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Mobile IP

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Outline

Part I: Mobile Internet

- Trends in networks
- Technology
  - 3rd Generation Mobile Networks
  - Bluetooth
  - Internet QoS
  - Mobile IP (see part II)
- Applications
- Conclusion

Part II: Mobile IP

- IP Refresher
- Mobile IP Basics
- 3 parts of Mobile IP:
  - Advertising Care-of Addresses
  - Registration
  - Tunneling
- Problems \ extensions
- Mobility for IPv6
- Conclusion

What is the Internet?

- A large collection of networks,
  - of various types (e.g. Ethernet, ATM, POS, modem, IEEE 802.11, Bluetooth),
  - broadcast as well as point-to-point,
  - at various speeds (kbit/s - Gbit/s),
- interconnected by routers,
  - all acting on a common protocol: IP,
- with applications running on the end systems (hosts),
  - using either TCP or UDP as a transport protocol,
  - example applications are WWW (using http), email (smtp / pop3 / imap), news (nntp), telnet, ftp.

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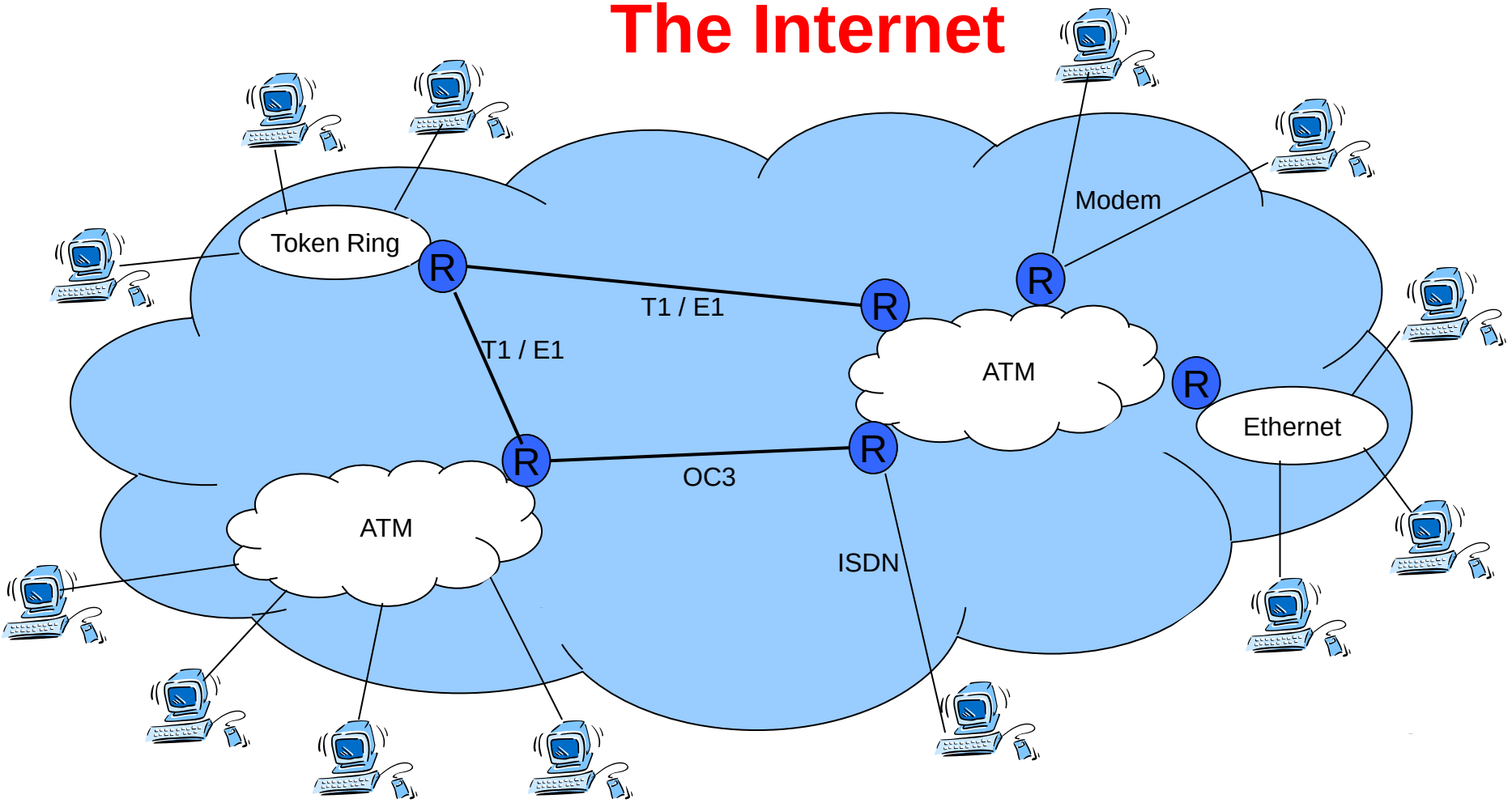
The Internet



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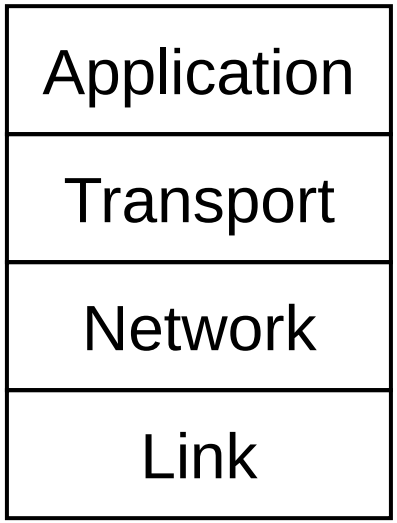
Internet Protocol Stack



