Impact of Mobility on TCPIP

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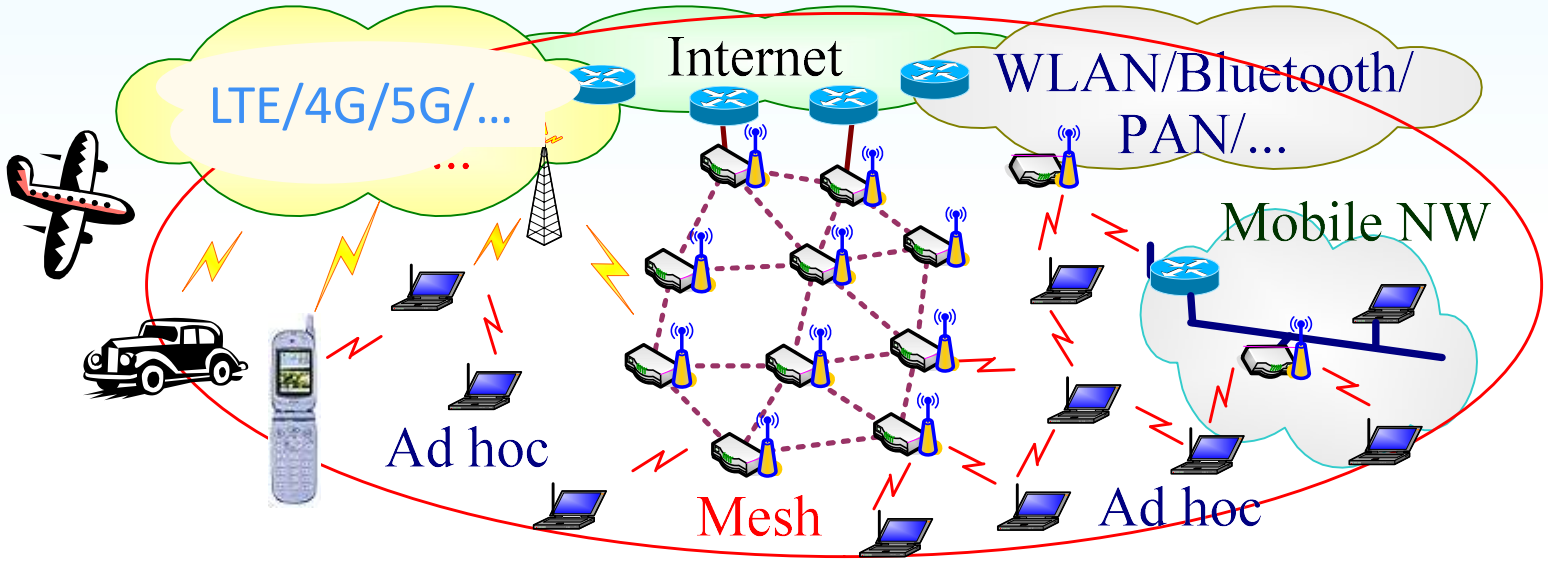
References:

Wireless Access to Internet



- Global Satellite Networks
- Cellular Networks: GSM, CDPD, GPRS, WCDMA/cdma2000, LTE, …
- Wireless LANs: IEEE 802.11, 802.11a, b, n, ac, ax (WiFi 6)
  - Wireless Mesh 802.11s
- Personal Area Networks: IEEE 802.15, Bluetooth

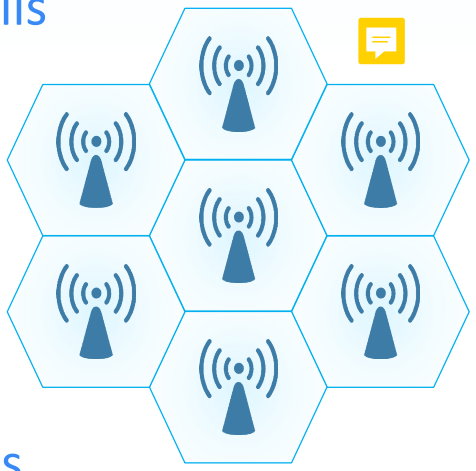
802.11 Technologies

年份	Wi-Fi	標準	頻段	最高傳輸率
1997 年	第一代	IEEE 802.11	2.4GHz	2Mbit/s
1999 年	第二代	IEEE 802.11a IEEE 802.11b	5GHz 2.4GHz	54Mbit/s 11Mbit/s
2003 年	第三代	IEEE 802.11g	2.4GHz	54Mbit/s
2009 年	第四代	IEEE 802.11n（Wi-Fi 4）	2.4GHz 或 5GHz	600Mbit/s
2013 年	第五代	IEEE 802.11ac（Wi-Fi 5）	5GHz	6,933Mbit/s
2019 年	第六代	IEEE 802.11ax（Wi-Fi 6）	2.4GHz 或 5GHz	9,607.8MBit/s

- Source: https://www.sogi.com.tw/articles/wifi_6/6254363

Cellular Architecture

- Adjacent **neighboring Base Stations** (BSs) can not use same frequencies
  - Due to co-channel interference.
- Cellular networks divide service area into regular shaped cells
  - Hexagonal cells are conventional.



- Cellular architecture
  - Each cell uses different frequencies from neighboring cells,
    - Avoid interference
    - Provide guaranteed bandwidth (capacity) within each cell
  - Two cells **sufficiently far apart** can operate on the same frequency

Features of Cellular Architecture

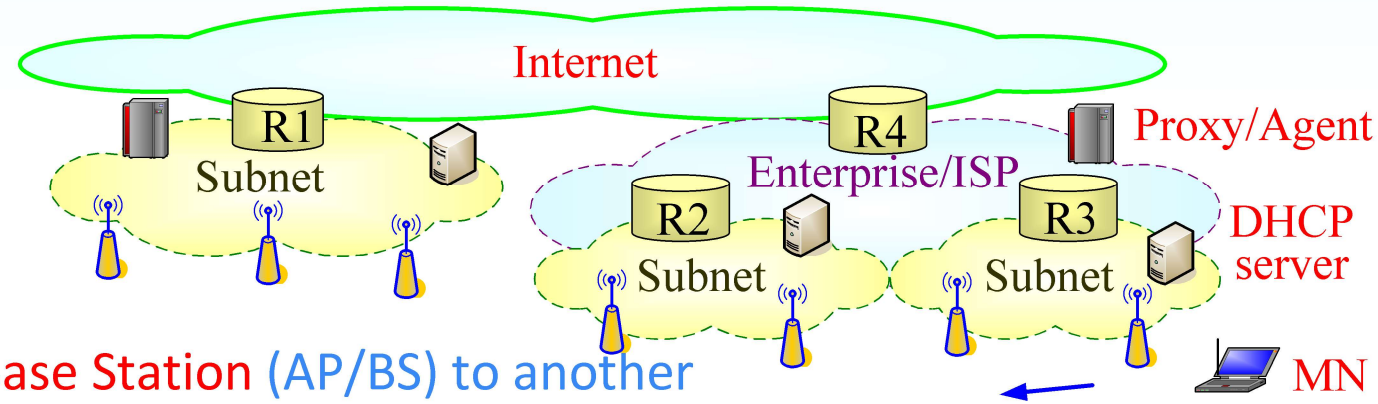
- Advantages of Cellular Architecture
  - More capacity than a single large transmitter,
    - Same frequency can be **used simultaneously** by cells far apart
  - Mobile devices use less power than with a single transmitter
    - Because cell towers are closer
  - Better coverage area than a single terrestrial transmitter,
    - Additional cell towers can be added indefinitely and are not limited by the horizon

✓ Cell could be very small in areas of high demand

➢ Various sizes of cells:
  - Femtocell, Picocell, Microcell, Macrocell, Global satellite cell

Cell Crossing and Handovers

- Recall: Cellular architecture could reuse frequencies
- Cellular architecture may result in cell crossing when an MN moves:
  - Mobile Node (MN) changes its point of attachment



