

King Fahd University of Petroleum & Minerals Computer Engineering Dept

**COE 543 – Mobile and Wireless
Networks**

Term 072

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Lecture Contents

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Main References

this is the one you
are responsible for

Charles E. Perkins, "Mobile IP," IEEE Communications Magazine, May 1997, pp. 84-99.

- Notes for Prof. İbrahim Körpeoğlu of Bilkent University - Bilkent / ANKARA
- Prof. Dr.-Ing. Jochen Schiller, <http://www.jochenschiller.de/> MC SS02 – Chapter 8 material
- Charles E. Perkins, "Mobile IP – Design Principles and Practices," Addison-Wesley, 1997

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Background Information

- Internet
- TCP/IP
- Subnet-ing
- ICMP
- ARP
- DHCP

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Introduction

- Mobility vs. Portability
- DHCP requirements
- Other solutions
 - E.g. TCP connection migration

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Motivation for Mobile IP

Routing

- based on IP destination address, network prefix (e.g. 129.13.42) determines physical subnet
- change of physical subnet implies change of IP address to have a topological correct address (standard IP) or needs special entries in the routing tables

Specific routes to end-systems?

- change of all routing table entries to forward packets to the right destination
- does not scale with the number of mobile hosts and frequent changes in the location, security problems

Changing the IP-address?

- adjust the host IP address depending on the current location
- almost impossible to find a mobile system, DNS updates take to long time
- TCP connections break, security problems



Requirements to Mobile IP (RFC 3220, was: 2002)

Transparency

- ❑ mobile end-systems keep their IP address
- ❑ continuation of communication after interruption of link possible
- ❑ point of connection to the fixed network can be changed

Compatibility

- ❑ support of the same layer 2 protocols as IP
- ❑ no changes to current end-systems and routers required
- ❑ mobile end-systems can communicate with fixed systems

Security

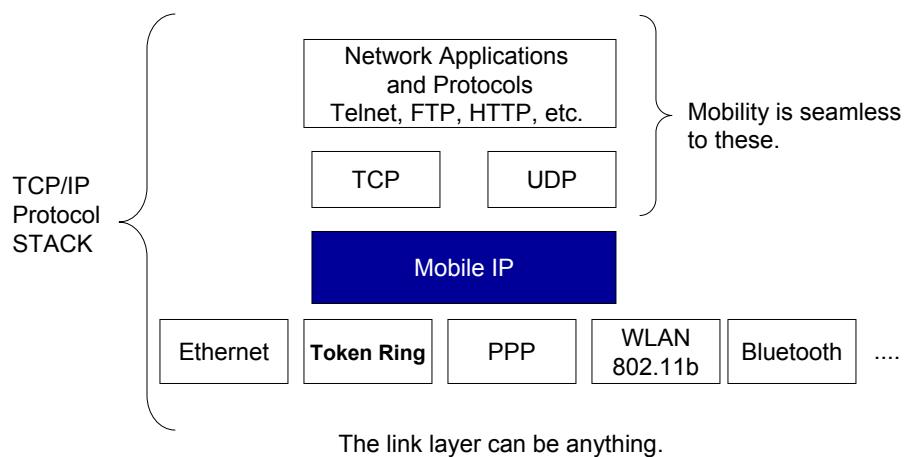
- ❑ authentication of all registration messages

Efficiency and scalability

- ❑ only little additional messages to the mobile system required (connection typically via a low bandwidth radio link)
- ❑ world-wide support of a large number of mobile systems in the whole Internet



Mobile IP



Why we need mobile IP

- Current Internet architecture and protocols (without mobile IP support) do not support seamless mobility for mobile users
 - Internet is designed assuming hosts (computer) are **static** and do not change location frequently.
 - When you move to a new location with your laptop and connect it to a Ethernet cable at the new location, you have **re-configure** your laptop.
 - Obtain new IP address,
 - Learn the subnet mask.
 - Learn the default router IP address
 - Learn the local DNS servers IP addresses
 - When you re-configure your laptop with this information, most of the time you have **re-start** your laptop.
 - Whether you re-start or not your laptop, previously running network applications will **stop working** properly when you **change the IP address** of your laptop.

Why we need mobile IP

- Initially we had desktops, workstations, main-frames and super-computer all of which are static and heavy enough so that you can not carry them with you!
 - Initial design of Internet was for these computers.
 - Now, we have
 - Laptop and handheld computers which you carry to new places when you travel
 - Palmtop and Pocket PC computers which you carry in your pocket even if you go to a movie.
 - And these are powerful enough to run a lot of interesting network applications like web browsers, etc.
 - Hence you still need **Internet access** for these highly **mobile computers and devices**
 - That is why we need mobility support to be added to the Internet.
- **Mobile IP** has been designed for this purpose!

Problems with Internet for Mobility

- In Internet, IP addresses are used for two purposes
 - Identification of hosts
 - Both an IP address or domain name address (FQDN) can be used to identify a host.
 - DNS servers does the mapping between IP addresses and domain names
 - Usually there is one to one mapping.
 - Network protocol in TCP/IP stack usually use IP addresses to identify the end-point
 - Applications may use the domain names so that they are more user friendly to the humans.
 - Locating mobile hosts: for Routing
 - IP addresses are structured and correspond to well-specific locations in Internet.
 - They are used for determining the routes that packets will follow from a source machine to a destination machine.
 - For static hosts, we can use its IP address for very long times, since the location dependent IP address does not have to be changed, since a static host do not change location.

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Problems with Internet for Mobility

- When mobile hosts come into picture in Internet:
 - We need a **location-independent identifier** for the mobile hosts so that any user who wants to contact to the mobile host should be able to use this identifier to send information to the mobile host without getting bothered with the current location of the mobile.
 - We also need a **new location-dependent IP address** (all IP addresses are location-dependent) for a mobile host when it moves to a new location in order to route the packets destined for the mobile to the new location so that the mobile can receive them at the new location.
- Hence, a single IP address for the a mobile host can not serve both purposes (*identity* and *location/routing*) at the same time.

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Mobile IP Approach

- Use two IP addresses per mobile host
 - One permanent IP address (also called **home-address**)
 - Used for *Identification*
 - An other IP address that is changing depending on the current location the mobile host (**called care-of-address**)
 - Used for *Routing*
- The binding (association) between these two IP addresses are kept at a well-known location, called *home agent*.

Why DHCP is not enough

- DHCP: Dynamic Host Configuration Protocol
 - An Internet Protocol that allows host that does not have an IP address to obtain an IP address and other configuration information when it connects to a network at a new location.
 - Network to be connected can be for example an Ethernet link
 - Network to be connected should support DHCP protocol
 - The mobile host should support DHCP protocol
 - The **configuration info** that can be obtained via DHCP at the new location includes:
 - A registered IP address
 - Subnet mask of the network
 - Local DNS server IP addresses (primary and secondary IP addresses)

DHCP does not provide seamless mobility

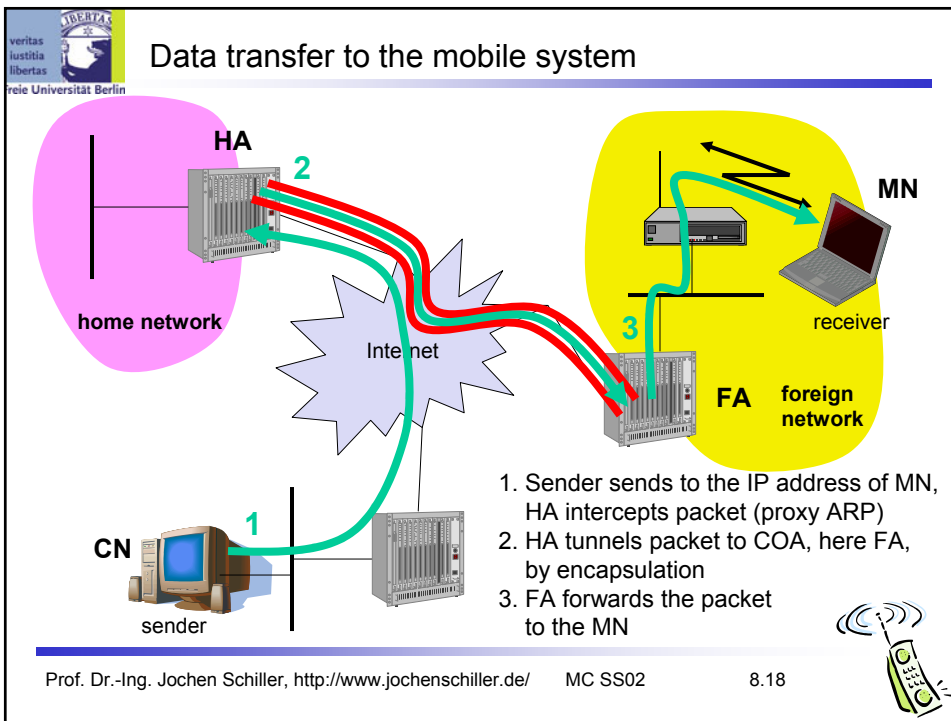
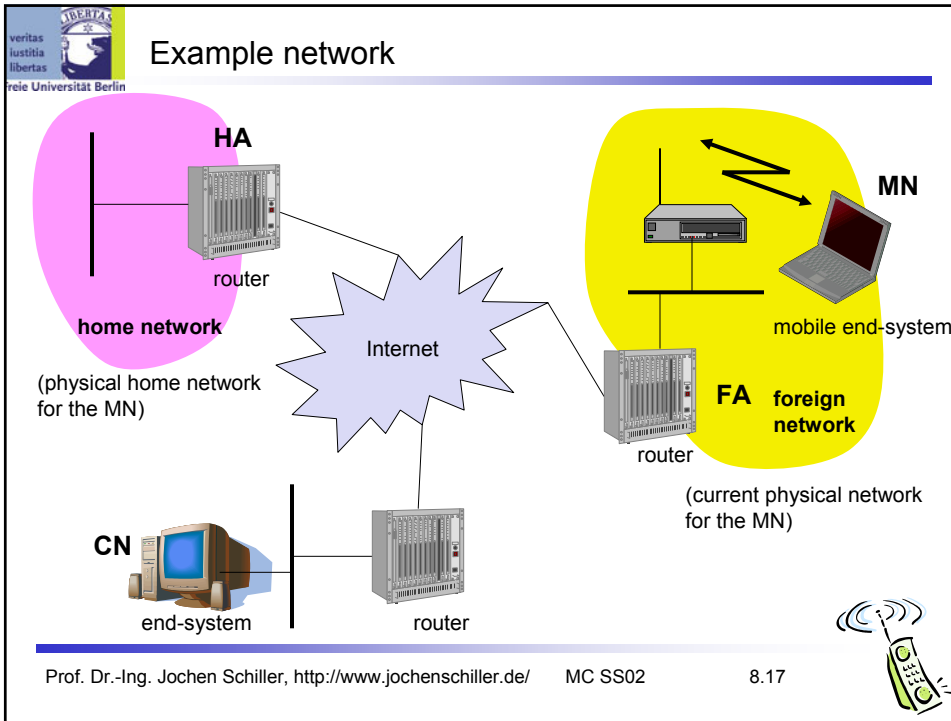
- Since you obtain a new IP address at every new location, applications have to be restarted
 - Restart is not a problem for web page access
 - Restart is a problem for telnet and ftp sessions and some other network and TCP applications.
- Other people can not connect to you when you move to a new location unless they learn your new IP address
 - You have to call them and let your IP address at every move!!!
 - DNS servers are not dynamic enough currently to update the binding between your machine's domain name (host name) and its IP address. This binding will be stale when you move to a new location. Your friend who wants to contact you and uses your machine's host name, will have the old IP address returned from the DNS server. Hence the packets (messages) he will send will be routed to your old IP address.

