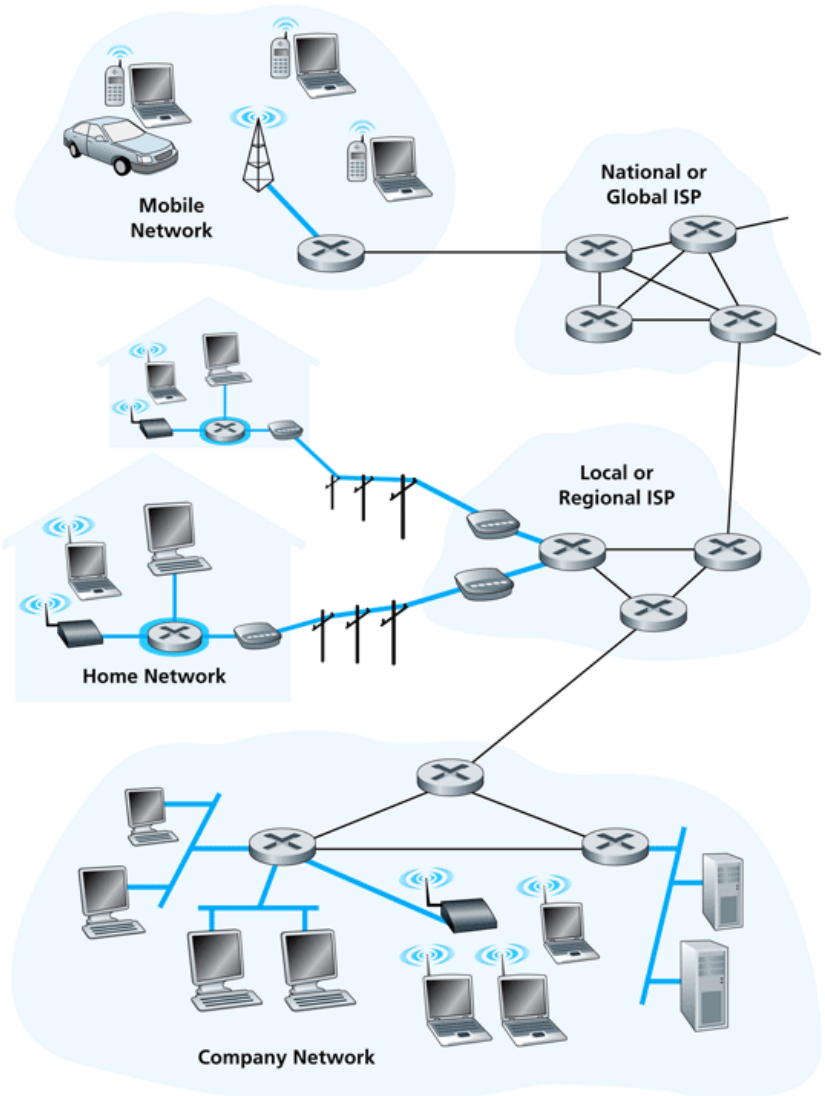


Figure 1.4 ♦ Access networks

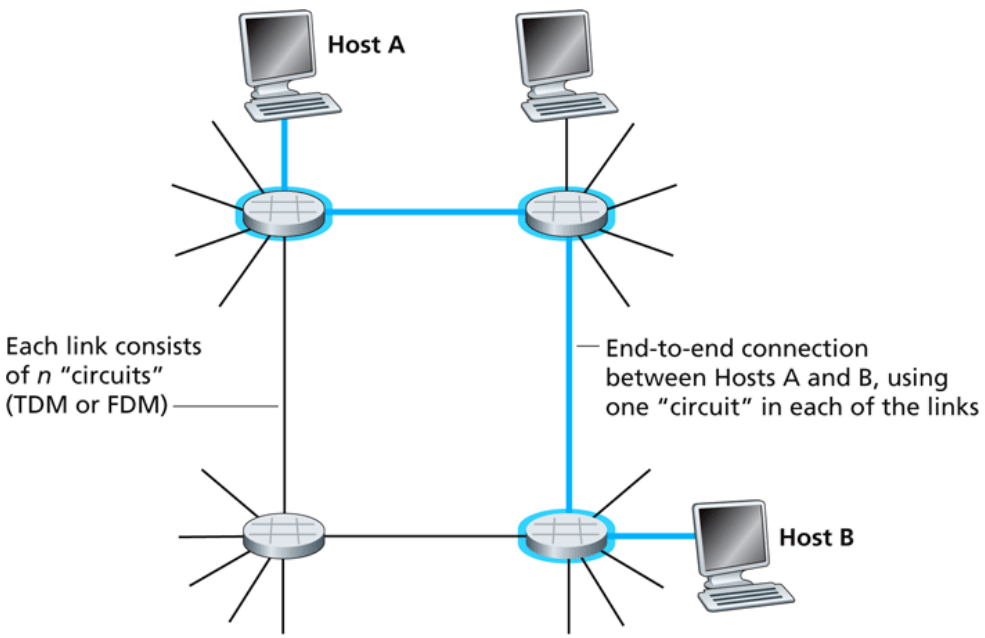
- technologies and speeds
  - modem (56 kbps)
  - DSL (35 Mbps)
  - cable (42 Mbps)
  - satellite
  - fiber optic (10 Gbps)
  - cellular (10 Mbps)
  - WiFi (54 Mbps)

How do you transfer data across a worldwide network?

(comprised of heterogeneous systems and organizations)

