Introduction to IPv6

(Chapter 4 in Huitema)

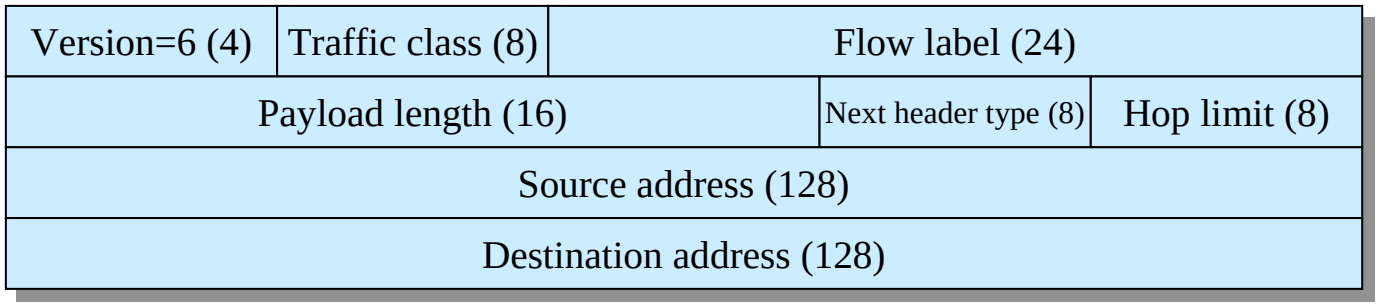
IPv6 addresses

- 128 bits long
- Written as eight 16-bit integers separated with colons
  - E.g. 1080:0000:0000:0000:0000:0008:200C:417A
    = 1080::8:800:200C:417A
- Types
  - Unicast
    - Defines one interface within their scope of validity
  - Multicast
    - Delivers packets to all members of a group
  - Anycast
    - Delivers packets to the *nearest* member of a group

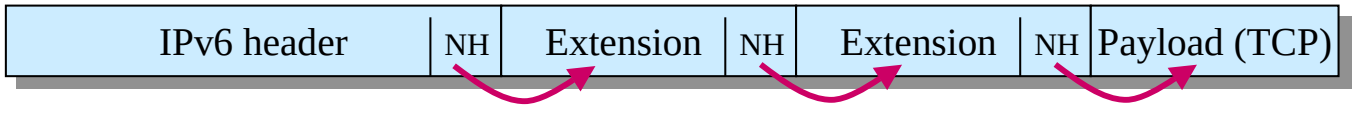
Special IPv6 addresses

- Unspecified = 0:0:0:0:0:0:0:0 = ::
  - Only as source address
- Loopback = 0:0:0:0:0:0:0:1 = ::1
  - For sending datagrams to itself
- IPv4 addresses prepended with zeroes
  - 0:0:0:0:0:0:AABB:CCDD = ::a.b.c.d
- Site-local addresses
  - FEC0:0000:0000:subnet:station
- Link-local addresses
  - FEB0:0000:0000:0000:station

IPv6 header



- Differences between v4 and v6
  - No checksum (performed at lower layers)
  - No fragmentation (path MTU discovery instead, min. 1280)
  - No options (linked extension headers instead)
- Extension headers replace options



IPv6 supports strict or loose source routing

- Routing header

Hext header	Header ext. length	Routing type = 0	Segments left
Reserved			
IPv6 address 1			
IPv6 address 2			
. . .			
IPv6 address N			

- Only the router whose address is destination address in IPv6 header examines this extension ⇒ better performance
- Forwarder
  - Moves the next address to the IPv6 header
  - Decrements the number of segments left

Fragmentation is performed by the sender

- Packets larger than the next hop's MTU are rejected
- Large packets must be fragmented by the sender
- Fragment header:

Hext header	Reserved	Fragment offset	Reserved	M
Identification				

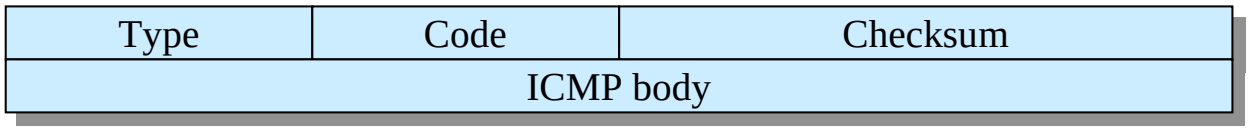
- Offset: Least significant 132 bits of 16-bit word
- M: More fragments

Other extensions

- Authentication Header (AH)
- Encrypted Security Payload (ESP)
- Destination options header
  - Only examined by the destination
  - Contains one or several parameters
  - Also defines handling for unrecognized parameters
- Hop-by-hop options header
  - Examined by each router
  - Similar format and coding as destination options header
  - E.g. jumbo payload
- Processing order is important
  - IPv6 → Hop-by-hop → Destination options (for tunneling) → Routing → Fragment → Authentication → Destination options → Upper layers (TCP/UDP)