Telnet, FTP, HTTP, SMTP, POP3, IMAP, NNTP

TCP, UDP

IP, ICMP

device driver and interface card

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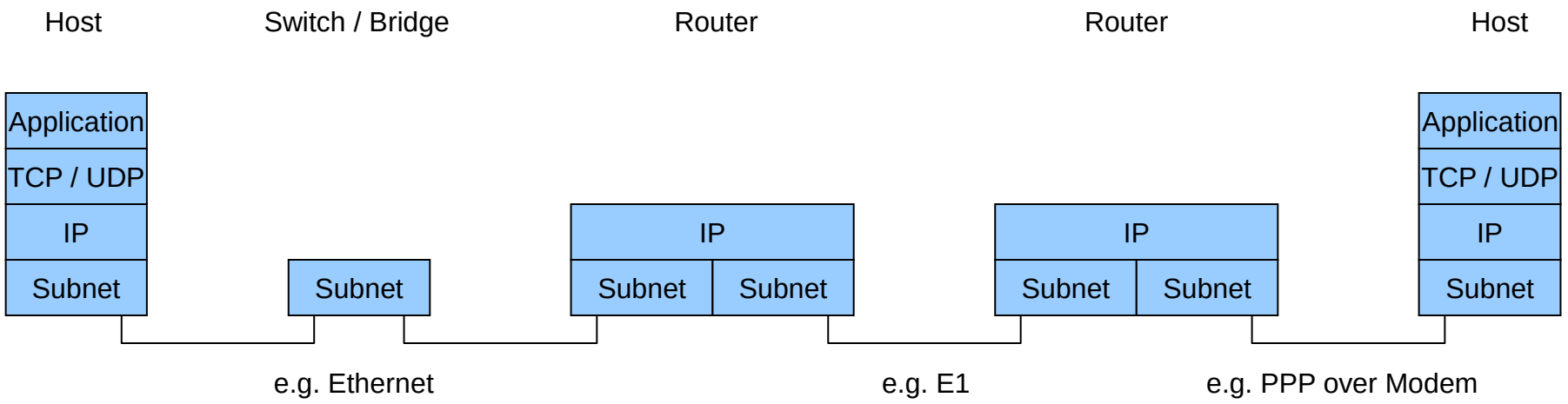
The Internet (2)



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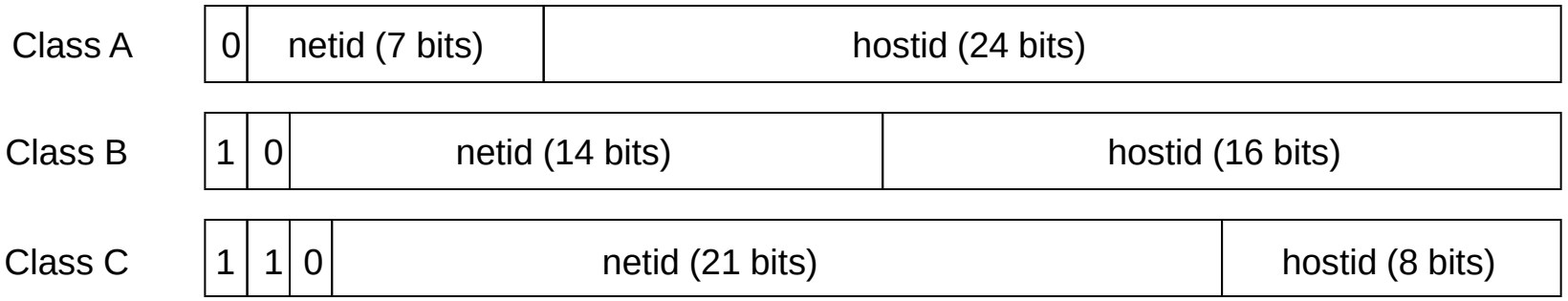
IP Addresses

- **4 bytes**
- **Dotted decimal notation, e.g., 130.89.16.82**

Address Classes:



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IP Addresses (2)

Subnet Mask

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0

IP Address

Prefix Length

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How to obtain an IP Address

- **Manually**
- **Automatically**
  - **PPP (Point-to-Point Protocol) / IPCP (IP Control Protocol)**
  - **BOOTP (Bootstrap Protocol)**
  - **DHCP (Dynamic Host Configuration Protocol)**

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Routing Table

Target	Prefix Length	Next Hop	Interface
7.7.7.99	32	router 1	a
7.7.7.0	24	router 2	a
0.0.0.0	0	router 3	a

Example: Destination Address = 7.7.7.1

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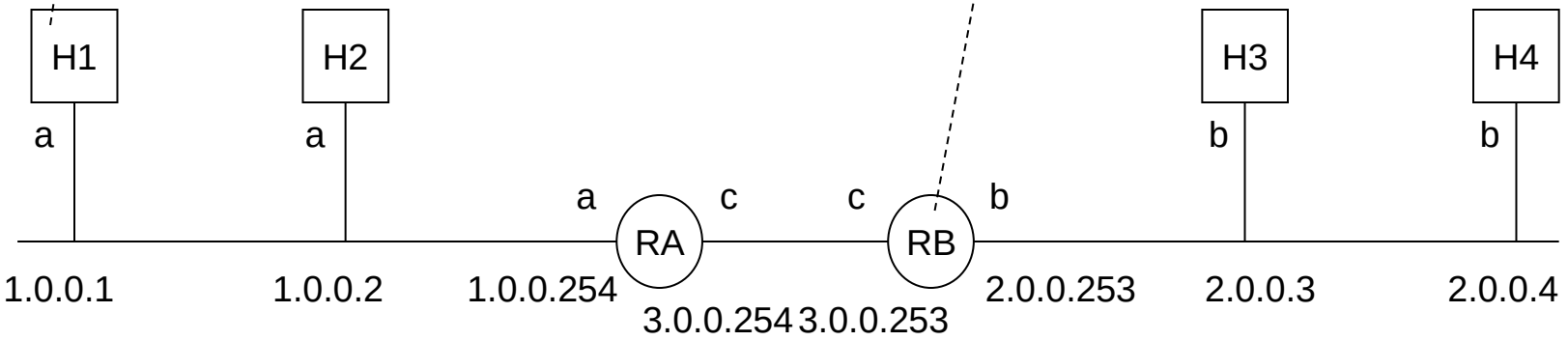
Routing Example

Target	Pref.L.	Next Hop	I/f
1.0.0.0	24	"direct"	a
0.0.0.0	0	1.0.0.254	a

Target	Pref.L.	Next Hop	I/f
1.0.0.0	24	3.0.0.254	c
2.0.0.0	24	"direct"	b
3.0.0.0	24	"direct"	c



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Levels of addresses in the Internet

Domain name (DNS address)

- a location independent identifier of a host
- utip145.cs.utwente.nl

Internet address (IP address)

- the logical location of a host (interface)
- I.e., (sub)network id followed by host id
- 130.89.16.82

Physical address (MAC address)

