

Agrawal ch 9

Mobile Communication Systems

3-4 hours

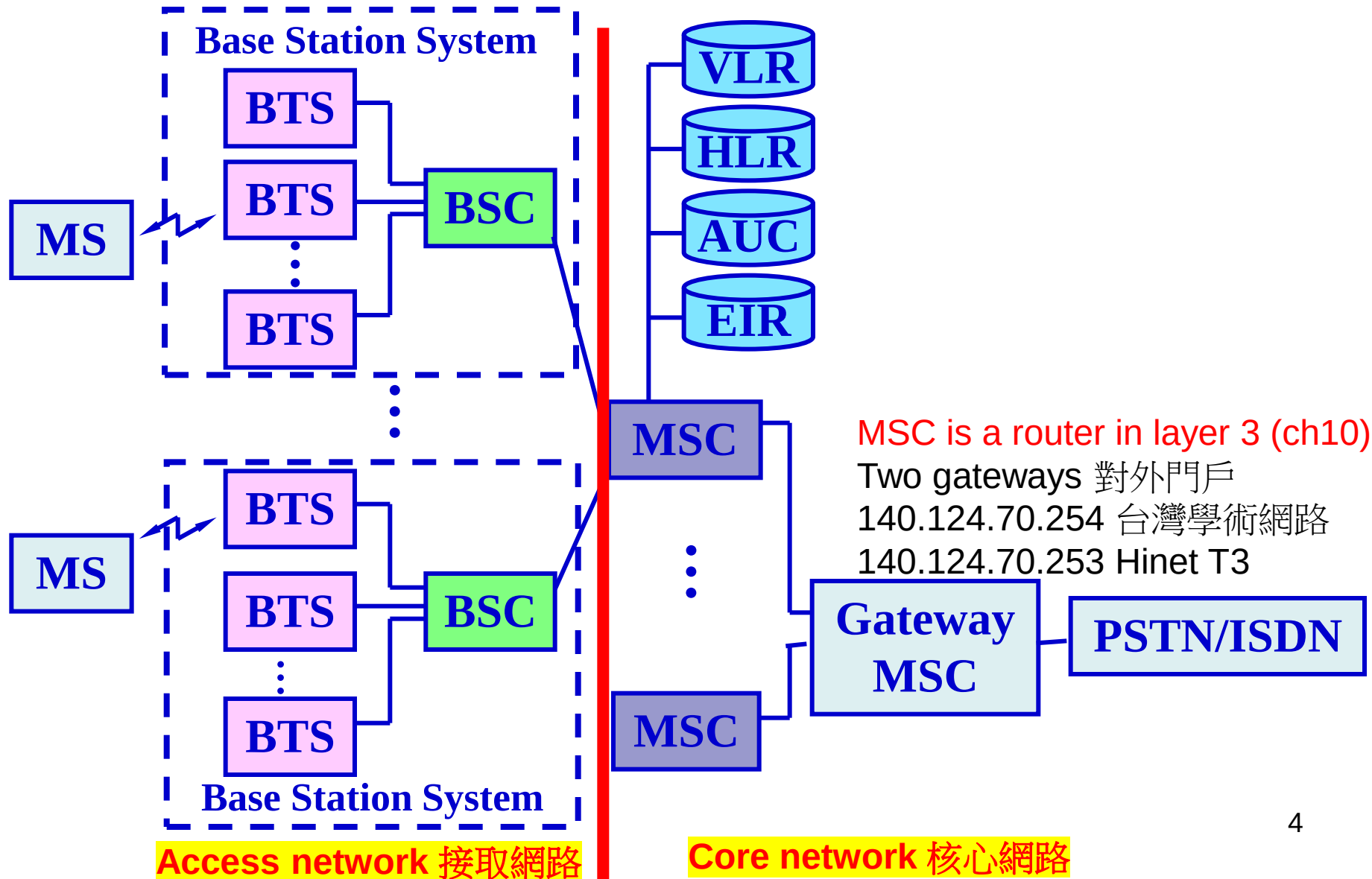
Outline

- Cellular System Infrastructure
- Registration
- Handoff
- Roaming Support
- HomeAgents, Foreign Agents and Mobile IP
- Multicasting
- Femtocell Networks

Acronyms

- MS(Mobile Station)
- BS (Base Station)
- BSC(Base Station Controller)
- BTS(Base Transceiver System)
- MSC(Mobile Switching Center) = router
- VLR(Visitor Location Register) 暫居地;通訊住址
- HLR(Home Location Register)老家;戶籍地址
- AUC(Authentication Center)
- EIR(Equipment Identity Register)-check IMEI

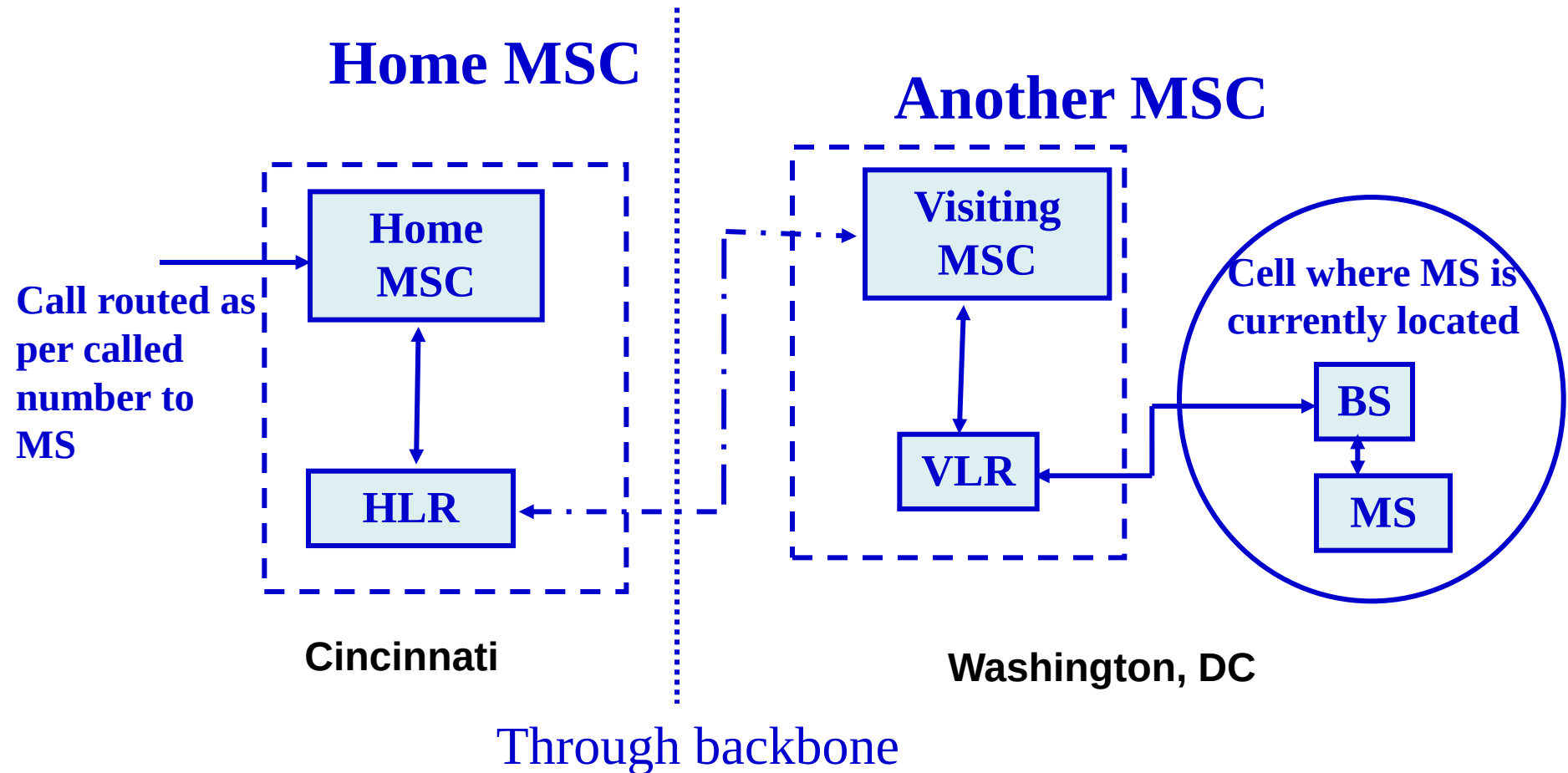
Cellular System Infrastructure



VLR/HLR

- VLR contains information about all visiting MSs in that particular area of MSC.
- VLR has pointers to the HLR's of visiting MS.
- VLR helps in billing (e.g. \$10/min) and access permission to the visiting MS.
- AUC provides authentication and encryption parameters
- EIR contains identity of equipments that prevents service to unauthorized MSs

Redirection of Call to MS at a Visiting Location



HLR-VLR Bi-direction link
for control signals between them

Prof. Shu-Ming Tseng

home MSC

the home MSC also maintains access information about all MSs registered,
including