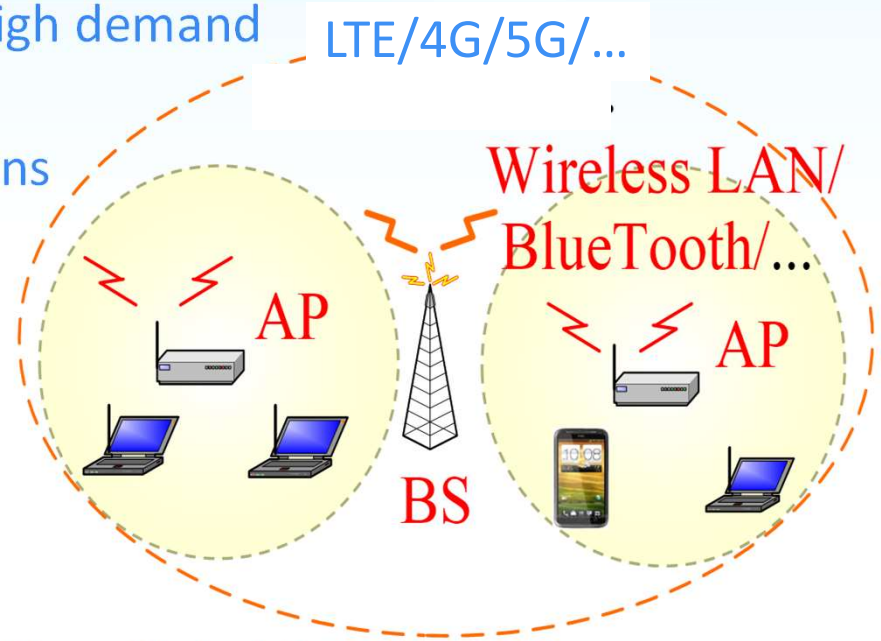
  - From an Access Point/Base Station (AP/BS) to another
  - From a Network (Subnet) to another
  - From a Service domain (Proxy/Agent) to another
- ✓ Handover or handoff (slightly different from roaming)
- ✓ Seamless (fast and smooth) handover: a cross-layer issue
  - Need cooperation of entities from multiple layers
    - BS/Subnet/Session or Proxy handoffs

- MN: Mobile Node

- Fast Handover: Short Delay
- Smooth Handover: Almost no packet loss

Wireless Network Overlay

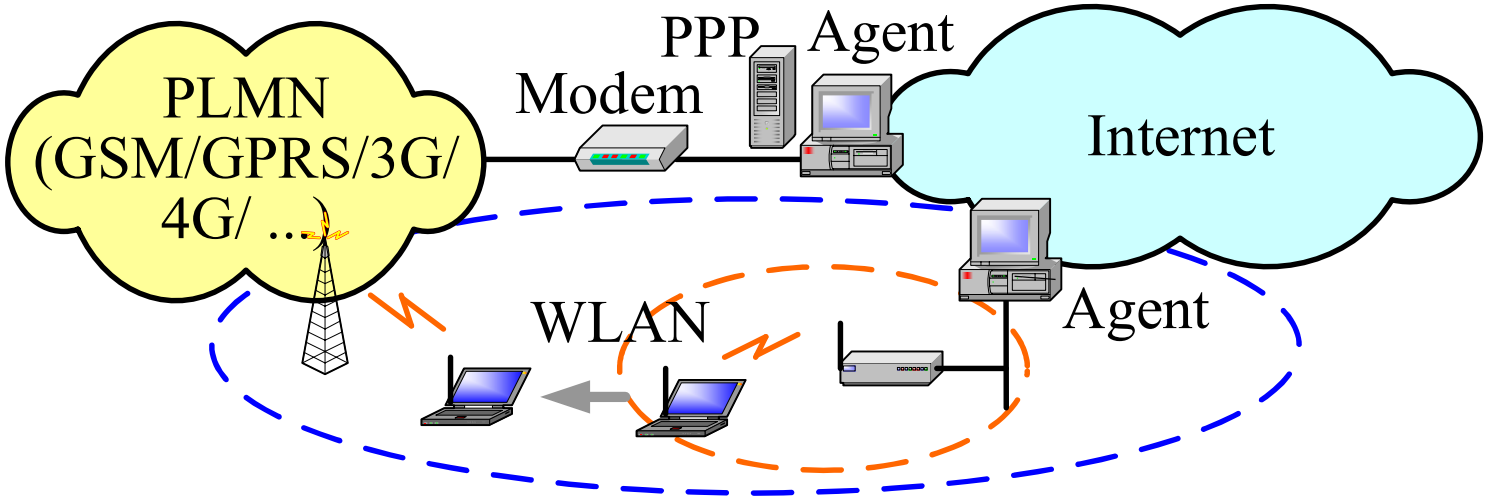
- Recall: Cell could be made very small in areas of high demand
  - Increases frequency of cell crossing
    - Need more distributed network control functions
      - A scalability issue
  - Tradeoffs of Cellular architectures:
    - Smaller cell,
      - more capacity and less power consumption
      - more hangovers
        - more signaling and disruption



  - Femtocells ↔ Picocell ↔ Microcell ↔ Macrocell ↔ Global Satellite cell
- Wireless Network Overlay
  - ✓Low-tier wireless system: higher bandwidth/reliability and/or low cost
  - ✓High-tier wireless system: larger coverage area

A Two-tier Wireless Network

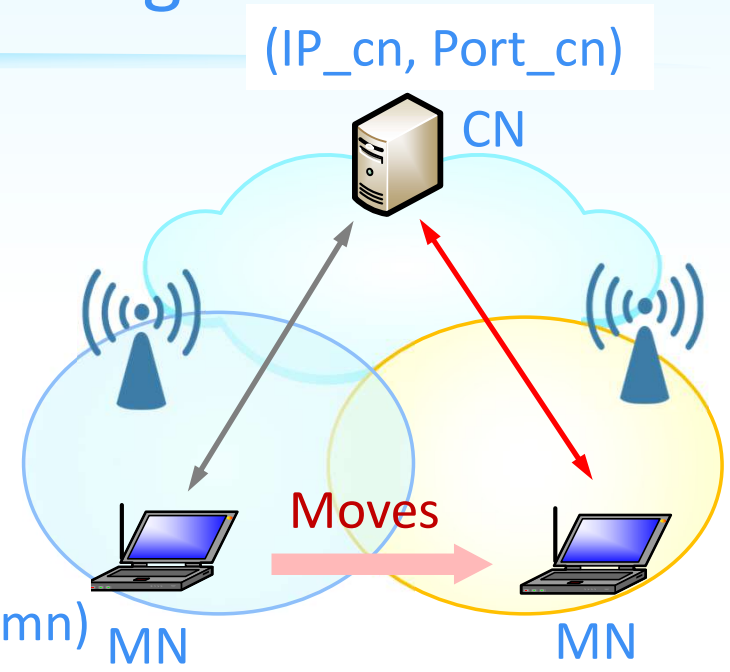
- Mobile Node (MN) equipped with multiple wireless adapters
  - Access Internet through appropriate interfaces according to
    - Connectivity,
    - Tariffs,
    - …
  - Mobile IP deployed to support wide-area mobility



Dilemma of IP Addressing

- Dual Roles of IP Addresses

1. Routing Directives
   - Internet Protocol uses **network-prefix** for routing
   - ➢MN must be associated with **a *new IP*** after moves
2. Endpoint Identifiers
   - From transport or application-layer perspective
     - e.g., a TCP connection:
       (IP, Port) ⟷ (IP, Port)
   - ➢MN must preserve its IP address, regardless of point of attachment
     - Otherwise, session breaks

