# Reti degli elaboratori

## Dealing with Mobility; Bluetooth Basics

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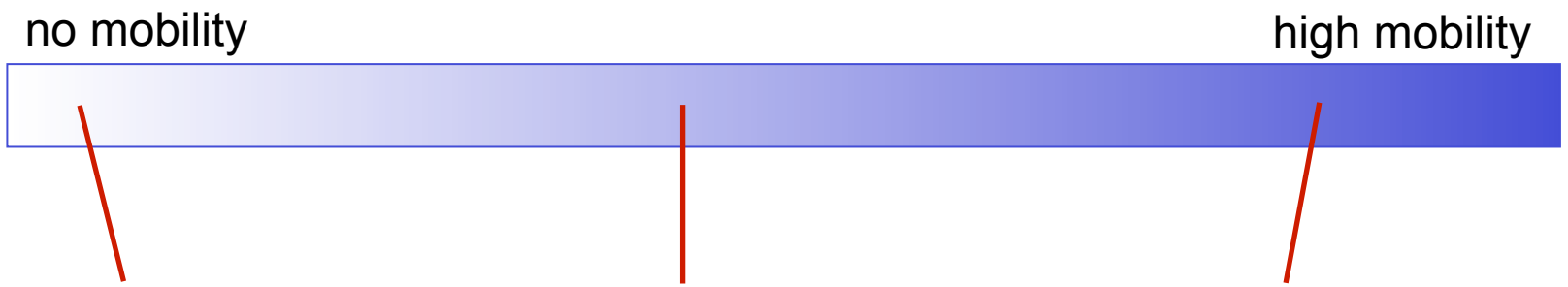
# What is mobility?

- spectrum of mobility, from the *network* perspective:




mobile wireless user, using same access point

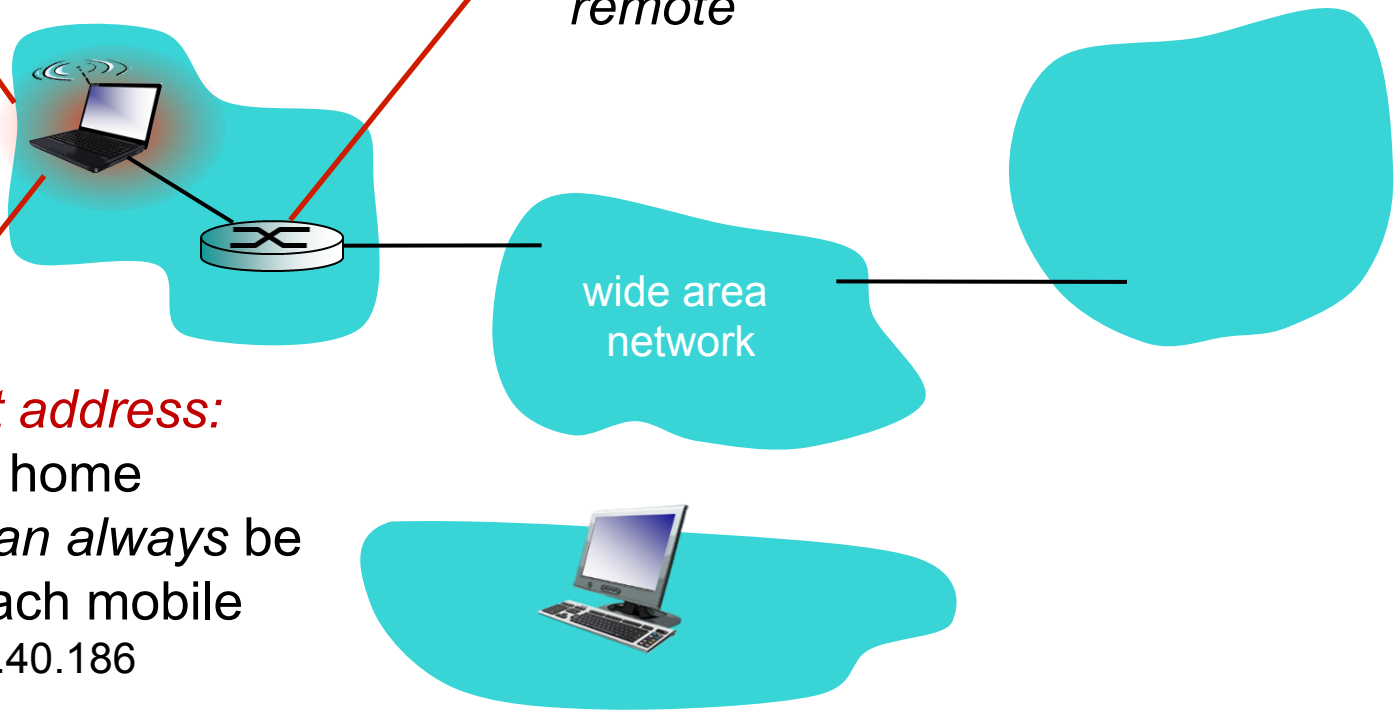
mobile user, connecting/ disconnecting from network using DHCP

mobile user, passing through multiple access point while maintaining ongoing connections (like cell phone)

# Mobility: vocabulary

*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*



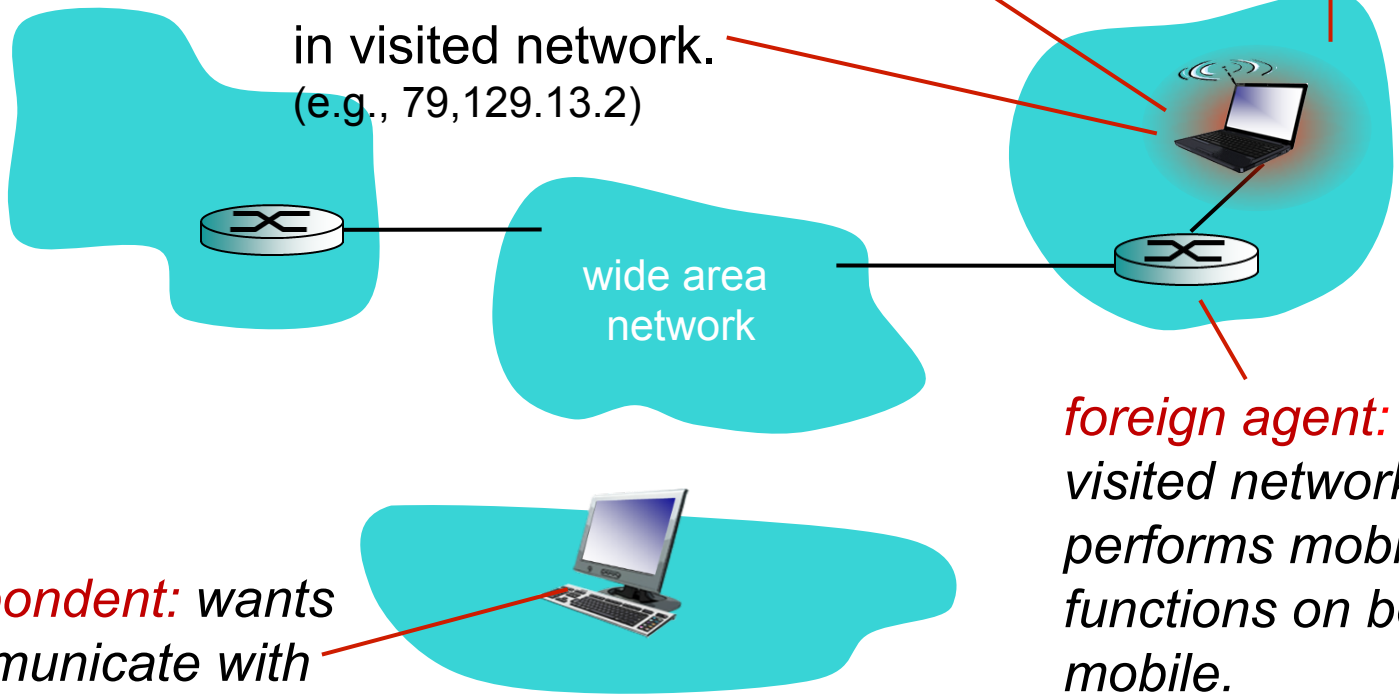

*permanent address:* address in home network, *can always* be used to reach mobile
e.g., 128.119.40.186

# Mobility: more vocabulary

*permanent address:* remains constant (e.g., 128.119.40.186)

*visited network:* network in which mobile currently resides (e.g., 79.129.13/24)

*care-of-address:* address in visited network. (e.g., 79,129.13.2)



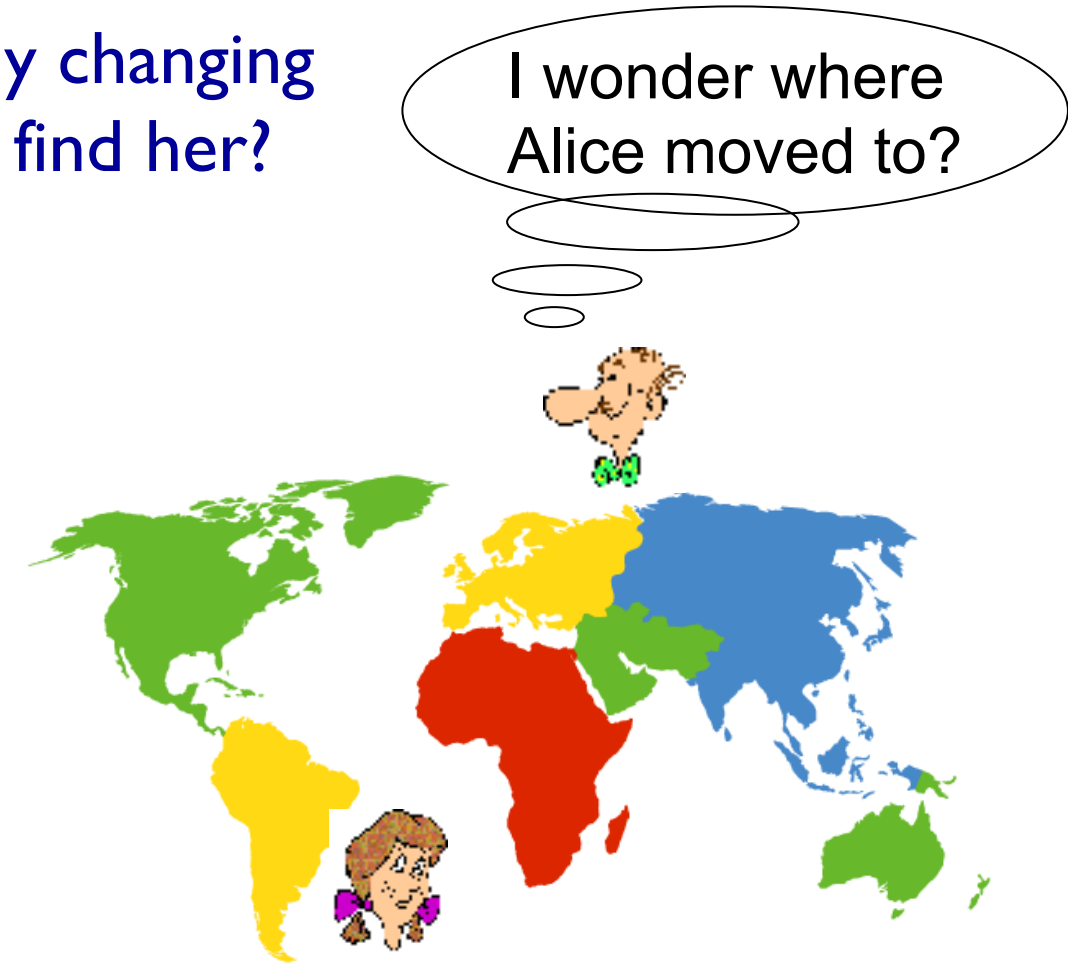

*foreign agent:* *entity in visited network that performs mobility functions on behalf of mobile.*

*correspondent:* *wants to communicate with mobile*

# How do *you* contact a mobile friend:

Consider friend frequently changing addresses, how do you find her?

