# Mobility

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COS 461: Computer Networks

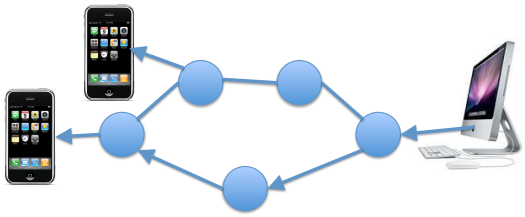
Lectures: MW 10-10:50am in Architecture N101

http://www.cs.princeton.edu/courses/archive/spr12/cos461/

## Why (and How) Things Move



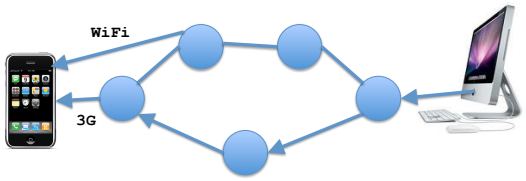
## Physical Mobility



- Device attaches to a new attachment point



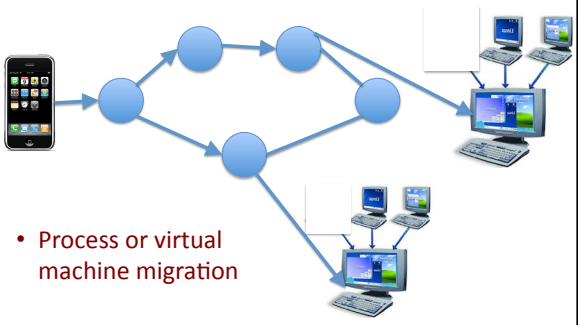
## Multi-Homing




- Device starts using a different attachment point



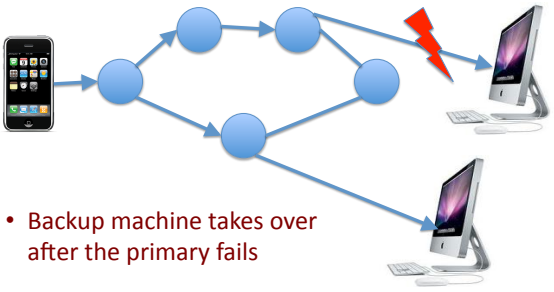
## Migration



- Process or virtual machine migration



## Failover

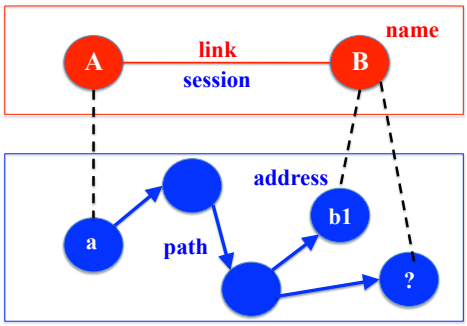


- Backup machine takes over after the primary fails

## Handling Mobility

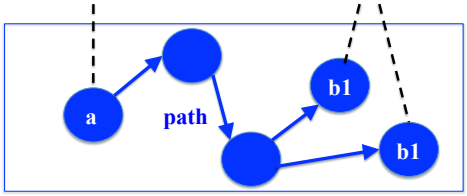


## Change Address of Mobile Node?





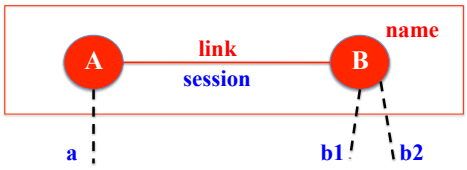

## Keeping the Address the Same




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



## Changing the Address




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



## 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




## Routing Solutions

Address Stays the Same

## 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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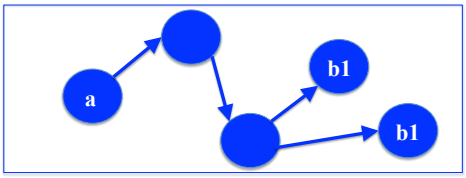
## Example #1: Ethernet




- 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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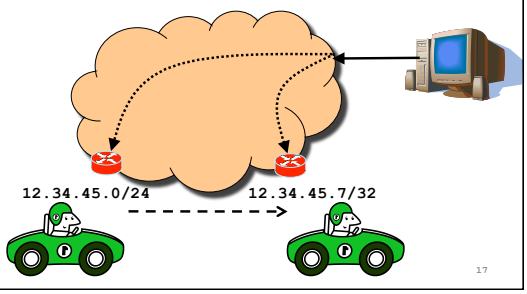
## Example #2: IP Routing

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

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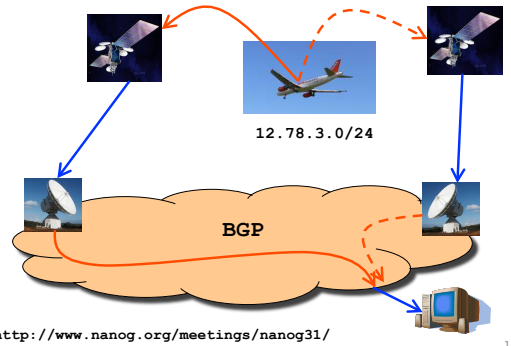
## Boeing Connexion: Wide-Area Mobility




