- **IEEE 802.21 MEDIA INDEPENDENT HANDOVER**
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- Title: Effects of IEEE 802.16 link parameters and handover performance for select scenarios.
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- Abstract: This document discusses the layer 2 trigger generation in 802.16 access networks and their impact on the handover performance. In addition, simulation results for realistic handover scenarios within 802.16 cells and between 802.16 cells and 802.11 hot spots are presented.

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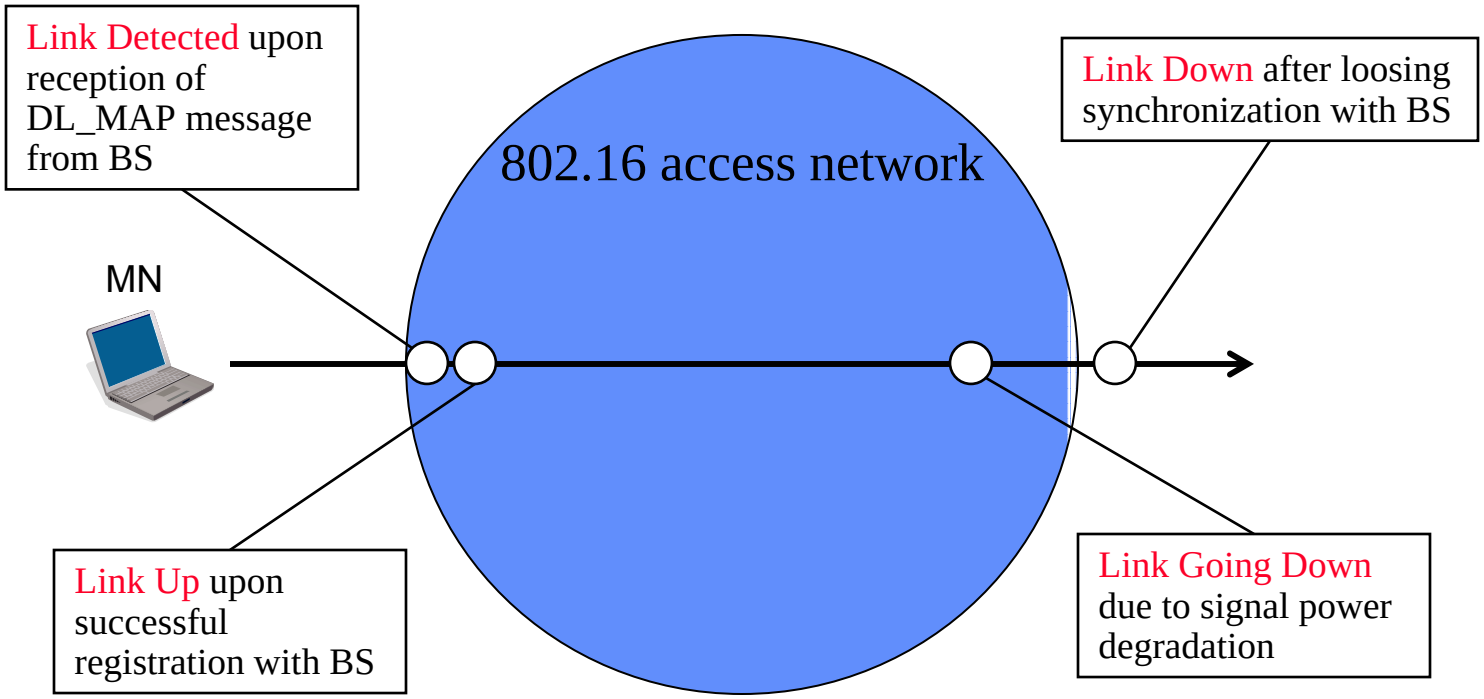
Motivation and objectives

1. Understand how link triggers are generated in 802.16 and evaluate their effects on the overall handover performance.
2. Measure the handover performance for realistic scenarios:
   - Within two 802.16 cells
   - Between an 802.16 cell and 802.11 hot spot.

IEEE 802.16 implementation

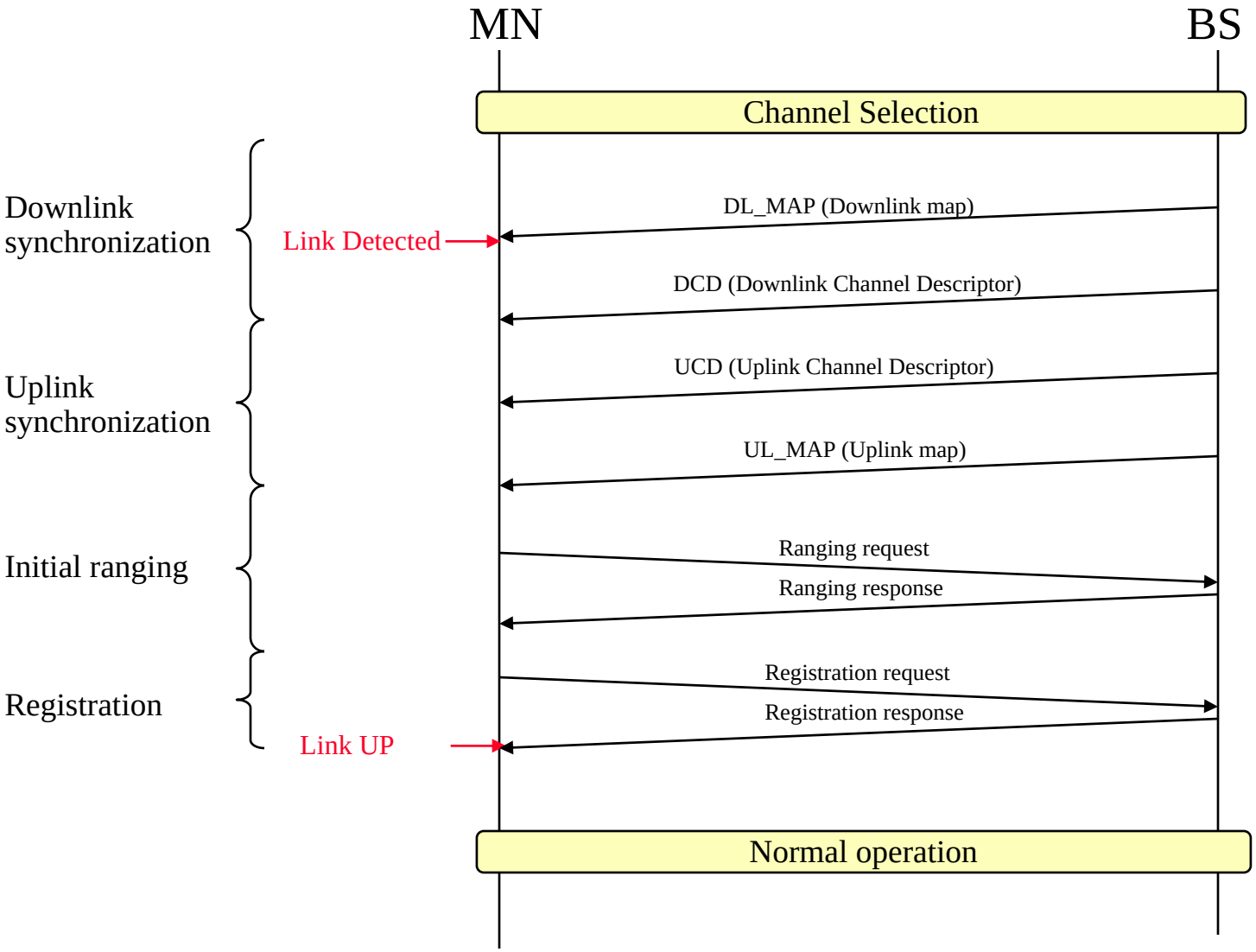
- A model of IEEE 802.16 has been developed using ns-2
- To date this implementation contains the following key features:
  - OFDM physical layer with support for different modulations
  - TDD
  - Mac layer implements synchronization messages
  - Round Robin scheduler
  - Supports bidirectional flows (without QoS)
  - Fragmentation/Reassembly
  - Mobility extension (IEEE 802.16e) for scanning and handoff without association.
  - Integrated in the IEEE 802.21 model

Link layer trigger generation



IEEE 802.16 message exchange sequence

network entry



- The DL_MAP and UL_MAP messages contain the burst allocation decided by the BS .
- The DCD and UCD messages contain burst profiles. They are periodically generated by the BS. The standard defines the maximum interval between two messages to 10 seconds.

