The Network Layer and the Internet Protocols

- Network Layer Concepts
  - Addressing
  - Routing
  - Forwarding
- The Internet Protocols: IPv4 and IPv6

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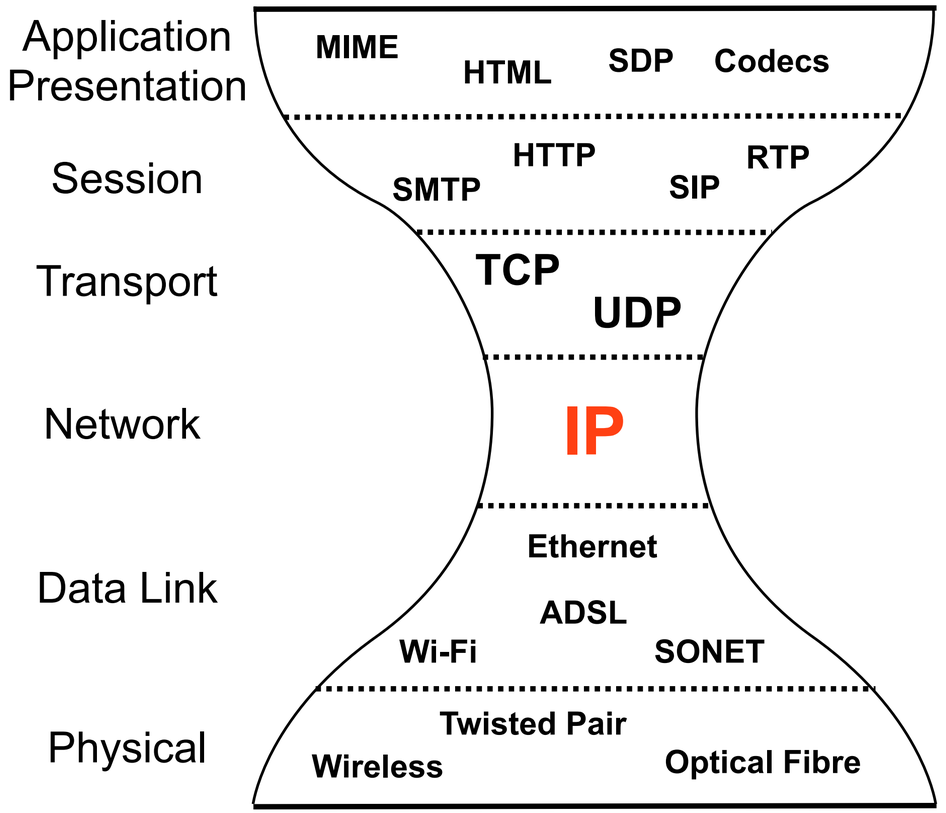
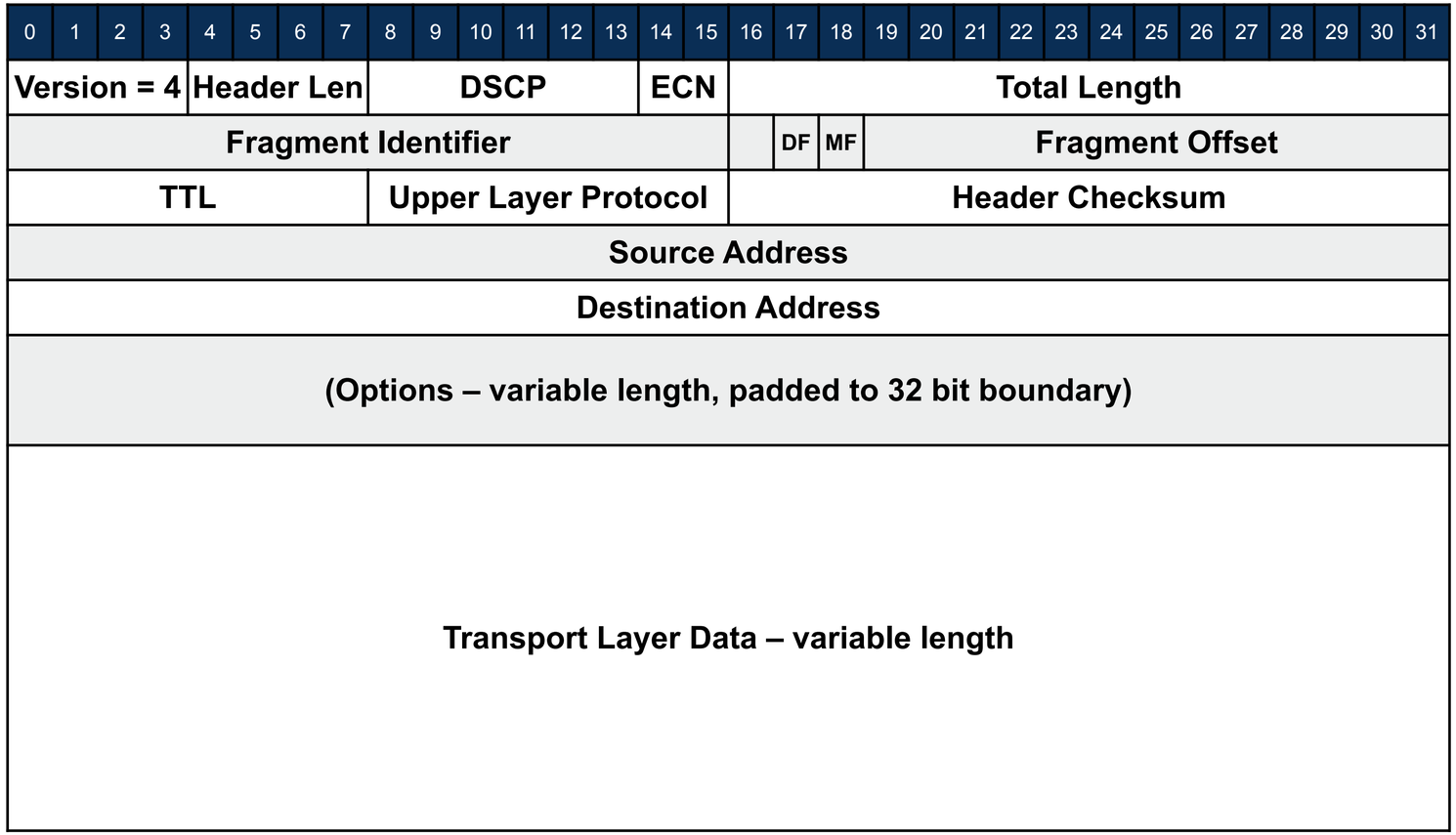
The Network Layer as an Internet Protocol

