The Internet and its Architecture

CS 360 Internet Programming

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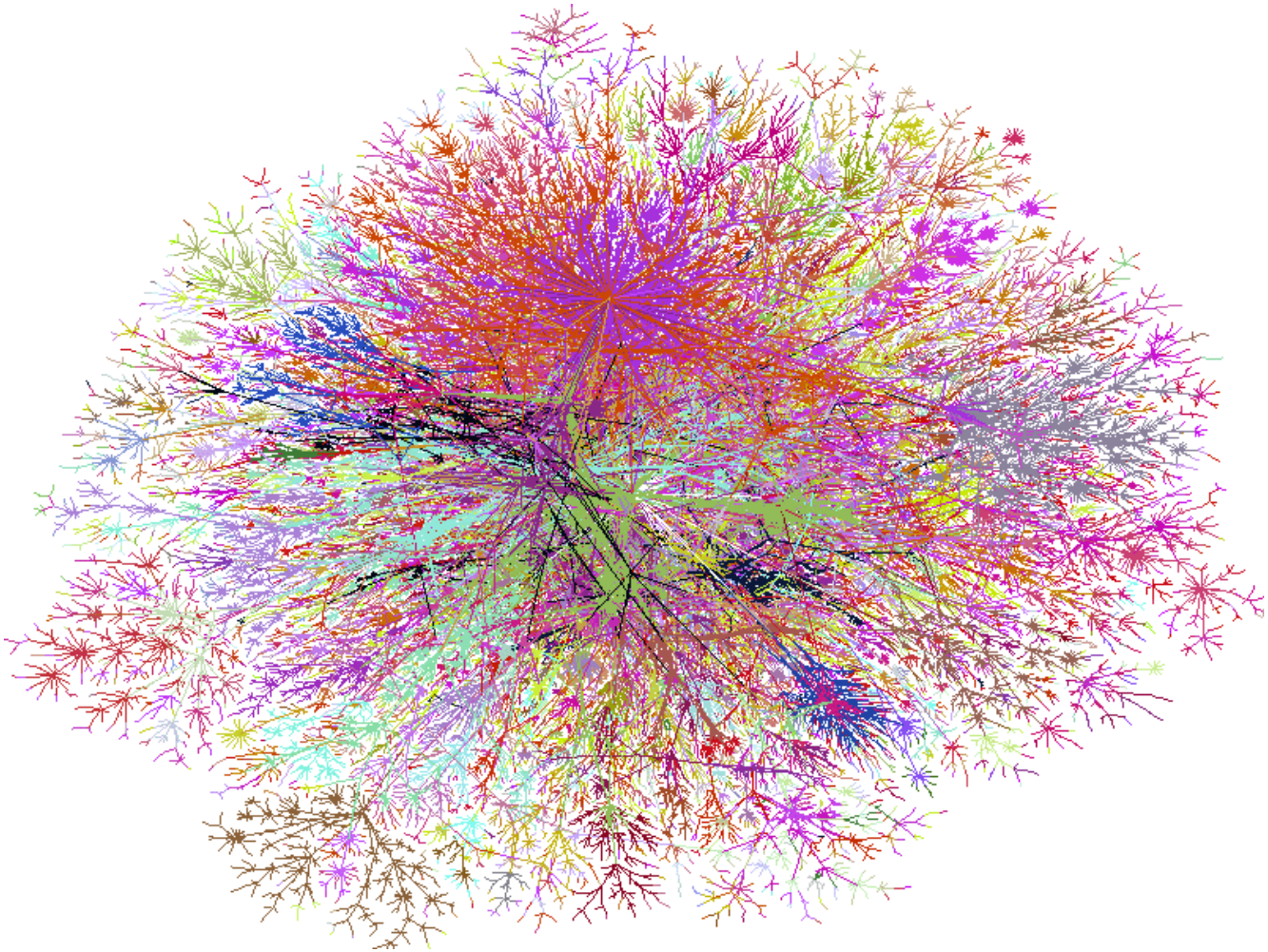
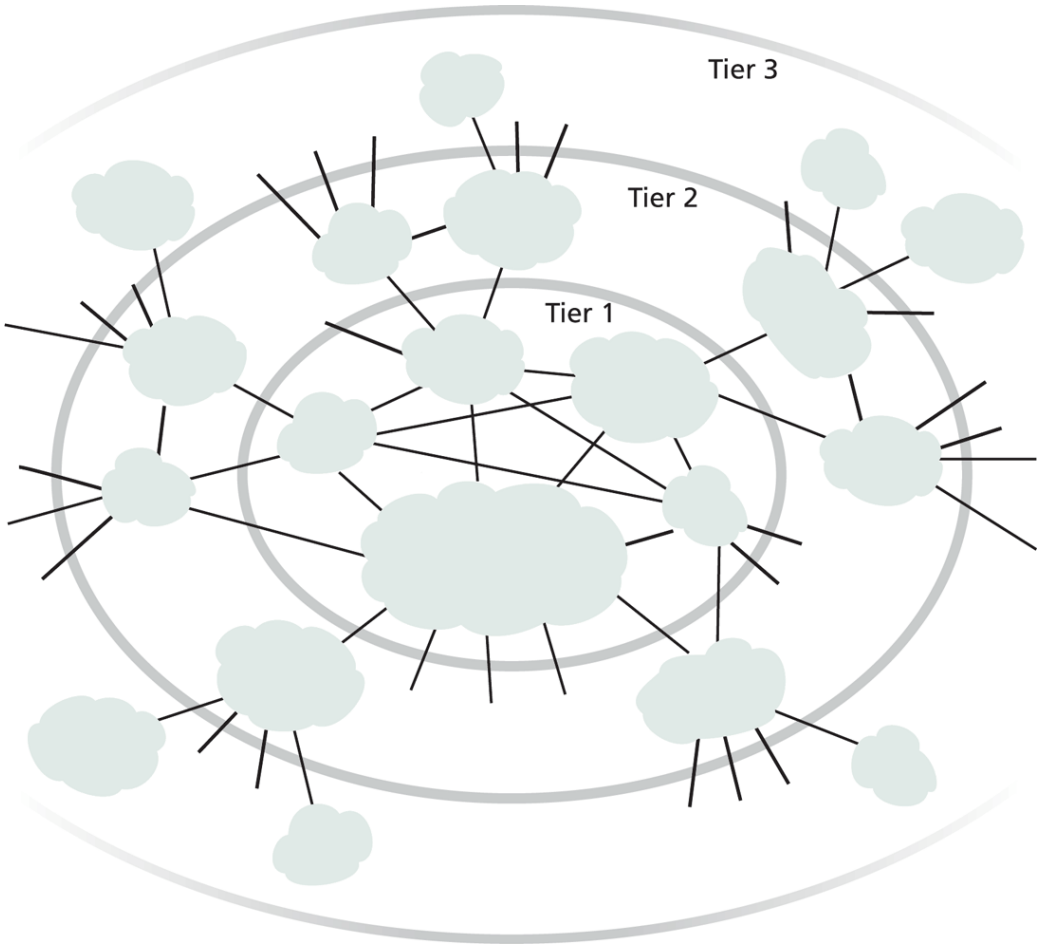
The Internet