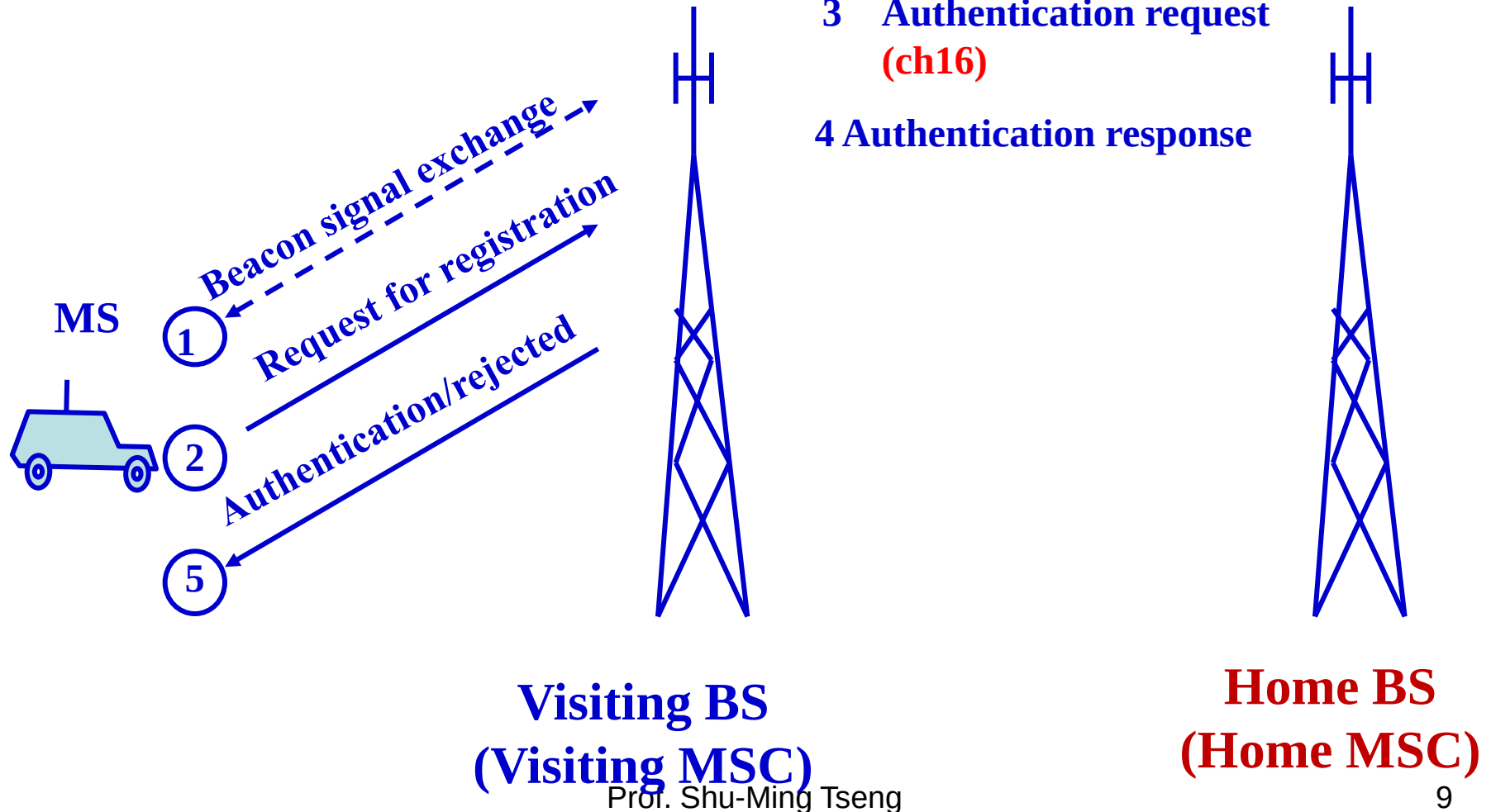
- state of the MS (active/ nonactive),
- type of allowed service (local/long distance/international calls)
- billing information (past credit, current charges, chronological order of calls made and timings of each call, etc.)

Registration

- Wireless system needs to know whether MS is currently located in its home area or some other area (routing of incoming calls).
- This is done by periodically exchanging signals between BS and MS known as **Beacons**.
- BS periodically broadcasts beacon signal (1 signal per second) to determine and test the MSs around.
- This information is used by the MS to locate the nearest BS.
- Information carried by beacon signal: cellular network identifier (中華電, Vodafone, etc), gateway address (Internet 也有設定) ID of the paging area (**control many MSCs**) , etc.

Using a Mobile Phone Outside the Subscription Area

Through backbone



Steps for Registration

1. MS listens to a new beacon, if it's a new one, MS adds it to the active beacon kernel table.
2. MS locates the nearest BS .
3. The visiting MSC asks its home MSC for authentication
4. Home site sends appropriate authentication response to the current serving MSC.
5. The MSC approves/disapproves the user access.

Handoff

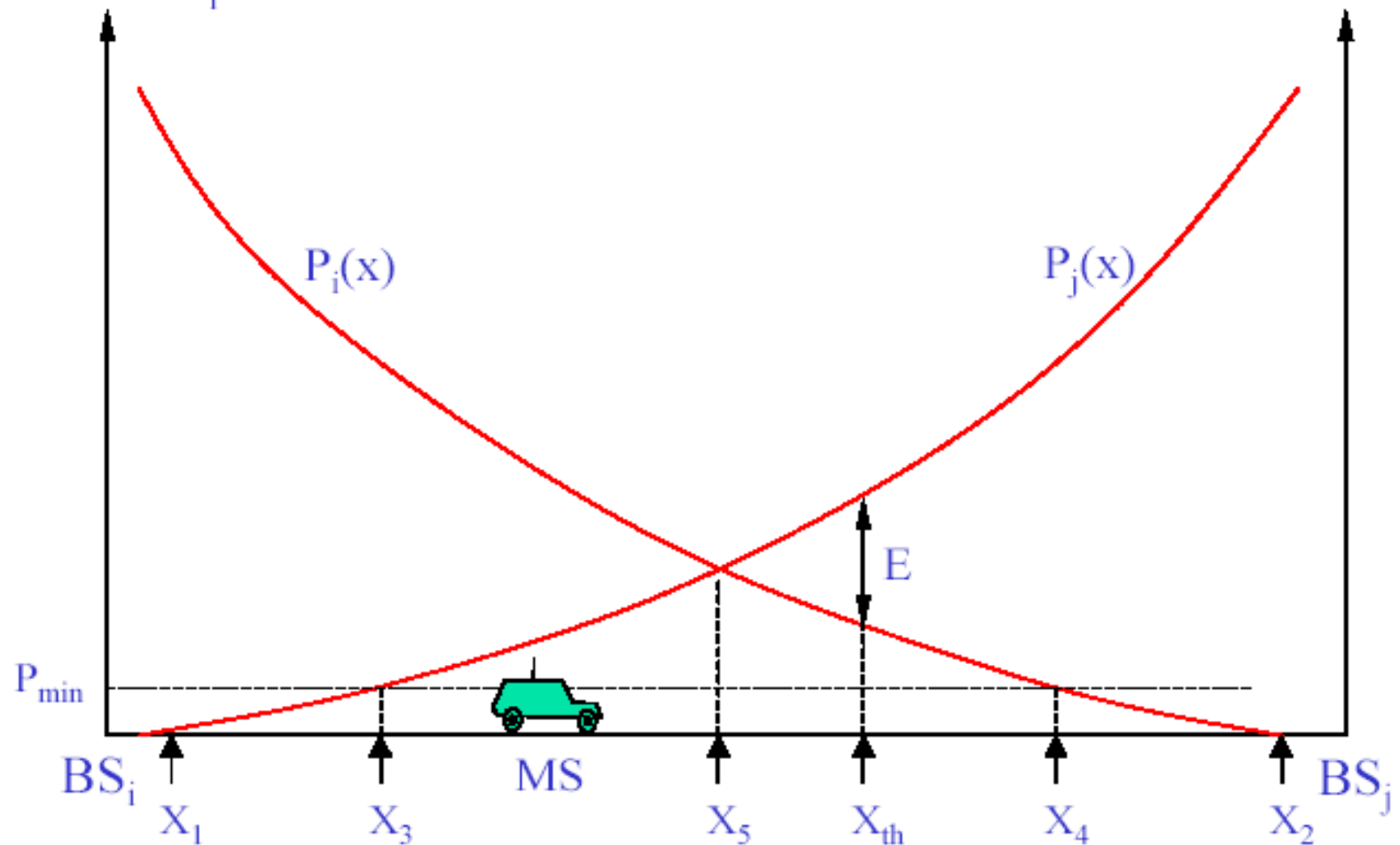
- Handoff is the change of radio resources (FDMA/TDMA/CDMA/OFDMA) from one cell to an adjacent one.
- Time to handoff is determined by:
 - Signal strength
 - CIR (carrier to interference ratio).

Handoff Initiation

Ex. Signal strength=distance⁻⁴

Signal strength
due to BS_i

Signal strength
due to BS_j



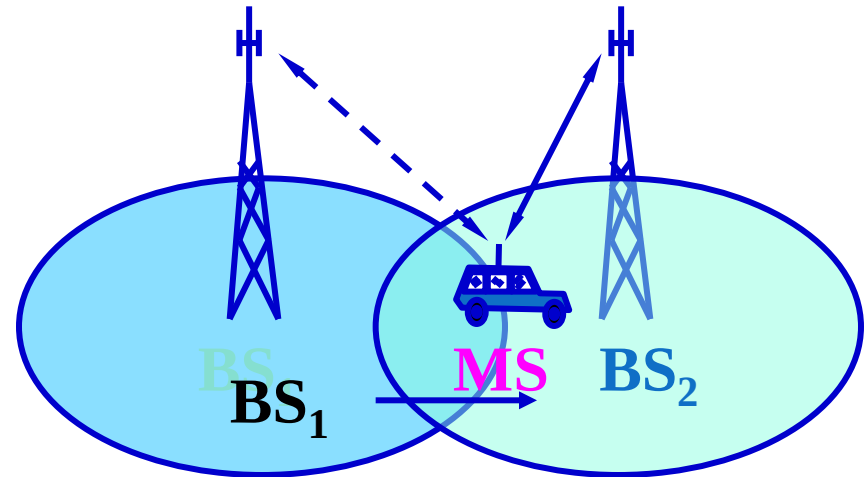
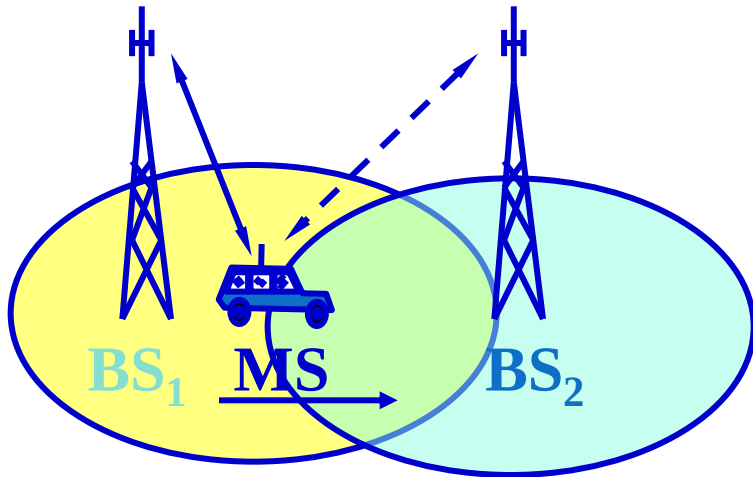
Handoff initiation (Cont'd)