Internet Control Message Protocol Version 6

- ICMPv6 header



- Also includes the functionality of IGMP
- ICMP message types:
  - 1. Destination unreachable
  - 2. Packet too big
  - 3. Time exceeded
  - 4. Parameter problem

  } errors
  - 128. Echo request
  - 129. Echo reply

  } for ”ping”
  - 133. Router solicitation
  - 134. Router advertisement
  - 137. Redirect

  } router discovery

Router discovery

- For building a local list of routers on the same network

Type = 134	Code = 0			Checksum
Cur. hop limit	M	O	Res.	Router lifetime
Reachable time				
Retransmission timer				
Options				

- Curr.hop limit: Suggestion for initial hop limit value
- Router lifetime: Seconds for holding in router list
- Reachable time: Expected time neighbors remain reachable after advertising the media address (in milliseconds)
- Reachable retransmission timer: Interval between successive solicitations of a neighbor that is not returning solicited neighbor advertisements (ms).

+ Source Link Layer option: contains media address of router

Neighbor discovery in IPv6 replaces ARP

- If there is no MAC address entry for the next hop, a ***neighbor solicitation*** message (comp. ARP-request) is sent:

Type = 135	Code = 0	Checksum
R S O	Reserved	
Solicited address		
Options...		

  - TTL=1, own MAC address in *source link-level address* option
- The message is sent to a *solicited node multicast address* derived from the address of the next-hop
- MAC address for the message derived from this address
- The host recognizing its address, replies with a ***neighbor advertisement*** message (comp. ARP-reply)
  - Format similar, but Type=136
  - MAC address in *link layer address* option
  - R=address is router, S=reply to solicitation, O=overides previous cache entry

Redirect works like in IPv4 but may include the media address of the next hop

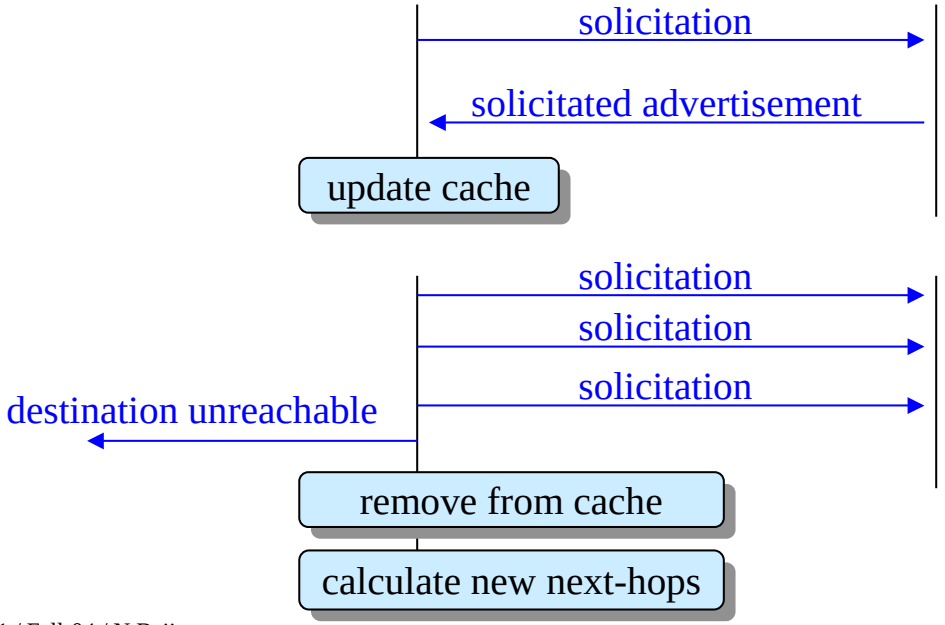
- Redirect message:

Type = 137	Code = 0	Checksum
Reserved		
Target address		
Destination address		
Options		