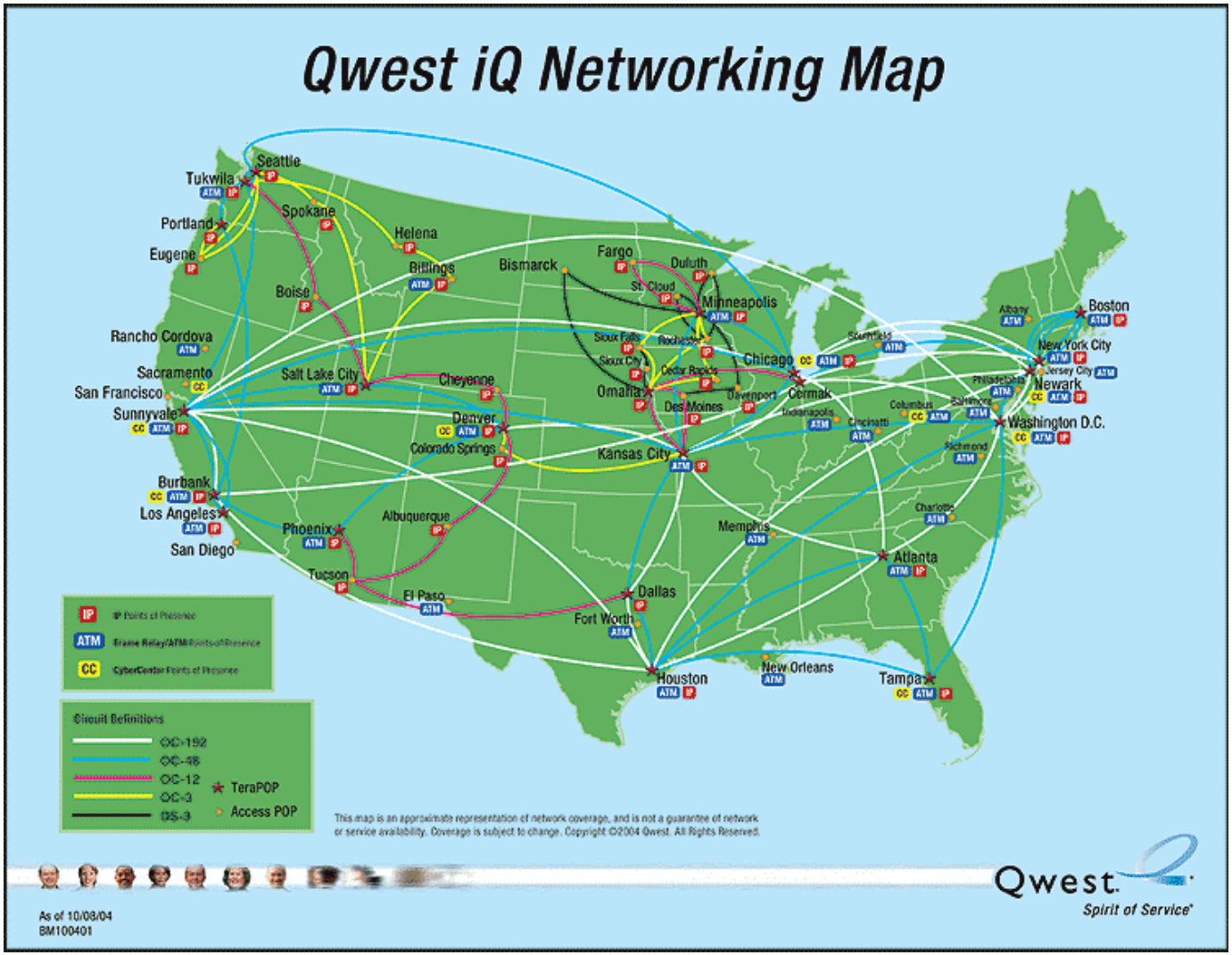
Internet Mapping Project, Bill Cheswick

A Network of Networks

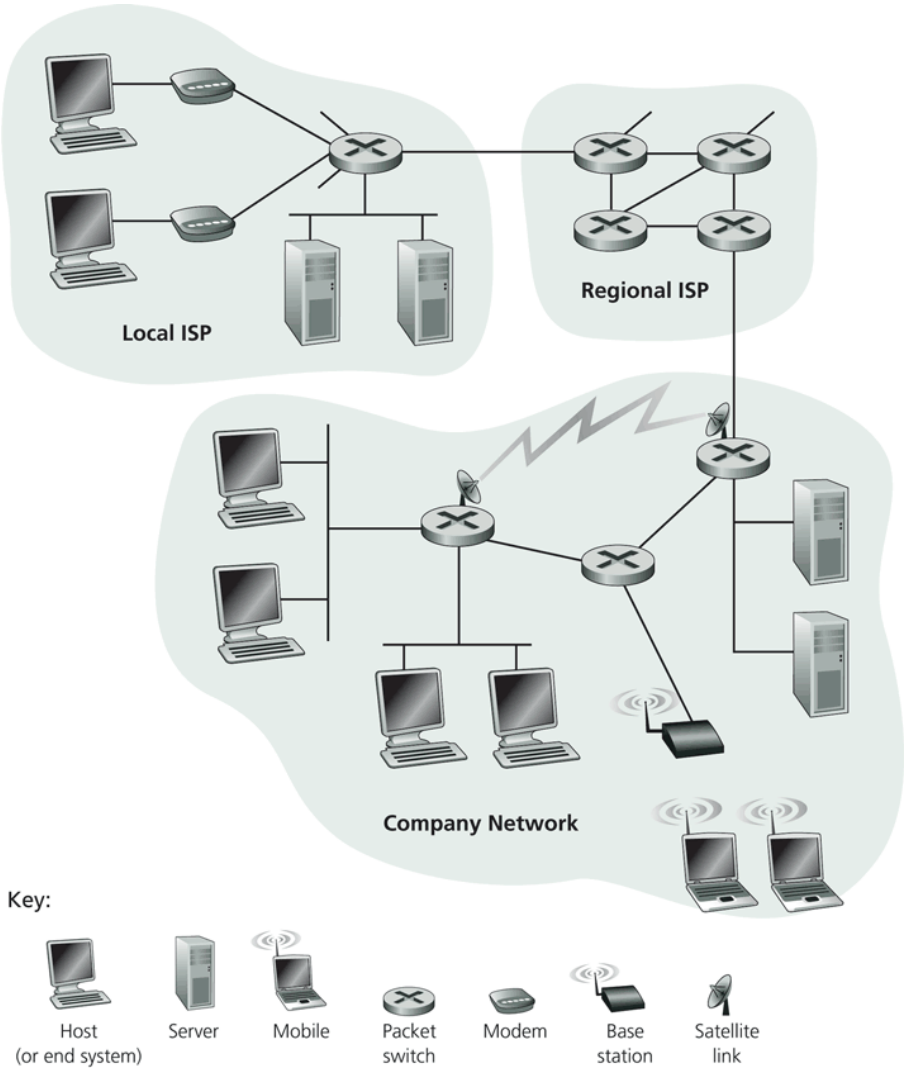


- roughly hierarchical
  - Tier-1 ISPs provide national, international coverage
  - Tier-2 ISPs provide regional coverage
  - Tier-3 and lower levels provide local coverage
- any tier may sell to business and residential customers
- any ISP may have a link to any other ISP (not strictly hierarchical)

