



Mobility

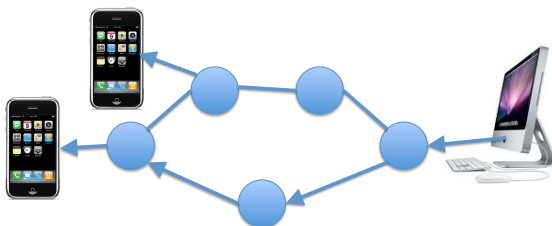
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COS 461: Computer Networks

<http://www.cs.princeton.edu/courses/archive/spr14/cos461/>

Why (and How) Things Move

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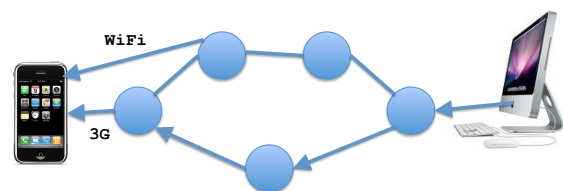
Physical Mobility



- Device attaches to a new attachment point

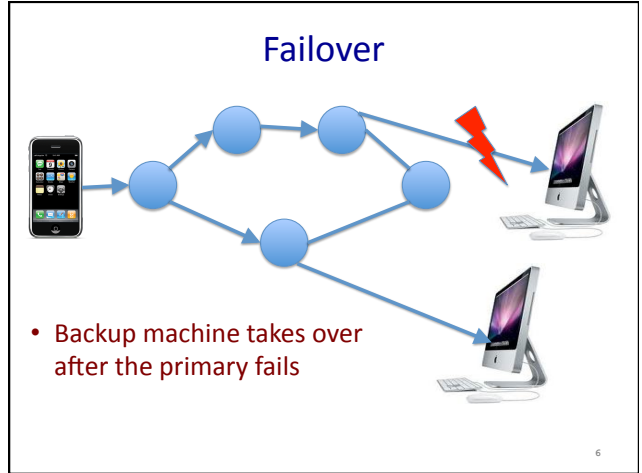
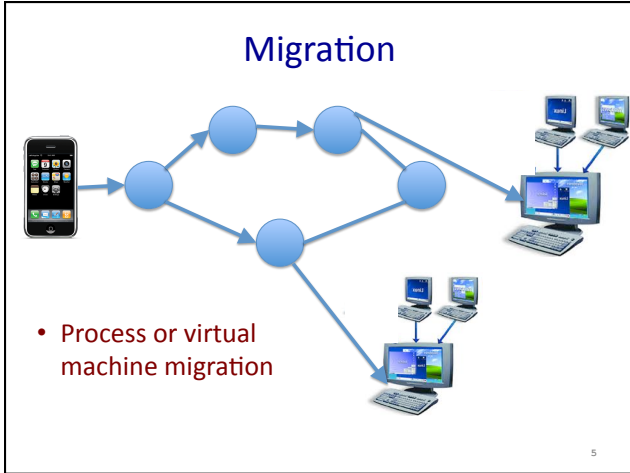
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Multi-Homing



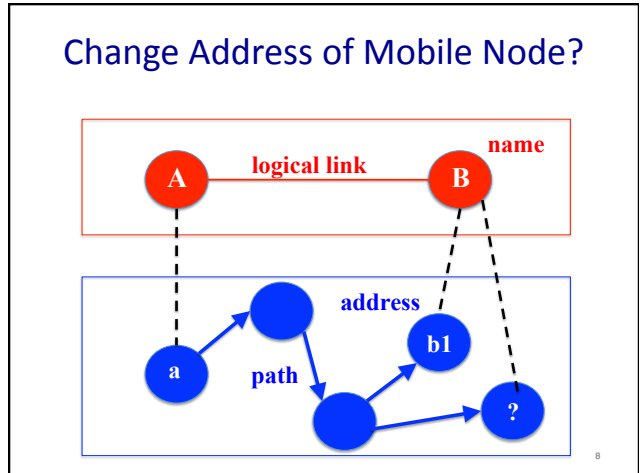
- Device starts using a different attachment point

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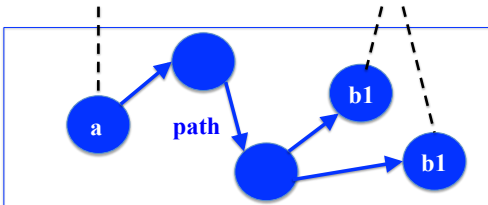