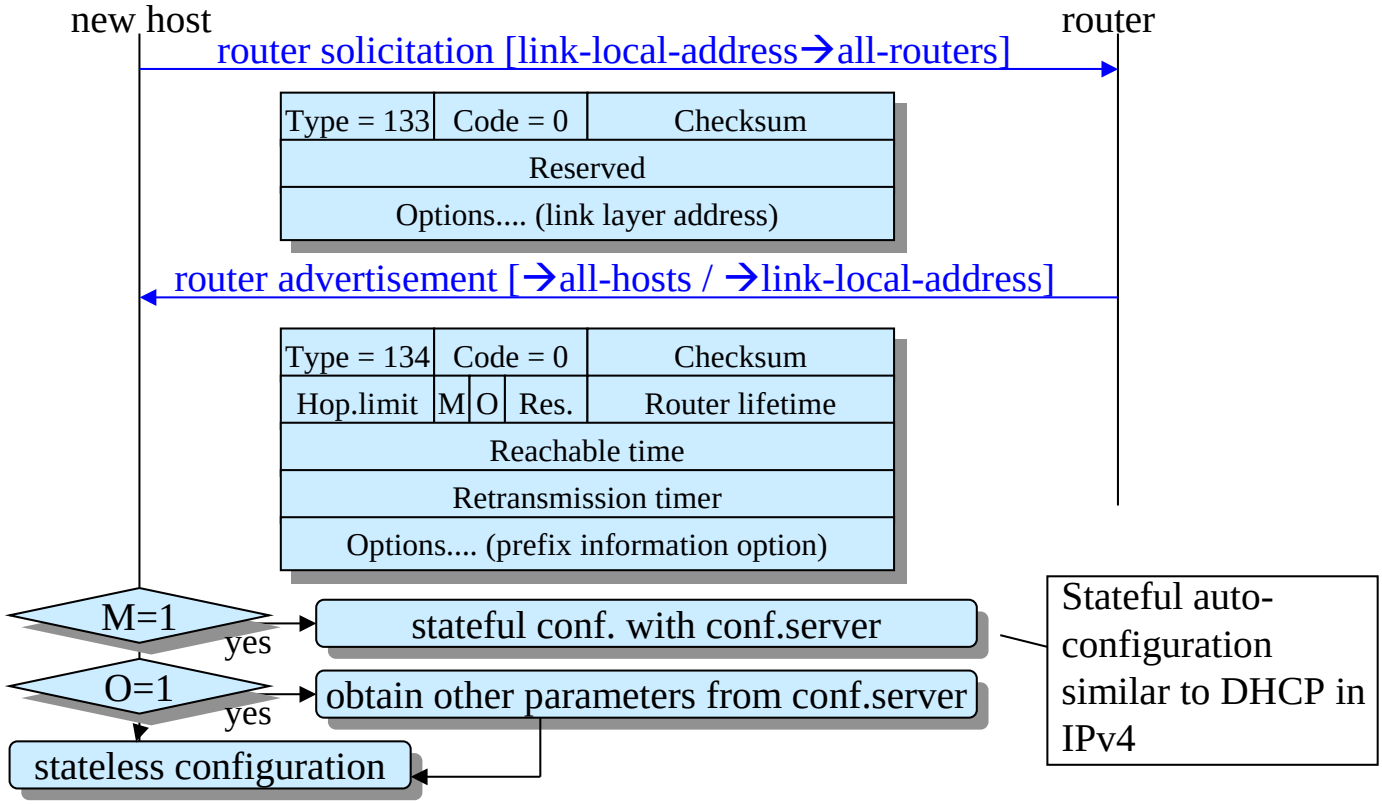
- Target address contains the better next hop for the destination
- The media address of the next hop may be included in a *target link layer address* option.

The sender needs feedback from the destiation so that it is not sending to a ”black hole”

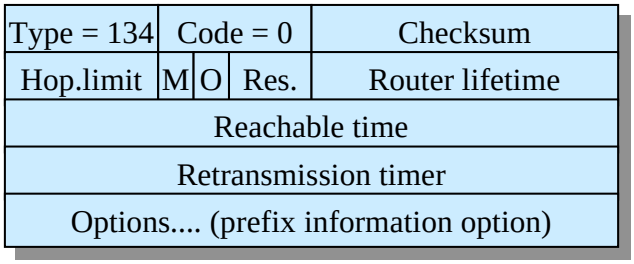
- If the sender does not get feedback (within 30 seconds), it checks the existence of the receiver with a solicitation message



Autoconfiguration can be stateful or stateless



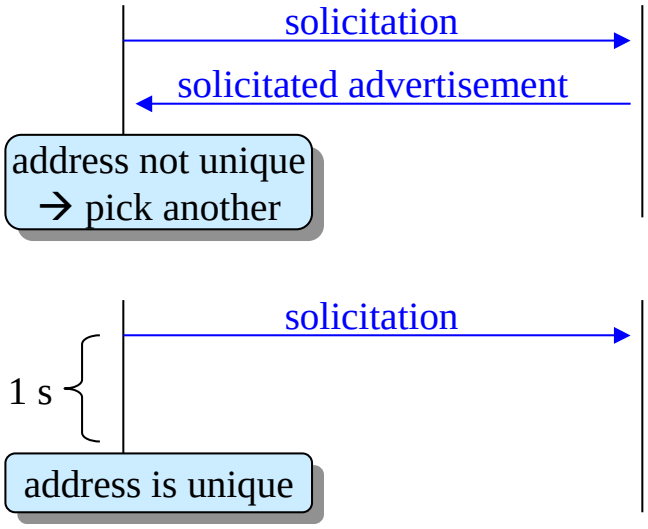
Stateless autoconfiguration



- Prefix information option contains list of prefixes with parameters
  - on-link bit → the prefix is specific to the local link
  - autonomous-bit → host can construct address by replacing the last bits of the prefix with EUI-64 identifier
- Stateless autoconfiguration properties
  - simple, no servers required
  - inefficient: 64 bits used for one local network
  - no access control

When a host generates an address with auto-configuration, it must check that it is unique

- In principle, addresses generated with the EUI-64 identifier should be unique, but...