- search all phone books?
- call her parents?
- expect her to let you know where he/she is?



# Mobility: approaches

- *let routing handle it:* routers advertise permanent address of mobile-nodes-in-residence via usual routing table exchange.
  - routing tables indicate where each mobile located
  - no changes to end-systems
- *let end-systems handle it:*
  - *indirect routing:* communication from correspondent to mobile goes through home agent, then forwarded to remote
  - *direct routing:* correspondent gets foreign address of mobile, sends directly to mobile

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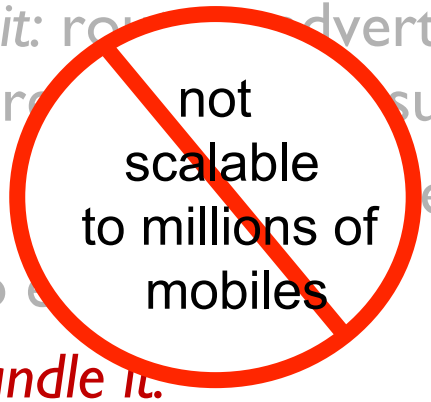
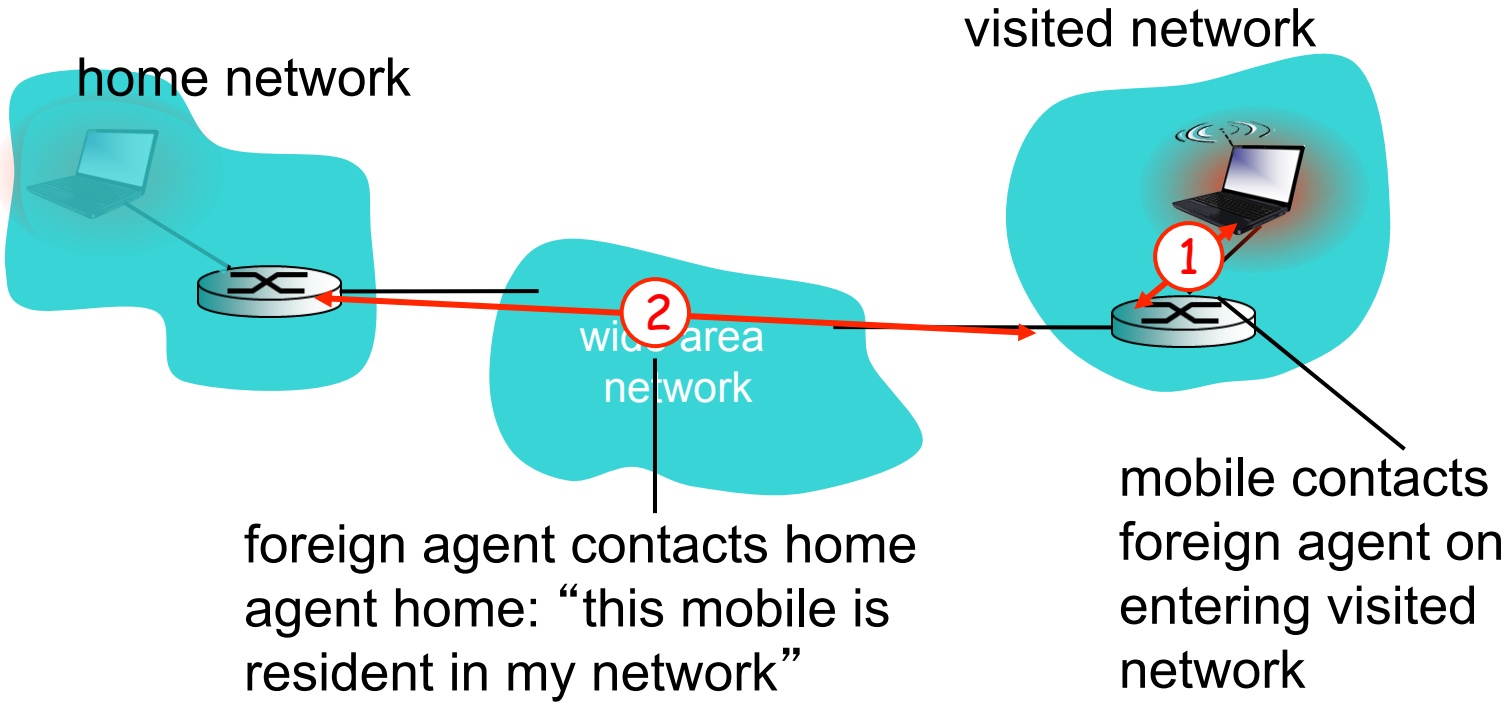


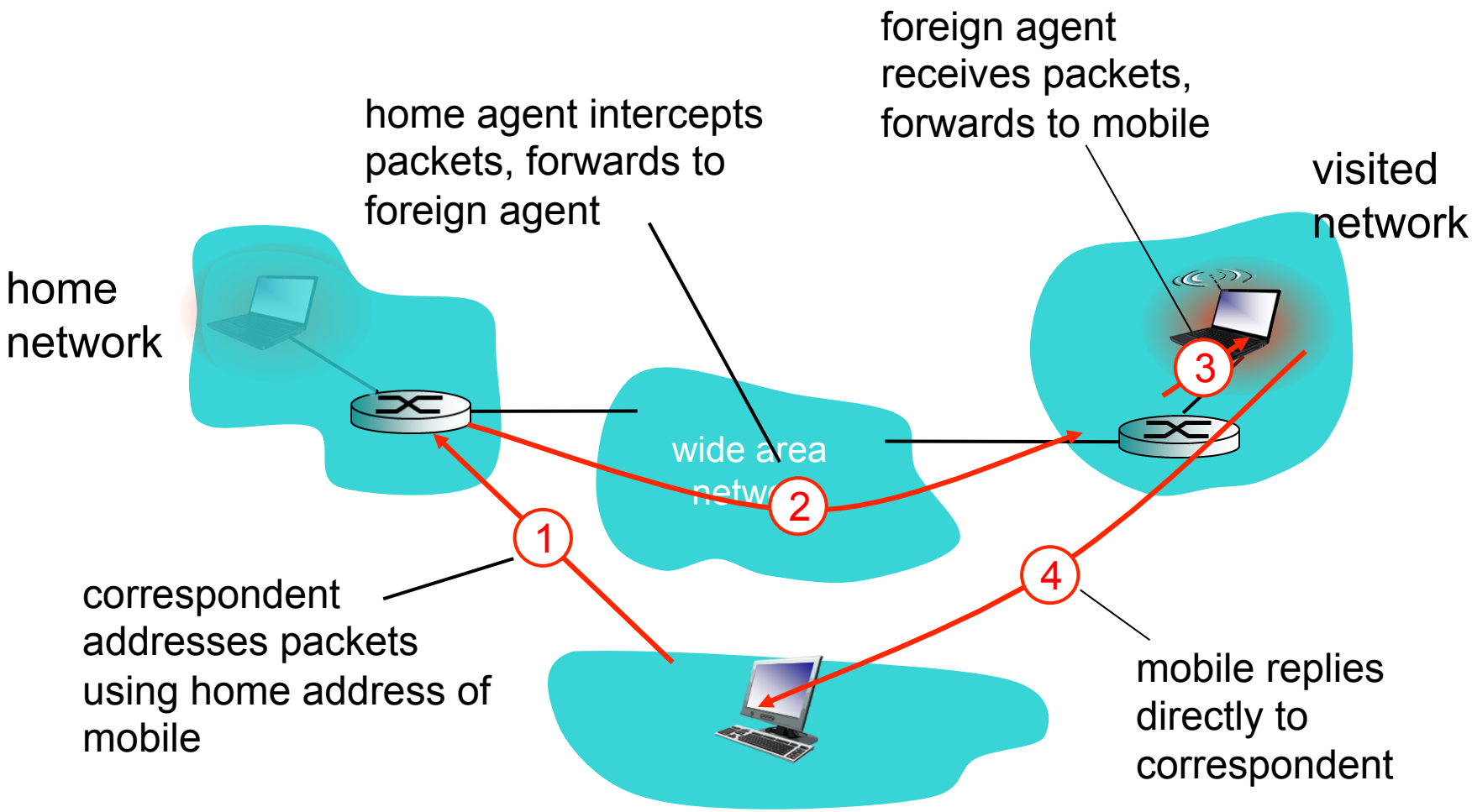
# Mobility: registration




end result:

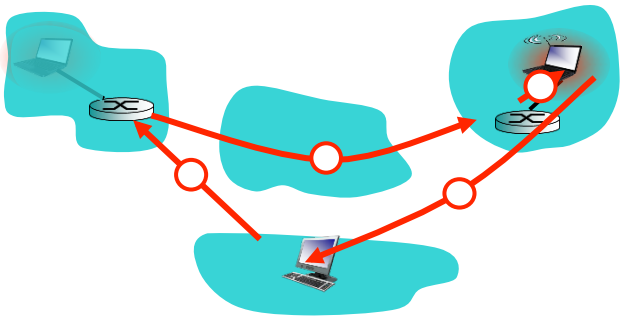
- foreign agent knows about mobile
- home agent knows location of mobile

