IPv6 and Multicast

Outline

- IPv6
- Multicast

IPv6 overview

- Motivation
  - Internet growth (address space depletion and routing information explosion)
  - CIDR has helped but eventually bigger address space is needed
    - ubiquitous networking, “Internet to the toaster!”
- Historical perspective
  - bigger address space $\Rightarrow$ changes in IP header $\Rightarrow$ new IP version
  - work initiated in IETF in early 90’s
    - name changed from IPng (next generation) to IPv6
  - “snow ball effect”: why not fix all problems at the same time!
    - added features: QoS, security, autoconfiguration, mobility, ...
    - note! most of these have in the mean time been introduced to IPv4
  - requirement: transition plan (from IPv4 to IPv6)
    - impossible to require an over night change in IP version in all routers
    - routers running only IPv4, IPv4 and IPv6, IPv6 will coexist for a long time
  - by now, most key specifications of IPv6 are Proposed or Draft Standards

IPv6 addressing

- IPv6 uses 128 bit addresses
  - enables up to 3.4×10^{38} nodes!
  - address notation: x:x:x:x:x:x:x:x (x = hex representation of a 16 bit number)

- IPv6 address space
  - IPv6 does not use classes
  - address space subdivided based on leading bits
  - leading bits indicate different uses of the address space

IPv6 address prefixes

- Aggregatable Unicast Address (001):
  - most important address group, like classless IPv4 addresses but longer
  - more on these later…
- NSAP (0000 001) and IPX (0000 010) addresses
  - NSAP addresses used by ISO protocols; IPX for Novell networks
- Link Local Address (1111 1110 10), Site Local Address (1111 1110 11):
  - enables host to construct an address to be used locally on a network (or site) without having to be concerned with global uniqueness (autoconfig.)
- Multicast Address (1111 1111)
- Reserved Address (0000 0000):
  - “IPv4 compatible IPv6” and “IPv4-mapped IPv6” addresses needed during IPv4 to IPv6 transition

Aggregatable Global Unicast Addresses (1)

- Aggregatable Global Unicast Addresses
  - normal unicast addresses in IPv6
  - problem: how to assign unicast addresses effectively to ASs, networks, hosts, routers?
    - issues: new nodes added at an increasing rate, routing scalability
- Address allocation plan
  - Internet not just an arbitrarily connected set of ASs:
    - **subscribers** (e.g. non transit ASs) connect to **providers** (transit ASs)
    - **providers** can be *direct* (connect primarily subscribers) or *indirect* (connect other providers, backbone networks)
  - problem: how to use this hierarchy without imposing restrictive limitations?
    - subscribers may be connected to several providers
  - idea: allocate addresses to enable route information aggregation (scalability)
    - by using variable length prefixes (same as in CIDR)
    - direct provider allocated a prefix and that provider can then assign longer prefixes to its subscribers (provider based addressing)
    - thus, provider needs to advertise only one prefix to all its subscribers
  - drawback: if site changes provider, whole numbering in a site must be changed

Aggregatable Global Unicast Addresses (2)

- Is hierarchical aggregation always useful?
  - aggregation at national or continental level:
    - continental boundaries form natural aggregation points for example, all addresses in Europe have the same prefix
  - given that a provider connects to many backbones, not meaningful for providers to get their prefix from one backbone provider
  - subscriber connects to several providers:
    - if subscriber takes prefix from provider X, provider Y must advertise provider X's networks (can not be aggregated with Y's own prefixes)
    - if subscriber numbers its network using prefixes from X and Y and if connection to X goes down, hosts with prefix from X become unreachable
    - possible solution: provider X and Y share common prefix for all subscribers having connections with X and Y

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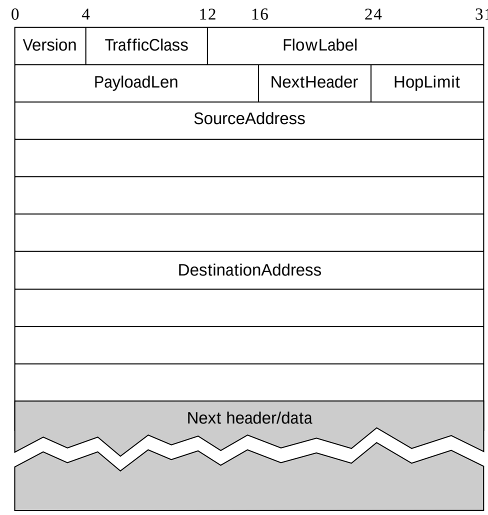
IPv4 to IPv6 transition

