Last Lecture: Data Link Layer

1. *Design goals and issues*
2. *(More on) Error Control and Detection*
3. *Multiple Access Control (MAC)*
4. *Ethernet, LAN Addresses and ARP*
5. *Hubs, Bridges, Switches*
6. *Wireless LANs* ✔
7. Mobile Networking
8. WLAN Security

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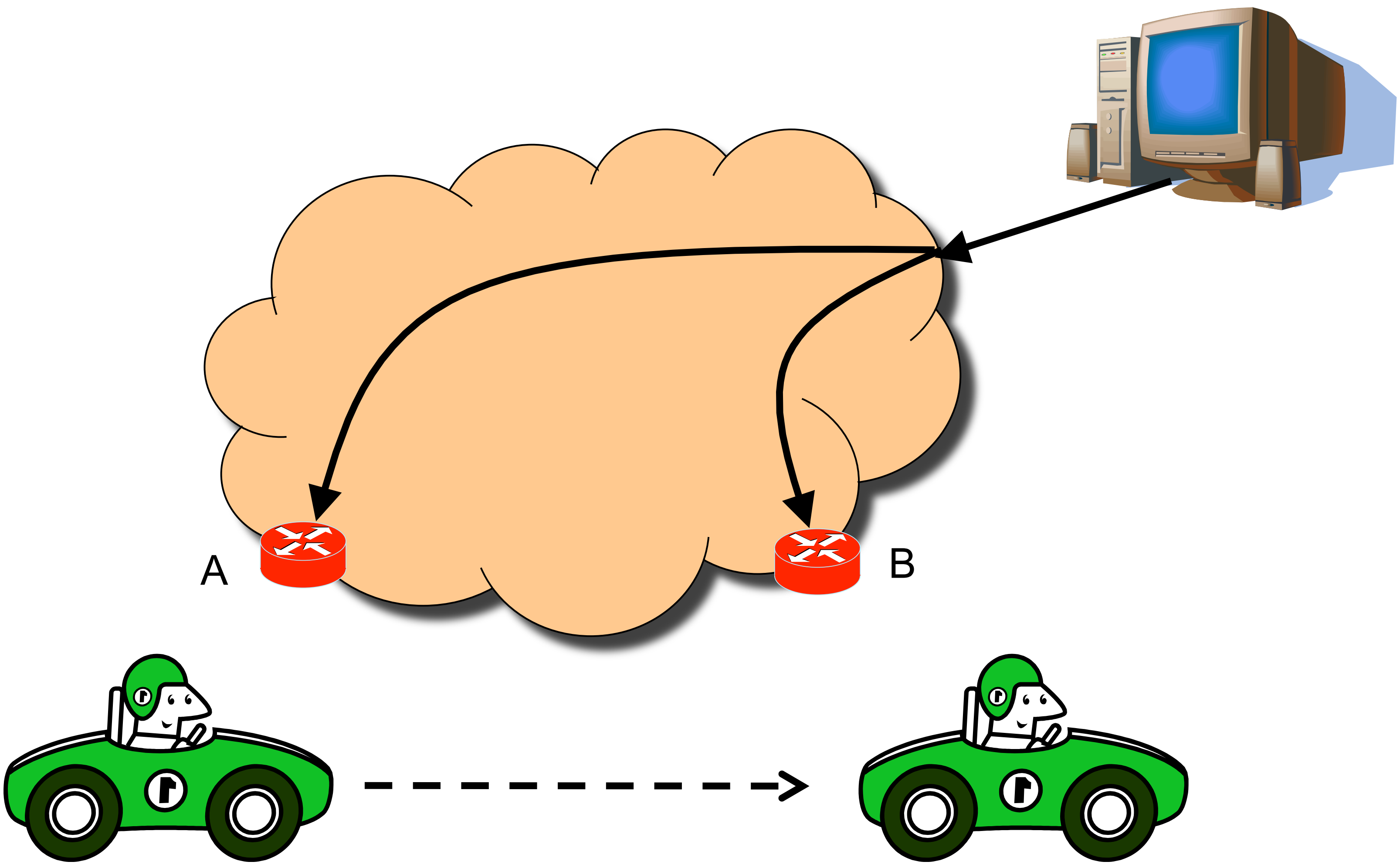
7. Mobile Networking ✔
   - *Credits: some slides from Jennifer Rexford @ Princeton*
8. WLAN Security