- the hardware address of an interface card
- 00 a4 24 4a 82 07

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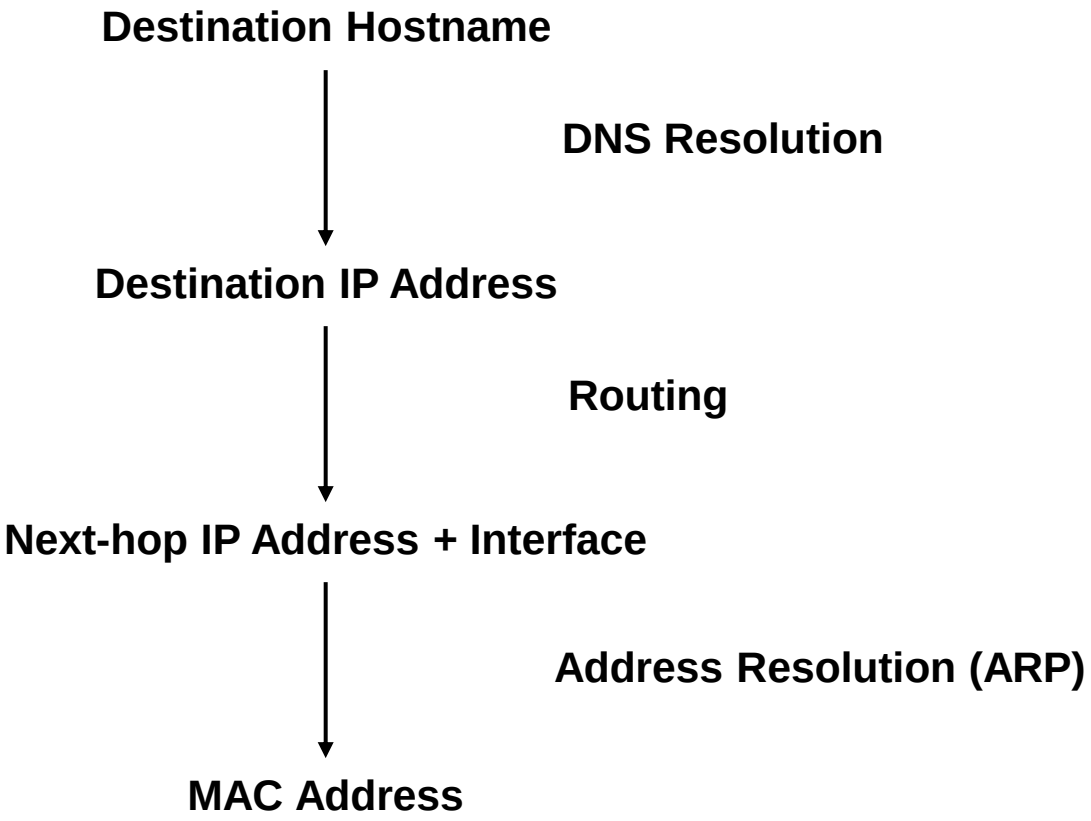
Address Resolution



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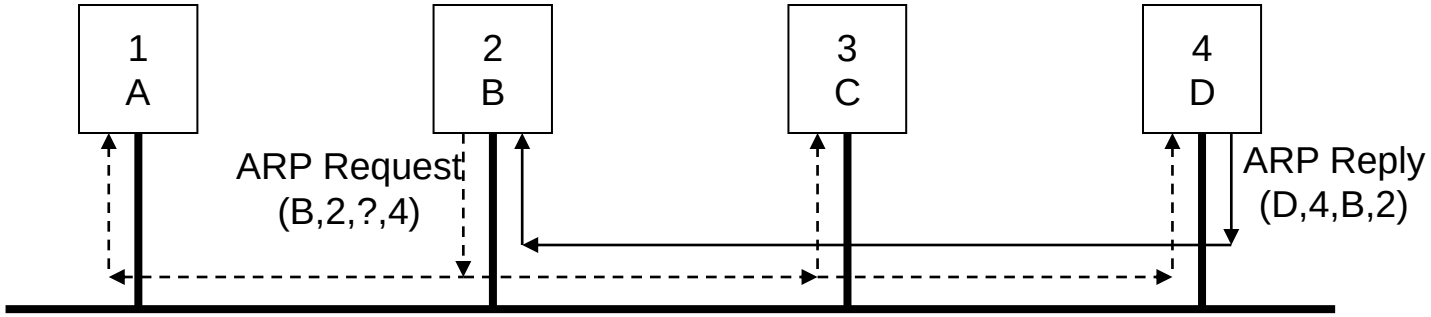
ARP

- **ARP: Address Resolution Protocol**
- **Used to find (Physical) MAC address if IP address is known**
- **ARP Request is a broadcast**
- **ARP Reply is returned to requester**



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Proxy ARP and Gratuitous ARP

- **Proxy ARP: Proxy Replies to ARP requests on behalf of other host, giving its own MAC address**
- **Gratuitous ARP: Host broadcasts a not requested ARP**

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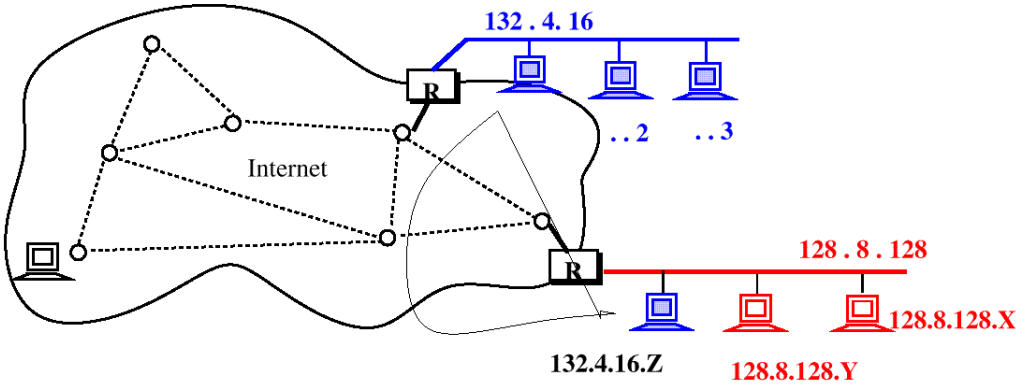
Routing in the Internet



- **Packets flow from link (subnetwork) to link via routers**
- **Packets are routed individually, based on their IP addresses (not on DNS name)**
- **Routing is based on the (sub)network prefix of the IP address**