# Mobility via indirect routing



# Indirect Routing: comments

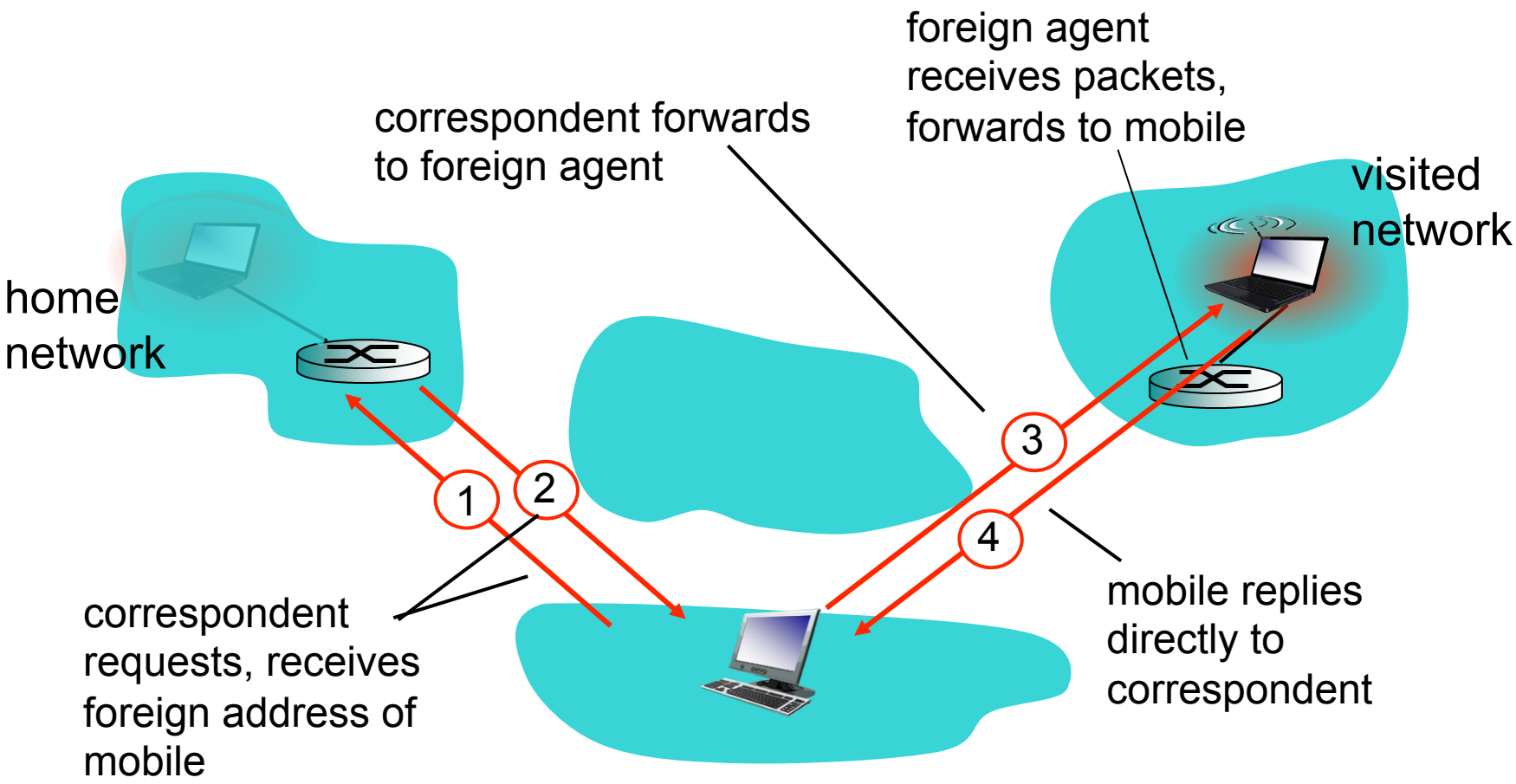
- mobile uses two addresses:
  - permanent address: used by correspondent (hence mobile location is *transparent* to correspondent)
  - care-of-address: used by home agent to forward datagrams to mobile
- foreign agent functions may be done by mobile itself
- triangle routing: correspondent-home-network-mobile
  - inefficient when correspondent, mobile are in same network



# Indirect routing: moving between networks

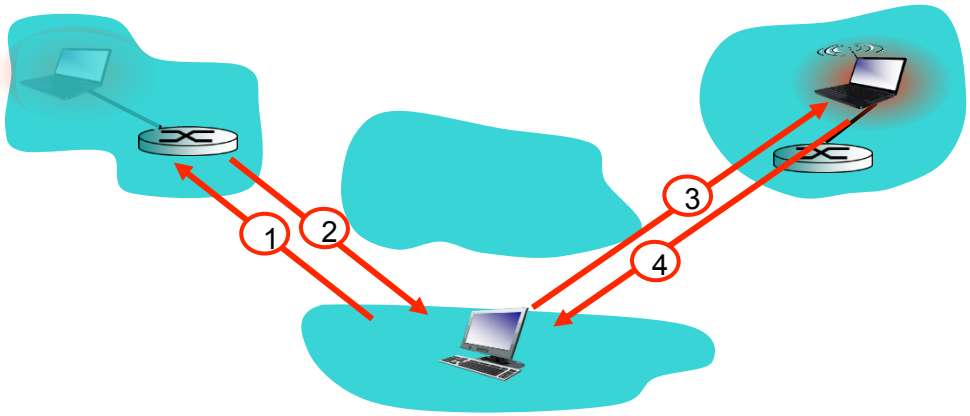
- suppose mobile user moves to another network
  - registers with new foreign agent
  - new foreign agent registers with home agent
  - home agent update care-of-address for mobile
  - packets continue to be forwarded to mobile (but with new care-of-address)
- mobility, changing foreign networks transparent: *on going connections can be maintained!*

# Mobility via direct routing



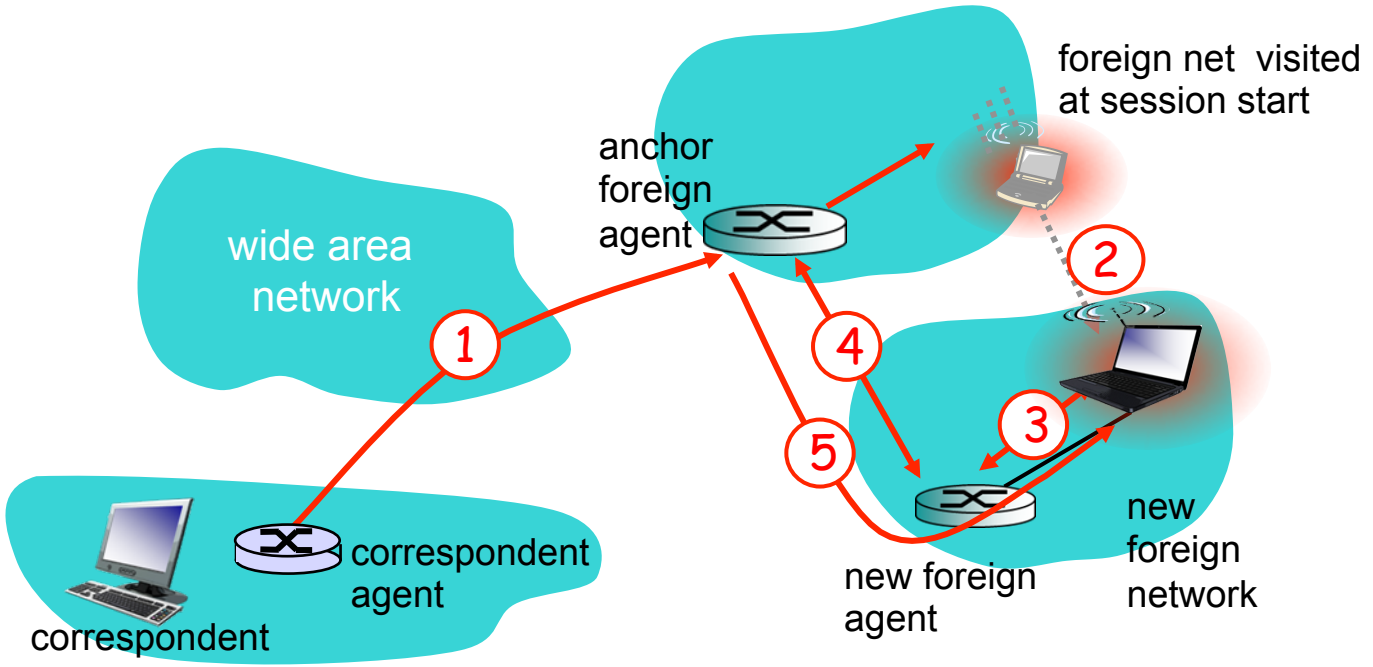
# Mobility via direct routing: comments

- overcome triangle routing problem
- *non-transparent to correspondent:* correspondent must get care-of-address from home agent
  - what if mobile changes visited network?



# Accommodating mobility with direct routing

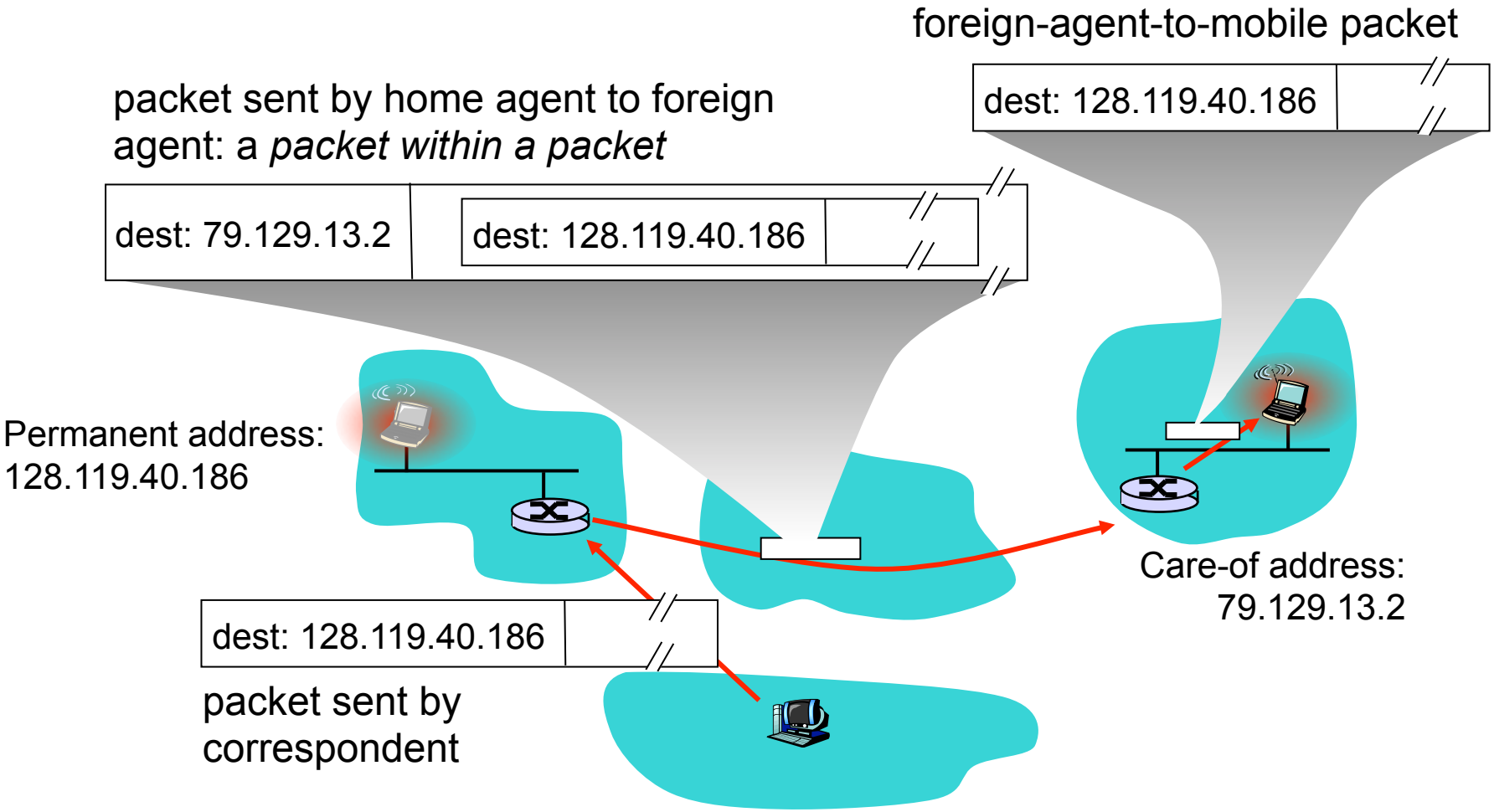
- anchor foreign agent: FA in first visited network
- data always routed first to anchor FA
- when mobile moves: new FA arranges to have data forwarded from old FA (chaining)