Varying Degrees of User Mobility

- Moves only within same access network
  - Single access point: mobility is irrelevant
  - Multiple access points: only link-link layer changes
  - Either way, users is not mobile at the network layer
- Shuts down between changes access networks
  - Host gets new IP address at the new access network
  - No need to support any ongoing transfers
  - Applications have become good at supporting this
- Maintains connections while changing networks
  - Surfing the 'net while driving in a car or flying a plane
  - Need to ensure traffic continues to reach the host

Maintaining Ongoing Transfers

- Seamless transmission to a mobile host



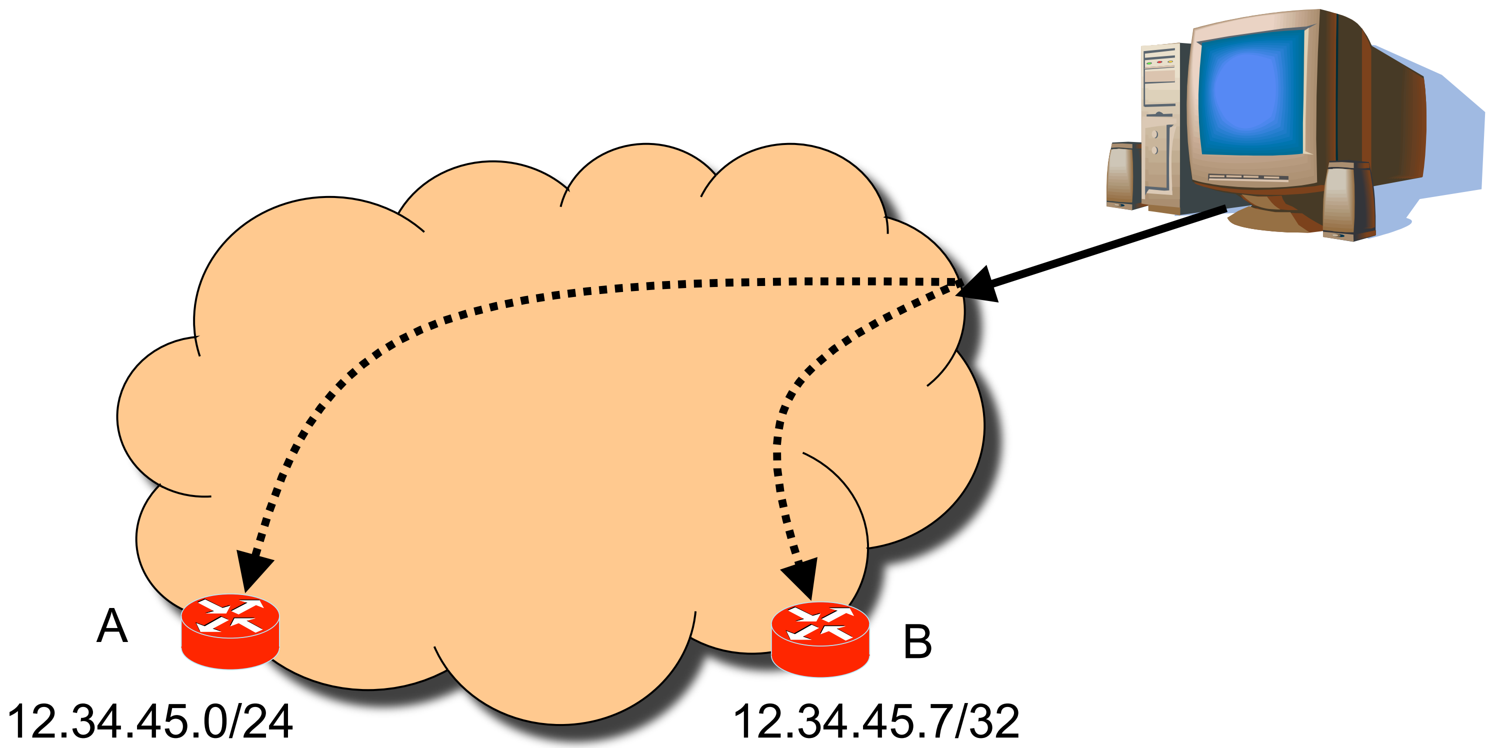
E.g., Keep Track of Friends on the Move

- Sending a letter to a friend who moves often
  - How do you know where to reach him?
- Option #1: have him update you
  - Friend contacts you on each move
  - So you can mail him directly
  - E.g., *Boeing Connexion service*

