

# Mobile IP

Stefano Ferrari

# Outline

## Part I: Mobile Internet

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

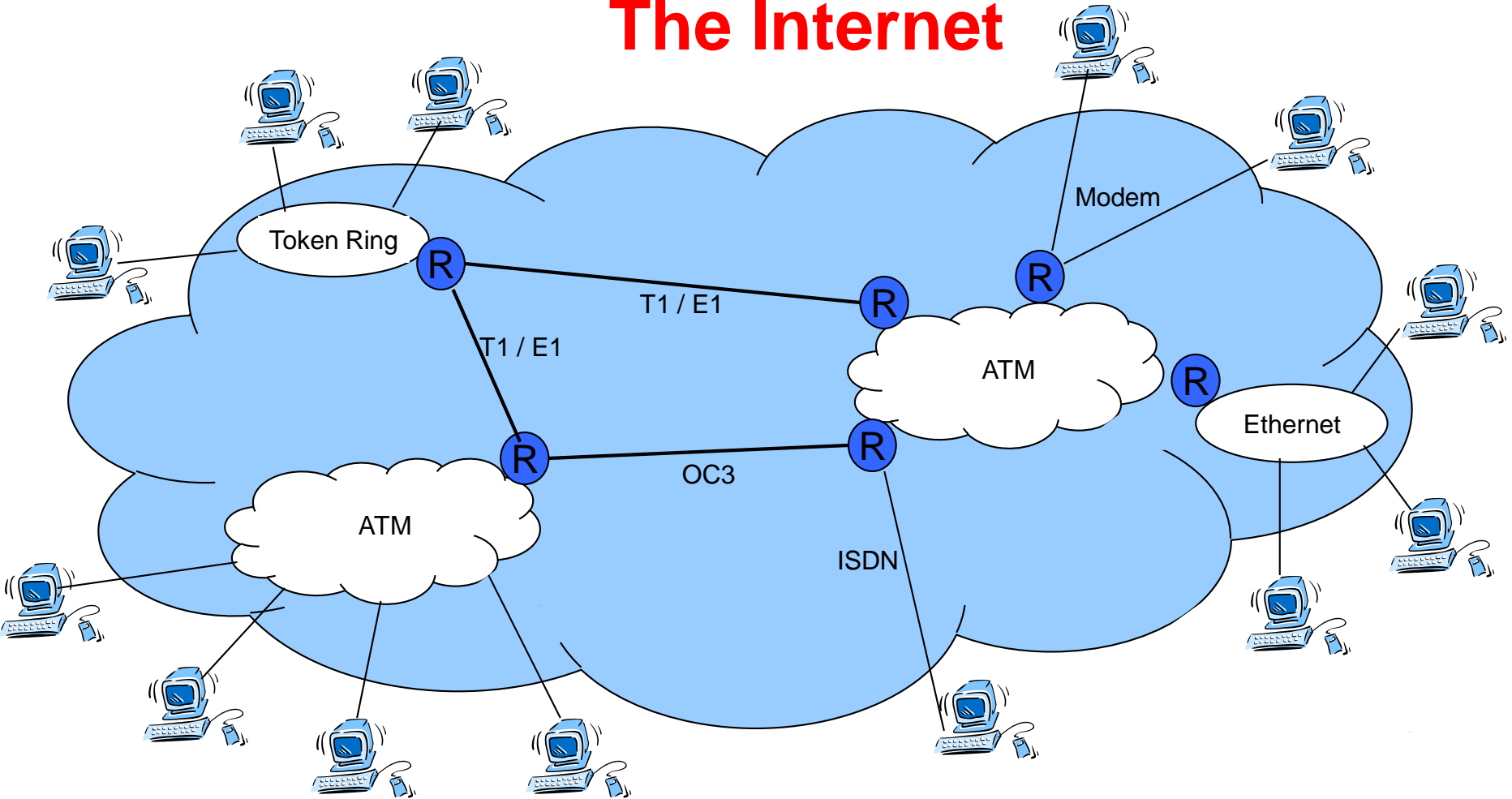
## Part II: Mobile IP

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

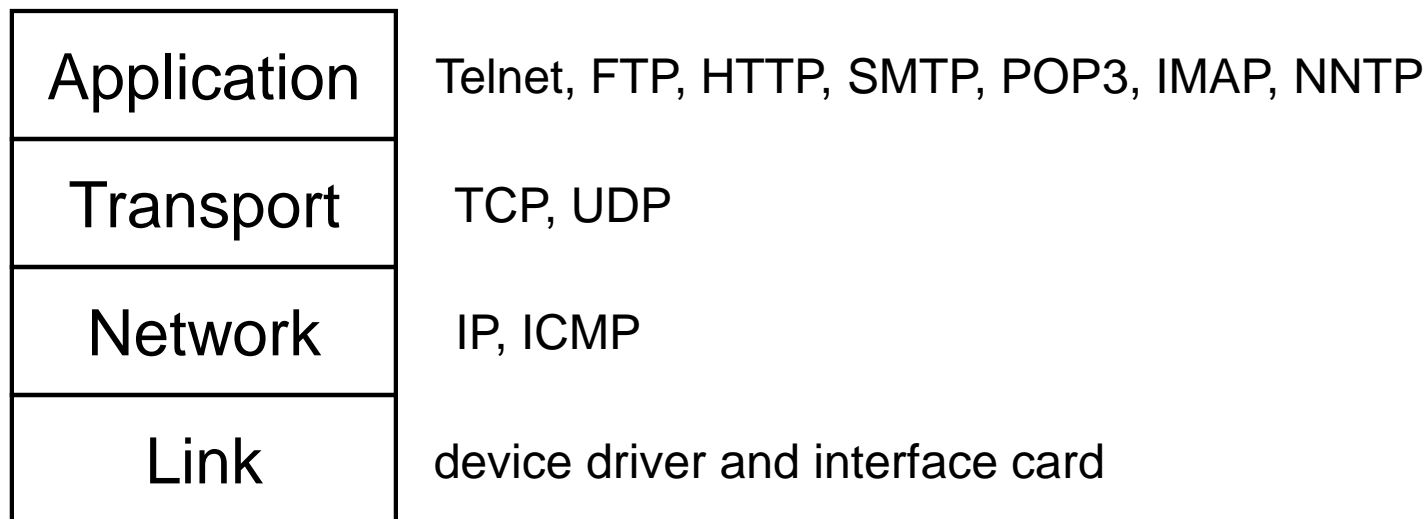
# What is the Internet?

- **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.