- Lost messages ⇒ retry several times

Mobile IP

(Chapter 13 in Huitema)

Different types of mobility

- Computers transported and connected from different locations
  - Dynamic configuration ⇒ new IP address
  - Access through modem/ISDN

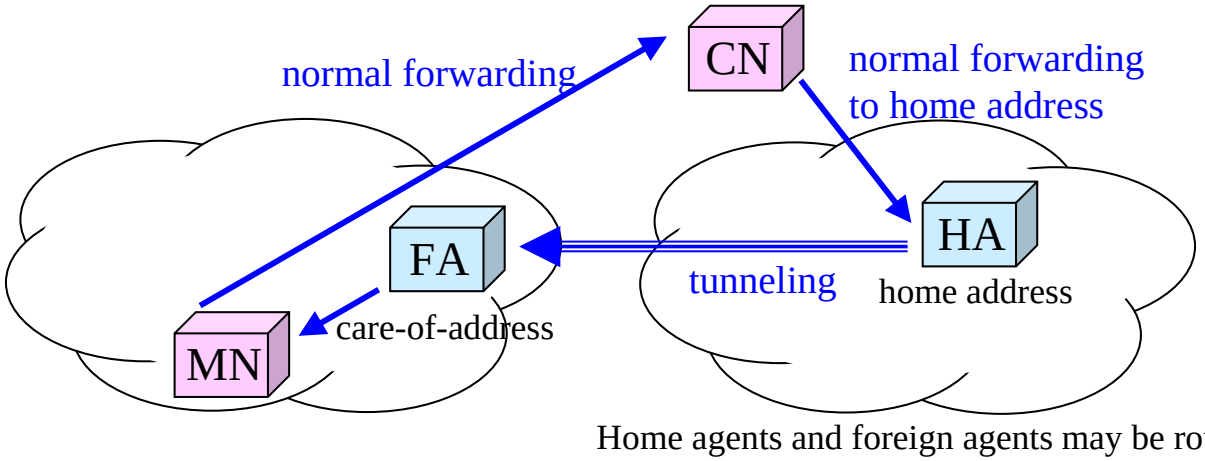
  ⇒ new IP address

  ⇒ TCP connection cut off
- Mobile computers, which stay connected during movements
  - Radio, infrared

  ⇒ same IP address
- Mobile networks, e.g. in cars, planes, trains, ships
  - Recursive mobility (mobile host in mobile network)

