ECE 435 – Network Engineering
Lecture 14

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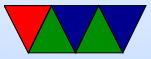
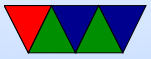
Announcements

- HW#6 was due
- HW#7 will be posted

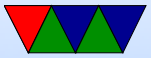


IPv4 Catastrophe



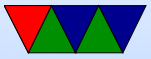
Out of IPv4 Addresses Problem

- IPv4 address exhaustion
- CIDR not enough
- Addresses managed by IANA globally and five regional registrars (RIR)
- Top level ran out in 2011
- 4 of 5 RIRs are out too
- Why are we out?
  - Always active connections – unlike dialup, many machine are on all the time



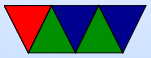
- So many devices – 4G mobile devices all have one
- Inefficiencies originally handing out. Companies like Apple, MIT, DEC, all got 16 million address Class A addresses even if didn't need them
- Despite being out, in 2011 reportedly only 14% of addresses being used

- Why not reclaim unused, such as Class E? The bane of network programmers, the out-of-date router that makes assumptions
- Stanford gave back a class A in 2000

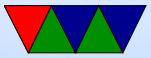


Network Address Translation (NAT)

- Private IP ranges, defined in RFC 1918
  - 1 Class A: 10.0.0.0 - 10.255.255.255 (10.0.0.0/8)
  - 16 Class B: 172.16.0.0 - 172.31.255.255 (172.16.0.0/12)
  - 256 Class C: 192.168.0.0 - 192.168.255.255 (192.168.0.0/16)
- Can use for various reasons, most recently due to network depletion
- NAT: map IP addresses from one group to another. often public to private.
- NAT and NAPT (port translation) RFC 3022

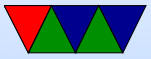


- Basic NAT has one to one mapping of external to internal IPs. Each internal host maps to unique external IP

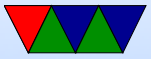


Network Address Port Translation (NAPT)

- NAPT: based on port, only one external IP
  - Full cone – most common
    once an internal address (iaddr/port) has been mapped to an external (eaddr/port) all packets from iaddr/port are sent out and any incoming are passed through with no additional checks
  - Restricted cone – same as above, but only external that have received packets from internal can send through
  - Port restricted cone – same as above, but also checks

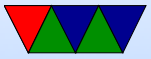


port numbers
  - Symmetric – best security – outgoing packets mapped to different eaddr/port if the destination or port differs
- When passing through, NAT needs to re-write dest/source/port and recompute header checksum
- Linux: IP-masquerade/iptables
- Many IP people hate NAT:
  - violates the IP identifies one machine rule
  - hard to connect two machines if both behind different NATs
  - changes IP to be connection oriented, router has to



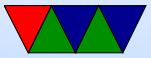
remember connections

- layering violation, looks at TCP/UDP port numbers
- only works for TCP/UDP
- Some protocols (like FTP) are even more annoying, send address in plain text in data and that has to be adjusted too
- can only NAT up to 64k machines (why? how many ports are there?)



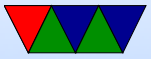
The Internet Protocol v6

- RFC2460 - RFCC466
- Started work in 1991
- Many problems with IPv4. Most notable shortage of addresses.
- IPng. (IPv5 was an experimental stream protocol)
- Migration happening, a large amount of web traffic, especially that from phones, is already switched.
- *not* backwards compatible
- As of July 2016 12.5% of traffic is IPv6



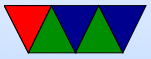
The Internet Protocol v6 Goals

- Support billions of hosts
- Reduce size of routing tables
- Simplify the protocol (so routers can be faster)
- Better security
- Pay more attention to type of service
- Aid multicasting
- Allow roaming w/o changing address
- Co-exist with existing protocols

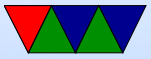


The Internet Protocol v6 features

- Address size 128 bits
  a lot of addresses. 7×10^{23} for ever square meter
- Simpler fixed length header (speeds up processing)
  Many fields not really used in IPv4 dropped (or made optional)
- Better support for options
- Better security support
  IPSEC. Originally mandatory, made optional
  Can encrypt packets at the network layer

