

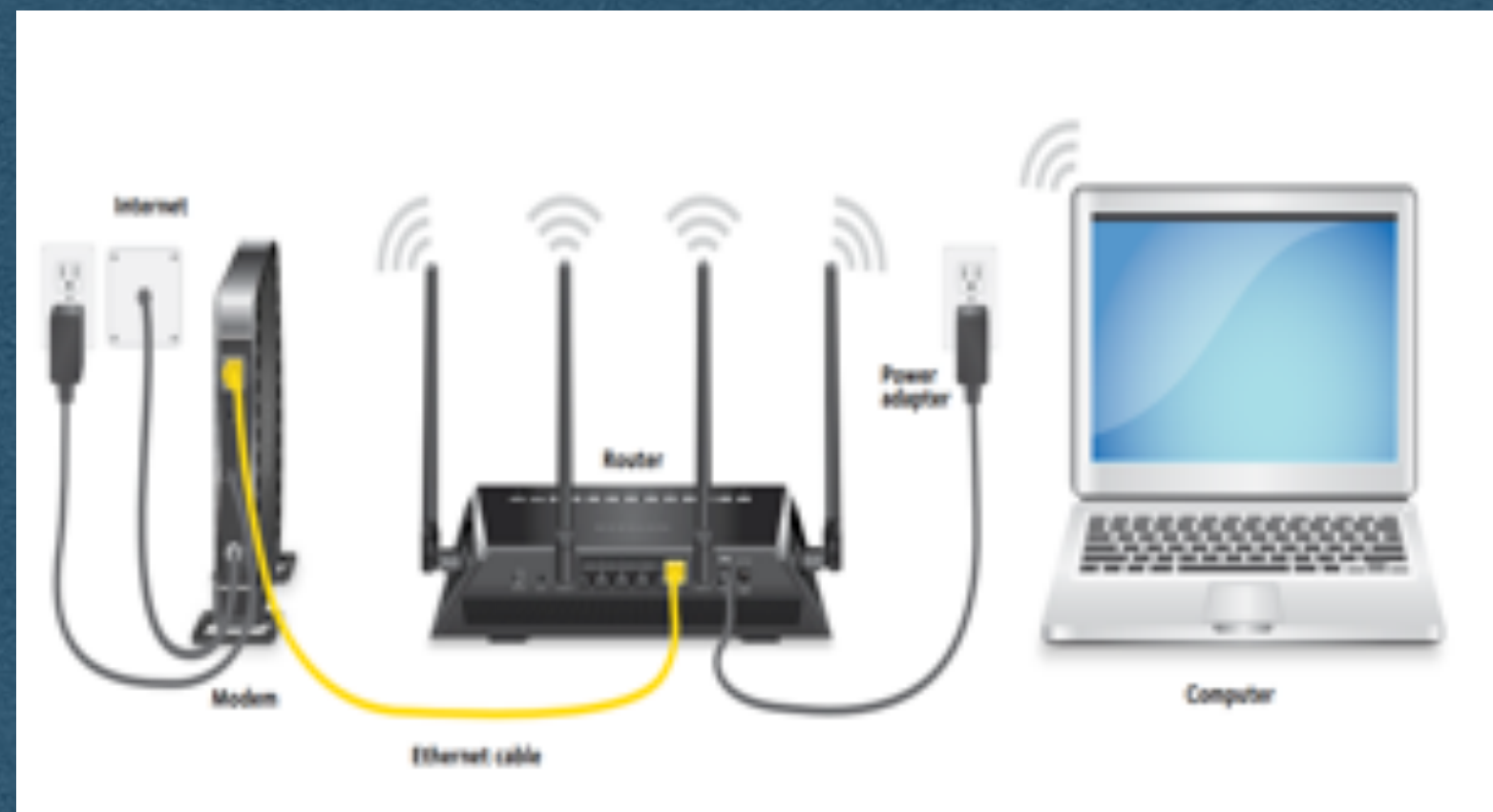
# The Internet

Networks, TCP/IP



# Local Area Network (LAN)

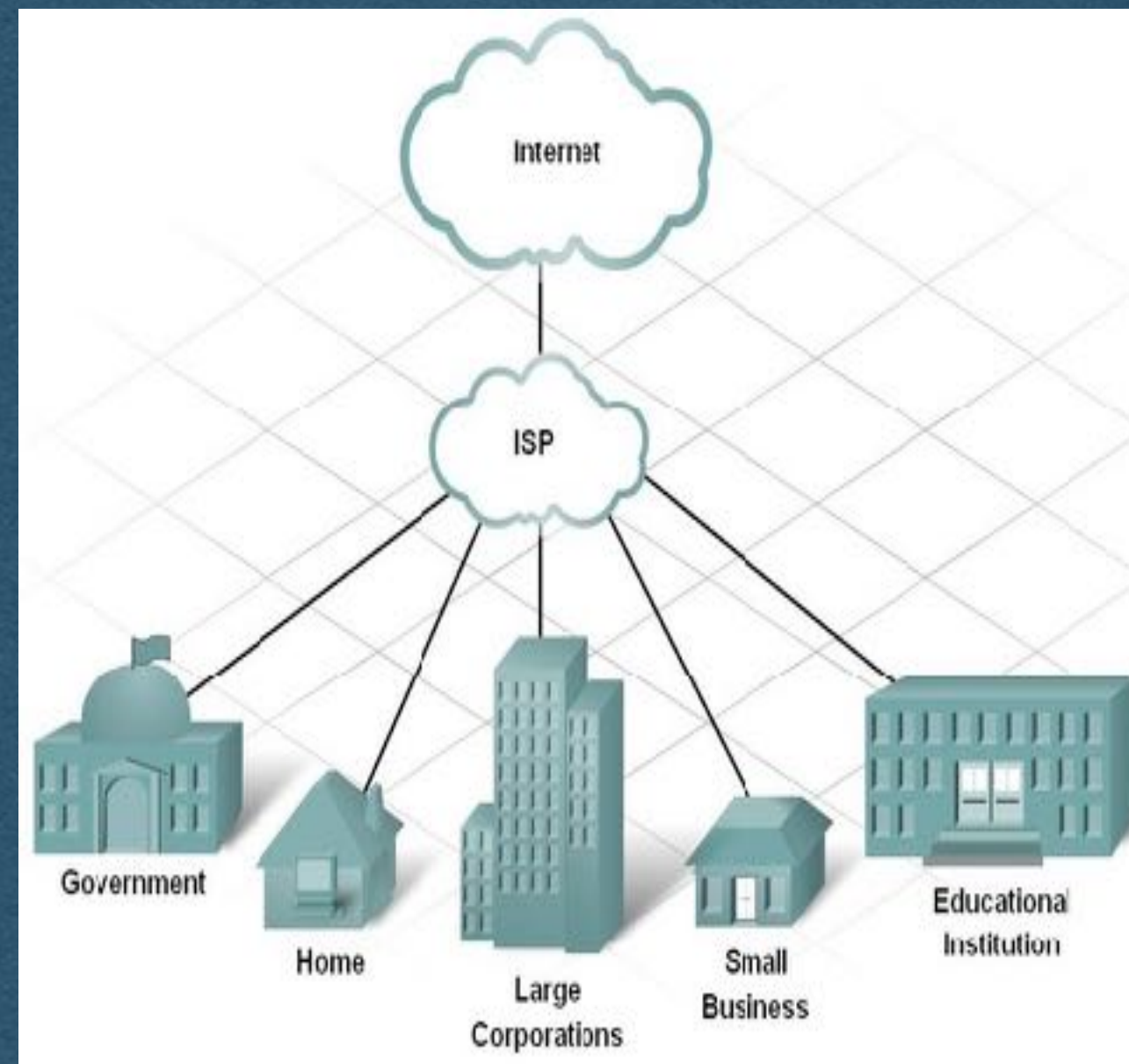
- Connect a small group of devices
  - Devices use the Internet Protocol (IP) to communicate
- Router
  - hardware that connects devices and routes IP packets
- Wifi
  - This is the only place you'll find wireless connections