Link Detected trigger

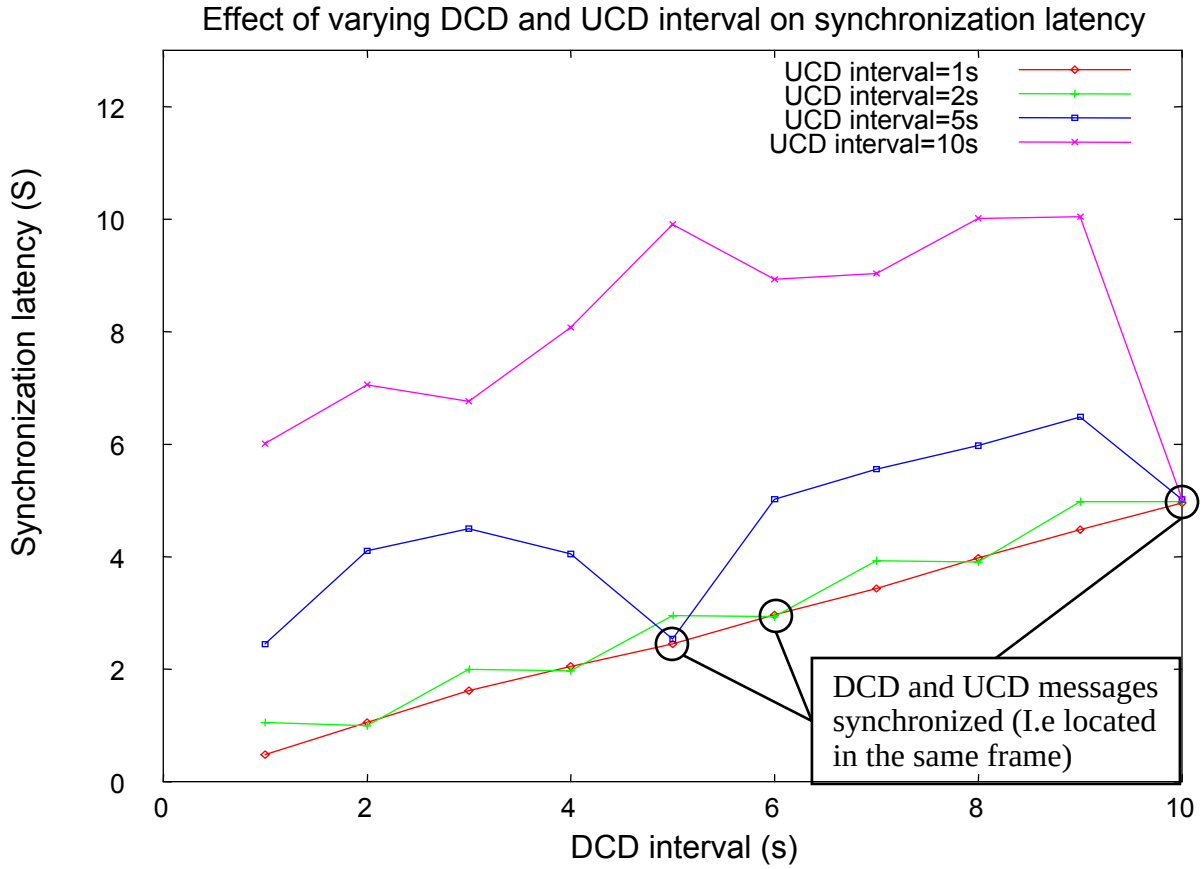
- The MN needs to listen to the channel in order to find a BS:
  1. Select a channel
  2. Listen for a preamble message
  3. If a preamble is found
     - Wait for DL_MAP message
     - If DL_MAP message trigger link detected
     - Else goto 1 after timeout
  4. Else goto step 1.
- In the simulation implementation, DL_MAP messages are sent in every frame and the timeout for the DL_MAP message is set to 50 ms.

Minimum time is 2 frames (8ms)

Maximum time is 10s

Link UP trigger: synchronization

simulation results



- The delay contributed by the synchronization component is the most significant (order of magnitude is in seconds!!!)
- when both UCD and DCD are synchronized, the delay between the downlink and the uplink synchronization is minimized.