- Region X3-X4 indicates the handoff area, where depending on other factors, the handoff needs to be performed.
- One option is to do handoff at X5 where the two signal strengths are equal.
- If MS moves back and forth around X5, it will result in too frequent handoffs (*ping-pong effect*).
- Therefore MS is allowed to continue with the existing BS till the signal strength decreases by a threshold value E (no handoff until Xth).
- Different cellular systems follow different handoff procedures.

Types of Handoff

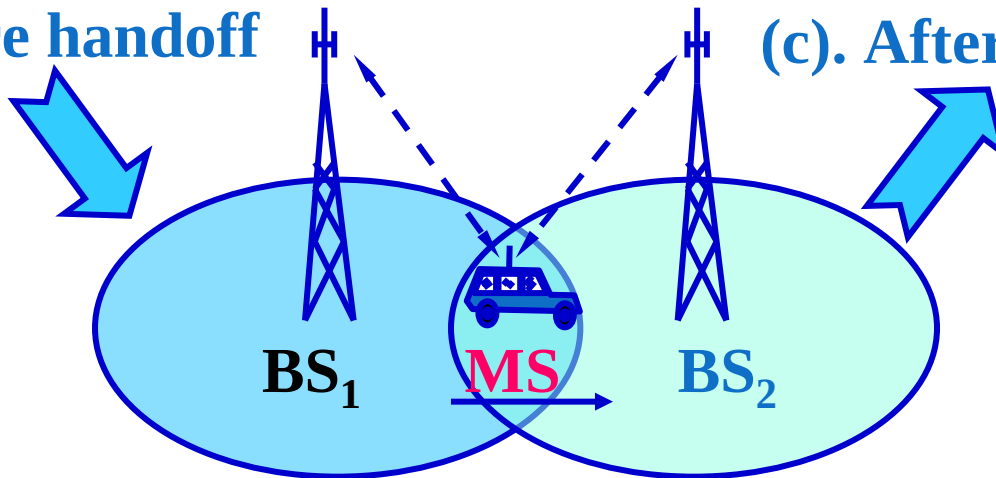
- Hard Handoff (*break before make*)
Releasing current resources from the prior BS before acquiring resources from the next BS.
FDMA, TDMA follow this type of handoff.
- Soft Handoff (*make before break*)
the MS to communicate simultaneously with the prior BS as well as the new BS. CDMA has two receivers for two paths of the same BS => one receiver for each BS.

Hard Handoff



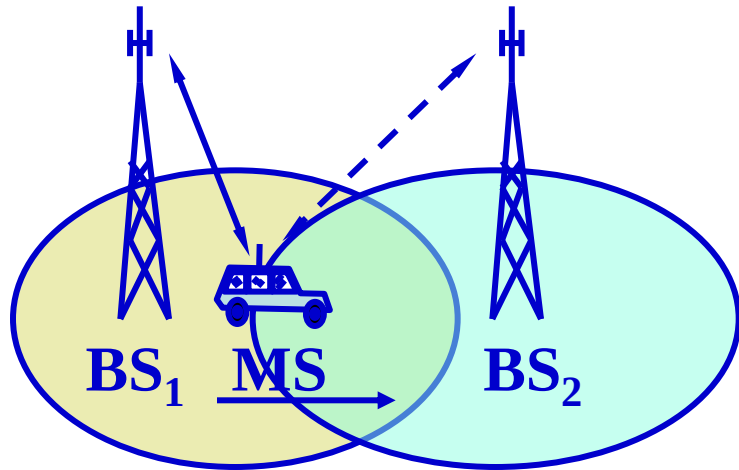
(a). Before handoff

(c). After handoff

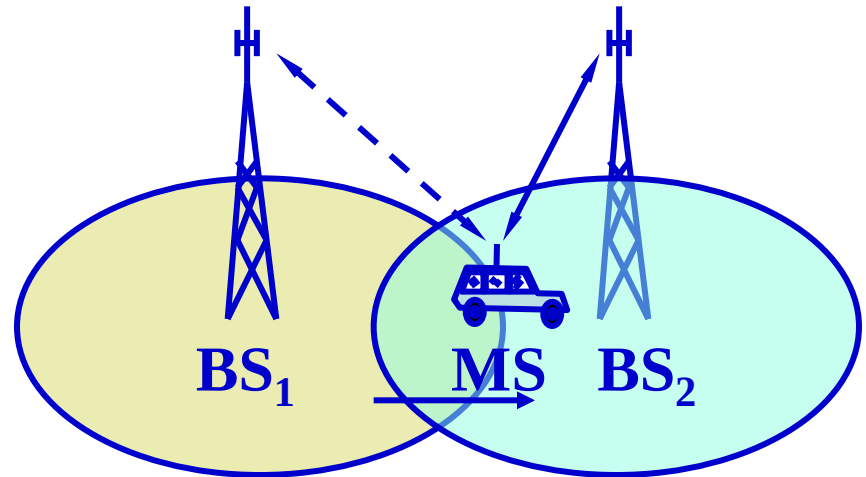


(b). During handoff (**No connection**)