# Mobile IP

- RFC 3344
- has many features we have seen:
  - home agents, foreign agents, foreign-agent registration, care-of-addresses, encapsulation (packet-within-a-packet)
- three components to standard:
  - indirect routing of datagrams
  - agent discovery
  - registration with home agent

# Mobile IP: indirect routing

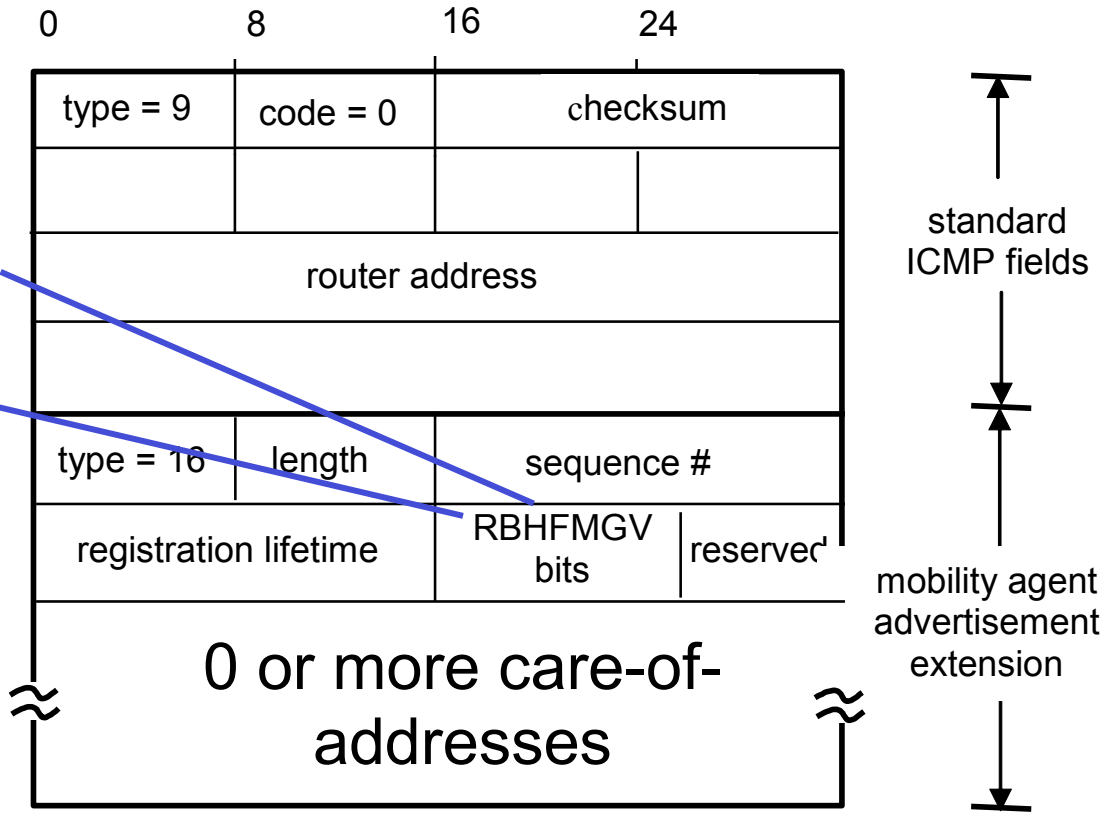


# Mobile IP: agent discovery

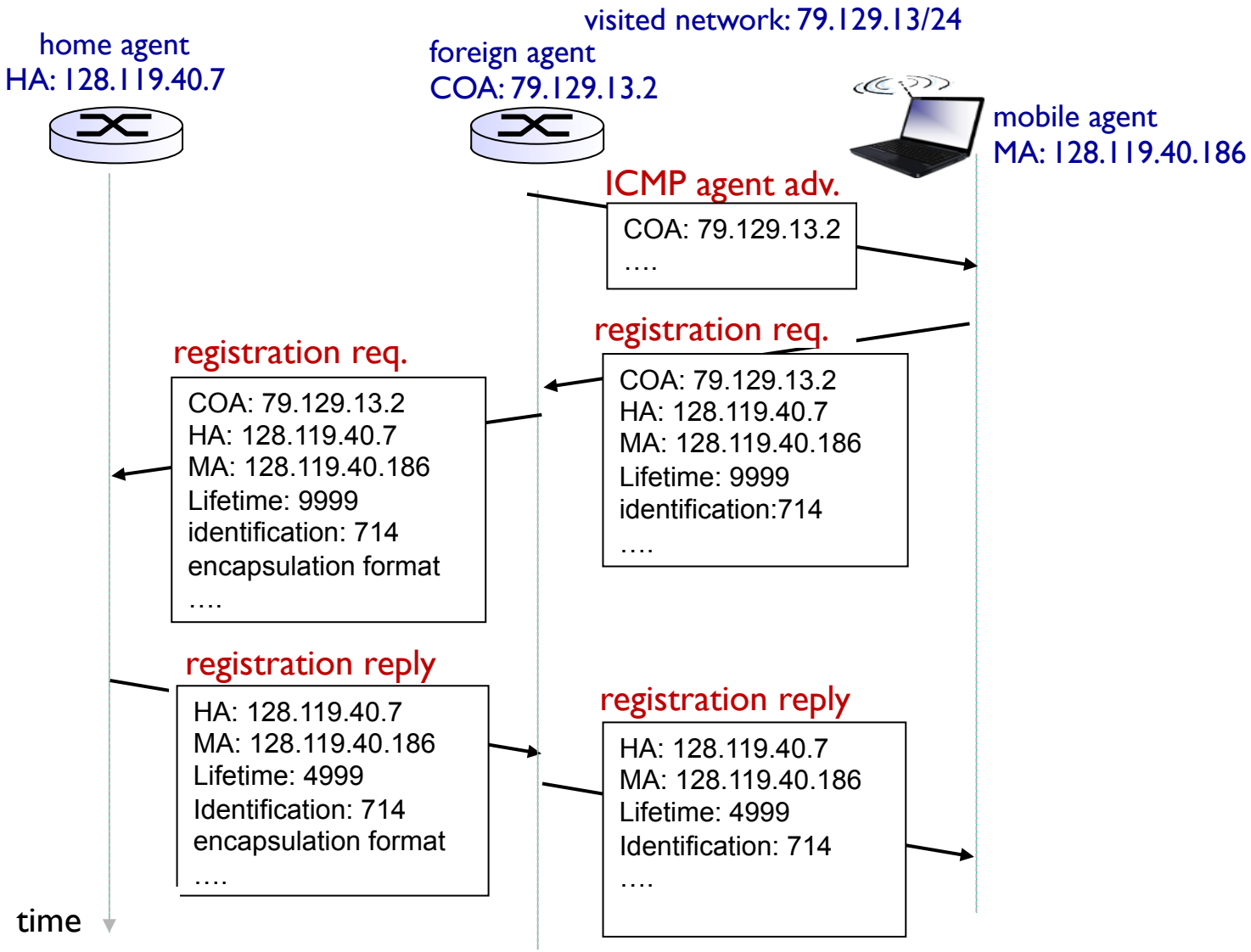
- *agent advertisement:* foreign/home agents advertise service by broadcasting ICMP messages (typefield = 9)

H,F bits: home and/or foreign agent

R bit: registration required

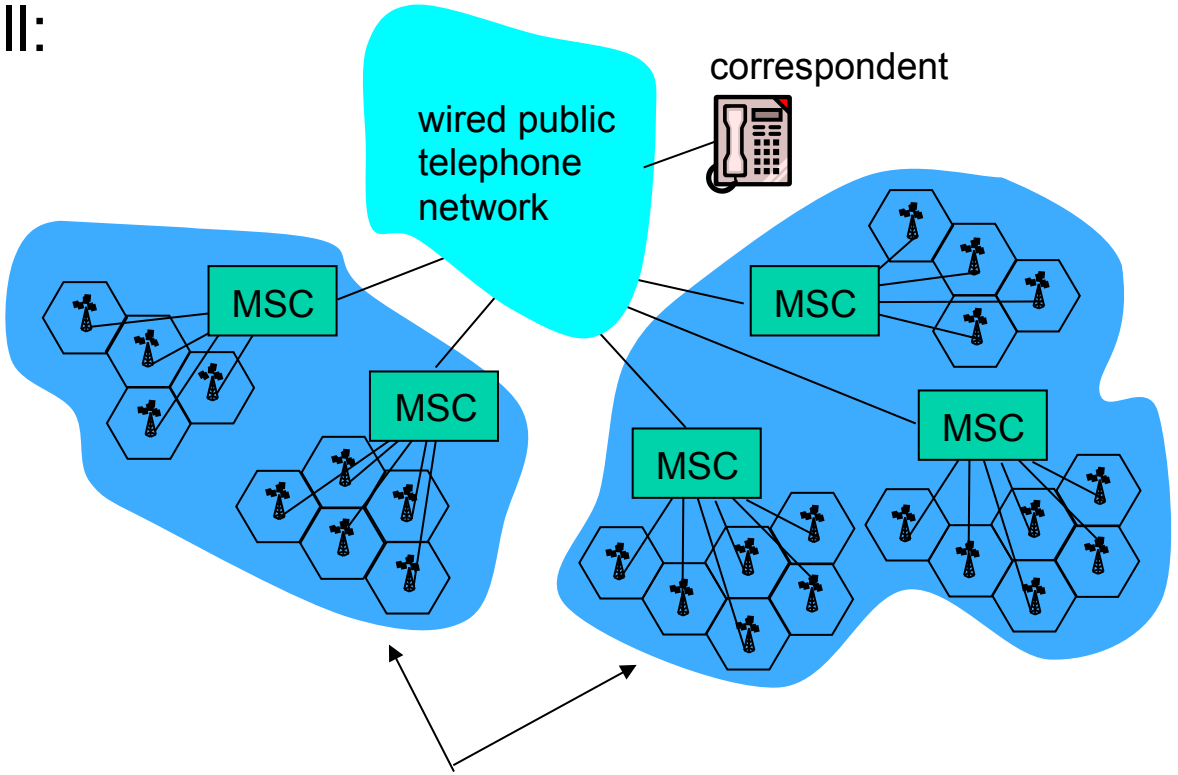


# Mobile IP: registration example



# Components of cellular network architecture

recall:

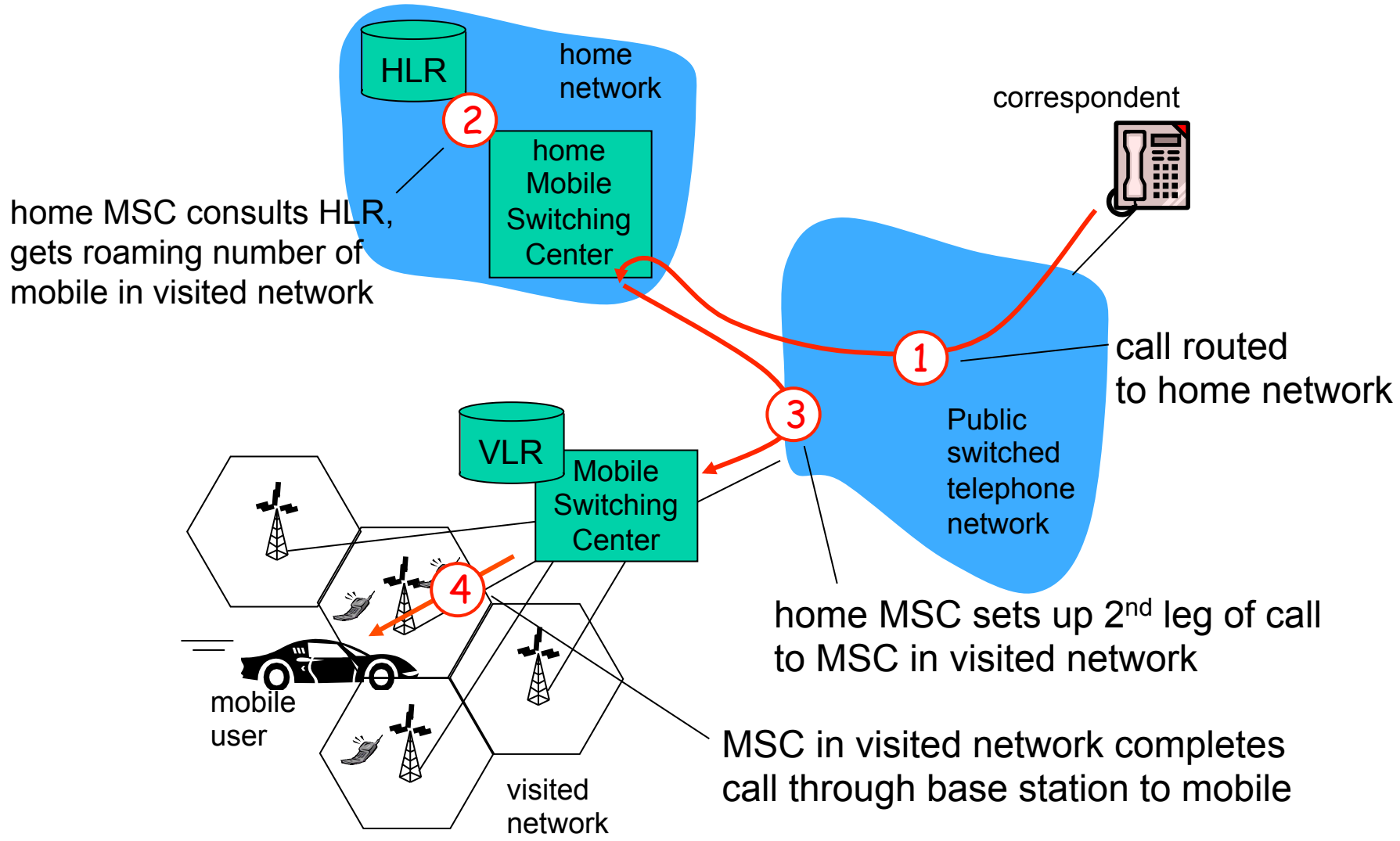



different cellular networks,
operated by different providers

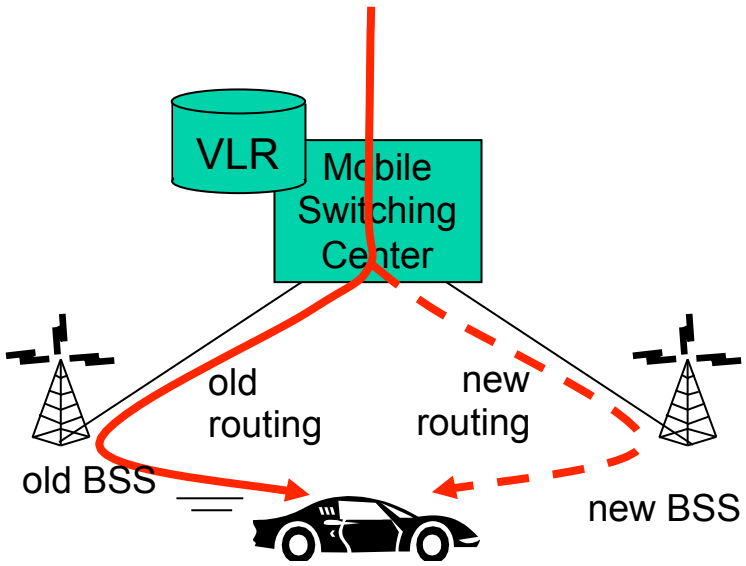
# Handling mobility in cellular networks

- *home network:* network of cellular provider you subscribe to (e.g., Sprint PCS, Verizon)
  - *home location register (HLR):* database in home network containing permanent cell phone #, profile information (services, preferences, billing), information about current location (could be in another network)
- *visited network:* network in which mobile currently resides
  - *visitor location register (VLR):* database with entry for each user currently in network
  - could be home network

# GSM: indirect routing to mobile

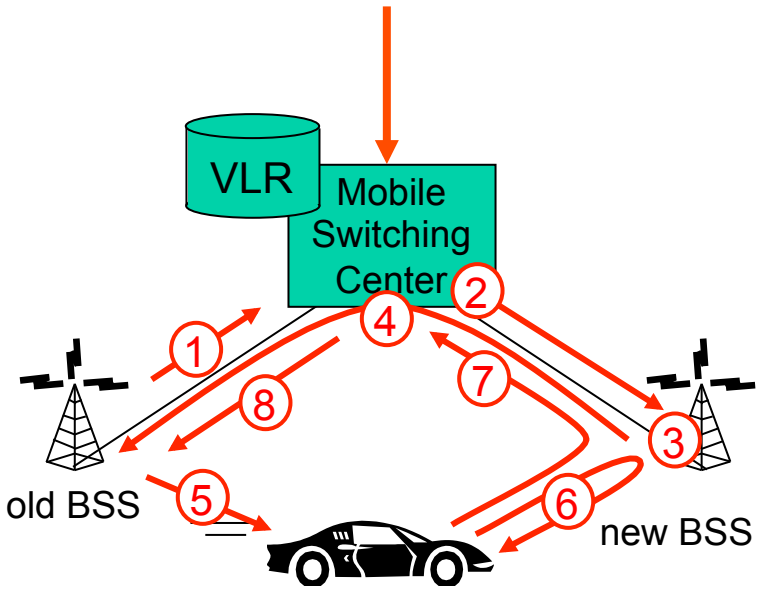


# GSM: handoff with common MSC




- *handoff goal:* route call via new base station (without interruption)
- reasons for handoff:
  - stronger signal to/from new BSS (continuing connectivity, less battery drain)
  - load balance: free up channel in current BSS
  - GSM does not mandate why to perform handoff (policy), only how (mechanism)
- handoff initiated by old BSS

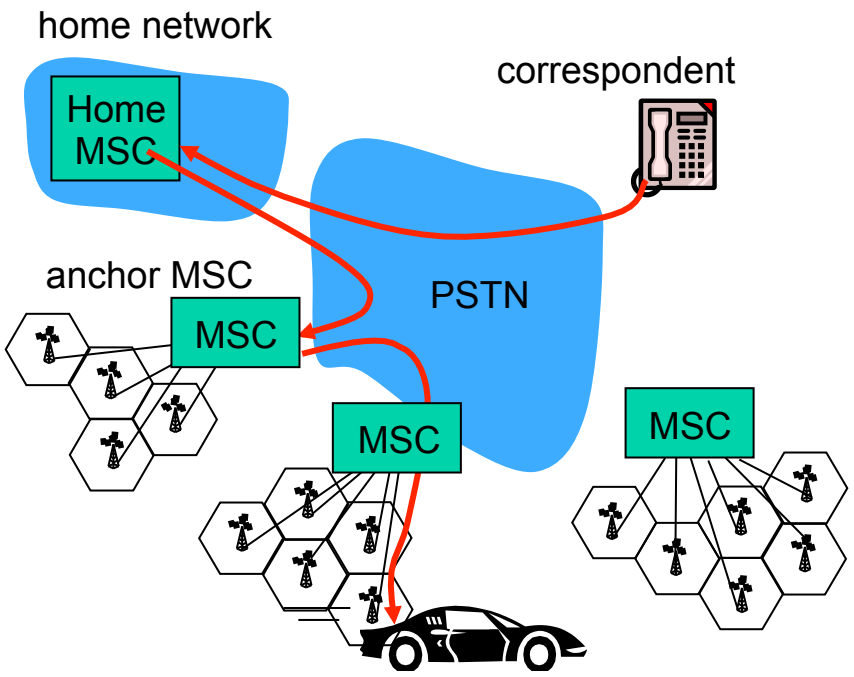
# GSM: handoff with common MSC




1. old BSS informs MSC of impending handoff, provides list of 1+ new BSSs
2. MSC sets up path (allocates resources) to new BSS
3. new BSS allocates radio channel for use by mobile
4. new BSS signals MSC, old BSS: ready
5. old BSS tells mobile: perform handoff to new BSS
6. mobile, new BSS signal to activate new channel
7. mobile signals via new BSS to MSC: handoff complete. MSC reroutes call