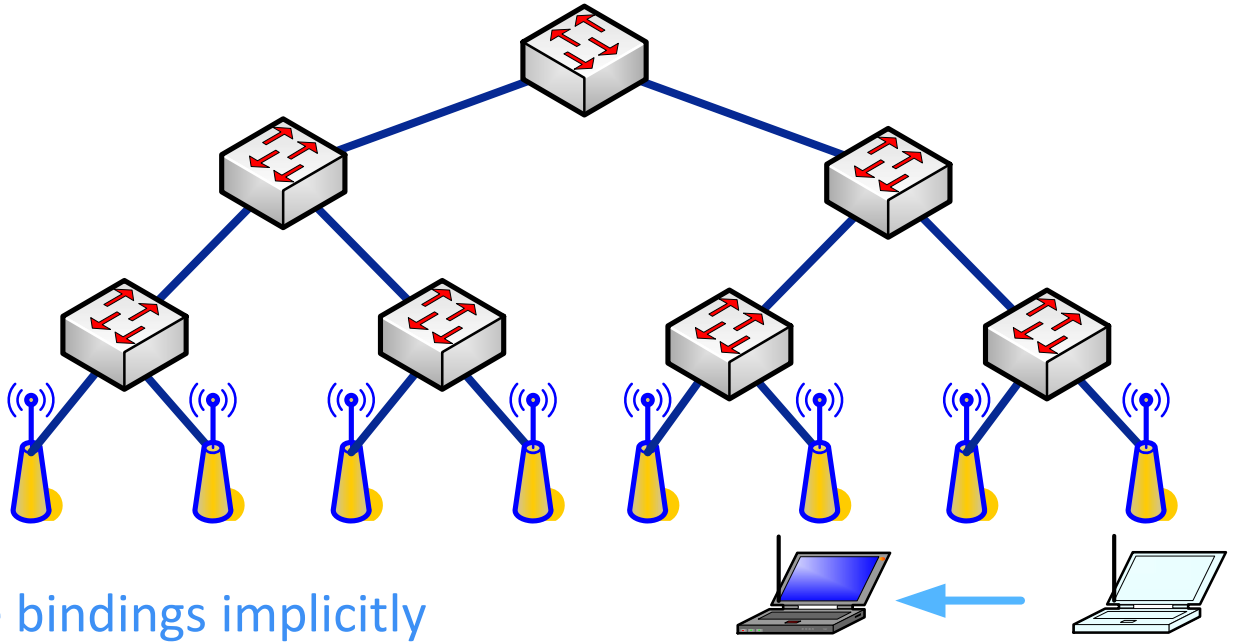


- MN: Mobile Node
- CN: Corresponding Node

Approaches to Mobility

L2 Approach– MAC Learning

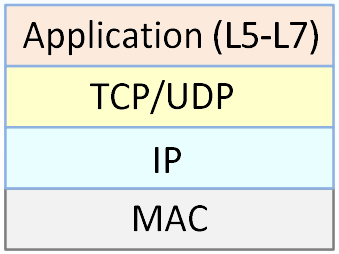
- Iwander:
  - Interconnected off-the-shelf Ethernet Switches
  - Identifies hosts with MAC Addresses
  - ➢ Use MAC Learning function of Ethernet Switches to support host mobility



- Uplink data packets update bindings implicitly

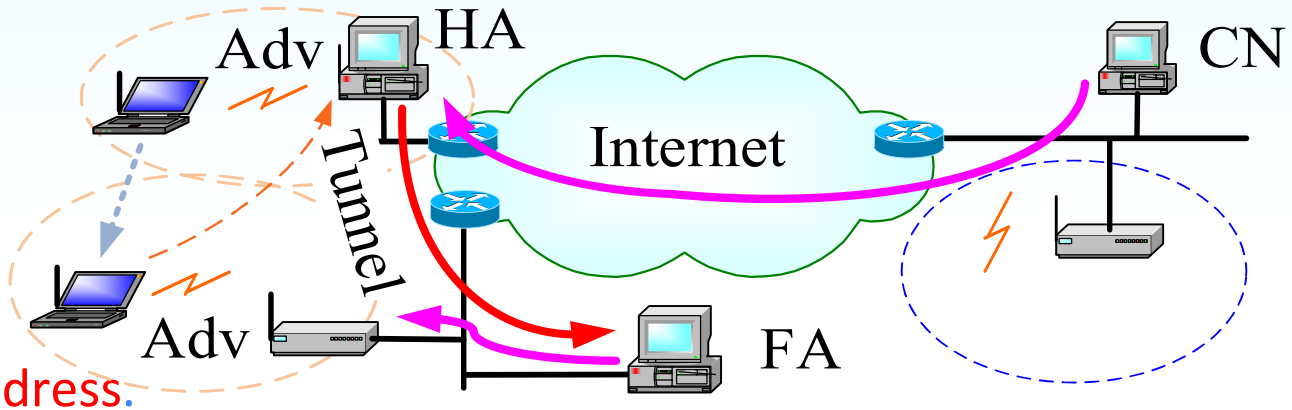
Layer 3 Approaches

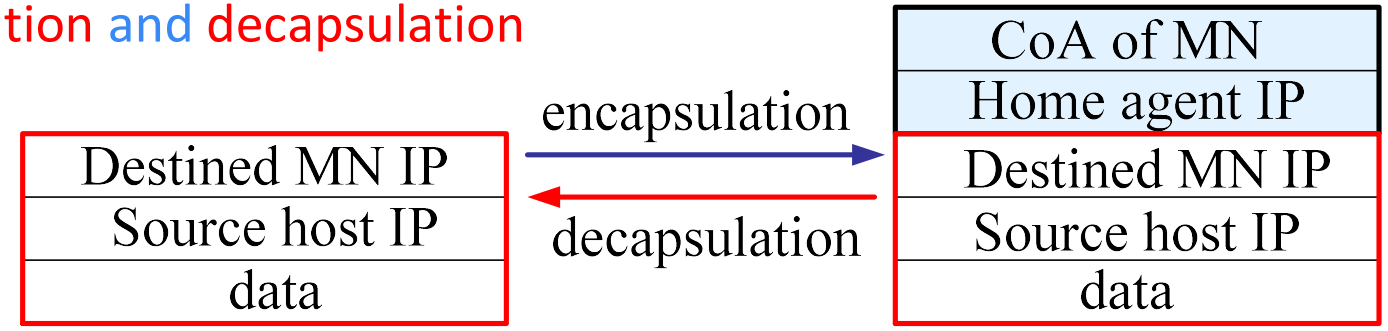
- For cross-network (subnet) mobility
- L3: Mobile IP
- Achieving Reachability:
  - Unique ID:
    - Care-of IP for new location
    - Permanent IP for Transport
  - Directory service: map Permanent IP to Care-of IP (CoA)
    - Care-of IP ⇔ location
  - Registration Messages: update Permanent IP/CoA binding
- Achieving Session Continuity:
  - Permanent IP for transport
    - No changes in transport
    - ➢ Session continues after movement



L3 Approach: Mobile IP and Tunneling

- Two Addresses:
  - Care-of IP for new location
  - Permanent IP for Transport
- Packets destined to an MN
  - Routed to its HA
    - using its permanent IP address.
  - HA tunnels packets to the MN
    - using IP-in-IP encapsulation
- Encapsulation and decapsulation