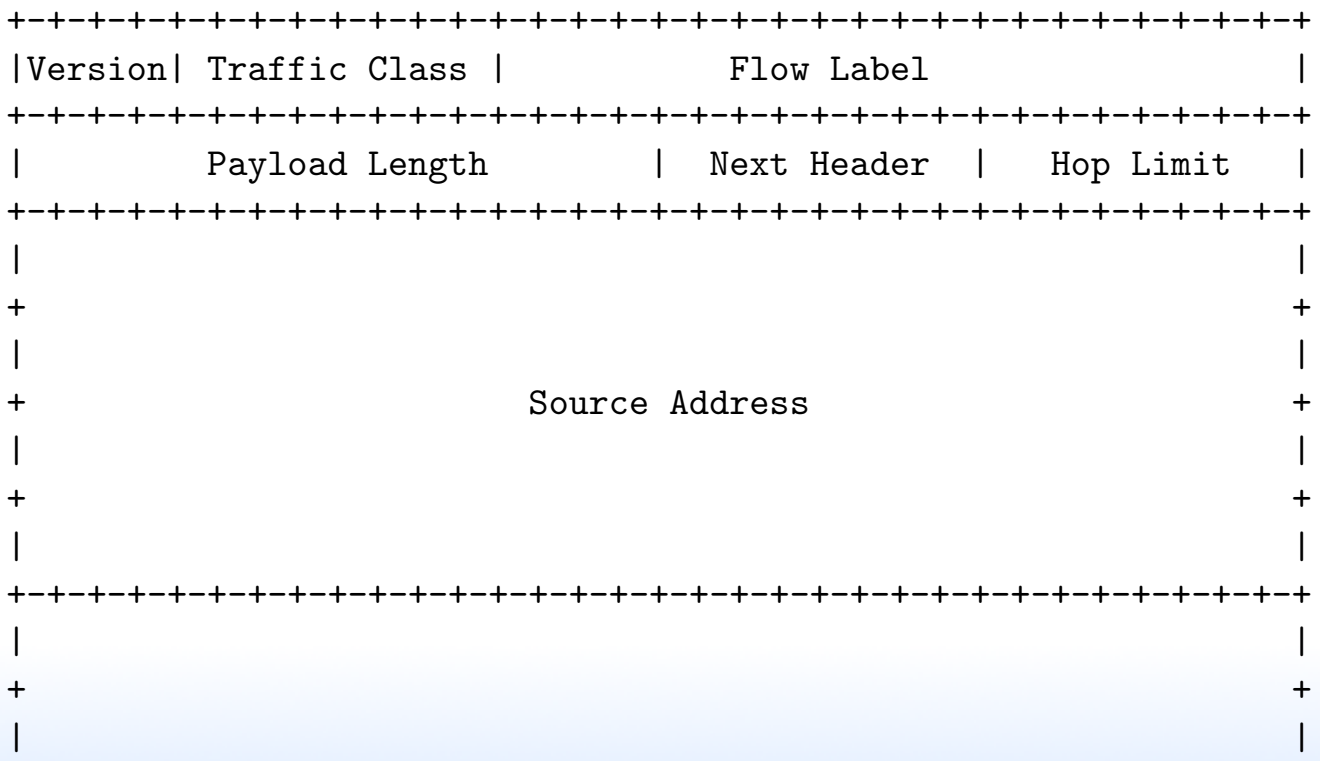


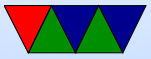
- Quality of service (???)
- Anycast (see end of slides)
- Autoconfiguration (like DHCP)
- Minimum fragment size 1280 (up from 576)
- No checksum – was slow and recalculated often

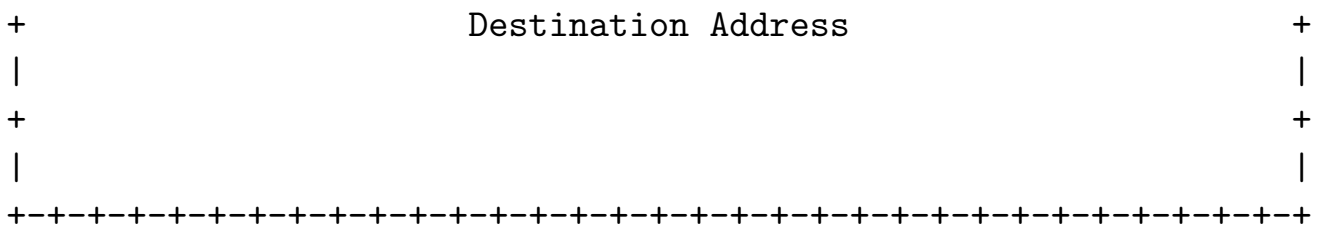


IPv6 header

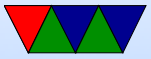
- Header fixed length of 40 bytes, with Extension headers
- ASCII art from RFC 2460





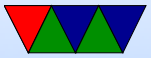


- **Version Number** (1 nibble [4-bits]) = 6
- **Traffic Class** (8-bits)
- **Flow label** (20-bits) (for streaming?)
- **Payload Length** (16-bits) 64k (header bytes not counted anymore) (if you want longer, extension for Jumbograms)
- **Next header** (8-bits) If nothing special identifies TCP or UDP If special options (fragmentation, security)



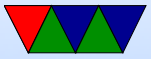
indicated
(TCP=0x6, UDP=0x11)

- **Hop Limit** (8-bits) TTL, big debate about whether 8-bits was enough
- **Source Address** (128-bits)
- **Destination Address** (128-bits)
- Why not 64-bit addresses?
- No checksum, link or transport catches issues
  What does this mean for UDP?