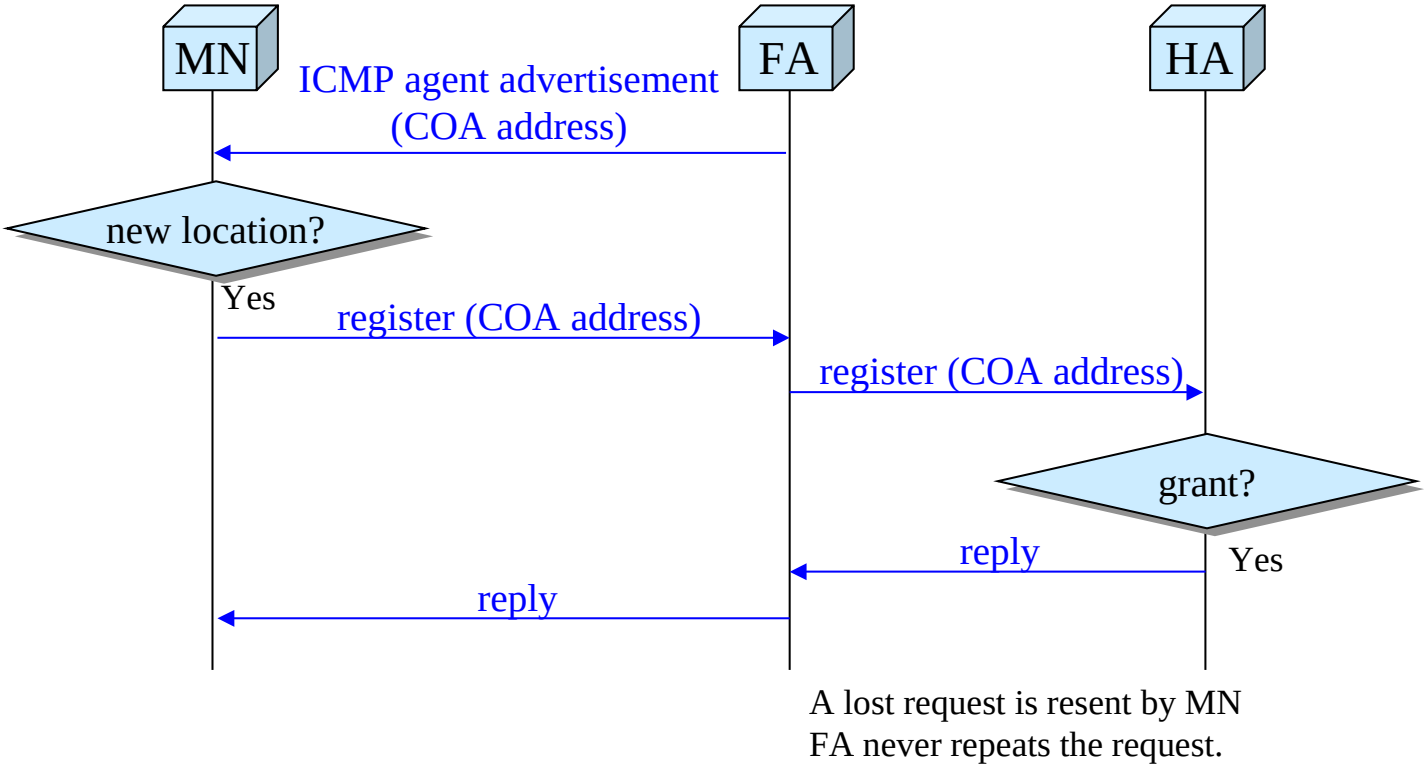
The traffic to a mobile node is tunneled from the home agent to the foreign agent

- ***Mobile Node*** (***MN***) – Node, who has a *home address* in the home network, and obtains a *care-of-address* (COA) in the visited foreign network
- ***Home Agent*** (***HA***) – Belongs to the home network and serves the home address
- ***Foreign Agent*** (***FA***) – Serves the visiting mobile node
- ***Corresponding Node*** (***CN***) – A node exchanging data with the mobile node



Home agents and foreign agents may be routers

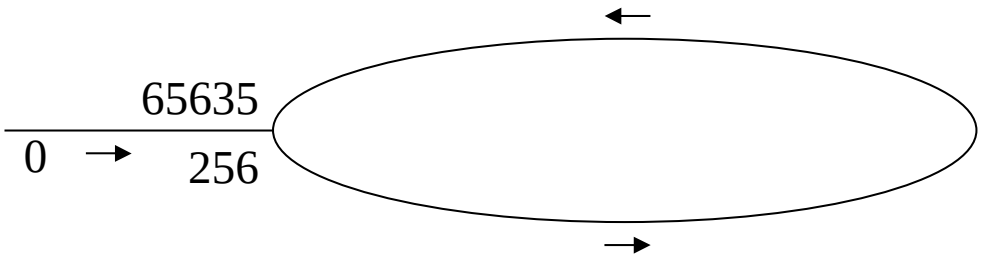
Discovery and registration



Discovery of a Home Agent or Foreign Agent using periodical ICMP messages

- Agent advertisements are extensions to ICMP router advertisements
- The agent advertisements contain
  - Sequence number
  - Life-time of registration
  - Flags
    - Registration required
    - Foreign agent or home agent
    - Minimal encapsulation (RFC-2003)
    - Generic Routing Encapsulation (GRE) (RFC-1701)
    - Header compression used
  - List of care-of-addresses
  - Length of prefixes

The sequence numbers in the agent adverstisement are similar to ”lollipop” sequence numbers in OSPF



- If one of the number is < 256
  - The higher number is ”higher”
- If both numbers are ≥ 256
  - If (b-a) < (65635-256)/2 then b is ”higher”
- If the received is ”lower” than the previous, then the server has been restarted

  ⇒ Register again

Alternative discovery mechanisms

- Periodic broadcast of ICMP messages wastes transmission capacity, especially on wireless LANs
- The MN can detect changed location through media-level information
  - e.g. analyzing power of different basestations
- Instead of waiting, the MN can solicit the information
  - Similar to ICMP router solicitation
  - TTL = 1
  - Agent replies with agent advertisement

Registration request

- Registration request message contains
  - Message type = 1
  - Flags
    - FA co-located with MN
    - preferred encapsulation
  - Requested lifetime
    - 0 = cancellation of previous
  - Home address of MN
  - HA address
  - COA address
  - Request identification
  - Extensions
    - E.g. authentication