# 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

([https://en.wikipedia.org/wiki/Tier\\_1\\_network](https://en.wikipedia.org/wiki/Tier_1_network) for more)



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





# 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



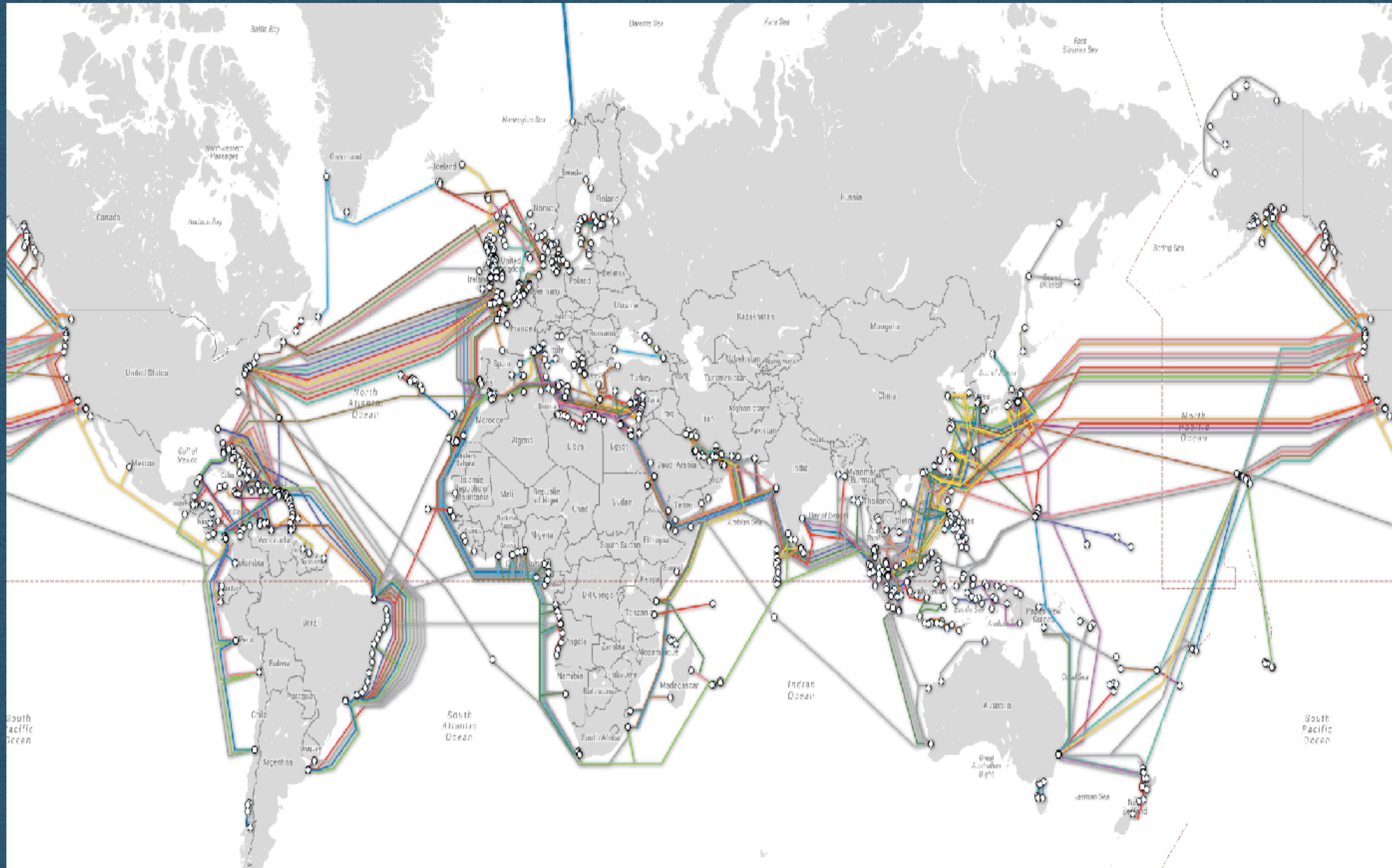
<https://www.wired.com/2015/11/peter-garritano-where-the-internet-lives/>