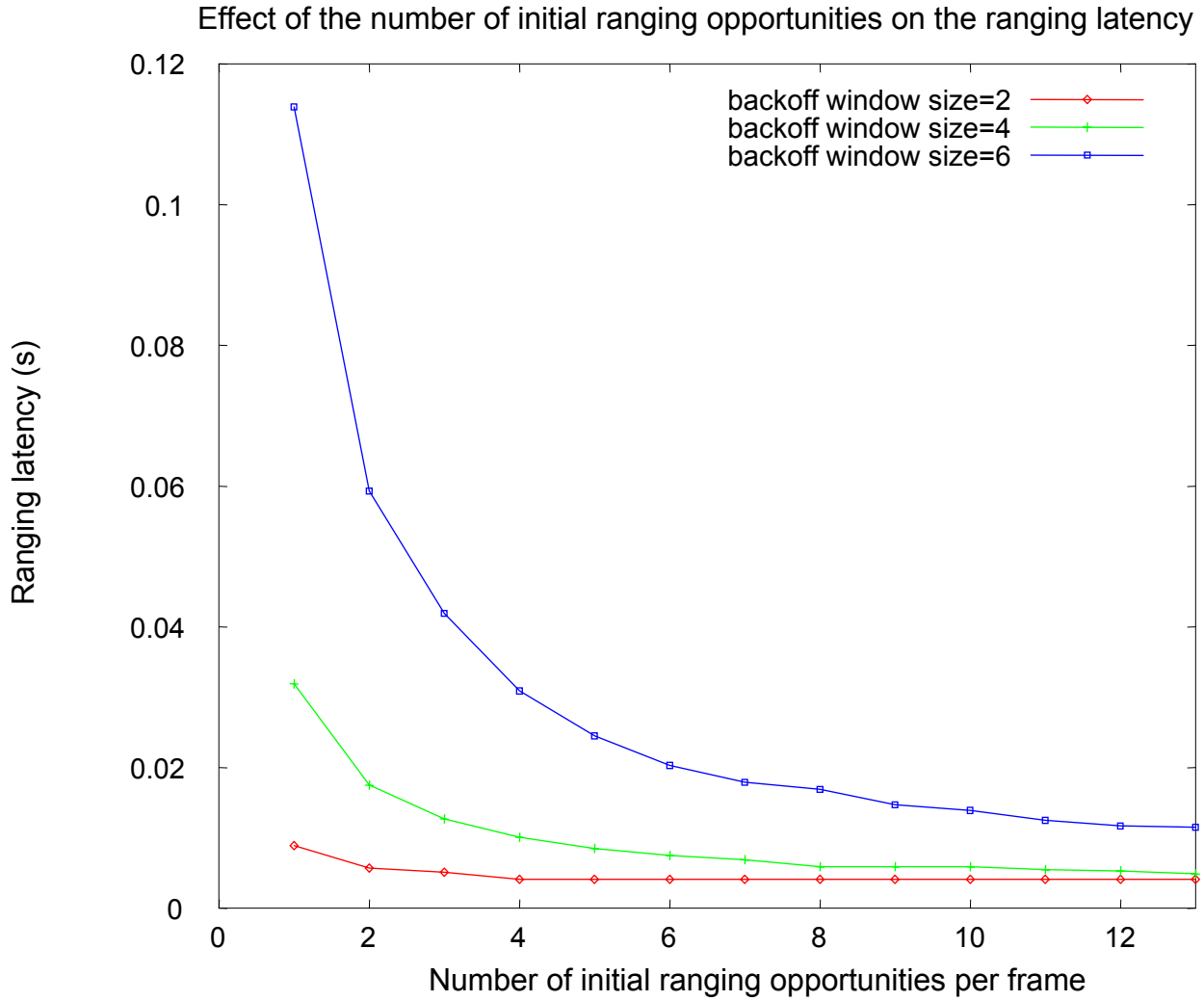
Link UP trigger: initial ranging

message sequence

- To execute *Initial Ranging* with the BS, the MN picks a backoff window (parameter described in the UCD message) and waits for contention opportunities in the frames. It decrements the backoff at each contention opportunity and sends a ranging request when it reaches 0.
- The BS sends a ranging response containing the status information of the transmission parameters received.
- The layer 2 parameters affecting the ranging process are:
  - The number of contention opportunities in a frame
  - The window size of the backoff
- The BS is responsible for assigning contention opportunities and a backoff window size so that a response to a successful transmission will be sent within 200 ms (T3 timeout).

Link UP trigger: initial ranging

simulation results



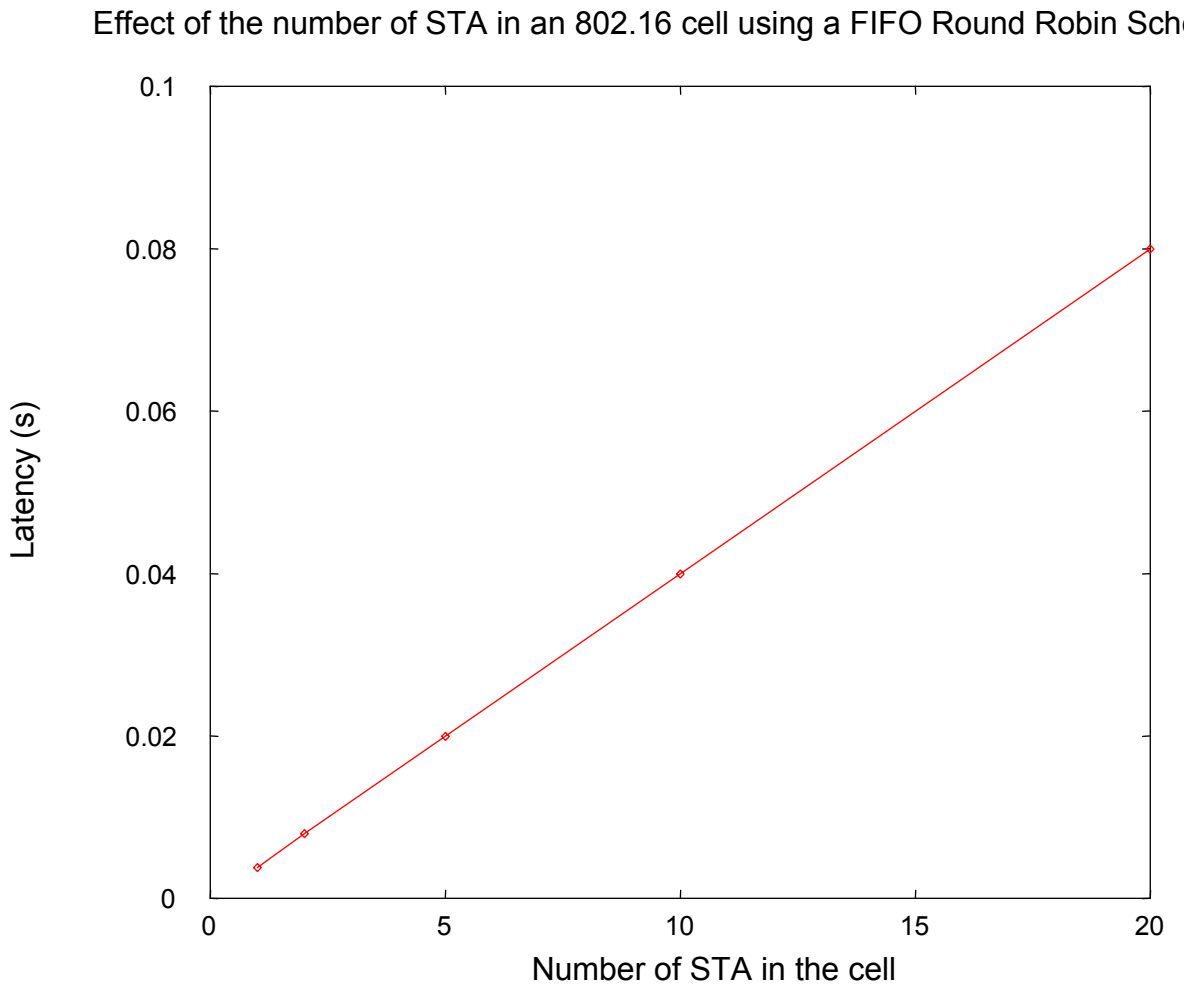
Link UP trigger: registration

message sequence

- The registration allows the MN to connect to the BS and enter the network.
- A scheduler assigning uplink transmission opportunities to MNs in a round robin fashion is used in the simulation.
- When a new MN arrives, it is assigned to the end of the scheduling list (FIFO).
- According to the IEEE 802.16 standard, the registration step is completed within a maximum interval of 3s before having to repeat it or aborting.

Link UP trigger: registration

Simulation results



Link UP trigger: results summary

Link Up step	Layer 2 parameters	Latency range (s)
Downlink and uplink synchronization	-DCD interval -UCD interval	0.2-10
Initial ranging	-Backoff window size -Number of ranging opportunities per frame	0.005-0.110
Registration	-Transmission opportunity allocation	0.005-0.080

To speed up network entry, the time to acquire the downlink and complete the uplink synchronization must be reduced

Link Going Down trigger

- The link Going Down trigger predicts that the MN will be leaving the coverage area within a certain period of time.
- The generation of this trigger is based on a measurement algorithm used (instantaneous value, weighted average, etc) of link layer performance parameters: Carrier-to-Interference-and-Noise Ratio (CINR), Received Signal Strength Indicator (RSSI), or MAC delay.