Registration reply

- Registration reply message contains
  - Message type = 3
  - Reply code (granted or denied)
    - Who denied (FA or HA)
    - Why denied
  - Accepted lifetime
    - Same or smaller than requested lifetime
  - Home address of MN
  - HA address
  - Request identification
    - Same as in request
  - Extensions
    - E.g. authentication

Security issues (1)

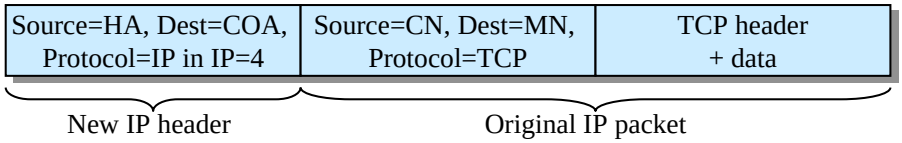
- Attack types
  - Attacker pretends to be a FA to capture traffic 
  - Attacker replays old registration messages
- Authentication extension proves the origin of the message and that the contents has not been changed
  - Security parameter index (SPI) together with HA, COA, or NM identifies security context
  - Shared secret, signature algorithm (e.g. keyed MD5) parameters of security context
  - Data and secret key → authentication field
  - MN to HA authentication mandatory
  - FA to HA and MN to FA authentications optional

Security issues (2)

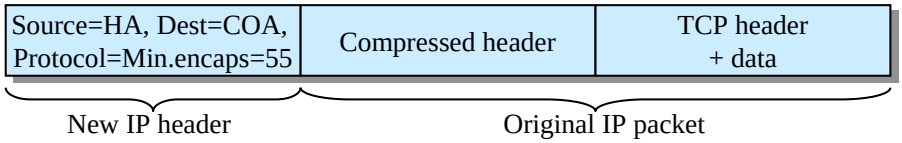
- Attack types
  - Attacker pretends to be a FA to capture traffic
  - Attacker replays old registration messages 
- Two requests must not contain the same identification
  - NTP timestamps (64-bit)
    - Only requests with higher timestamps are accepted
    - The timestamps must be close to the current time
  - Random numbers used only once (nonce)

Encapsulation

- Basic encapsulation, RFC-2003

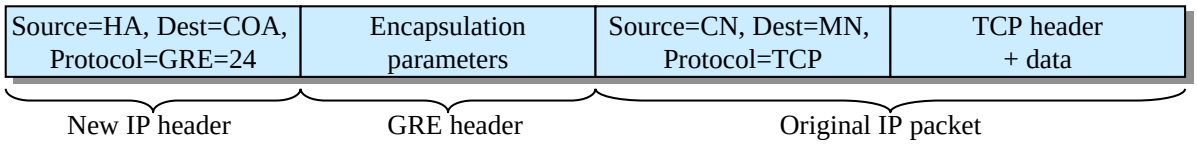


- Minimal encapsulation, RFC-2004



Compressed header: Protocol type of encaps. packet (e.g. TCP), Destination address of encaps. packet, Optional source address of encaps. packet, Header checksum

- Generic Routing Encapsulation (GRE), RFC-1701

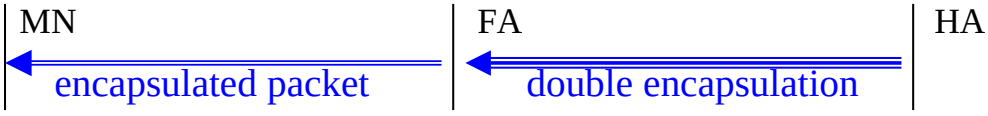


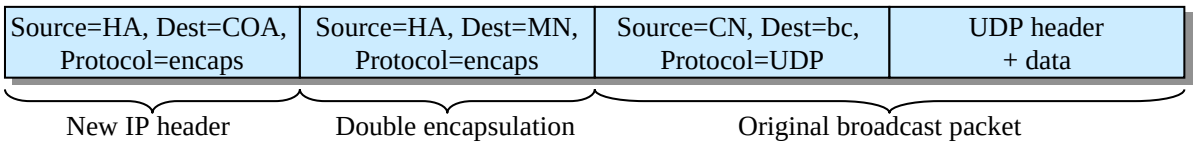
Parameters: Protocol type (similar to the one in Ethernet packet), optional checksum, optional sequence number, optional authentication key, (source) routing field