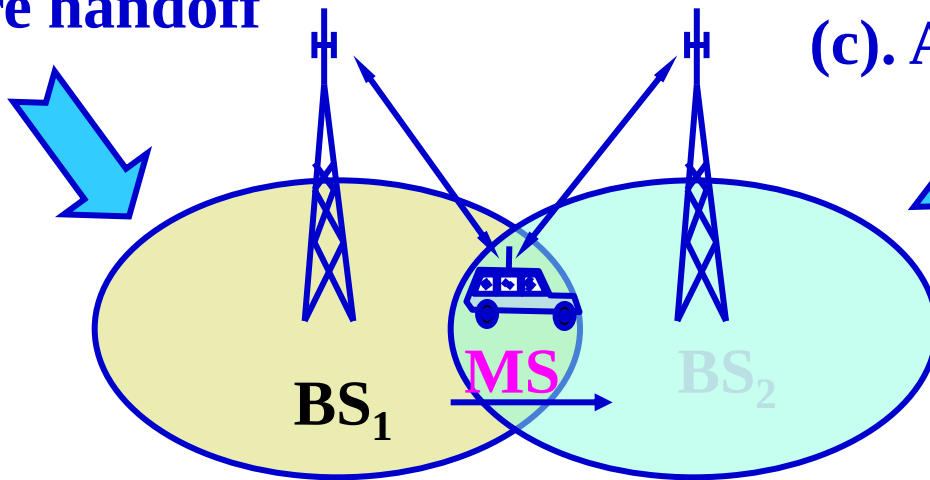
Soft Handoff



(a). Before handoff



(c). After handoff

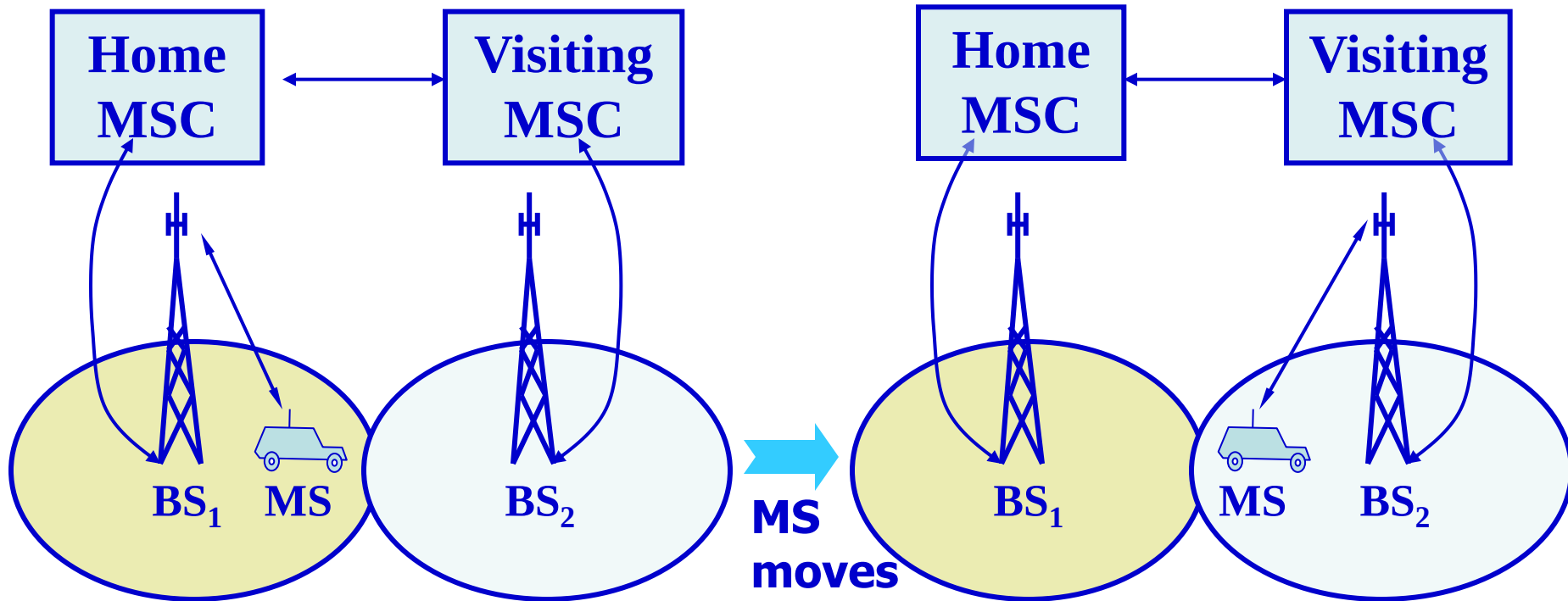


(b). During handoff

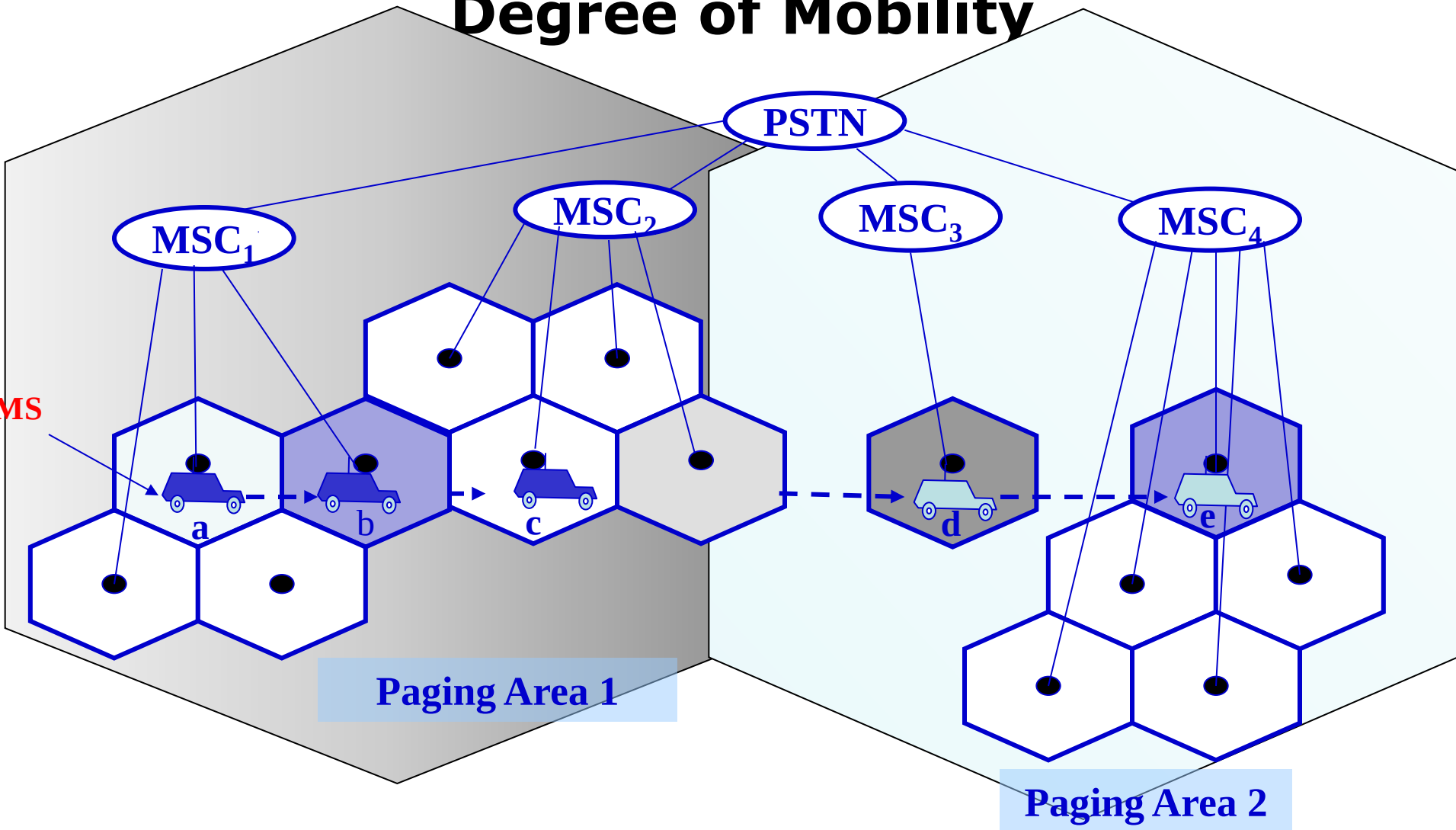
Roaming

- To move from a cell controlled by one MSC area to a cell connected to another MSC.
- Beacon signals and the use of HLR-VLR allow the MS to roam anywhere provided we have the same service provider

Roaming



Handoff Scenarios with Different Degree of Mobility



Possible Handoff Situations

- Assume MSC1 to be the home of the MS for registration, billing, authentication, etc.
- When handoff is from position “a” to “b”, the routing can be done by MSC1 itself.
- When handoff is from position “b” to “c” , then bi-directional pointers are set up to link the HLR of MSC1 to VLR of MSC2.
- When handoff occurs at “d” or “e”, routing of information using HLR-VLR may not be adequate in the long term(“d” is in a different *paging area*).

Information Transmission Path when MS Hands Off from “b” to “c”

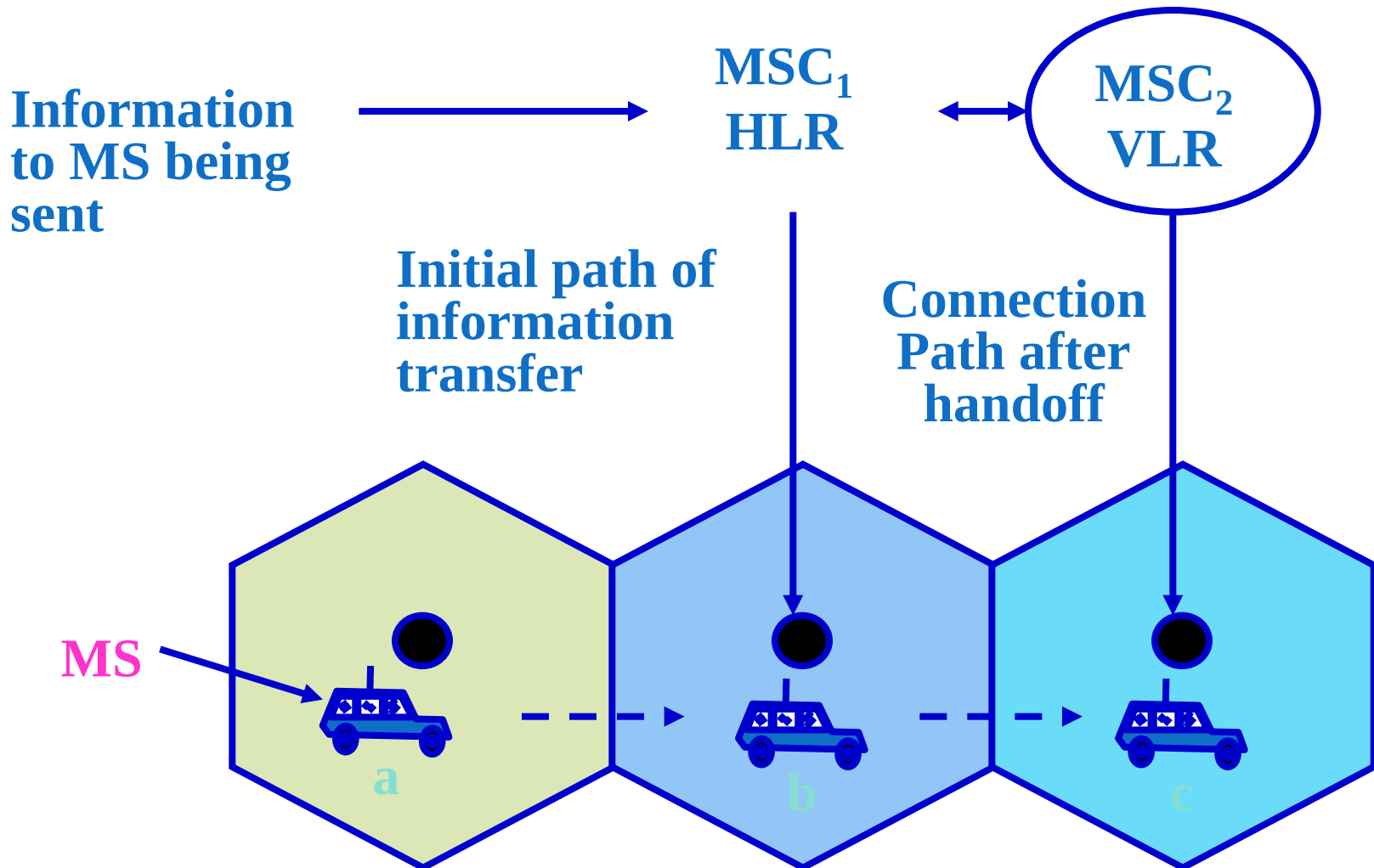
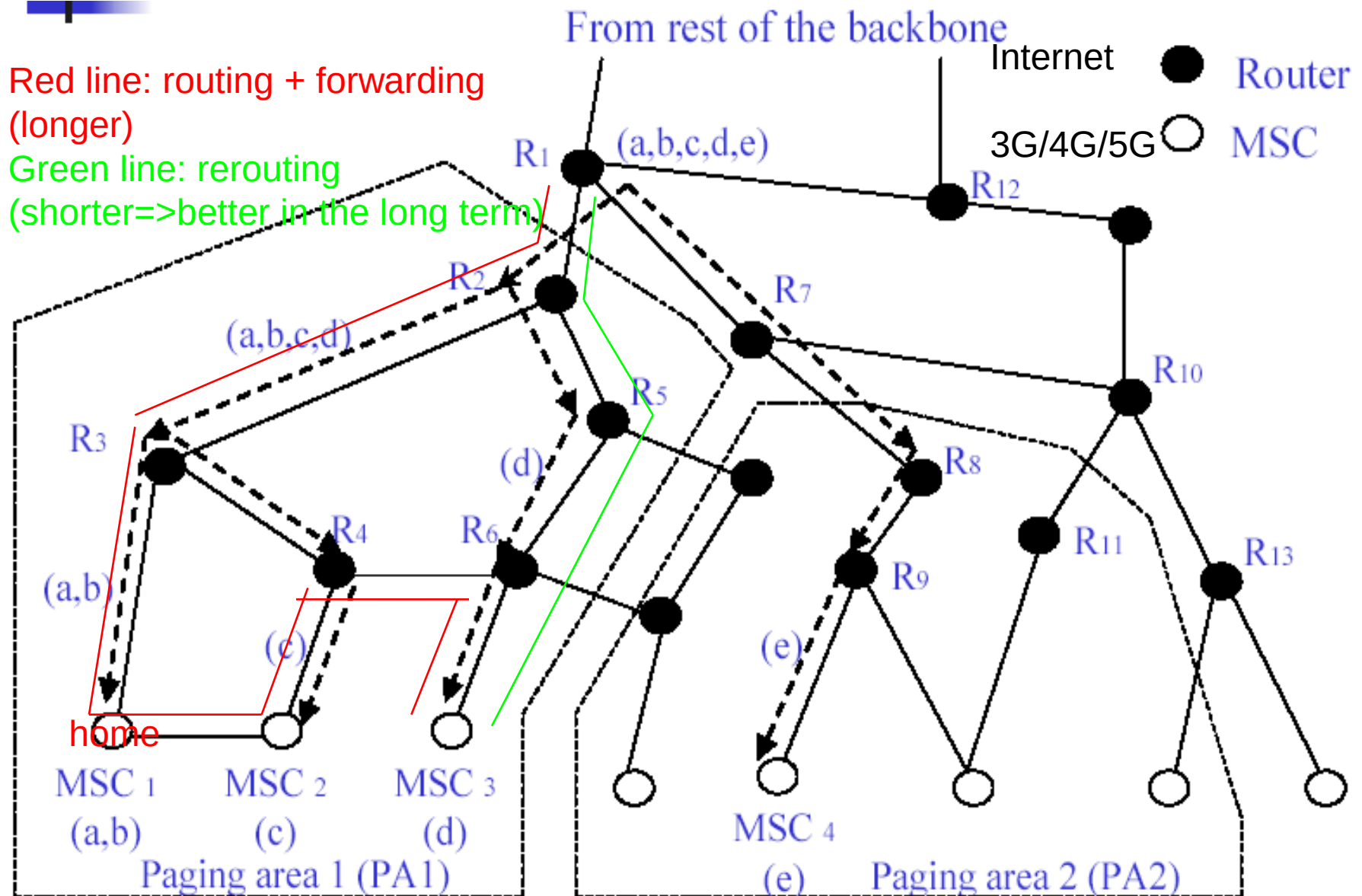