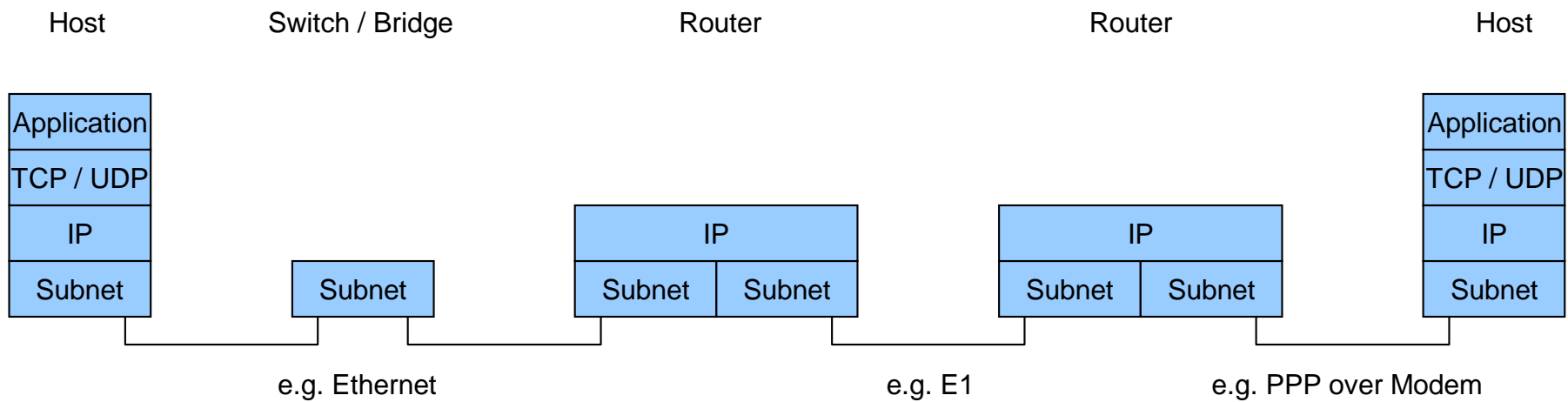
# The Internet



# Internet Protocol Stack



# The Internet (2)



# IP Addresses

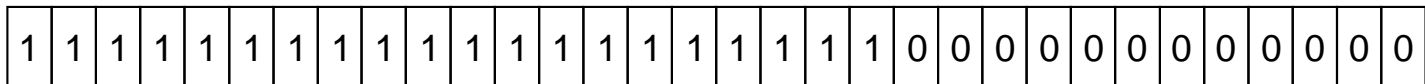
- **4 bytes**
- **Dotted decimal notation, e.g., 130.89.16.82**

## Address Classes:

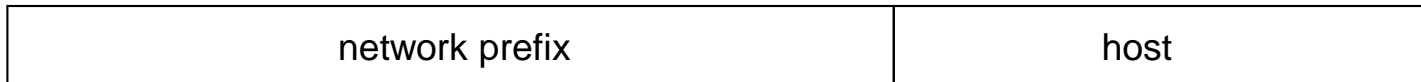
Class A	0	netid (7 bits)	hostid (24 bits)
Class B	1	0	netid (14 bits)   hostid (16 bits)
Class C	1	1	0   netid (21 bits)   hostid (8 bits)

# IP Addresses (2)

## Subnet Mask



## IP Address



## Prefix Length





## 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)**

# Routing Table

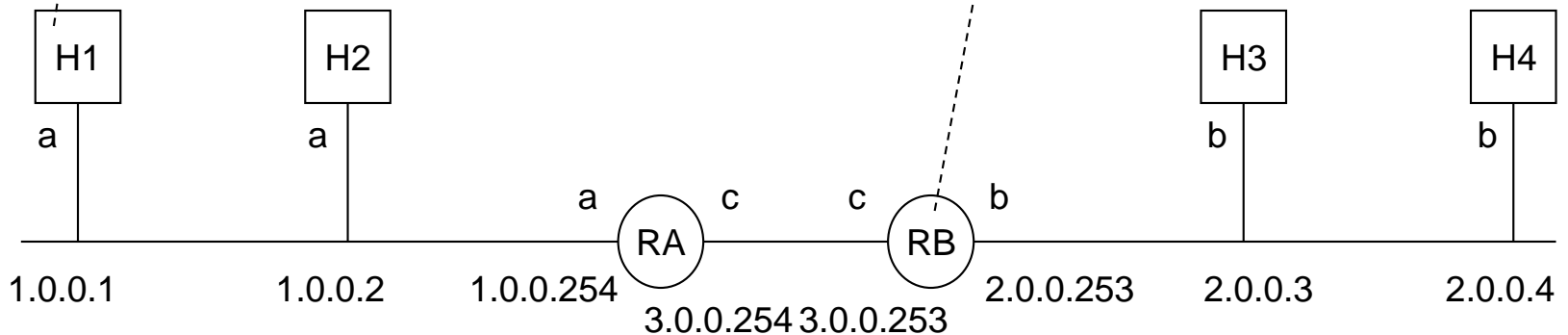
<b>Target</b>	<b>Prefix Length</b>	<b>Next Hop</b>	<b>Interface</b>
<b>7.7.7.99</b>	32	router 1	a
<b>7.7.7.0</b>	24	router 2	a
<b>0.0.0.0</b>	0	router 3	a