[https://en.wikipedia.org/wiki/60\\_Hudson\\_Street](https://en.wikipedia.org/wiki/60_Hudson_Street)





# Cables Connect Continents

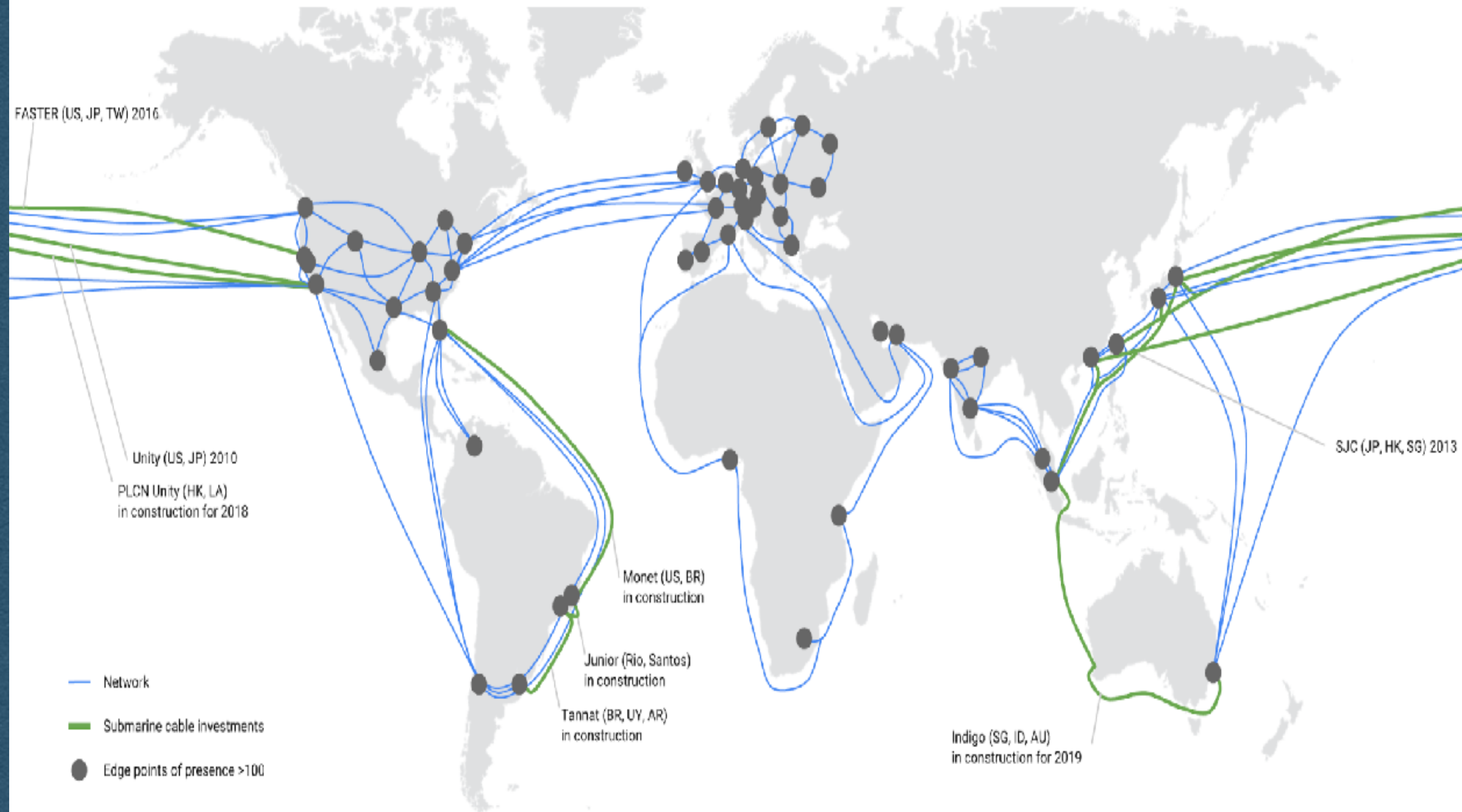


<https://arstechnica.com/information-technology/2016/05/how-the-internet-works-submarine-cables-data-centres-last-mile/>