Qwest Tier-1 USA Map



Many Different Internet Service Providers

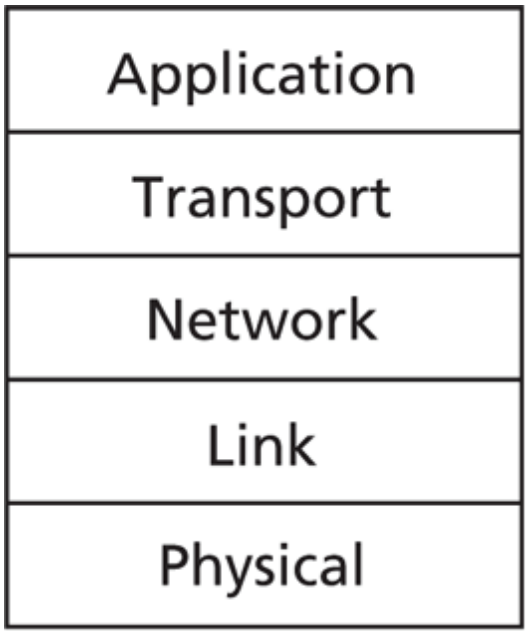


- Each network is independent
- Interoperability requires using Internet standards: IP, TCP
  - the Internet is global and must run these standards
  - your private intranet can do whatever you want it to do

Standardization

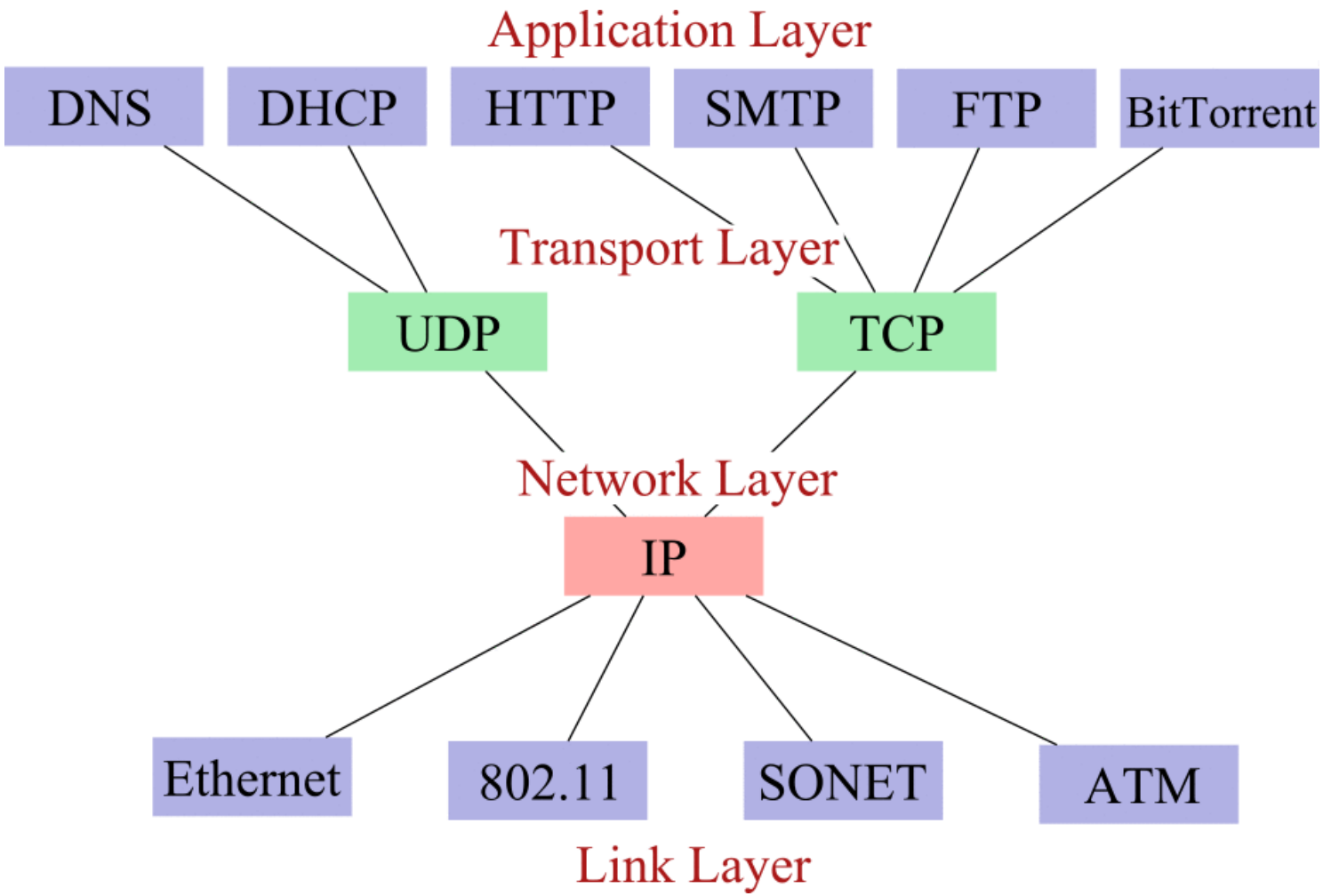
- standards are essential to interoperability on the Internet
- Internet Engineering Task Force *www.ietf.org*
  - standardizes Internet protocols: IP, TCP, HTTP, etc
  - open to all to participate, free of charge
  - relies on working code and rough consensus
- W3C *www.w3c.org*
  - standardizes web protocols and formats
  - industry-oriented consortium
  - requires approved and paid membership ($6,350 - $63,500 per year)
  - many standards do not require Internet-wide deployment