- Option #2: ask his parents when needed
  - Parents serve as “permanent address”
  - So they can forward your letter to him
  - E.g., Mobile IP

Option #1: Let Routing Protocol Handle It

- Mobile node has a single, persistent address
- Address injected into routing protocol (e.g., OSPF)



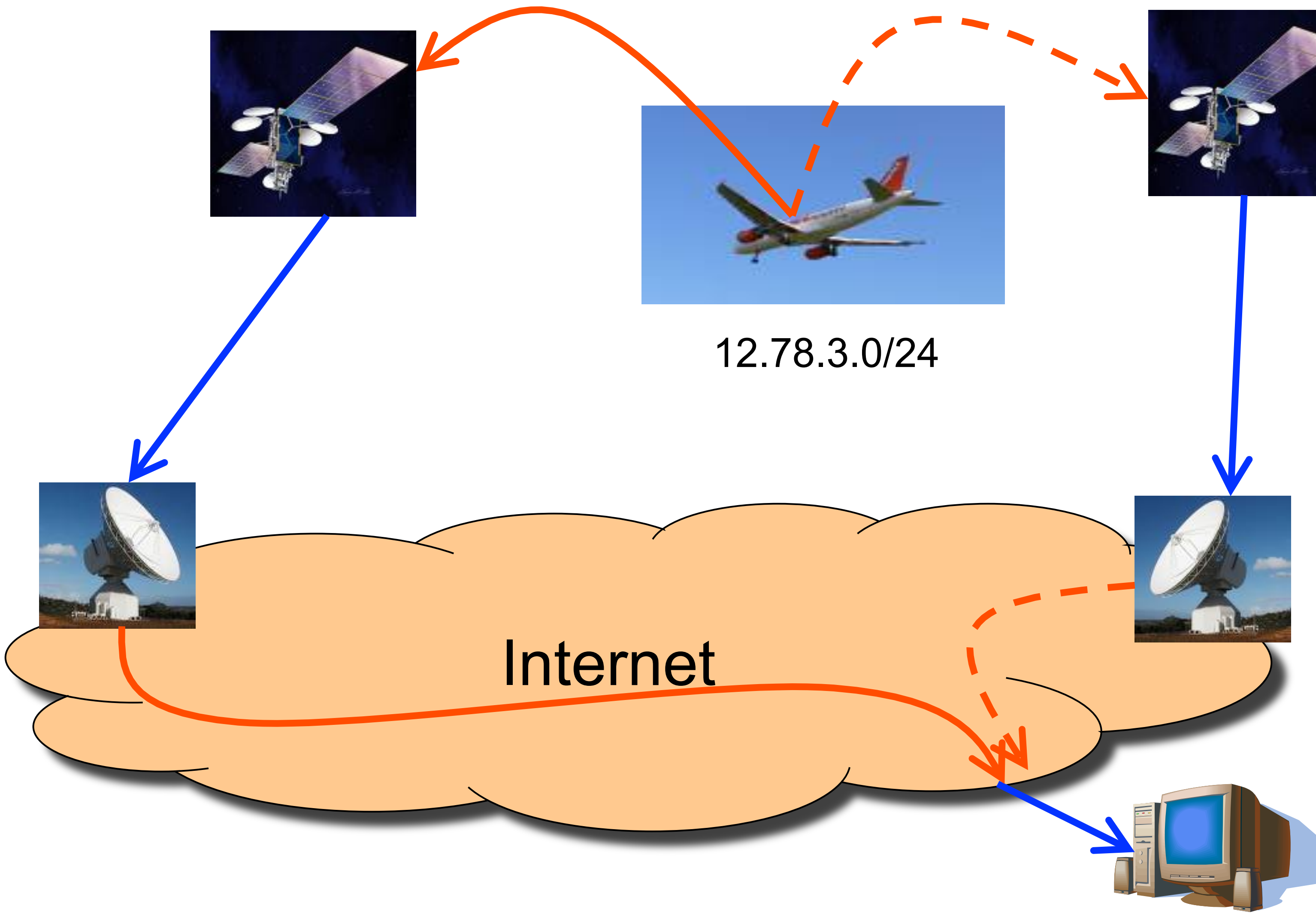
Mobile host with IP address 12.34.45.7

Example: Boeing Connexion Service

- Example: Boeing Connexion service
  - Mobile Internet access provider
  - WiFi "hot spot" at 35,000 feet moving 600 mph