Terminology

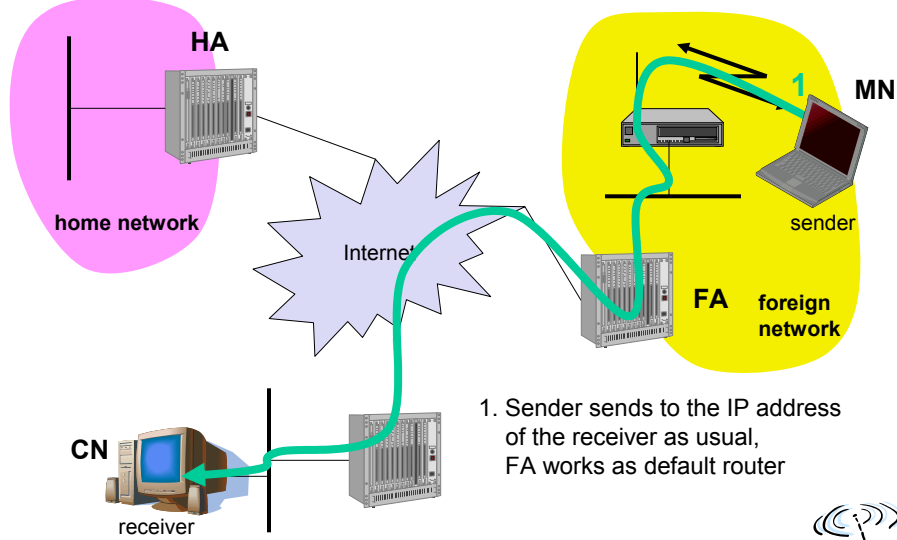
refer to Perkins's paper for the full list of definitions

- Mobile Node (MN)**
 - system (node) that can change the point of connection to the network without changing its IP address
- Home Agent (HA)**
 - system in the home network of the MN, typically a router
 - registers the location of the MN, tunnels IP datagrams to the COA
- Foreign Agent (FA)**
 - system in the current foreign network of the MN, typically a router
 - forwards the tunneled datagrams to the MN, typically also the default router for the MN
- Care-of Address (COA)**
 - address of the current tunnel end-point for the MN (at FA or MN)
 - actual location of the MN from an IP point of view
 - can be chosen, e.g., via DHCP
- Correspondent Node (CN)**
 - communication partner

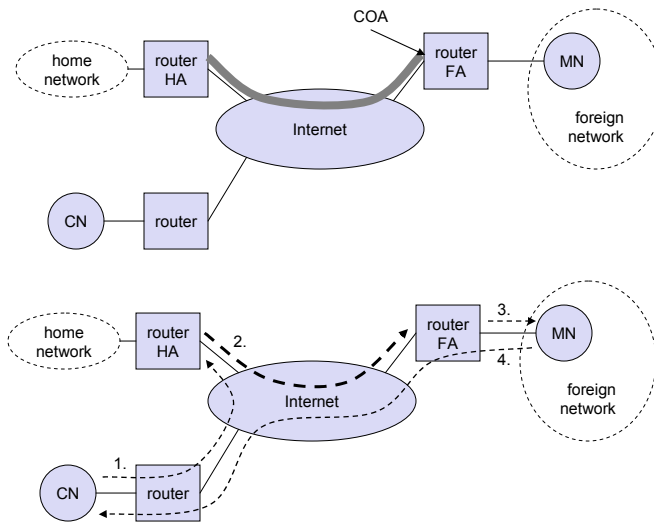
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Data transfer from the mobile system



Overview

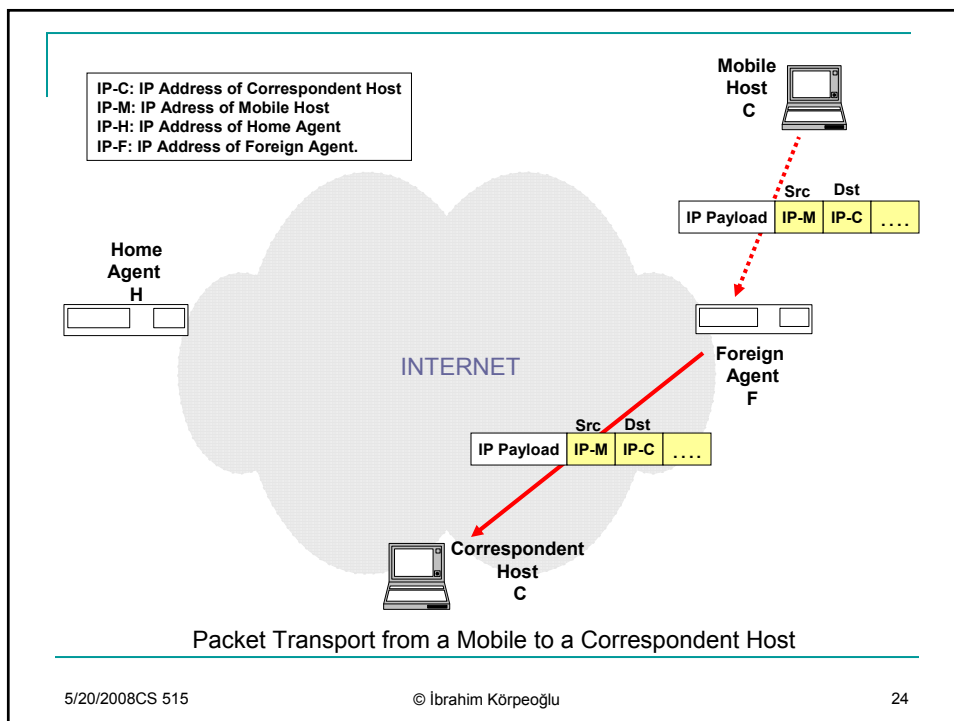
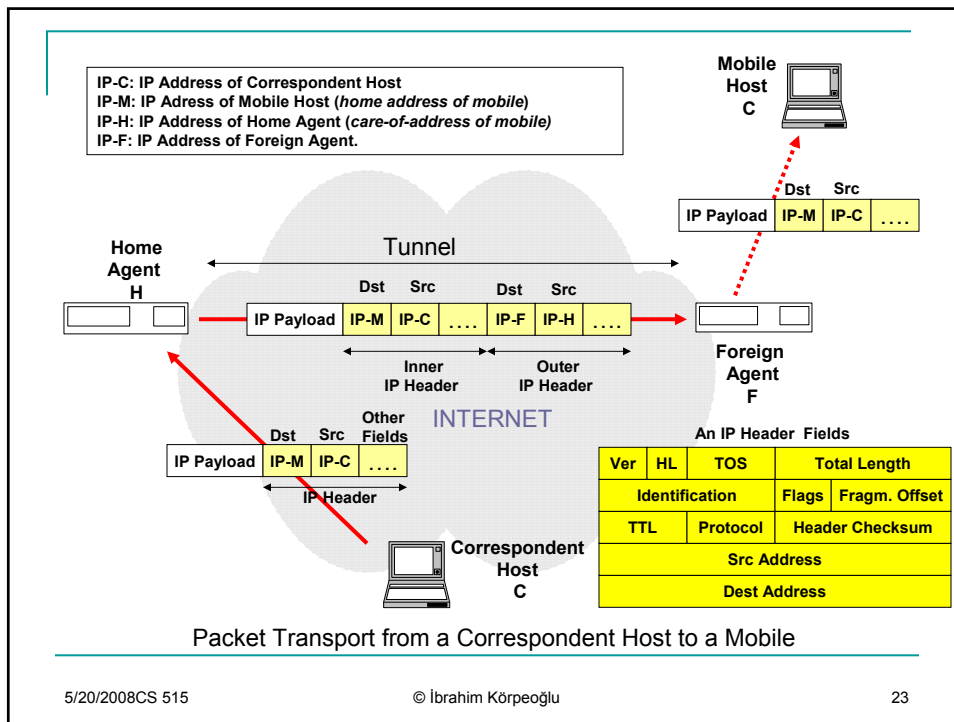


Example

- A correspondent host C wants to send an IP packet to a mobile host M.
 - It generated the IP packet so that the IP packet has **destination address** equal to mobile's home address
 - The IP packet is send to the **mobile's home address**
 - Routers forward the packet **using normal Internet routing mechanisms** to the home network of the mobile.
 - Assume mobile is away from home network and currently is located in a foreign network. Hence **mobile will not be able to receive** (capture) the packet that is sent to the mobile's home network.
 - A home agent located in the mobile's home network will **intercept** the packet aimed for mobile
 - This interception is done with the help of **proxy ARPing**.
 - Home agent will know the whereabouts of the mobile, if the mobile has **registered** with the home agent previously.