Internet Architecture



- an architectural model that separates communication protocols into layers
  - defines the functionality of each component and the interfaces between components
  - layering helps to build complex systems, like using modules to build large programs
- a particular implementation is free to combine layers or create new layers to create a more efficient or flexible system

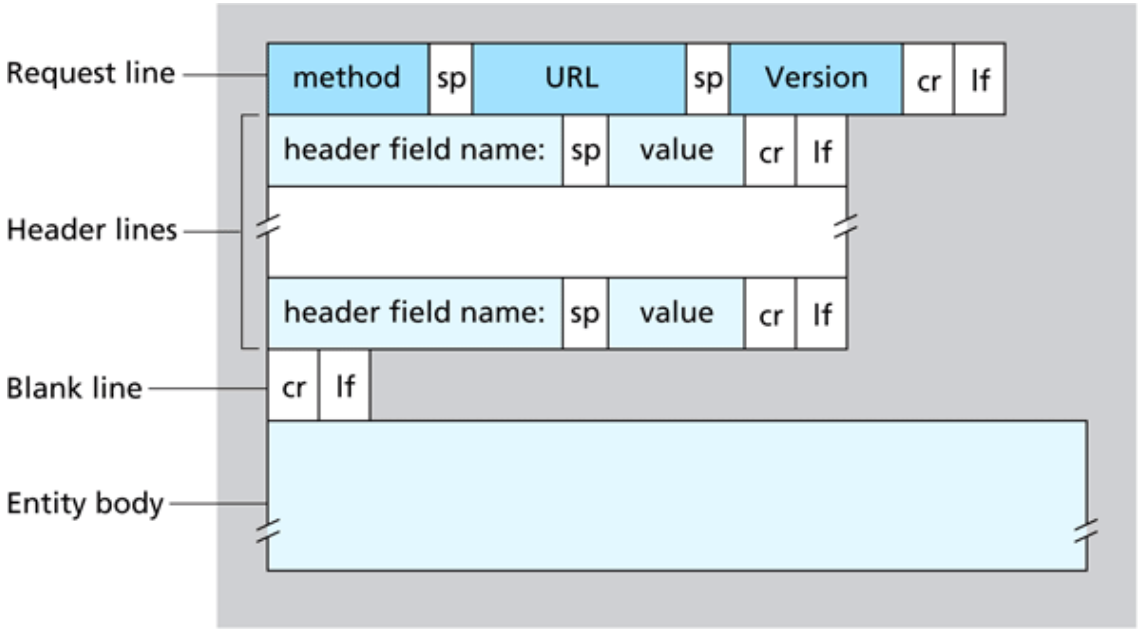
The Internet Hourglass



Protocols

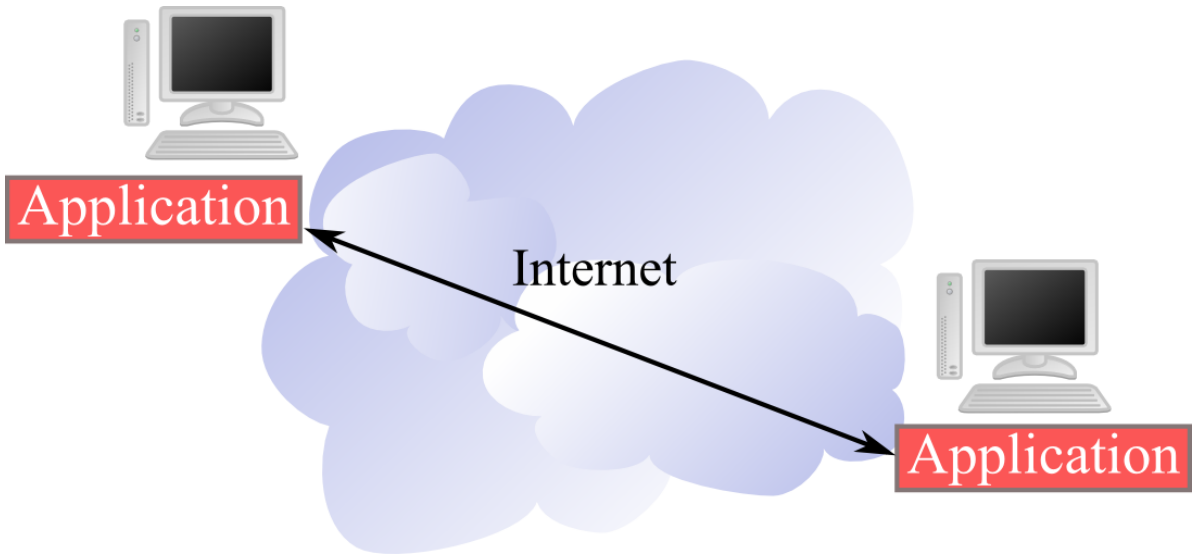
- a formal definition of how two or more entities communicate
- includes
  - format of messages
  - actions taken when a message is sent or received
  - actions taken when an event occurs