- Global inter-networking protocol
- Hour glass protocol stack
  - Single standard network layer protocol (IP)
    - Packet switched network, best effort service
    - Uniform network and host addressing
    - Uniform end-to-end connectivity – subject to firewall policy
  - Many transport & application layer protocols
  - Range of link-layer technologies supported
- Decouples end-to-end functionality from per-hop functionality

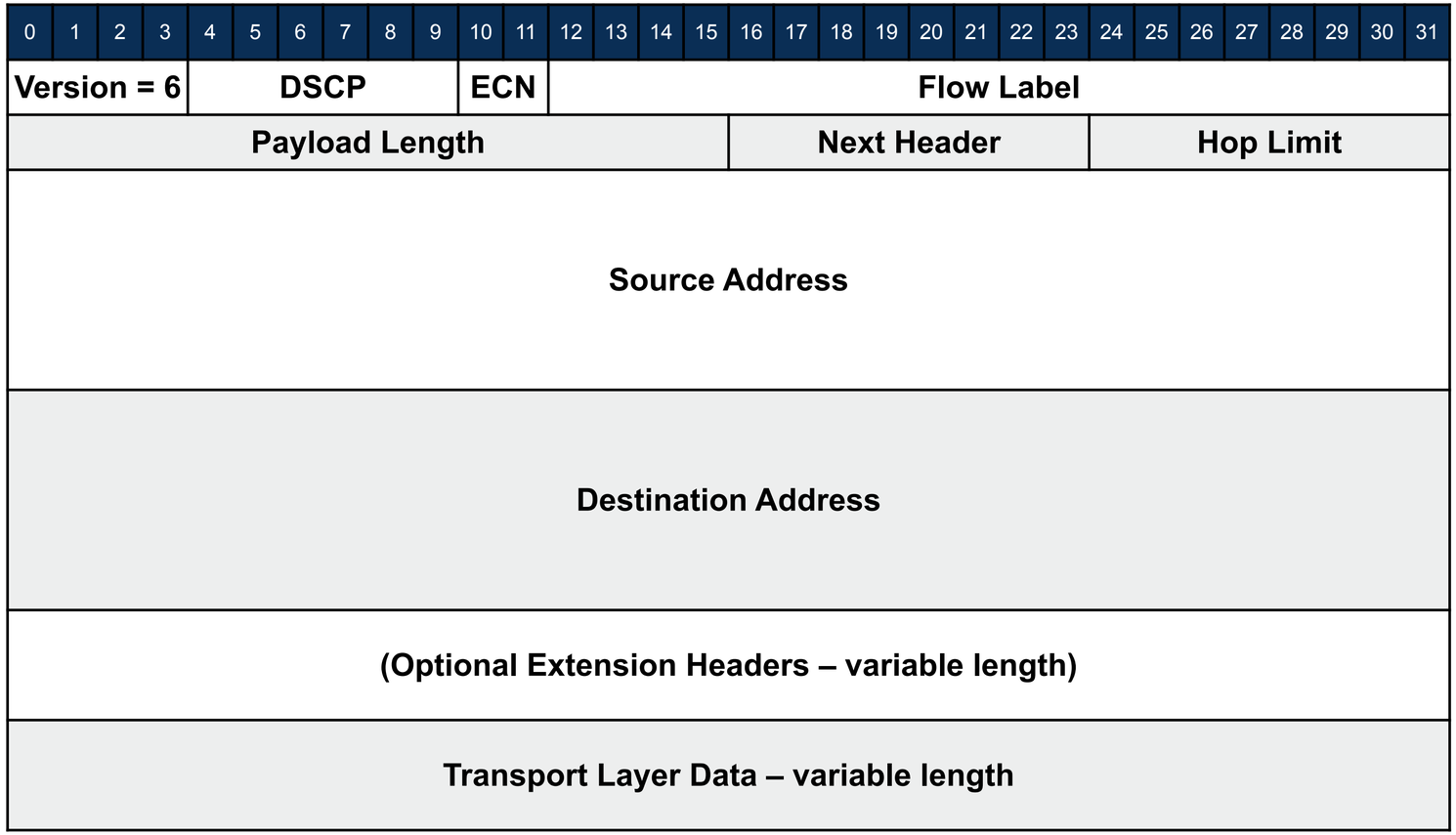


IPv4



- 32 bit addresses insufficient
- Fragmentation difficult at high data rates
- Limited extensibility

IPv6



- Larger address space
- No in-network fragmentation
- No unnecessary checksum
- Simpler header format

What About IPv5?