**Example: Destination Address = 7.7.7.1**

# 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



# 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

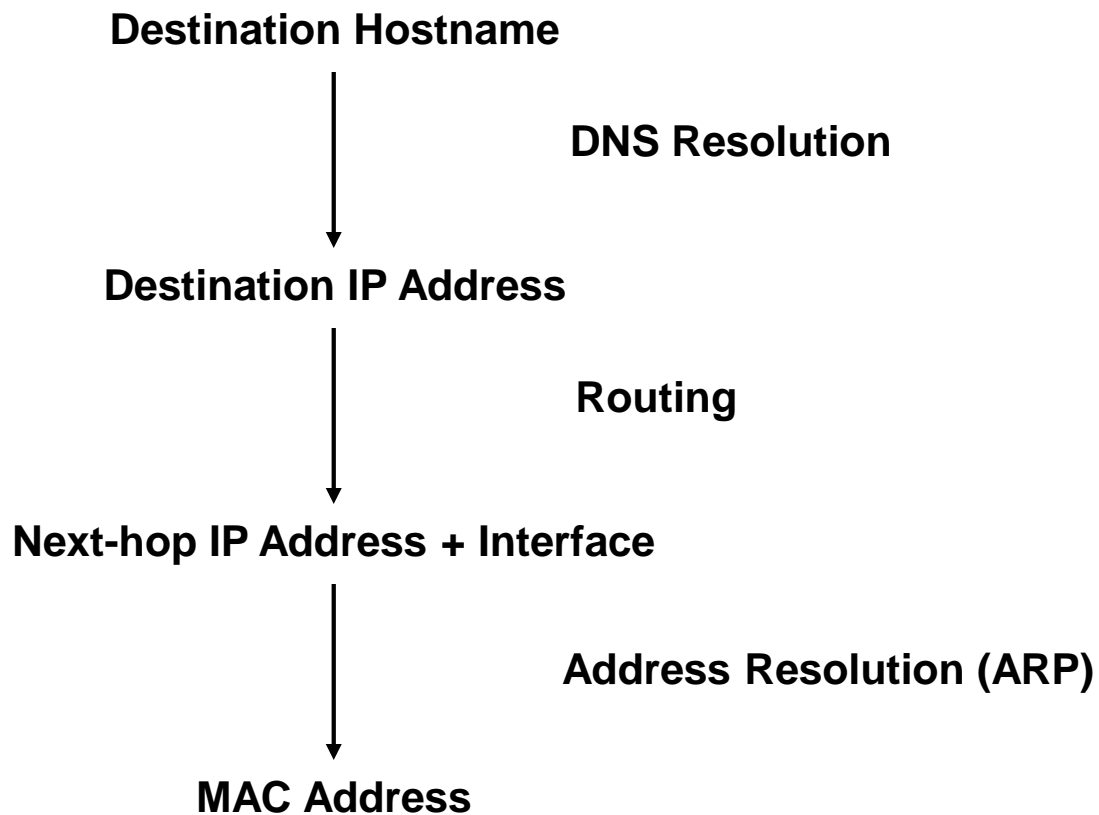
130.89.16.82

## Physical address (MAC address)

the hardware address of an interface card

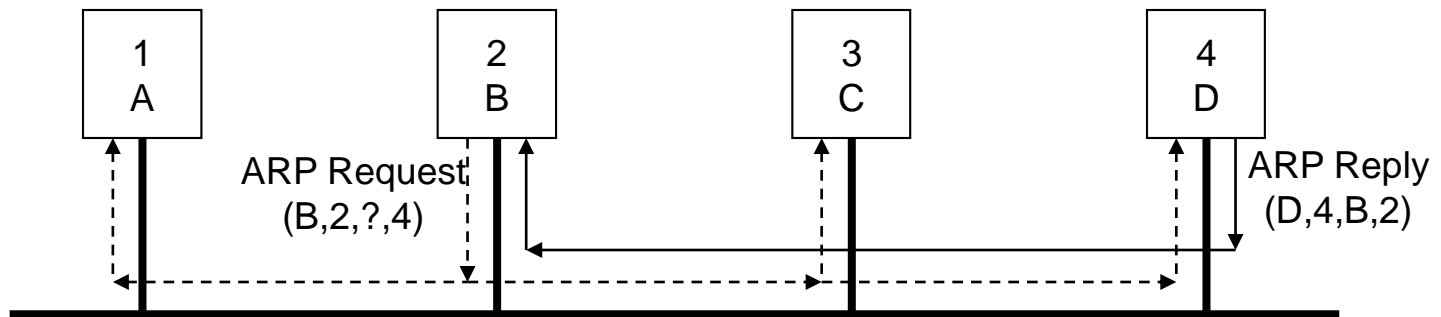
00 a4 24 4a 82 07

# Address Resolution



# ARP

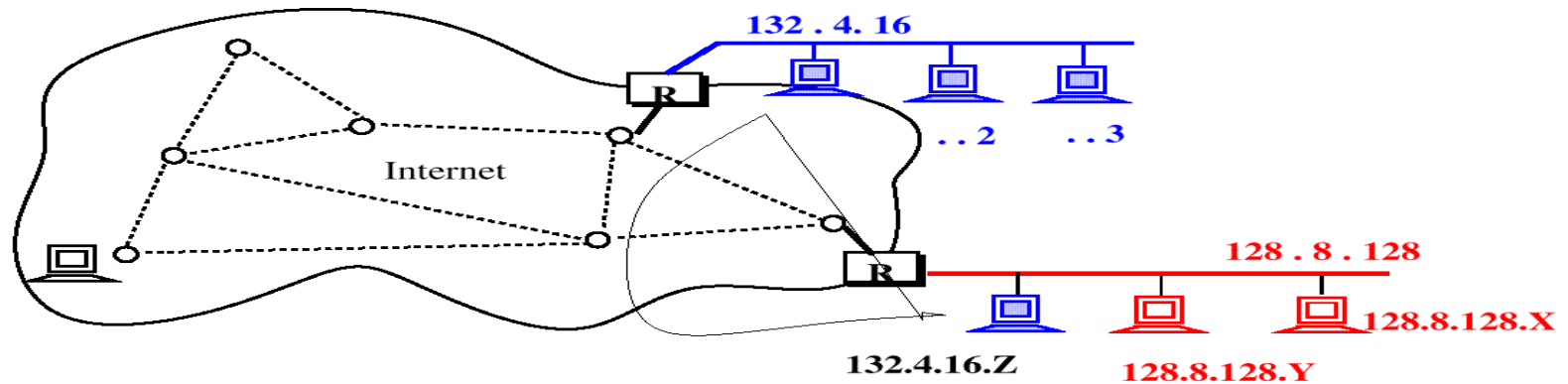
- **ARP: Address Resolution Protocol**
- **Used to find (Physical) MAC address if IP address is known**
- **ARP Request is a broadcast**
- **ARP Reply is returned to requester**



