IPv6

IPv4 & IPv6 Header Comparison

IPv4 Header

Ver	IHL	Type of Service	Total Length
Identification		Flags	Fragment Offset
Time to Live	Protocol	Header Checksum	
Source Address			
Destination Address			
Options			Padding

IPv6 Header

Ver	Traffic Class	Flow Label
Payload Length	Next Header	Hop Limit
Source Address		
Destination Address		

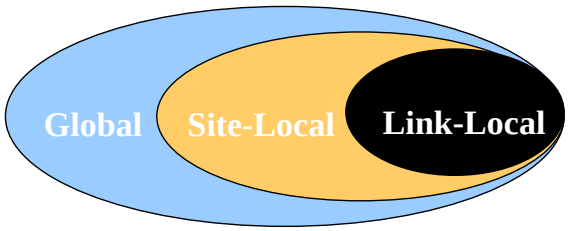
IPv6 Address Scope

Address assigned to interface

- Interface ID

Addresses depend on scope

- Link Local
  - Local hardware connection
  - Broadcast domain
- Site Local
  - Autonomous system (AS)
  - Network of one organization
- Global



Types of IPv6 Addresses

Unicast

- One address on a single interface
- Delivery to single interface

Multicast

- Address of a set of interfaces
- Delivery to all interfaces in set

Anycast

- Address of a set of interfaces
- Delivery to closest single interface in set

No broadcast addresses

IPv6 Address

128-bit address

340,282,366,920,938,463,463,374,607,431,768,211,456 addresses

50,000 addresses per square meter of land on Earth

Colon-separated 16-bit hex

2031:0000:130F:0000:0000:09C0:876A:130B

Leading zeros optional

2031:0:130F:0:0:9C0:876A:130B

Successive 16-bit 0 fields written :: (once)

legal **2031:0:130F::9C0:876A:130B**

illegal **2031::130F::9C0:876A:130B**

IPv4 compatible — used in tunneling IPv6 through IPv4

0:0:0:0:0:0:1.2.3.4 = ::0102:0304

IPv4 mapped — used by IPv6 source sending to IPv4 dest

0:0:0:0:0:FFFF:1.2.3.4 = ::FFFF:0102:0304

IPv6 Prefix

Prefix Format (PF)		Type	Application
Binary	Hex		
0000 0000	0::/8	Reserved address	Not assigned
0000 001	0200::/7	Reserved for ATM	Used in telephony
001	2000::/3	Aggregatable Global Unicast Address	Aggregation of host addresses into networks and subnets
1111 1110 10	FE80::/10	Link Local Address	Address hosts on LAN segment
1111 1110 11	FEC0::/10	Site Local Address	Addresses used with an AS (like 10.0.0.0 in IPv4)
1111 1111	FF00::/8	Multicast Address	Assigned to a group

Unicast Address Formats

Link Local

FP (10 bits)	Reserved (54 bits)	Interface ID (64 bits)
1111111010 FE80::/10	MUST be 0	MAC derived

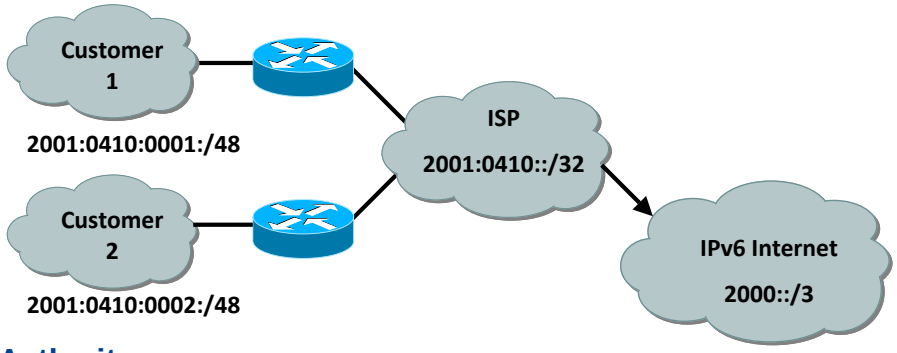
Site Local

FP (10 bits)	Subnet (38 bits)	Subnet (16 bits)	Interface ID (64 bits)
1111111011 FEC0::/10	Locally Administered		MAC derived