# 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





# 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

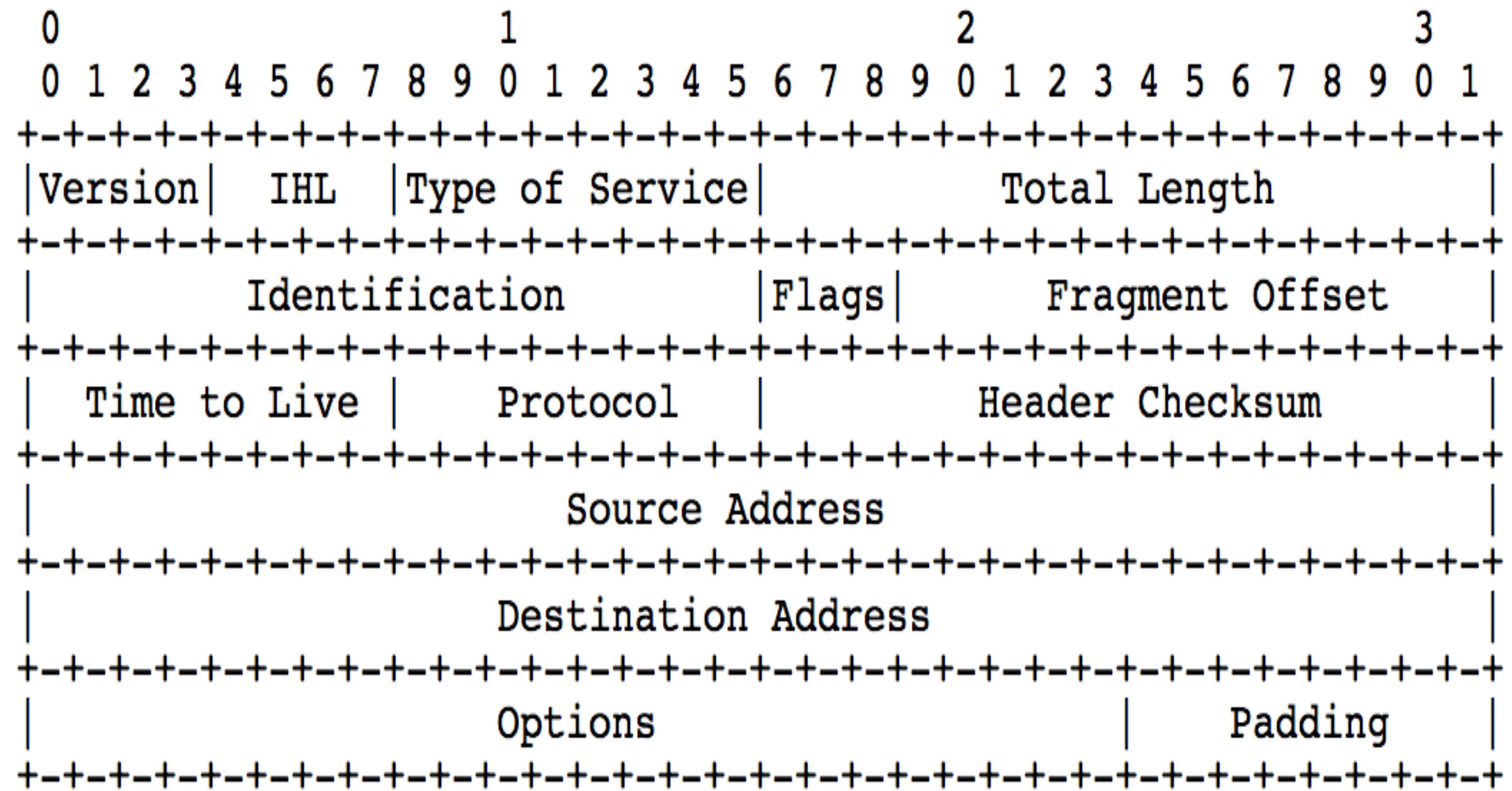
- IPv4 (8.8.4.4)
  - Consists of 4 numbers ranging from 0 to 255
  - How many total addresses?
    - 4 numbers, 8 bits each, 32 total bits,  $2^{32}$  total addresses
    - 4,294,967,296
  - A lot, but not enough
- IPv6 (2001:4860:4860:0000:0000:0000:0000:8844)
  - 128 bit addresses
  - $2^{128}$  total 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

