# Lecture 17:
# Protocols

# Protocols

- **precise rules that govern communication between two parties**
- **TCP/IP: the basic Internet protocols**
- **IP: Internet protocol  (bottom level)**
  - all packets shipped from network to network as IP packets
  - no guarantees on quality of service or reliability: "best effort"
  - 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, remote file systems, ...

# Packets

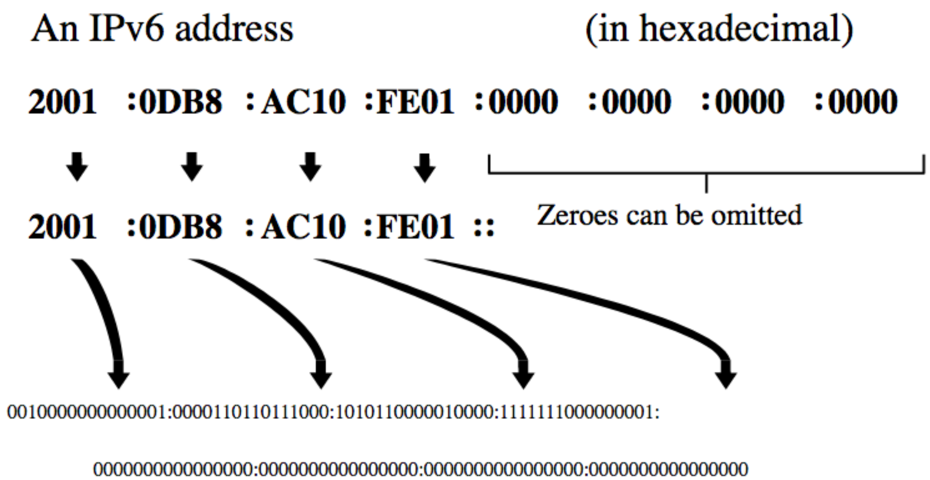
- packet: a sequence of bytes carrying information
  - usually over a network connection
- bytes have a specific sequence, format, organization
  - usually as specified in a protocol
- typical network packet includes
  - source (where it comes from)
  - destination (where it goes to)
  - size or length 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 (Ethernet packets)
  - 100-65000 (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
- actual data
  - up to 64 KB of payload
  - IPv4:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| version | type | hdr len | total len | frag | TTL | source address | dest address | chk | data... |

# IPv6 header




**Fixed header format**

| *Offsets* | Octet | 0 | | | | | | | | 1 | | | | | | | | 2 | | | | | | | | 3 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Octet | Bit | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| 0 | 0 | *Version* | | | | *Traffic Class* | | | | | | | | *Flow Label* | | | | | | | | | | | | | | | | | | | |
| 4 | 32 | *Payload Length* | | | | | | | | | | | | | | | | *Next Header* | | | | | | | | *Hop Limit* | | | | | | | |
| 8 | 64 | *Source Address* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | 96 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | 128 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 160 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | 192 | *Destination Address* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | 224 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32 | 256 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 36 | 288 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

# 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

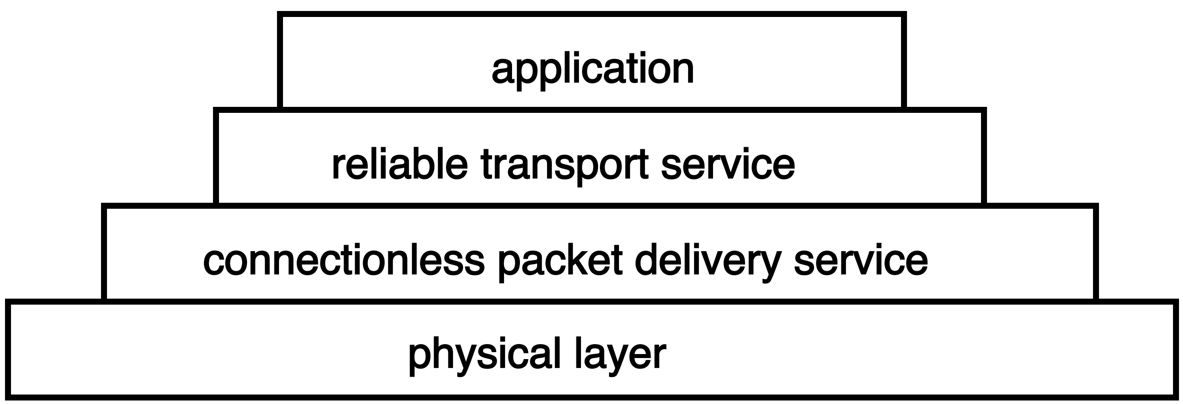
- a reliable 2-way byte stream built with IP
- a TCP connection is established to a specific host
  - and a specific "port" at that host
- each port provides a specific service
  - SSH = 22, SMTP = 25, HTTP = 80, ...