Global

FP (3 bits)	ISP assigned (45 bits)	Subnet (16 bits)	Interface ID (64 bits)
001 2000::/3	Provider Administered	Locally Administered	MAC derived or Locally Administered or Random

Hierarchical Addressing & Aggregation



Authority

Assigns **2001:0410::/32** to ISP

ISP

Assigns **2001:0410:1:/48** to customer 1

Assigns **2001:0410:2:/48** to customer 2

Customer 1

Assigns subnets **2001:0410:1:1/64 , 2001:0410:1:2/64**

Extension Headers

Next header field

Points to header following IPv6 header

Upper Layer Protocol	
6	TCP Header
17	UDP Header
41	IPv6 Header
45	Interdomain Routing Protocol
46	Resource Reservation Protocol
58	IPv6 ICMP Packet

IP Option Header	
0	Hop-by-Hop Options Header
43	IPv6 Routing Header
44	IPv6 Fragment Header
50	Encapsulating Security Payload
51	IPv6 Authentication Header
59	No Next Header
60	Destination Options Header

Extension headers

Multiple of 8 bytes

Syntax depends on option

Headers (except 60) appear only once

IPv6 Option Headers

Tunneling

Option 41

IPv6 datagram in data field of IPv6 datagram

Example — used with fragmentation when router adds option field

Hop-by-hop header

Options checked by every router and destination node

Destination options header

Options checked by destination node

Routing header

Source sets route through network

Fragment header

Handles fragmentation

Authentication header / Encapsulating Security Payload

Implement IPsec

Option Header Examples

IPv6 Header Next = TCP	TCP Header + Data

IPv6 Header Next = Routing	Routing Header Next = TCP	TCP Header + Data

IPv6 Header Next = Routing	Routing Header Next = Fragment	Fragment Header Next = TCP	TCP Header + Data Fragment

IPv6 Header Next = Routing	Hop-by-Hop Header Next = Fragment	Fragment Header Next = TCP	TCP Header + Data Fragment

Traffic Class + Flow

DSCP — 6 bits

Differentiated Services Code Point

Sets per-hop behavior according to service

ECN — 2 bits

Explicit Congestion Notification

Router can set congestion indication

Flow

Stream of related packets from 1 source to 1 destination

Require particular handling by routers

- Requirements cached in routers
- Example — real time priority

24 bit flow label

- Chosen randomly from 1 to FFFFF
- 0 — not part of a flow

Flow identified by label + src IP + dest IP

ICMPv6

ICMP — Internet Control Message Protocol

Offset	0 – 7	8 – 15	16 – 31
0	Type	Code (subtype)	Checksum
32	ICMP Message		

1	Destination Unreachable
2	Packet Too Big
3	Time (Hop Count) Exceeded
4	Parameter Problem

128	Echo Request
129	Echo Reply
130	Group Membership Query
131	Group Membership Report
132	Group Membership Reduction
133	Router Solicitation
134	Router Advertisement
135	Neighbor Solicitation
136	Neighbor Advertisement
137	Redirect Message

Neighbor Discovery

Identify hosts and routers on physical LAN segment

Replaces ARP

Address resolution

Obtain MAC address for neighbors

Neighbor Solicitation

Node sends ICMP neighbor solicitation message to host

64-bit local link multicast prefix	64-bit host address
FF02::	Interface ID

Neighbor advertisement

Neighbor sends ICMP neighbor advertisement with MAC address

Router and Prefix Discovery

Router advertisements

- Routers send ICMP messages to hosts on some schedule
- Addressed to FF02::1
  - Multicast address — all systems on local link
- Provides configuration parameters
  - MTU
  - Global IP prefix
  - IP address configuration method (ICMP / stateless)

Router solicitation message

- Host sends ICMP message to request router service
- Addressed to FF02::2
  - Multicast address — all routers on local link
- Routers respond with router advertisement