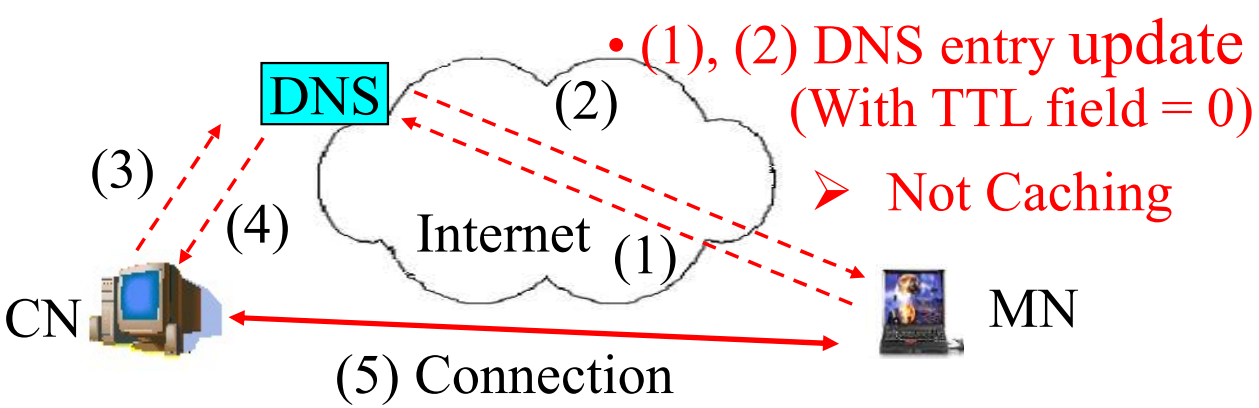




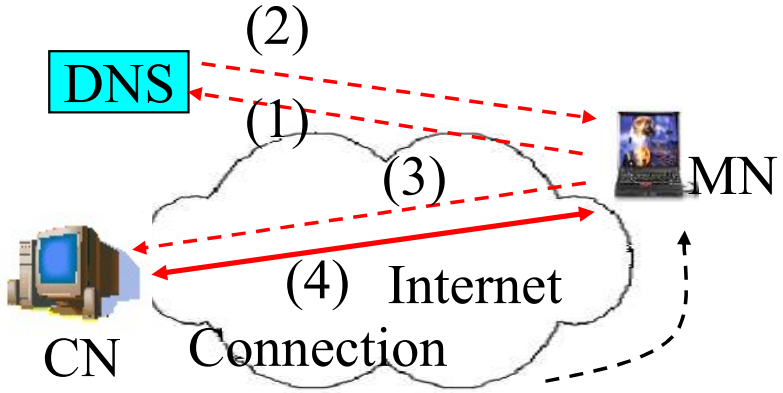
L4 Approach: Dynamic DNS with TCP Connection Migration

- Use DNS and TCP connection migration to support mobility
  - Need to modify TCP protocol stacks of CNs and MNs,
    - for TCP Connection Migration Handover
  - No Mobility Agents are required
- When an MN changes its IP address,

1) MN updates corresponding DNS entry
2) CN queries DNS to find MN's IP address when CN wants to connect to MN



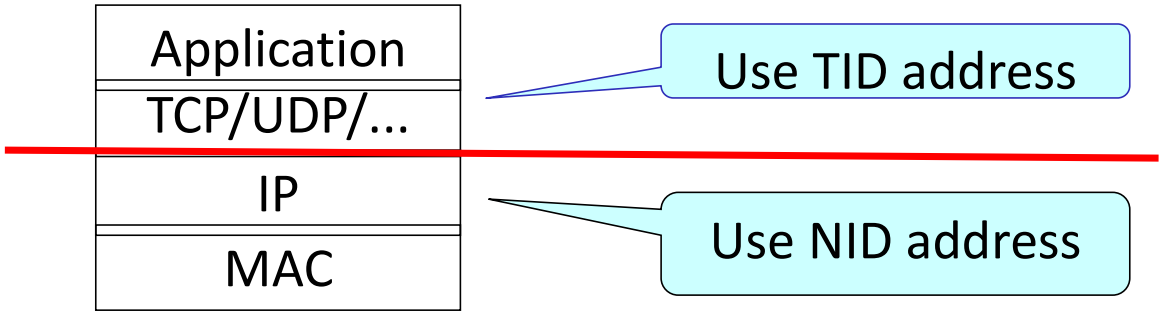
- (1), (2) DNS entry update (With TTL field = 0)
  - Not Caching
- (3), (4) DNS Query/Response



✍ *A. C. Snoeren* and *H. Balakrishnan*. "An End-to-End Approach to Host Mobility," *MobiCom* '00

L4 Approach: IP-Decoupling

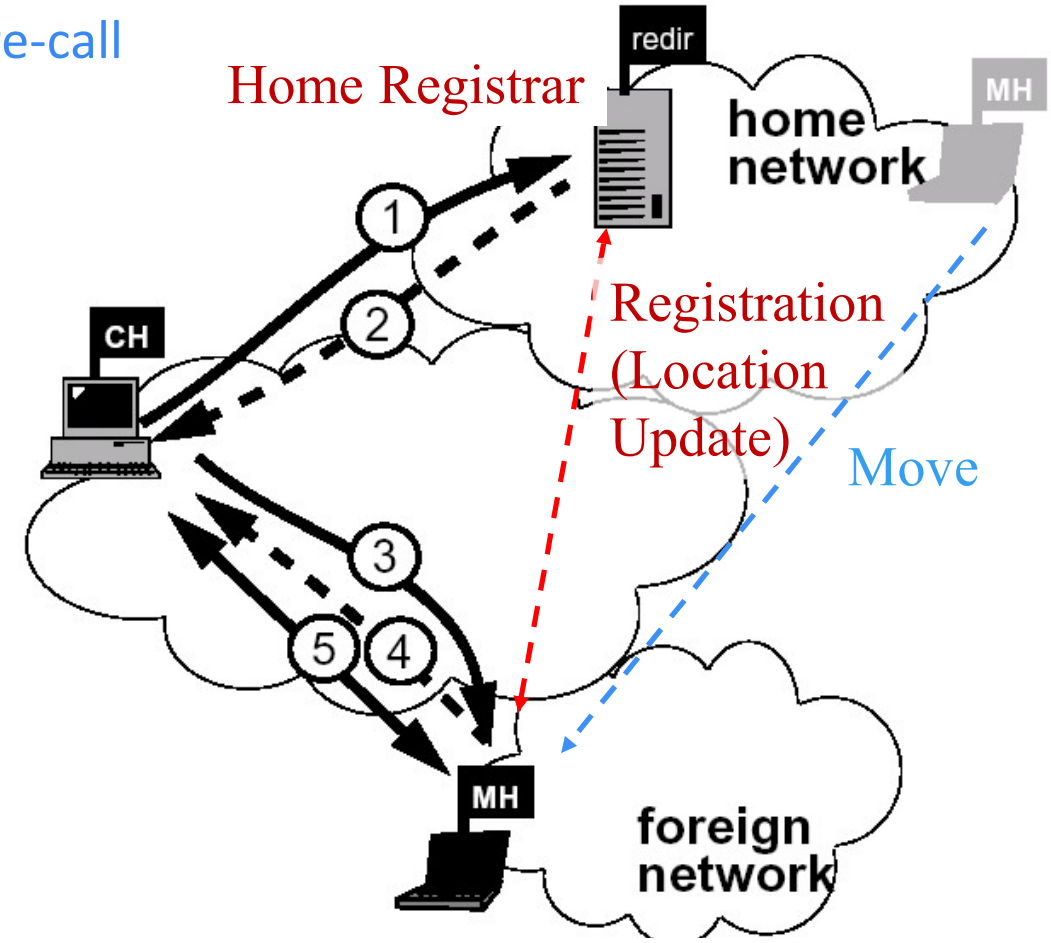
- Decouple the dual purposes of IP Addresses
  - Transport-Identifier Address (TID Address)
    - Used to identify a host
    - Never change in a session
  - Network-Identifier Address (NID Address)
    - Used to identify a location (IP)
    - Change after moving to a new network



- Chun-Chieh Wang, Kuang-Hui Chi, and Chien-Chao Tseng. "An IP-decoupling Approach to Host Mobility," Journal of Information Science and Engineering,

Application Layer: Mobility Using SIP (1/2)