- Experiments with voice over the ARPAnet – the precursor to the Internet – started in the early 1970s
  - Network Voice Protocol https://www.ietf.org/rfc/rfc741.txt
- This evolved into the Internet Stream Protocol, ST-II, that was assigned IPv5 – an experimental multimedia streaming protocol developed between 1979 and 1995, but never widely deployed
  - ST-II+ specification: http://www.ietf.org/rfc/rfc1819.txt

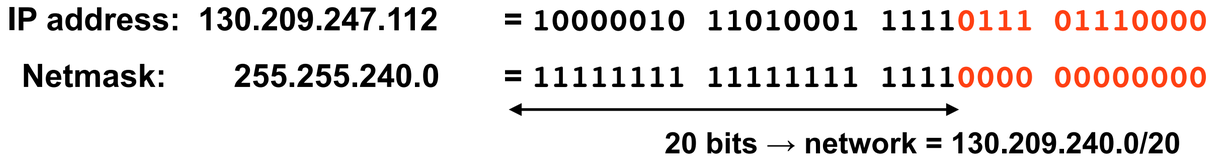
Danny Cohen, developer of the Network Voice Protocol

Aside: Danny Cohen also wrote “On Holy Wars and a Plea for Peace” (https://www.ietf.org/rfc/ien/ien137.txt) that introduced the terms big- and little-endian for numeric data and message byte order

IP Addressing

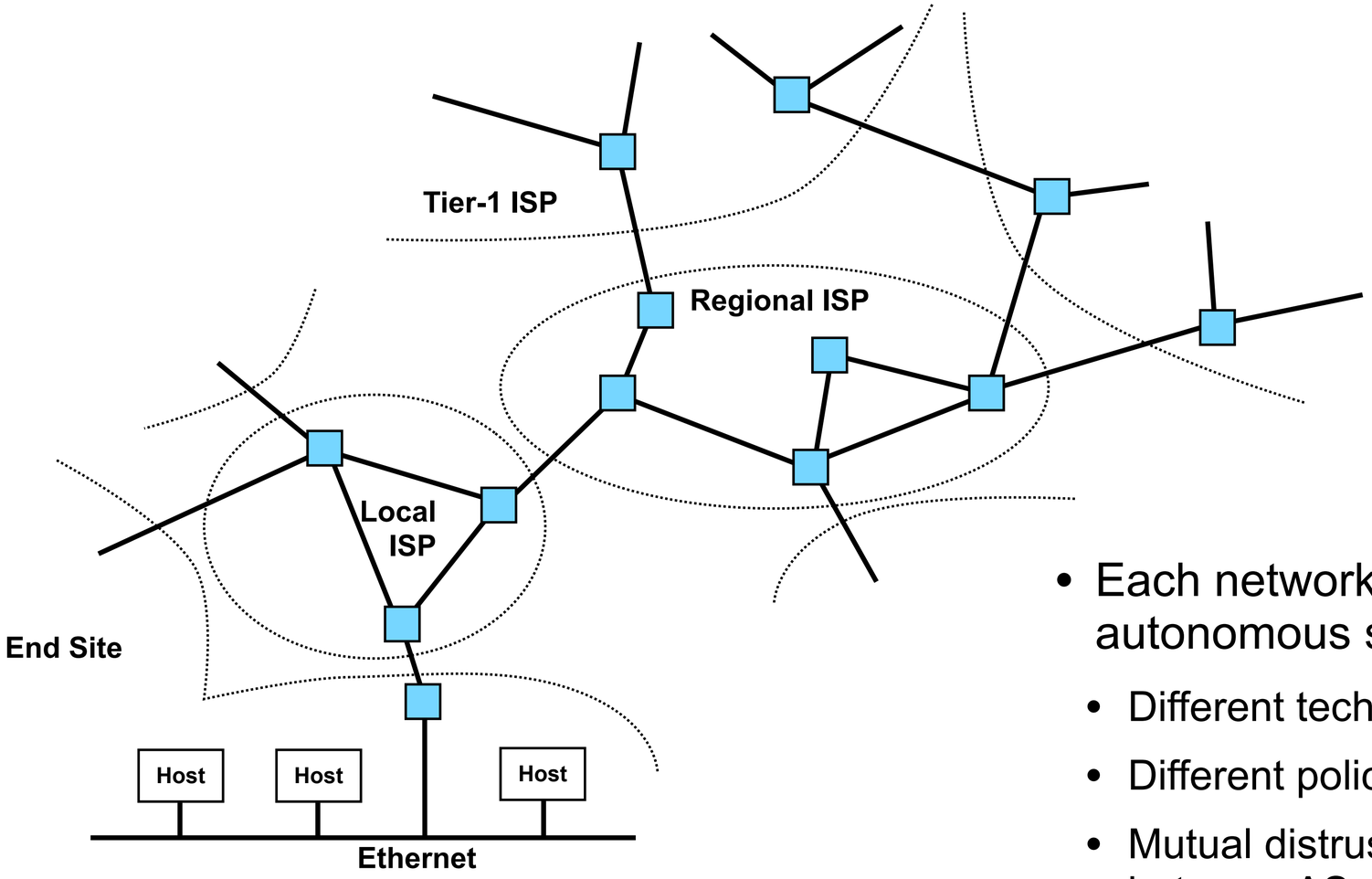
- IP addresses encode location of network interface
  - If a host has multiple network interfaces (e.g., Wi-Fi and Ethernet), it will have multiple IP addresses
  - A host can support both IPv4 and IPv6 on each interface
  - A host can have multiple IP addresses of each type assigned to each interface
- DNS names are an application concept – not used by the network