- Communication technology
  - Antenna on the plane to leased satellite transponders
  - Ground stations serve as Internet gateways
- Using BGP for mobility
  - IP address block per airplane
  - Ground station advertises into BGP
  - http://www.nanog.org/mtg-0405/abarbanel.html

Example: Boeing Connexion Service



In-Flight Wi-Fi Access

- Boeing Connexion Service
  - Cost structure horrible: installation took weeks, gears too heavy (800 pounds) ➔ Cost > benefit
  - Worked well! Went out of business in December 2006 …

- 2009: other in-flight ISPs started to "take off"
  - PDAs, Laptops, Social Networking more popular → nore users "need" Internet access in-flight
  - Better cost structures
  - AirCell & Row 44 in the US
  - OnAir in Europe and the Middle East

Some restrictions

- No US airline allows VoIP calling, voice chats, video chats, or any variant thereof
  - People prefer quiet flights
  - Aircell blocks well-known ports
  - If you use VPN, you can do it anyhow!

AirCell

- In a 2006 auction, AirCell won
  - 3 MHz in the 800 MHz band
  - Split into 1.5 MHz for uplink and 1.5 MHz for downlink
- AirCell uses 3G-cellular technology
  - Qualcomm's *EVDO Rev. A* service
  - Few Mbps to the plane, few hundred Mbps from the plane
  - Built a network of ground stations that have antennas that point up
- Example service: gogo Inflight Internet

AirCell's Antennas (under the Jet planes)

Row 44

- Similar to Connexion: use satellites
  - K_u-band satellites
  - 4 to 20 Mbps to a single plane
  - Can cover larger areas (than that of AirCell)
- Satellites are geostationary, orbiting above the equator
  - Flights near the poles can't have service
- BTW, OnAir uses satellites too (Inmarsat fourth-generation BGAN)

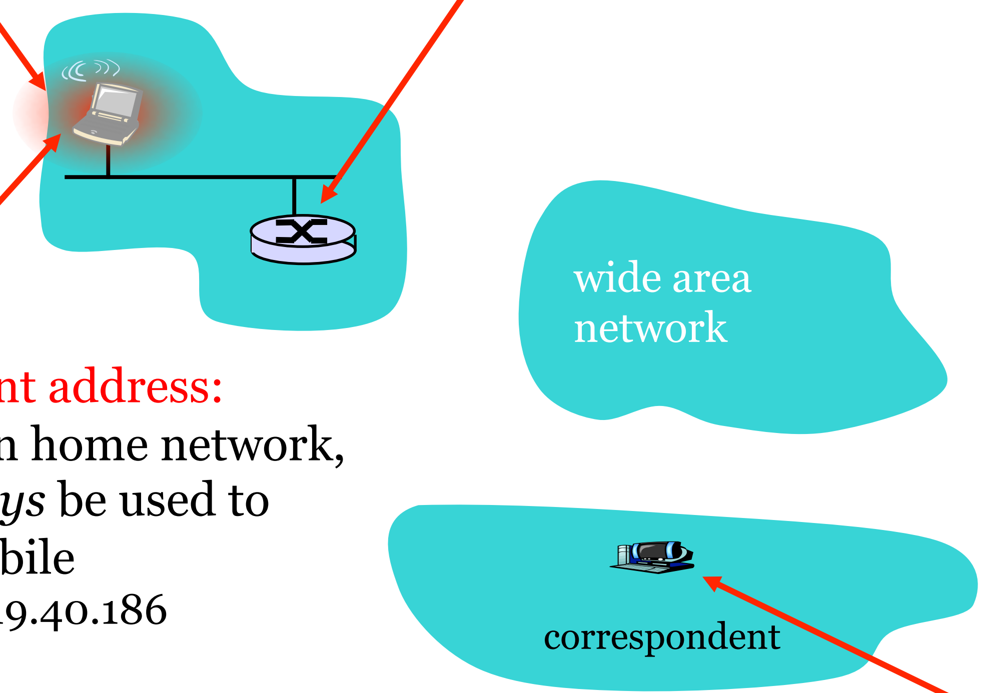
Summary: Letting Routing Handle It

- Advantages
  - No changes to the end host
  - Traffic follows an efficient path to new location
- Disadvantages
  - Does not scale to large number of mobile hosts
    - Large number of routing-protocol messages
    - Larger routing tables to store smaller address blocks
- Alternative
  - Mobile IP

Option #2: Home Network and Home Agent

Home network: permanent "home" of mobile (e.g., 128.119.40/24)