- Pre-call



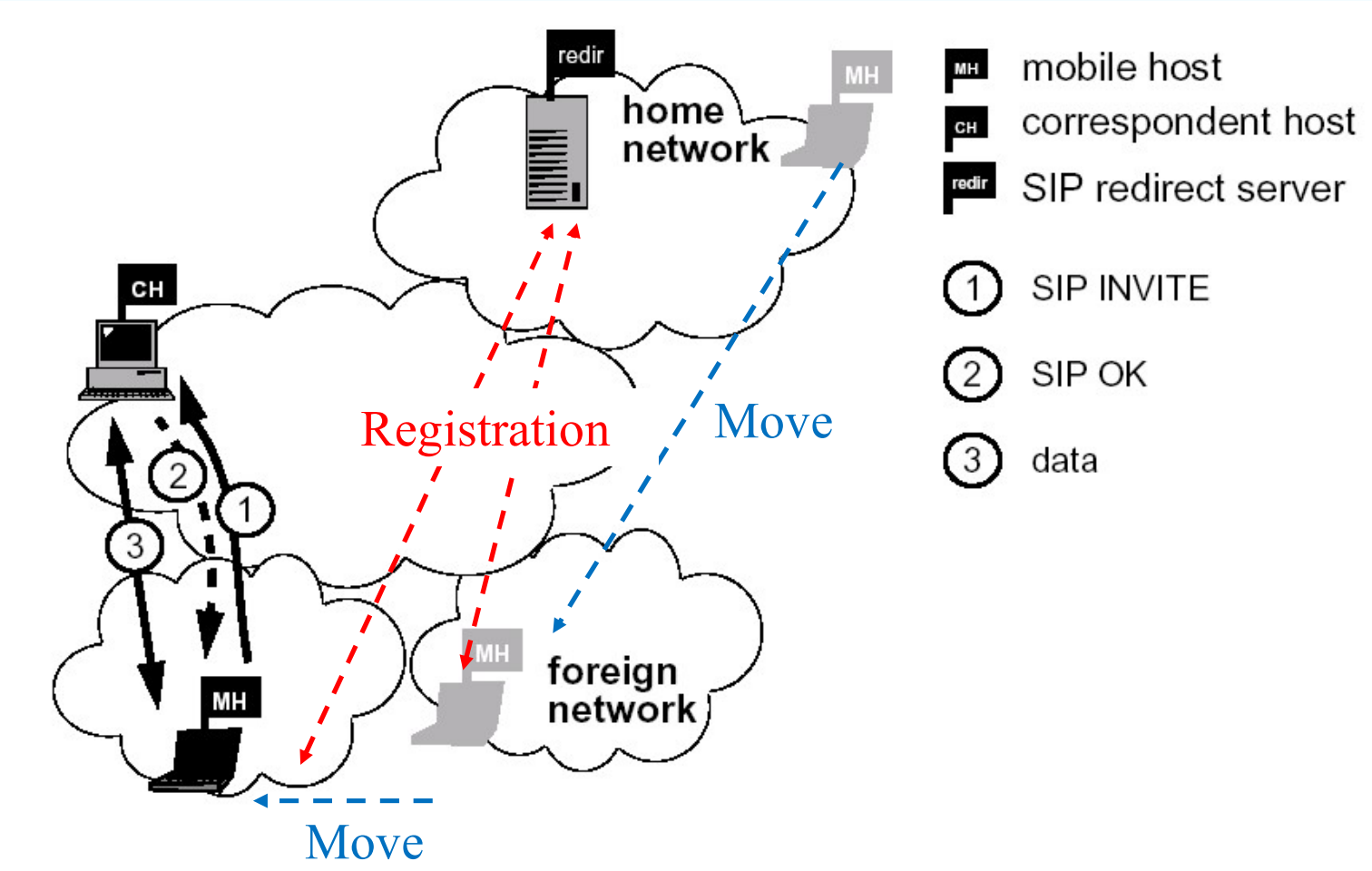
MH mobile host
CH correspondent host
redir SIP redirect server

1 SIP INVITE
2 SIP 302 moved temporarily
3 SIP INVITE
4 SIP OK
5 data

Reference: Henning Schulzrinne and Elin Wedlund. Application Layer Mobility Using SIP, *ACM* Mobile Computing and communications (MC2R), Vol 4, No 3, 2000

Application Layer: Mobility Using SIP (2/2)