- a message is broken into 1 or more segments
- each TCP segment has a header (src, dest, 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

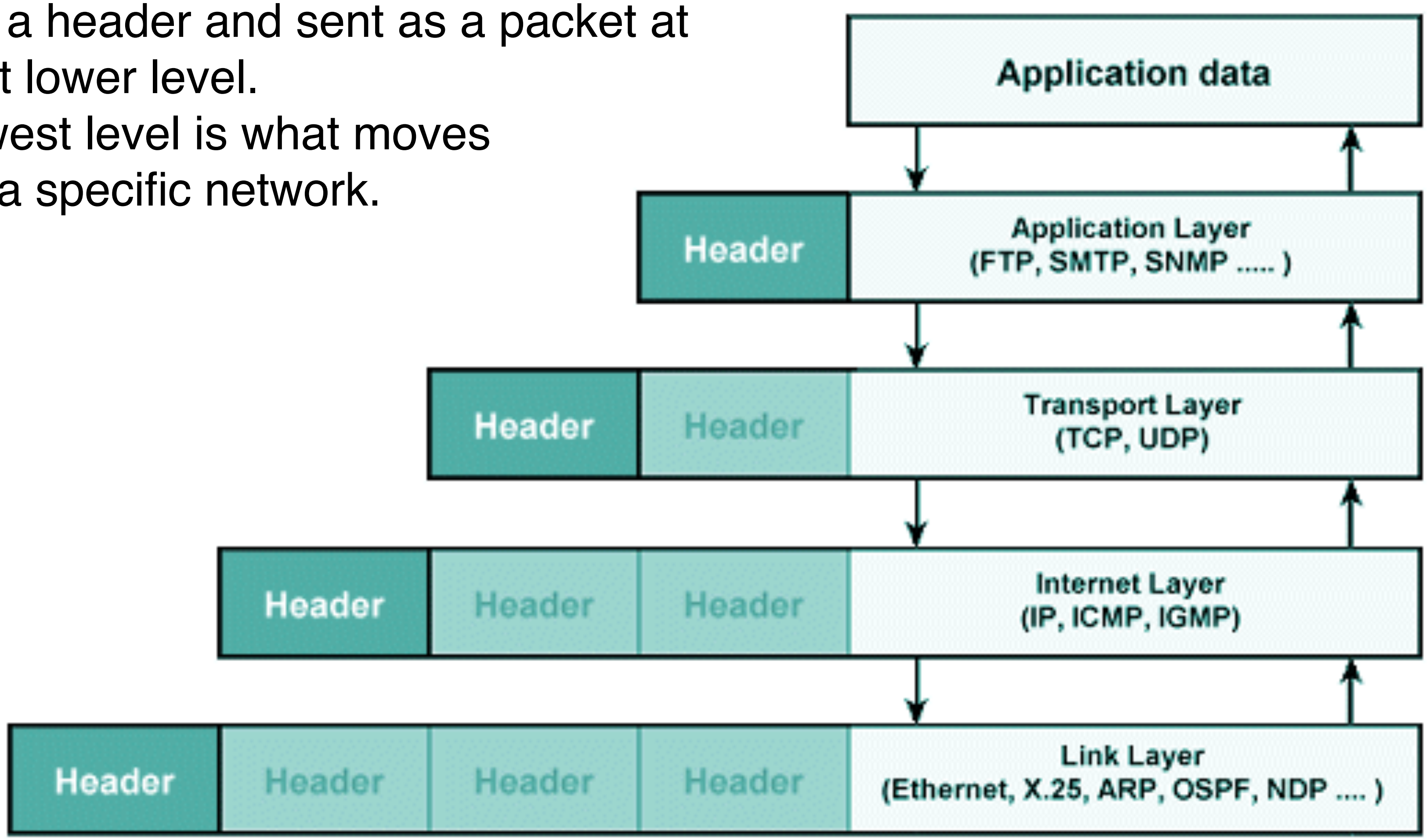
# Higher level protocols

- 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



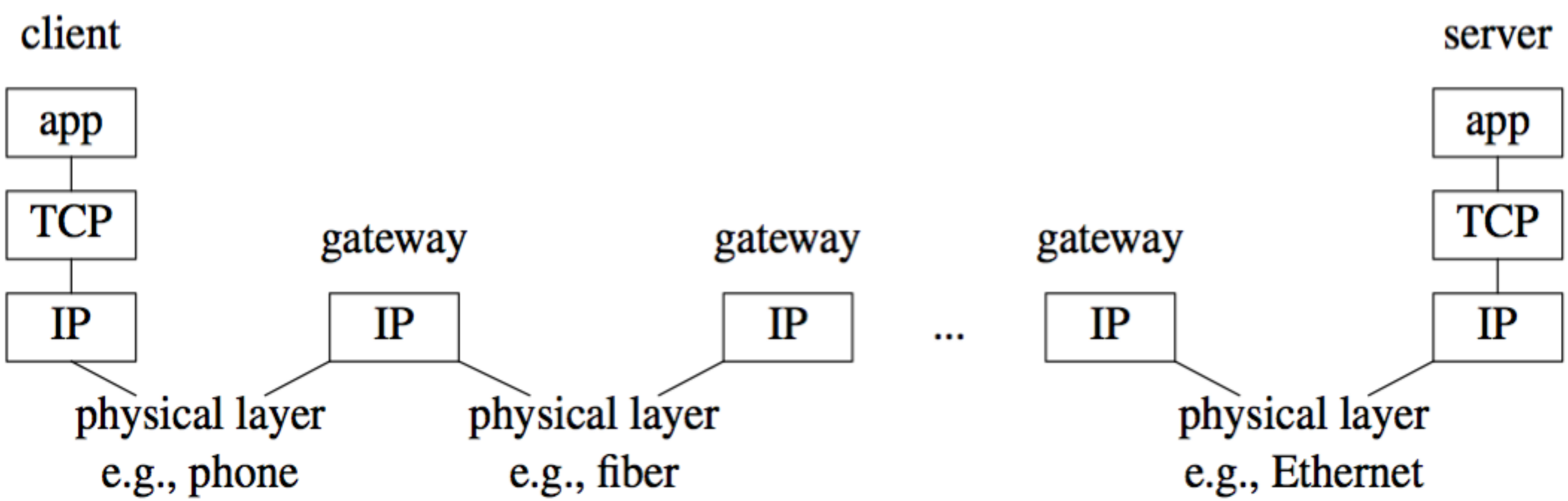
# Encapsulation

Each piece of data at one level is wrapped up with a header and sent as a packet at the next lower level.
The lowest level is what moves across a specific network.