8 MSC-old-BSS resources released

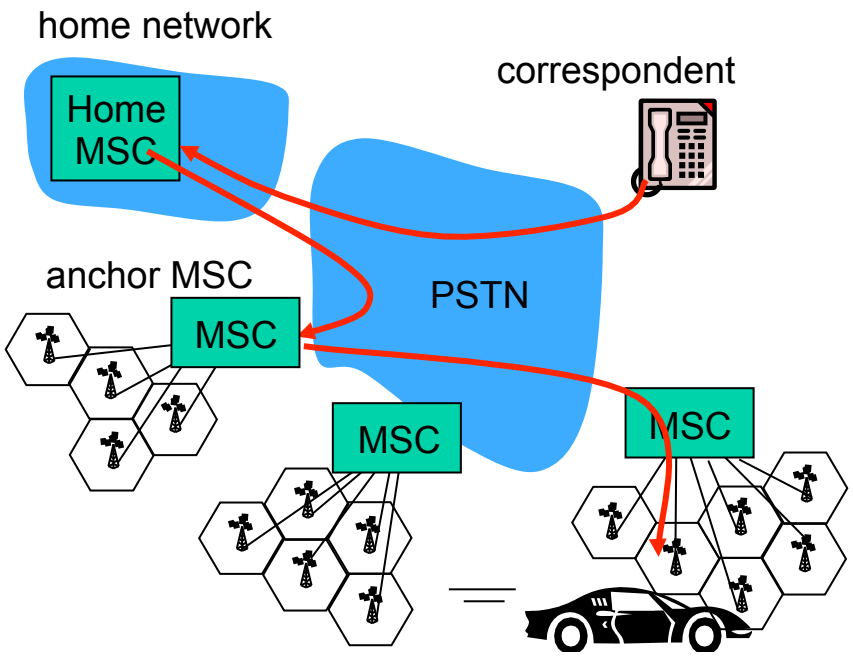
# GSM: handoff between MSCs




(a) before handoff

- *anchor MSC:* first MSC visited during call
  - call remains routed through anchor MSC
- new MSCs add on to end of MSC chain as mobile moves to new MSC
- optional path minimization step to shorten multi-MSC chain

# GSM: handoff between MSCs




(b) after handoff

- *anchor MSC:* first MSC visited during call
  - call remains routed through anchor MSC
- new MSCs add on to end of MSC chain as mobile moves to new MSC
- optional path minimization step to shorten multi-MSC chain

# Mobility: GSM versus Mobile IP

| GSM element | Comment on GSM element | Mobile IP element |
|---|---|---|
| **Home system** | Network to which mobile user's permanent phone number belongs | **Home network** |
| **Gateway Mobile Switching Center, or "home MSC". Home Location Register (HLR)** | Home MSC: point of contact to obtain routable address of mobile user. HLR: database in home system containing permanent phone number, profile information, current location of mobile user, subscription information | **Home agent** |
| **Visited System** | Network other than home system where mobile user is currently residing | **Visited network** |
| **Visited Mobile services Switching Center. Visitor Location Record (VLR)** | Visited MSC: responsible for setting up calls to/from mobile nodes in cells associated with MSC. VLR: temporary database entry in visited system, containing subscription information for each visiting mobile user | **Foreign agent** |
| **Mobile Station Roaming Number (MSRN), or "roaming number"** | Routable address for telephone call segment between home MSC and visited MSC, visible to neither the mobile nor the correspondent. | **Care-of-address** |

# Wireless, mobility: impact on higher layer protocols

- logically, impact *should* be minimal …
  - best effort service model remains unchanged
  - TCP and UDP can (and do) run over wireless, mobile
- … but performance-wise:
  - packet loss/delay due to bit-errors (discarded packets, delays for link-layer retransmissions), and handoff
  - TCP interprets loss as congestion, will decrease congestion window un-necessarily
  - delay impairments for real-time traffic
  - limited bandwidth of wireless links

# Wireless and mobile networks: summary

## *Wireless*

- wireless links:
  - capacity, distance
  - channel impairments
- IEEE 802.11 ("Wi-Fi")
  - CSMA/CA reflects wireless channel characteristics
- cellular access
  - architecture
  - standards (e.g., GSM, 3G, 4G LTE)

## *Mobility*

- principles: addressing, routing to mobile users
  - home, visited networks
  - direct, indirect routing
  - care-of-addresses
- case studies
  - mobile IP
  - mobility in GSM
- impact on higher-layer protocols

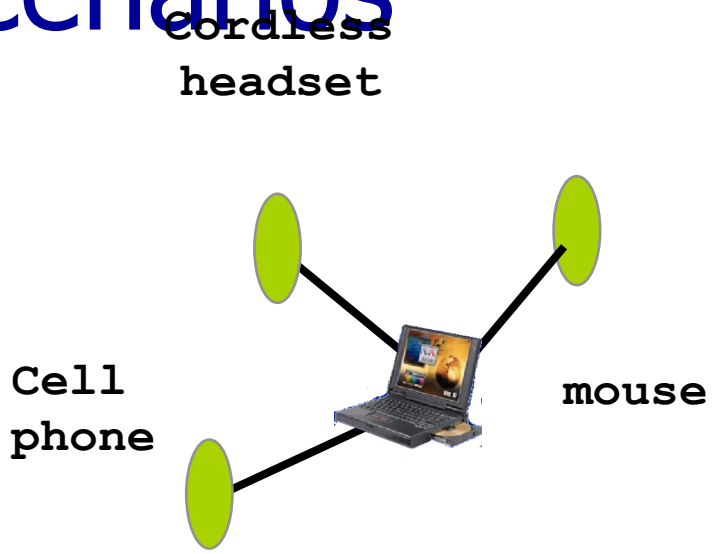
# The Bluetooth Technology (BT)

- Need to connect cell phones to other devices
- BT SIG: Special interest group created Ericsson, IBM, Nokia, Intel and Toshiba
  - Now more than 15000 companies
- Purpose: Building a short range, low power, inexpensive wireless radios
- Bluetooth: A Viking king who unified Denmark and Norway (without cables)

# Why Should One Care About It?

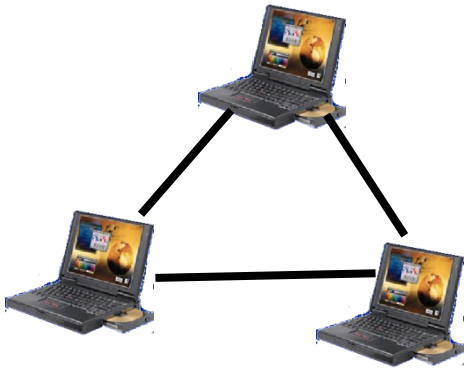
- Established and pervasive technology
  - In billions of devices by 2005 (*Business Week*, 18 September 2000)
    - The one-billionth chip was actually counted in late 2006
- Practical and cool
  - Cordless desktop
  - Briefcase e-mail
  - Wire-free headphones
- Cheap
  - As little as 29¢

# Bluetooth Application Scenarios



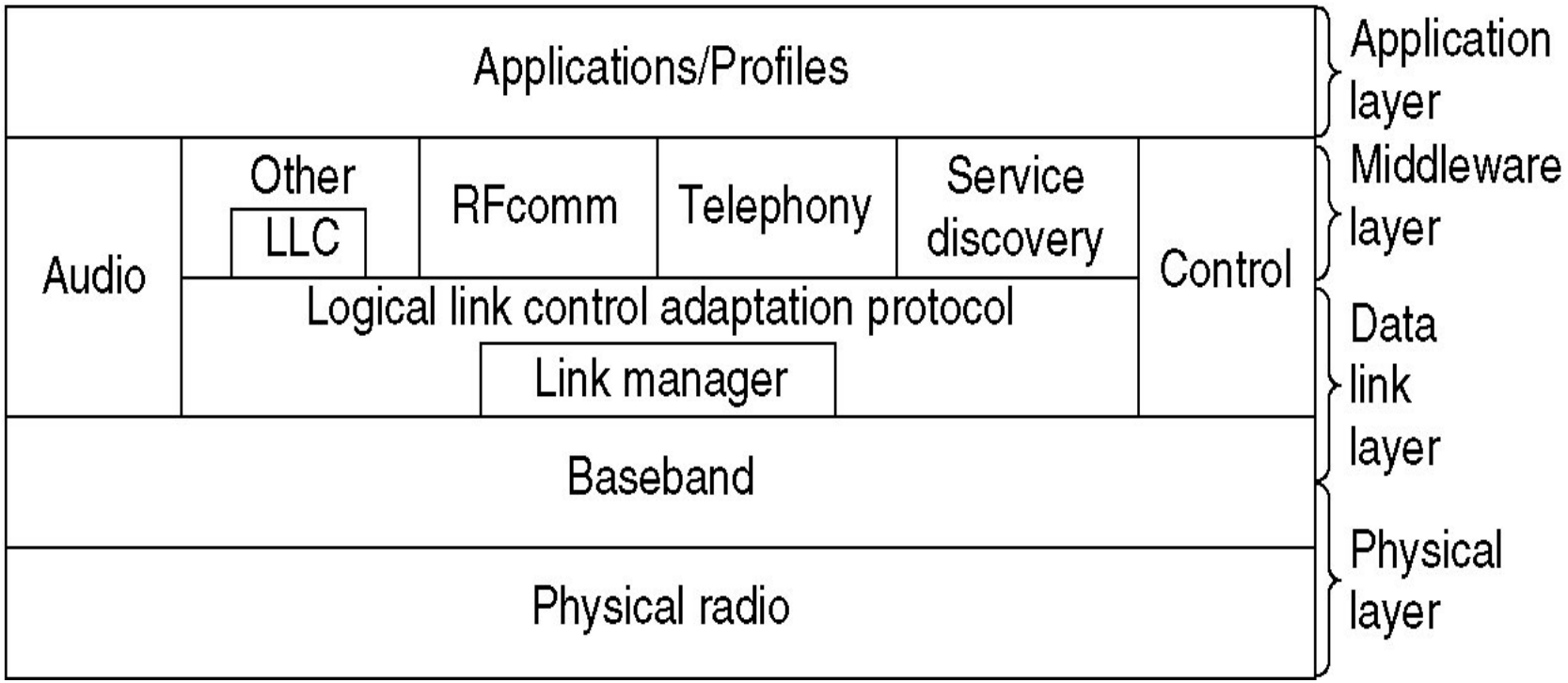

Cable replacement


Internet access



Ad hoc networking

# BT Protocol Stack, 4




The 802.15.1 version of the Bluetooth protocol architecture

# Application Profiles

| Name | Description |
|---|---|
| Generic access | Procedures for link management |
| Service discovery | Protocol for discovering offered services |
| Serial port | Replacement for a serial port cable |
| Generic object exchange | Defines client-server relationship for object movement |
| LAN access | Protocol between a mobile computer and a fixed LAN |
| Dial-up networking | Allows a notebook computer to call via a mobile phone |
| Fax | Allows a mobile fax machine to talk to a mobile phone |
| Cordless telephony | Connects a handset and its local base station |
| Intercom | Digital walkie-talkie |
| Headset | Intended for hands-free voice communication |
| Object push | Provides a way to exchange simple objects |
| File transfer | Provides a more general file transfer facility |
| Synchronization | Permits a PDA to synchronize with another computer |