Illustration of MSC Connections to Backbone Network and Routing/Rerouting



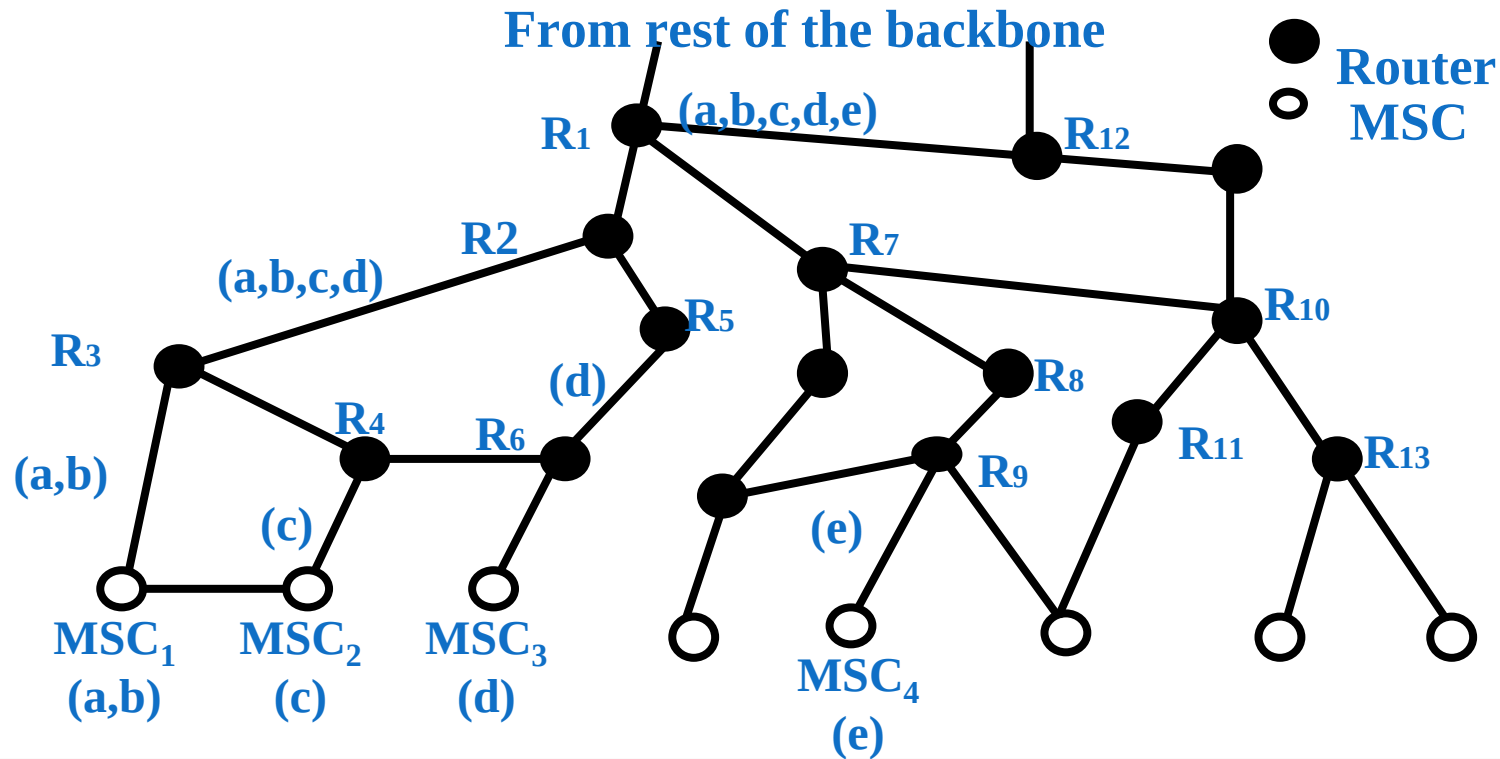
Backbone Network (TCP/IP)

- Routing done according to the topology connectivity of the backbone network.

Home Agents (HA) and Foreign Agents (FA) in Mobile IP (enhancement of IPv4)

- Two important software modules are associated with routers, home agent (HA) and foreign agent (FA).
- MS is registered with a router, mostly a router closest to the home MSC can be used to maintain its HA.
- Once a MS moves from the home network, a software module in the new network FA assists MS by forwarding packets for the MS.
- This functionality is somewhat similar to HLR-VLR (MSC level) , but HA-FA (router level) can across different service provider- because TCP/IP (internet)