## 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**

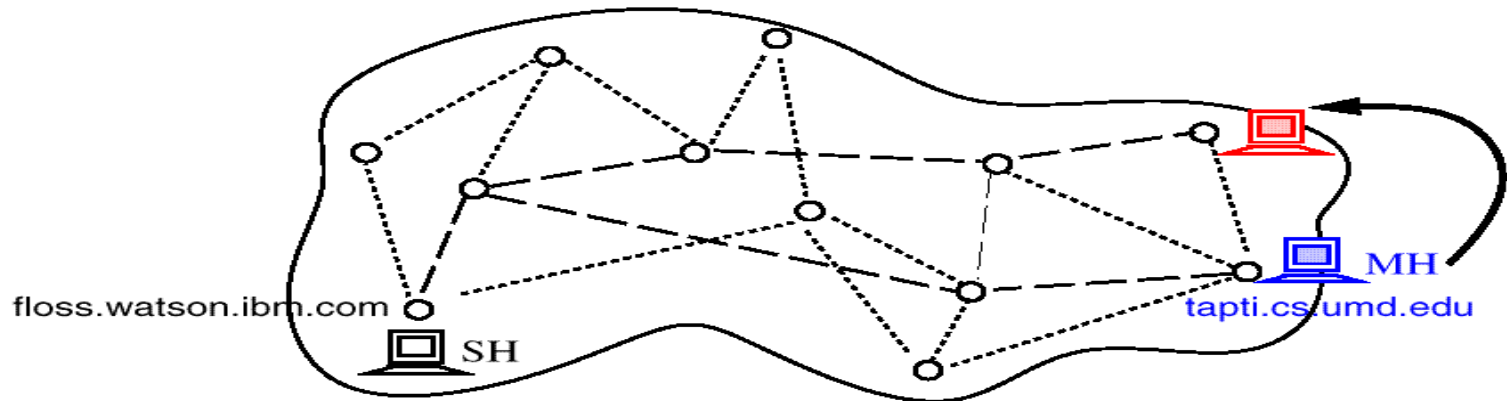
# Routing in the Internet



- 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**



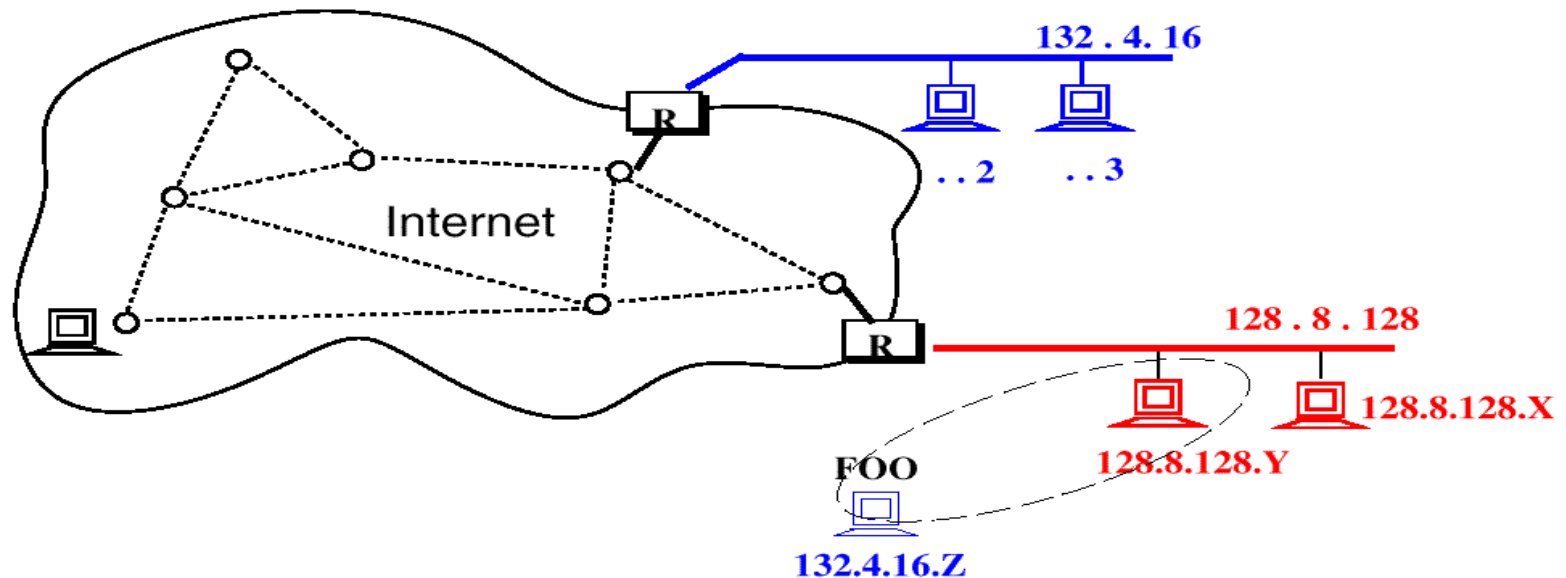
# Connections between Internet computers



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**

# 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**

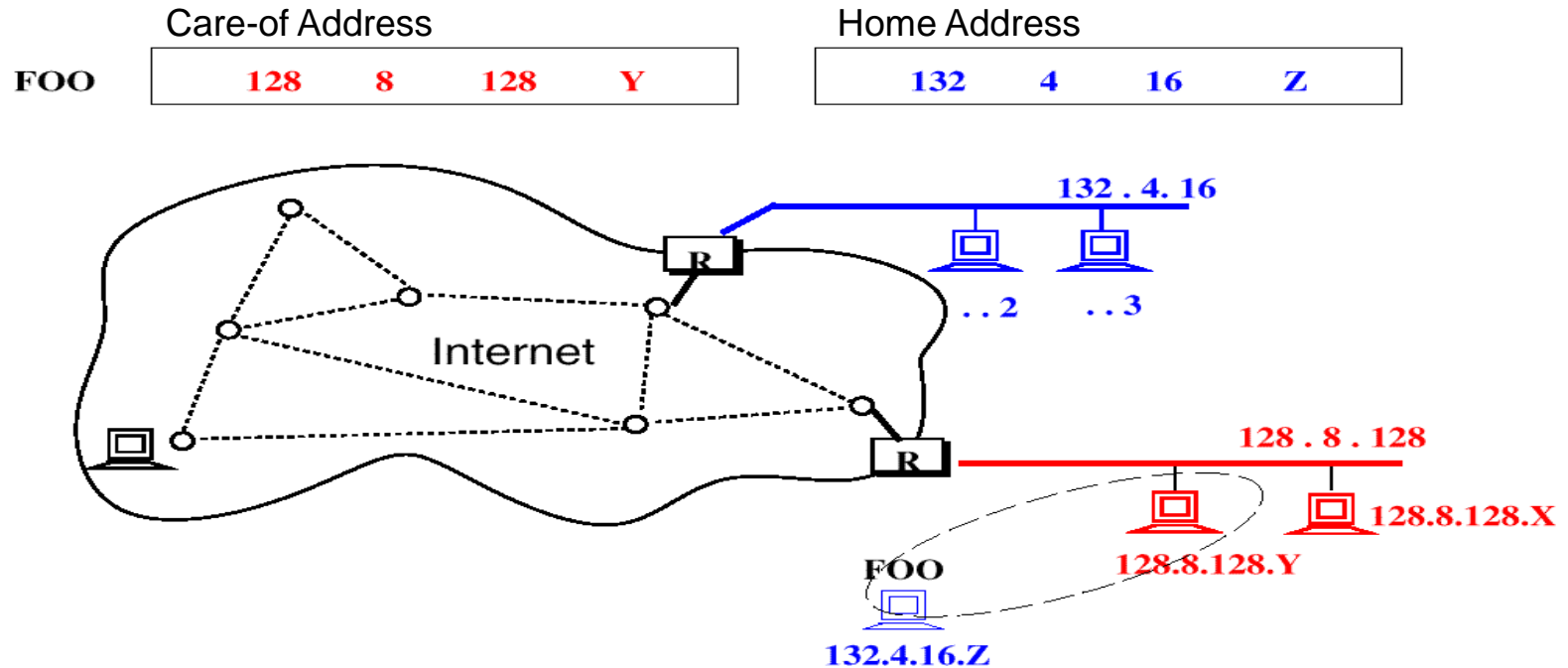
# Why Mobility at the Network (IP) Layer?

