Lecture 14
IP Wrap up

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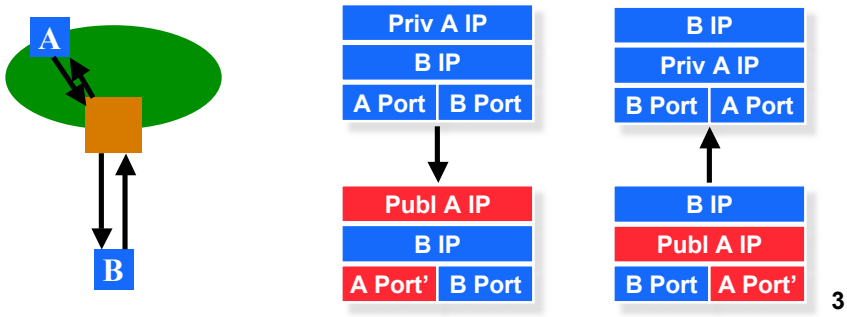
15-441 Networking, Spring 2005

Outline

- NAT.
- IPv6.
- Tunneling / Overlays
- Network Management
  - » Autoconfiguration
  - » SNMP

Network Address Translation

- NAT maps (private source IP, source port) onto (public source IP, unique source port)
  - reverse mapping on the way back
  - destination host does not know that this process is happening
- Very simple working solution.
  - NAT functionality fits well with firewalls



3

Types of NATs

- Bi-directional NAT: 1 to 1 mapping between internal and external addresses.
  - E.g., 128.237.0.0/16 -> 10.12.0.0/16
  - External hosts can directly contact internal hosts
  - Why use?
    - Flexibility. Change providers, don't change internal addrs.
    - Need as many external addresses as you have *hosts* - can use sparse address space internally.
- "Traditional" NAT: Unidirectional
  - Basic NAT: Pool of external addresses
    - Translate source IP address (+checksum,etc) only
  - Network Address Port Translation (NAPT): What most of us use
    - Also translate ports.
      - E.g., map (10.0.0.5 port 5555 -> 18.31.0.114 port 22) to (128.237.233.137 port 5931 -> 18.31.0.114 port 22)
    - Lets you share a single IP address among multiple computers

4

NAT Considerations

- NAT has to be consistent during a session.
  - » Set up mapping at the beginning of a session and maintain it during the session
  - » Recycle the mapping that the end of the session
    - – May be hard to detect
- NAT only works for certain applications.
  - » Some applications (e.g. ftp) pass IP information in payload
  - » Need application level gateways to do a matching translation
- NAT has to be consistent with other protocols.
  - » ICMP, routing, …
- NAT is loved and hated
  - » Breaks a lot of applications. Inhibits new applications like p2p.
  - » Little NAT boxes make home networking simple.
  - » Saves addresses. Makes allocation simple.

5

NAT Research Plug

- Want to play with your own NAT, and help out some researchers who are looking at techniques to communicate from behind NATs?
- http://nutss.gforge.cis.cornell.edu/stunt-client.php

6

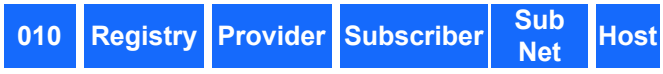
IP v6

- "Next generation" IP.
- Most urgent issue: increasing address space.
  - » 128 bit addresses
- Simplified header for faster processing:
  - » No checksum (why not?)
  - » No fragmentation (?)
- Support for guaranteed services: priority and flow id
- Options handled as "next header"
  - » reduces overhead of handling options

7

IPv6 Addressing

- Do we need more addresses? Probably, long term
  - » Big panic in 90s: "We're running out of addresses!"
  - » Big reality in 2005: We're about 50% used.
    - – CIDR
    - – Tighter allocation policies; voluntary IP reclamation
    - – NAT
  - » Big worry: Devices. Small devices. Cell phones, toasters, everything.
- 128 bit addresses provide space for structure (good!)
  - » Hierarchical addressing is much easier
  - » Assign an entire 48-bit sized chunk per LAN -- use Ethernet addresses
  - » Different chunks for geographical addressing, the IPv4 address space,
  - » Perhaps help clean up the routing tables - just use one huge chunk per ISP and one huge chunk per customer.