» **A mobile host must be assigned a new address when it moves**

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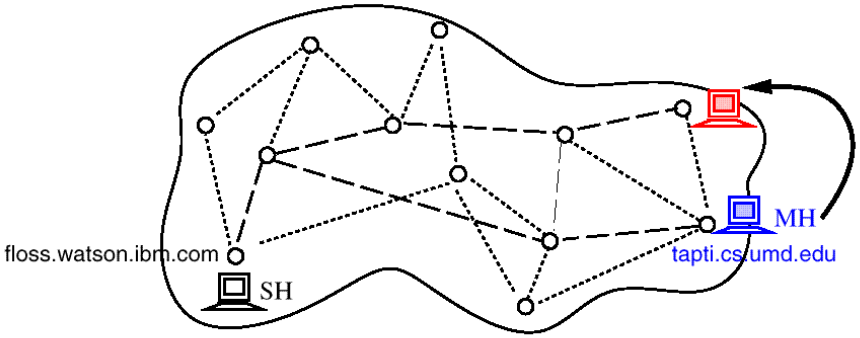
Connections between Internet computers



Connection := <129.34.16.43, sh_port #, 128.8.128.45, mh_port #>

- **TCP connections are defined by source and destination IP addresses and port numbers**
- **Change of host address would cause the connection to break**

» **Host address must be preserved regardless of a hosts location**

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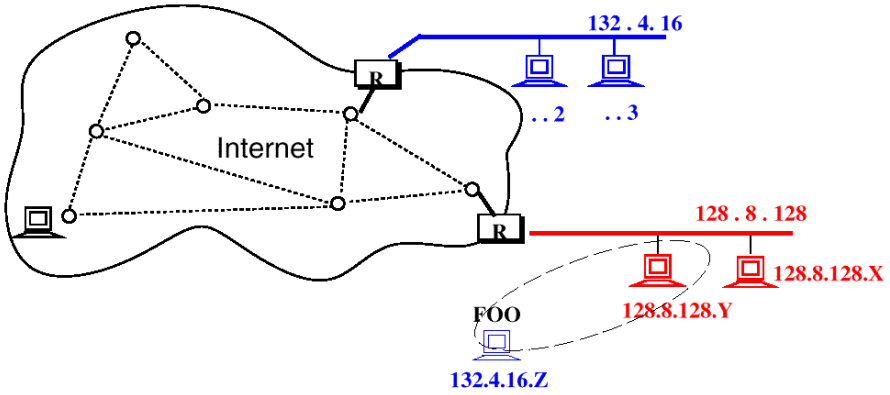
The Mobile IP problem



A mobile host must be assigned a new address when it moves

«»

Host address must be preserved regardless of a hosts location

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Why Mobility at the Network (IP) Layer?

- **Network layer is present in all Internet nodes**
- **Network layer is responsible for routing packets to the proper location**
- **Mobility across the entire Internet, even changing physical medium is possible**
- **Application transparent**
- **Universal solution for all applications**

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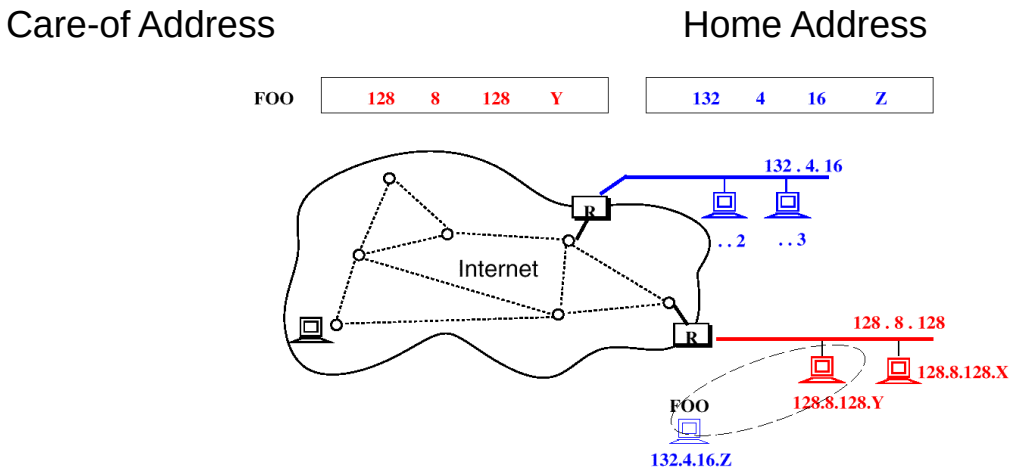
Design constraints for Mobile IP

- **Interoperability with the TCP/IP protocol suite**
- **Existing networking applications should run unmodified on mobile hosts**
- **System should provide Internet wide mobility**
- **No modifications to existing routing infrastructure required**
- **No modifications to existing protocols required**
- **Independence of wireless hardware technology**
- **Good scaling properties**

Mobile IP: Basics



- **A mobile host keeps its *home address*, but on a foreign network, it borrows a *care-of address***
- **Mobile IP takes care of all issue related to the mapping of the care-of address to the home address**