- **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**

## **Design constraints for Mobile IP**

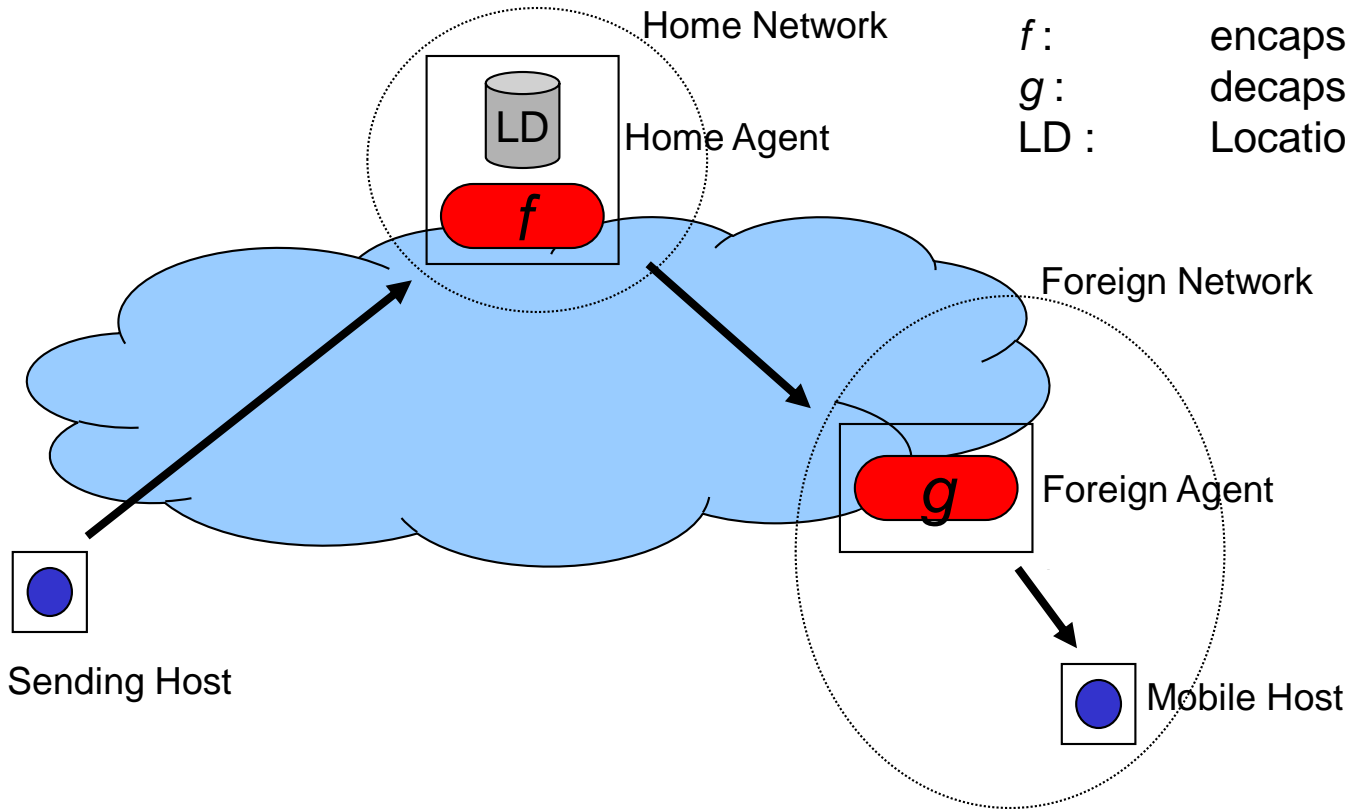
- **Interoperability with the TCP/IP protocol suite**
- **Existing networking applications should run unmodified on mobile hosts**
- **System should provide Internet wide mobility**
- **No modifications to existing routing infrastructure required**
- **No modifications to existing protocols required**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

# Mobile IP: Basics

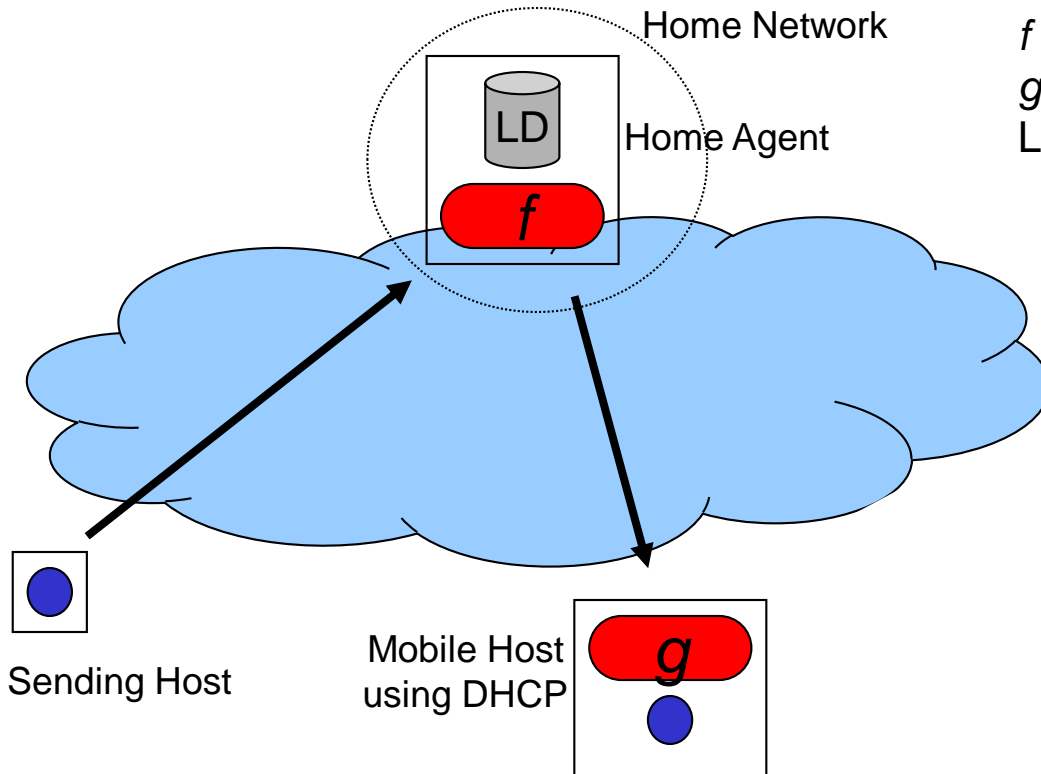


- A mobile host keeps its *home address*, but on a foreign network, it borrows a *care-of address*
- Mobile IP takes care of all issue related to the mapping of the care-of address to the home address