Protocol Example



- HTTP Request message format
  - sent in ASCII format
  - *request line*: method, URL, version
  - *header lines*: additional method parameters
  - ends with a carriage return and line feed
- actions: what happens when a server gets a request?

Application Layer

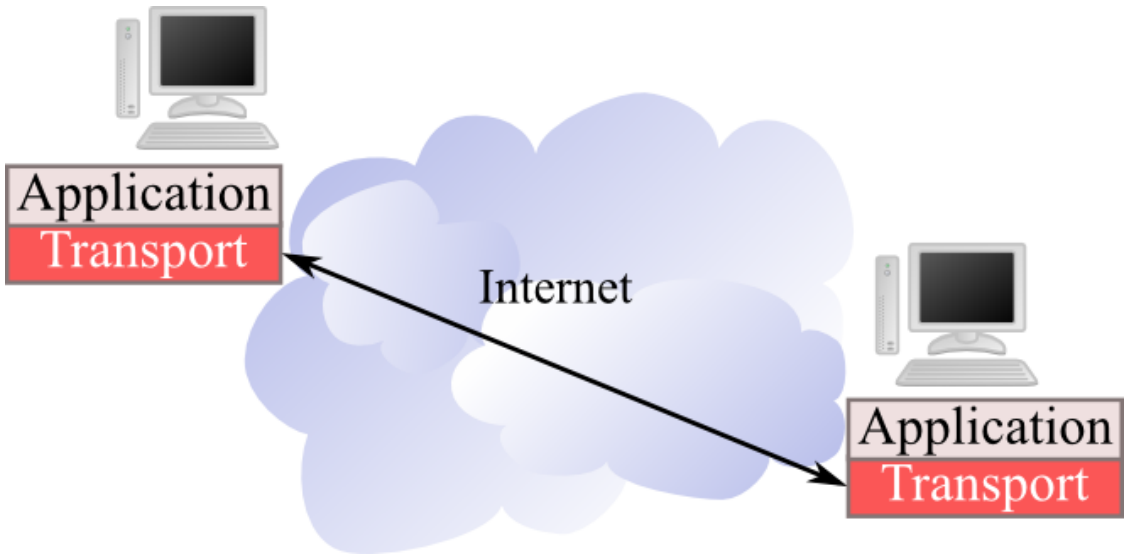


- the focus of this class: client-server, peer-to-peer, web apps
- important topics
  - design
  - concurrency
  - performance evaluation
  - security
- use socket API to access transport protocols

Application Layer Services

- query-response: basic services
  - DHCP
  - DNS
- client-server communication: a server provides a service to clients
  - web
  - video and audio streaming
  - email
  - file transfer
- peer-to-peer communication: host collaborate to share content, acting as both clients and servers
  - Gnutella (and variants): file searching and sharing among peers
  - BitTorrent: file distribution from a well-known source
  - Coral: peer-to-peer web caching