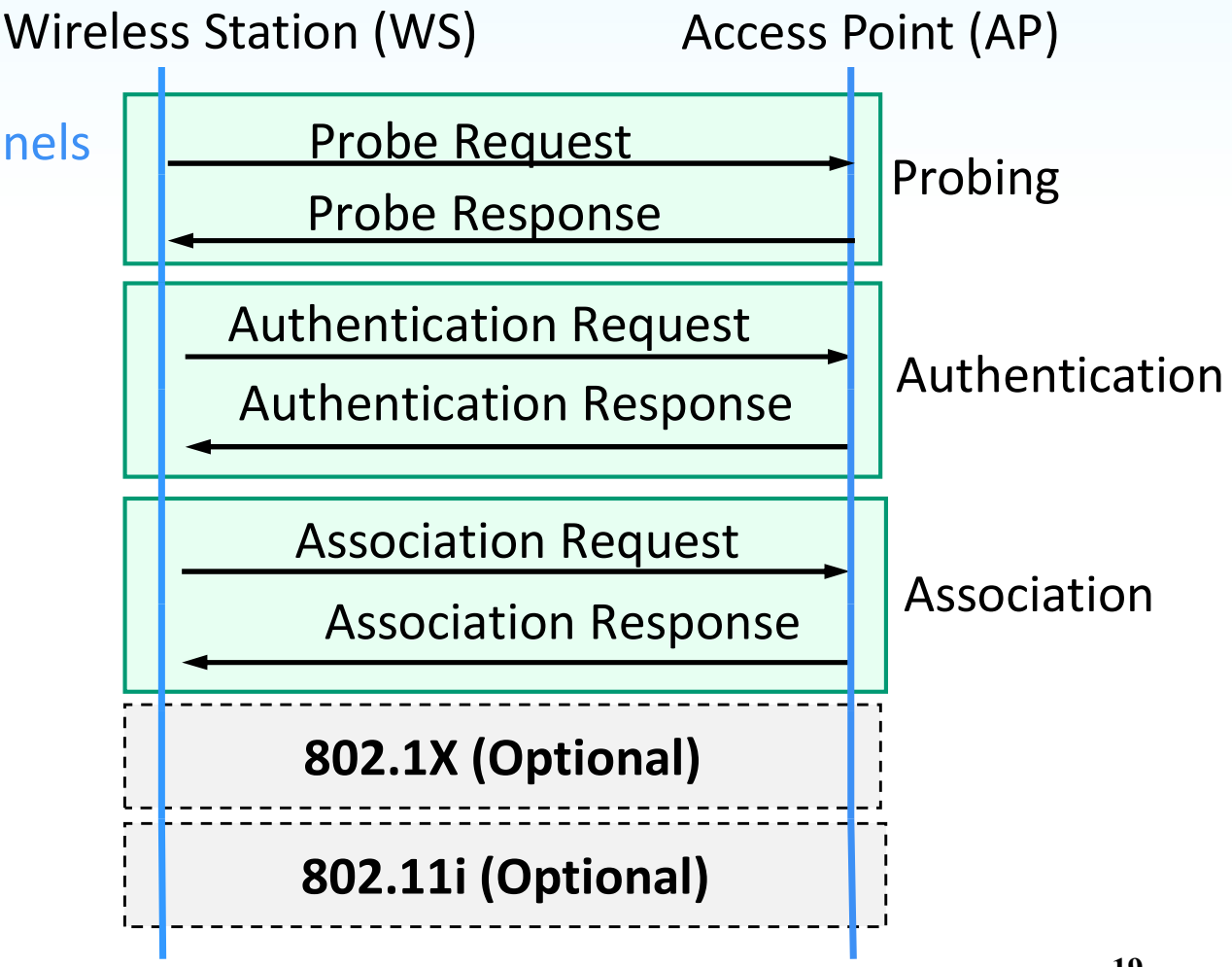
- **Mid-call:**



Handover Procedures

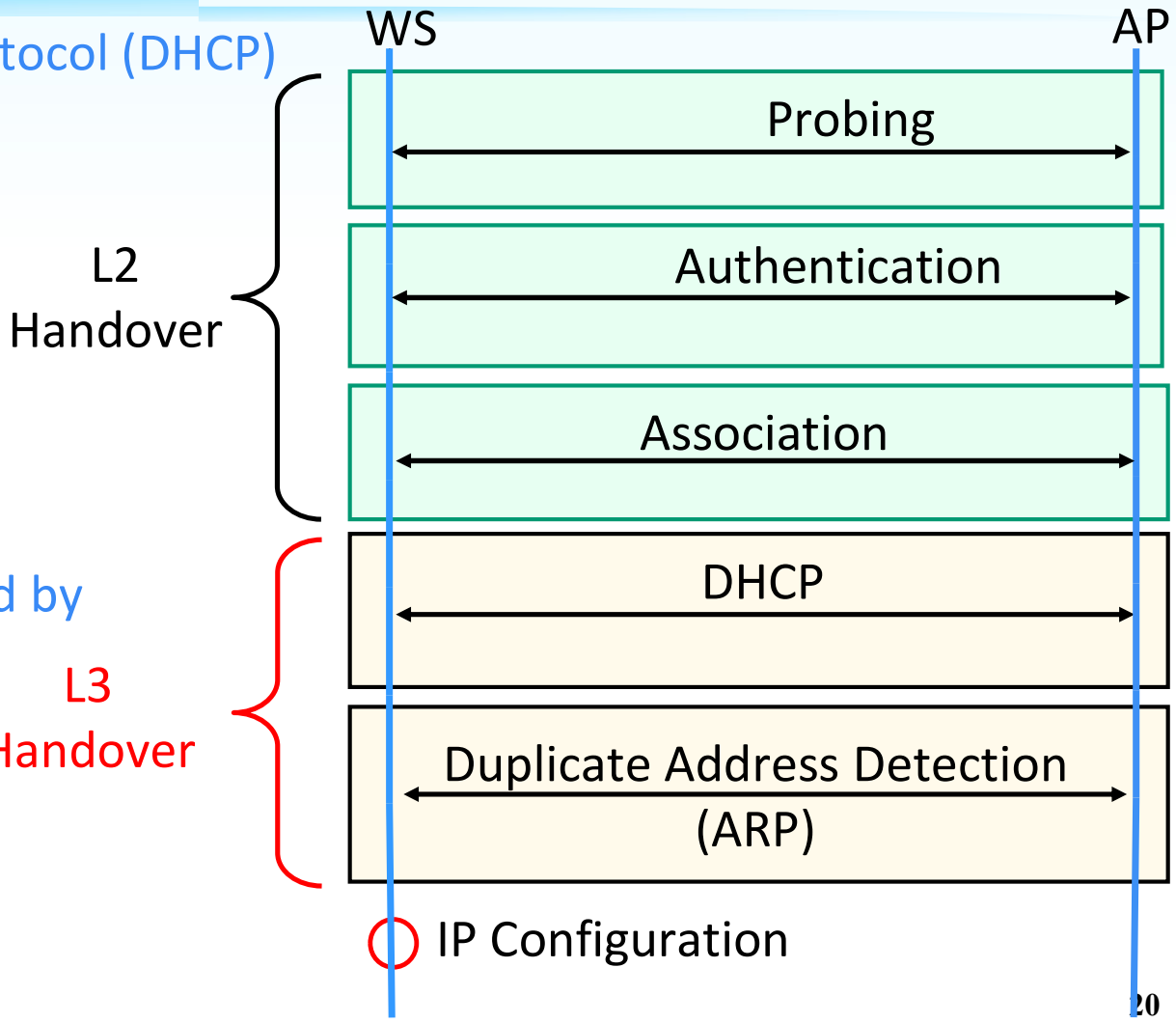
L2 Hanover Sequence Diagram

- **Probing**
  - Searches other APs
    - APs within range on all channels
  - Two modes
    - Active Scanning
    - Passive Scanning
- **Authentication**
  - Authenticates with new AP
- **Association**
  - Connects to new AP



L3 Hanover Sequence Diagram

- Dynamic Host Configuration Protocol (DHCP)
  - Acquires a new IP address
  - when MN changes subnet
- Duplicate Address Detection
  - Avoid using an IP address used by another host in the subnet

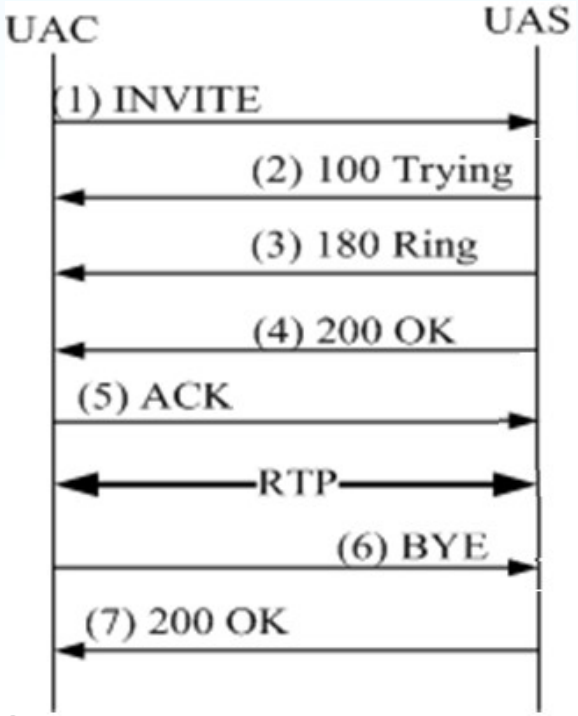


Application Layer Handover Sequence

UAC: User Agent Client
UAS: User Agent Server

- **Session Initiation Protocol** (SIP)
  Signaling protocol used for **initiating**, **maintaining**, and **terminating** real-time sessions
  - for voice, video and messaging applications.
- **SIP-based Application Handover**, by
  - SIP Re-invite or
  - RTP (data) with SSRC

- SIP Call flow



- Application layer Handover

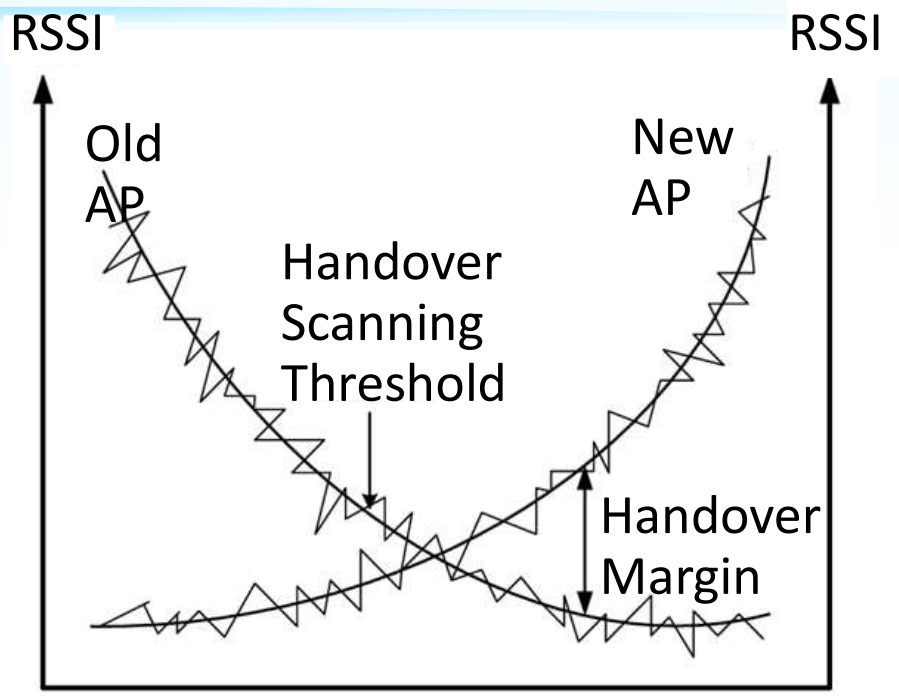
L2	Probing Authentication Association
L3	DHCP DAD
Application	SIP Re-invite (RTP SSRC)

- RTP: Real-time Transfer Protocol
  Protocol for end-to-end, real-time transfer of streaming media (audio and video) over IP network.
  - typically runs over UDP

Handover Detection and Initiation

L2 Hanover Detection

- Detect the need to start an L2H (probing)
- Various methods
  - Received Signal Strength Indicator (RSSI)
  - Signal to Noise Ratio (SNR)
  - Bit error rate
  - Frame error rate
- Should differentiate
  intermittent bad communication state
  from **persistent one** that necessitates an L2H
- Detection time can't be too short!