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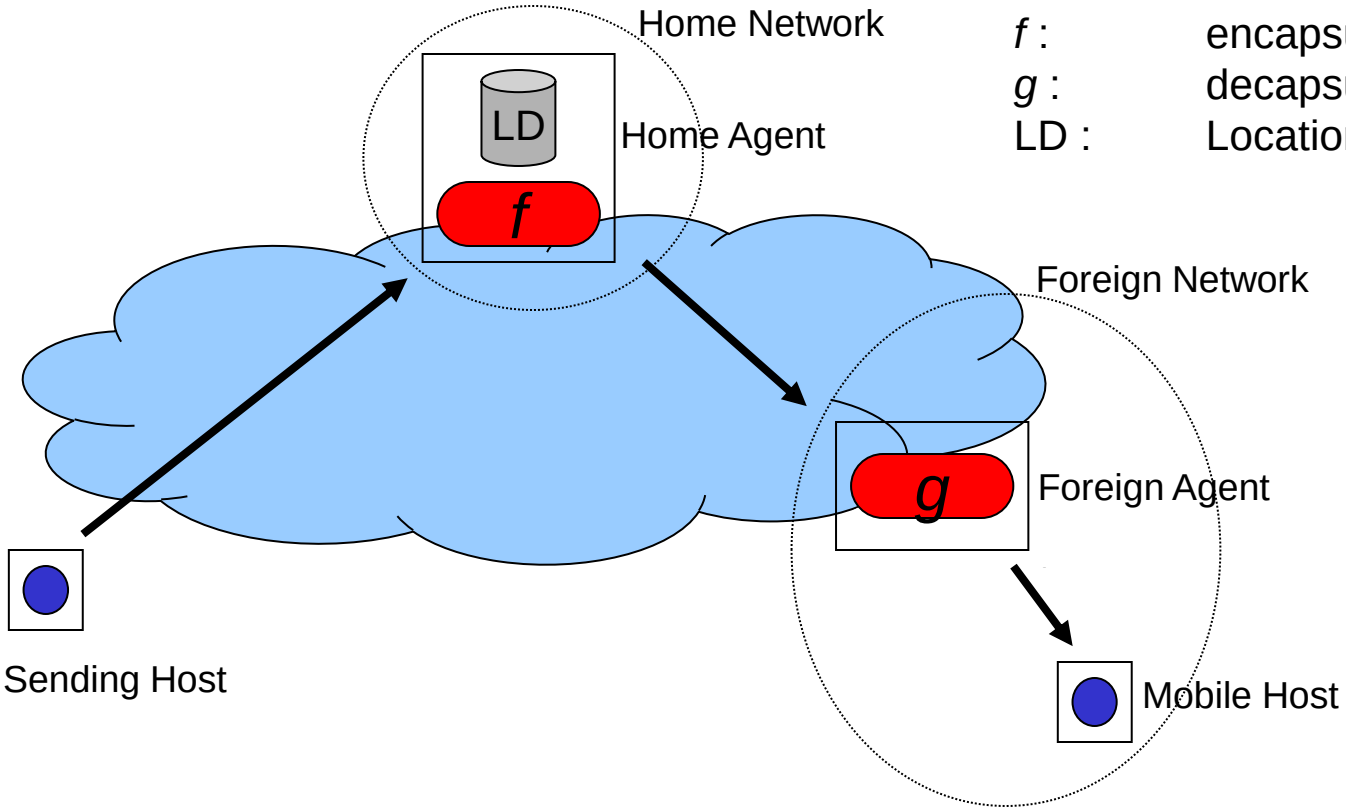
Mobility Model



f : encapsulation and re-addressing
g : decapsulation and forwarding
LD : Location Directory

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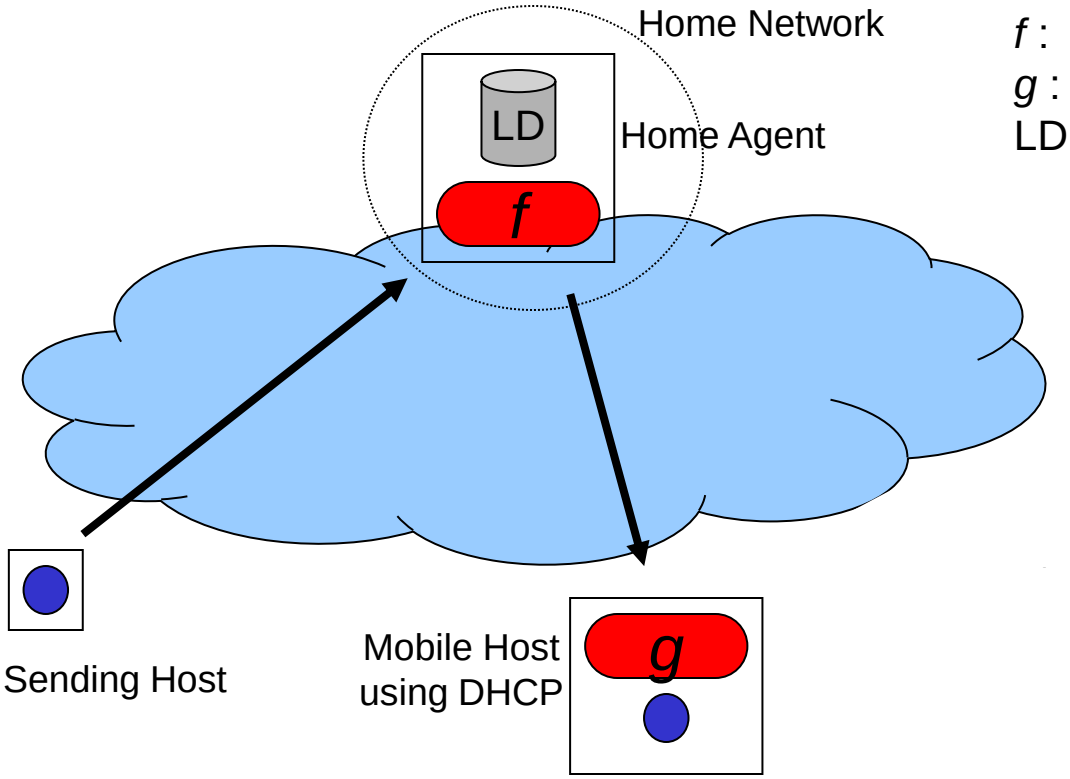
Mobility Model



f : encapsulation and re-addressing
g : decapsulation and forwarding
LD : Location Directory

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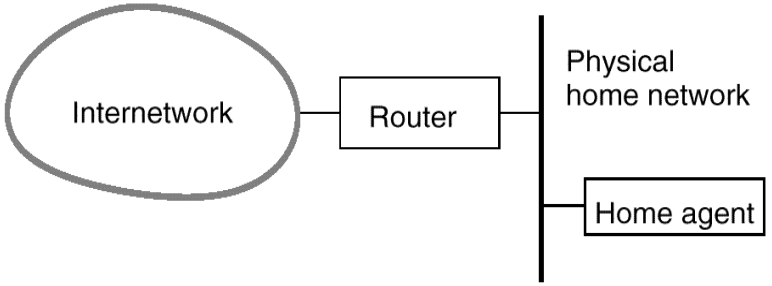
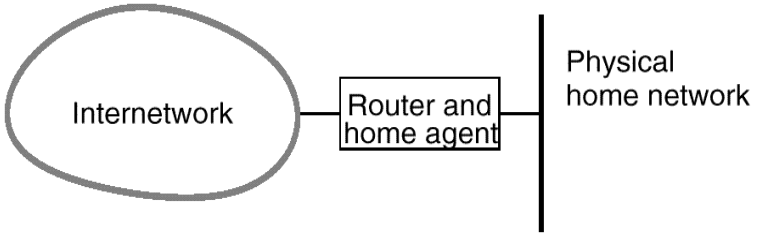
Types of Home Networks