Transport Layer

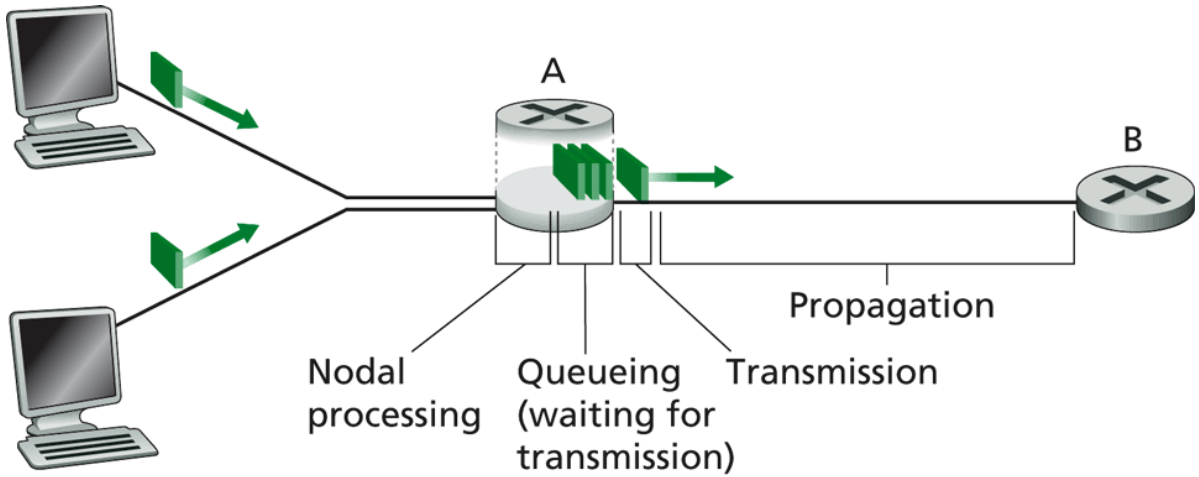


- delivers data between hosts on the Internet
- treats the Internet as a service that provides a virtual, but unreliable link between two computers

Transport Layer Services: TCP

- connection-oriented: requires state setup at sender and receiver
- provides a reliable, ordered byte stream
  - reliable: retransmits any segments that are lost
  - ordered: buffers and re-orders segments before delivery to application
  - byte stream: transfers bytes, not messages
- provides flow control: avoid overflowing the receiver's buffer
- provides congestion control: avoid persistently overflowing network buffers
- applications: web, file transfer, remote login, email

Queues and Congestion Control

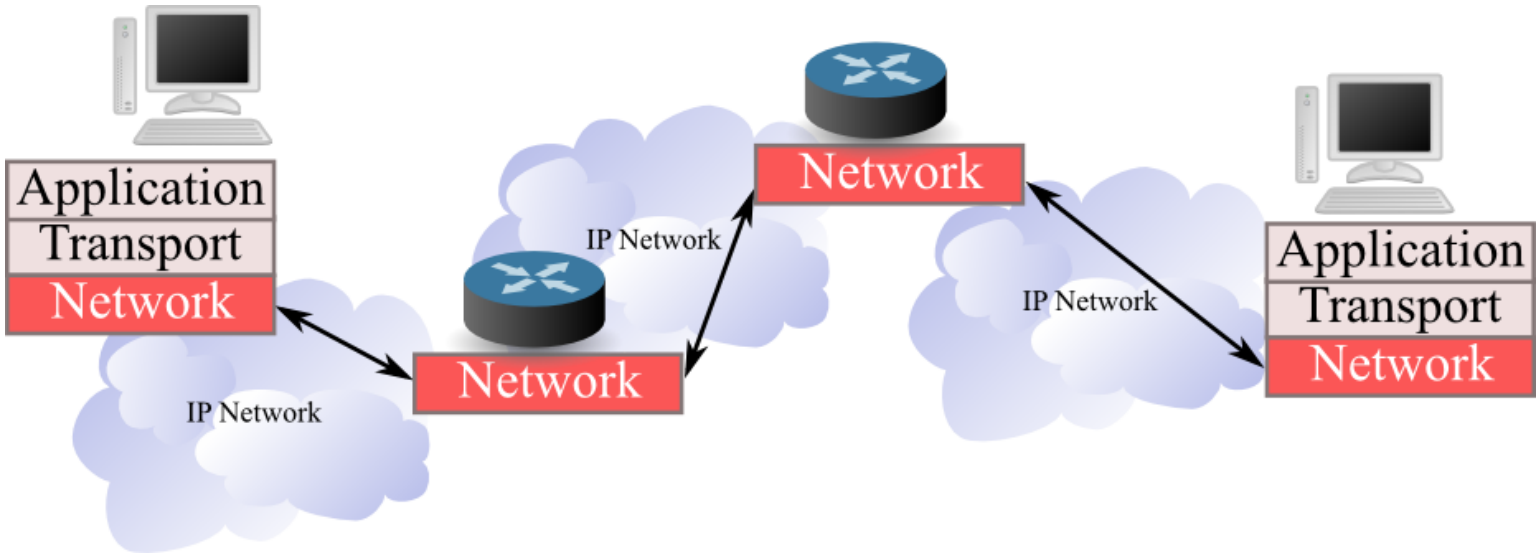


- delay is primarily caused by queueing
- loss is caused by queue overflow
- both are signs of congestion
  - packets are arriving faster than they can be serviced
  - delay and loss are signals to TCP congestion control algorithm – slow down
  - **the Internet needs congestion control to avoid persistent queue overflow**
  - fundamental control problem

Transport Layer Services: UDP

- connectionless: no state setup
- unreliable: lost packets are not re-sent
- no flow control
- no congestion control
- applications: query-response (DNS, DHCP), streaming media (voice, video), some peer-to-peer protocols