Home MSC and Home Agent (HA) for the Previous Network

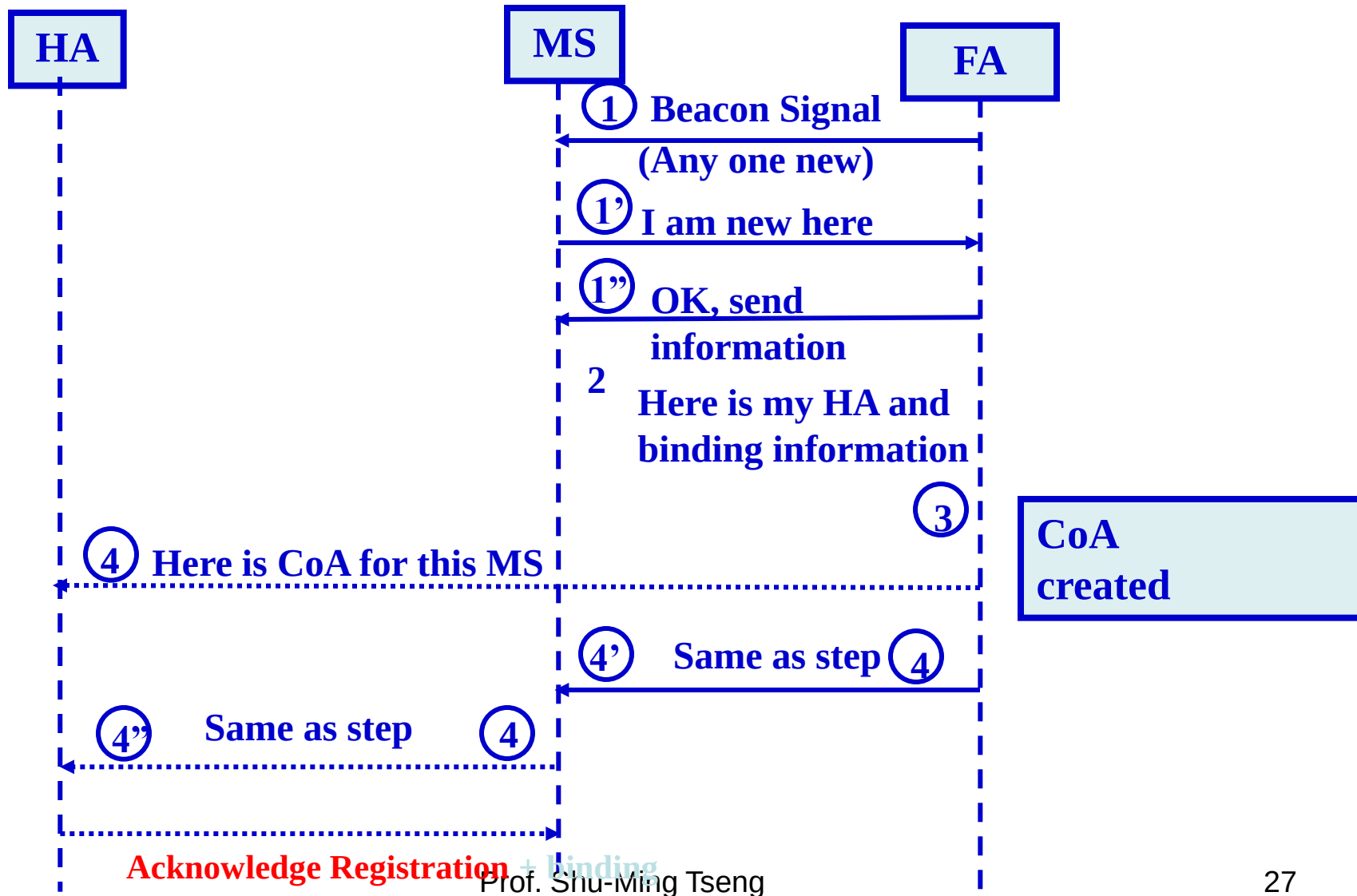


Home MSC	MSC ₁	MSC ₂	MSC ₃	MSC ₄
Selected router for maintaining its home agent	R ₃	R ₄	R ₆	R ₉

Call Establishment using HA-FA

- Whenever a MS moves to a new network, it still retains its initial HA.
- The MS detects the FA of the new network, by sensing the periodic beacon signals which FA transmits.
- When FA detects a new MS, it allocates a COA (care of address, FA address) to the MS
- Once MS receives COA, it registers its COA with its HA and the time limit binding for its validity (like expiration date of food).

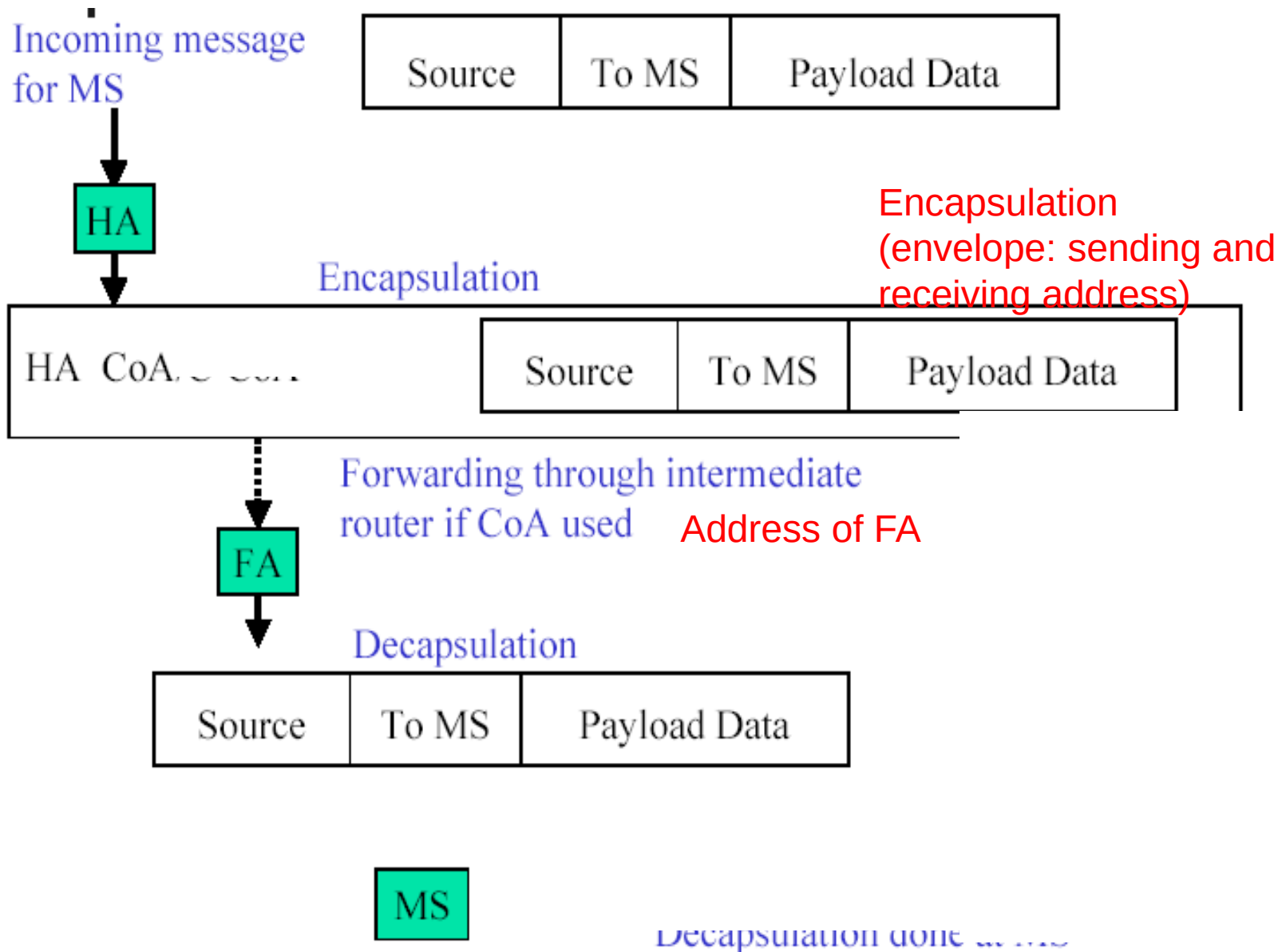
Registration Process Between FA, MS, and HA When the MS Moves to a Paging area



Call Establishment (Cont'd)- tunneling

- HA confirms its binding through a reply to the MS.
(**Acknowledge Registration on previous page**)
- A message sent from an arbitrary source to the MS at the home address is received by the HA.
- Binding is checked, the COA of the MS (FA address) is encapsulated (next page) in the packet and forwarded to the network.
- When packet reaches FA, it decapsulates the packet and passes to MS at the link layer.
- After binding time, if MS still wants to have packets forwarded through HA, it needs to renew its registration.
- When MS returns to its home network, **it tells its HA, so no forwarding in the future.**

(After HA get MS's CoA, previous page) Message Forwarding using HA-FA Pair



Routing in Backbone Routers

- How FA finds HA of the MS ?
- One approach is to have a global table at each Router of each MSC so that the route from FA to HA for that MS can be determined.
- Disadvantages: Information too large, one network might not like to give out information about all its routers to any external network (only gateways information is provided).
- Use of *Distributed Routing Scheme* (*simple, so widely used*).
- **Details in next chapter TCP/IP**