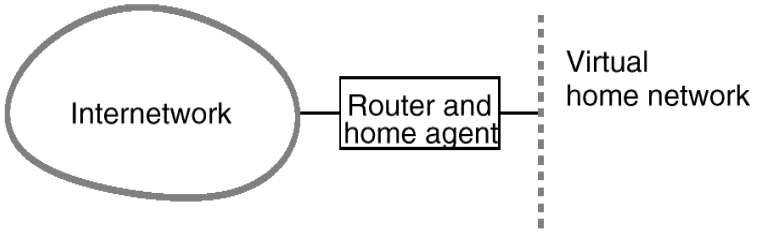
- **Home agent as a separate system on the home network**



- **Home agent integrated with a router on the home network**



- **A virtual home network**



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3 Parts of Mobile IP

- **Advertising Care-of Addresses**
- **Registration**
- **Tunneling**

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Advertising Care-of Addresses

A *mobility agent* is either a foreign agent or a home agent or both

- Mobility agents broadcast agent advertisements (ICMP messages)
- Mobile hosts can solicit for an advertisement
- Advertisements contain:
  - mobility agent address
  - care-of addresses
  - lifetime
  - flags

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Home Network & Move Detection

Home Network is detected if:

- **Network Prefix IP Source Address advertisement = Network Prefix Home Address**

Move is detected if:

- **No advertisement has been received within Lifetime**
- **Network Prefixes have changed**

no advertisements --> use promiscuous mode

assistance from higher / lower layers

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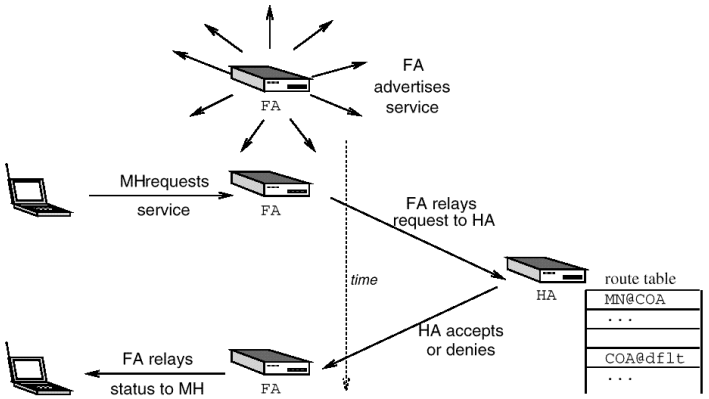
Registration



- ***binding*** **: (home address, care-of address, lifetime)**
- **registration is needed to update the binding**
- **registration requires authentication**
- **registration uses UDP**

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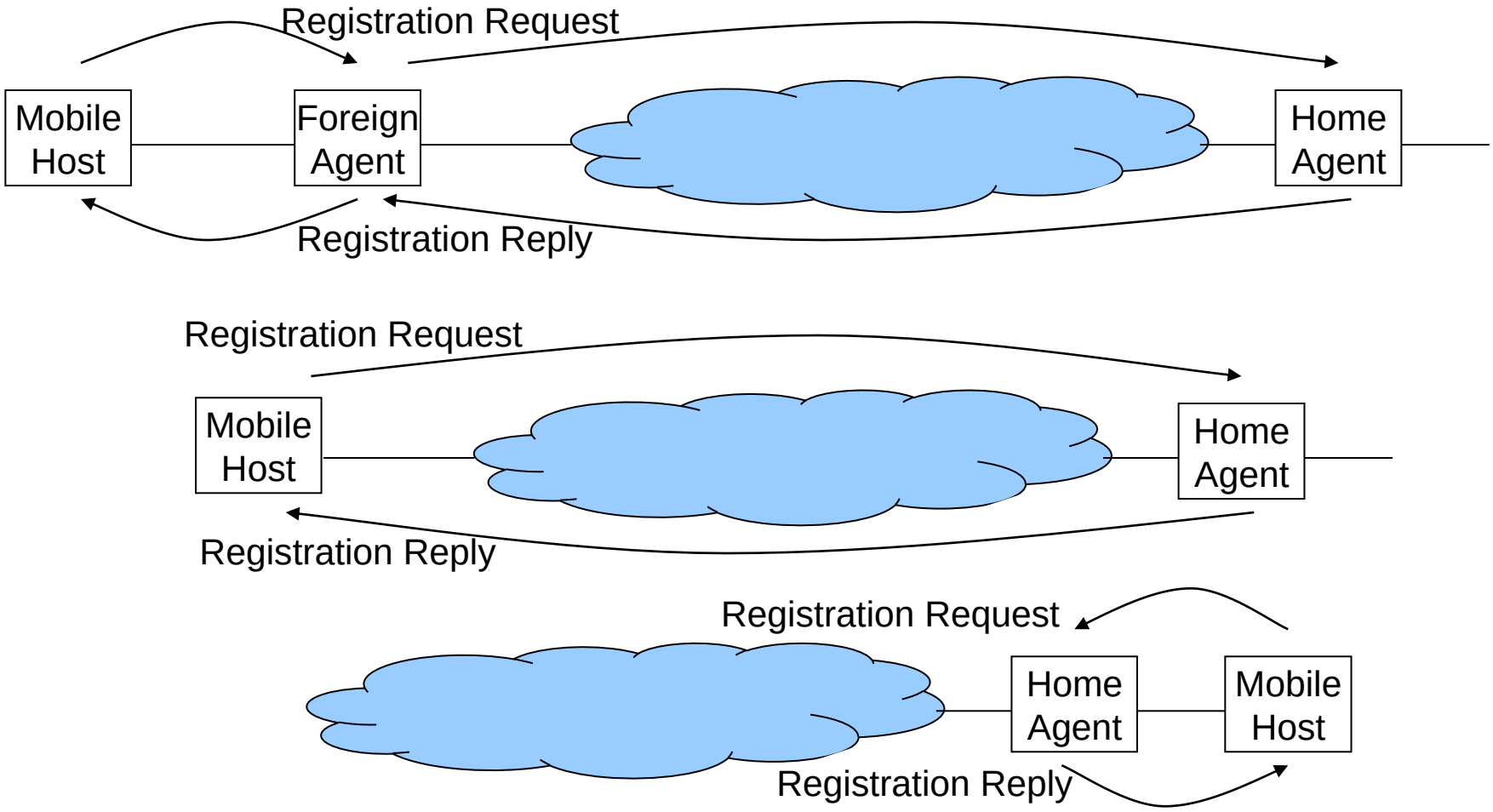
Registration Scenarios



