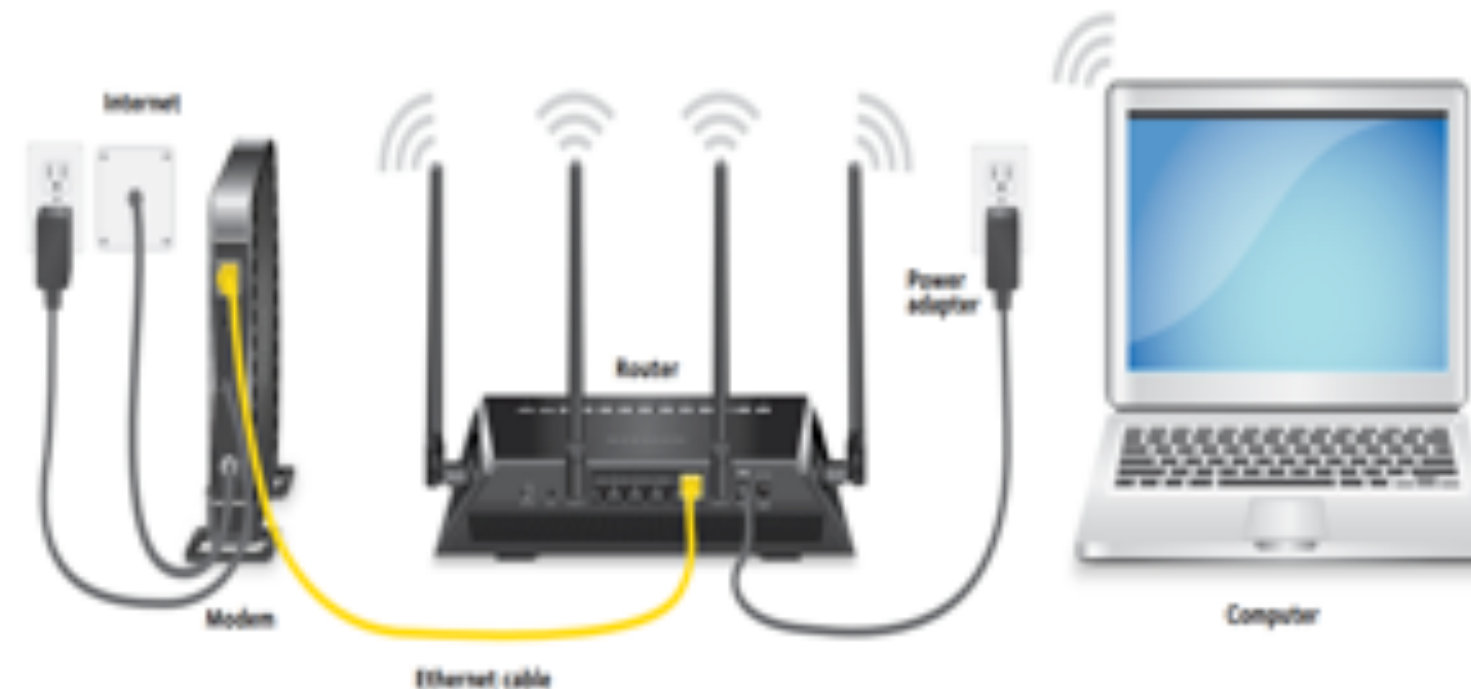


The Internet

Networks, TCP/IP

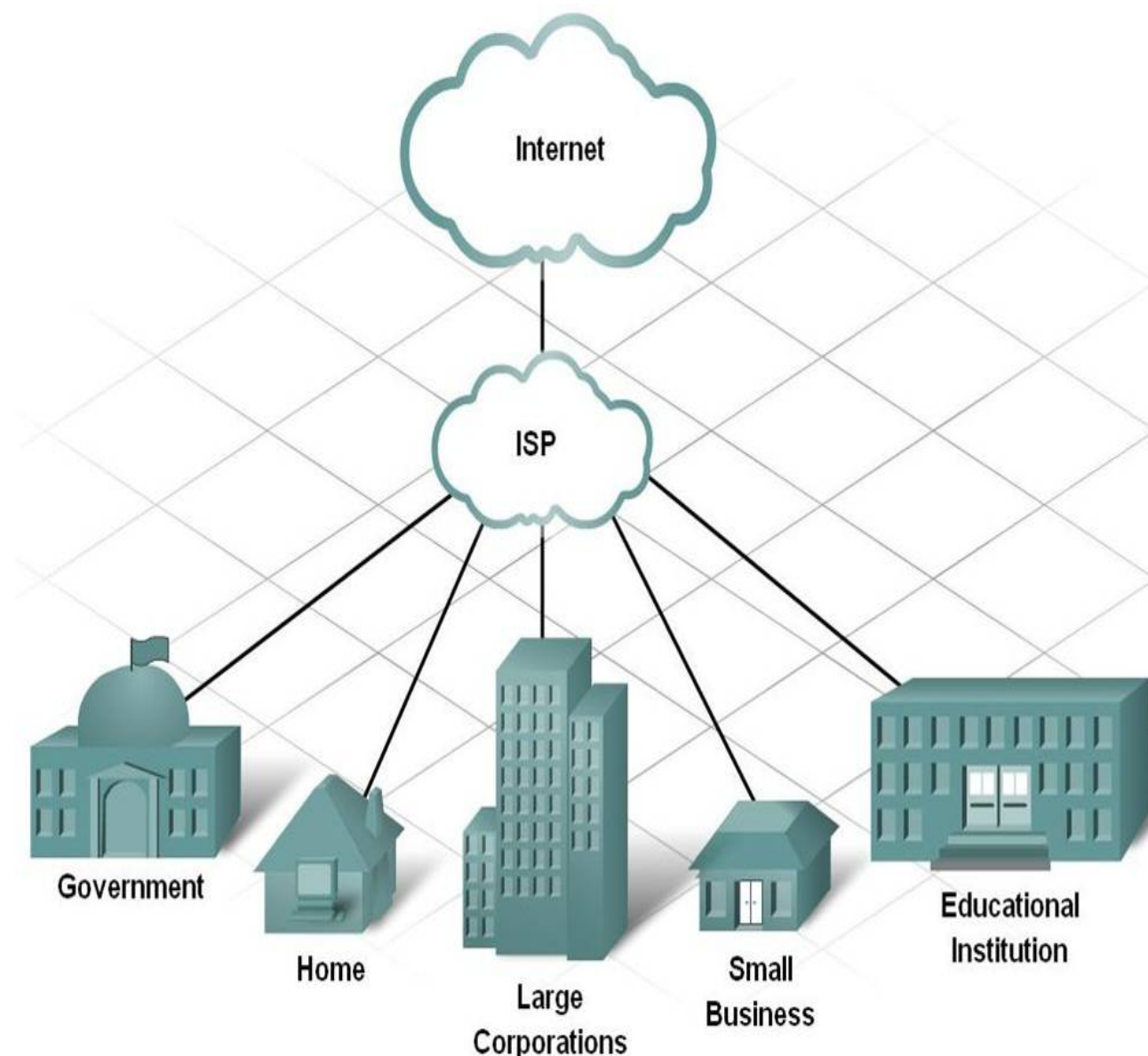
Local Area Network (LAN)

- Connect a small group of devices
 - Devices use the Internet Protocol (IP) to communicate
- Router
 - hardware that connects devices and routes IP packets
- Wifi
 - This is the only place you'll find wireless connections



Internet Service Provider (ISP) Networks

- Internet Service Provider
- Connects customers to the Internet
- Maintain city and regional networks
- Addresses the last mile problem



<https://bijanghayyoomi.files.wordpress.com/2010/08/picture20.jpg>



<http://oldforum.paradoxplaza.com/forum/showthread.php?837998-Underground-power-lines-and-capacity/page2>

Tier 1 Networks

- A network that is connected to all other networks on the Internet
 - Does not rely on any other network
 - Tier 1 networks form the backbone of the Internet
- ISPs pay for tier 1 access just like we pay ISPs
 - Some tier 1 companies also offer ISP services to individuals in certain regions
- Often peer with each other allowing them to use each other's networks, increasing the overall speed and reliability of the Internet