**http://www.technologyuk.net/the_internet/**

# How information flows

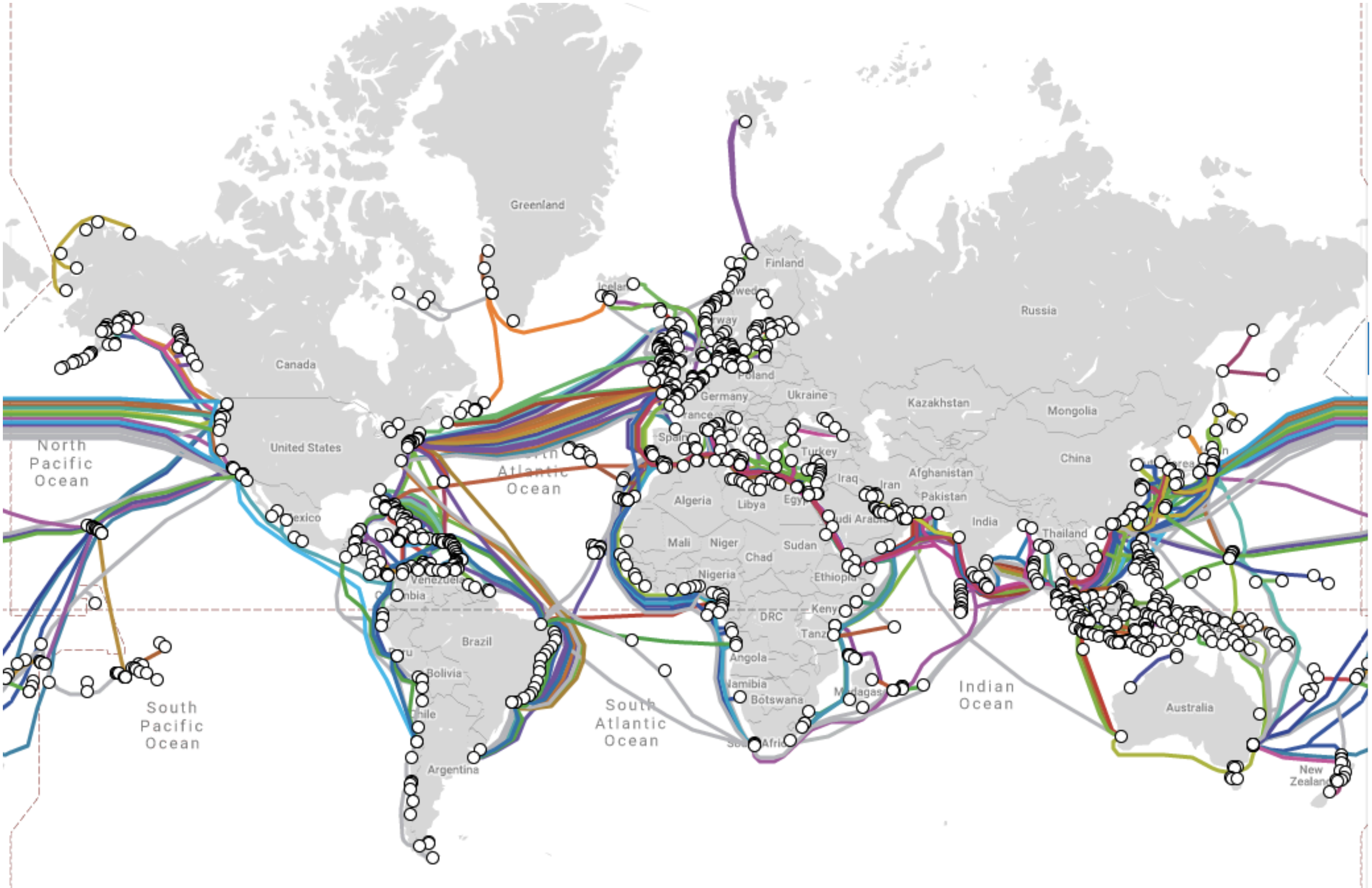


# How things are connected

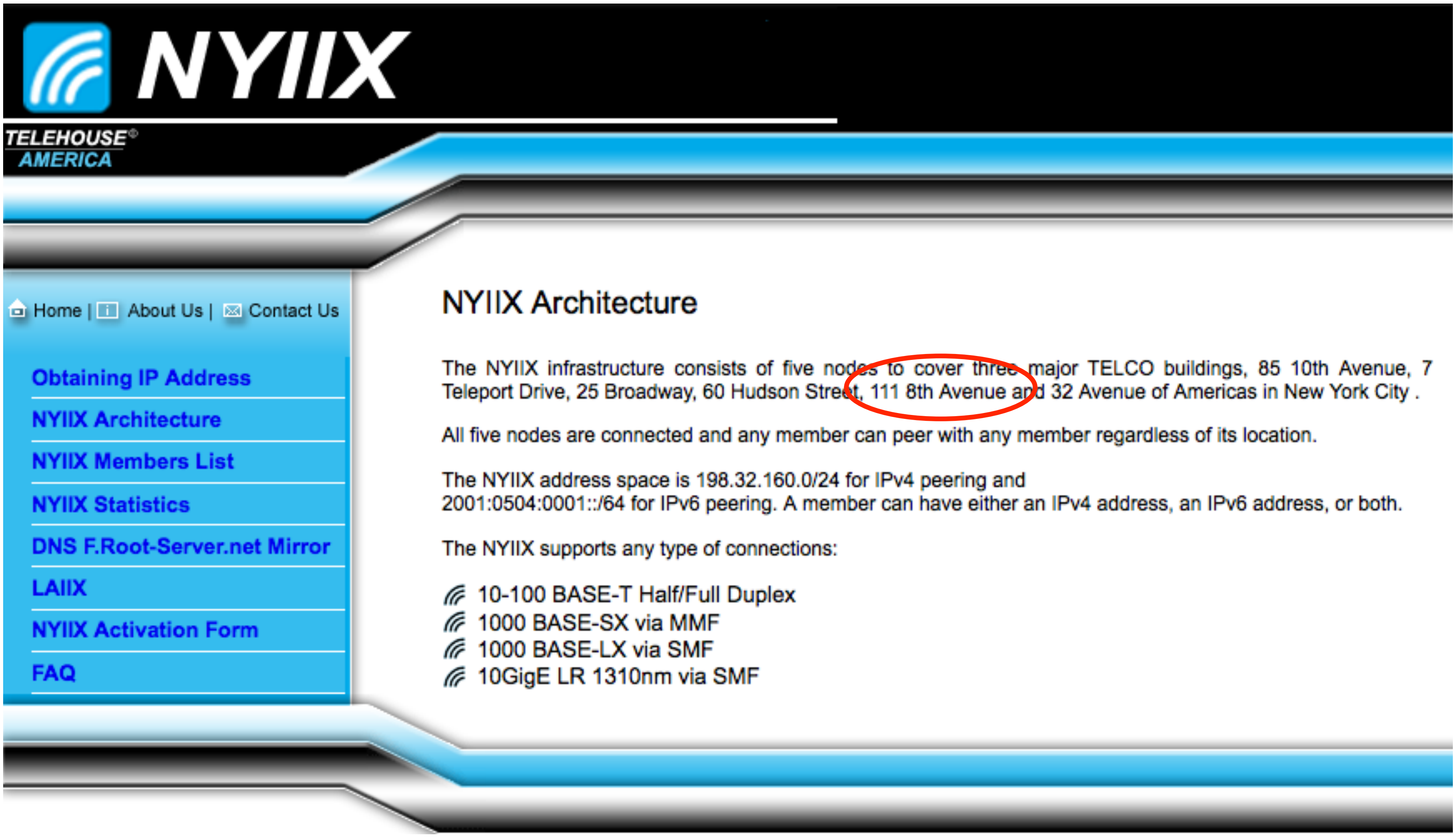
- local nets connected to local Internet Service Provider (ISP)
- these in turn connect to regional ISPs
- and then to larger ones like Comcast, Verizon, AT&T, Sprint, …
- traffic exchanged at Internet exchanges (IXP)
  - large and small, formal and informal, profit and non-profit

- bandwidth (bit-carrying capacity) of connections is usually higher for larger ISPs
  - cable, DSL: maybe 10-100 Mbps (you to your ISP)
  - optical fiber: 100 Mbps and up (large carriers)