Handling Mobility

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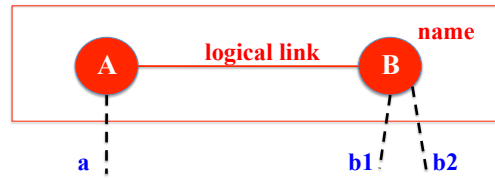
Keeping the Address the Same



- Mobility is a *routing* problem
 - Change the routes to reach the new location
 - Challenge: scalability of the routing protocol

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Changing the Address

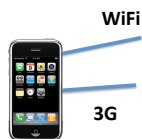


- Mobility is a *directory* problem
 - Change the mapping of name to address
 - Challenge: scalability of directory, updating neighbor

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Two Internet Design Decisions

- **Socket abstraction**
 - Connection between a pair of fixed IP addresses and port numbers
 - Leads to more emphasis on routing solutions
- **Interface addresses**
 - Addresses refer to interfaces (adaptors)
 - Not the host, or the service



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Routing Solutions

Address Stays the Same

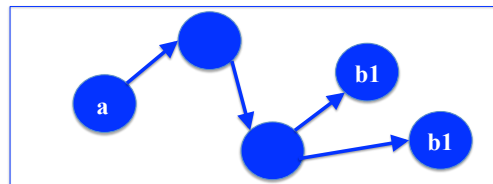
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Three Examples

- **Ethernet**
 - MAC learning of the new location
- **IP routing**
 - Inject IP address(es) at new location
- **Mobile IP**
 - Stationary home agent directs traffic to new location

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Example #1: Ethernet



- **MAC learning**
 - Learn b1's location when b1 sends a frame
 - Soft state: timeout the cached information

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Making Larger Ethernet Segments

- **Ethernet handles mobility**
 - IP address and MAC address stay the same
 - Switches learn to route to the new location
- **But, larger networks have multiple segments**
 - Cannot retain your IP address as you move
- **Solution: virtual local area networks (VLAN)**
 - Logical Ethernet segment spanning a campus
 - E.g., interconnecting the WiFi access points

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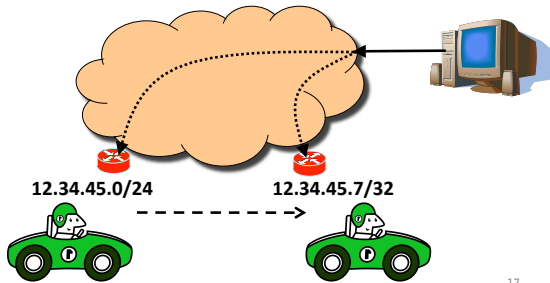
Pros and Cons

- **Advantages**
 - Seamless mobility, no changes to hosts or apps
 - No changes to MAC or IP addresses
- **Disadvantages**
 - Ethernet does not scale
 - Long paths, state per MAC address, flooding, ...
- **Widely used approach in campus networks**

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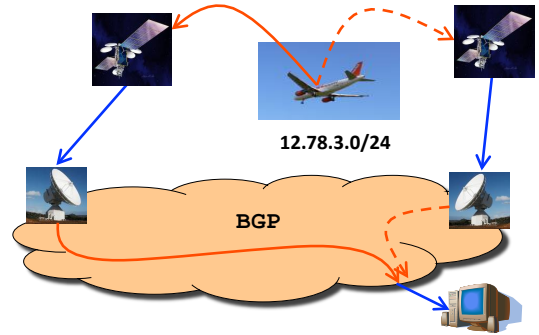
Example #2: IP Routing

- Node has a persistent address (e.g., 12.34.45.7)
- Injected into routing protocol (e.g., OSPF)



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Boeing Connexion: Wide-Area Mobility



<http://www.nanog.org/meetings/nanog31/abstracts.php?pt=NTk1Jm5hbm9nMzE=&nm=nanog31>