Example – continued.

- **Home agent will encapsulate** the IP packet using IP-IP encapsulation (tunneling) method and will send the encapsulated IP packet to the new location (care-of-address) of the mobile. The new location is the foreign network that the mobile currently resides in.
- The **encapsulated IP** packet will be transported to the care-of-address of the mobile using **normal Internet routing mechanisms**.
 - Care-of-address can be the **IP address of a foreign agent** or **the new IP address of the mobile** at the new location obtained via methods like DHCP, etc. In this case the foreign agent could be co-located at the mobile host.
- The holder of the care-of-address (a foreign agent) will receive the encapsulated IP datagram, will strip off the outer header (**decapsulate**) and will forward the original IP packet to the mobile host.
- The mobile host will receive the packet as it is coming from a correspondent host directly without going through the home agent (if foreign agent functionality is not co-located at the mobile host).



Mobile IP Functions

- **Agent Discovery – using extension to ICMP**
 - When a mobile node moves into a new subnetwork (or network), it has to discover the foreign agent in that network
 - For this, mobile agents (home and foreign) advertise their presence periodically using ICMP messages.
- **Registration – using UDP**
 - When a mobile moves to a new network and obtains a new care-of-address there, it has to register that address with the home agent (binding), so that home agent knows where to forward the packets aimed for mobile.
 - Registration should be secure
- **Tunneling**
 - When packet aimed for mobile are intercepted by home agent, they are forward to the current location (care-of-address) of the mobile using a mechanism called Tunneling
 - There are various forms of tunneling: IP-IP, Minimum Encapsulation, GRE, etc.

Mobile Agent Discovery

- How a mobile node discovers the home and foreign agents when it travels?
- Agents periodically broadcast their presence (advertisement) on a link (a wireless link – 802.11, or a wired link – ethernet)
 - These broadcasts are **agent advertisement messages**.
- A mobile node receiving the advertisement understand from the IP addresses included in the advertisement:
 - Whether it is in the home network or not?
 - Whether it has moved to new location or not.
- This understanding is at the IP level
 - (A mobile already knows that it has moved at the physical link level if has moved).

Mobile Agent Discovery

- An agent advertisement message is an **ICMP router advertisement message** with special extension.
- Original router discovery protocol (ICMP) is specified by RFC 1256
- The special extension is called Mobility Agent Extension.

- No Authentication is required!! – Why?
- A mobile node may also solicit a mobile agent discovery message
- Why?
 - Allow detection of mobility agents
 - Lists one or more care-of-address
 - Informs mobile node of special features of that mobility agent

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Router Discovery Protocols - background

- Original router discovery protocol (ICMP) is specified by RFC 1256

- **Type:** 9
- **Code:** 0
- **Checksum:**
- **Num addr:** the number of router addresses advertised in this message
- **Addr entry size:** the number of 32-bit words of info for each router address (typically 2)
- **Lifetime:** the maximum number of seconds that the router addresses may be considered valid
- **Router address(i):** $i=1..num\ addr$, the sending router's IP addresses on the interface from which this message is sent
- **Preference level(i):** $i=1..num\ addr$, the preferability of each corresponding router address as a default router address relative to other router addresses on the same subnet

| Type | Code | Checksum |
|----------------------|-----------------|----------|
| Num addr | Addr entry size | Lifetime |
| Router address (1) | | |
| Preference level (1) | | |
| . | | |
| . | | |

Router Advertisements (From RFC 1256)

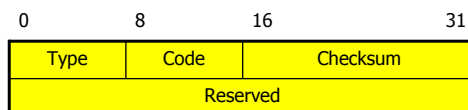
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Router Discovery Protocols - background

- Router solicitation – when a host needs a timely information
- **Type:** 10
- **Code:** 0
- **Checksum:**
- **Reserved:** sent as 0 – ignored on reception



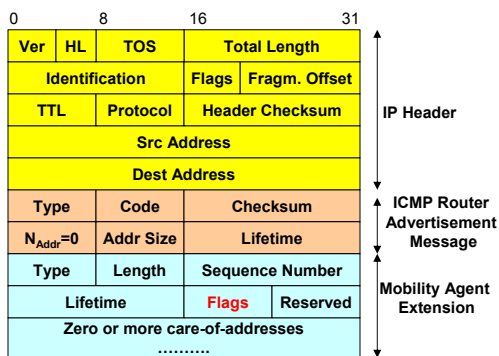
Router Solicitations (From RFC 1256)

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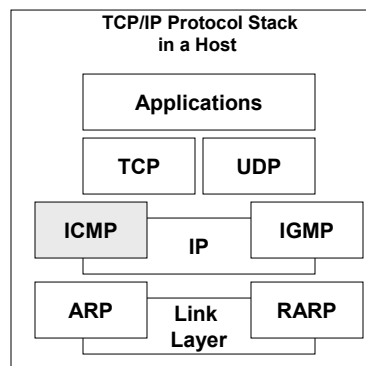
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Agent Advertisement Message



FLAGS
 R: Registration required (with the foreign agent)
 B: Foreign agent is busy
 H: The agent is home agent.
 F: The agent is foreign agent
 M: Minimum encapsulation
 G: GRE encapsulation
 V: Van Jacobson Header Compression



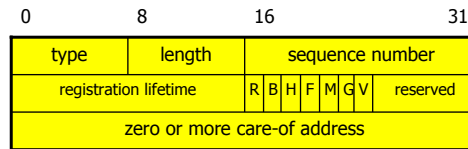
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Mobility Agent Advertisement Extensions

- **Type:** 16
- **Length:** $(6+4*N)$, where N is the # of care-of addresses advertised
- **Sequence number:** the count of agent advertisement messages sent since the agent was initialized
- **Registration lifetime:** the longest lifetime (measured in seconds) that this agent is willing to access in any registration request; 65535 indicates infinity
- **R, B, H, F, M, G, V:** see previous slide
- **Care-of address:** The advertised foreign agent care-of address provided by this foreign agent. An agent advertisement is required to include at least one care-of address if the F bit is set.



Mobility Agent Advertisement Extension

Registration

Once the mobile node obtains its care-of-address it has to **REGISTER** with the home mobile agent

- After a **mobile** detects at the IP (ICMP) layer that it has moved to a new location, it starts **registration procedure with the home agent**.
 - The aim of the registration is to let the home agent know mobile's current care-of-address. Mobile obtains this care-of-address either from the foreign agent or from a server like DHCP server.
- Registration procedure consists of sending a Registration Request Message from mobile to home agent and a Registration Reply Message from home agent to mobile
- Registration messages has to go through Foreign agent.
 - Foreign Agent just forwards these registration messages back and forth
 - Foreign agent is a passive entity in registration. .
- Registration messages sent over UDP to port number 434.

Registration Objectives

ALWAYS

- Request forwarding services when visiting a foreign network
- Inform their home agent of their current COA
- Renew a binding that is due to expire
- De-register when they return home

OPTIONAL

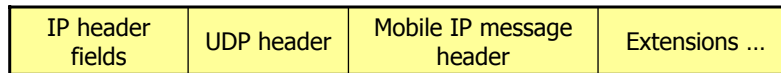
- Discover the address of the home agent if the mobile node is not configured with this info
- Select certain alternative tunneling protocols (minimal encapsulations or GRE) - Required of the use of Van Jacobson header compression
- Maintain multiple simultaneous registration so that a copy of each datagram will be tunneled to each active COA
- De-register certain COAs while retaining others

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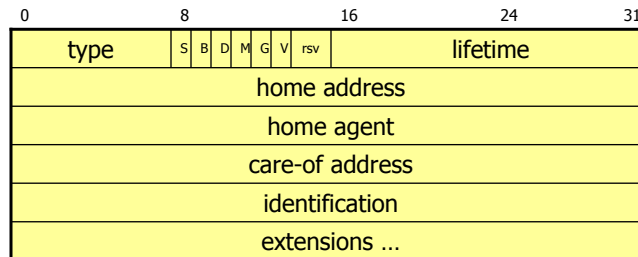
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Registration Packet



General Mobile IP Registration Message



Registration request packet format

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Registration Request

| 0 | 8 | 16 | 31 |
|---------------------|-------|----------|----|
| Type | Flags | Lifetime | |
| Home address | | | |
| Home agent | | | |
| Care-of-address | | | |
| Identification | | | |
| Extensions | | | |

Registration Request Format



Type: Type of the Mobile IP Message:
1 – Registration Request.

Lifetime: Number of seconds registration is valid.

Home address: The home IP address of the mobile

Home agent: The IP address of the home agent.

Care-of-address: The current IP address of the mobile – this is then end of the tunnel.

Identification: Used for replay protection.

Extensions: Security extensions can be added to protect from malicious people.

Flags:

S: Simultaneous binding (retain previous binding).

B: Broadcast – Home agent will tunnel broadcast datagrams to the mobile

D: Mobile node is using a *collocated* care-of-address – that means there is no foreign agent and mobile node will decapsulate the packets itself.

