Lecture 15: Protocols

- **precise rules that govern communication between two parties**
- **TCP/IP: the basic Internet protocols**
- **IP: Internet protocol (bottom level)**
  - all packets are shipped from network to network as IP packets
  - "best effort": no guarantees on quality of service or reliability
  - each physical network has its own format for carrying IP packets
- **TCP: transmission control protocol**
  - creates a reliable 2-way data stream using IP

    errors are detected and corrected
  - most things we think of as "Internet" use TCP
- **"application-level" protocols, mostly built from TCP**
  - HTTP (web), SMTP (mail), SSH (secure login), FTP (file transfer), …

- **UDP: user datagram protocol**
  - simple unreliable datagram protocol (errors not detected)
  - used in DNS, voice, video, gaming, ...

Packets

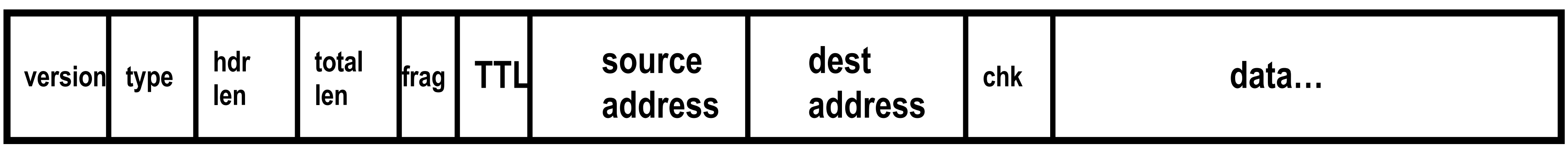
- **packet: a sequence of bytes carrying information**
  - usually over a network connection
- **bytes have a specific sequence, format, organization**
  - usually as specified in a protocol
- **typical network packet includes**
  - source (where it comes from)
  - destination (where it goes to)
  - size or length information (how big is the data part)
  - miscellaneous information (type, version, info to detect errors, ...)
  - the data itself ("payload")
- **typical sizes range from**
  - a few bytes
  - 150-1500 bytes (Ethernet packets)
  - 100-65,000 bytes (IP packets)

What's in an IP packet

- **a "header" that contains**
  - protocol version, type of packet, length of header, length of data
  - fragmentation info in case it was broken into pieces
  - time to live: maximum number of hops before packet is discarded

    each gateway decreases this by 1
  - source & destination addresses (32 bits for IPv4, 128 bits for IPv6)
  - checksum of header information

    redundant info to detect errors in header information only, not data itself
  - etc.; about 20-40 bytes in header
- **the actual data**
  - up to 64 KB of data ("payload")
  - IPv4:



IP: Internet Protocol

- **IP provides an unreliable connectionless packet delivery service**
  - every packet has full source & destination addresses
  - every packet is independent of all others
- **IP packets are *datagrams***
  - individually addressed packages, like postcards in the postal system

    "connectionless"
  - stateless: no memory from one packet to next

    each packet is independent of others, even if in sequence and going same place
  - unreliable: packets can be lost or duplicated ("best effort" delivery)
  - packets can be delivered out of order
  - contents can be wrong (though error rates are usually very low)
  - no speed control: packets can arrive too fast to be processed
  - limited size: long messages have to be split up and then reassembled

- **higher level protocols use IP packets to carry information**
- **IP packets are carried on a wide variety of physical media**

TCP: Transmission Control Protocol

- **a reliable 2-way byte stream built with IP**
- **a TCP connection is established to a specific host**
  - and a specific "port" at that host
- **each port provides a specific service**
  - SSH = 22, SMTP = 25, HTTP = 80, HTTPS = 443, ...

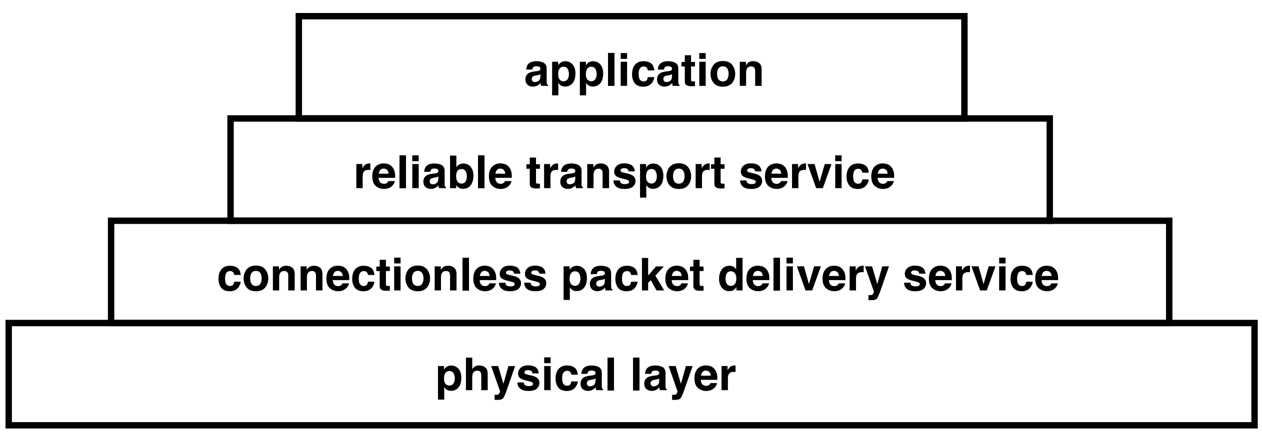
- **a message is broken into 1 or more segments**
- **each TCP segment has a header (source, destination, etc) + data**
  - header includes checksum for error detection, and sequence number to preserve order and detect missing or duplicated packets
- **each TCP segment is wrapped in an IP packet and sent**
  - has to be positively acknowledged to ensure that it arrived safely