submarinecablemap.com



# Internet Exchange Point (IXP)



NYIIX

TELEHOUSE® AMERICA

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- Obtaining IP Address
- NYIIX Architecture
- NYIIX Members List
- NYIIX Statistics
- DNS F.Root-Server.net Mirror
- LAIIX
- NYIIX Activation Form
- FAQ

## NYIIX Architecture

The NYIIX infrastructure consists of five nodes to cover three major TELCO buildings, 85 10th Avenue, 7 Teleport Drive, 25 Broadway, 60 Hudson Street, 111 8th Avenue and 32 Avenue of Americas in New York City .

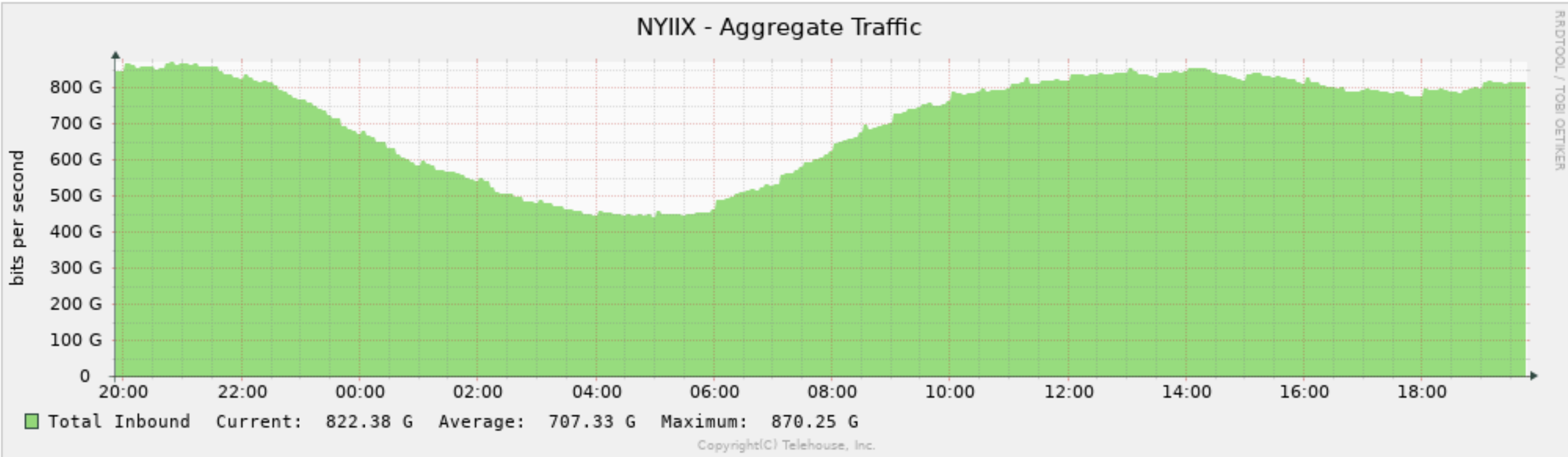
All five nodes are connected and any member can peer with any member regardless of its location.