Illustration of Paging Areas (PAs) and Backbone Router Interconnect

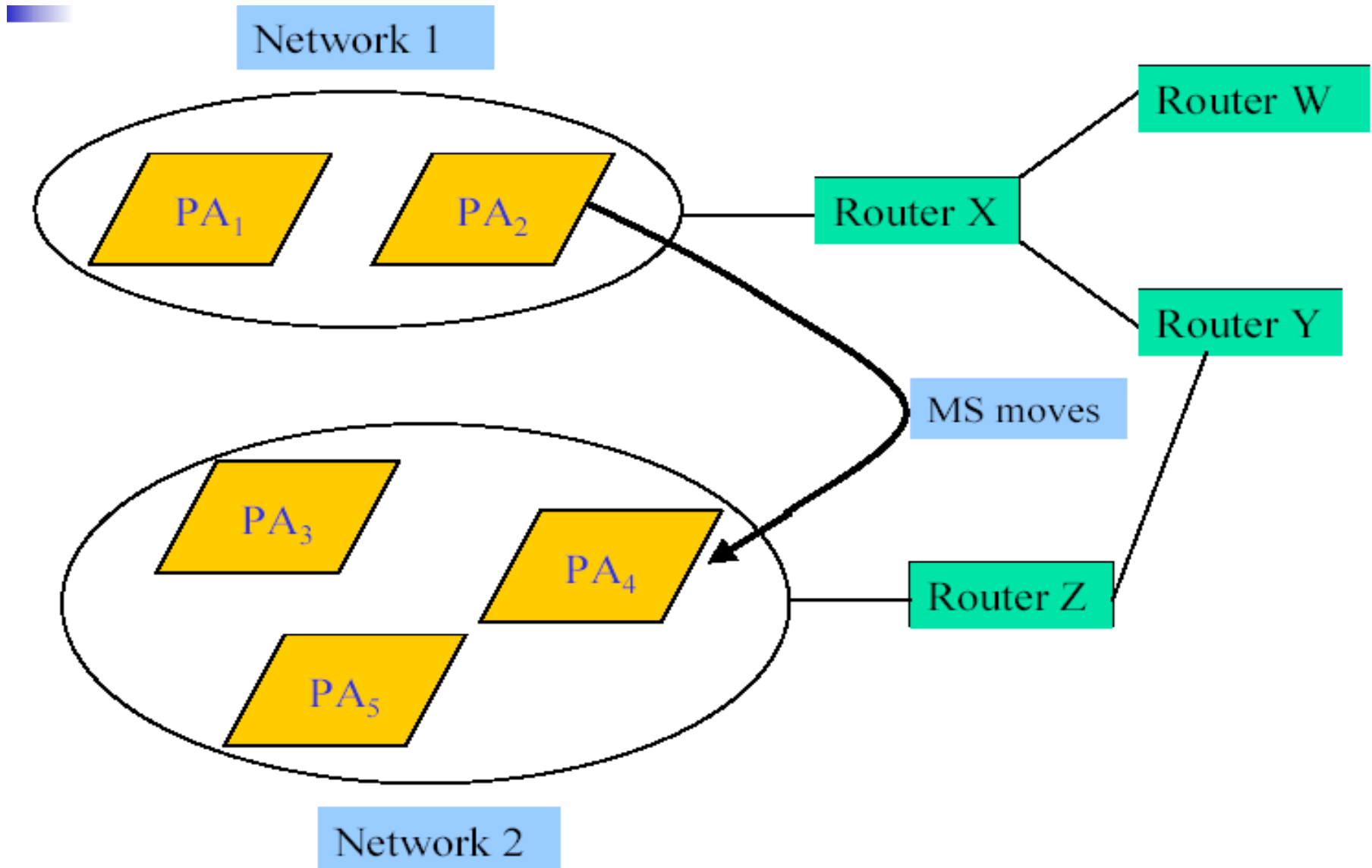


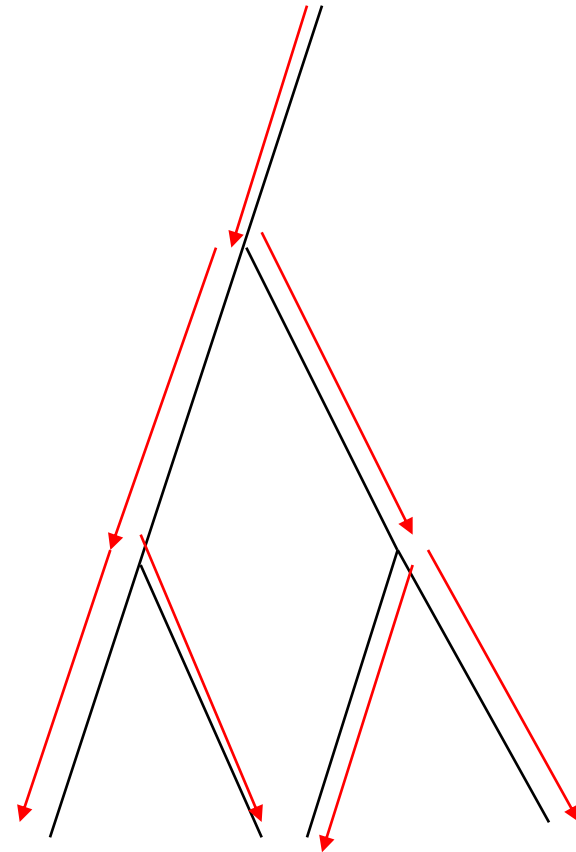
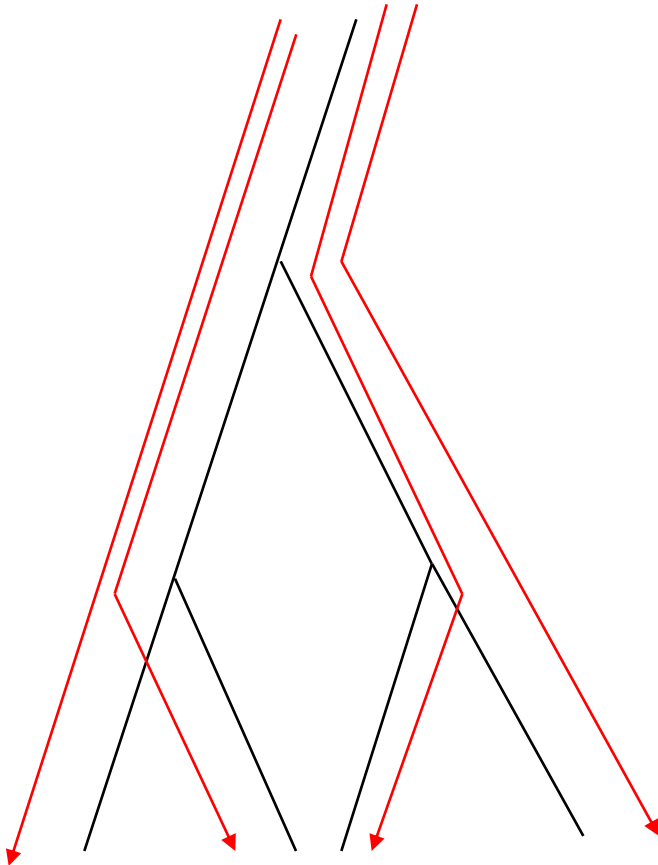
Table 9.3 Distributed Routing Table (next step: forward, left, or right) and Location PAs

Table at router W		Table at router X		Table at router Y		Table at router Z	
Route to PA	Next hop	Route to PA	Next hop	Route to PA	Next hop	Route to PA	Next hop
1	X	1	-	1	X	1	Y
2	X	2	-	2	X	2	Y
3	X	3	Y	3	Z	3	-
4	X	4	Y	4	Z	4	-
5	X	5	Y	5	Z	5	-

Multicasting

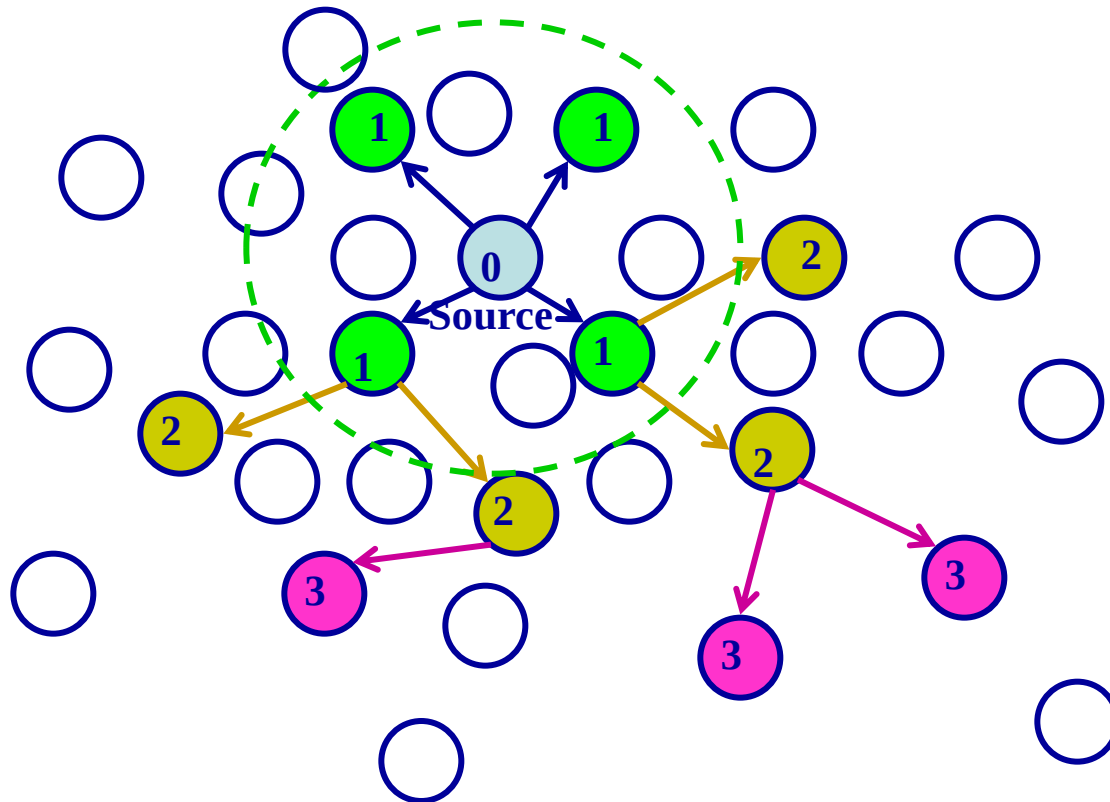
- Process of transmitting messages from a source to multiple recipients by using a *group address* for all hosts that wish to be the members of the group.
- Reduces number of messages to be transmitted as compared to multiple unicasting.
- Useful in video/audio conferencing, multi party games.