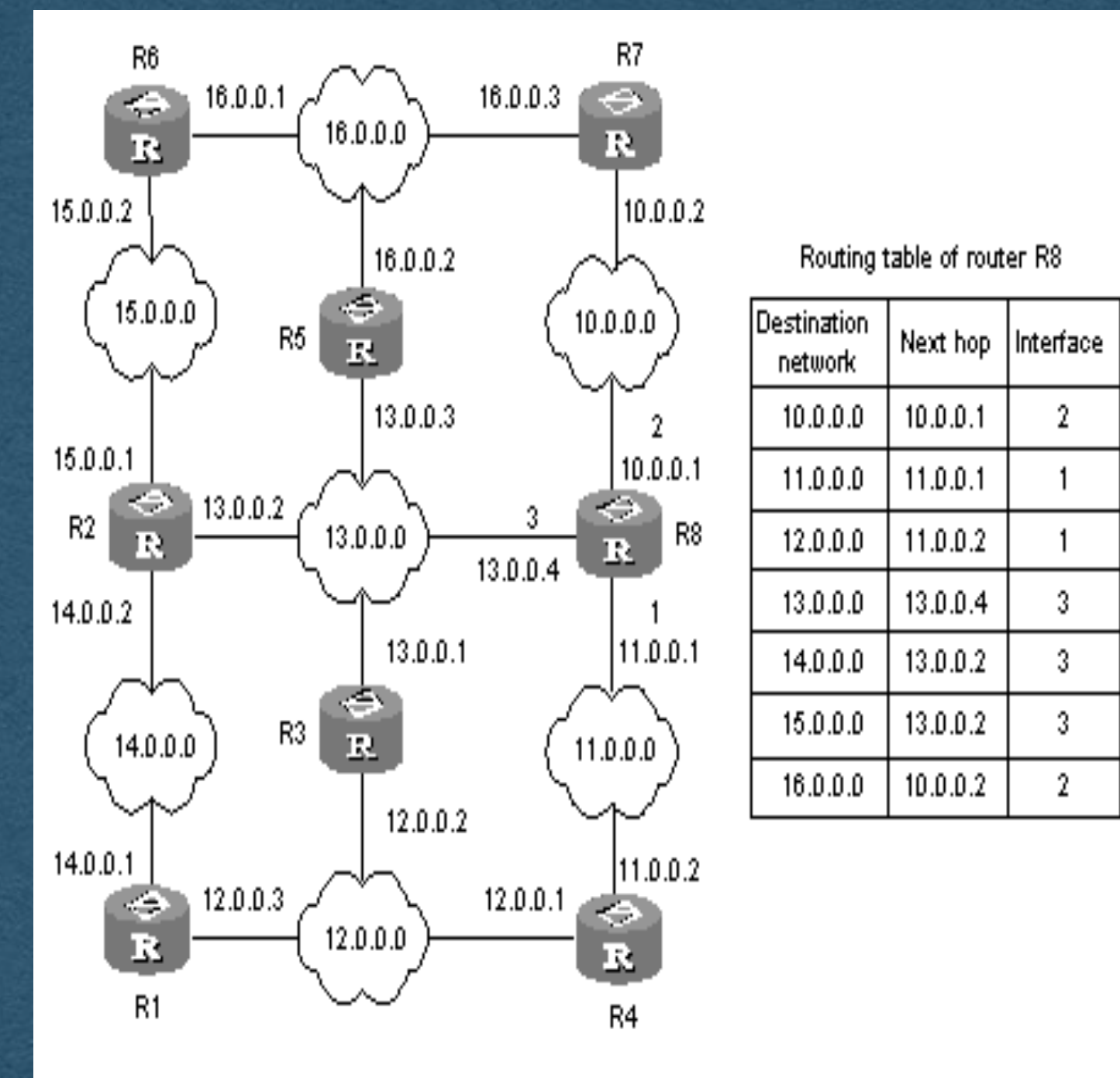
Figure 4.