Tier 1 Networks

AT&T

CenturyLink

Global Telcon & Communications

Level 3 Communications

NTT Communications

Verizon Enterprise Solutions

Zayo Group



<http://www.vootwerk.com/network.html>



(https://en.wikipedia.org/wiki/Tier_1_network for more)

Internet Exchanges (IX)

- Tier 1 networks must connect to ISP networks and other Tier 1 networks
- These connections are made in Internet Exchanges
- 60 Hudson Street (pictured) houses one such IX in Manhattan

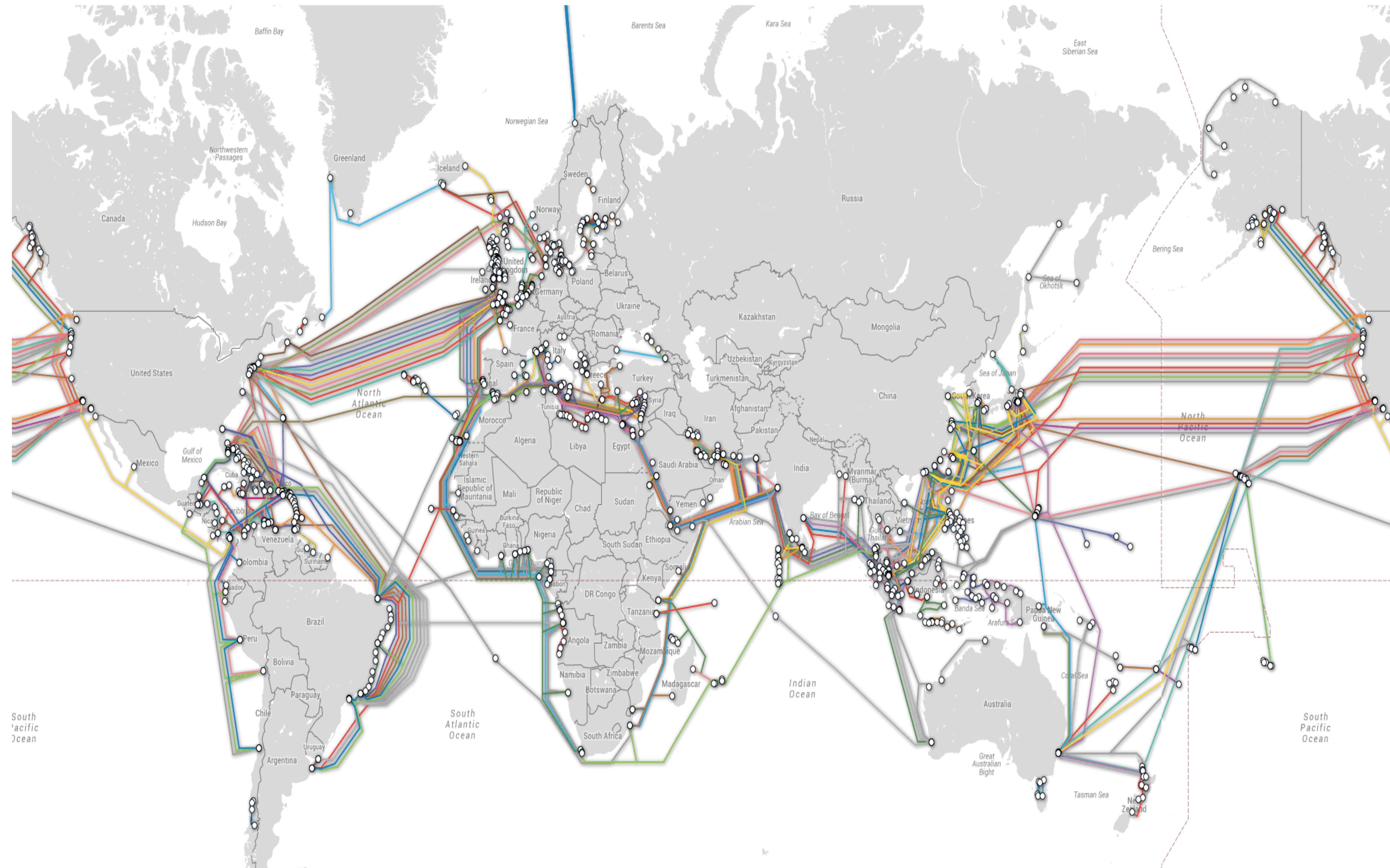


<https://www.wired.com/2015/11/peter-garritano-where-the-internet-lives/>

https://en.wikipedia.org/wiki/60_Hudson_Street



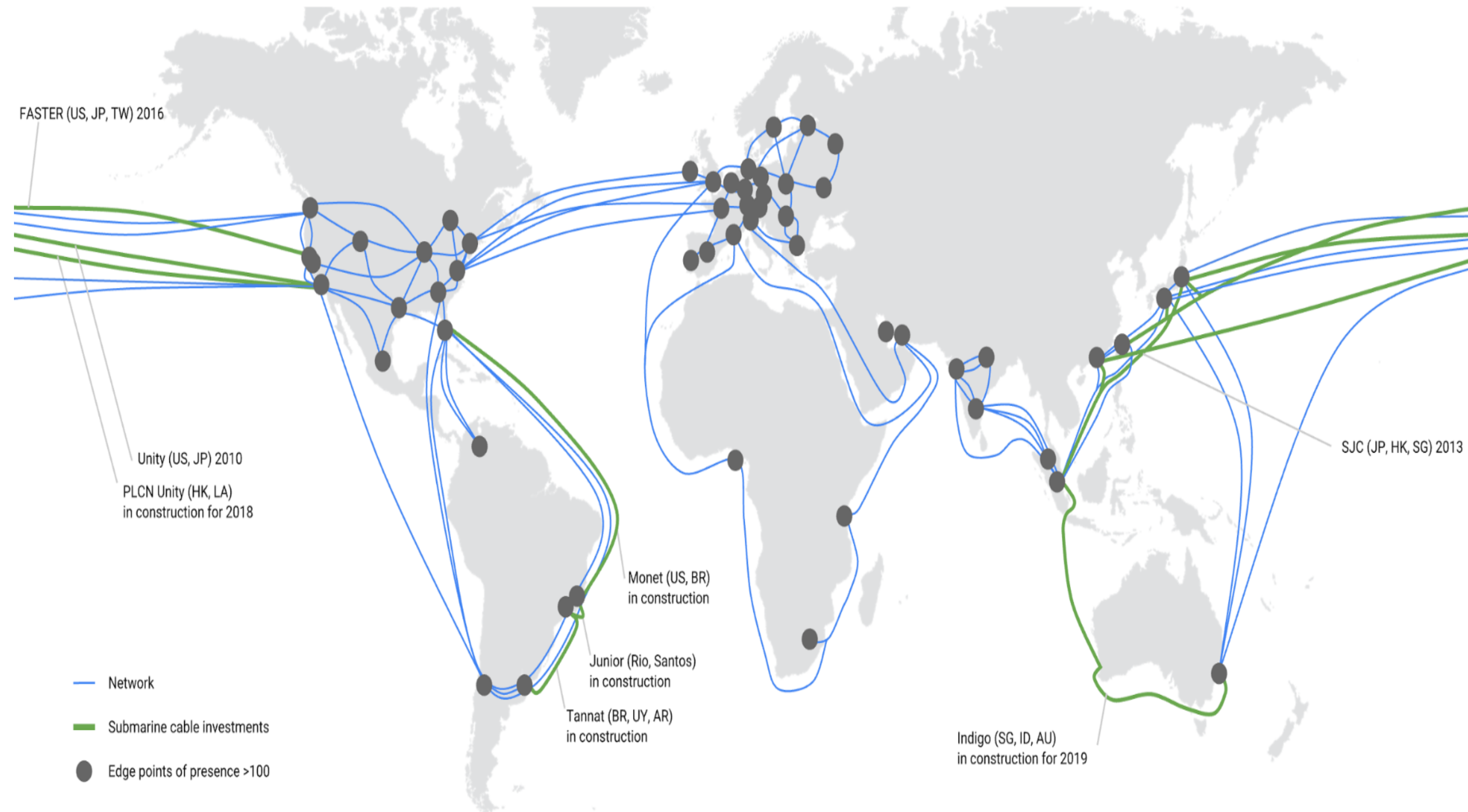
Cables Connect Continents



<https://arstechnica.com/information-technology/2016/05/how-the-internet-works-submarine-cables-data-centres-last-mile/>