    otherwise, re-send it after a time interval

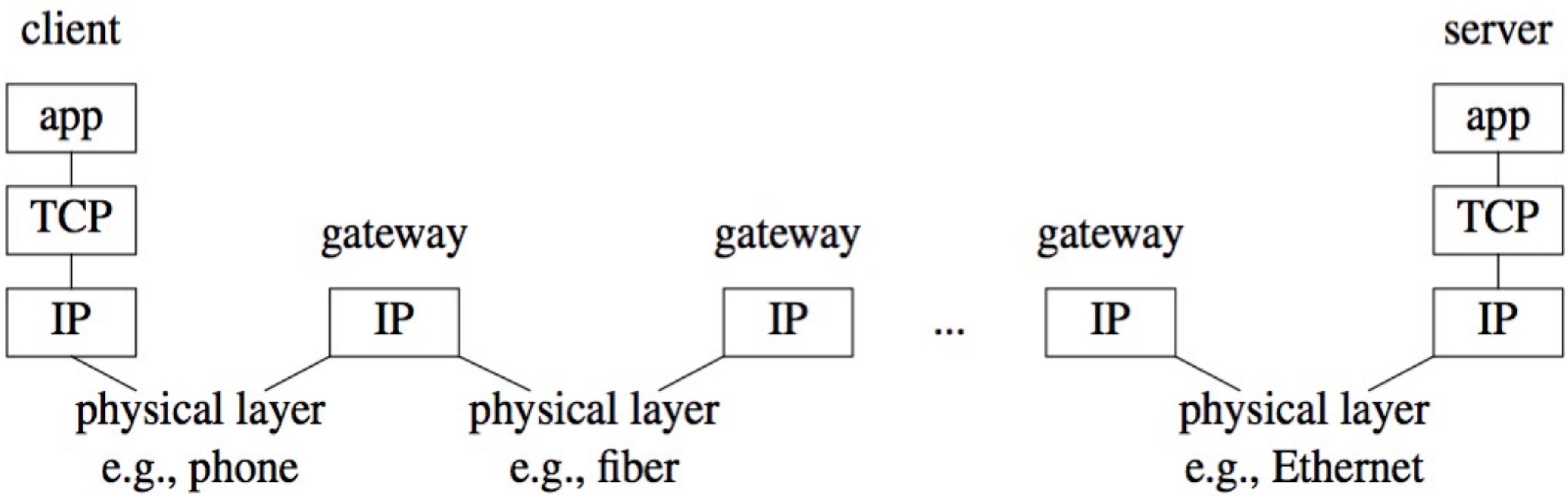
- **TCP is the basis of most higher-level protocols**

Higher level protocols

- **SSH: secure login**
- **SMTP: mail transfer**
- **HTTP: hypertext transfer => Web**
- **protocol layering:**
  - a single protocol can't do everything
  - higher-level protocols build elaborate operations out of simpler ones
  - each layer uses only the services of the one directly below
    and provides the services expected by the layer above
  - all communication is between peer levels: layer N destination receives exactly the object sent by layer N source