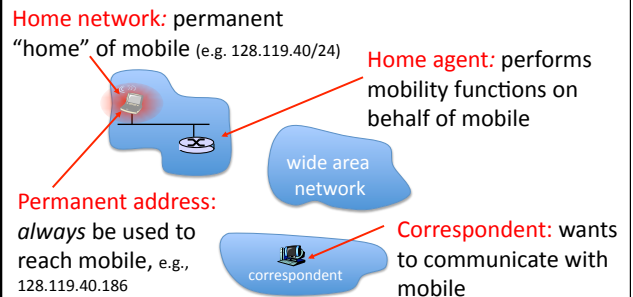
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Pros and Cons

- **Advantages**
 - Seamless mobility, no MAC or IP address changes
 - Traffic follows an efficient path to new location
- **Disadvantages**
 - Does not scale to large number of mobile hosts
 - More routing-protocol messages
 - Larger routing tables to store smaller address blocks

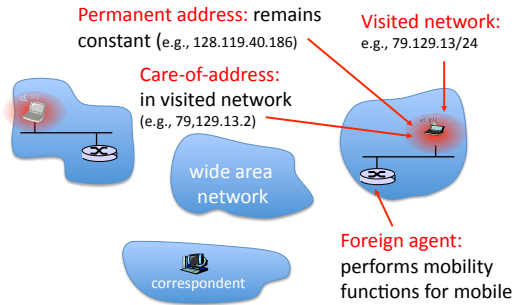
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Example #3: Mobile IP



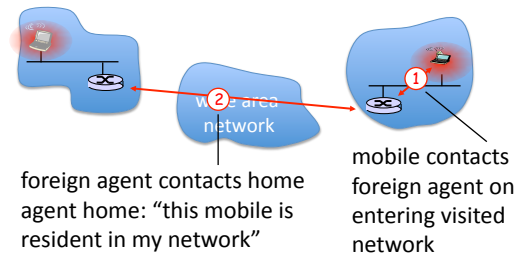
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Example #3: Mobile IP



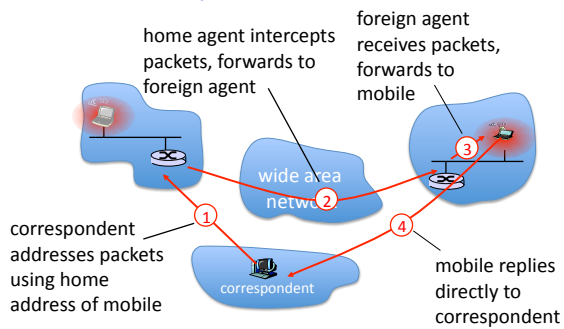
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Example #3: Mobile IP



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Example #3: Mobile IP



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Pros and Cons

- **Advantages**
 - Seamless to the remote end-point
 - No routing-protocol overhead
- **Disadvantages**
 - Overhead of running home and foreign agents
 - Inefficient "triangle routing" (high "stretch")
 - Foreign agent sends "spoofed" IP source address

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Questions

Between three mobility choices

(A) Ethernet (B) IP Routing (C) Mobile IP (D) All

Which option:

1. Scales to entire Internet
2. Less efficient communication when mobile
3. Seamless to endhosts
4. Mobility solution does not run risk of filtering

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Directory Solutions

Change the mapping of name to address

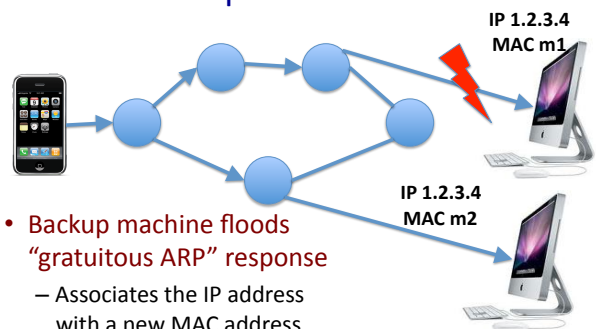
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Three Examples

- **Ethernet**
 - Gratuitous ARP to change the MAC address associated with an IP address
- **Dynamic DNS**
 - DNS updates to change the IP address(es) associated with a domain name
- **Various recent proposed designs**
 - Updating the remote end-point (e.g., end host, edge switch) to use a new address

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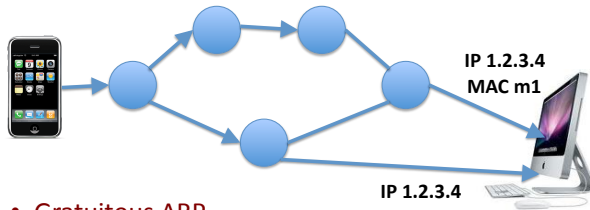
Example #1: Ethernet



