# PMIPv6

## PROXY MOBILE IPV6

OVERVIEW OF PMIPV6, A PROXY-BASED MOBILITY PROTOCOL FOR IPV6 HOSTS

Peter R. Egli
peteregli.net

## Contents

# 1. Why PMIPv6 when we have MIP?

**MIP (*Mobile IP*, originally RFC2002) is an early approach to get mobility in the Internet.**

**Problems with MIP:**

**1. Clients must implement MIP in the kernel (MIP mobility is *host-based*).**
**→ difficult to implement kernel changes**
**→ difficult to deploy (clients need software upgrade to get MIP support)**
**2. *Handoff* procedure is not efficient → large delay.**
**3. Security concerns (MIP support in the kernel provides an additional attack vector).**

**PMIPv6 solution:**

- **PMIPv6 (RFC5213) is completely *transparent* to mobile nodes (use of a „proxy" to do the handoff work).**
- **PMIPv6 is meant to be used in *localized networks* with limited topology where handoff signalling delays are minimal.**

## 2. PMIPv6 terminology (1/3)

**Local Mobility Domain (LMD):**
**Network that is PMIP-enabled. The LMD contains 1 LMA and multiple MAGs.**

**Local Mobility Anchor (LMA):**
**All traffic from and to the mobile node is routed through the LMA.**
**The LMA maintains a set of routes for each MN connected to the LMD.**

**Mobile Access Gateway (MAG):**
**The MAG performs the mobility related signalling on behalf of the MNs attached to its access links.**
**The MAG is usually the access router (first hop router) for the MN.**

**Mobile Node (MN):**
**Any device that connects through a wireless network (WLAN, WiMAX, MBWA, G3/G4) to the LMD.**

**Corresponding Node (CN):**
**Any node in the Internet or also in the LMD that communicates with an MN.**

**NetLMM:**
**Network based Localized Mobility Management (IETF working group for network-based mobility support).**

## 2. PMIPv6 terminology (2/3)

**Binding Cache:**
**Cache maintained by the LMA that contains BCEs.**

**Binding Cache Entry (BCE):**
**Entry in the LMA's binding cache. An entry has the fields MN-ID, MAG proxy-CoA and MN-prefix.**

**Binding Update List:**
**Cache maintained by the MAG that contains information about the attached MNs.**

**Proxy Binding Update (PBU):**
**PMIP signalling packet sent by the MAG to the LMA to indicate a new MN. The PBU has the fields MN-ID (e.g. MN MAC), MAG address (proxy-CoA) and handoff indicator to signal if the MN-attachment is a new one or a handoff from another MAG.**

**Proxy Binding Acknowledge (PBA):**
**Response to a PBU sent by the LMA to the MAG. The PBA contains the MN-ID, the MAG address and the prefix assigned to the MN.**

## 2. PMIPv6 terminology (3/3)

**Proxy care of address (proxy-CoA):**

**IP address of public interface of MAG. The proxy-CoA is the tunnel endpoint address on the MAG. The LMA encapsulates packets destined to the MN into a tunnel packet with destination address = proxy-CoA.**