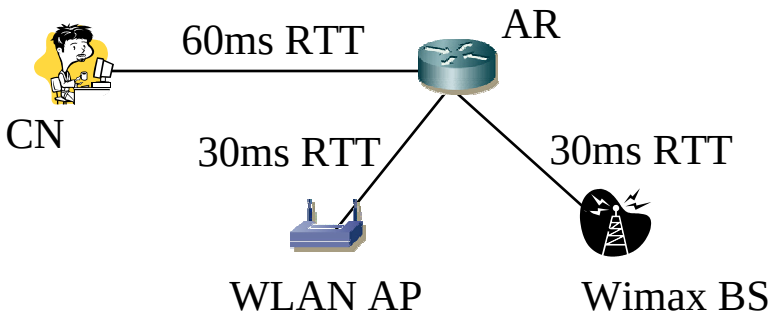
Link Down trigger:
link layer parameters that effect performance

- A MN expects to receive DL_MAP and UL_MAP messages at short intervals. The standard defines a timeout with a maximum value of 600ms. If the timeout expires, the MN considers that the synchronization with the BS is lost.
- Other timeout exists for messages such as DCD and UCD but their magnitude is in seconds (default value is 5*interval).
- At the BS, when a MN is assigned bandwidth, it is required to send messages even if there is no data to send. The base station can then monitor that the MN is responding to messages and can decide when it is considered out of the network.

Performance evaluation of handovers scenarios

Simulation Parameters

- Neighbor Discovery
  - RA interval: U[200s,600s]
  - Max delay between RA: 0.5s
  - Router lifetime: 1800s
- Application traffic
  - UDP CN → MN
    - Video streaming (396.8kbps, 4pkt/100ms, 1240 bytes)
- Delay between CN and MN: 90ms RTT + Mac access delay (depends on the technology used)

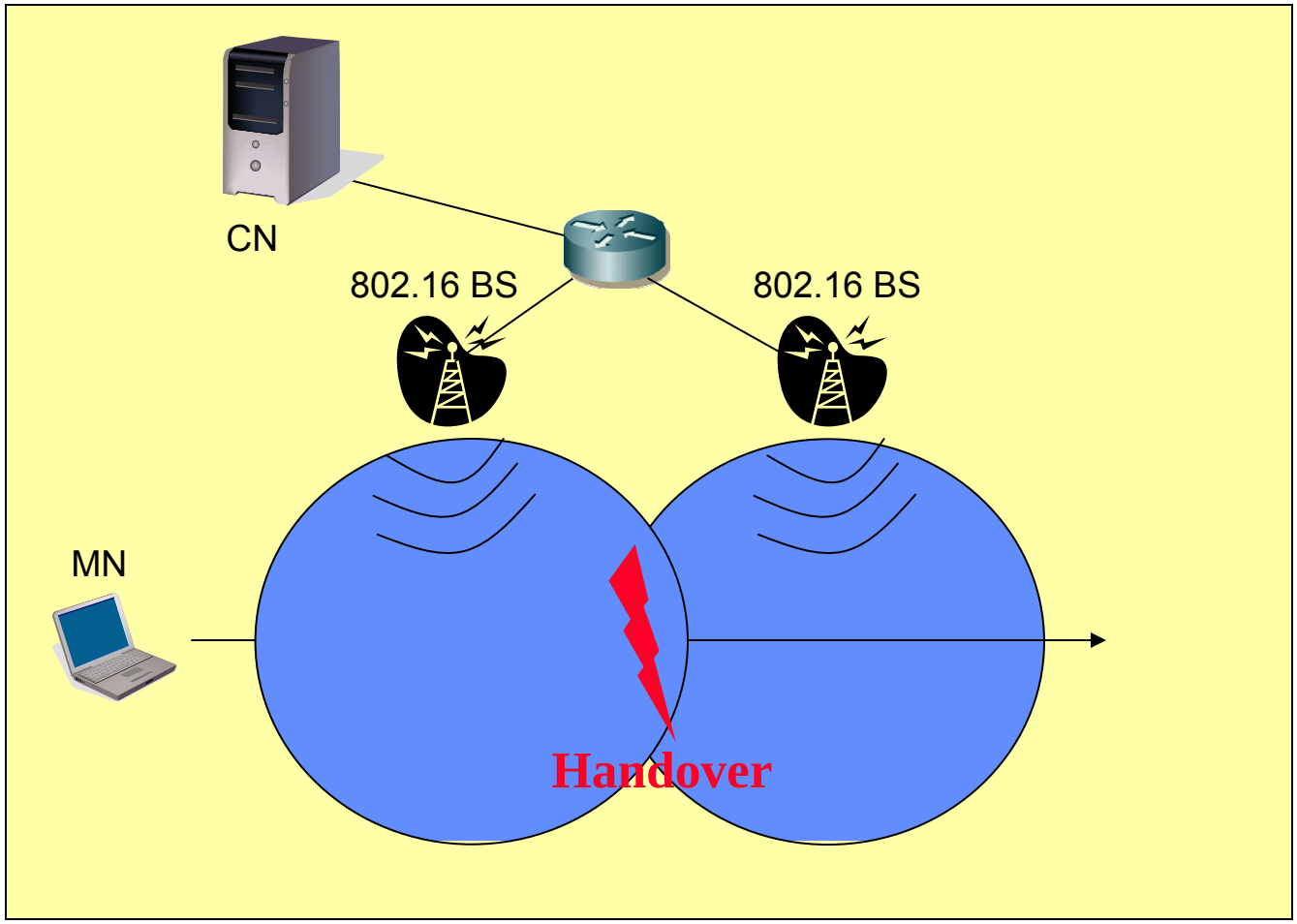


Simulation parameters (cont.)

- IEEE 802.16 parameters
  - Coverage: 1 km radius
  - DCD/UCD interval: 5s
  - Frame duration: 4ms
  - Contention opportunity per frame: 5
  - Backoff window size start for contention: 2
  - Scanning: duration=250 frames, interleaving=40 frames, iteration=5
- IEEE 802.11 parameters
  - Coverage: 20 m radius
  - Beacon interval: 100ms
  - Scanning mode: passive

Handover between two 802.16 networks:

scenario 1

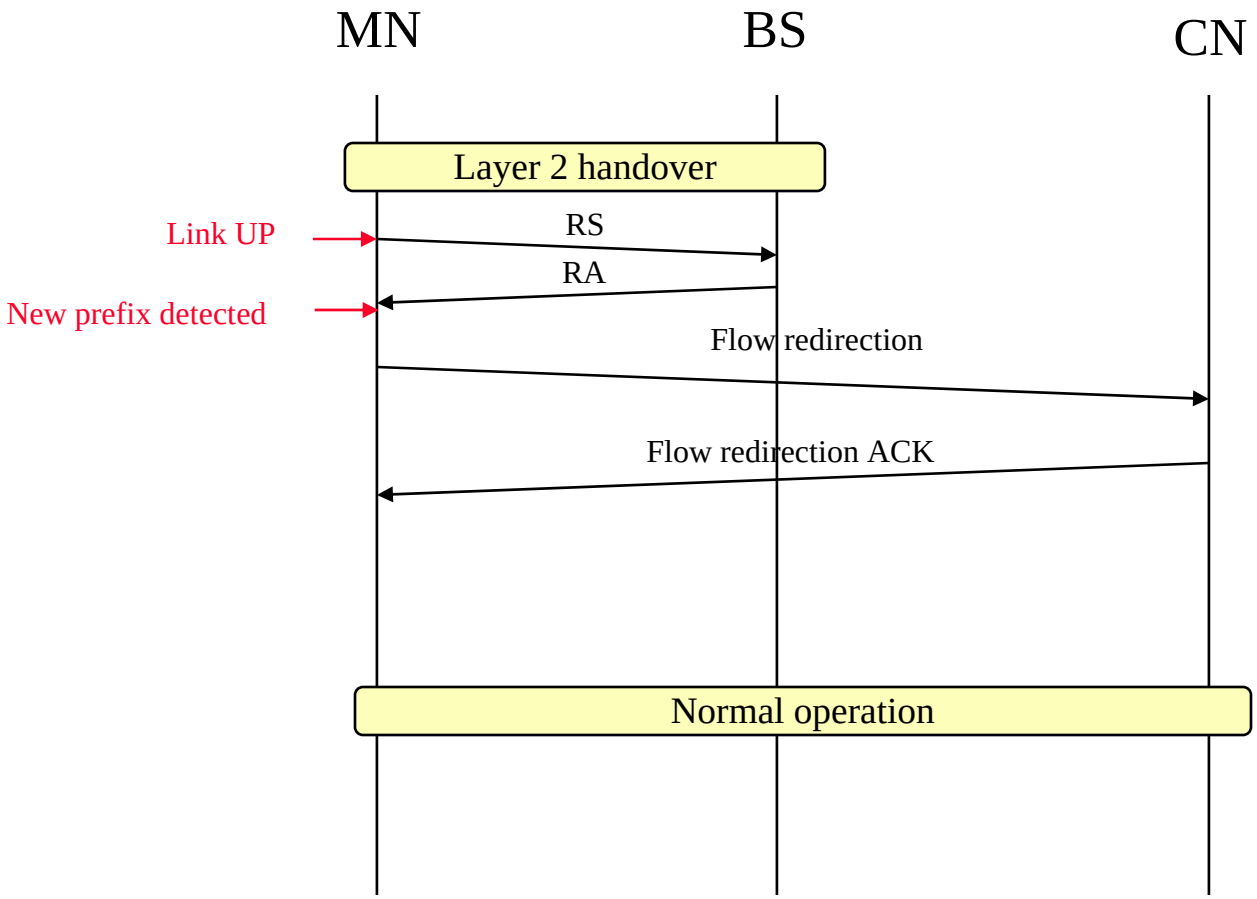


Scenario 1 description

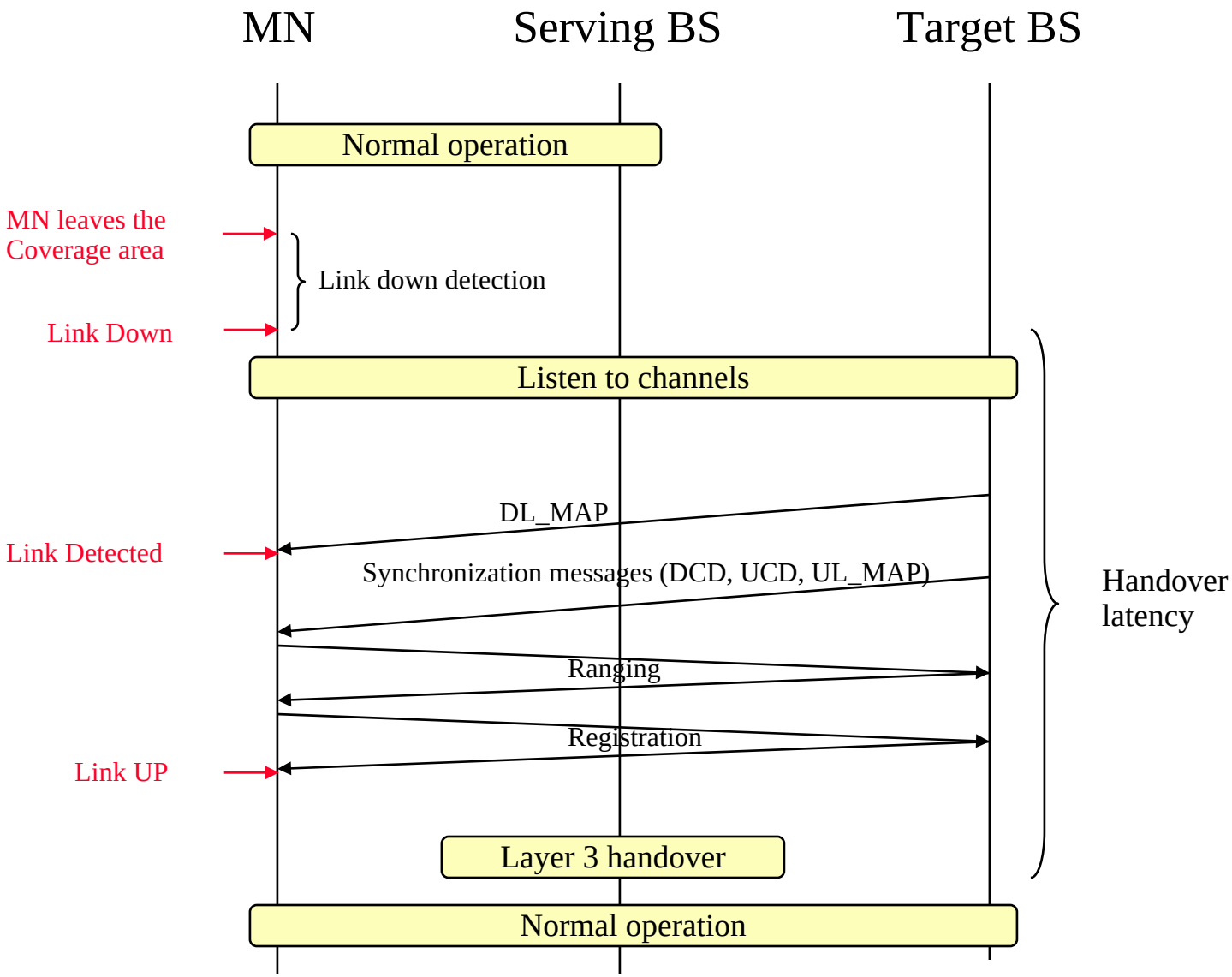
We evaluate two types of handover mechanisms in 802.16:

- Using ***Link Down*** trigger, the MN will first detect the loss of synchronization with the serving BS before starting to look for another station.
- Using ***Link Going Down*** trigger, the MN will request the serving BS to allocate time for scanning. After the scanning is over, the MN will handover to the target BS. We identify two additional cases:
    1. At the time of handover, the MN receiving the DL_MAP and UL_MAP cannot decode the messages because the information received during the scanning expired or has changed. The MN is required to perform full downlink and uplink synchronization (**full network entry**)
    2. During handover, the MN can decode the DL_MAP and UL_MAP received by the target BS using the DCD and UCD information collected during the scanning period. In this case, the MN can execute faster network entry (**partial network entry**)