Stateful Auto-Configuration

DHCP service

Similar to IPv4

DHCP messages

- Solicit
- Advertise
- Request
- Reply
- Release
- Reconfigure

DHCP client

- Waits for DHCP advertisement
- Sends DHCP request

DHCP server

- Sends DHCP reply
- Provides IP address + configuration parameters

Stateless Auto-Configuration

Node reads 48-bit MAC address from hardware

Converts 6-byte MAC address to 8-byte node address

- 48-bit MAC address ⟶ 24 bits FFEE 24 bits
- Example: 11 22 33 44 55 66 ⟶ 11 22 33 FF EE 44 55 66

Extends link-local prefix to 64 bits

- FE80::/10 ⟶ FE80::/64

Attaches link-local prefix to node address

- Creates temporary link-local unicast address
- Example: FE80::1122:33FF:EE44:5566

Verifies unique address with neighbor solicitation

- No response to link-level address ⟶ assigns address to interface

Sends router solicitation

- Routers respond with router advertisement
  - No response ⟶ node attempts DHCP
- Response message provides parameters — MTU, global prefix

Replaces FE80::/64 ⟶ global prefix to form global unicast address

Mobile IP (RFC 2002)

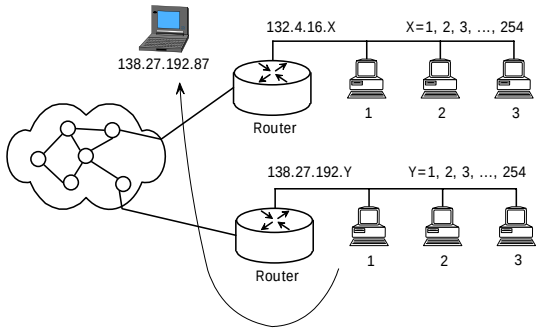
Internet protocol supporting host mobility

- Maintains TCP connections as host changes location
- Supports authentication

Mobile host maintains single long-term IP address

- Version 4 IP address and address format are unaffected

Routing tunnel replaces standard IP routing



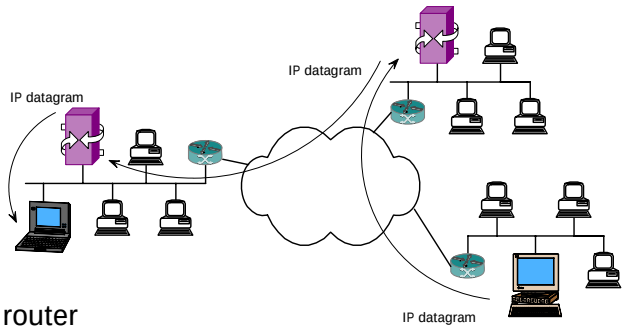
Mobile IP — Basic Idea

Similar to

- Call forwarding
- Mail forwarding at post office

Mobile Node

- Permanent IP address
- Usual home service router
- Finds mobile service routers when roaming



Home router and mobile service router coordinate

IP datagrams

- Sent to usual home router
- Forwarded by home router to mobile service router
- Forwarded to Mobile Node

Mobile IP Entities

Mobile Node (MN)

- Host or router that can change its point of attachment

Home Address

- Permanent IP address assigned to MN

Correspondent Node (CN)

- Node that sends datagrams to MN home address

Home Agent (HA)

- Maintains table of registered mobile nodes
- Forwards datagrams addressed to mobile node

Foreign Agent (FA)

- Delivers datagrams between MN and HA

Mobility Agent

- HA or FA supporting mobility

Care-of-Address (COA)

- FA address used to identify current location of MN

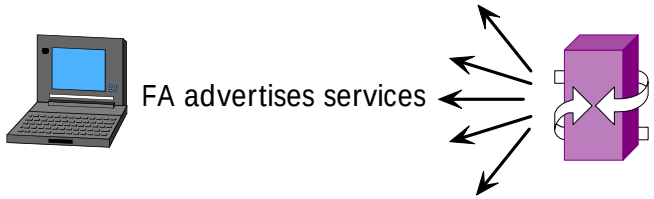
Agent Discovery

Mobility Agents broadcast availability

- Home Agents (HA)
- Foreign Agents (FA)

Mobile Node (MN) looks for

- Local router services when connected to home network
- Foreign Agent (FA) services when connected to foreign network



