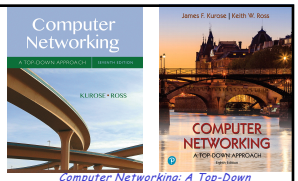
CS 655
Computer Networks

Abraham Matta
Computer Science
Boston University

Chapters 4 & 5
Internetworking



Computer Networking: A Top-Down Approach, 7th or 8th editions. Jim Kurose, Keith Ross. Pearson.

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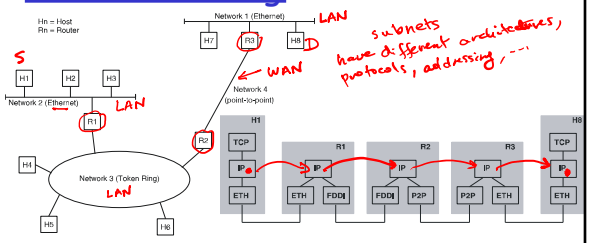
Internetworking



- Service Model:
  - Packet Delivery Model
  - Global Addressing Scheme

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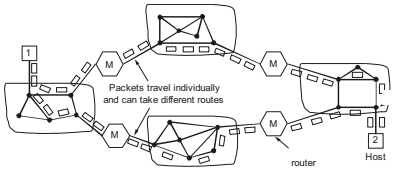
Packet Delivery Model



- Connectionless (datagram-based)
- Best-effort delivery (unreliable service)
  - packets can be lost
  - packets can be delivered out of order
  - duplicate copies of a packet can be delivered
  - packets can be delayed for a long time

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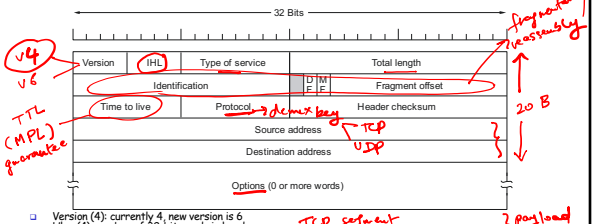
Datagram Format



- Version (4): currently 4, new version is 6
- Hlen (4): number of 32-bit words in header
- TOS (8): type of service (not widely used)
- Length (16): number of bytes in this datagram
- Ident (16): used by fragmentation to identify fragments belonging to same original IP packet (datagram)
- Flags/Offset (16): used by fragmentation to identify where this fragment belongs in original datagram
- TTL (8): number of hops this datagram has traveled, used to detect datagram loops
- Protocol (8): demux key (TCP=6, UDP=17)
- Checksum (16): of the header only
- DestAddr & SrcAddr (32), Options: source route, record route, ...

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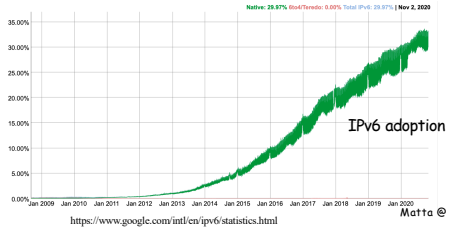
IPv6 deployment

- IPv6 standardized around 1998
- In 2008, IPv6 still accounted for less than 1% of Internet traffic
- Since 2011, IPv6 has been increasingly implemented in Operating Systems, mandated by governments and cellular providers for new network devices, ...



IPv6 adoption by Google users

https://www.google.com/intl/en/ipv6/statistics.html

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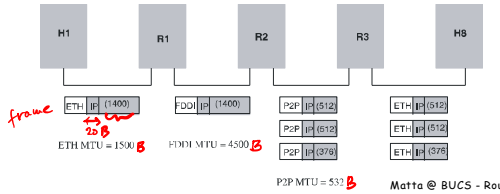
Fragmentation and Reassembly

- Each network has some MTU (Max Transfer Unit)
- Strategy
  - fragment when necessary (MTU < Datagram Size)
  - try to avoid fragmentation at source host
  - re-fragmentation is possible
  - fragments are self-contained datagrams
  - delay reassembly until destination host
  - do not recover from lost fragments



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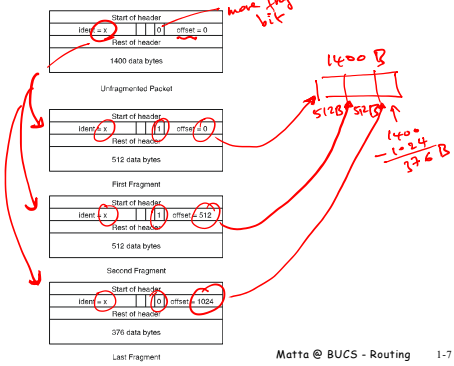
Fragmentation Example



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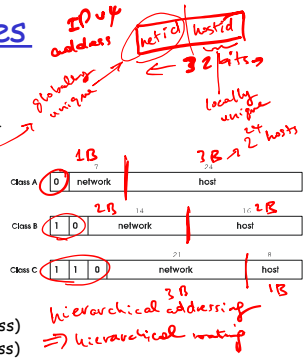
Global Addresses

- Properties
  - globally unique
  - hierarchical: network + host
  - network part assigned by ICAAN
  - a router has one IP address for each interface
- Format
- Dot notation
  - 10.3.2.4 (class A address)
  - 128.96.33.81 (class B address)
  - 192.12.69.77 (class C address)



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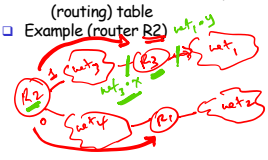
Datagram Forwarding

- Strategy
  - every datagram contains destination's address
  - if directly connected to destination network, then forward to host
  - if not directly connected to destination network, then forward to some router
  - forwarding table maps network number into next hop
  - each host has a default router
  - each router maintains a forwarding (routing) table
- Example (router R2)



Net Number	Next Hop
1	R3 → net3 = X
2	R1
3	Interface 1
4	Interface 0

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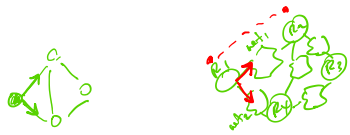
How do IP Routers Maintain Routing Tables?

- Routing table contains {address of destination network, address of next-hop}
- In distance-vector routing, ***neighbor*** routers exchange their distances to destination networks
- In link-state routing, each router broadcasts (to ***all*** other routers) the status of attached networks



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Scalability

1) Routing table explosion
2) address space exhaustion

IP ``hides'' hosts in address hierarchy, but...

- Inefficient use of address space
  - class C network with 2 hosts (2/255 = 0.78% efficient)
  - class B network with 256 hosts (256/65535 = 0.39% efficient)

class B: 2B, 2B ⇒ 2^{16} hosts = 64K
class C: 3B, 1B ⇒ 2^{8} hosts = 256
class B: 256 hosts / 64K ≈ 0.4%

- Too many networks
  - today's Internet has hundreds of thousands of networks
  - routing tables do not scale
  - route propagation protocols do not scale

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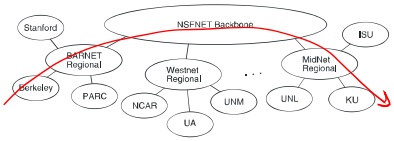
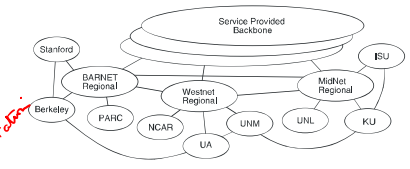
Internet Structure

- Before



- After



constrained shortest-path computation

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