- **Backup machine floods "gratuitous ARP" response**
 - Associates the IP address with a new MAC address
 - Hosts update their ARP cache

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Ethernet Multi-Homing



- **Gratuitous ARP**
 - Balance traffic over two interfaces
 - Fail over from one interface to the other

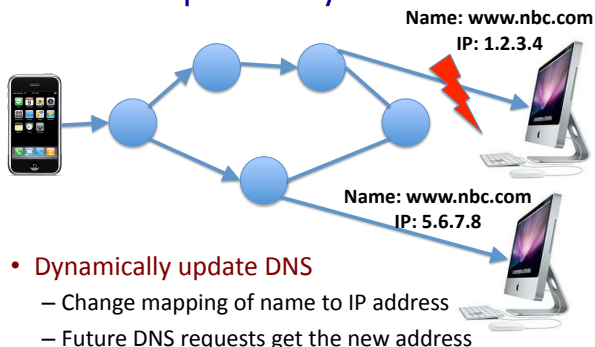
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Pros and Cons

- **Advantages**
 - Seamless change from one MAC address to another
- **Disadvantages**
 - Works only within a single Ethernet subnet
 - Scalability limitations of Ethernet
- **Used in data-center networks**
 - But doesn't help with smart phones homed to multiple administrative domains

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Example #2: Dynamic DNS



- **Dynamically update DNS**
 - Change mapping of name to IP address
 - Future DNS requests get the new address

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Applications of Dynamic DNS

- **Replicated services**
 - Direct future requests to a different replica
 - E.g., for failover, load balancing, performance, etc.
- **Services on dynamically-assigned IP addresses**
 - Residential user with a dynamic IP address
 - Directs clients to the server's current address
- **"Fast flux" in botnets**
 - Hiding phishing and malware delivery servers
 - ... behind constantly changing IP addresses

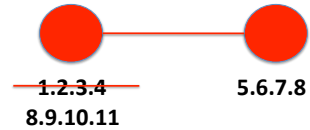
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Pros and Cons

- **Advantages**
 - No new infrastructure
 - Leverages existing DNS servers
- **Disadvantages**
 - Only helps for new connections
 - Overheads of updating DNS servers
 - Stymied by DNS caching

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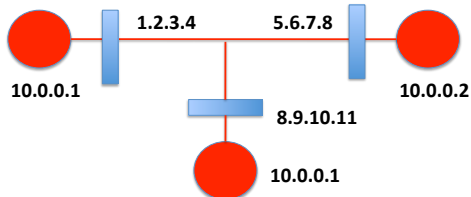
Example #3: Updating the End-Points



- **Mobile node updates the remote end-point**
 - Sends the remote end-point the new IP address
 - Allowing ongoing connection to continue
 - Can be used in conjunction with Dynamic DNS

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Updating the Edge Switches



- **Update the switches**
 - Hosts retain their addresses
 - Switches rewrite the addresses, or encapsulate
 - Used in some data-center networks

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Pros and Cons

- **Advantages**
 - Scalability of hierarchical addressing
 - Efficiency of routing along short paths
- **Disadvantages**
 - Changes to the end host (e.g., apps, TCP, etc.)
 - ... or support from the edge switches
 - Difficulty when both end-points move at once
- **Work in progress**
 - Used in some data centers, recent standards/projects
 - E.g. Princeton's Serval project (www.serval-arch.org)

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Mobility Today

- **Limited network support for mobility**
 - E.g., within a single Ethernet subnet
 - E.g., among base stations on a campus
- **Applications increasingly robust to mobility**
 - Robust to changes in IP address, and disconnections
 - E.g., e-mail client contacting the e-mail server, and allowing reading/writing while disconnected

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Mobility Tomorrow

- **Increasing demand for seamless IP mobility**
 - E.g., continue a VoIP call while on the train
 - E.g., virtual machine migration within and between data centers
- **Increasing integration of WiFi and cellular**
 - E.g., multi-homed cell phones that can use both networks (announced for Samsung Galaxy S5)
 - E.g., servers with multiple interface cards
- **Need better mobility & multi-homing solutions!**

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