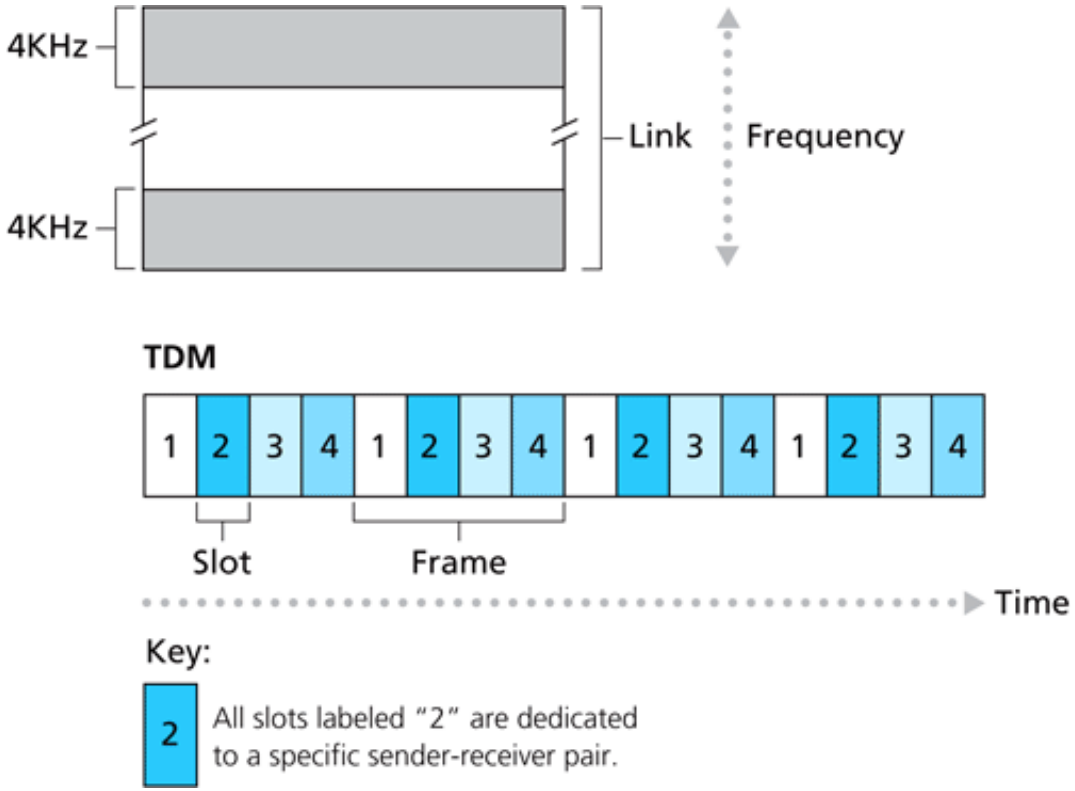
Circuit Switching and Packet Switching

Circuit Switching



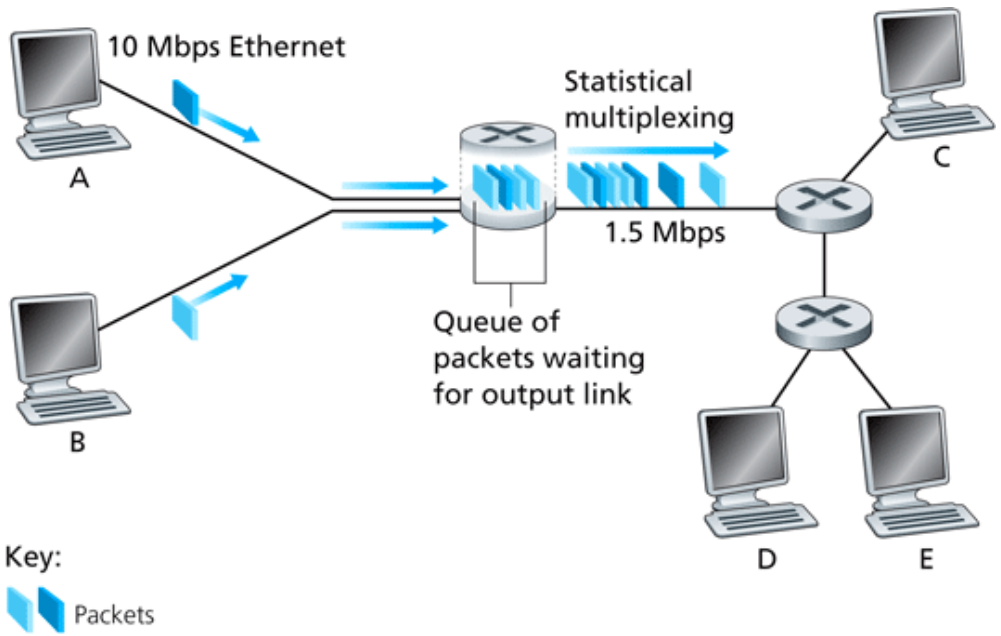
- circuit is established between sender and receiver
- circuit reserves resources for the "call"
  - link bandwidth, switch capacity
  - resources cannot be shared among calls
- guaranteed performance (no packet loss, low delay)
- used in telephone network

Circuit Switching: FDM and TDM



- link bandwidth must be divided into "pieces"
  - pieces allocated to calls
  - pieces cannot be shared
- Frequency Division Multiplexing (FDM)
- Time Division Multiplexing (TDM)

Packet Switching



- data is divided into packets
- all packets from all sources share each link
- each packet uses full link bandwidth
- packets are *stored* before being *forwarded*
- link never idle if some packets in the queue

Circuit Switching vs. Packet Switching

packet switching: better use of resources for one active source

- transmit a 100,000,000 bit file on a 100 Mbps link
- packet switching
  - 100,000,000 bits / 100,000,000 bits/s = 1 second
- TDM with 100 slots
  - 100,000,000 bits / 1,000,000 bits/s = 100 seconds
- TDM also adds circuit setup time
  - latency a problem for short transactions, e.g. DNS lookup

Circuit Switching vs. Packet Switching

packet switching: more users allowed

- 1 Mbps link, each user 100 kbps when active, active 10% of time
- TDM
  - 10 slots, 10 users, 100 kbps each
- packet switching
  - with 35 users, probability $>$ 10 active is less than 0.004, if more active it just reduces bandwidth to each user

Circuit Switching vs. Packet Switching

packet switching may lose packets

- packet loss whenever the queue at a link overflows
- too many sources sending too many packets too quickly
- requires transport protocol for reliability, congestion control

circuit switching provides guaranteed service

- if you send at your slot rate, there is no loss
- no interference from other sources

The Triumph of Packet Switching

- one of the founding principles of the Internet
- makes Internet routers very simple, with complexity at the edges
  - see ▸ End-to-End Argument
- enables the Internet to support a wide variety of applications
- for a long time, circuits were considered best for voice and video but we now use Skype and watch movies over the Internet
  - never underestimate the power of lots of bandwidth and caching