Broadcast and multicast should only be received by the MN, not the network of MN

- Easy if FA is colocated with MN

- Double encapsulation of broadcast/multicast traffic



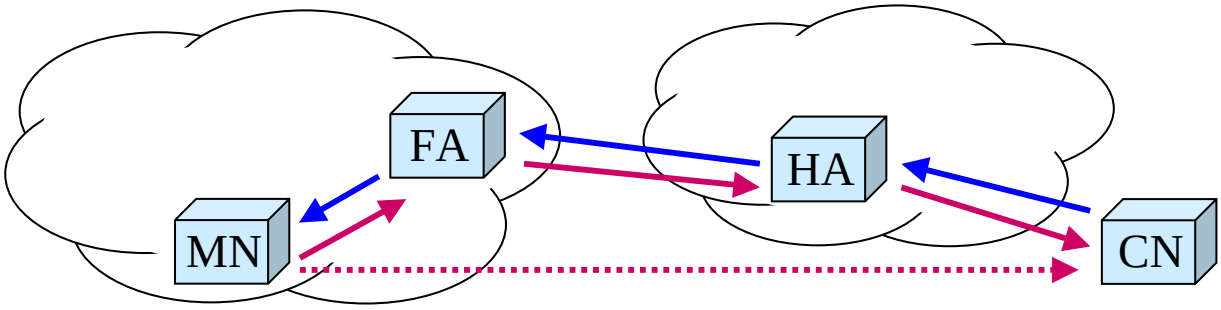


- ICMP messages are encapsulated MN→HA
- Instead, MN can subscribe to groups on the foreign network

Source address filtering is a problem in Mobile IP (1)

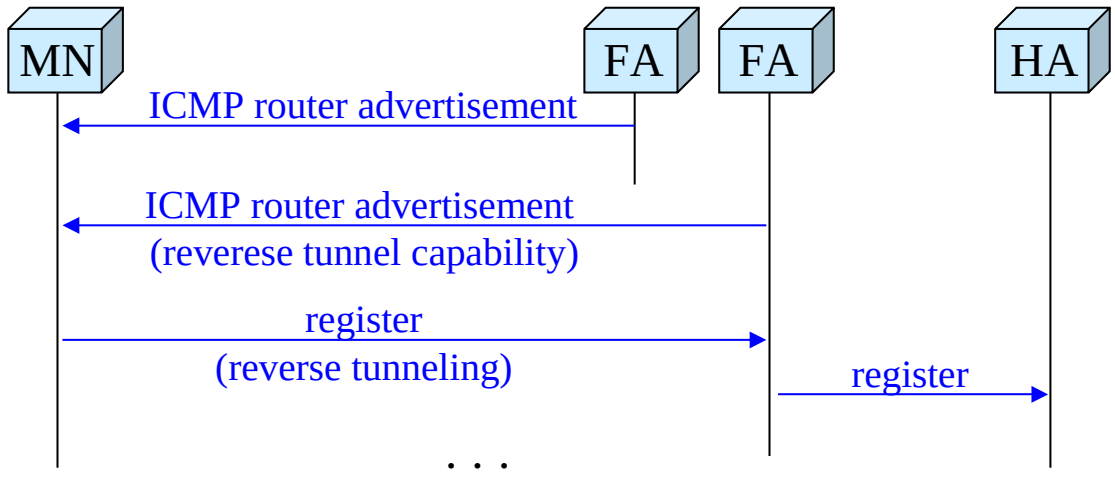
- Why source address filtering?
  - Address spoofing hides identity of attacker, helps targeting third parties' replies, helps gaining privileges
- Source address filtering is performed in firewalls, between ISP and customer, at peering points between provides, etc.

⇒ Packets sent by MN must be tunneled through the HA



Source address filtering is a problem in Mobile IP (2)

- FAs capable of tunneling packets back to HA, advertise it with a flag in agent advertisement message
- The MN requests reverse tunneling



Considerations

- Path MN→CN is shorter than the path CN→MN
  - Asymmetry
- If the MN moves relatively fast, it must choose a new FA often

  ⇒ Many registration messages to HA

Mobile IPv6

(Chapter 13 in Huitema)

Mobility in IPv6

- Discovery performed with IPv6 neighbor discovery and address configuration mechanisms
- Security ⇒ MN can notify their COA to the CN in addition to the HA
- Efficient encapsulation with the source routing header

Discovery

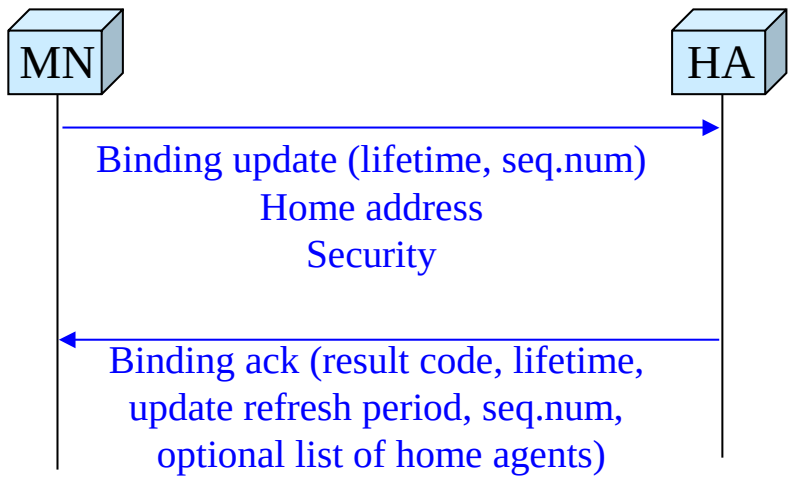
- The MN and FA are usually colocated ⇒ No separate FA
- Hosts listen to router advertisements to the learn prefixes of the link
  - Hosts can detect that they are visiting a foreign network
- COA obtained with address configuration procedures
- Routers willing to act as home agents indicate it in the router advertisement