How information flows



How things are connected

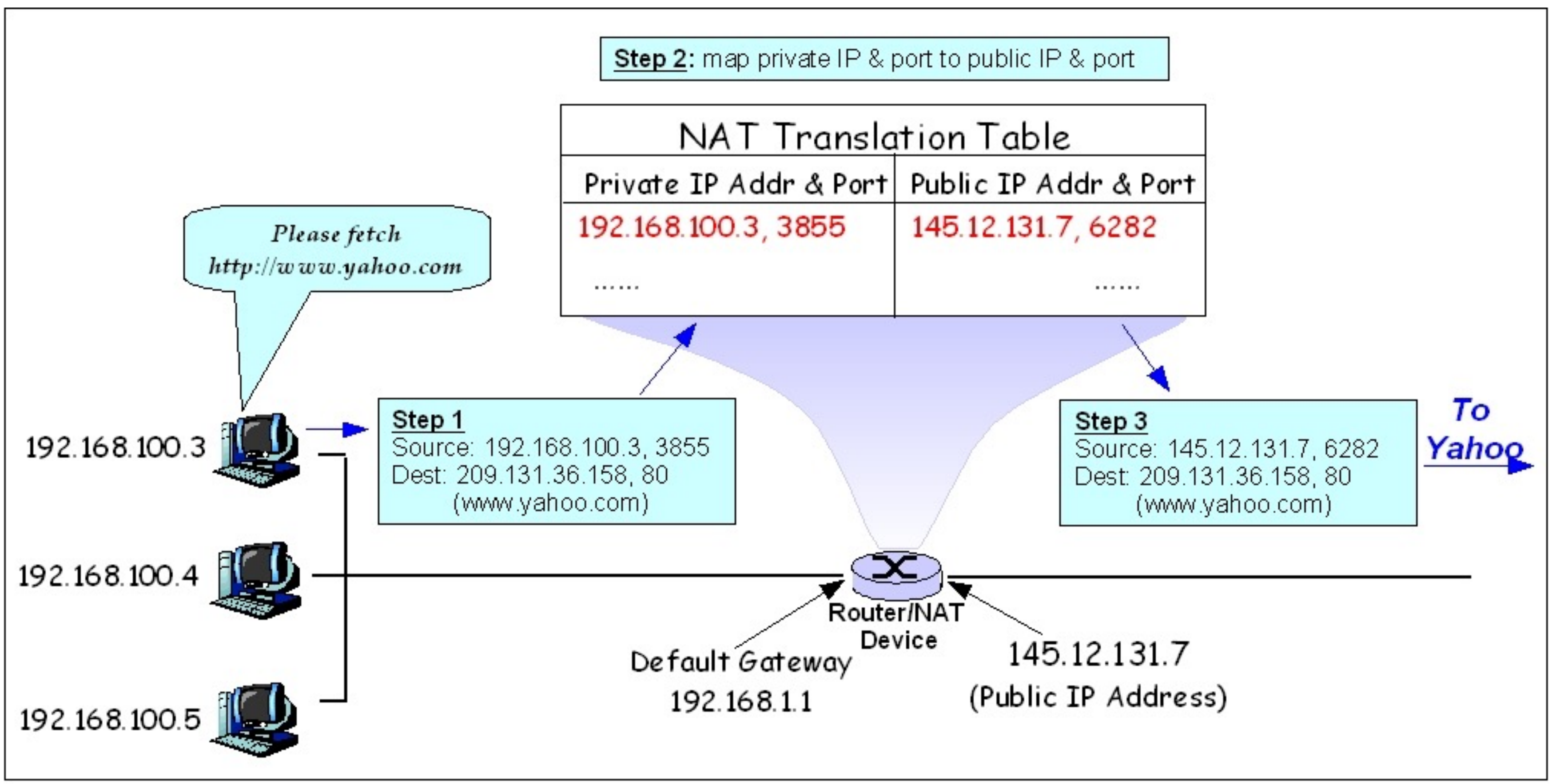
- **local nets connected to local Internet Service Provider (ISP)**
- **these in turn may connect to regional ISPs**
- **and then to larger ones like Comcast, Verizon, AT&T, …**
  - but it may be all one provider

- **traffic is exchanged at Internet exchanges (IXP)**
  - large and small, formal and informal, profit and non-profit

- **home connections**
  - cable, fiber: maybe 100-500 Mbps (you to/from your ISP)
  - 5G wireless: 100-300 Mbps

Network Address Translation (NAT)

- **a partial solution to running out of IPv4 addresses**
- **router maps multiple private hosts to one public IP address**
  - private net (usually 192.168.0.0 to 192.168.255.255 for home routers)
  - maintains a table of (internal IP, port) to (external IP, port) addresses
  - converts headers in both directions as traffic flows



Coping with bandwidth limits

- **data flows no faster than the slowest link**

- **limits to how much data can pass per unit time**
  - no guarantees about packet delivery
  - no guarantees about bandwidth, delay or quality of service
    - IP telephony is hard because voice traffic requires limited delay and jitter
    - video is somewhat easier but needs a lot more bandwidth

- **caching**
  - save previous data so it doesn't have to be retrieved again

- **compression, encoding**
  - to improve use of available bandwidth
  - don't send redundant or unnecessary information
    - text, code, etc., can be compressed and recreated exactly
    - music, pictures, movies are compressed with some information discarded

Internet ideas

- **packets versus circuits**
  - different models (mail vs phone)
- **names and addresses**
  - what is a computer called, how to find it
- **routing**
  - how to get from here to there
- **protocols and standards**
  - Internet works because of IP as common mechanism
    - higher level protocols all use IP
    - specific hardware technologies carry IP packets
- **layering**
  - divide system into layers
    - each of which provides services to next higher level
    - while calling on service of next lower level
  - a way to organize and control complexity, hide details

Internet technical issues

- **privacy & security are hard**
  - data passes through shared unregulated dispersed media and sites
    scattered over the whole world
  - it's hard to control access & protect information along the way
  - many network technologies (e.g., Ethernet, wireless) use broadcast
    encryption is necessary to maintain privacy
  - many mechanisms are not robust against intentional misuse
  - it's easy to lie about who you are
- **service guarantees are hard**
  - no assurance of reliable delivery, let alone of bandwidth, delay or jitter
- **some resources are running low**
  - IPv4 addresses are all assigned
  - IPv6 (the next generation) uses 128-bit addresses
    acceptance growing, by necessity

- **but it has handled exponential growth amazingly well**