Google Cloud Submarine Cable Investments

Google Cloud's well-provisioned global network is comprised of hundreds of thousands of miles of fiber optic cable and seven submarine cable investments



<https://www.blog.google/topics/google-cloud/google-invests-indigo-undersea-cable-improve-cloud-infrastructure-southeast-asia/>

Data Centers Power Apps



<http://americanbuildersquarterly.com/2015/yahoo/>



<http://imgur.com/gallery/7NPNf>

How do we use these cables?

Internet Protocol

Internet Protocol (IP)

- *The Internet is a network of networks connected by cables*
- Now, how do these networks and devices communicate with each other?
- Internet Protocol
 - Official standard for IPv4: <https://tools.ietf.org/html/rfc760>
- Every device connected to the Internet has an IP address
 - Routers use this address to send data to its destination

Internet Protocol

- Data is sent in packets/datagrams
 - Large messages are sent in multiple packets
- Each packet contains a header and a payload
- Header
 - Metadata about the packet
 - Most importantly, contains the source and destination IP addresses
- Payload
 - The data to be sent to the destination device
 - IP has no concern about the content of the payload
 - Payload often/always follows additional protocols agreed upon by the source and destination
 - Ex: TCP, UDP, HTTP[S]

IP Address

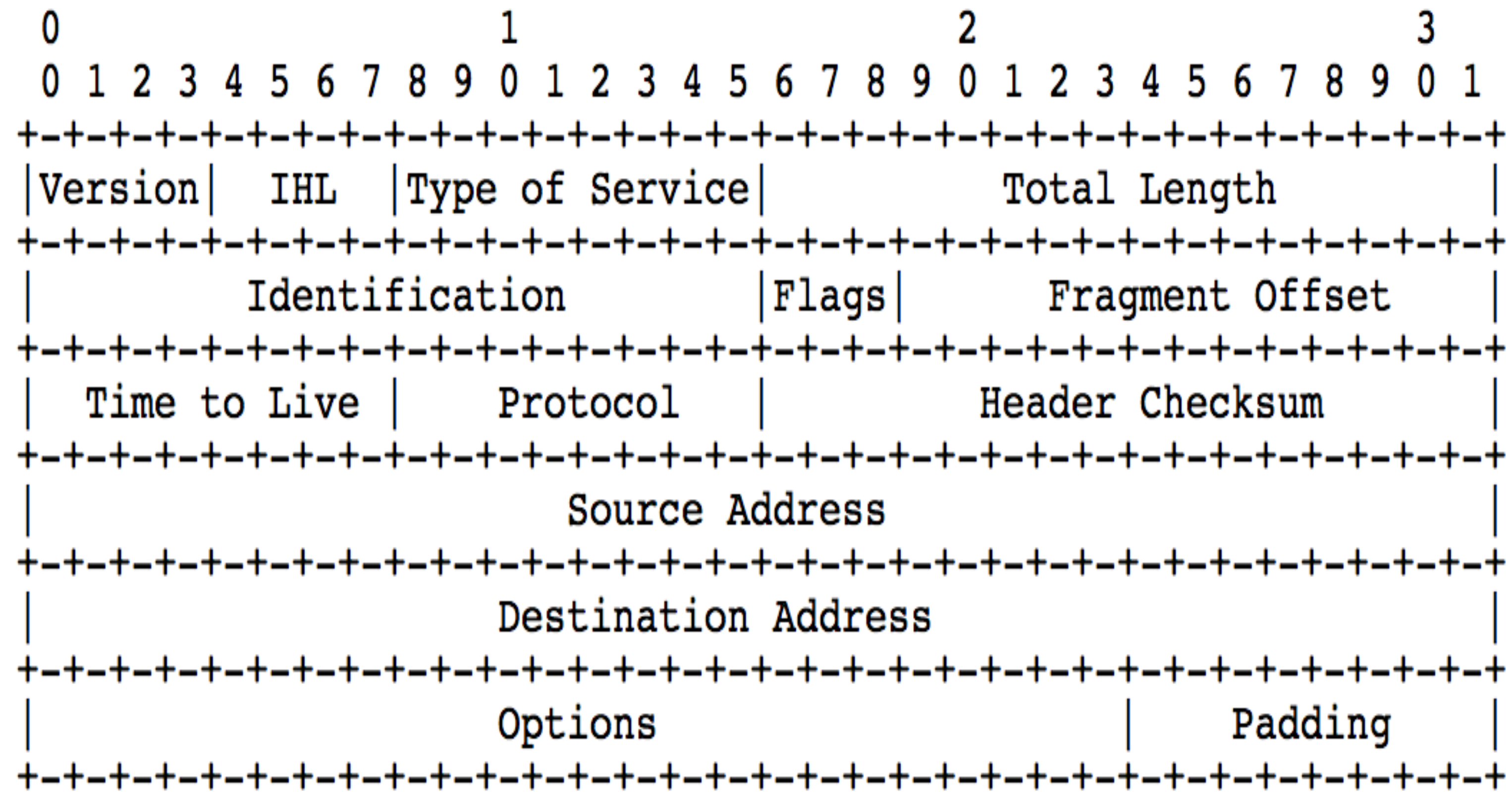
- Address of a machine on the Internet
 - Ex: 172.217.12.211
- Routers read the address and send it to the next step
- IP Addresses with a common prefix are related
 - Two parts: Network, host
- Organizations have a prefix and own all IP's that start with that prefix
 - One of Google's ranges: 172.217.0.0-172.217.255.255
 - Network prefix: 172.217.x.x