8

IPv6 Cleanup - Router-friendly

- **Recall router architecture:**
  - Common case: Switched in silicon ("fast path")
  - Weird cases: Handed to CPU ("slow path", or "process switched")
  - Typical division:
    - Fast path: Almost everything
    - Slow path:
      - Fragmentation
      - TTL expiration (traceroute)
      - IP option handling
  - Slow path is evil in today's environment
    - "Christmas Tree" attack sets weird IP options, bits, and overloads router.
    - Developers can't (really) use things on the slow path for data flow.
      - If it became popular, they'd be in the soup!
  - Other speed issue: Touching data is expensive. Designers would like to minimize accesses to packet during forwarding.

9

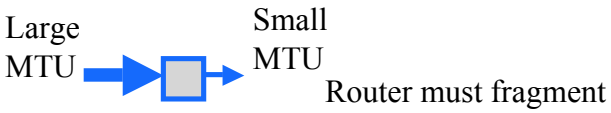
IPv6 Header Cleanup

- **No checksum**
  - Why checksum just the IP header?
    - Efficiency: If packet corrupted at hop 1, don't waste b/w transmitting on hops 2..N.
    - Useful when corruption frequent, b/w expensive
    - Today: Corruption rare, b/w cheap
- **Different options handling**
  - IPv4 options: Variable length header field. 32 different options.
    - Rarely used
    - No development / many hosts/routers do not support
    - Processed in "slow path".
  - IPv6 options: "Next header" pointer
    - Combines "protocol" and "options" handling
      - Next header: "TCP", "UDP", etc.
    - Extensions header: Chained together
    - Makes it easy to implement host-based options
    - One value "hop-by-hop" examined by intermediate routers
      - Things like "source route" implemented only at intermediate hops

10

IPv6 Fragmentation Cleanup

- **IPv4:**



- **IPv6:**
  - » Discard packets, send ICMP "Packet Too Big"
    - – Similar to IPv4 "Don't Fragment" bit handling
  - » Sender must support Path MTU discovery
    - – Receive "Packet too Big" messages and send smaller packets
  - » Increased minimum packet size
    - – Link must support 1280 bytes;
    - – 1500 bytes if link supports variable sizes
- Reduced packet processing and network complexity.
- Increased MTU a boon to application writers
- Hosts can still fragment - using fragmentation header. Routers don't deal with it any more.

11

Migration from IPv4 to IPv6

- **Interoperability with IP v4 is necessary for gradual deployment.**
- **Two complementary mechanisms:**
  - » dual stack operation: IP v6 nodes support both address types
  - » tunneling: tunnel IP v6 packets through IP v4 clouds
- **Alternative is to create IPv6 islands, e.g. corporate networks, ...**
  - » Use of form of NAT to connect to the outside world
  - » NAT must not only translate addresses but also translate between IPv4 and IPv6 protocols

12

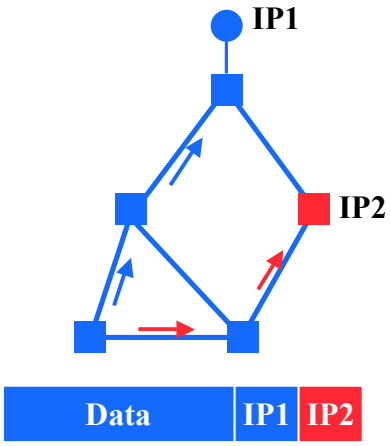
IPv6 Discussion

- **IPv4 Infrastructure got better**
  - » Address efficiency
  - » Co-opted IPv6 ideas: IPSec, diffserv, autoconfiguration via DHCP, etc.
- **Massive challenge**
  - » Huge installed base of IPv4-speaking devices
  - » Chicken & Egg problem
    - – Who's the first person to go IPv6-only?
- **Steady progress in deployment.**
  - » Most hosts & big routers support.
  - » Long-term: The little devices will probably force IPv6