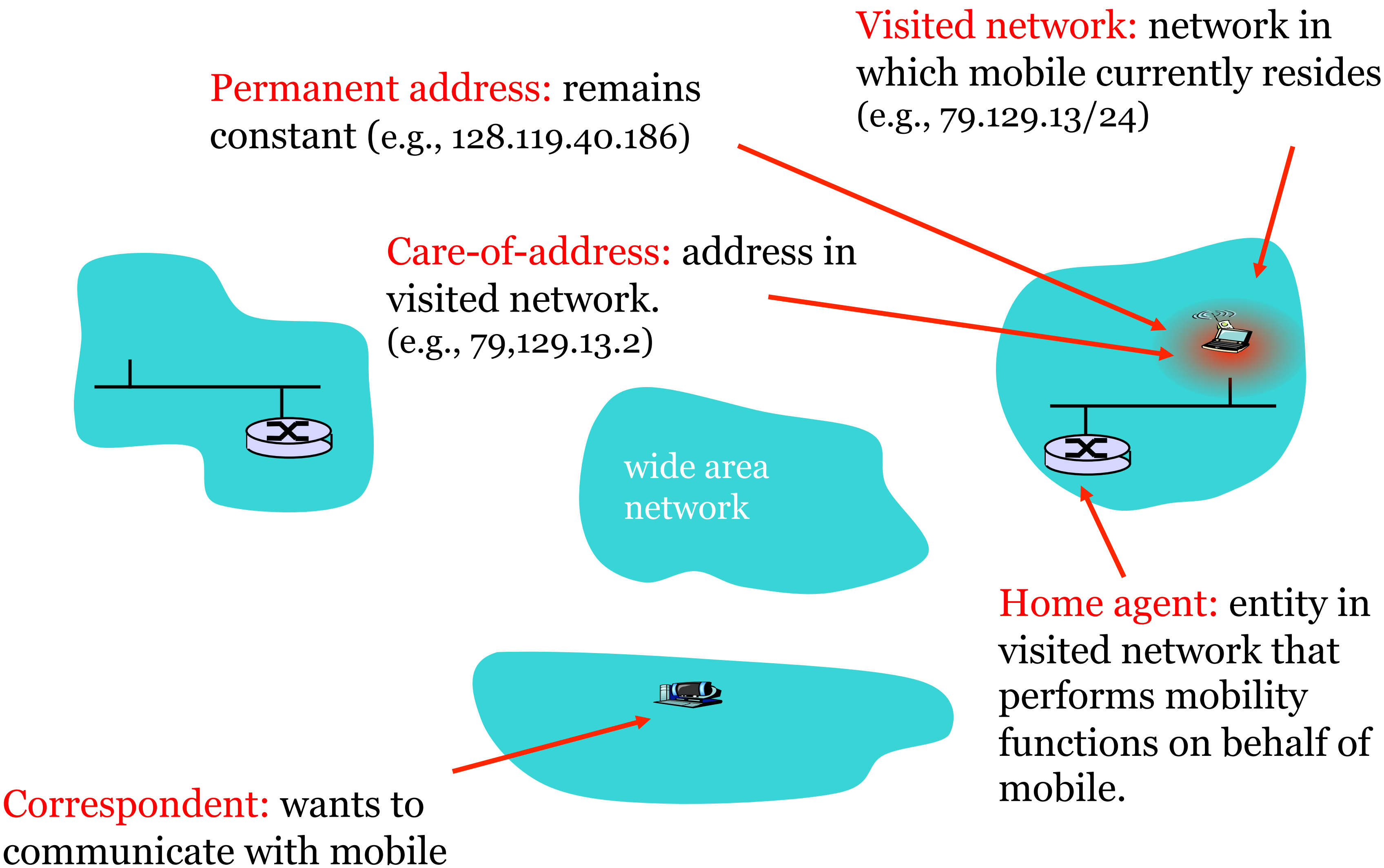
Home agent: entity that will perform mobility functions on behalf of mobile, when mobile is remote