IP Address

- IPv4 (8.8.4.4)
 - Consists of 4 numbers ranging from 0 to 255
 - How many total addresses?
 - 4 numbers, 8 bits each, 32 total bits, 2^{32} total addresses
 - 4,294,967,296
 - A lot, but not enough
- IPv6 (2001:4860:4860:0000:0000:0000:0000:8844)
 - 128 bit addresses
 - 2^{128} total addresses
 - 340,282,366,920,938,463,463,374,607,431,768,211,456
 - That should be enough
 - Used in conjunction with IPv4
 - Routers must be able to route both versions

Domain Name Service (DNS)

- We don't want to remember IP address for all our favorite sites
- With DNS, we don't have to
- DNS
 - Remember a Domain Name instead of an IP address
 - Domain Name: google.com
 - When you click a link, first a DNS request is made to get the IP address for that Domain Name
 - Then the IP address is used to make your request
- Can access sites directly by IP
 - <http://172.217.6.228/>
- Not all sites allow direct IP access
 - <http://104.16.40.2/>



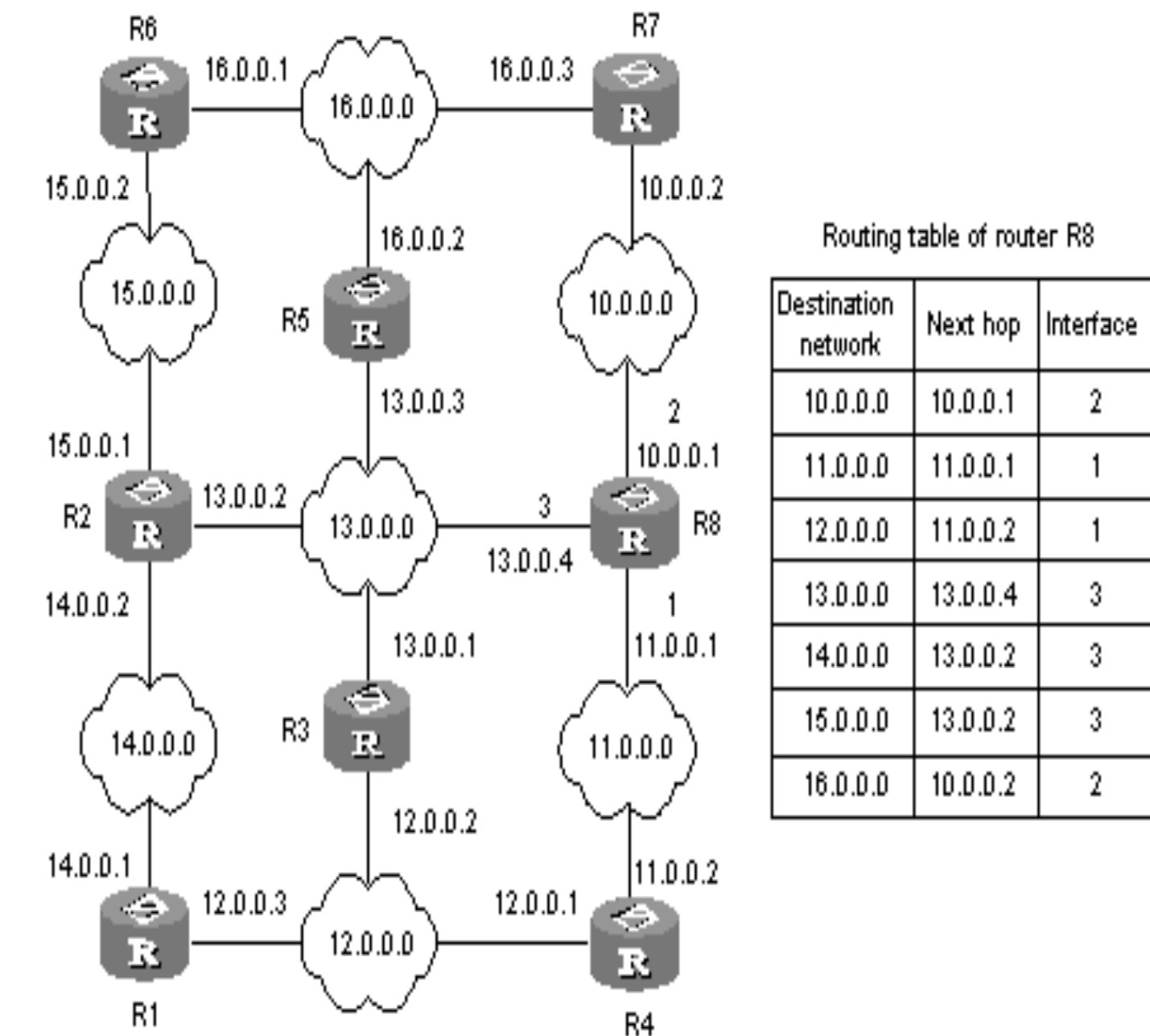
Example Internet Datagram Header

Figure 4.

From the IPv4 official standard: <https://tools.ietf.org/html/rfc791>

Routing Through the Internet

- ISP and Tier 1 networks contain many routers to direct Internet traffic
 - These routers are made for speed!
 - To maximize speed, they are simple
- Router reads the destination IP address of a packet and sends it to the next router
 - Only knows the next step
 - No one needs to map the entire Internet
 - Routing tables can be updated



<https://superuser.com/questions/959242/how-is-next-hop-defined-in-routing-table>