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Simultaneous Bindings

- A Mobile Node may register multiple bindings simultaneously
- The Home Agent makes multiple copies of packets destined for the mobile host, and tunnels a copy to each care-of address
- Simultaneous bindings may be used to
  - facilitate seamless hand-off
  - avoid too frequent registrations

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Home Agent Address Discovery

- **Mobile Node sends Registration Request as home network directed broadcast (network-prefix.11111…1)**
- **Home Agents reply with a negative Registration Reply (registration denied)**
- **Mobile Node learns Home Agent address from the reply, and initiates a registration**

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3 Parts of Mobile IP

- Advertising Care-of Addresses
- Registration
- **Tunneling**

Tunneling

- Packet destined to the mobile node are routed to the home network (normal IP operation)
- Home Agent intercepts packets on the home network
- Home Agent encapsulates packets, and tunnels them to the care-of address
- At the care-of address (either Foreign Agent or co-located, the packet is decapsulated, and delivered to the mobile node

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Packet Interception by Home Agent

- **Advertise reachability of Mobile Node Home Address**
- **Proxy and Gratuitous ARP:**
  - **Home Agent Replies to ARP requests for the Mobile Node (Proxy ARP)**
  - **The Home Agent (or Mobile Node) Broadcast a not requested ARP after a change has occurred (Mobile Node has roamed out (or in)) (Gratuitous ARP)**

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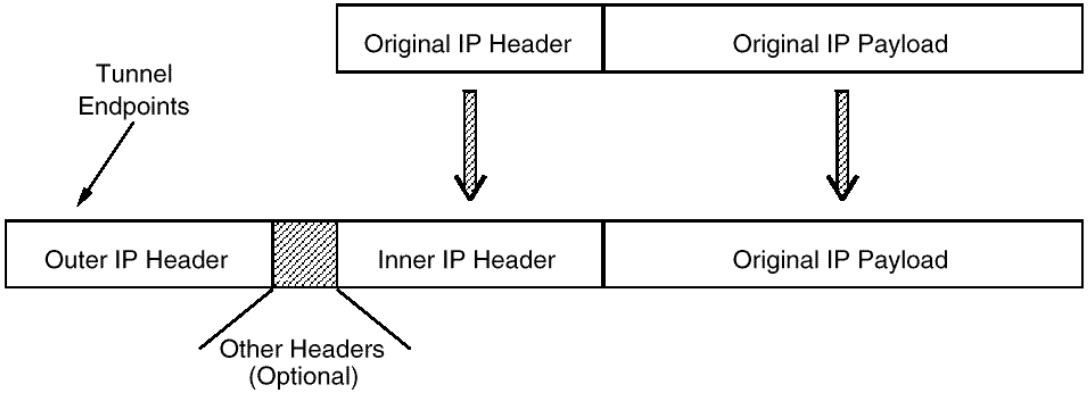
Tunneling

- **Home agent tunnels (encapsulates) packets to care-of address**
- **Tunnel source is the home agent's address**
- **Tunnel destination is the care-of address**

- **IP within IP (other ways exist):**



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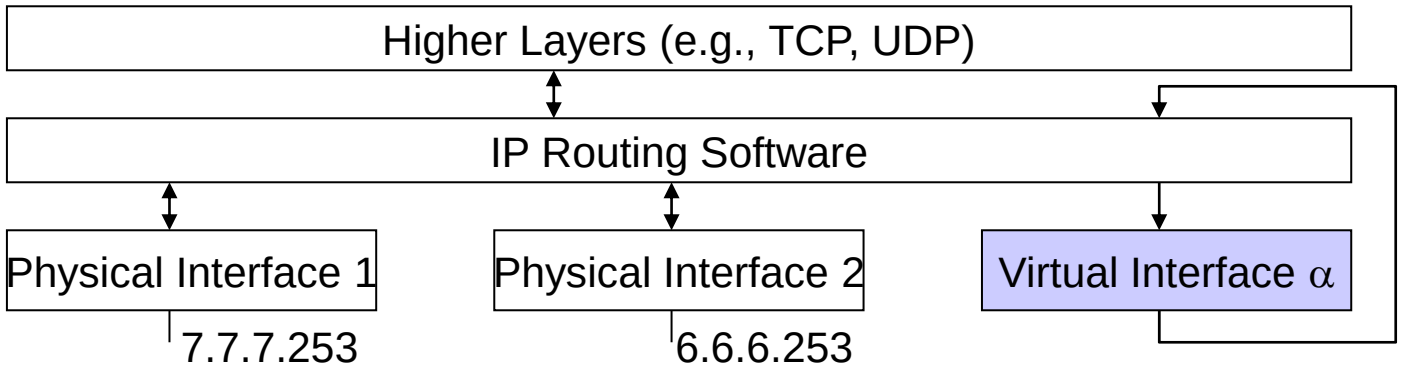
Encapsulation Implementation (HA)

Target	Prefix Length	Next Hop	Interface
7.7.7.0	24	“Direct”	1
default	0	6.6.6.254	2
7.7.7.1 (MN Home Address)	32	1.1.1.1 (MN Care-of Address)	α



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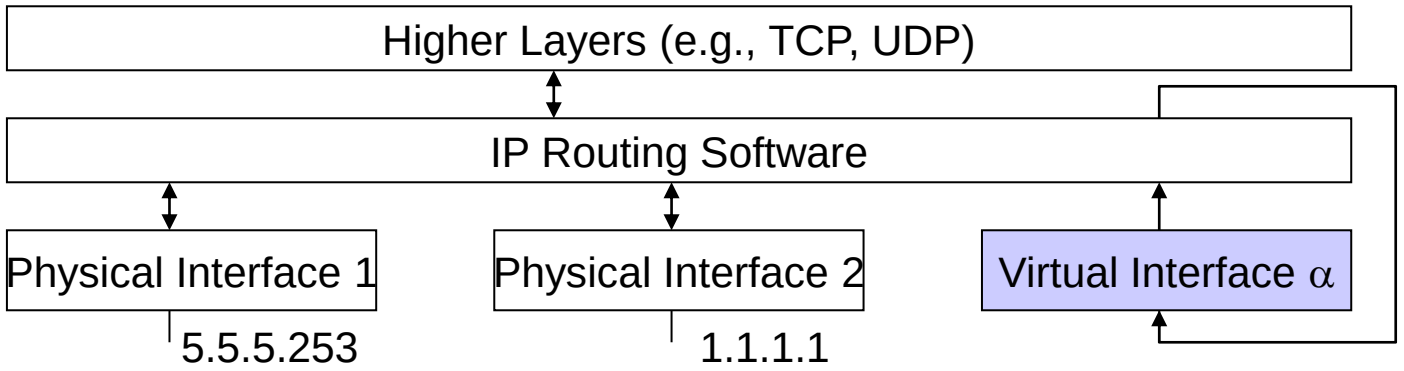
Decapsulation Implementation (FA)