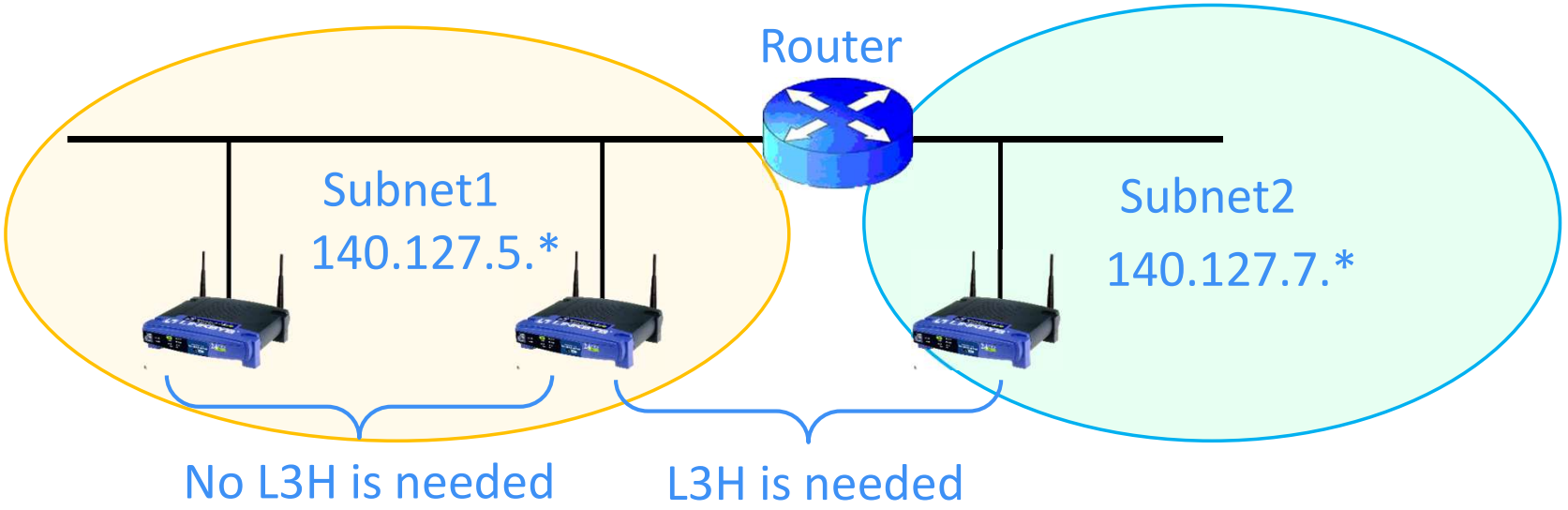


To avoid false alarm

- Source: RY Kim, https://www.semanticscholar.org/paper/A-Novel-IEEE-802.11p-Make-Before-Break-Handover-for-Kim/c67916e508e0696a1c8024c25fa425f66e43f308 Car

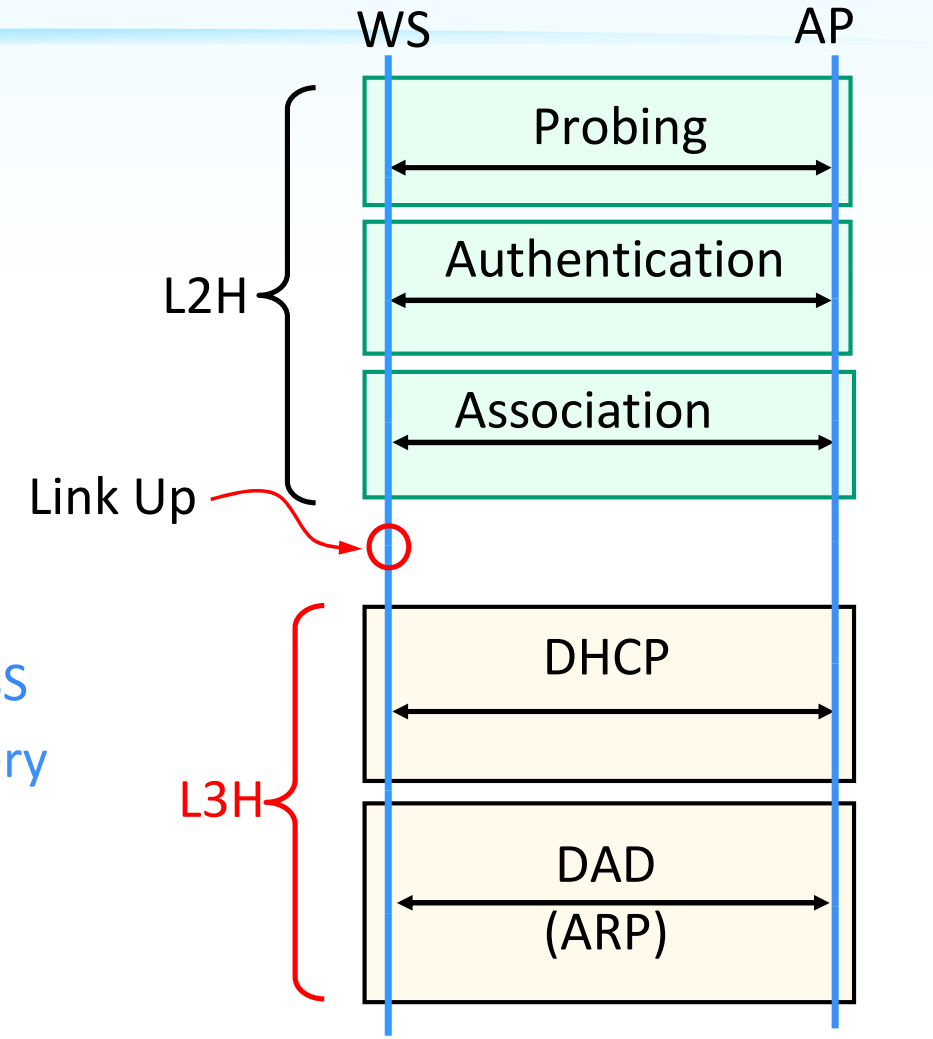
Layer-3 Handoff (L3H)

- Needed when the new and previous APs belong to different network domains
- Should renew network-layer settings
  - IP address, default gateway, etc.