# Mobility Model



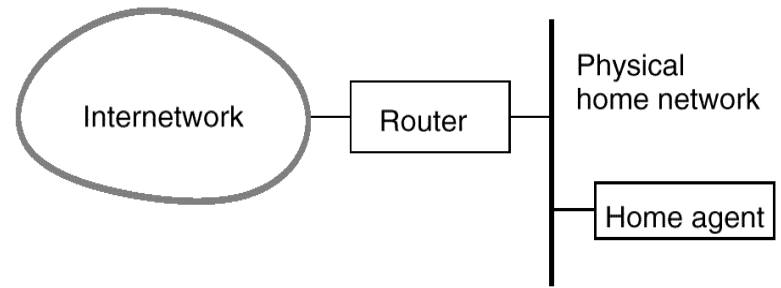
# Mobility Model



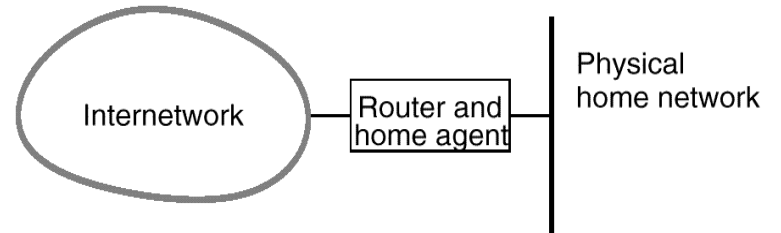
$f$ : encapsulation and re-addressing  
 $g$ : decapsulation and forwarding  
LD: Location Directory

# Types of Home Networks

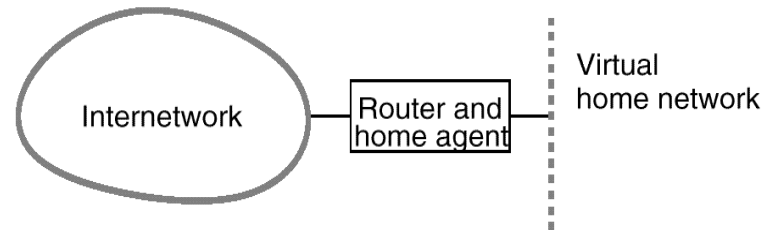
- Home agent as a separate system on the home network



- Home agent integrated with a router on the home network



- A virtual home network





## **3 Parts of Mobile IP**

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

# 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**

# Home Network & Move Detection

**Home Network is detected if:**

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

**Move is detected if:**

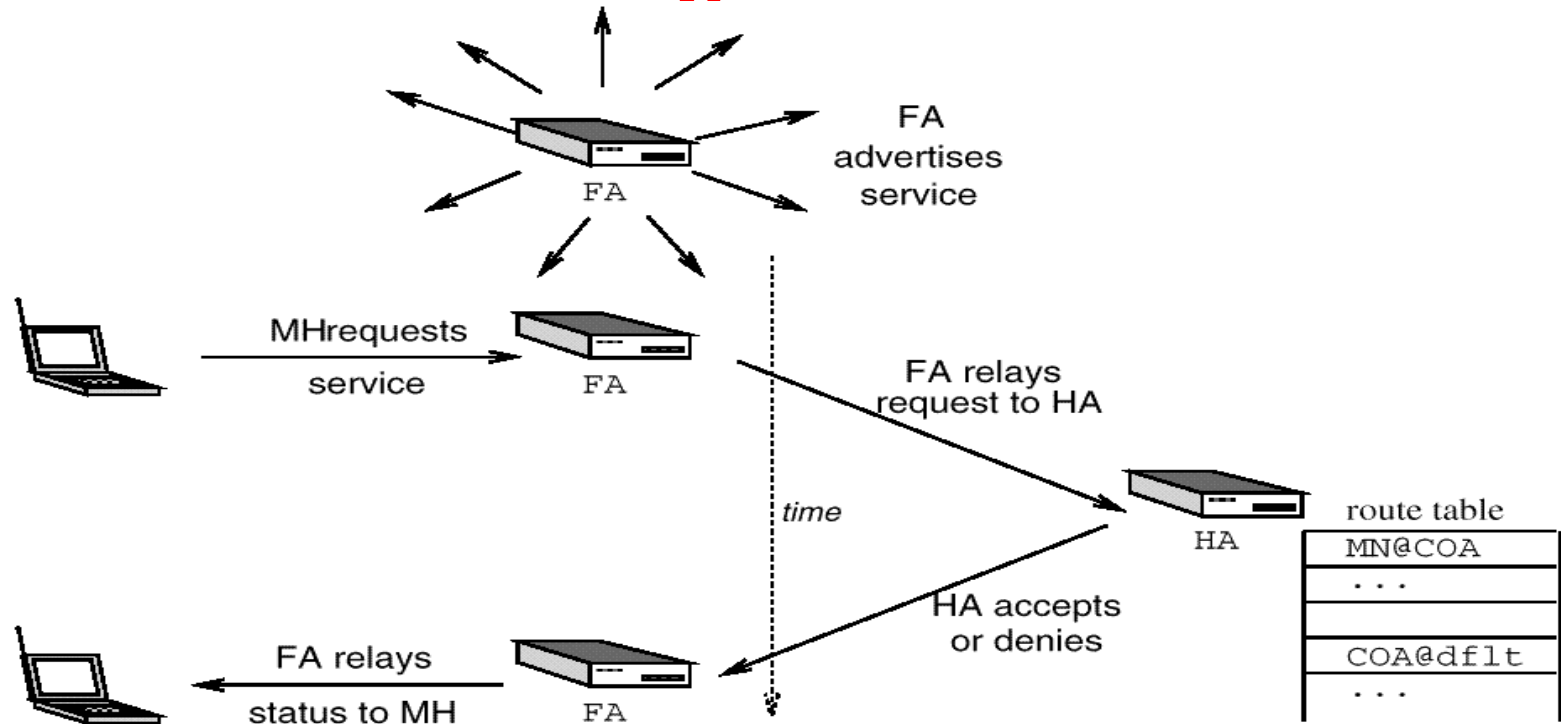
- **No advertisement has been received within Lifetime**
- **Network Prefixes have changed**