M: Mobile node requests the home agent to encapsulate the packets using Minimal Encapsulation

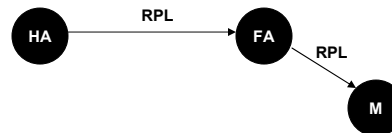
G: Mobile node requests the home agent to encapsulate the packets using GRE Encapsulation

| | | | |
|-----------|------------|-------------------|------------|
| IP Header | UDP Header | Mobile IP Message | Extensions |
|-----------|------------|-------------------|------------|

Registration Reply

| 0 | 8 | 16 | 31 |
|---------------------|------|----------|----|
| Type | Code | Lifetime | |
| Home address | | | |
| Home agent | | | |
| Identification | | | |
| Extensions | | | |

Registration Reply Format



Type: 3 – Registration Reply

Code: Indicates the result of registration

Some code values:

0 registration accepted

66 insufficient resources at foreign agent

70 poorly formed request

130 insufficient resources at home agent

131 mobile node failed authentication

Lifetime: The granted life time by home agent for registration

Identification: depends on the identification in the request

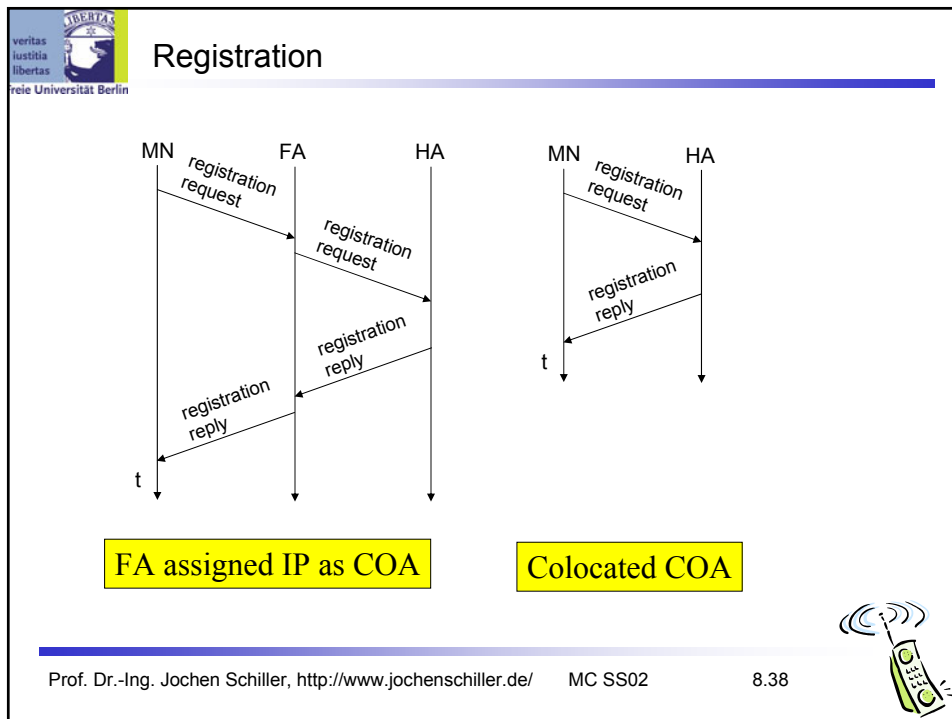
Care-of-Address Types

- Normal Care-of-address
 - The care-of-address that mobile obtains at a new location is the IP address of a foreign agent serving at that new location.
 - Registration and communication has to go through foreign agent
- Collocated care-of-address
 - There is no separate foreign agent present at the new location
 - Mobile obtains an IP at the new location through some standard mechanisms like DHCP.
 - This IP address is called collocated IP address.
 - The foreign agent functionality is executed at the mobile node itself.
 - The mobile node decapsulates the tunneled packets coming from home agent.
 - Registration and communication is done directly between mobile and home agent.

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Securing the registration procedure

- Security problem
 - Fraudulent registrations should be detected.
 - A bad person can send registration packets to home agent as if the packets are coming from a legitimate mobile user.
 - In this way, the bad user can redirect the traffic destined to mobile node to itself and obtain the packets.
 - Hence we need authentication
- There are three authentication extensions defined for Mobile IP
 - The mobile-home authentication extension
 - The mobile-foreign authentication extension
 - The foreign-home authentication extension.

Authentication Overview

- Mobility Security Association = SPI + IP
 - Security Parameter Index (SPI)
 - For mobile node, IP = home address not COA

Securing the registration procedure

| | | | | |
|--------------------|--------|---------------|----|----|
| | 0 | 8 | 16 | 31 |
| Type | Length | SPI | | |
| SPI....continued | | Authenticator | | |
| Authenticator..... | | | | |

Mobile IP Authentication Extension
Added to the Registration Request
Message

Type: 32 – Mobile-Home authentication extension
33 – Mobile-Foreign authentication extension
34 – Foreign-Home authentication extension
SPI: Security Parameter Index. Defines the security
context (algorithm, mode, key) to compute
the authenticator.

Authenticator: variable length.

What are the potential dangers?
What are “replay” attacks?

Default Authentication Algorithm:

Keyed-MD5 in prefix-suffix mode

128 bit authenticator: message digest of the registration message.

Computed over:

shared secret key,
spi index,
protected fields of registration message,
shared secret again.

Example 1: (section 4.11 of book)

| | |
|----------------------------------|---------------|
| Mobile node IP home address | 129.34.78.5 |
| Mobile node's home agent | 129.34.78.254 |
| Foreign agent's wireless address | 137.0.0.11 |
| Foreign agent coa | 9.2.20.11 |
| DHCP-allocated coa | 9.2.43.94 |
| Mobile node's source port | 1094 |
| Foreign agent's source port | 1105 |
| coa registration lifetime | 60,000 sec |
| Home agent granted lifetime | 35,000 sec |

Example 1: (section 4.11 of book)- 2

Agent Advertisement

| IP header fields | ICMP header | Router Adv. fields | Mobile Service Extension |
|--|---------------------|--------------------|--------------------------------------|
| S = 137.0.0.11 D = 255.255.255.255 F = 1 | Type = 9 Code 16 | ... | Lifetime = 60,000 COA = 9.2.20.11 |

Mobile → Foreign Agent

| IP header fields | UDP header | Mobile IP msg fields | Authentication Ext. |
|--|---------------------|--|---------------------|
| S = 129.34.78.5 D = 137.0.0.11 TTL = 1 | S = 1094 D = 434 | Type = 1 Lifetime = 60,000 COA = 9.2.20.11 HA = 129.34.78.254 MA = 129.34.78.5 | SPI = 302 |

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Example 1: (section 4.11 of book)- 3

Foreign Agent → Home

| IP header fields | UDP header | Mobile IP msg fields | Authentication Ext. |
|--|---------------------|--|---------------------|
| S = 9.2.20.11 D = 129.34.78.254 TTL = 64 | S = 1105 D = 434 | Type = 1 Lifetime = 60,000 COA = 9.2.20.11 HA = 129.34.78.254 MA = 129.34.78.5 | SPI = 302 |

Home → Foreign Agent

| IP header fields | UDP header | Mobile IP msg fields | Authentication Ext. |
|--|---------------------|---|---------------------|
| S = 129.34.78.254 D = 9.2.20.11 TTL = 64 | S = 434 D = 1105 | Type = 3 Lifetime = 35,000 HA = 129.34.78.254 MA = 129.34.78.5 | SPI = 303 |

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Example 1: (section 4.11 of book)- 4

Foreign Agent → Mobile

| IP header fields | UDP header | Mobile IP msg fields | Authentication Ext. |
|--|---------------------|---|---------------------|
| S = 137.0.0.11 D = 129.34.78.5 TTL = 1 | S = 434 D = 1094 | Type = 3 Lifetime = 35,000 HA = 129.34.78.254 MA = 129.34.78.5 | SPI = 303 |

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Example 2: (section 4.11 of book)

| | |
|-----------------------------|---------------|
| Mobile node IP home address | 129.34.78.5 |
| Mobile node's home agent | 129.34.78.254 |
| DHCP-allocated coa | 9.2.43.94 |
| Mobile node's source port | 1094 |
| coa registration lifetime | 60,000 sec |
| Home agent granted lifetime | 35,000 sec |

Mobile enters a foreign network that contains no foreign agents. The mobile obtains an address from a DHCP server for use as a co-located care-of address. The mobile support minimal encapsulation and GRE.

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Example 2: (section 4.11 of book)- 2

Mobile → Home Registration Request

| IP header fields | UDP header | Mobile IP msg fields | Authentication Ext. |
|--|---------------------|---|---------------------|
| S = 129.34.78.5 D = 129.34.78.254 TTL = 64 | S = 1094 D = 434 | Type = 1 Lifetime = 665535 COA = 9.2.43.94 HA = 129.34.78.254 MA = 129.34.78.5 D.M.G.B = 1,1,1,1 | SPI = 302 |

Home → Mobile Registration Reply

| IP header fields | UDP header | Mobile IP msg fields | Authentication Ext. |
|--|---------------------|---|---------------------|
| S = 129.34.78.254 D = 129.34.78.5 TTL = 64 | S = 434 D = 1094 | Type = 3 Lifetime = 35000 COA = 9.2.43.94 HA = 129.34.78.254 MA = 129.34.78.5 | SPI = 303 |

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Example 3: (section 4.11 of book)

Mobile returns home and wishes to de-register all of care-off addresses with its home agent. The care-off address fields are the same as the mobile node's home address, and the requested (and granted) lifetimes are 0.