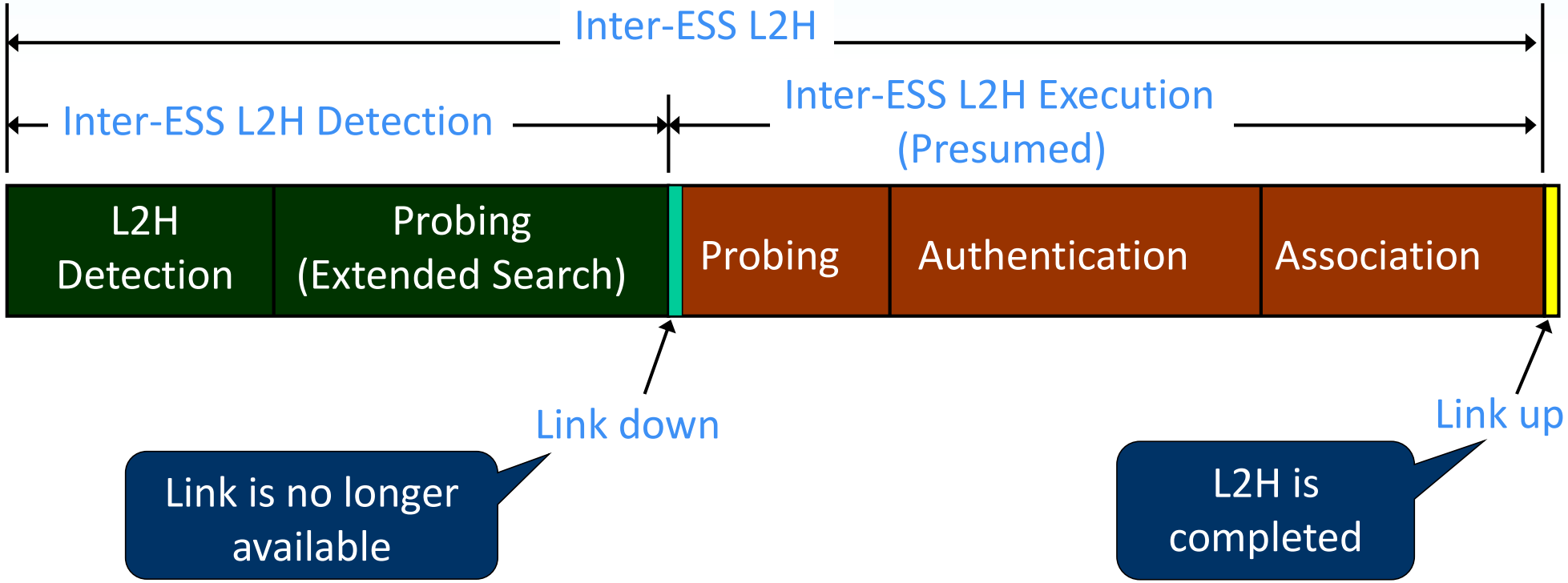
L3 Handover Detection

- No standard way
- Most OS provide link events as **indications of L2 statuses**
  - Link Down: L2 connection breaks
  - Link Up: L2 connection is established
- Normally, a Link Up occurs when L2 connection is established
- But no Link Down occurs when roaming among **APs with well-coverage** within an ESS
  - ➢Avoiding Address Nullification and Recovery



Link Down Triggers L3H

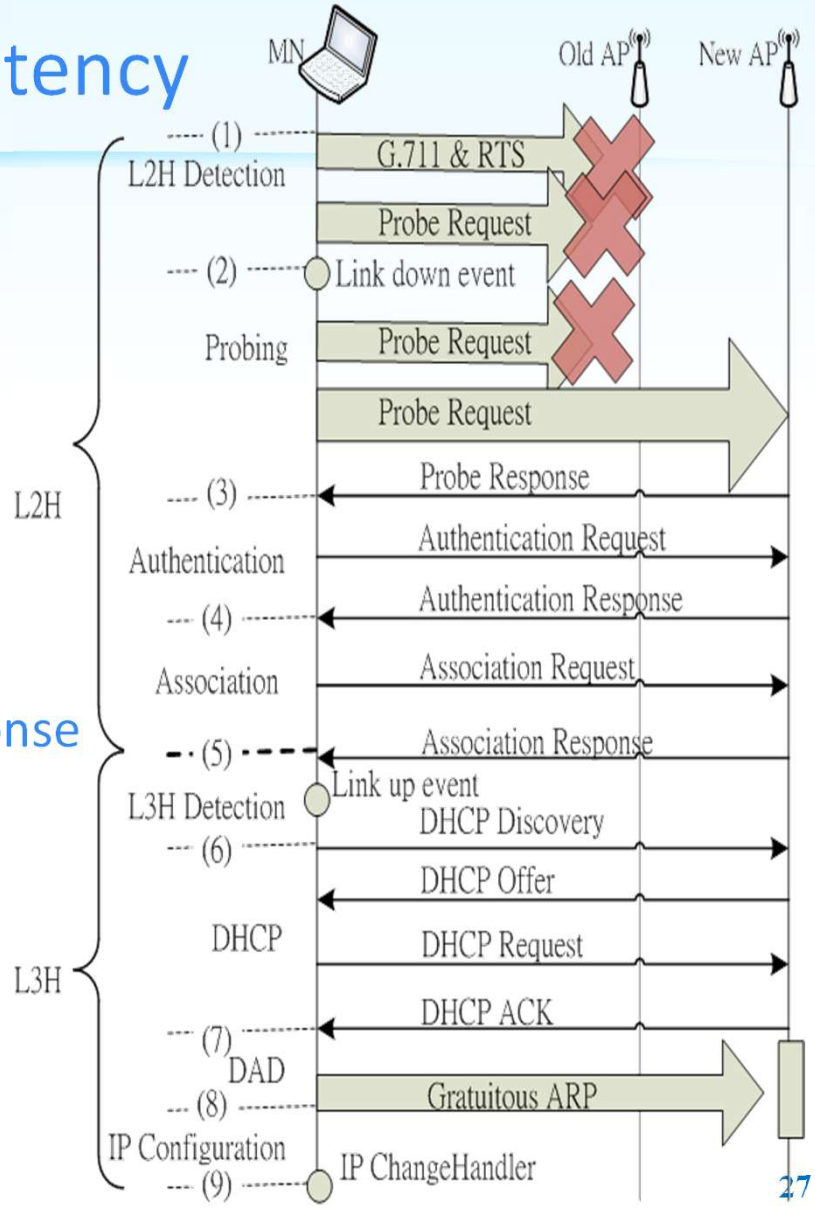
- Link Down indicates ESS may change
  - Presuming an L3 change



  - Perform L3H after Link Up

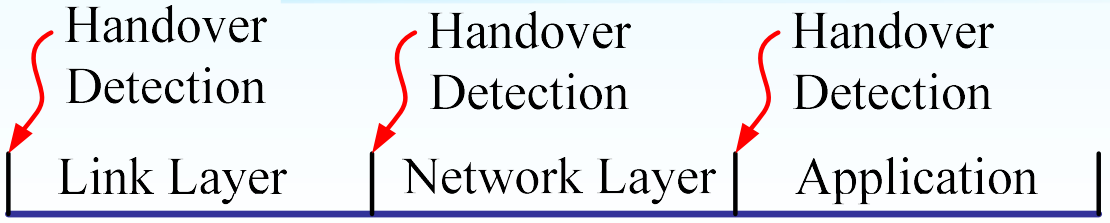
Application Perceivable Latency

- Handover Latency of VoIP Applications
  1) First retry G.711 after last ACK from old AP
  2) Link down event
  3) Last Probe Response before Authentication Request
  4) Authentication Response
  5) Association Response
  6) First DHCP Discovery after Association Response
  7) DHCP ACK before GARP
  8) Last GARP
  9) IP ChangeHandler event

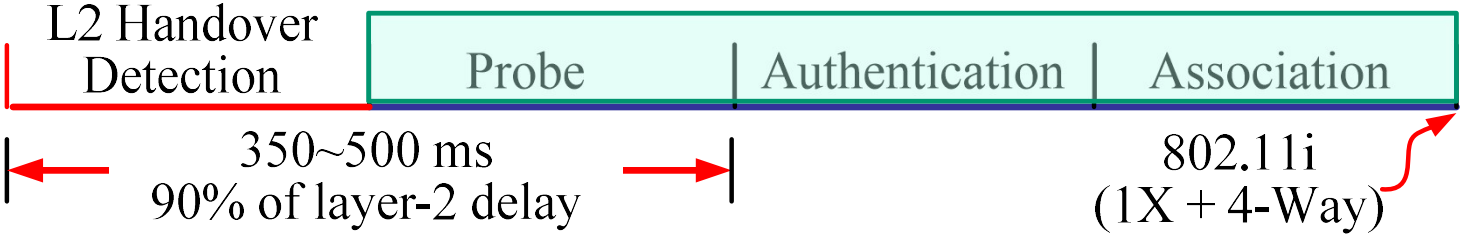


Constituents of Handover Latency (revision)

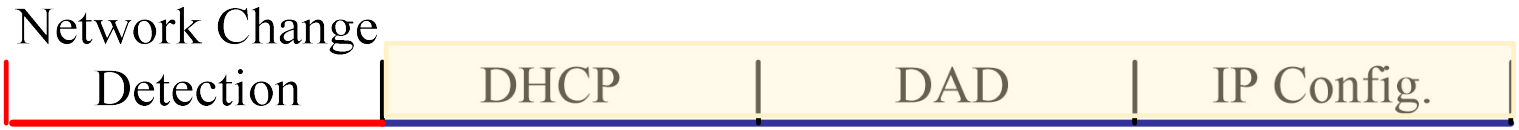
- **Overall Hanover Latency**



- **Link Layer**



- **Network Layer** (Order of seconds or even minutes)



- **Application Layer** (Session may terminate)