**no advertisements --> use promiscuous mode assistance from higher / lower layers**

## 3 Parts of Mobile IP

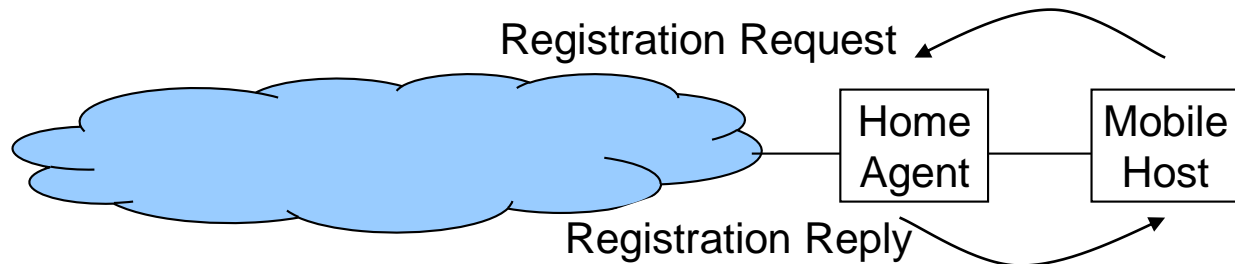
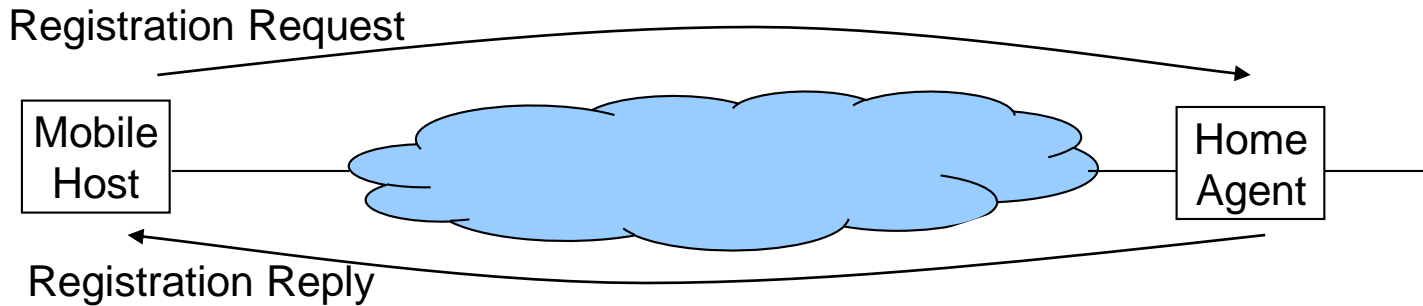
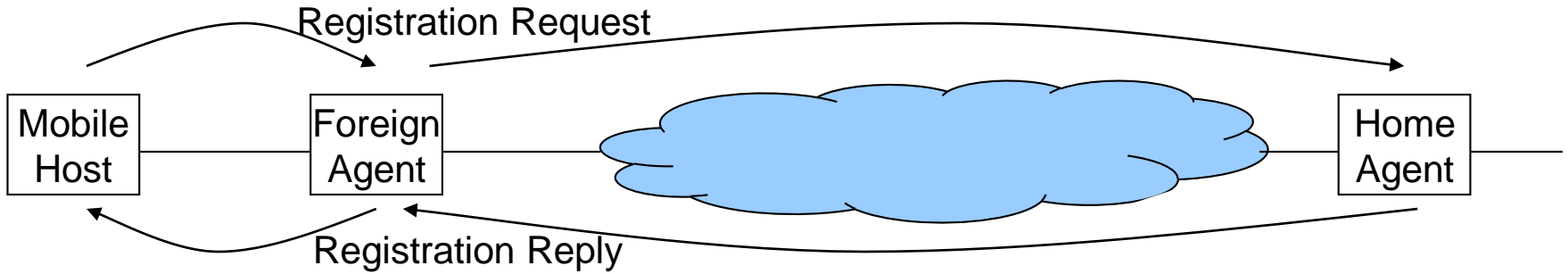
- Advertising Care-of Addresses
- **Registration**
- Tunneling

# Registration



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

# Registration Scenarios



## 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**

## 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**



## 3 Parts of Mobile IP

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

# Tunneling

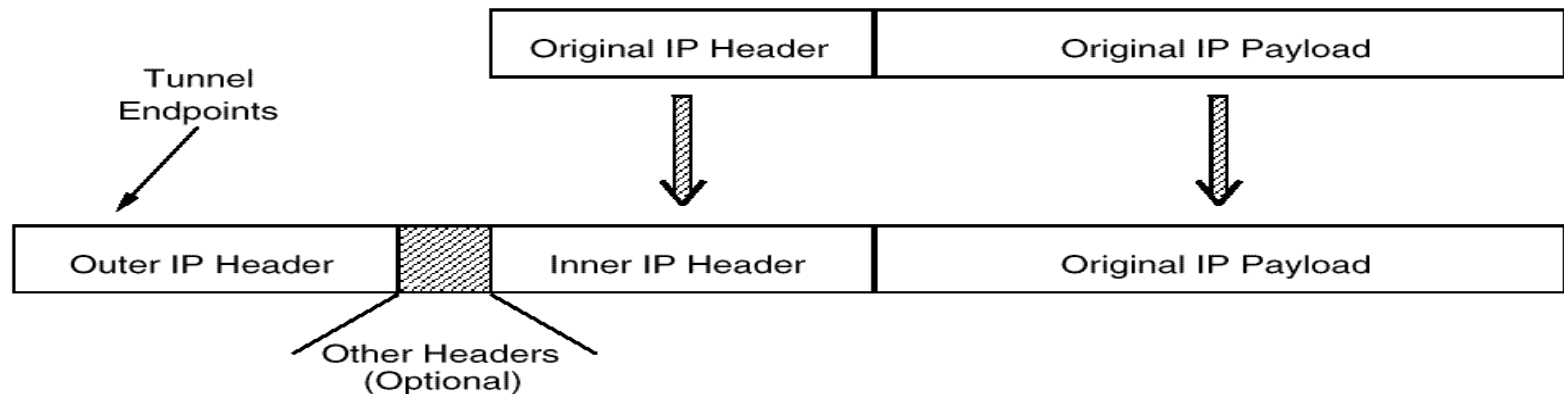
- **Packet destined to the mobile node are routed to the home network (normal IP operation)**
- **Home Agent intercepts packets on the home network**
- **Home Agent encapsulates packets, and tunnels them to the care-of address**
- **At the care-of address (either Foreign Agent or co-located, the packet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