**Mobile Node Identifier (MN-ID):**

**Unique identifier of mobile node, e.g. one of its MAC addresses.**

**Home Network Prefix:**

**Prefix assigned to the MN by the LMA.**

# 3. Where can PMIPv6 be deployed?

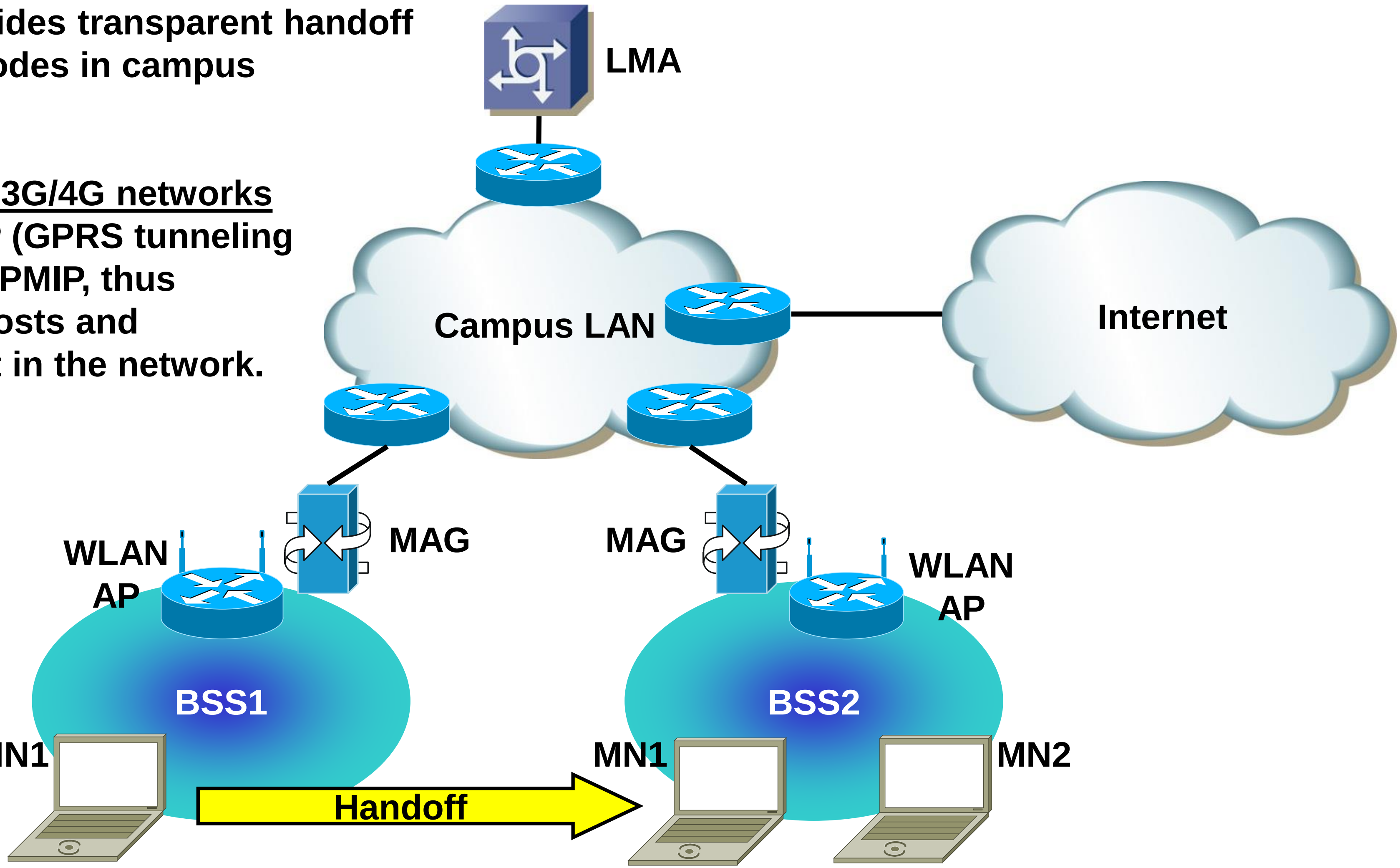
**PMIPv6 is primarily targeted at the following networks:**