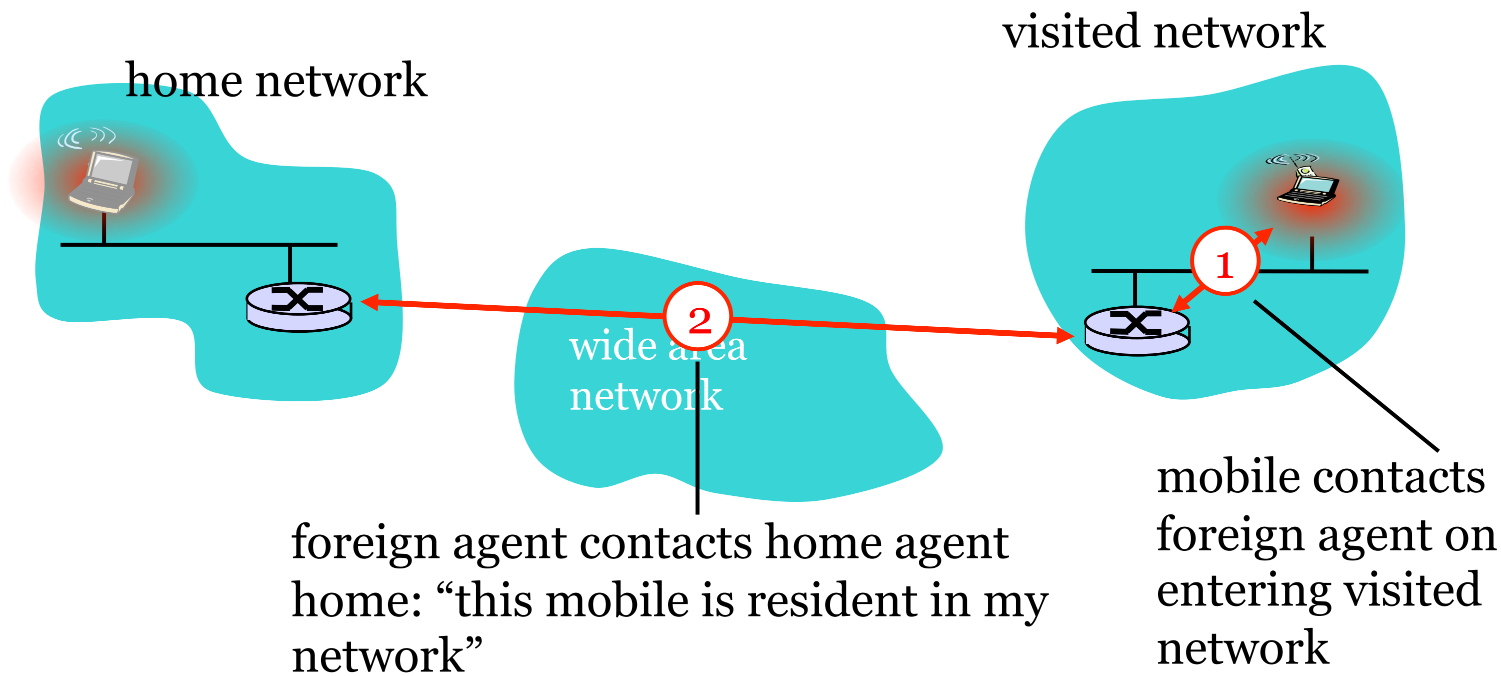
Permanent address: address in home network, *can always* be used to reach mobile
e.g., 128.119.40.186

