IPv4

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"Sites need to be able to interact in one single, universal space." – Tim Berners-Lee



The Network Layer

- Transports datagrams from sending to receiving host
- Network layer protocols are implemented on *every* host and router

The network layer is commonly referred to as layer 3.



The Internet Network Layer





Routing and Forwarding





Datagram networks

- No call setup at network layer
- Routers keep no state about end-toend connections
- Packets between the same sourcedestination pair may take different paths





IPv4 Address Format

• 32 bits

IPv4

- 4 billion¹ possible values
- Notation is dotted decimal, big-endian: 132.149.42.193
- Many values have special meanings

 $^{1}1$ billon = 1,000,000,000



IP Addressing

- IP addresses identify interfaces
- Routers have multiple interfaces
- Hosts typically have only one network interface
- One interface can have multiple IPs



223.1.1.1 = 11011111	00000001	0000001	0000001
223	1	1	1



Subnets (1/3)



network consisting of 3 subnets

Devices in a **subnet** share the same subnet part (higherorder bits) of the IP address and can physically reach each other without the help of a router.



To determine the subnets, detach each interface from its host or router, creating islands of isolated networks. Those are the subnets.



223.1.3.0/24

Subnet mask: /24

Question: which **devices** count as routers?



Subnets (3/3)





Classless InterDomain Routing (CIDR)

- Subnet part of IP address are the higher-order bits
- Address format a.b.c.d/x specifies that subnet part has x bits



Binary Trie, Path-Compressed-Trie and Level-Compressed Trie²



²http://drdobbs.com/windows/184410638



How are subnet identifiers assigned?

Administrators get a portion of their providers ISP's address space:

- ISP has 200.23.16.0/20
- ISP gives Org 1 200.23.16.0/23: 11001000 00010111 00010000
- ISP gives Org 2 200.23.18.0/23: 11001000 00010111 00010010
- ISP gives Org 3 200.23.20.0/23: 11001000 00010111 00010100
- . . .
- ISP gives Org 7 200.23.30.0/23: 11001000 00010111 00011110



Longest Prefix Matching

Prefix match	Interface
11001000 00010111 00010	0
11001000 00010111 00011000	1
11001000 00010111 00011	2
otherwise	3

Example: 11001000 00010111 00011000 10101010?



Route aggregation





Route aggregation





Offset	0-3	4-7	8-15	16-18	19-31
0	Version	Hdr Len	TOS	Tot	tal Length
32	Identification		Flags	Frag. Offset	
64	Time to Live		Protocol	Hdr.	Checksum
96	Source Address				
128	Destination Address				
160	Options (optional)				
160+	Data				



Where is the IP Header?





IP Fragmentation & Reassembly

- Network links have a Maximum Transfer Unit (MTU)
- IP datagrams that exceed the MTU are divided on the network
- Reassembly only happens at the final destination
- IP header bits are used to identify, order related fragments



Example





How does a host get an IP address?

- Hard-coded by system administrator in configuration
- Reverse ARP
- Determined by network service: DHCP
- other options (\Rightarrow IPv6)



Reverse ARP

- ARP is used to map IP to MAC address: /proc/net/arp
- Uses broadcasts for discovery, cache, below Layer 3
- Ethernet hardware supplies the MAC address
- Reverse ARP maps MAC address to IP address



The Dynamic Host Configuration Protocol



ТΠ

The Internet Control Message Protocol

Communicate network-level information:

- Error reporting
- Diagnostics

Туре	Code	Function
3	0	dest net unreachable
3	1	dest host unreachable
3	2	dest prot unreachable
3	3	dest port unreachable
3	6	dest net unknown
3	7	dest host unknown
0	0	Echo reply
8	0	Echo request
4	0	source quench
9	0	router advertisement
10	0	router discovery
11	0	TTL expired
12	0	bad IP header



Traceroute

- Source send series of UDP segments to destination
- First has TTL=1, second TTL=2, etc.
- n-th router discards and sends ICMP TTL expired
- Ultimate destination returns ICMP PORT UNREACHABLE
- traceroute measures average RTTs for each step



 Internet Corporation for Assigned Names and Numbers (ICANN)



- ICANN (not really)
- Internet Assigned Numbers Authority (IANA)



- ICANN (not really)
- IANA (not really)
- Regional Internet Registry (RIR)



- ICANN (not really)
- IANA (not really)
- RIR (IPv4 only until 2011-2012)

"Their Internet usage is growing very rapidly, and even they can do the math: If everyone in China needed an IPv4 address — just one — this country would use up one third of the entire public IP address space." – Vinton Cerf



Questions





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