**1. WLAN-based campus-style networks:**

**PMIPv6 provides transparent handoff for mobile nodes in campus networks.**

**2. Advanced 3G/4G networks**

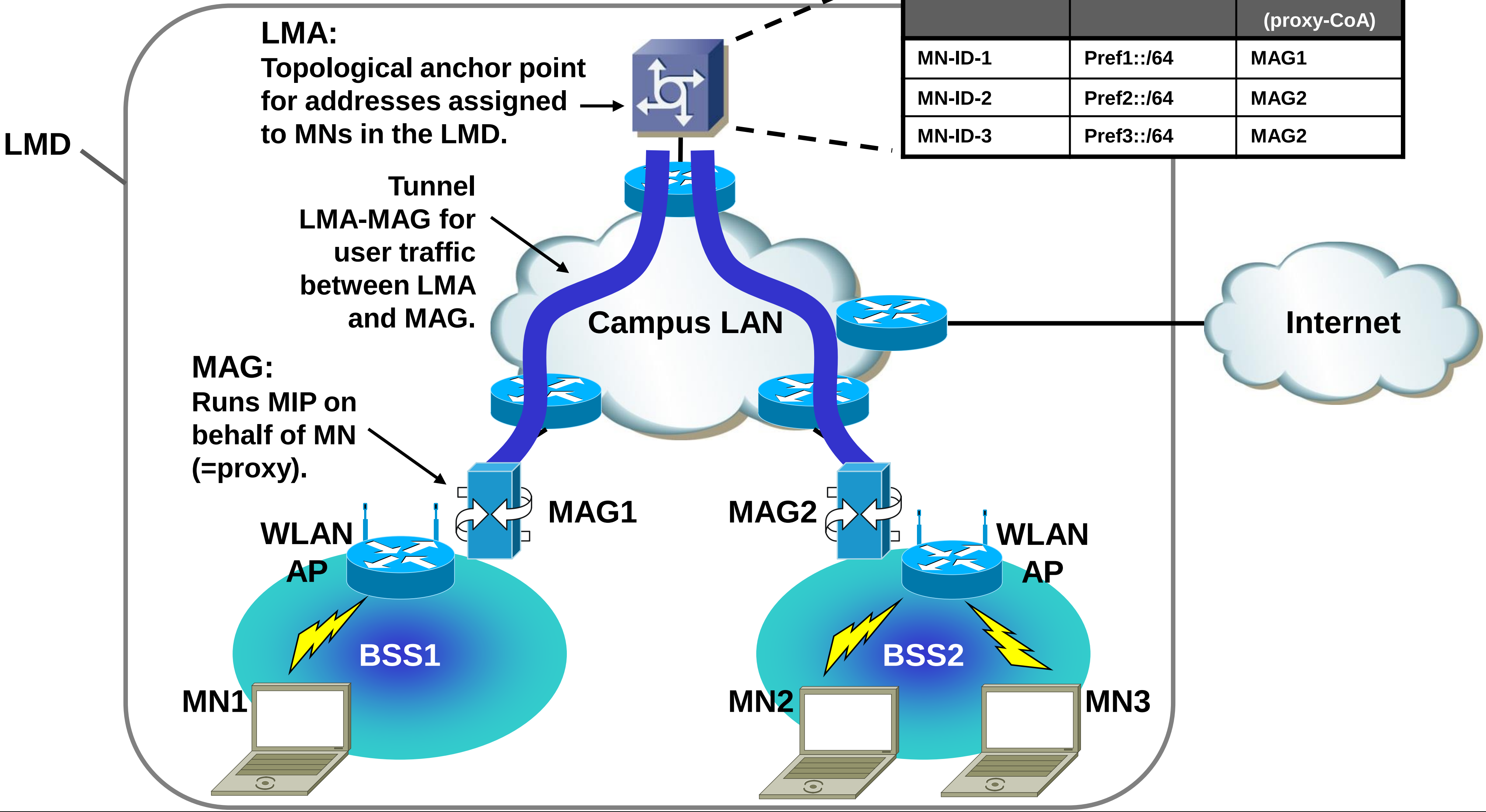
**Replace GTP (GPRS tunneling protocol) by PMIP, thus reduce the costs and management in the network.**