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Example 3: (section 4.11 of book)- 2

Agent Advertisement

| IP header fields | ICMP header | Router Adv. fields | Mobile Service Extension |
|---|---------------------|--------------------|-------------------------------------|
| S = 129.34.78.254 D = 255.255.255.255 H = 1 | Type = 9 Code 16 | ... | ... no COAs ... Lifetime = 35000 |

Mobile → Home Agent

| IP header fields | UDP header | Mobile IP msg fields | Authentication Ext. |
|---|---------------------|---|---------------------|
| S = 129.34.78.5 D = 129.34.78.254 TTL = 1 | S = 1094 D = 434 | Type = 1 Lifetime = 0 COA = 129.34.78.5 HA = 129.34.78.254 MA = 129.34.78.5 | SPI = 302 |

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Example 3: (section 4.11 of book)- 2

Home → Mobile

| IP header fields | UDP header | Mobile IP msg fields | Authentication Ext. |
|---|---------------------|---|---------------------|
| S = 129.34.78.254 D = 129.34.78.5 TTL = 1 | S = 434 D = 1094 | Type = 3 Lifetime = 0 COA = 129.34.78.5 HA = 129.34.78.254 MA = 129.34.78.5 | SPI = 303 |

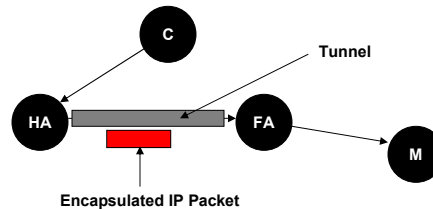
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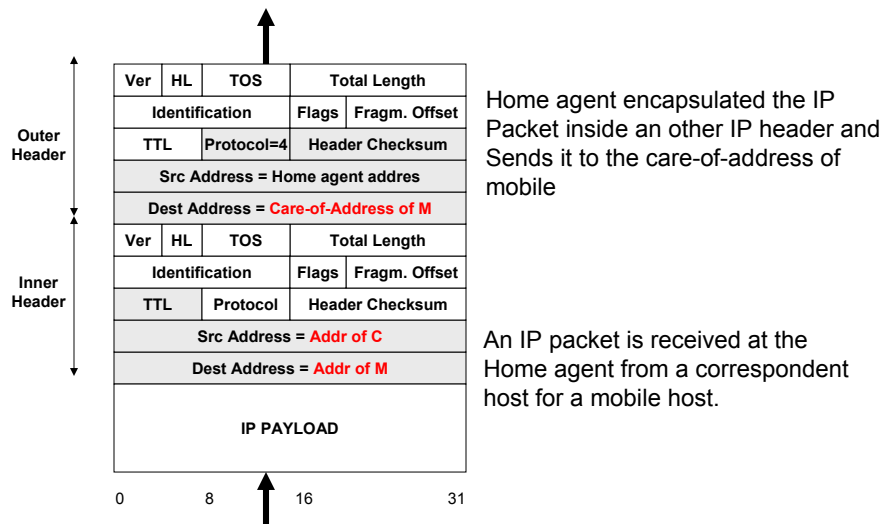
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Routing and Tunneling

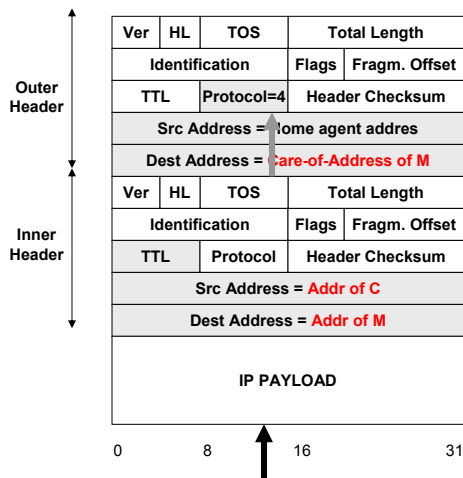
- When a correspondent host sends an IP packet to a mobile (to its home address), packet is routed first to home agent of mobile through normal routing.
- Home agent intercepts the packet and encapsulates it and tunnels it to the care-of-address (tunnel exit point) of the mobile.
 - The encapsulated packet is delivered to the care-of-address using **normal routing**.
- There are various encapsulation methods:
 - IP-IP Encapsulation
 - Minimal Encapsulation
 - GRE (Generic Routing Encapsulation) Encapsulation.



IP-IP Encapsulation at Home Agent



IP-IP Decapsulation at the Care-of-Address

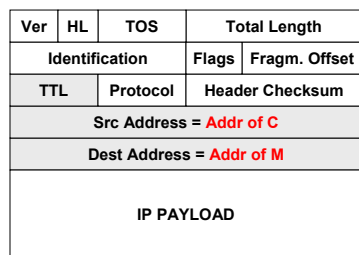


An encapsulated IP packet is received at the foreign agent (or at the mobile itself for a collocated care-of-address).

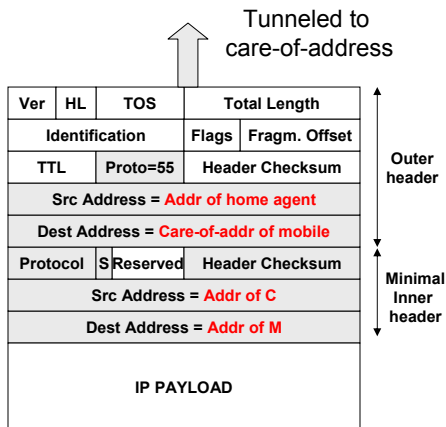
Receiver understands that the packet is IP-IP encapsulated by looking to the protocol field (which is 4).

Receiver forwards (not routes) the decapsulated IP packet to the mobile node using link-level mechanisms!

Minimal Encapsulation at Home Agent



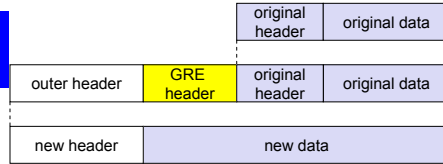
Packet comes from Correspondent host



Encapsulated using Minimal Encapsulation Method

Generic Routing Encapsulation

GRE = A protocol for encapsulation of an arbitrary network layer protocol over another arbitrary network layer protocol



RFC 1701

| | | | | |
|----------------------------|------|-------------------|-----------------|---|
| ver. | IHL | DS (TOS) | length | |
| IP identification | | flags | fragment offset | |
| TTL | GRE | | IP checksum | |
| IP address of HA | | | | |
| Care-of address COA | | | | |
| C | R | K | S | s |
| rec. | rsv. | ver. | protocol | |
| checksum (optional) | | offset (optional) | | |
| key (optional) | | | | |
| sequence number (optional) | | | | |
| routing (optional) | | | | |
| ver. | IHL | DS (TOS) | length | |
| IP identification | | flags | fragment offset | |
| TTL | lay. | 4 prot. | IP checksum | |
| IP address of CN | | | | |
| IP address of MN | | | | |
| TCP/UDP/ ... payload | | | | |

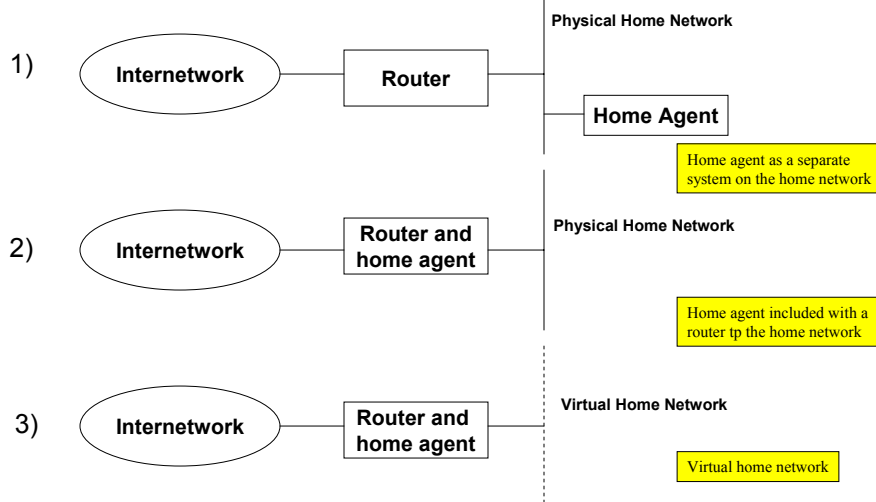
RFC 2784

| | | | |
|---------------------|-----------|----------------|----------|
| C | reserved0 | ver. | protocol |
| checksum (optional) | | reserved1 (=0) | |

More details about GRE @:
 - RFC 2784 (<http://www.faqs.org/rfcs/rfc2784.html>)
 - <http://www.networksorcery.com/enp/protocol/gre.htm>,