- IPv6 is deployed incrementally
  - IPv4 and IPv6 routers need to coexist

- Dual stack operation and tunneling
  - dual stack
    - IPv6 node runs both IPv4 and IPv6 (Version field identifies packets)
    - node may have separate IPv4 and IPv6 addresses or an "IPv4 mapped IPv6 address"
  - tunneling
    - used to send IPv6 packets over IPv4 network
    - IPv6 packet encapsulated inside IPv4 header
    - tunneling automatic if end point has "IPv4 mapped IPv6 address"
    - otherwise, tunnel configured manually

IPv6 packet format (1)

- IPv6 header format simpler than IPv4
  - goal was to have simplified header processing
  - constant length 40 bytes
- Version = 6
- TrafficClass & FlowLabel related to QoS
  - lecture 10
- PayLoadLen = length of packet in bytes (without header)
- HopLimit = TTL of IPv4
- NextHeader
  - replaces Options and Protocol field of IPv4
  - if options are required they are carried in one or several **extension headers** following the IP header
  - if no extension headers, NextHeader identifies higher layer protocol (TCP, UDP)
  - type of extension header identified by the NextHeader field in the header preceding it



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IPv6 packet format (2)

- Improved Options handling in IPv6
  - IPv4: if any Options are present every router must parse the whole Options field to see if any Options are relevant; Options form an unsorted list
  - IPv6: options treated as extension headers appearing in a specific order $\Rightarrow$ router can quickly determine which options are relevant by looking at the NextHeader field
  - no upper limit on nof options

- Some extension headers
  - fragmentation header
  - authentication header
  - routing header
    - enables source-directed routing: sender can specify nodes or topological areas that the packet should visit en route to destination
    - used also for supporting multicast and mobility

Autoconfiguration

- Traditionally, host configuration required considerable system administration expertise (IP address, subnet mask, name server)
- IPv6 provides “plug-and-play” functionality
  - DHCP can be used in IPv4
  - longer address format enables **stateless autoconfiguration** that does not require the use of any dedicated server
- Stateless autoconfiguration
  - each host has globally unique 48 bit LAN address (link level address)
    - LAN address used as the least significant bits for IPv6 address
  - not globally unique IPv6 address: IPv6 address prefix Link Local Address (1111 1110 10) + “70 zeros” + LAN address
    - adequate for local devices, e.g., printers, local servers
  - globally unique IPv6 address: router advertises appropriate global prefix and host uses as its address (prefix + “enough zeros” + LAN address)
  - possible because address 128 bits long!

Outline

- IPv6
- Multicast

Multicast overview (1)

- Basic problem: host wants to send same data to multiple receivers
  - on a LAN this is handled in hardware
  - In Internet, multicasting must serve hosts residing on different networks and separated by large distances
- IP multicast service model:
  - hosts wishing to receive a particular multicast transmission belong to a **multicast group**
    - any given host may belong to many groups simultaneously
  - a multicast group is associated with an **IP multicast address**
  - packet delivery: host sends one copy of a packet to a multicast address and Internet delivers it to all members of a group

Multicast overview (2)

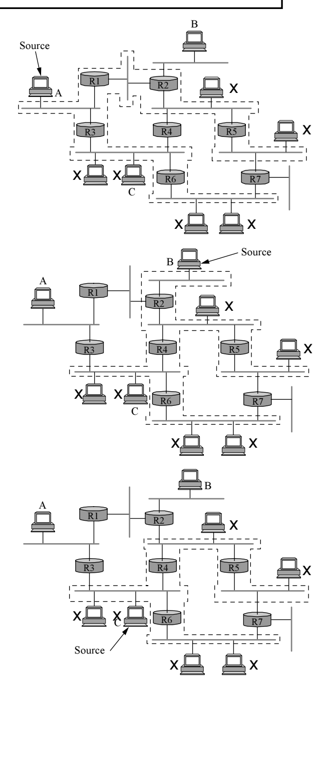
- Here we look at how packets get distributed to the correct routers
- Group management or multicast address advertising is not considered in detail
  - hosts join/leave groups dynamically by informing their local routers using IGMP (Internet Group Management Protocol)
  - knowledge of available multicast groups handled by out-of-band means (tools exist for advertising multicast addresses in the Internet)
- Multicast packet delivery implemented by extending forwarding and routing functionality of IP routers
  - three approaches:
    - link-state
    - distance vector
    - protocol independent