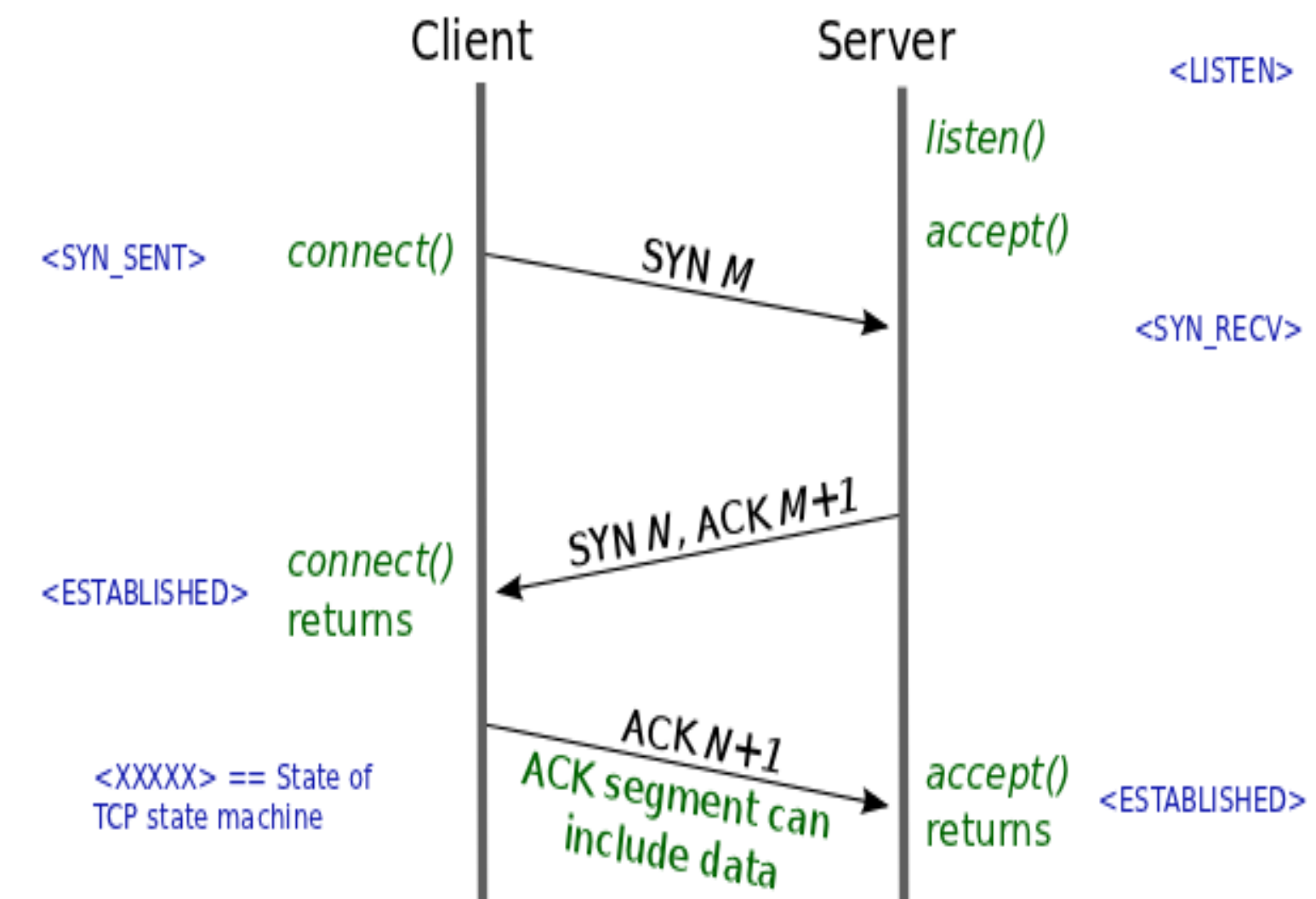
Transmission Control Protocol

Transmission Control Protocol (TCP)

- The Internet is unreliable
- Router sends a packet to its next step, then forgets about it
 - May have sent packets to a failed router
 - Cables may be cut
 - Regions can have power outages
 - Router never gets confirmation of delivery even if the packet made it to its destination
- Internet users (Browsers) and apps are responsible for reliability

TCP: Making a Connection

- 3-way handshake to confirm a connection
- SYN
 - Client sends a packet with a random number to the server
- SYN-ACK
 - Server acknowledges that it received the client's SYN by returning the random number+1
 - Also send another random number
- ACK
 - Client returns the server's random number plus 1
- After all three steps, both side have verified the connection



<https://lwn.net/Articles/508865/>

TCP: Transmitting Data

- When request/response is too large for a single packet
 - Receiver reassembles the packets on the other side of the connection
- Once a connection is established, send all the packets
- Packets can arrive out of order
 - Each packet contains a sequence number for reordering
 - If a sequence number is missing, request a resend
- Many apps use the Internet simultaneously
 - TCP uses port numbers
 - Connect to a port number/IP address combination (TCP/IP)

TCP: In code

- Use TCP sockets in your language of choice to listen for TCP connections on a chosen port

TCP/IP

- Much more coverage in **CSE489: Modern Networking Concepts!**
- Covers these protocols, and many more, in great depth
- In CSE312, we assume TCP/IP just works
 - Use libraries to make TCP connections