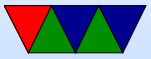


IPv6 Options

- Happen immediately after the header.
- Should occur in numerical order (though routers might be able to handle if they don't)
- Routers should inspect in order as some later might depend on earlier.
- Plain: IPV6:Next=TCP, TCP, Data
- Example: IPV6:Next=Routing, Routing:Next=TCP, TCP, Data
- Various types

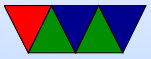


- Hop-by-hop (Pad1, Pad2, Jumbo Frame?)
- Source Routing
- Fragmentation
- Authentication
- Encryption

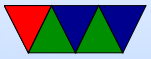


IPv6 fragmentation

- Info is in an extension header
- Routers cannot fragment, only at source
- How can this work when not know MTU?
- MTU is always greater than 1280
- Path MTU discovery protocol to discover MTU along the way (RFC 1981). (IPv4 too, set DNF and get error via ICMP) If too big, sends an error back and source needs to fragment it smaller
- Easier to have source fix things then every router along

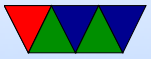


the way being able to



IPv6 addresses

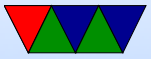
- Too long for dotted decimal, use colon hexadecimal
- X:X:X:X:X:X:X:X where X is 16 bit chunk
- F000:0123:5678:0000:0000:ABCD:0001:CAFE
- Can drop leading zeros, as well as groups of zeros
  F000:123:5678::ABCD:1:CAFE
  Note, cannot drop two sets of groups of zeros. Why? Ambiguous.
- Do not have classes RFC 4291
- encoding ipv4 addresses in ipv6?



- autoconfig – generate a unique ID, often based on MAC address and send it to router (Router solicitation). Router sends back router advertisement which has subnet prefix and can be used to generate global address
  Stateless address auto-config (SLAAC). Can also use DHCPv6
- ::1 ip6-localhost, fe00::0 ip6-localnet
- Example

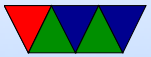
```
inet 130.111.218.23  netmask 255.255.254.0  broadcast 130.111.219.255
inet6 2610:48:100:8da:230:18ff:feab:1c39  prefixlen 64  scopeid 0x0<global>
inet6 fe80::230:18ff:feab:1c39  prefixlen 64  scopeid 0x20<link>
```

  inet6, both global and local contain MAC address



IPv6 Privacy Concerns

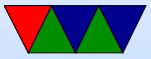
- Security – have MAC in your IPv6 address?



IPv6/IPv4 compat

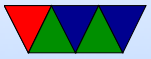
- Dual stack – host runs both IPv4 and IPv6
  or internal is IPv6 but router converts to IPv4 before passing on

- Tunneling – encapsulate IPv6 inside of IPv4, tunnels across IPv4, split back out to IPv6 on other side of tunnel



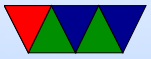
IPv6 Routing

- Much like IPv4
- IPv6 network address, “prefix-length” instead of netmask
- Routing table as before



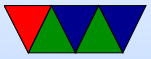
Casting

- Unicast – 1:1 – one sender, one destination
- Broadcast – 1:all
- Multicast – 1:many – specify a subset of all
- Anycast – a set of equivalent hosts, which one gets the packet depends on something like closeness / latency
- Geocast – broadcast to limited geographic area

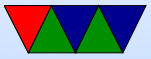


Anycast problems/benefits

- Can spread server load around (DNS servers, web servers, netflix servers)
- Can hijack connection if you can get your fake routing info into a server.

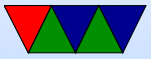


Broadcast Routing

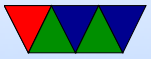


Unicast/Multicast/Broadcast

- Unicast – send from one machine to another
- What if want to send to multiple?
  - Multi-unicast – open direct connection to each destination. Inefficient
  - Broadcast – send to *every* destination? Waste bandwidth, but also need to know all possible destinations
  - Flooding? Also too much bandwidth
  - Multi-destination routing

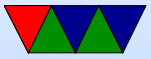


- Multicast Goals
  - Only send to users who want it
  - Each member only receives one copy
  - No loops
  - Path traveled should be optimal
- Spanning tree – tree with source as root and members as leaves
- Reverse-path forwarding



Multicast IP

- For IP, just join a class D network
- To both sender and receiver it's like sending/receiving a unicast packet
- all the hard work done by routers
- How do you join a multicast group?
- Router two tasks: group membership management, packet delivery.



- IGMP (Internet Group Management Protocol)
  IGMPv3 RFC 3376
  query, report, leave
  querier and noquerier
  router with lowest IP is querier
  no real controls on who can join or send