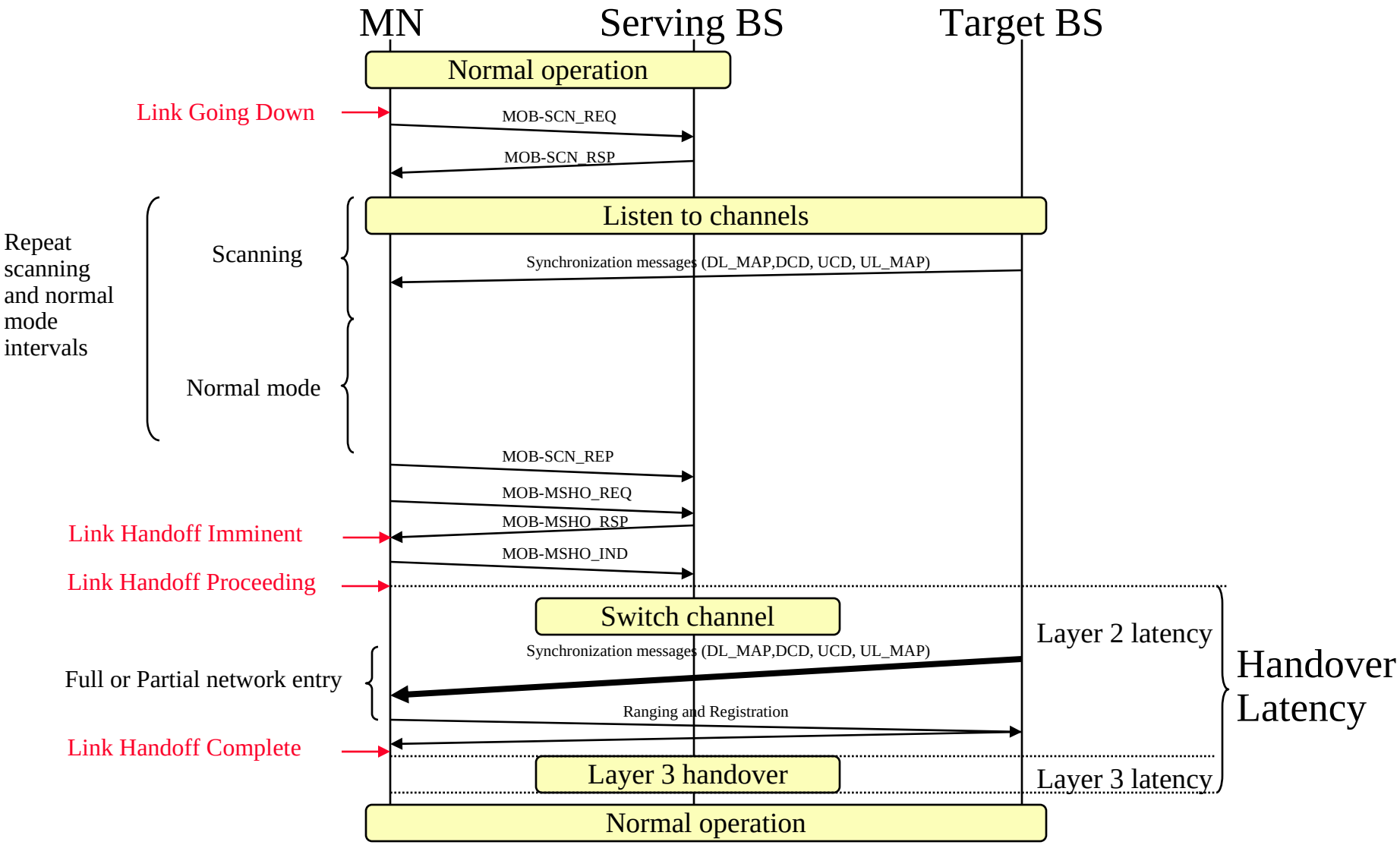
Layer 3 Handover process



Handover 802.16-802.16 using Link Down



Handover 802.16-802.16 using Link Going Down



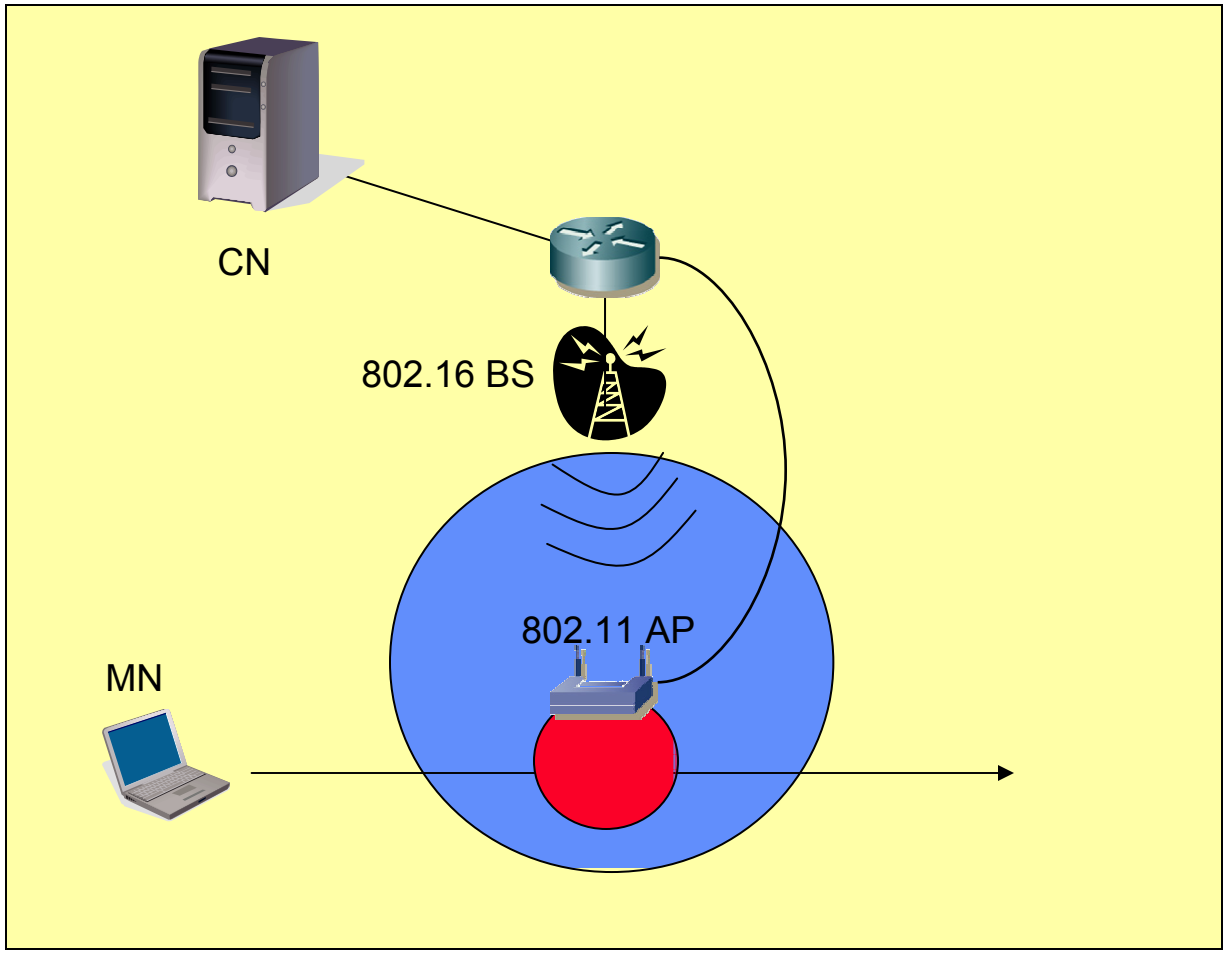
Handover 802.16-802.16: results

	Link Down	Link Going Down + full network entry	Link Going Down + partial network entry
Layer 2 handover latency (s)	2.864	2.639	0.220
Layer 3 handover latency (s)	0.387	0.390	0.386
Total handover latency (s)	3.25	3.029	0.606
Packet loss	129.8	124.6	27.68

- Using Link Going Down shows major improvements if the information contained in the DCD and UCD messages acquired during scanning can be used to decode the DL_MAP and UL_MAP during the handover.
- Additional improvements can be made if the BSs synchronize over the backbone (work in progress).