Correspondent: wants to communicate with mobile

Visited Network and Care-of Address

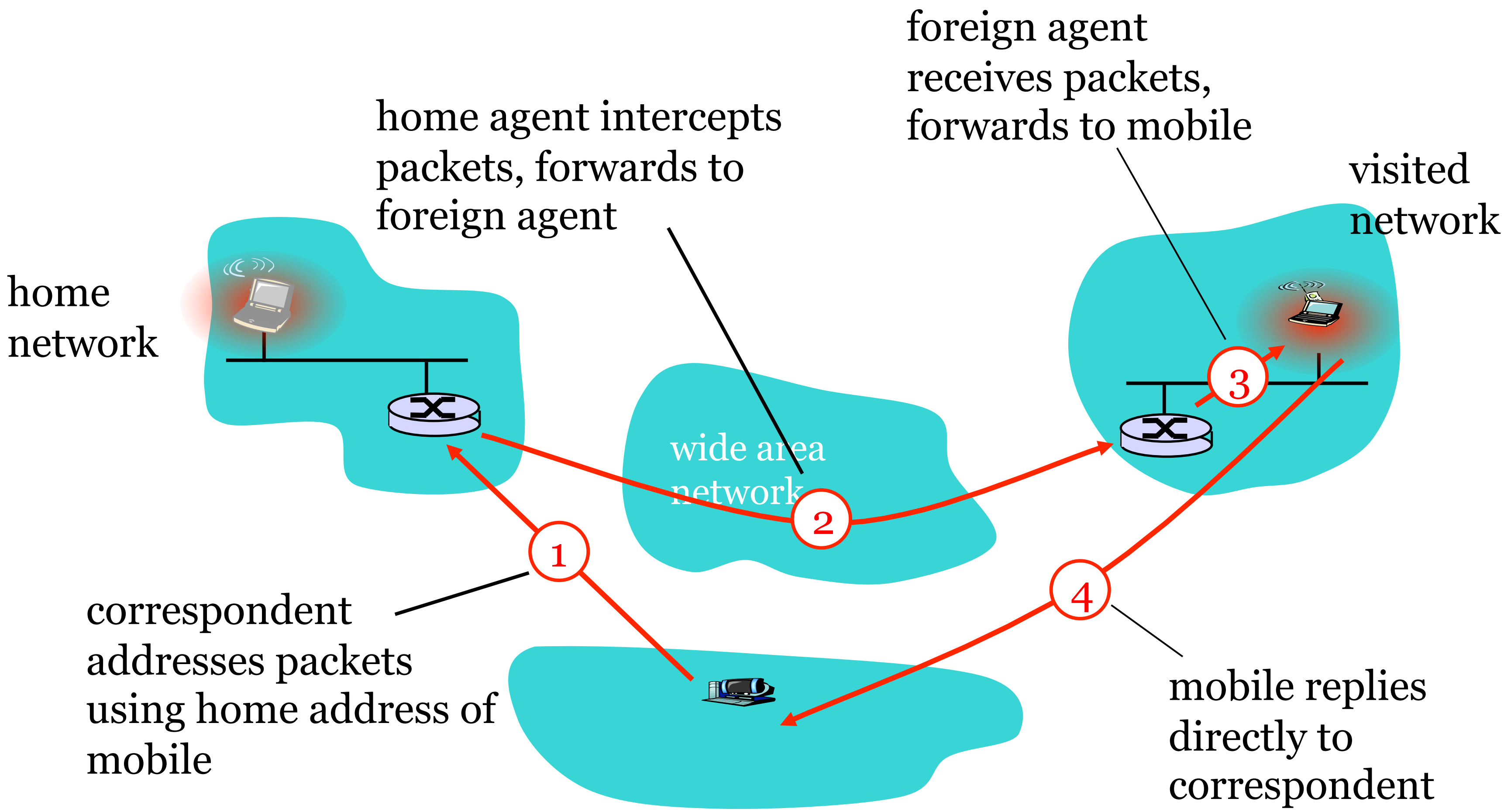


Mobility: Registration



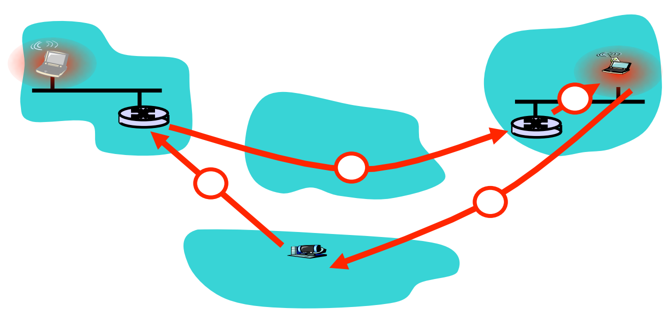
- Foreign agent knows about mobile
- Home agent knows location of mobile