13

Tunneling

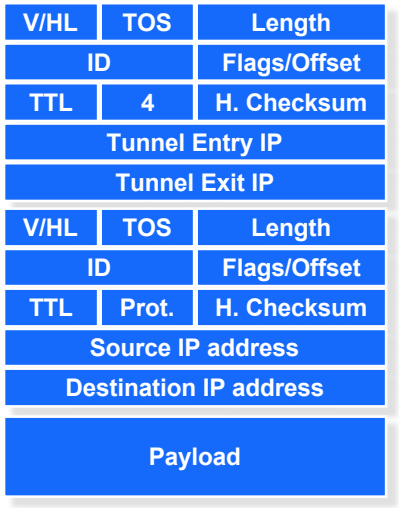
- **Force a packet to go to a specific point in the network.**
  - » Path taken is different from the regular routing
- **Achieved by adding an extra IP header to the packet with a new destination address.**
  - » Similar to putting a letter in another envelope
  - » preferable to using IP source routing option
- **Used increasingly to deal with special routing requirements or new features.**
  - » Mobile IP,..
  - » Multicast, IPv6, research, ..



14

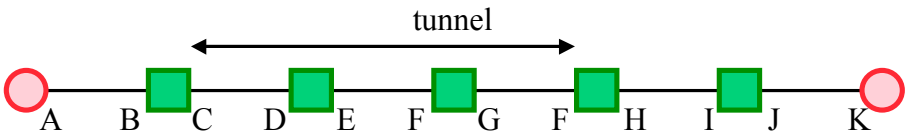
IP-in-IP Tunneling

- Described in RFC 1993.
- IP source and destination address identify tunnel endpoints.
- Protocol id = 4.
  - » IP
- Several fields are copies of the inner-IP header.
  - » TOS, some flags, ..
- Inner header is not modified, except for decrementing TTL.



15

Tunneling Example



16

Tunneling Considerations

- **Implementation diversity.**
  - » Some diversity in the implementation
  - » Sometimes merged with multicast code (early versions)
- **Performance.**
  - » Tunneling adds (of course) processing overhead
  - » Tunneling increases the packet length, which may cause fragmentation
    - – BIG hit in performance in most systems
    - – Tunneling in effect reduces the MTU of the path, but end-points often do not know this
- **Security issues.**
  - » Should verify both inner and outer header

17

Tunneling Applications

- **Virtual private networks.**
  - » Connect subnets of a corporation using IP tunnels
  - » Often combined with IP Sec
- **Support for new or unusual protocols.**
  - » Routers that support the protocols use tunnels to "bypass" routers that do not support it
  - » E.g. multicast
- **Force packets to follow non-standard routes.**
  - » Routing is based on outer-header
  - » E.g. mobile IP

18

Overlay Networks

- A network "on top of the network".
  - » E.g., initial Internet deployment
    - – Internet routers connected via phone lines
      - An overlay on the phone network
  - » Tunnels between nodes on a current network
- Examples:
  - » The IPv6 "6bone", the multicast "Mbone" ("multicast backbone").
- But not limited to IP-layer protocols…
  - » Can do some pretty cool stuff:

19

Overlay Networks 2

- Application-layer Overlays
  - » Application Layer multicast (last week)
    - – Transmit data stream to multiple recipients
  - » Peer-to-Peer networks
    - – Route queries (Gnutella search for "briney spars")
    - – Route answers (Bittorrent, etc. -- project 2)
  - » Anonymizing overlays
    - – Route data through lots of peers to hide source
      - (google for "Tor" "anonymous")
  - » Improved routing (Resilient Overlay Networks)
    - – (Shameless plug of my own research)
    - – Detect and route around failures *faster* than the underlying network does.
- Overlays provide a way to build interesting services / ideas without changing the (huge, hard to change) IP infrastructure.

20

Network Management

- Two sub-issues:
  - Configuration management
    - How do I deal with all of these hosts?!
  - Network monitoring
    - What the heck is going on on those links?