The Bluetooth profiles

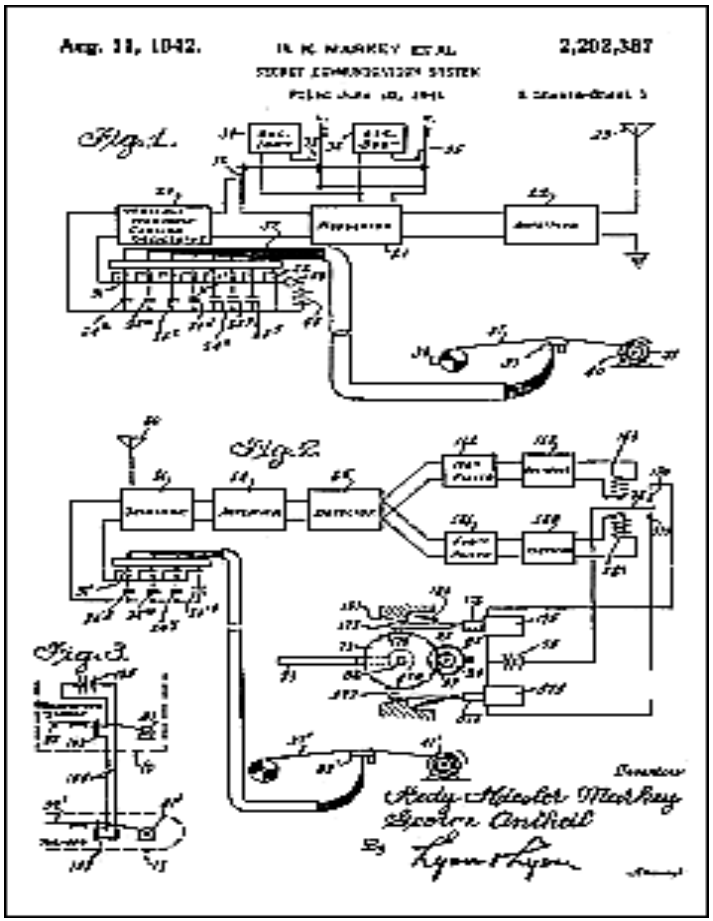
# Radio Layer

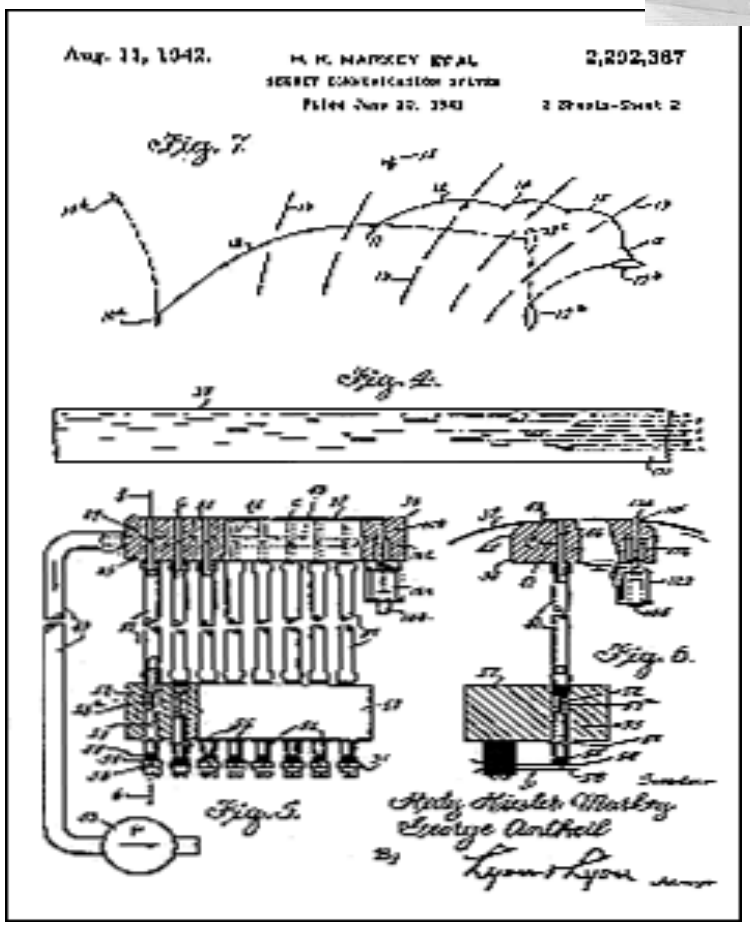
- Which Band? Worldwide deployment → Unlicensed band
  - 2.4 GHz ISM band
- How do we deal with collisions?
  - Especially with other technologies (e.g., IEEE 802.11)
- Frequency Hopping Spread Spectrum
  - Devices follow a FHSS sequence
  - Frequency used for transmission changes for every packet → low interference, enhanced security
- 79, 1MHz each spaced channels, GFSK modulation → 1Mb/s
- Need for a master-slave organization

# Frequency Hopping, Story

- The idea of Hedwig Eva Maria Kiesler
- Wife to Fritz Mandel, arm dealer to the Nazis
  - Jealous, took her always with him
- She learned about the problem of concealing torpedo signals
- She escaped husband and Nazis, and became Hedy Lamarr, a Hollywood phenomenon
- With artist George Antheil she invented FH technologies
  - Patent for a “secret communication system” on June 10 1941

# FH: The Patent



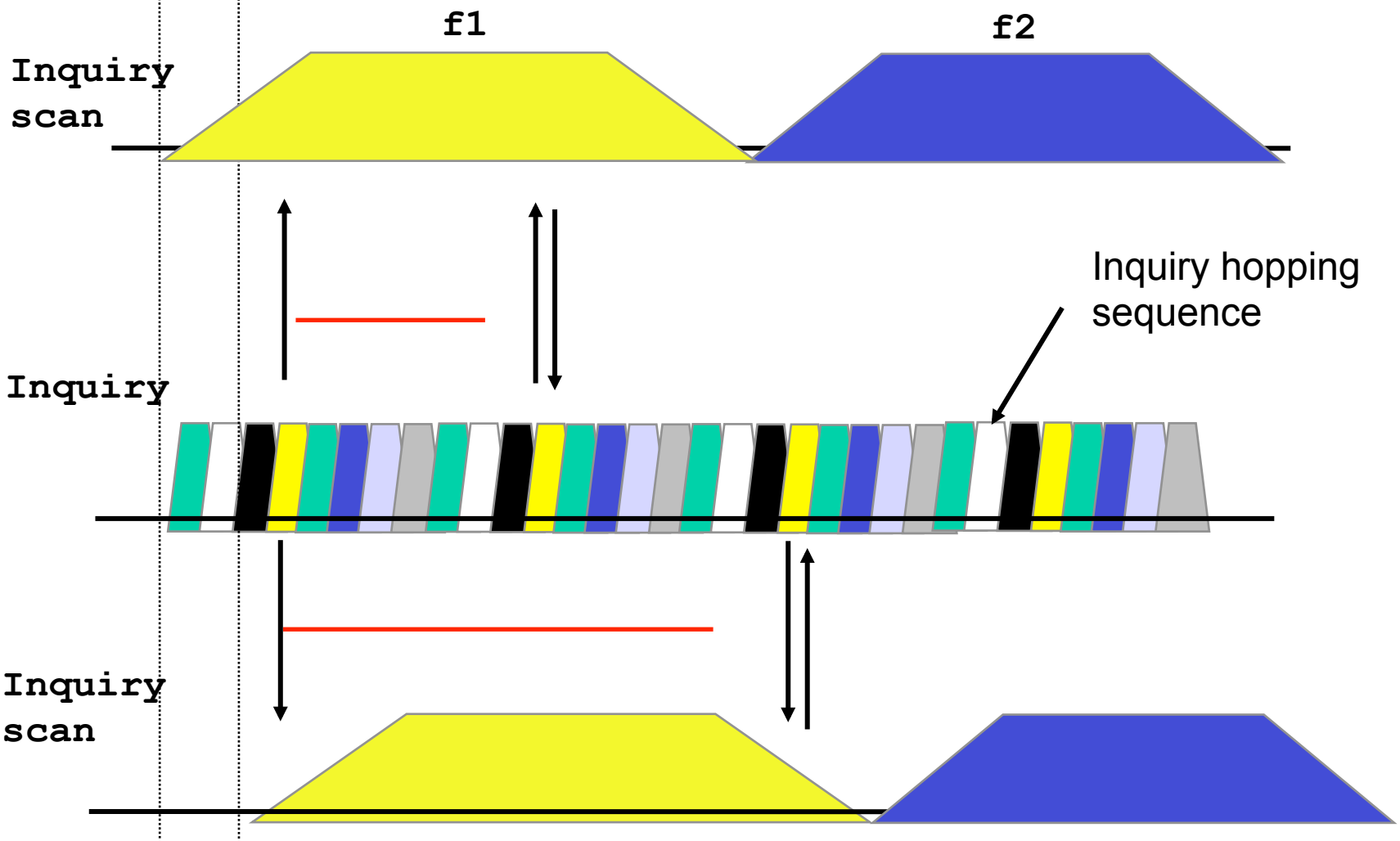
# Baseband Layer, 1

- Sorta like MAC
  - Organizes the bits into frames and defines key formats
- Masters define a series of 625μs slots
  - Even slots are for the master
  - Odd slots are for the polled slaves
  - This is called TDD: Time Division Duplex
- Frames can be 1, 3 or 5 slots