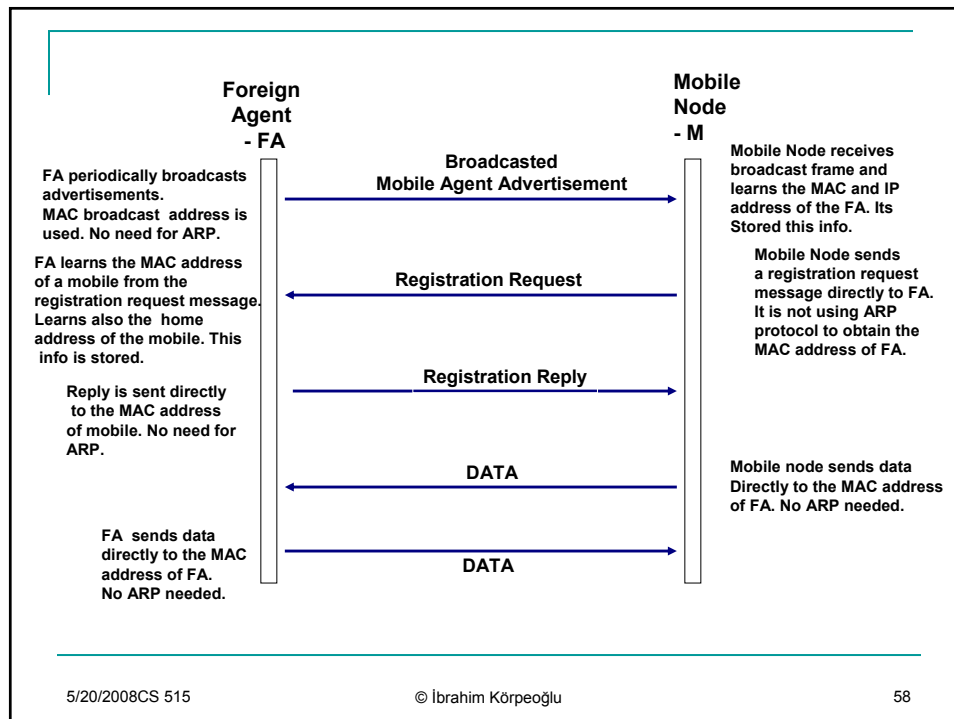


Home Network Configurations

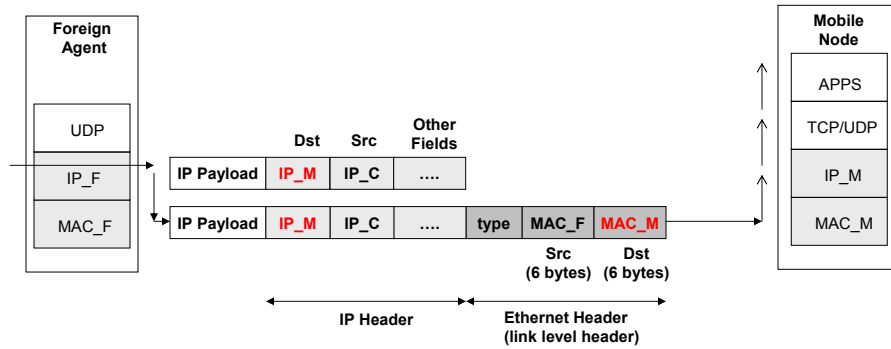


Sending packets between mobile and foreign agent

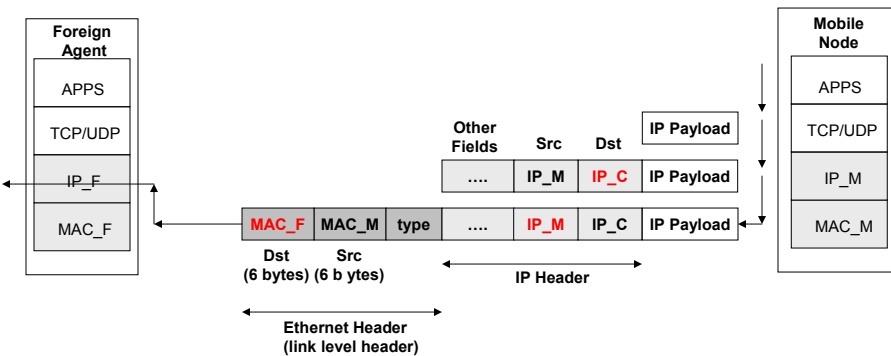
- When a mobile moves to a new location, a foreign should be broadcasting (IP and link layer broadcast) advertisements on the link (sub-network).
- Mobile will be able to receive this broadcast message and will learn:
 - The IP address of the foreign agent (this will be the care-of-address of the mobile most of the time).
 - The hardware (MAC or link-level address) of the foreign agent.
- When mobile sends a registration packet through this foreign agent, the foreign agent will learn:
 - The home address of the mobile
 - The hardware (MAC or link level) address of the mobile.
 - The registration packet will be sent directly to the foreign agent by using the MAC address of the foreign agent (No need to do ARP request).



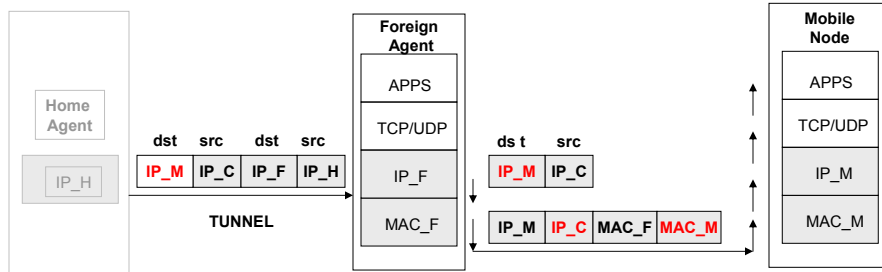
Sending Data from Foreign Agent to Mobile



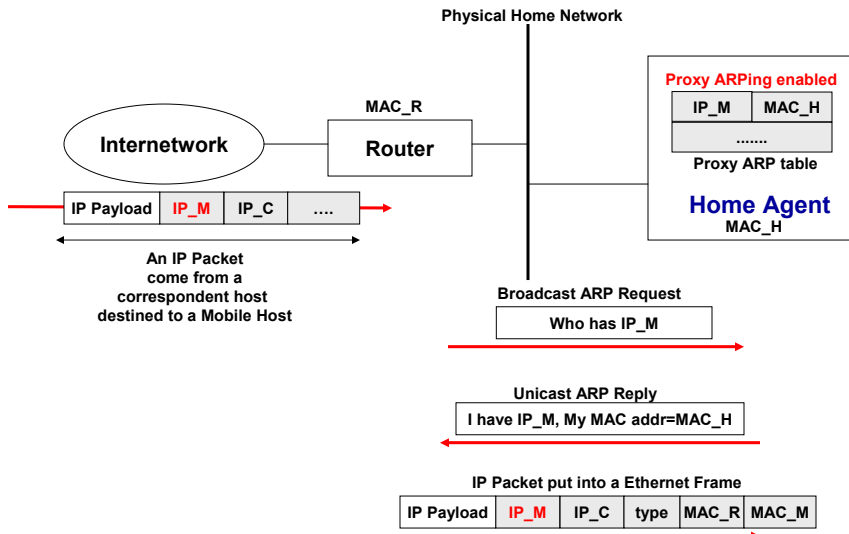
Sending Data from Mobile to Foreign Agent



Decapsulation again



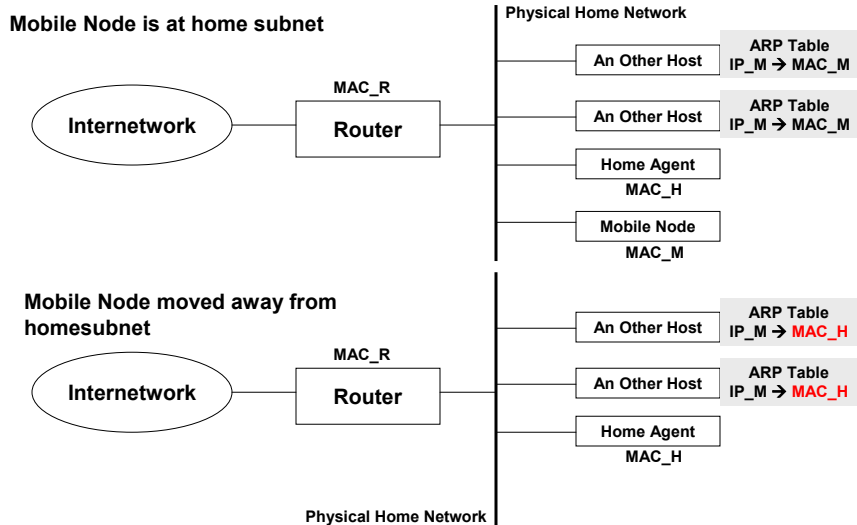
How to attract packets at the Home network



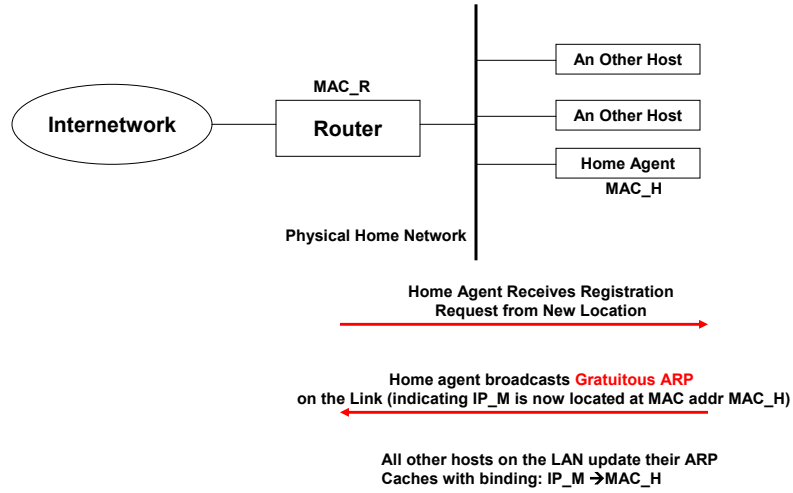
Proxy ARPing

- The packet comes to the last router that the home subnetwork is connected to.
- The router will try to resolve the IP address of Mobile (IP_M) into the corresponding MAC layer address (Hardware address).
- For this purpose, it will broadcast an ARP request packet
- Since the mobile is not at home subnet, it will not be able to answer ARP request.
- Home agent will answer instead of the Mobile node. In order to do this, home agent should be configured to do proxy ARPing.
- Home agent replies to the ARP request with an ARP reply, including its MAC address (MAC_H) as the MAC level address corresponding to the IP address of the Mobile.
- The router, upon receiving the ARP reply, will send the IP packet to the MAC address of the home agent.
- In this way, the home agent attracts the IP packets that are destined to the mobile node.