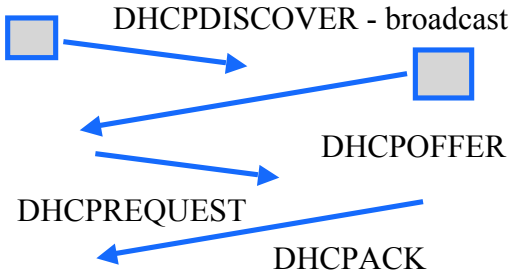
21

Autoconfiguration

- IP address, netmask, gateway, hostname, etc., etc.
  - Typing by hand: Ugh!
- IPv4 option 1: RARP (Reverse ARP)
  - Data-link protocol
  - Uses ARP format. New opcodes: "Request reverse", "reply reverse"
  - Send query: Request-reverse [ether addr], server responds with IP
- IPv4 option 2: DHCP
  - Dynamic Host Configuration Protocol
  - ARP is fine for assigning an IP, but is very limited
  - DHCP can provide the kitchen sink

22

DHCP



- DHCPOFFER
  - IP addressing information
  - Boot file/server information (for network booting)
  - DNS name servers
  - Lots of other stuff - protocol is extensible; half of the options reserved for local site definition and use.

23

DHCP Features

- Lease-based assignment
  - Clients can renew. Servers really should preserve this information across client & server reboots.
- Provide *host* configuration information
  - Not just IP address stuff.
  - NTP servers, IP config, link layer config,
  - X window font server (wow)
- Use:
  - Generic config for desktops/dialin/etc.
    - Assign IP address/etc., from pool
  - Specific config for particular machines
    - Central configuration management

24

IPv6 Autoconfiguration

- Serverless ("Stateless"). No manual config at all.
  - » Only configures addressing items, NOT other host things
    - – If you want that, use DHCP.
- Link-local address
  - » 1111 1110 10 :: 64 bit interface ID (usually from Ethernet addr)
    - – (fe80::/64 prefix)
  - » Uniqueness test ("anyone using this address?")
  - » Router contact (solicit, or wait for announcement)
    - – Contains globally unique prefix
    - – Usually: Concatenate this prefix with local ID -> globally unique IPv6 ID

25

Management: Monitoring

- What to do when there is a problem?
  - » Loss of connectivity, complaints of slow throughput, ..
- How do you know how busy your network is?
  - » Where are the bottlenecks, is it time for an upgrade, redirect traffic, ..
- How can you spot unusual activity?
  - » Somebody attacking a subnet, ..
- These are all hard problems that are typically addressed using multiple tools, but the ability to monitor network status is a common requirement.
  - » "Static" information: what is connected to what?
  - » Dynamic information: what is the throughput on that link?

26

Common Monitoring Tools

- SNMP
  - » Simple Network Management Protocol
    - – Device status
      - 5 minute traffic average on outbound links
      - Amount of disk space used on server
      - Number of users logged in to modem bank
      - Etc.
    - – Device alerts
      - Line 5 just went down!
  - » Netflow
    - – Detailed traffic monitoring
      - Break down by protocol/source/etc.
      - ("Who's serving 5 terabytes of briney spars photos??")

27

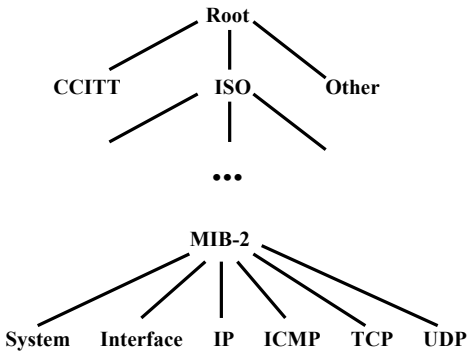
Simple Network Management Protocol (SNMP)

- Protocol that allows clients to read and write management information on network elements.
  - » Routers, switches, …
  - » Network element is represented by an SNMP agent
- Information is stored in a management information base (MIB).
  - » Have to standardize the naming, format, and interpretation of each item of information
  - » Ongoing activity: MIB entries have to be defined as new technologies are introduced
- Different methods of interaction supported.
  - » Query response interaction: SNMP agent answers questions
  - » traps: agent notifies registered clients of events
- Need security: authentication and encryption.

28

MIB

- **Information is represented in an object tree.**
  - » To identify information you specify a path to a leaf
  - » Can extend MIB by adding subtrees
  - » Different standard bodies can expand different subtrees
    - – E.g. Ethernet and ATM groups are independent
- **Uses ASN.1 standard for data representation.**
  - » Existing standard
  - » How is information stored?
  - » How is information encoded on the wire (transfer syntax)



29