Target	Prefix Length	Next Hop	Interface
5.5.5.0	24	“Direct”	1
1.1.1.0	24	1.1.1.254	2
7.7.7.1 (MN Home Address)	32	“Direct”	1



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Mobile Node sending packets

- **Use Home Address as source address**
- **Exception:**
  Ingress Filtering --> Reverse Tunneling

- **Never send Home Address in ARP Request!**

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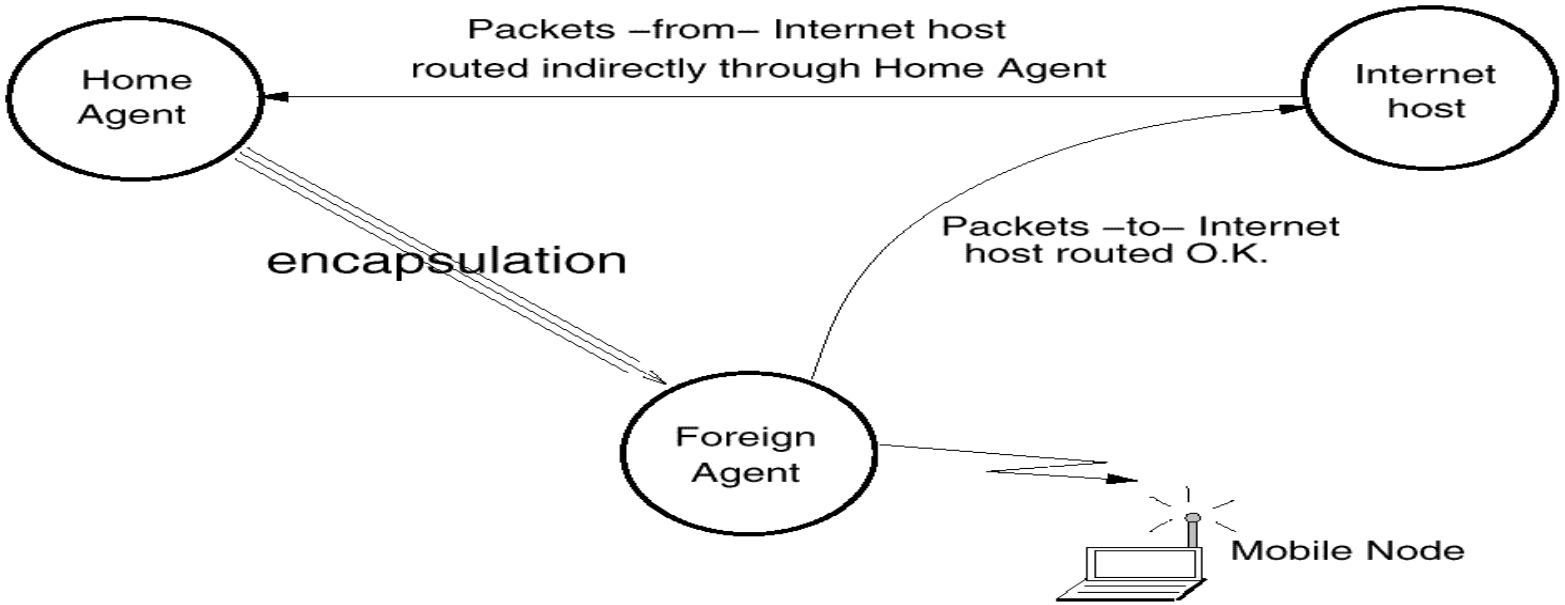
Router Selection by Mobile Node

- **Use Foreign Agent**
  - **Use MAC Address from Advertisement**
- **Listen to Router Advertisements (No FA)**
  - **Use MAC Address from Advertisement**
- **Use DHCP / PPP IPCP (No FA, no Router Adv.)**
  - **Use ARP with Care-of Address as source address**

Triangle Routing



Triangle routing is undesirable because

- **home agent is the bottleneck**
- **more network load, and sensitivity to network partition**

In case of reverse tunneling, the situation is even worse

⇒ Route optimization: Get binding to the correspondent host

(Smooth) Handoff

- **Mobile host moves along subnetworks, from FA to FA.**
- **Packets already in flight to old FA are lost after handoff to new FA**
- **Route optimization allows old FA to forward packets to new care-of address**

Route Optimization (1)

Get binding to relevant correspondent hosts for optimal routing:

- **binding warning (mobility agent → correspondent host)**
- **binding request (correspondent host → home agent)**
- **binding update (home agent → correspondent host)**
- **binding acknowledge (optional)**

security association between correspondent host and home agent is needed for authentication

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Route Optimization (2)

Get binding to old Foreign Agent for smooth handoff:

- **previous foreign agent notification extension (mobile host → new FA)**
- **binding update (new FA → old FA)**
- **binding acknowledge (old FA → mobile host)**

mobile host and foreign agent need to exchange registration key for authentication

last resort: special tunnel (old FA tunnels packet back to the HA)

Mobility for IPv6

- All nodes can handle bindings
  - No triangular routing
- Binding updates are carried in Destination Option
  - Small overhead for distributing bindings
- Mobile host can create its own care-of address using link-local address and automatic address configuration (combine advertised subnet prefix with own hardware address)
  - No need for foreign agent

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Conclusion

- **Mobile IP consists of 3 parts:**
  - **Advertising Care-of Addresses**
  - **Registration**
  - **Tunneling**
- **Mobility will be an important feature of the next generation Internet (Mobile Internet)**
- **Other solutions exist:**
  - **cellular solution (HLR / VLR)**
  - **application specific solutions (e.g., SIP)**

  but Mobile IP provides global, application independent Internet mobility

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Further reading

- **http://www.ctit.utwente.nl/~heijenk**

- **“Mobile Networking Through Mobile IP”**
  Tutorial by Charlie Perkins:
  http://computer.org/internet/v2n1/perkins.htM
- **“Mobile IP, Design Principles and Practices”**
  Book by Charles E. Perkins
- **“Mobile IP, The Internet Unplugged”**
  Book by James D. Solomon
- **IETF Mobile IP WG:**
  http://www.ietf.org/html.charters/mobileip-charter.html