Gratuitous ARP Functionality

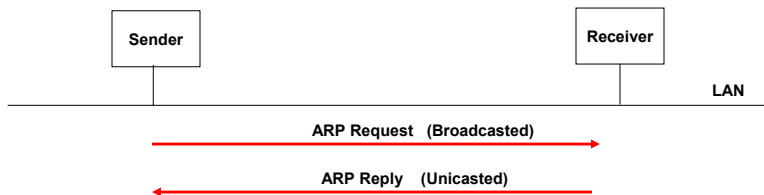
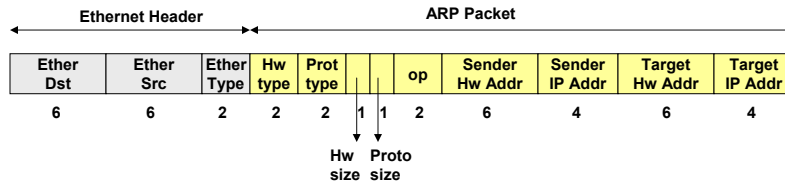


Gratuitous ARP Operation

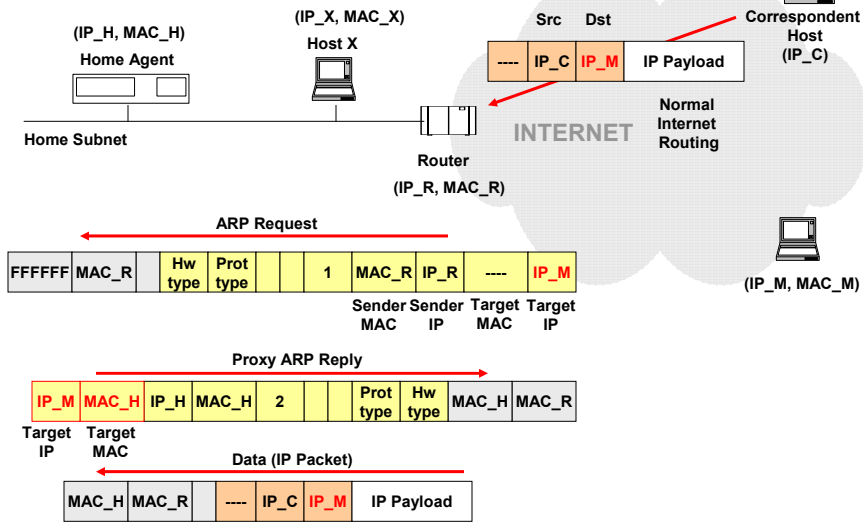


ARP Packet Format

Ether Type: 0x8006 ARP protocol
 Op Field: 1 – ARP Request
 2 – ARP Reply



Example: Proxy ARP

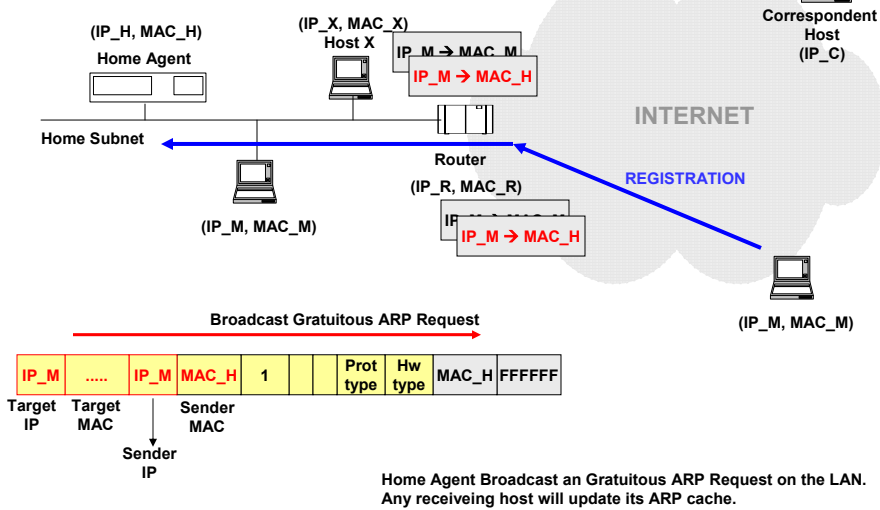


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Example: Gratuitous ARP



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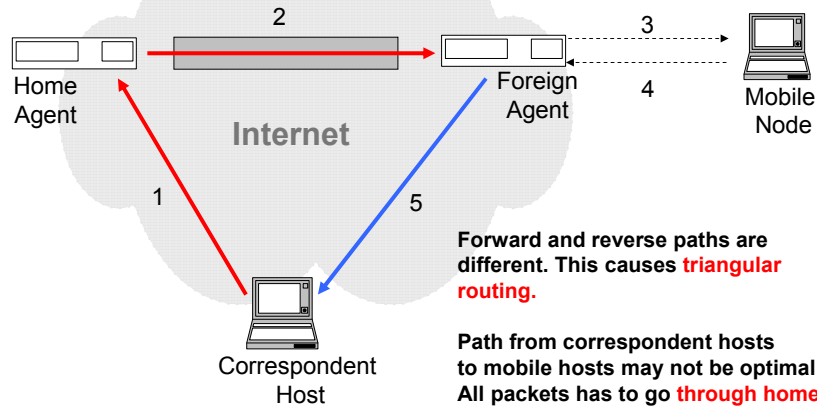
Route Optimization in Mobile IP

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Triangular Routing



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Solution Approach

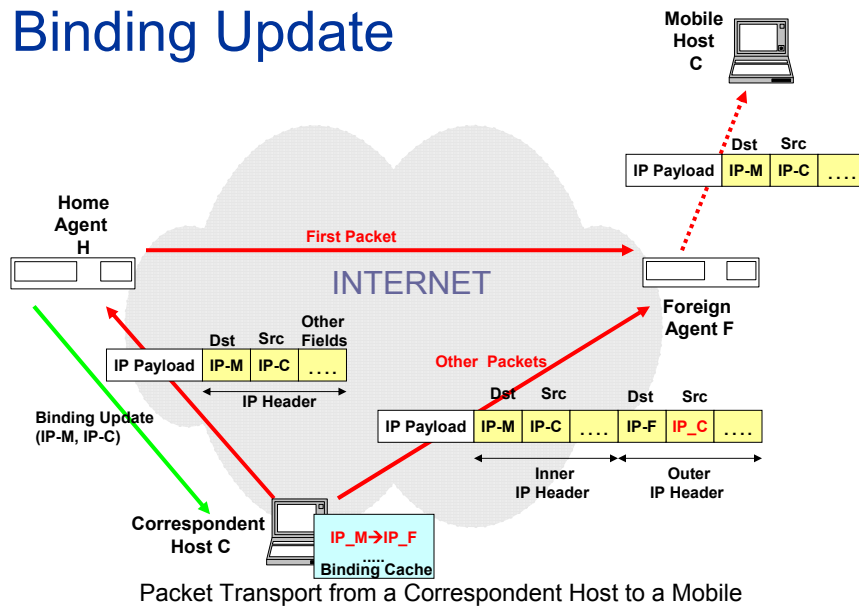
If the COA is a collocated address, the CN sends directly to the mobile host (no FA intervention)
Else
The en/de-capsulation are used and the tunnel ends at the FA

- Let the correspondent hosts know the current mobility binding or just binding (home address → care-of-address mapping) for mobile hosts.
 - They will **store this binding**.
 - They will use this binding to **directly send the packets** to the current location of the mobile.
 - They will again use encapsulation since the care-of-address may not be always collocated at the mobile node (foreign agent should decapsulate).
 - The **encapsulated packets** will go to the care-of-address directly without going through the home agent.
 - Correspondent hosts should support the binding protocol: Need for **modification at correspondent hosts!**.

Binding Update

- How does a correspondent host will learn the current binding for the mobile node?
 - Let the mobile node inform the correspondent host!
 - For example when it receives a packet from a correspondent host
 - Let the home agent inform the correspondent host.
 - This is the method chosen, since it is **easier to establish security association** between a home agent and a correspondent host (Binding update should be secure so the malicious users can not send binding updates to the correspondent hosts without **authenticating** themselves).

Binding Update



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Binding Warning/Request

- A correspondent host may request a binding Update message from Home agent.
 - Correspondent host sends a **Binding Request** message and waits for a Binding Update Message.
- A mobile node may warn a Home agent (or some other agent) to send a **Binding Update** message to a particular host (a correspondent host or to some other host).
 - Mobile node sends a **Binding Warning** message.
 - Binding warning message include the host IP address (called target address field) to where an Update will be sent.
- A host receiving a **Binding Update** message should send back a **Binding Acknowledgement** message.
 - The sender of Binding Update may retransmit Binding Update if it did not received a Binding Acknowledgement message. The retransmission should occur after a backoff time.
- All binding messages are **sent over UDP**.

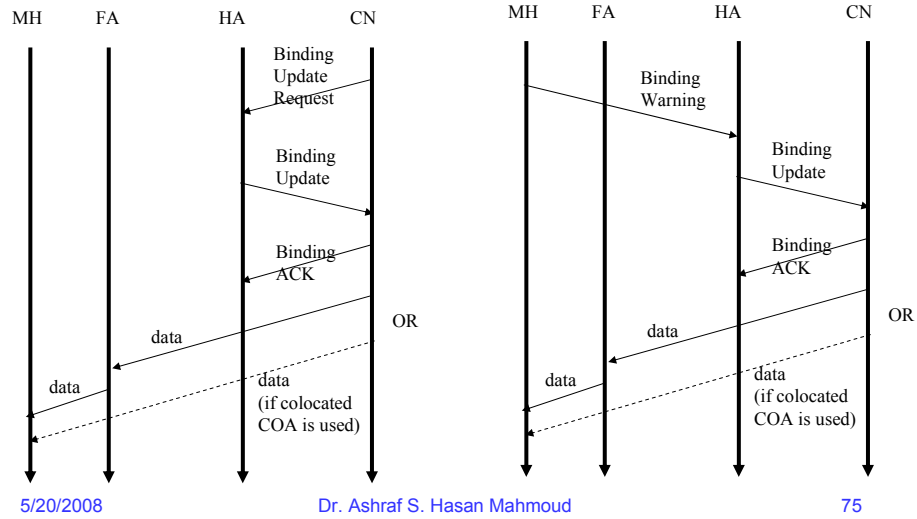
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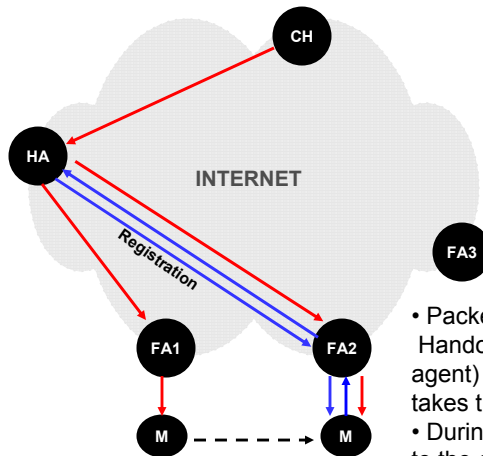
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- Questions:
1. Why should CN continue to do IP encapsulation?
 2. What are the modifications at the CN required for this Binding update method to work?