Multiple unicast vs. multicast



Tree-based Multicasting

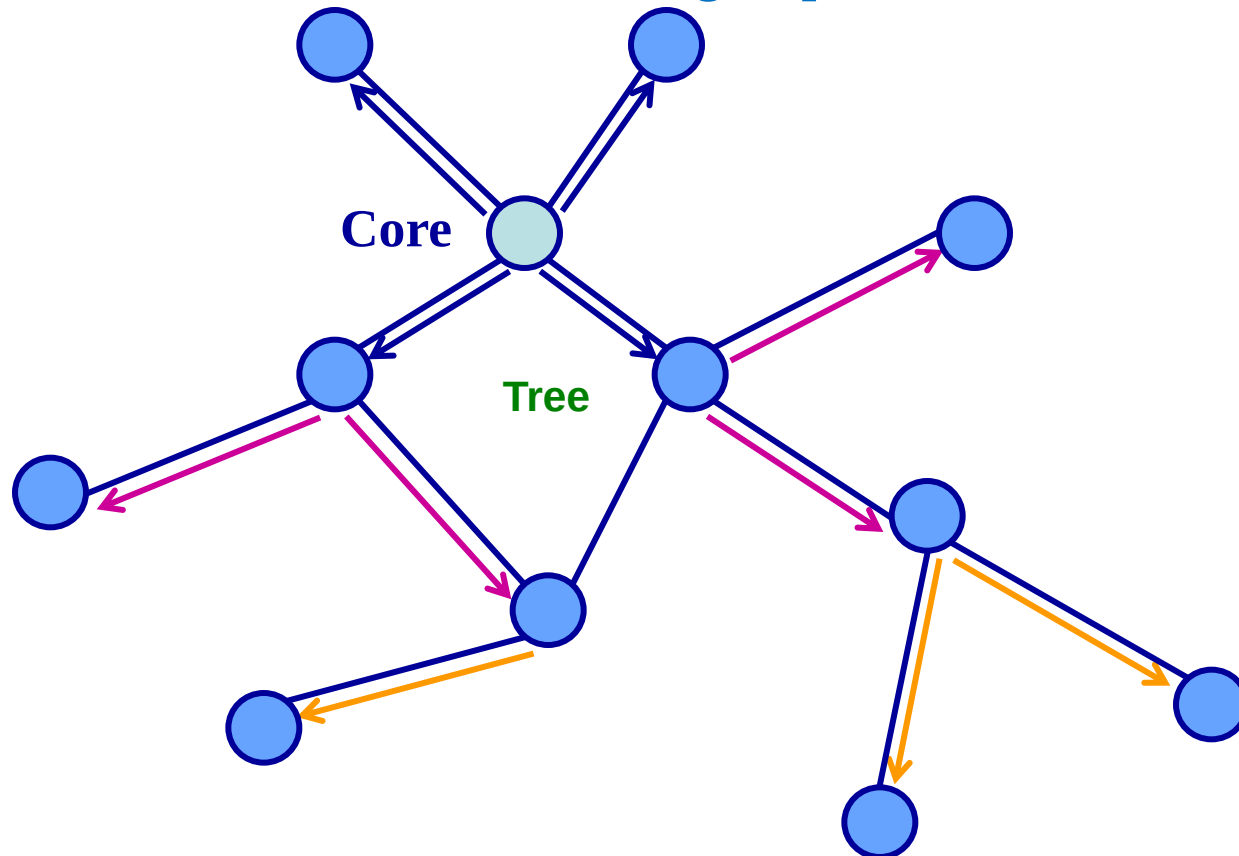
- Multicasting can be performed either by building a *source based tree* or *core based tree*
- In *source based tree*, for each source of the group a shortest path is maintained, encompassing all the members of the group, with the source being the root of the tree



○ Nodes not a part of Multicast group

Core-based Multicasting

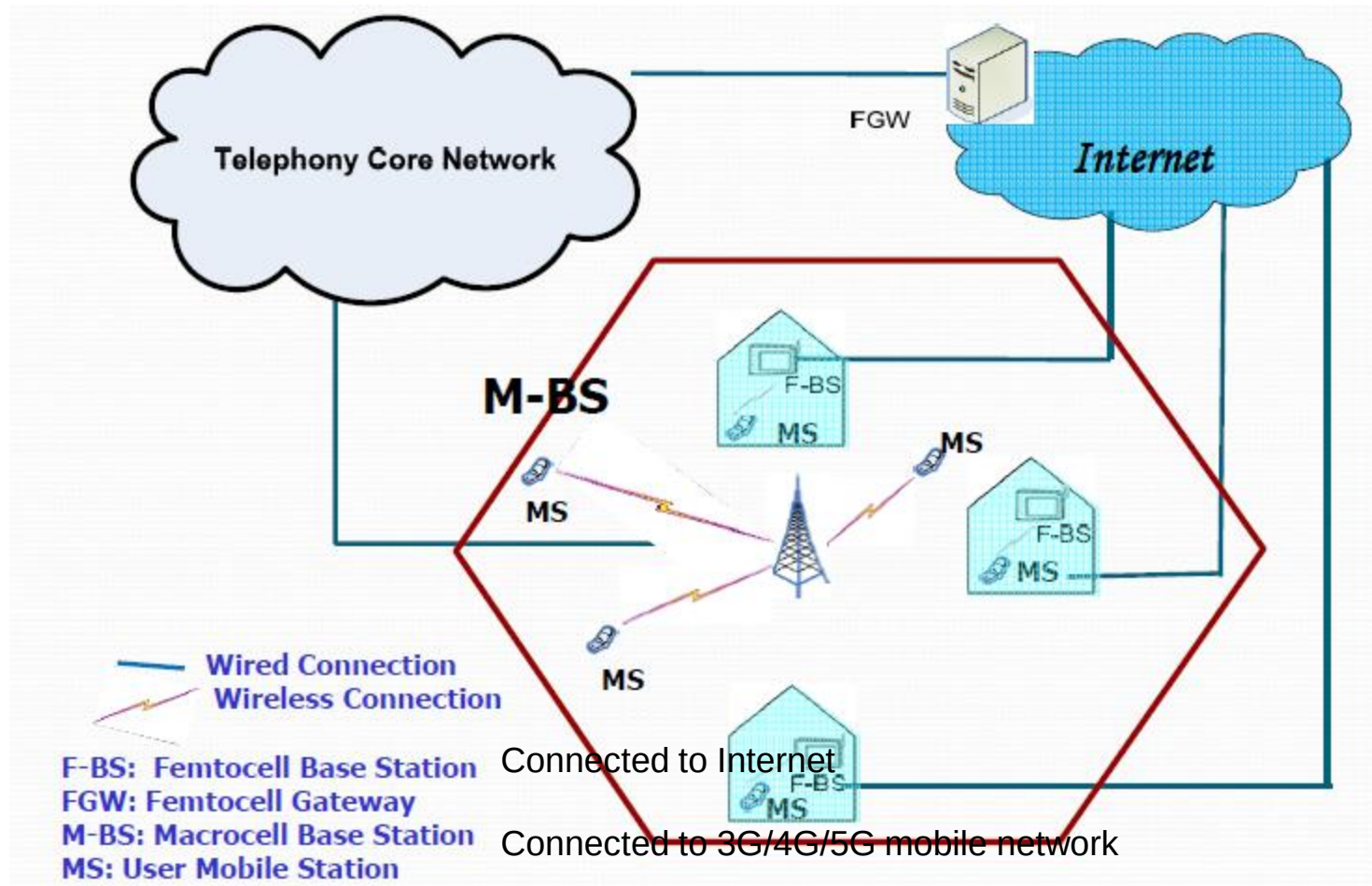
- In **core based tree**, a particular router is chosen as a core and a tree is maintained with the core (not source) being the root
- Every source forwards the packet to a core router, which then forwards it on the tree to reach all members of the multicast group



Femto cell network

- Defined in **3gpp** (3rd Generation Partnership Project, **3G/4G/5G/...**) R9
- High data rate and seamless coverage
- Signal strength is weak inside buildings
- More than 50% voice call and more than 70% data traffic start from an indoor environment
- Easier solution is to deploy some indoor devices serving only the indoor users
- Femtocell Network is an effective way to remedy coverage holes

Femtocell for coverage hole



Femtocell Characteristics

Femtocell Base Station (F-BS)

- Wireless Interface (3gpp) with MS
- Internet Interface (DSL/cable modem etc.) to public access internet

Benefits of Femtocell Network

- Better and seamless coverage
- Enhanced capacity
- Lower transmit power
- Prolong handset battery life
- Higher signal-to-interference-noise ratio(SINR)

Characteristics	Femtocell	Macrocell
Air interface	Telecommunication standard	Telecommunication standard
Backhaul	Broadband Internet	Telephony network
Cost	\$200/year	\$60,000/year
UE	Power consumption low	high
Radio Range	10-50 meters	300-2000 meters

F-BS vs. AP

Characteristics	F-BS	AP
Spectrum	Licensed	Unlicensed
Wireless MAC	Connection-based	Contention-based
Backhaul	Broadband Internet	Broadband Internet
Power	100mW	~1.5 W
Air interface	Telecommunication standard	802.11a/b/g/n
Range	10-50m	35-70m
Service	Primarily voice	Primarily data
Current cost	\$200-\$250	\$50-\$100

HW

P9.2. You have temporarily moved to a new area and you would like to use your cell phone. What alternatives do you have if :

- (a) There is no service provider in that area?
- (b) There is no agreement between your wireless phone service provider and the service provider in the new area?
- (c) The area is covered only by a satellite phone service?

[Hint] (b) Same technology, frequency band, get new 門號

P9.9. In wireless network, the radio signal is broadcast through the air. Therefore, what is the significance of multicasting in this context? Explain in detail.

[Solution] When a wireless network use a common channel, only stations in the radio range of the sender can receive the signal. Multicasting implies formation of group members beyond the radio range so that all can receive intended message.

HW

(new) P9.8. What is the use of “attachment points” from one network to another network? Explain their significance in wireless network routing?

[Solution] They are the gateway routers which route the packets into/out of one network to another network. Gateway routers simply support routing within the backbone.

為何去日本玩「用不了AI」

核心網路 vs 接取網路

eSIM 多數封包繞經中國移動香港的**核心網路**
雖然接取網路用當地aoft bank etc.(手機顯示)

- 一是資安：IMSI、地理位置、DNS 查詢等敏感元資料全經中國管轄區，台灣旅客的行蹤等於攤在中國當局眼前
- 二是使用體驗：因為 IP 被判定為香港或中國，使用者出國時 ChatGPT、Claude、Gemini 等 AI 工具會直接被擋。