The NYIIX address space is 198.32.160.0/24 for IPv4 peering and 2001:0504:0001::/64 for IPv6 peering. A member can have either an IPv4 address, an IPv6 address, or both.

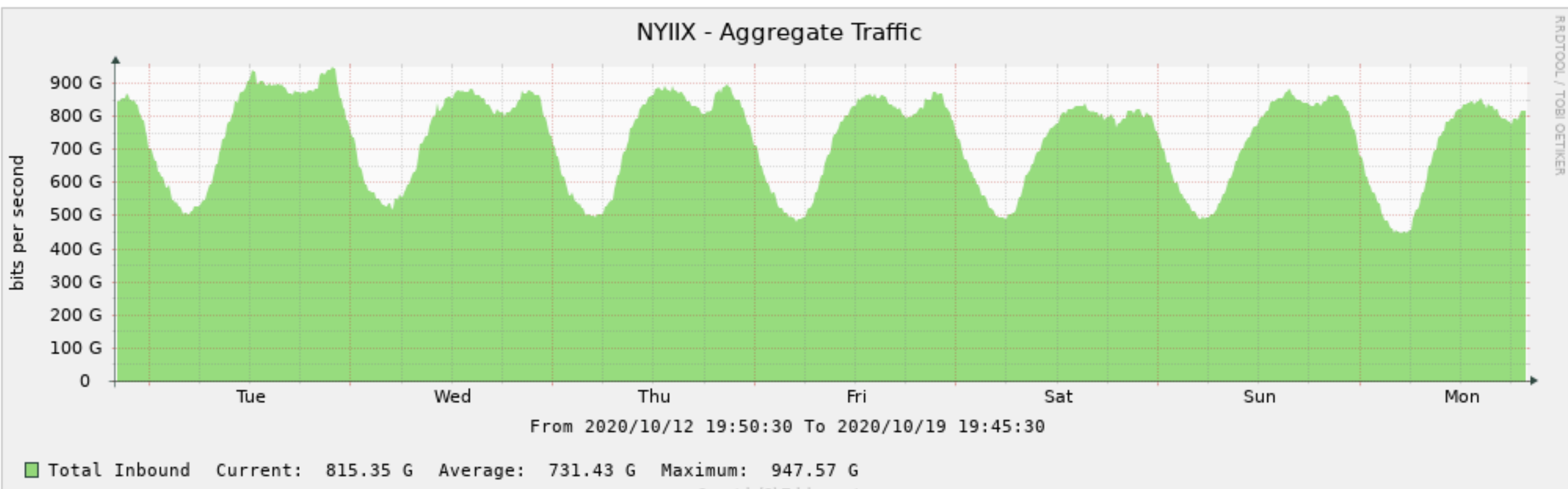
The NYIIX supports any type of connections:

- 10-100 BASE-T Half/Full Duplex
- 1000 BASE-SX via MMF
- 1000 BASE-LX via SMF
- 10GigE LR 1310nm via SMF

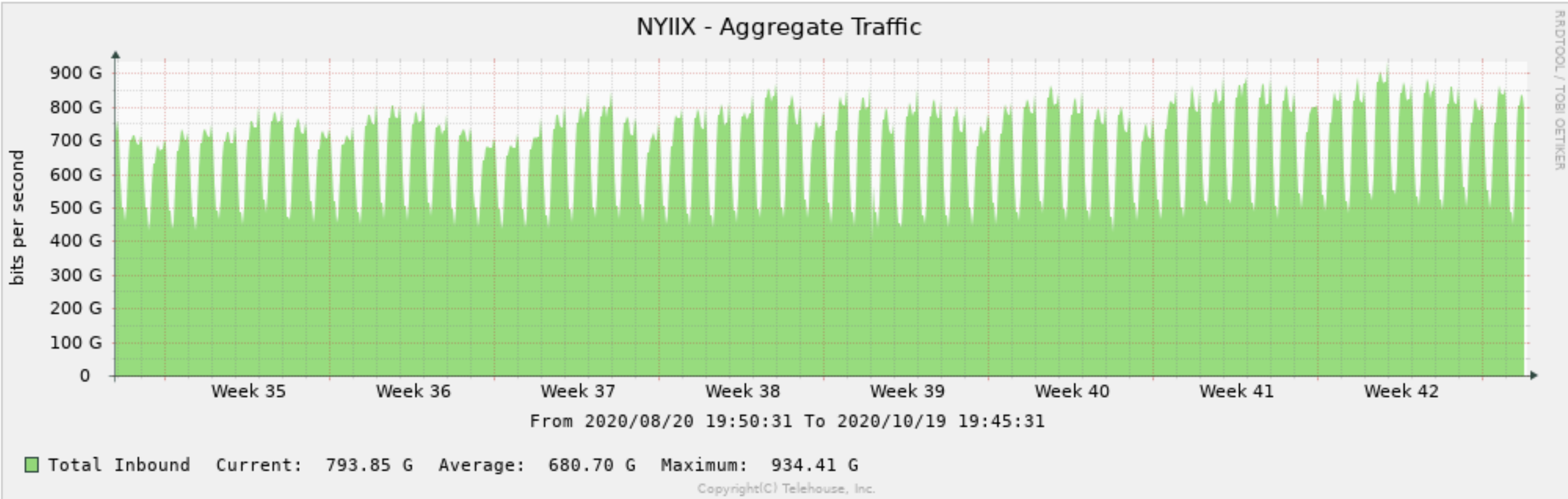
## `Daily' Graph (5 Minute Average)