## 4. General PMIPv6 setup

Proxy Binding Cache

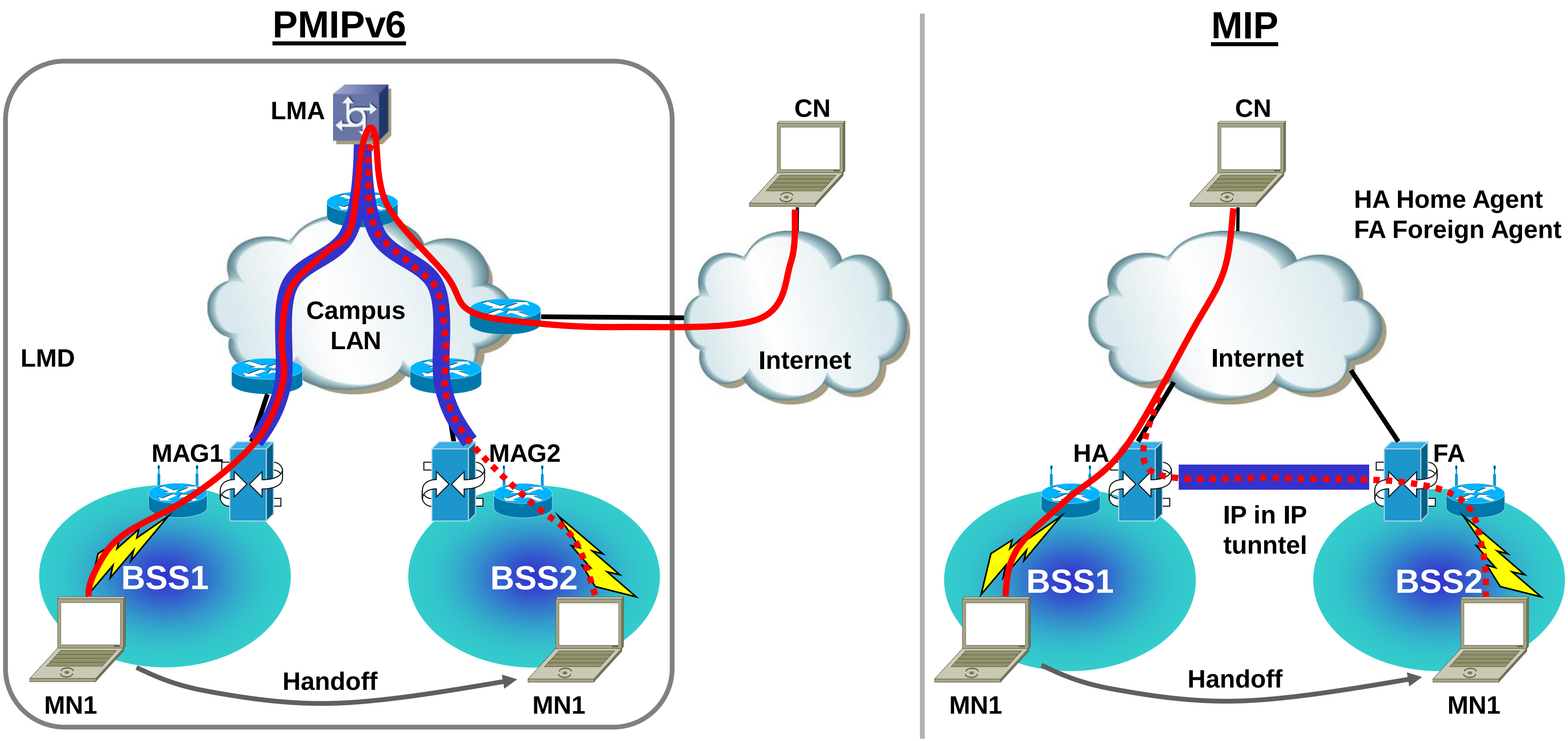
| ID | Prefix | MAG (proxy-CoA) |
|---|---|---|
| MN-ID-1 | Pref1::/64 | MAG1 |
| MN-ID-2 | Pref2::/64 | MAG2 |
| MN-ID-3 | Pref3::/64 | MAG2 |