Binding Update/Request/Warning

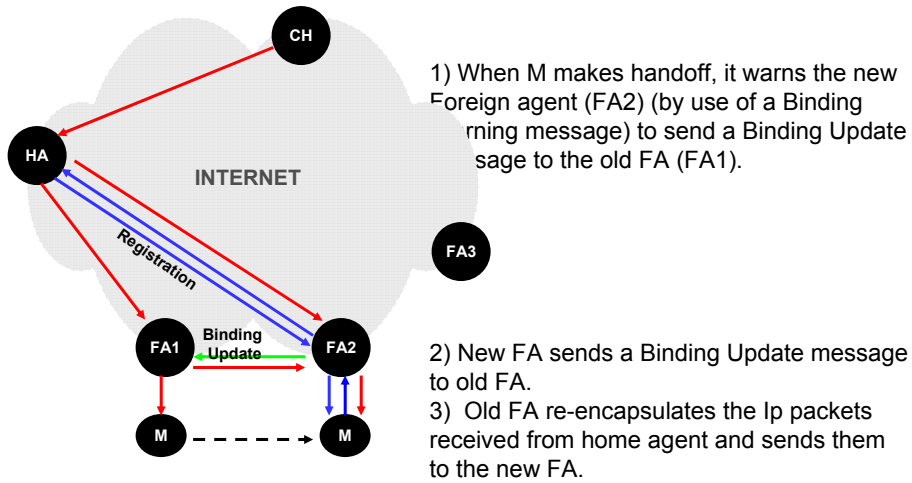


Smooth Handoffs



- Packets may be dropped during handoffs. Handoff to a new base station (or foreign agent) and registration with home agent takes time.
- During this time, packets will be forwarded to the old base station (FA), where the mobile node moved away from.

Smooth Handoffs



Supporting Fast Handoffs in Mobile IP

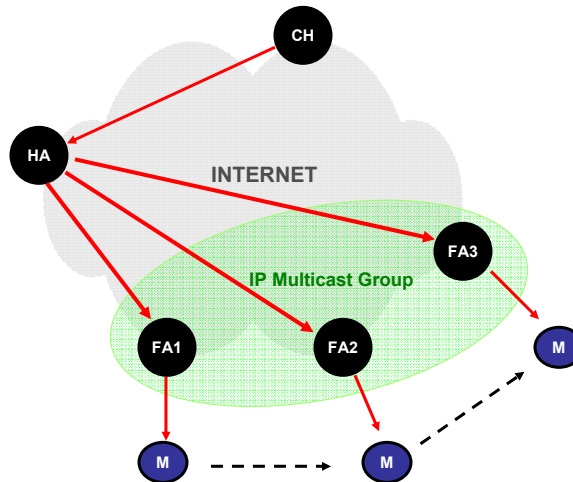
Fast Handoffs

- For highly mobile users, handoffs will be too frequent. Implications of this:
 - Handoffs should be very fast in order to minimize packet delays and packet losses.
 - Registration will be too frequent:
 - Registration causes delay
 - Registration causes extra signaling (control) traffic in the wireless link and infrastructure.
- Two solution approaches to support fast handoffs:
 - Use of IP **multicasting**
 - Use of **hierarchical foreign agents**.

Use of IP Multicasting

- A collection of foreign agents in the vicinity of each other join to a multicast group. The group will have a **multicast IP address**.
- Mobile node will use this multicast IP address as the care-of-address.
- The home agent will send the encapsulated packets for the mobile to this multicast IP address.
- Foreign agents in the multicast group will **buffer the received encapsulated IP packets** for a while before discarding
 - In this way, when a mobile handoffs from one FA to an other FA (in the same multicast group), it will be able to recover the packets transmitted during handoff from the new FA.

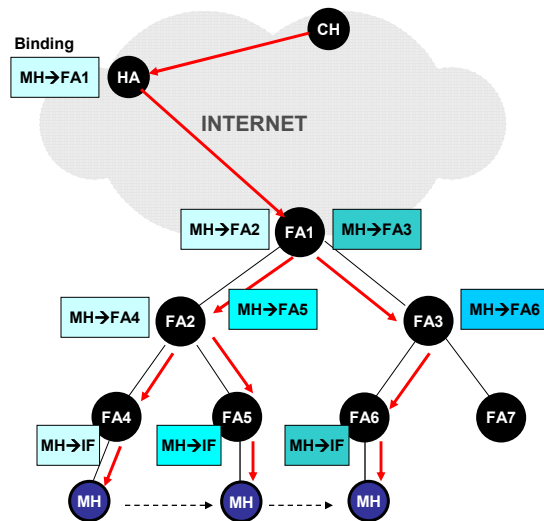
Use of IP Multicasting



Hierarchical Foreign Agents

- Uses a hierarchy of foreign agents between mobile node and home agent.
- **Aims is to localize handoffs and registration.**
- The hierarchy could be consisting of for example:
 - Base stations (access points) at the lowest level – leaf.
 - Intermediate routers between base stations and campus edge routers in a campus.
 - Campus edge router at the highest level (root) of the foreign agent hierarchy.

Hierarchical Foreign Agents



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Hierarchical Foreign Agents

- The following functions of Mobile IP is enhanced:
 - Agent Advertisements
 - Registration
 - Data Forwarding

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Agent Advertisements

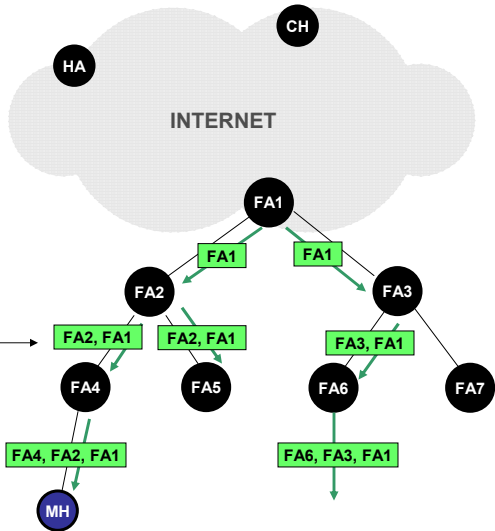
Mobility Agent Extension to ICMP Router Advertisement

| Type | Length | Sequence Number |
|--------------------------------|--------|-----------------|
| Lifetime | Flags | Reserved |
| Zero or more care-of-addresses | | |
| | | |

Agent Advertisement message
Care-of-Address field content

In a message, FAx denotes the IP address of Foreign Agent X.

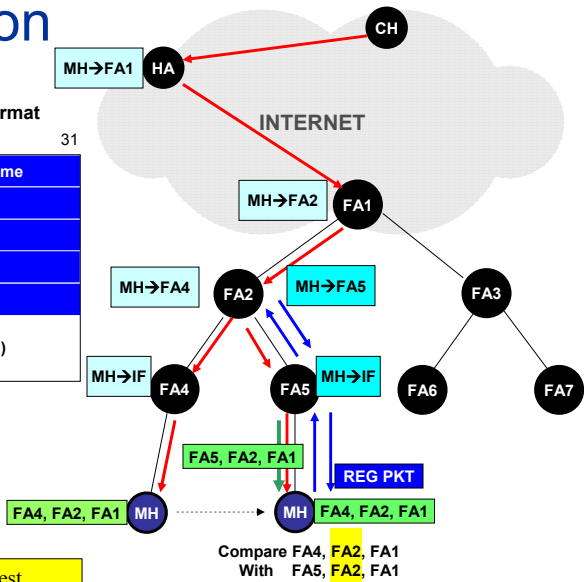
ICMP extension
-I bit (flag) – indicates a hierarchy of COAs



Registration

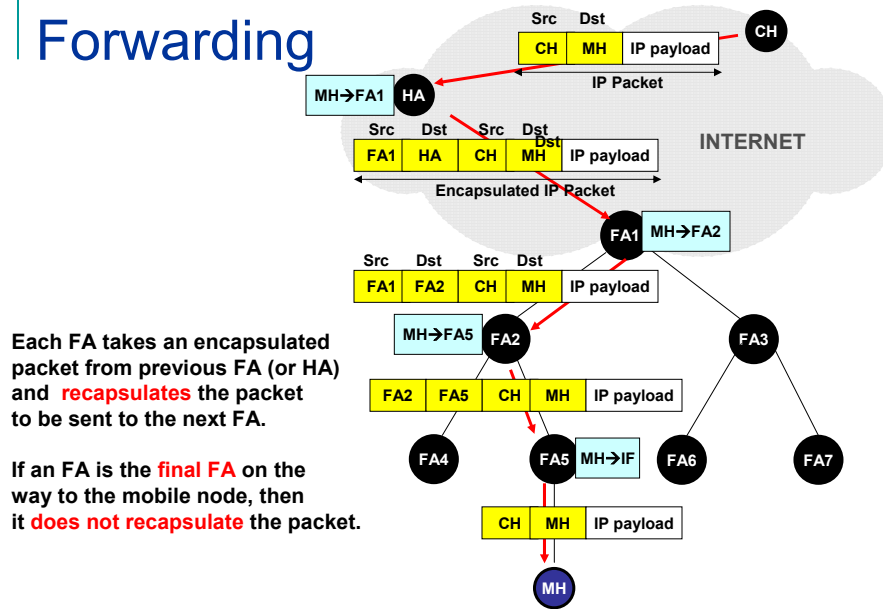
Registration Request Format

| Type | Flags | Lifetime |
|---------------------------------------|-------|----------|
| Home address=MH | | |
| Home agent=FA2 | | |
| Care-of-address=FA5 | | |
| Identification | | |
| Extensions (Authentication Extension) | | |
| | | |



REGIONAL Registration Request
- Sequence of tunnels
- Home agent: closest common ancestor

Forwarding



BACKUP SLIDES