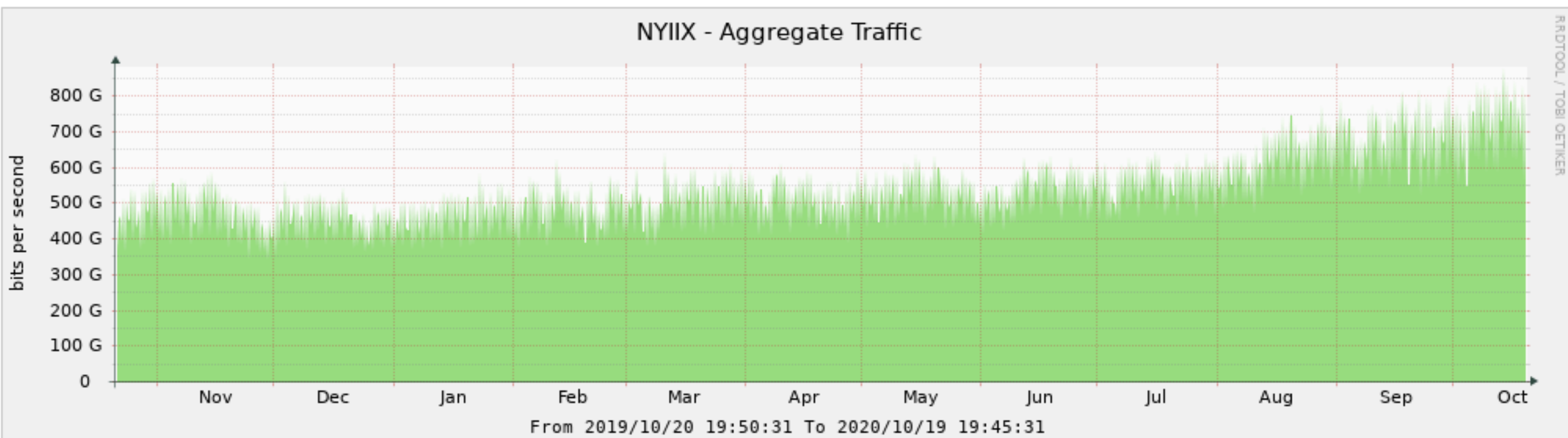

## `Weekly' Graph (30 Minute Average)



### `Monthly' Graph (2 Hour Average)

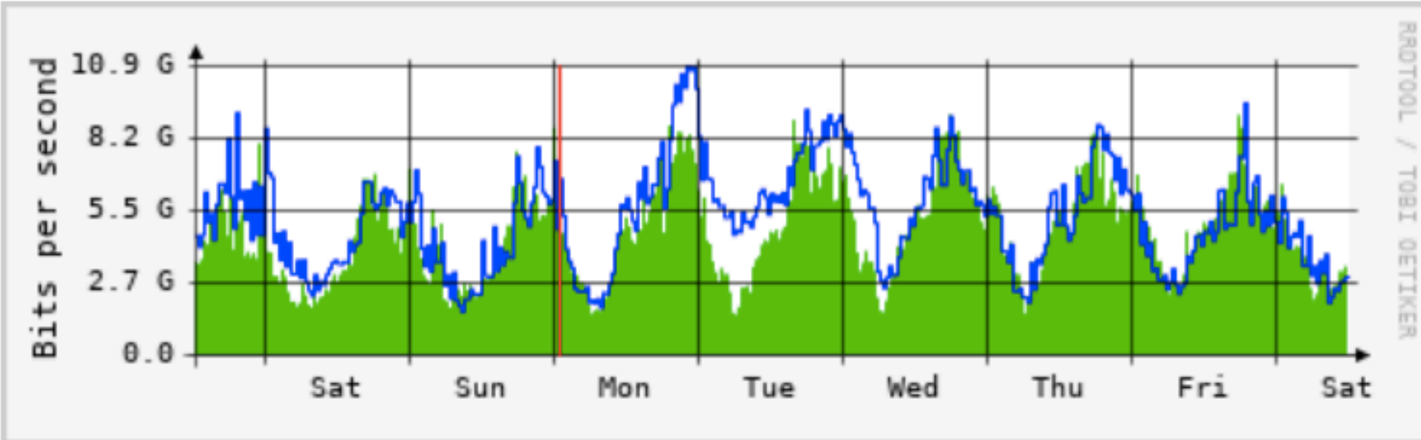



### `Yearly' Graph (1 Day Average)



OIT
11/9/19

`Weekly' Graph (30 Minute Average)




Max In: 9014.1 Mb/s (11.3%) Average In: 4606.7 Mb/s (5.8%) Current In: 3284.8 Mb/s (4.1%)
Max Out: 10.9 Gb/s (13.6%) Average Out: 5217.0 Mb/s (6.5%) Current Out: 2952.5 Mb/s (3.7%)