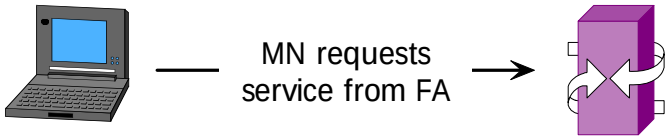
Care-of-Address Discovery

Mobile Node (MN)

- Requests service from Foreign Agent (FA)

Foreign Agent

- Assigns Care-of-Address (COA) to MN
- FA can have 1 or more available COAs
- Usually FA assigns same COA to all MNs



Registration

Foreign Agent

- Requests Mobile IP support from MN's Home Agent

Home Agent

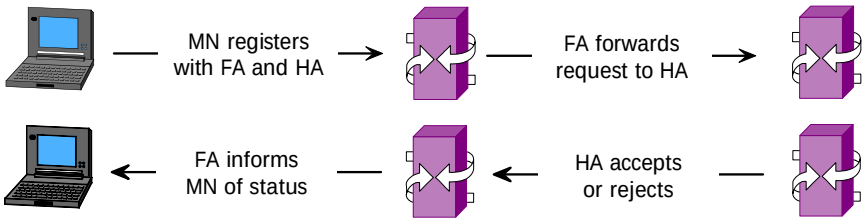
- Agrees to provide Mobile IP support

MN

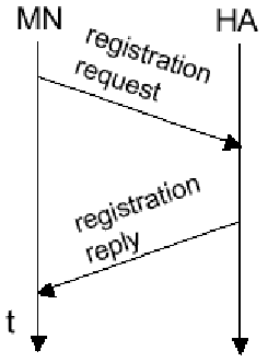
- Registers COA with its HA

HA forwards datagrams to FA

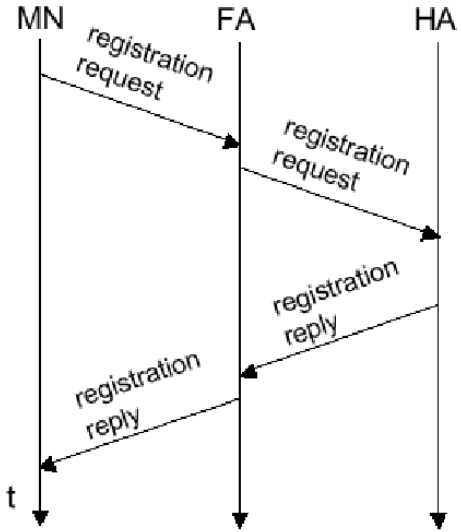
- Datagrams for MN arrive at HA



Establishment of Service in Mobile IP

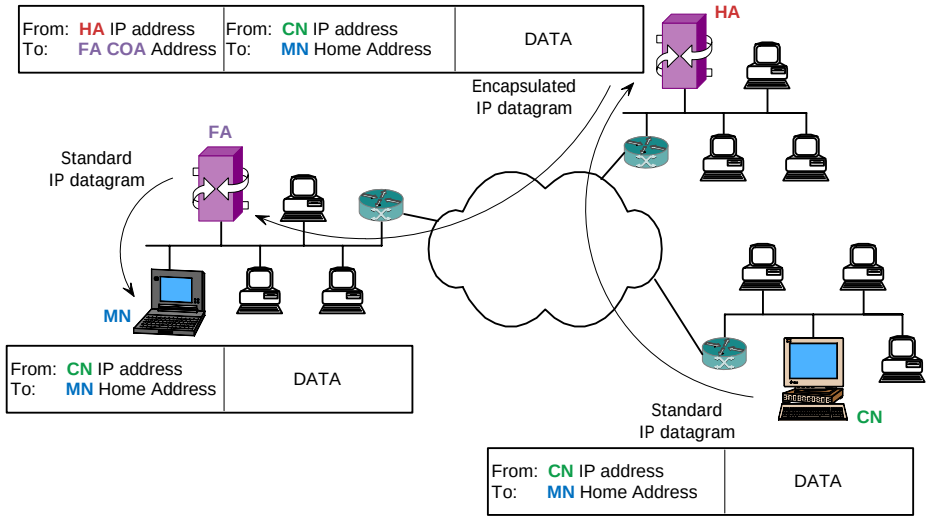


MN in home network



MN in foreign network

Mobile IP End-to-End Delivery



Roaming and Hand-Off

Roaming MN

- Moves to new attachment point (network)
- Requires change of FA

Multiple bindings

- Multiple COAs — old + new
- Avoid datagram loss
- Avoid too frequent registrations