Handover between 802.11 and 802.16:

scenario 2

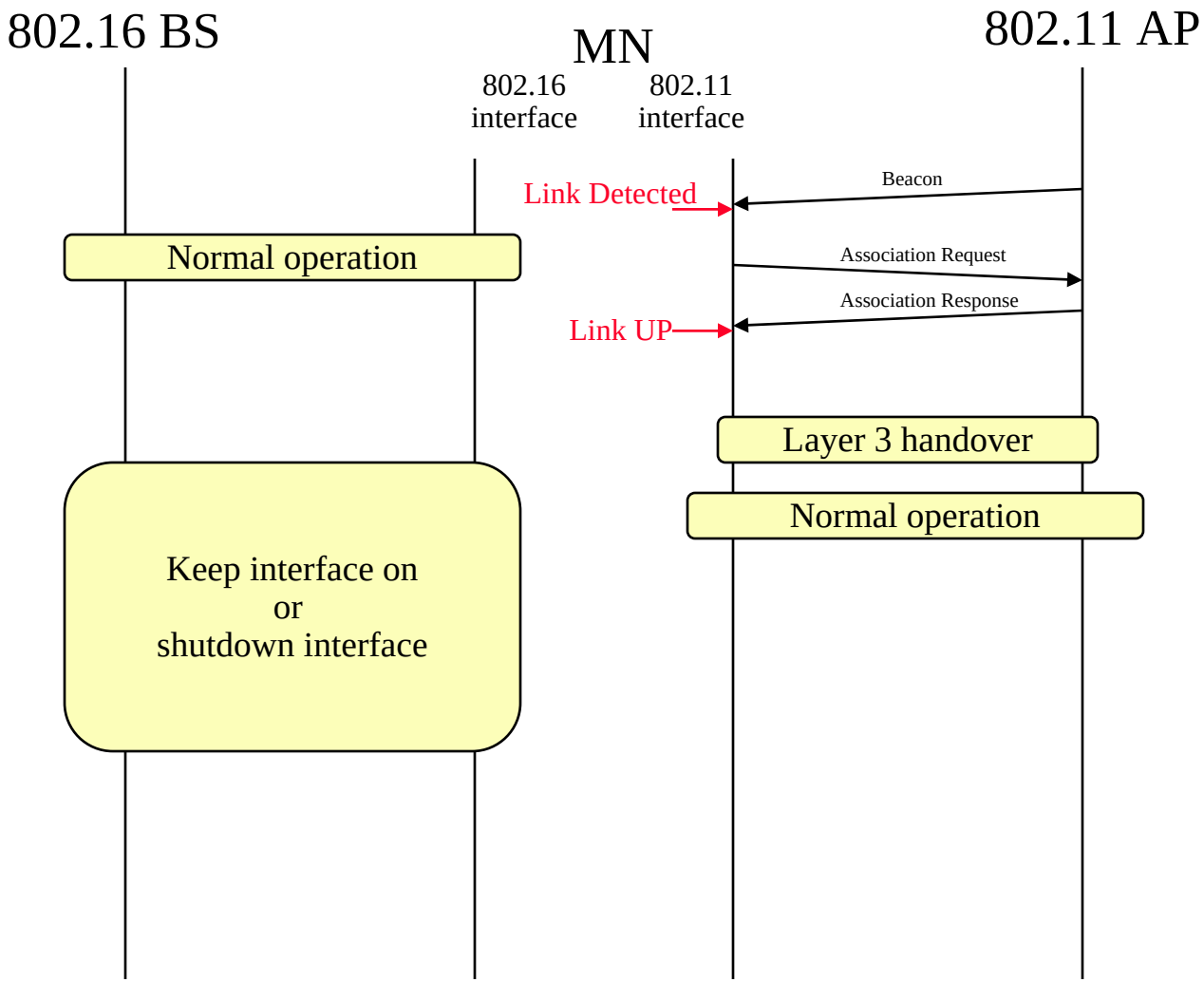


Scenario 2 description

- In this scenario, we study the vertical handover between 2 wireless technologies: 802.11 and 802.16
- A MN that is connected to 802.16 enters a hotspot. For cost and bandwidth performance, the MN executes a vertical handover to the 802.11 network. When leaving the cell, the MN reconnects to the 802.16 network.
- The MN uses the link Going Down trigger on the 802.11 interface.

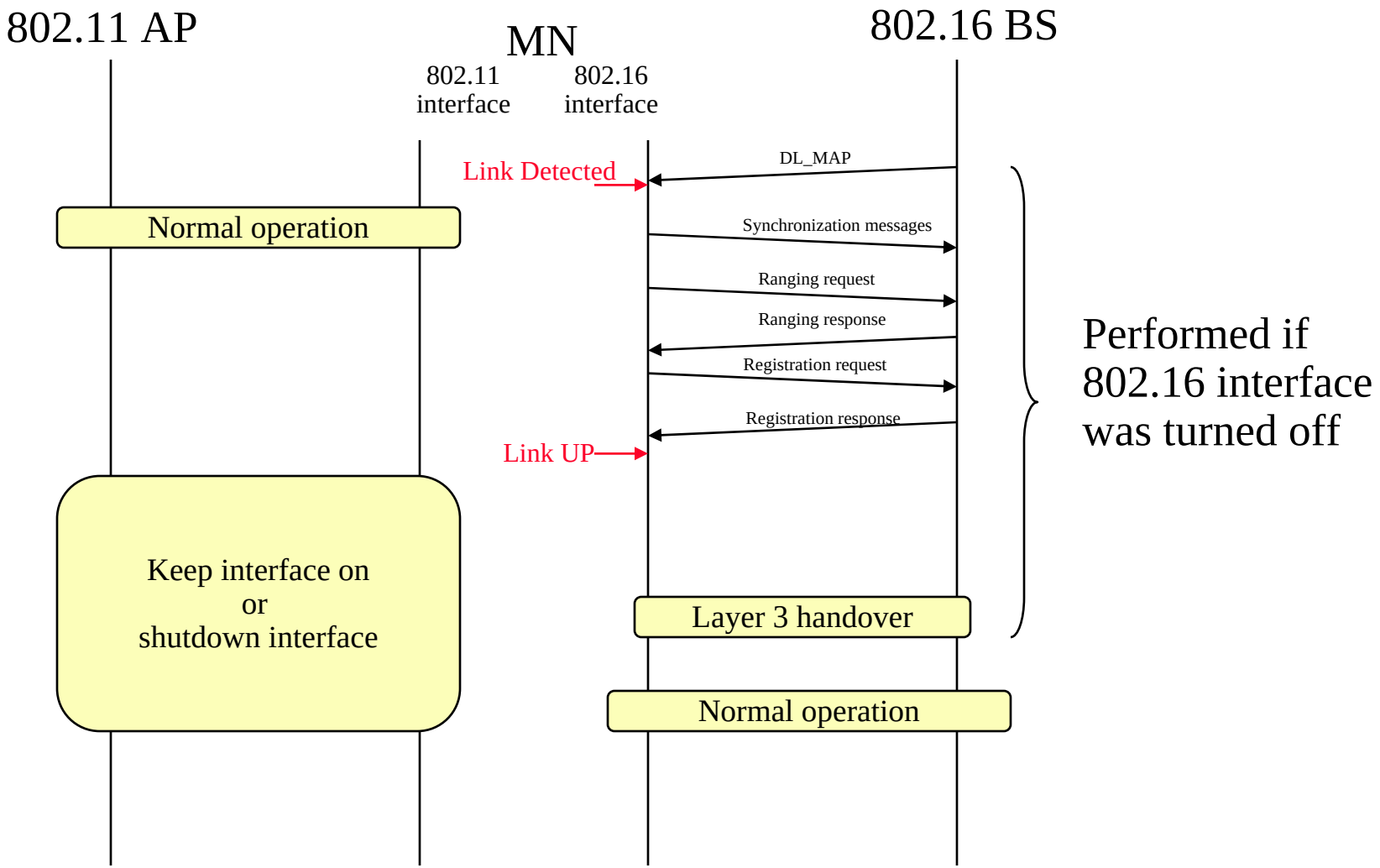
Handover 802.11-802.16:

entering WLAN



Handover 802.11-802.16:

leaving WLAN



Handover 802.11-802.16:

simulation results

	Interface 802.16 is always turned on, redirect on Link Down	Interface 802.16 always turned on, redirect on Link Going Down	Interface 802.16 activated upon Link Down of interface 802.11	Interface 802.16 activated upon Link Going Down of interface 802.11
Handover 802.16-802.11 latency (s)	0.368	0.364	0.368	0.364
Handover 802.11-802.16 latency (s)	0.397	0.097	3.08	2.917
Packet loss for 802.11-802.16 handover	13.98	0	137.3	0-137

Handover 802.16-802.11:

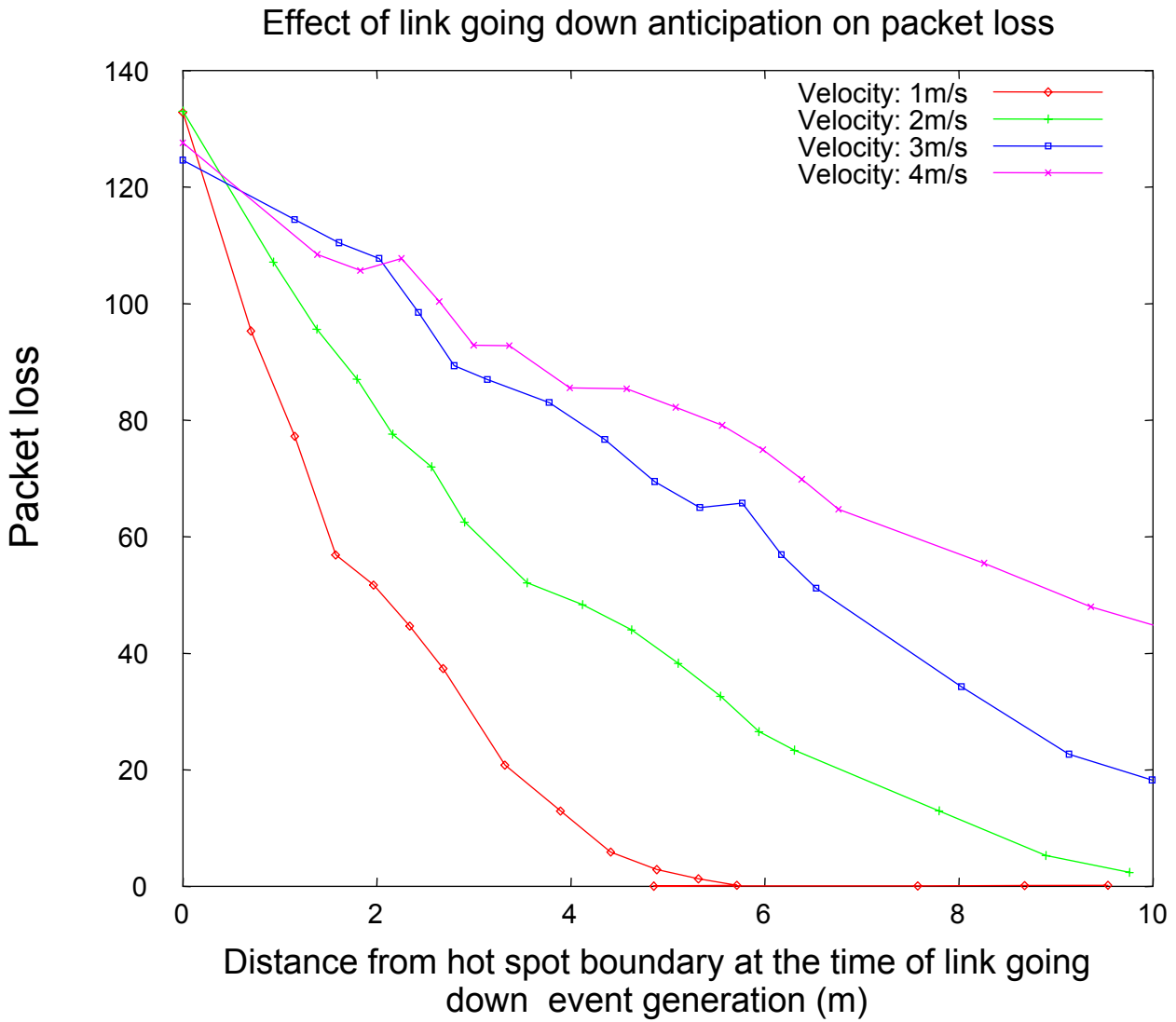
- starts at detection of 802.11 (Link Detected)
- RS/RA on 802.11 (average around 250ms, due to a random back to reply to RS U[0,500ms]
- message redirection to CN (90ms+medium access)

Handover 802.11-802.16:

- Starts on link Down (+300ms for loosing 3 beacons) or link Going Down
- If 802.16 is OFF, synchronization with BS (2.5s with DCD/UCD interval of 5s)
- message redirection to CN (90ms_medium access)

Handover 802.11-802.16:

a closer look at link going down



Handover 802.11-802.16:

results summary

- We note that even when the MN is using the Link Going Down trigger on the 802.11 interface, the network entry latency for 802.16 is still significant.
- Adjusting the link Going Down threshold to allow enough time to perform full network entry in 802.16 would require the MN to trigger an event while the connectivity to the 802.11 AP is still good.
- Some potential solutions to optimize the handover between 802.11 and 802.16 include:
  - Keep the 802.16 interface on
  - Use sleep mode
  - Speed up the network entry by providing heterogeneous information through the 802.11 interface (Information Service)

Summary

- 802.16 synchronization phase plays a key role in the handover latency:
  - Any prior knowledge for synchronization (channel descriptor messages) is critical in speeding up the handover.
  - Reducing the synchronization time by increasing the frequency of the channel descriptor messages comes generally at the cost of a higher bandwidth overhead (less bandwidth available for user traffic).
  - Keeping the 802.16 interface turned on is beneficial at the cost of additional power consumption and reduced battery life.
  - The use of 802.16e mechanisms including neighbor advertisement, BS synchronization, and sleep mode may prove to be helpful.