Mobility via Indirect Routing

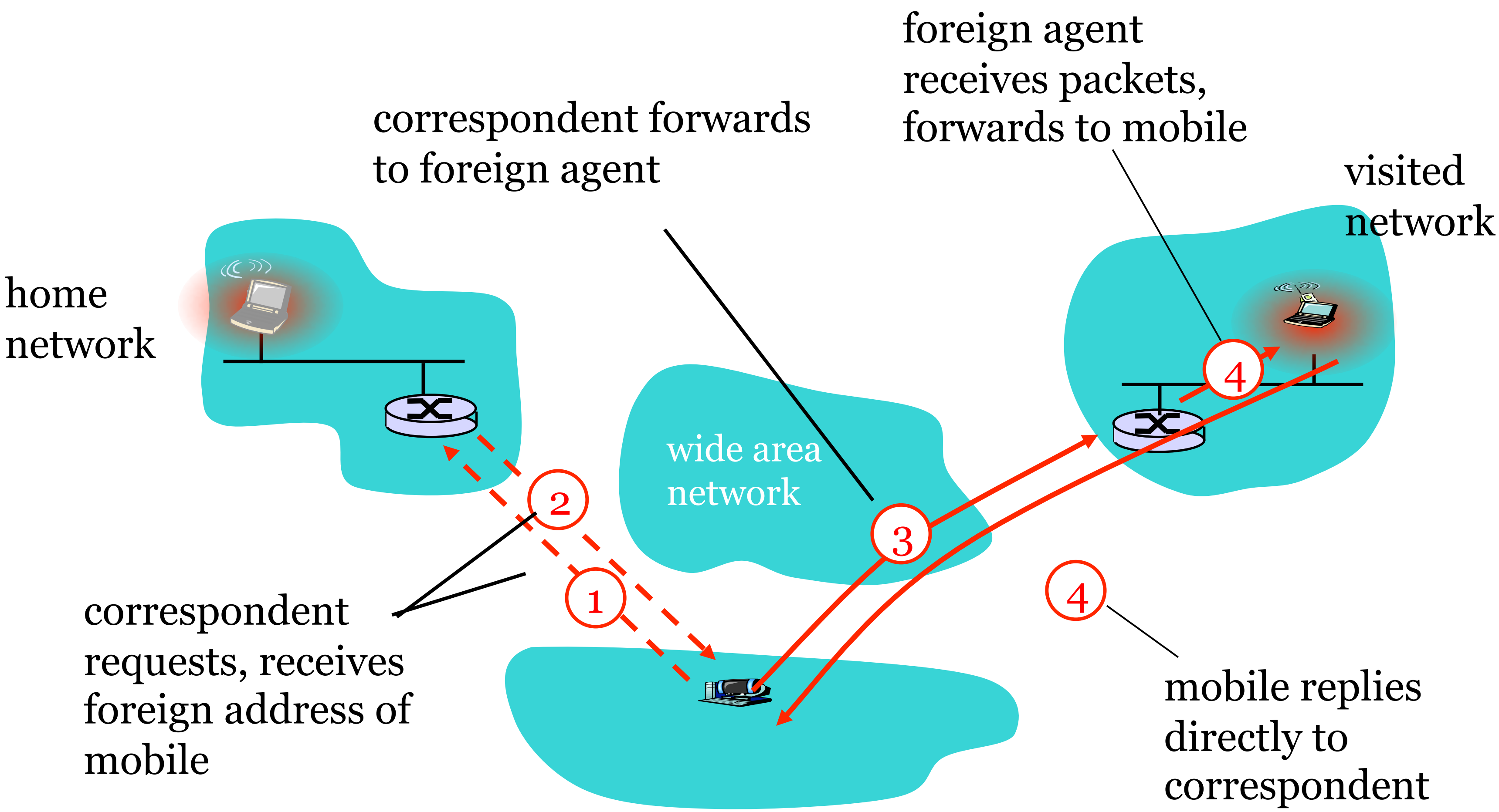


Indirect Routing: Efficiency Issues

- Mobile uses two addresses
  - Permanent address: used by correspondent (making mobile's location is transparent to correspondent)
  - Care-of-address: used by the home agent to forward datagrams to the mobile
- Mobile may perform the foreign agent functions
- Triangle routing is inefficient
  - E.g., correspondent and mobile in the same network



Mobility via Direct Routing



No longer transparent to the correspondent

Mobility Today

- Limited support for mobility
  - E.g., among base stations on a campus
- Applications increasingly robust under 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
  - New Google Gears for offline Web applications
- Increasing demand for seamless IP mobility
  - E.g., continue a VoIP call while on the train
- Increasing integration of WiFi and cellular
  - E.g., dual-mode cell phones that can use both networks
  - Called Unlicensed Mobile Access (UMA)

Impact on Higher-Layer Protocols

- Wireless and mobility change path properties
  - Wireless: higher packet loss, not from congestion
  - Mobility: transient disruptions, and changes in RTT
- Logically, impact should be minimal …
  - Best-effort service model remains unchanged
  - TCP and UDP can (and do) run over wireless, mobile
- But, performance definitely *is* affected
  - TCP treats packet loss as a sign of congestion
  - TCP tries to estimate the RTT to drive retransmissions
  - TCP does not perform well under out-of-order packets
- Internet not designed with these issues in mind