IPv4



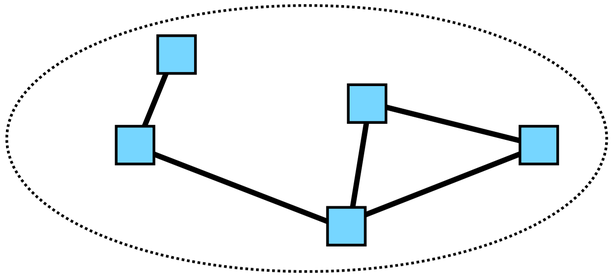
IPv6

Routing



- Each network administered separately - an autonomous system (AS)
  - Different technologies
  - Different policies
  - Mutual distrust – between AS and its peers; between AS and its customers

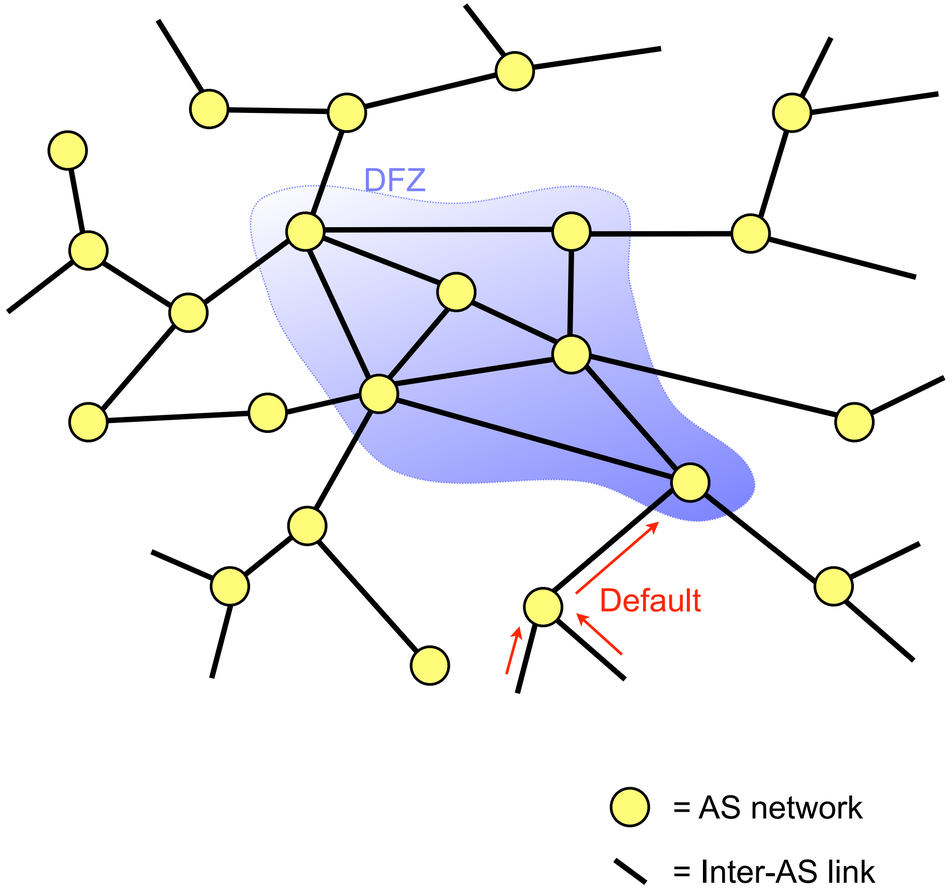
Autonomous Systems and Inter-domain Routing