# Device Discovery in Bluetooth

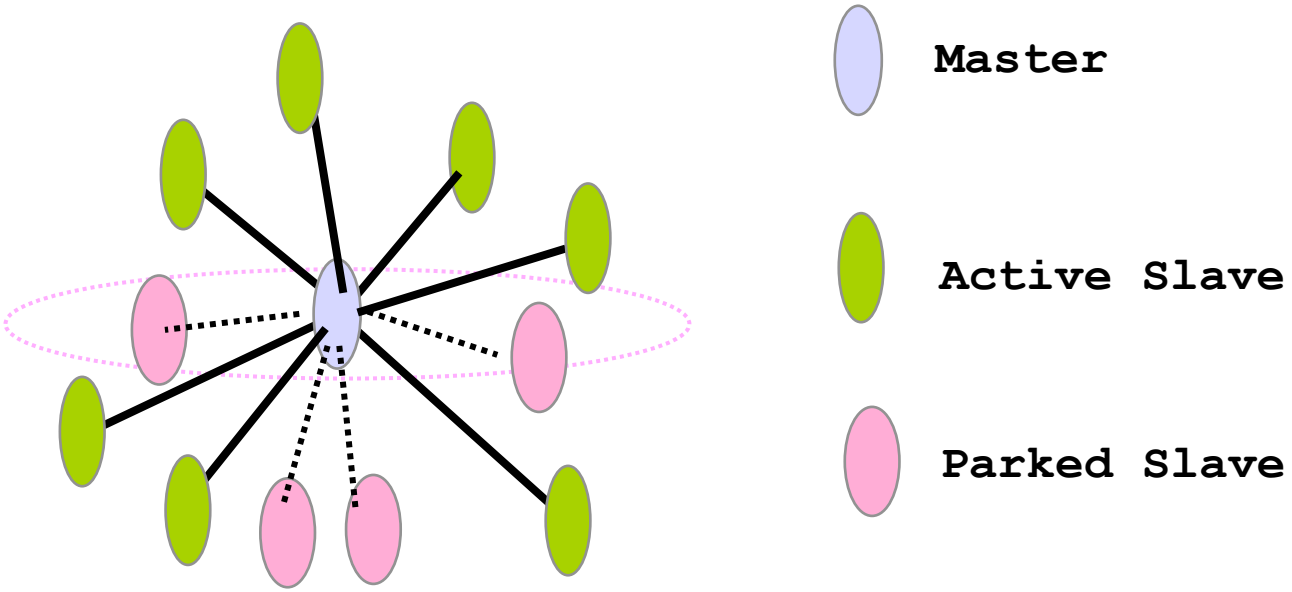
- Requires neighbor nodes to be in opposite modes (inquiry/inquiry scan)
- Leads to asymmetric neighbor discovery
  - The inquirer gathers information about the clock and the ID of the node in inquiry scan, not viceversa
- Inquirer scans 2 trains of 16 frequencies very fast
- Inquiree scans the same trains, slowly

# Inquiry procedure

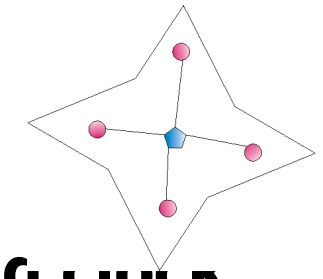


# Piconet Formation

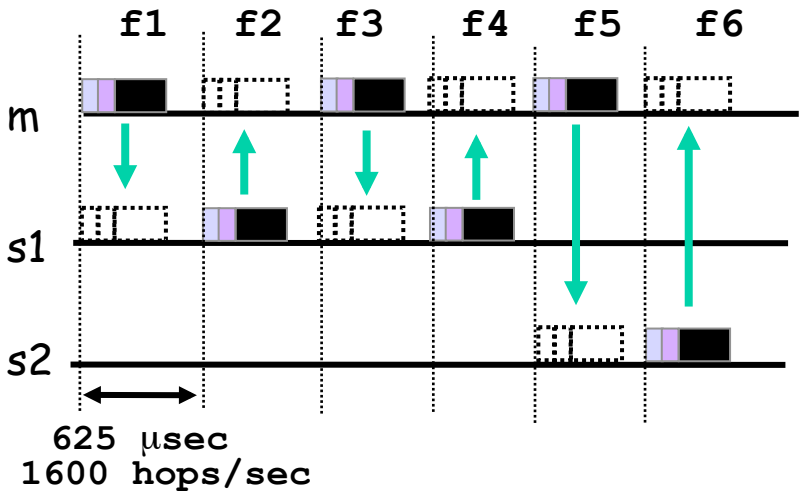
- Page/page scan protocol
  - To establish links with nodes in proximity



# BT Piconets

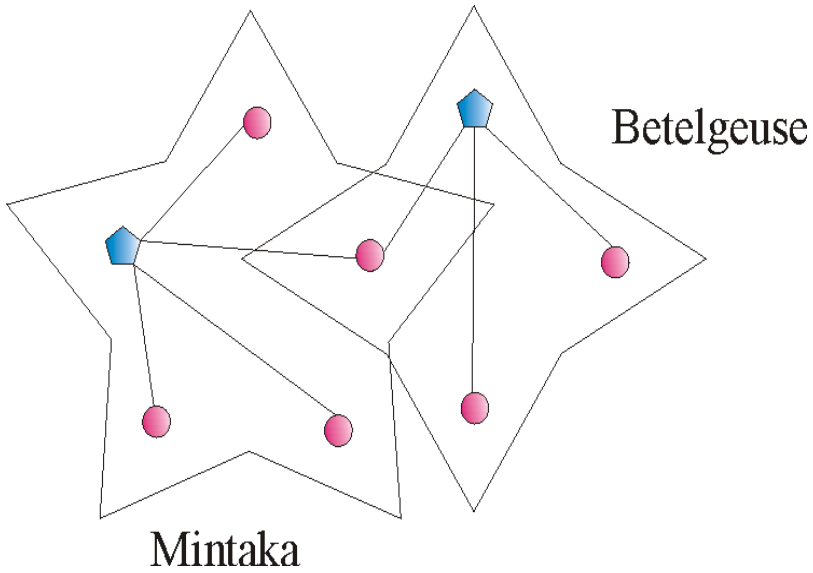


- **Synchronization is based on master ID and clock**
  - Master ID and clock → frequency hopping sequence
  - All devices in a piconet use the same sequence
- **Master (M) – Slave (S) communication**



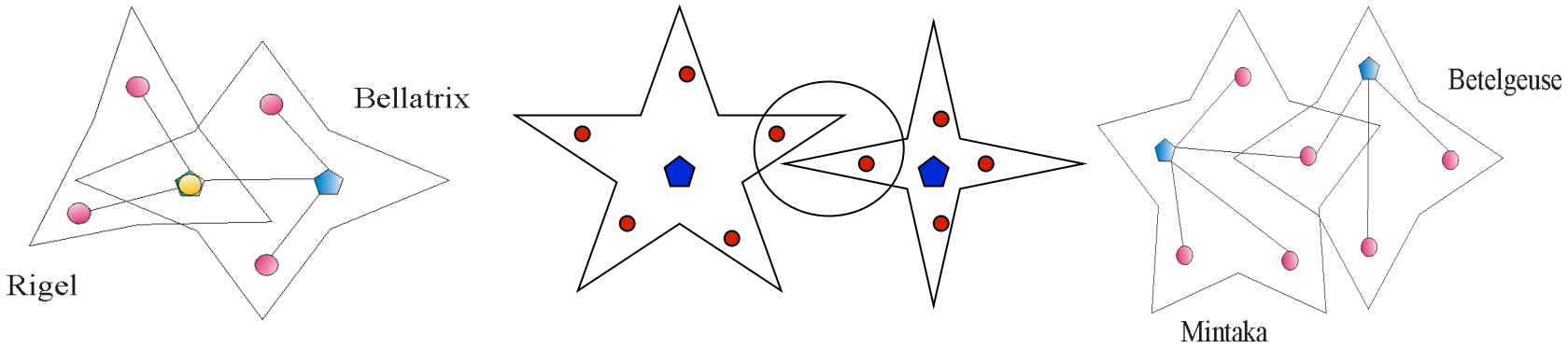

FH/TDD

# BT Scatternets




- Nodes can have multiple roles
- Nodes with multiple roles timeshare between multiple piconets
- A **scatternet** enables multi-hop communication

# Piconet Interconnection




master/slave

additional piconet interconnecting neighbor slaves

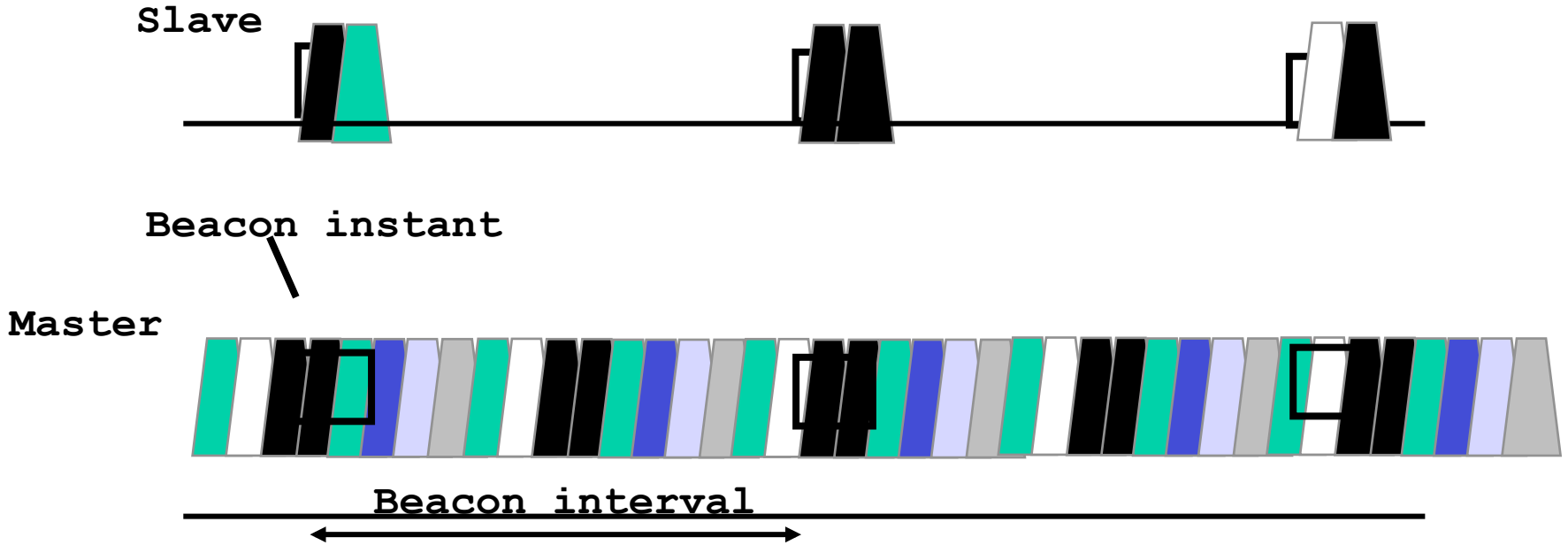
common slave

Efficiency

# Scatternet Formation

- Forming connected ad hoc networks of Bluetooth devices
- Three major problems:
  - Device discovery
    - Use BT standard inquiry and paging procedures
  - Piconet formation
  - Piconet interconnection

# Low Power mode (Park)




- Power saving + keep more than 7 slaves in a piconet
- Give up active member address, yet maintain synchronization
- Communication via broadcast LMP messages