HA

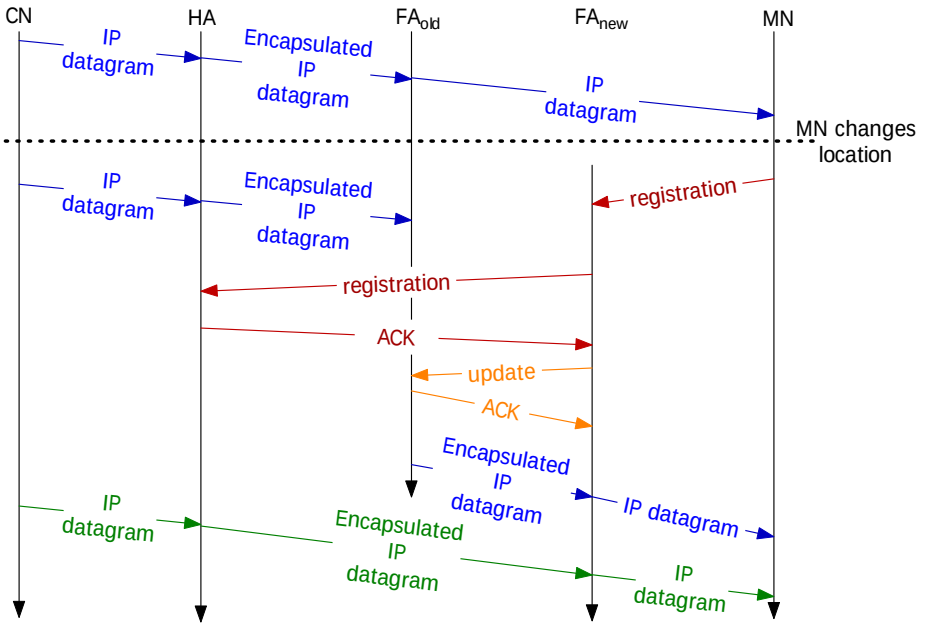
- Forwards each packet to multiple COAs

MN

- Receives packet at one COA

Route optimization after reconnection

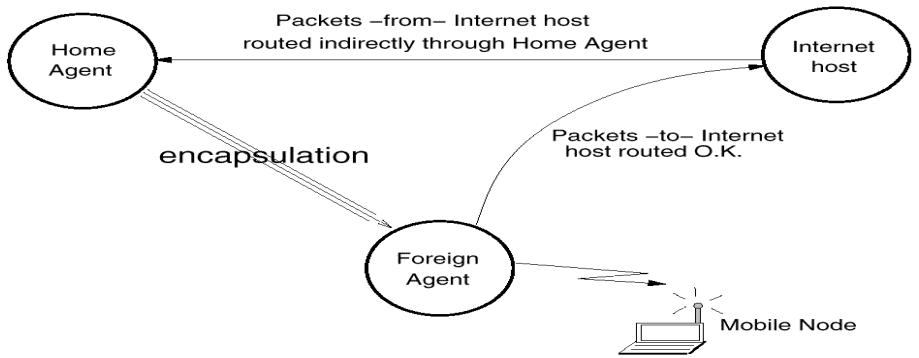
Change of Foreign Agent



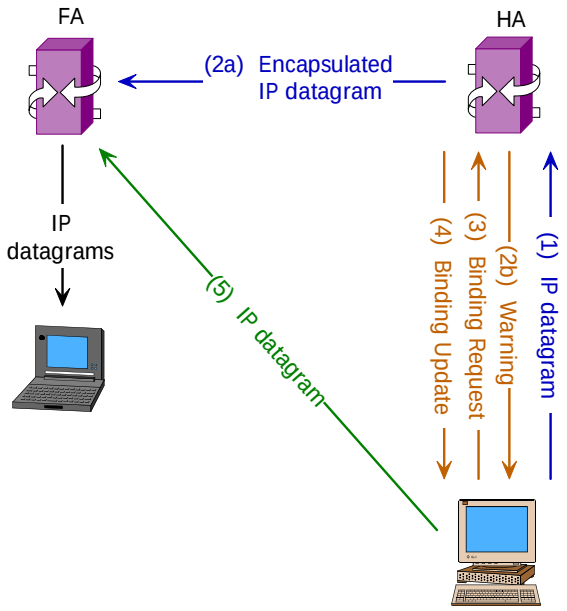
Triangle Routing

Home agent is bottleneck

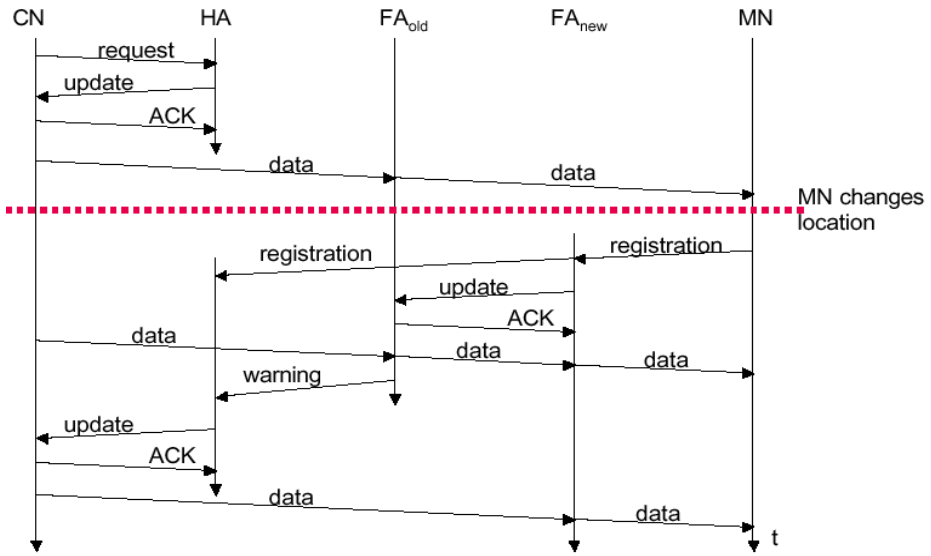
- Increases network load



Route Optimization



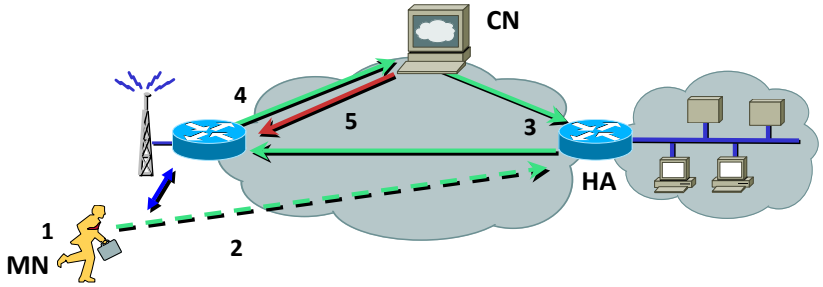
Roaming Under Route Optimization



IPv6 Mobile IP

Implements Mobile IP

1. Mobile node (MN) obtains local address using autoconfiguration
   Roaming address = care-of-address (CoA)
   No special Foreign Agent
2. MN registers with Home Agent by sending Binding Update
3. HA forwards traffic for registered MN
   Tunnels packets from CN to MN
4. MN sends packets to CN directly
5. Route optimization — HA provides CN with CoA



IPv6 Mobility Support

Node writes home address in destination option header

Destination node can identify datagram by home address

Tunneling

Using IPv6 routing extension headers instead of encapsulation

Reduces processing cost of delivering packets

Handover

Node moves from ESS to ESS

Layer 2 handover — change AP and ESS ID

Node detects change in on-link subnet prefix

Updates CoA

IPv6 Mobility header messages

Home Test Init, Home Test, Care-of Test Init, and Care-of Test

Binding Update / Acknowledgement

MN to notifies node or HA of current binding