Network Layer



- forwards packets between computers and routers on the Internet

Network Layer Services: IP

- common protocol needed to interoperate with other computers on the Internet
- data from transport layer is divided into packets (about 1.5 KB) and sent individually
- implements a best-effort service model - routers make their best effort to deliver all packets, but packets may be
  - delayed (long queues in the network)
  - dropped (queue overflow)
  - duplicated (mistaken retransmission by TCP)
  - re-ordered (packets may take different paths)
- reliability and ordering are the responsibility of TCP

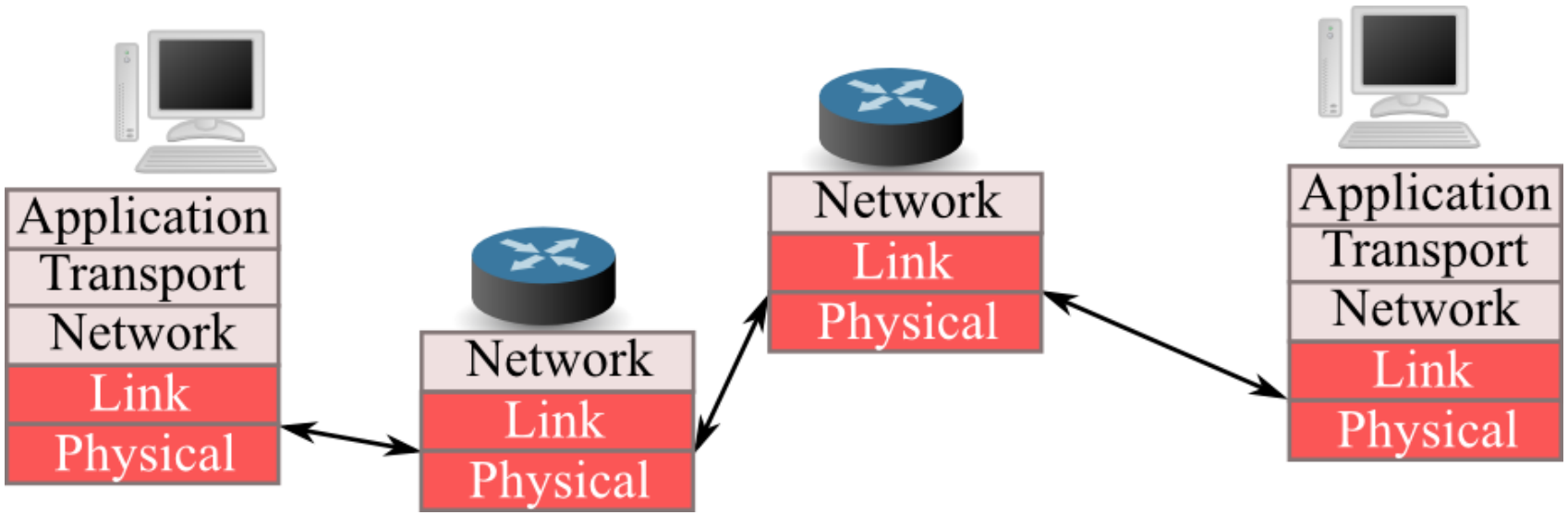
Host Names and Internet Addresses

- hosts can have one or more names
- each name can be associated with one or more addresses
- 32 bits, written in *dotted decimal form*
  - byu.edu: 128.187.16.167
  - google.com: 74.125.127.99, 74.125.127.103, 74.125.127.104, 74.125.127.105, 74.125.127.106, 74.125.127.147
- the Domain Name System DNS maps names to addresses
- a network is a group of hosts with the same prefix
  - 128.187.16.167 with a netmask of 128.187.16.167
  - 128.187.0.0
  - 128.187/16

Network Layer Services: Routing

- routing protocols decide which path to use when sending packets to a given destination
  - organized hierarchically: BGP in the backbone, anything you want (OSPF, IGRP, RIP) in your own network
  - choose the best path for each destination and tell the router to use this path
- primary goals
  - stability: paths must not change too often
  - scalability: must handle every possible destination on the Internet
  - policy: allow network adminstration to choose paths based on economic agreements between providers
  - security: prevent unauthorized re-routing and other attacks
- **scalable routing is currently a major concern for the Internet**

Link and Physical Layers



- link layer: sends a frame on one link
- physical layer: sends bits on one link

Types of Links

- key features
  - bandwidth - number of bits that can be transmitted per second, measured in bps, Kbps, Mbps or Gbps
  - latency - the time it takes to propagate a bit down a link
  - shared vs dedicated resources
- examples
  - modem: $<$ 56 Kbps
  - DSL: 256 Kbps up / 1 Mbps down (example)
  - Cable Internet: 2 Mbps up / 10 Mbps down, shared (example)
  - Ethernet: 10 - 1000 Mbps, shared or dedicated
  - wireless: wide range of bandwidths (54 Mbps for 802.11g), shared or dedicated with directional antenna

The Internet at each Hop