Link state multicast (1)

- Link state routing:
  - routers flood info related to directly connected links
    ⇒ nodes have full topology information
    ⇒ can construct shortest paths to any given node (Dijkstra)
- Generalization to multicast:
  - add set of groups with members on particular network to link state info
  - hosts on a given link (LAN) announce their participation to router
  - link state flooded to all other routers and each router can compute shortest path multicast trees for all sources in all groups
  - possible because in link state nodes learn full topology
  - trigger flooding when groups appear/disappear on a link

Link state multicast (2)

- Shortest path multicast tree:
  - tree rooted at source that minimizes the sum of the costs of the routes between source and all destinations belonging to a multicast group (solved by Dijkstra's algorithm)
  - Example: nodes marked with "x" belong to group G, picture shows multicast trees for nodes A, B and C
- Problems:
  - excessive amounts of route info: each router must keep separate shortest path multicast trees from every source to every multicast group
    - in practice, trees computed only for active source/group pairs
  - potential instability if group membership changes frequently



Distance vector multicast

- Distance vector routing:
  - neighbors exchange forwarding tables
  - that is, routers do not know full topology
- Generalization to multicast done in two steps:
  1. mechanism to broadcast packets to all networks
     - Reverse Path Broadcast, RPB
  2. pruning of networks that do not have hosts belonging to the multicast group
     - Reverse Path Multicast, RPM
- Real life example: MBone
  - overlay network on top of Internet
    - packets tunneled through Internet between MBone nodes
  - uses Distance Vector Multicast Routing Protocol
  - popular application: vic (multiparty videoconferencing)
    - IETF meetings have been broadcasted over MBone

Reverse Path Broadcast (RPB)

- Achieving flooding:
  - router forwards multicast packets of source S to all its links except on the link from where the packets were received
    - achieves flooding and packets do not loop back to S
    - creates excess traffic (router does not know if there are any group member's to receive the packets, treated in next slide)
    - if LAN network connected to Internet via several routers, same multicast packets will be sent onto the LAN by all connected routers
- Idea: eliminate duplicate broadcasts on LANs
  - designate one router as "parent" router relative to source S
    - routers connected to same LAN hear each other's distance vectors
    - router with shortest distance to S selected as parent (address used to break ties)
  - only parent router allowed to forward traffic from S to LAN
  - each router must maintain state for each source S/link (interface) pair if it is parent or not

Reverse Path Multicast (RPM)

- From broadcast to multicast
- First, need to recognize if a “leaf” network has any (multicast) group members
  - network is a leaf if no other router uses it to reach source S
  - hosts on leaf network periodically announce their group memberships $\Rightarrow$ router knows if any group members are present
- Second, propagation of “no members of G here” information
  - distance vector info extended to include info on the set of groups from which the leaf network wants to receive multicast traffic
  - routers can decide for its links for which groups it should forward the traffic
- Problem:
  - potentially a lot of routing state info for each router
  - in practice, routers use RPB until some node becomes active, and then those nodes not interested in this particular multicast traffic speak up

Protocol Independent Multicast (PIM)

- RPB and RPM do not scale
  - routers build multicast shortest path trees for all sources in all groups
  - in particular, amount of state info too large if only small proportion of routers want to receive traffic for a certain group (=“sparse” group)
- Solution: PIM
  - use single tree for sparse groups (shared tree, saves state info in routers)
  - use shortest path trees for dense groups (lot of traffic between many nodes)
  - supports different kinds of trees
  - trees can be mixed within same group depending on traffic
- PIM-SM (PIM Sparse Mode)
  - routers send Join and Prune messages to routers that have been assigned as Rendezvous Points (RP)
  - shared and source specific trees
    - initially a shared tree rooted at RP is created and source specific trees created only if traffic warrants it

PIM operation

1 R4 and R5 join the shared tree, R2 marks interfaces with (*,G) (all traffic from group G forwarded on this interface)

2 R1 tries to send packet to G: sends packet to R1 (designated router), R1 not part of shared tree so it **tunnels** packet to RP, RP sends packet via shared tree

3 RP can force R3 to know about multicast tree (removes need for encapsulation); R3 creates sender specific state ((S,G) state)

4 If data rate from R1 high enough, R4 and R5 can Join the sender specific tree (to avoid looping via RP)