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



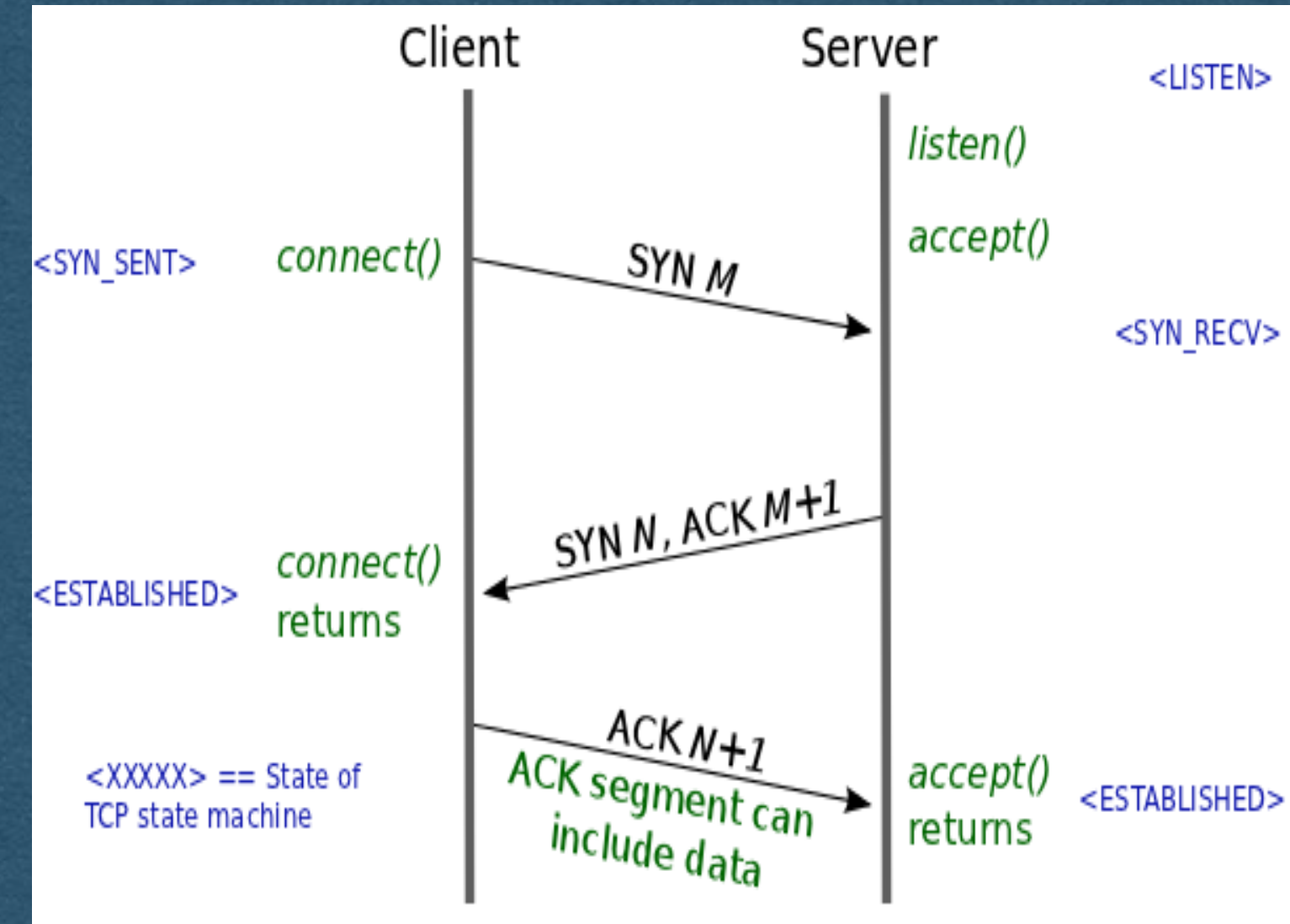
# Transmission Control Protocol (TCP)

- 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