Binding updates (1)

- Binding performed using destination options
  - Binding update – informs about the new COA
  - Binding ack – acknowledges the COA
  - Binding request – To request information about the current COA
  - Home address – Identifies the home address of the MN
- Authentication with the security option

Binding updates (2)

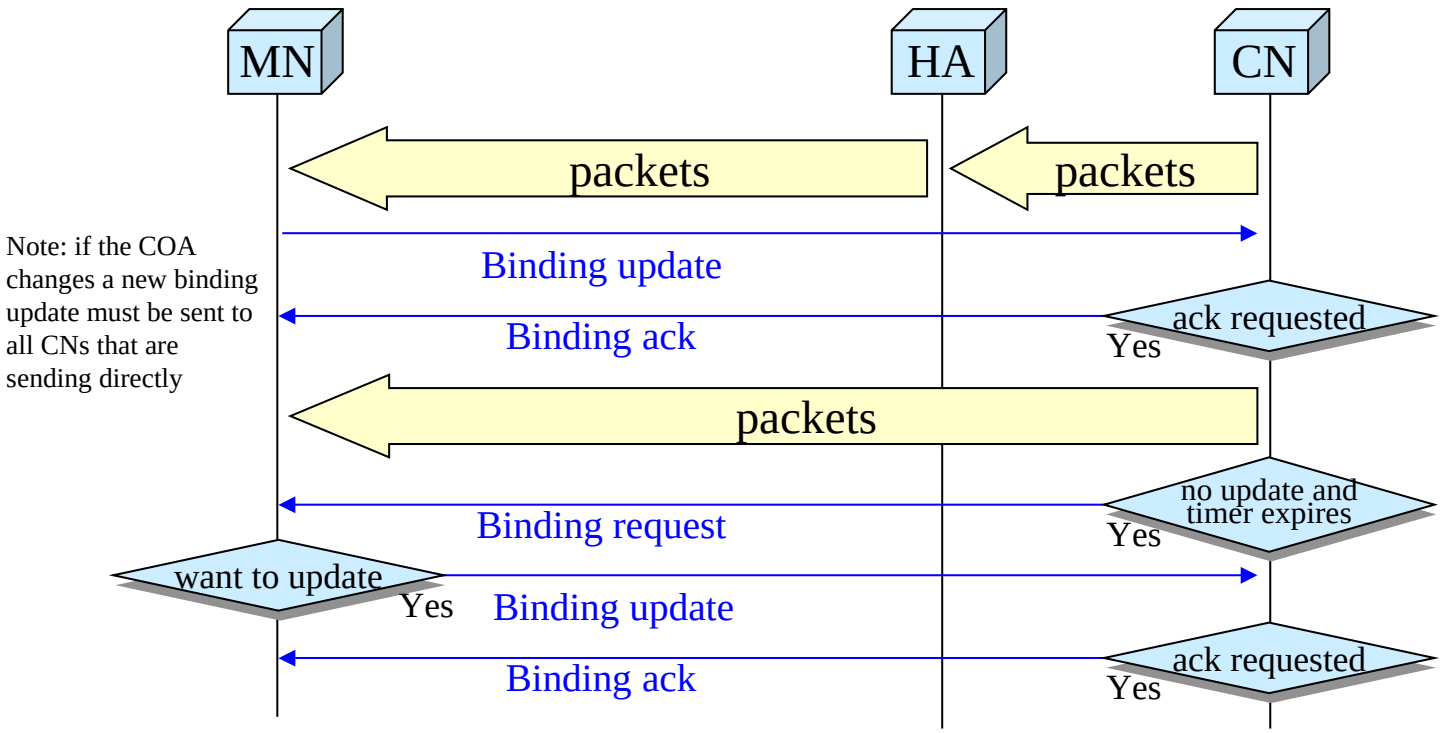
- COA transmitted in source address of IPv6 header
- Home address in the Home Address option



Source address filtering is not a problem in IPv6

- The mobile node does not put its home address in the IPv6 header. Instead, the home address is sent in the Home Address option. The IPv6 header contains the COA.
- Mandatory requirement.

The MN can send a binding update to the CN to optimize the route



IPv6 uses the routing header instead of encapsulation