# 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)**

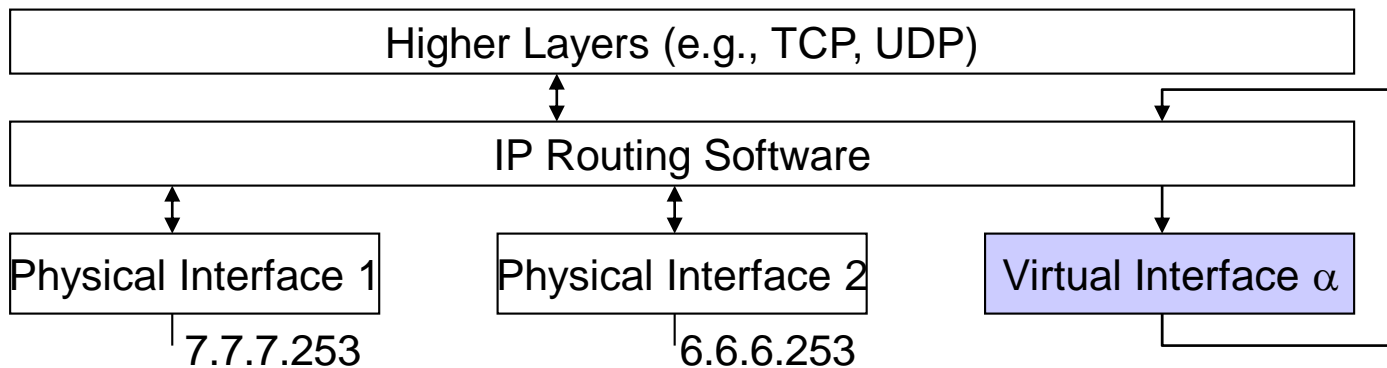
# Tunneling

- 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):



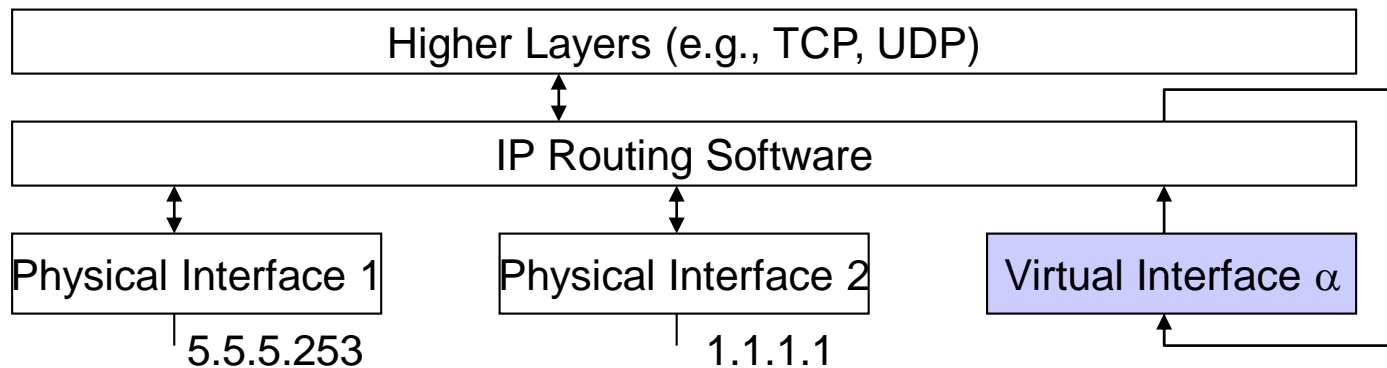
# Encapsulation Implementation (HA)

Target	Prefix Length	Next Hop	Interface
<b>7.7.7.0</b>	24	“Direct”	1
default	0	6.6.6.254	2
<b>7.7.7.1</b> (MN Home Address)	32	1.1.1.1 (MN Care-of Address)	$\alpha$



# Decapsulation Implementation (FA)

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



## **Mobile Node sending packets**

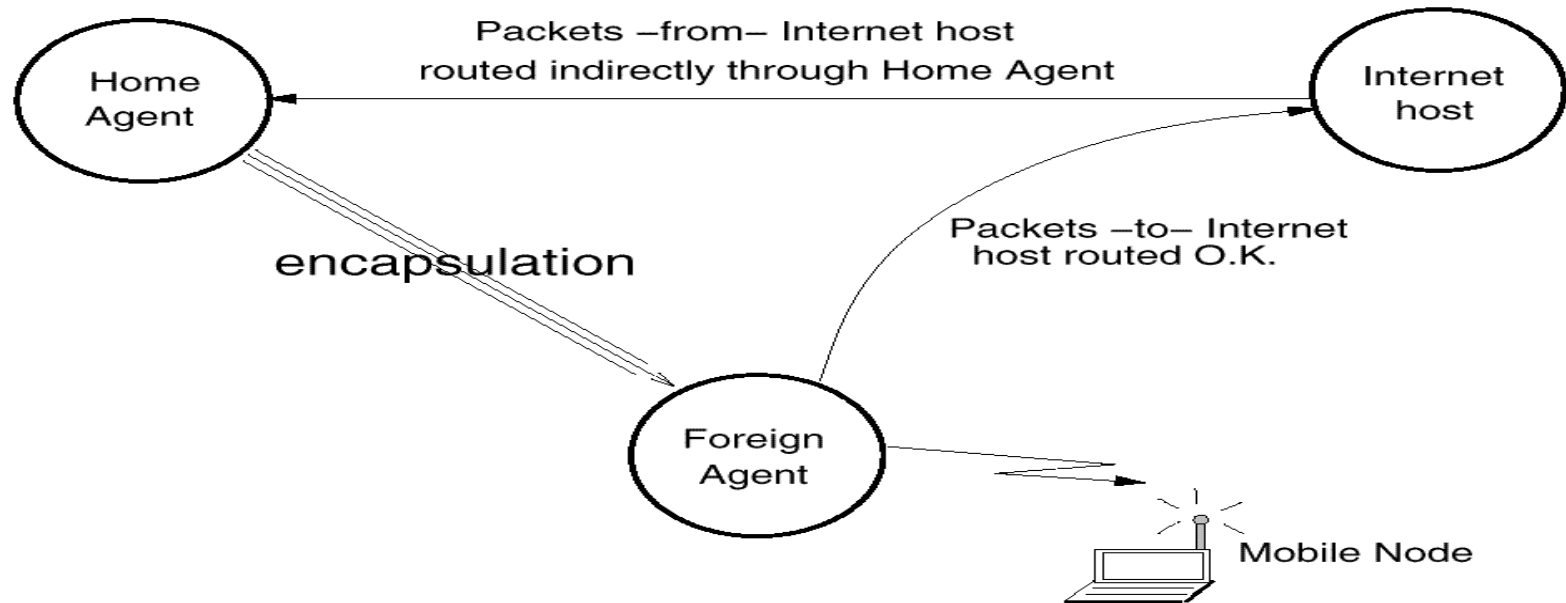
- **Use Home Address as source address**
- **Exception:**  
**Ingress Filtering --> Reverse Tunneling**
- **Never send Home Address in ARP Request!**

## 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**

## 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**

## 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**

## 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>**