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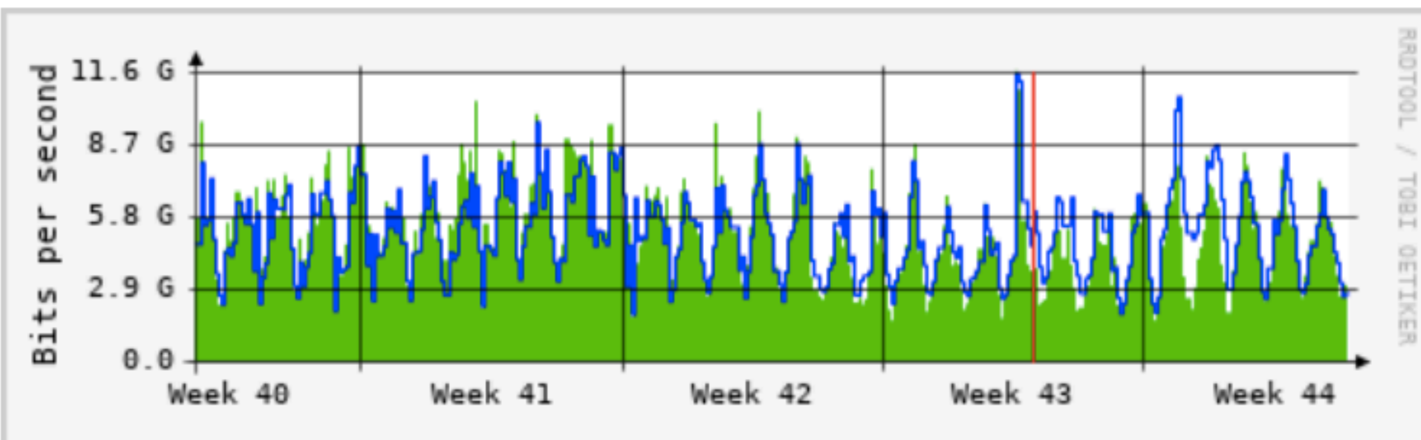
`Monthly' Graph (2 Hour Average)

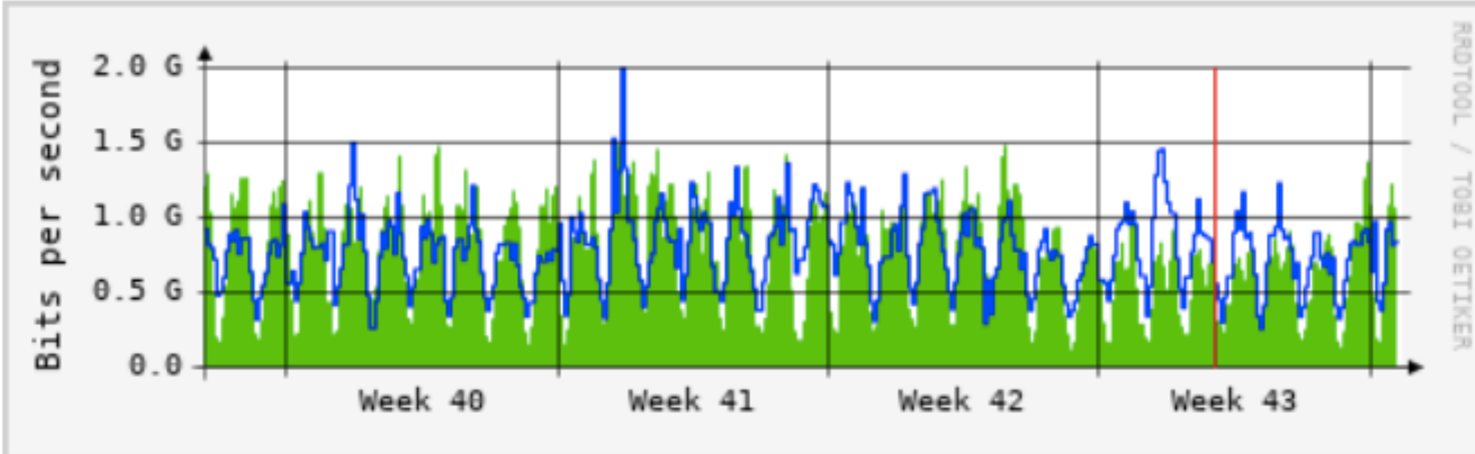



Max In: 11.6 Gb/s (14.5%) Average In: 5133.0 Mb/s (6.4%) Current In: 3014.9 Mb/s (3.8%)
Max Out: 11.6 Gb/s (14.5%) Average Out: 5186.1 Mb/s (6.5%) Current Out: 2738.2 Mb/s (3.4%)

# OIT

- 11/5/28

`Monthly' Graph (2 Hour Average)




Max In: 1489.3 Mb/s Average In: 764.0 Mb/s Current In: 1065.6 Mb/s
Max Out: 2023.4 Mb/s Average Out: 792.1 Mb/s Current Out: 845.2 Mb/s