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

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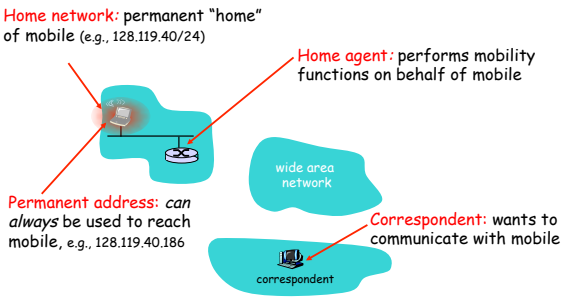
## Pros and Cons

- 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

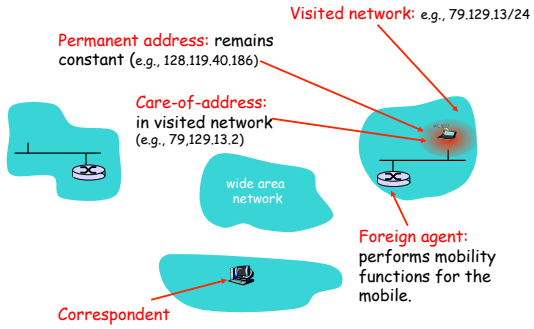


## Example #3: Mobile IP



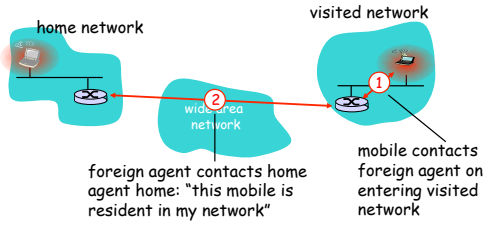



## Visited Network and Care-of Address





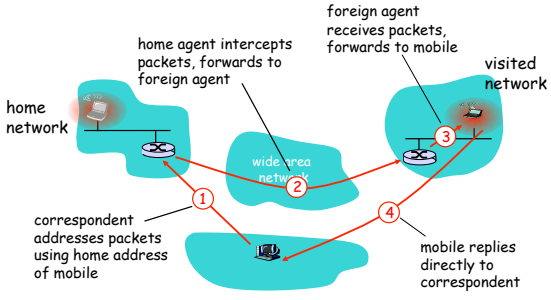

## Mobility: Registration




- Foreign agent knows about mobile
- Home agent knows location of mobile



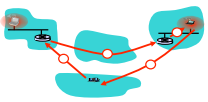
## Mobility via Indirect Routing






## 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



## 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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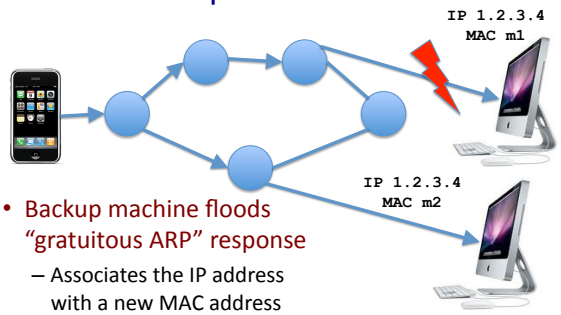
## Example #1: Ethernet




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

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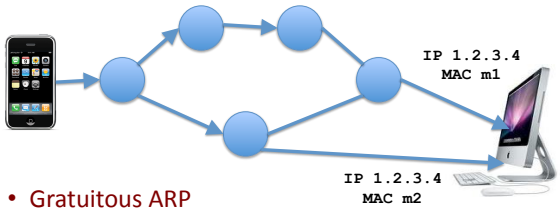
## Ethernet Multi-Homing




- 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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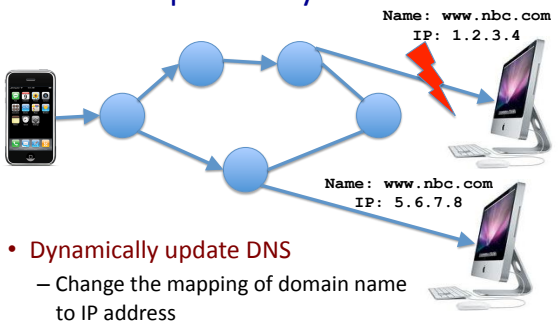
## Example #2: Dynamic DNS




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

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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

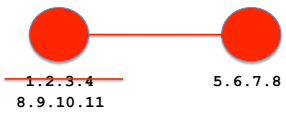


## Pros and Cons

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



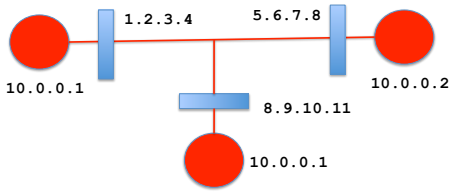
## Example #3: Updating the End-Points




- 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



## Updating the Edge Switches




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



## 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



## 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

## 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
  - E.g., servers with multiple interface cards
- Need better mobility & multi-homing solutions!



## Conclusions

- Mobility
  - Change is hard
  - Routing and directory solutions
  - Mobility is still a moving target… ☺
- Friday's precept: IP routers and assignment #2
- Midterm next week
  - Midterm next **Wednesday** during lecture time
  - In **Frist 302**, *not* in the lecture hall