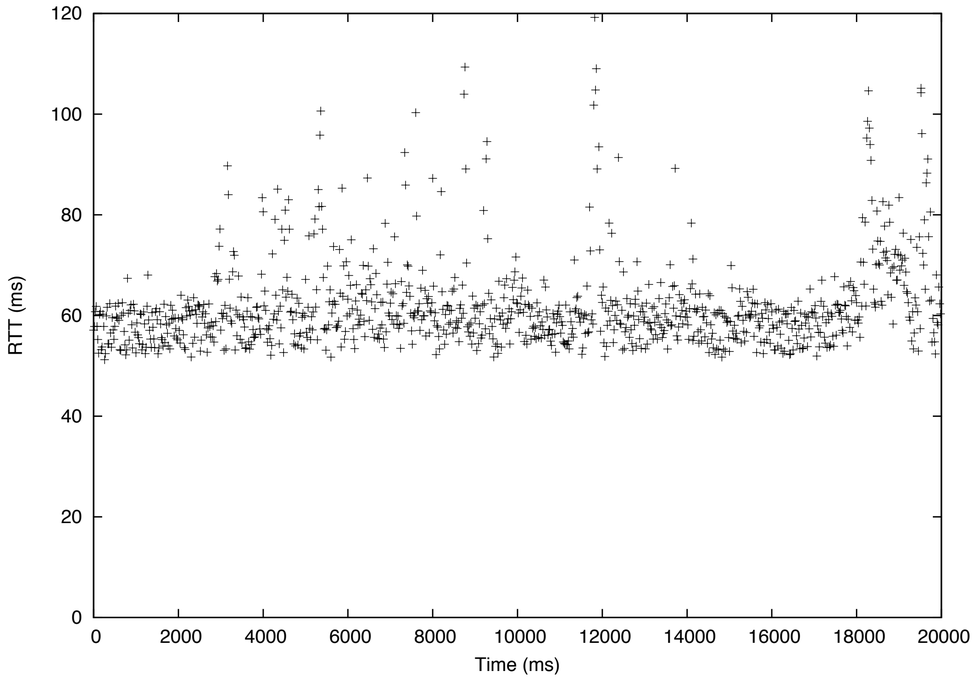
- Each network administered separately – an autonomous system (AS)
  - Separately administered; different technologies
  - Shortest path routing
  - Distance vector or link state algorithms

Inter-domain Routing and BGP

- Treats each network as a graph node and routes between ASes
- The AS-level topology:
  - Well connected core; sparse edges
  - Edge networks can use default route to the core
  - Core networks need full routing table: the default free zone (DFZ)
- Routing between competitors – no real trust between organisations
  - Policy, politics, and economics are key constraints; not shortest path
  - BGP routing protocol



Forwarding



- Best effort, connectionless, packet delivery
  - Just send – no need to setup a connection first
  - Network makes its best effort to deliver packets, but provides no guarantees
  - Time taken to transit the network may vary
  - Packets may be lost, delayed, reordered, duplicated or corrupted
  - The network discards packets it can't deliver
- Easily run over any type of link layer

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- The Internet Protocols: IPv4 and IPv6
- Addressing
- Routing
- Service model: best effort transport