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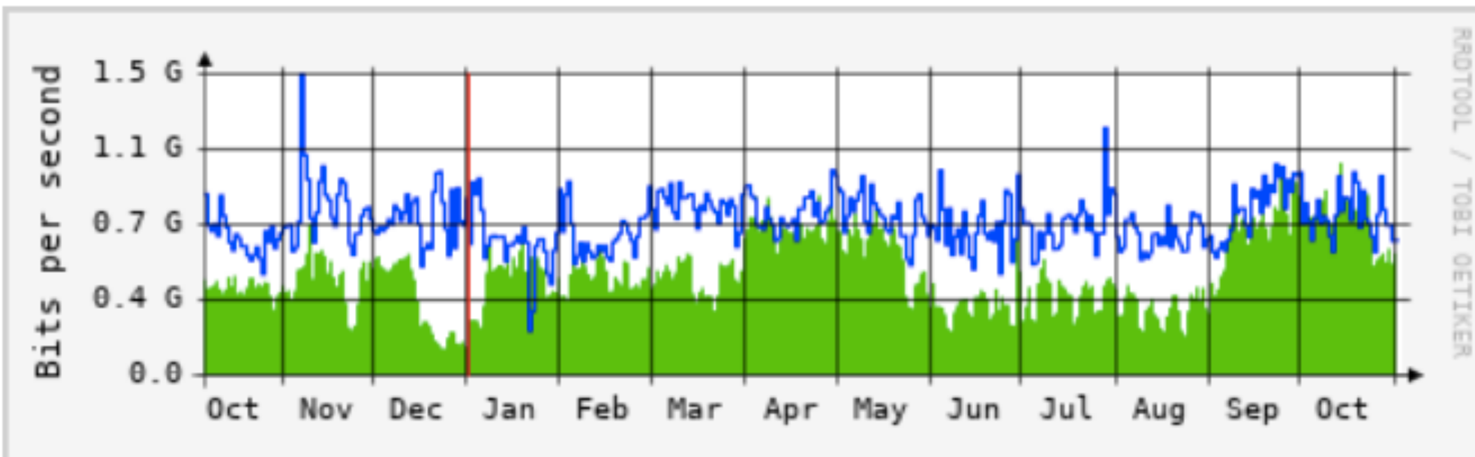
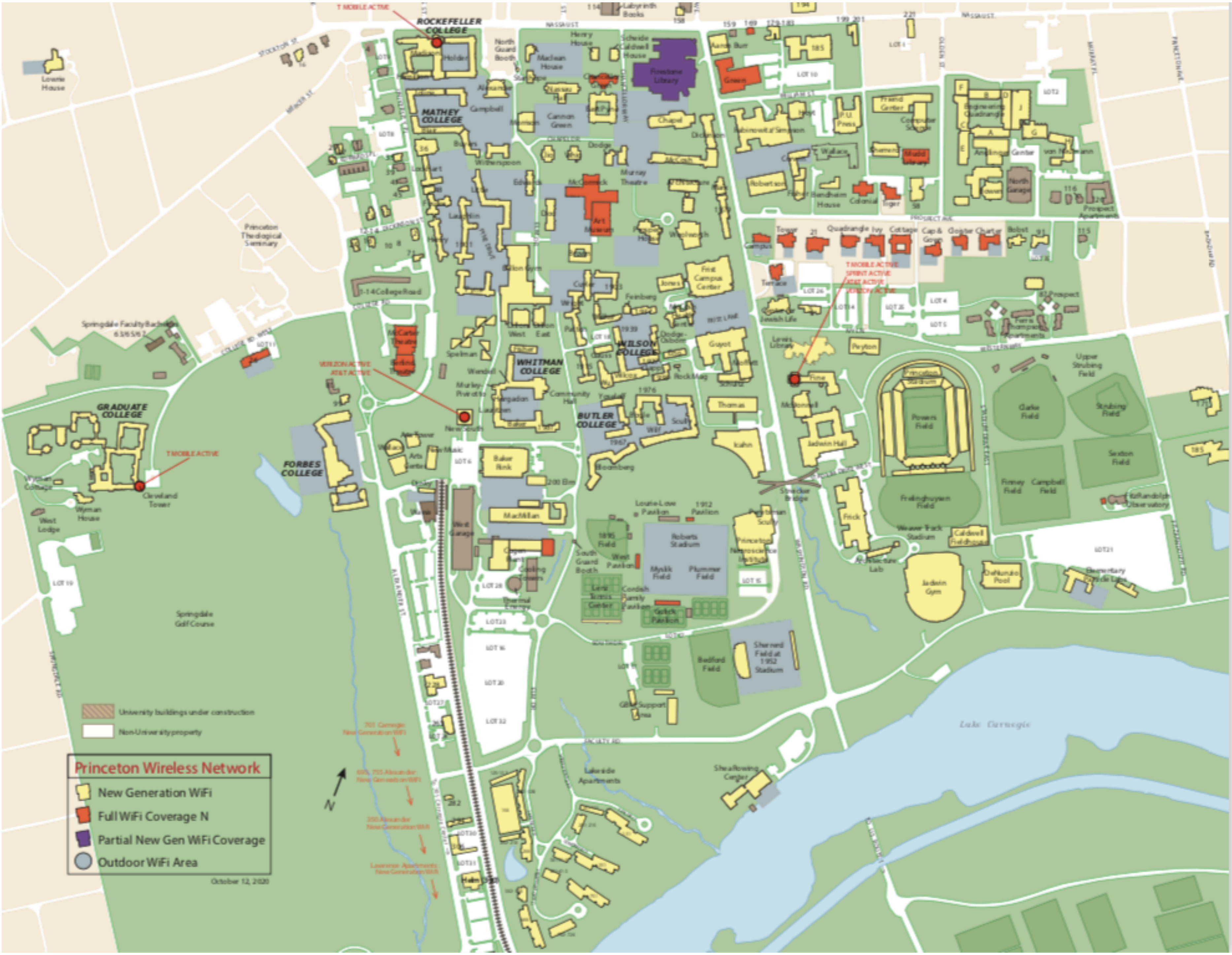
`Yearly' Graph (1 Day Average)




Max In: 1046.4 Mb/s Average In: 507.8 Mb/s Current In: 595.8 Mb/s
Max Out: 1497.8 Mb/s Average Out: 763.7 Mb/s Current Out: 670.1 Mb/s



ROCKEFELLER COLLEGE
MATHEY COLLEGE
WHITMAN COLLEGE
WILSON COLLEGE
BUTLER COLLEGE
FORBES COLLEGE
GRADUATE COLLEGE
T MOBILE ACTIVE
Firestone Library
Princeton Stadium
Powers Field
Jadwin Gym
Roberts Stadium
Lake Carnegie
Springdale Golf Course
University buildings under construction
Non-University property
Princeton Wireless Network
New Generation WiFi
Full WiFi Coverage N
Partial New Gen WiFi Coverage
Outdoor WiFi Area
October 12, 2020

# 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 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**