## 5. PMIPv6 versus MIP (Mobile IP)

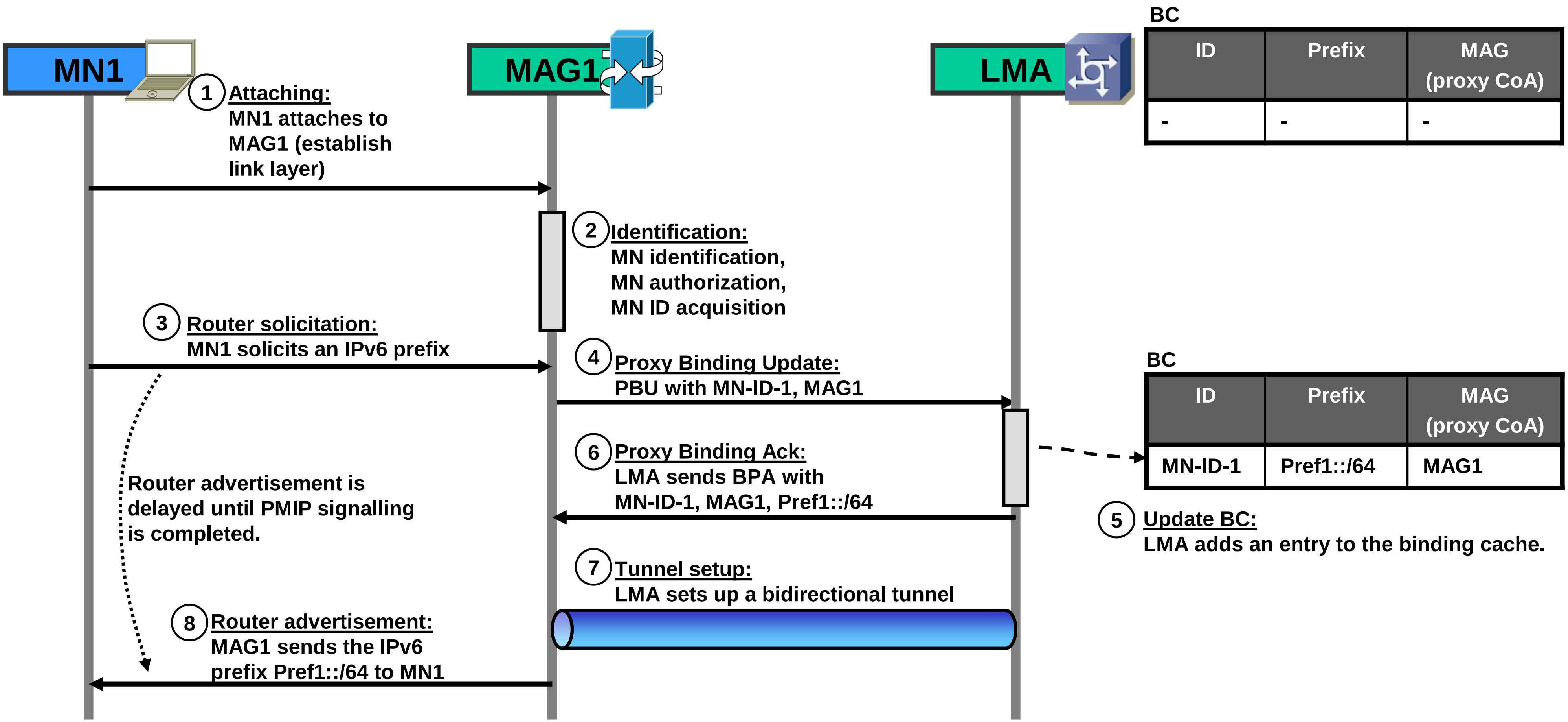
**In PMIPv6 the MAG assumes the role of the MIP client in MIP.**
**The LMA in PMIPv6 is similar to the home agent (HA) in MIP.**

Packet path before handoff. (solid red line)
Packet path after handoff. (dotted red line)
Tunnel (blue bar)



# 6. MN domain join sequence (1/2)

**The following sequence diagram shows the procedure when a MN joins a PMIPv6 domain:**




BC

| ID | Prefix | MAG (proxy CoA) |
|---|---|---|
| - | - | - |

BC

| ID | Prefix | MAG (proxy CoA) |
|---|---|---|
| MN-ID-1 | Pref1::/64 | MAG1 |

# 6. MN domain join sequence (2/2)

**1. Attaching:**
**MN1 attaches to the MAG through a point-to-point link and establishes the link layer. Any access technology is possible provided that it emulates a point-to-point behavior (e.g. PPP, PPPoE).**

**2. Identification:**
**MAG1 authenticates MN1 based on its link layer address (e.g. MAC address) and ascertains what MN1 is permitted to do (authorization). The authorization step may use existing services like LDAP or RADIUS.**

**3. Router solicitation:**
**MN1 sends a router solicitation to obtain an IPv6 prefix. MAG1 will not send a router advertisement until it obtained a prefix for MN1 from the LMA (step 6, PBA).**

**4. Proxy binding update (PBU):**
**MAG1 sends a proxy binding update to the LMA. This PBU associates the MAG1 address with the identity of the MN.**

**5. Allocate prefix, update BC:**
**The LMA allocates a prefix for MN1 (Home Network Prefix). The LMA creates an entry in its BC. The entry contains the MN1 ID (MN-ID-1), the address MAG1 of the proxy MAG (proxy-CoA) as well as the prefix assigned to MN1.**

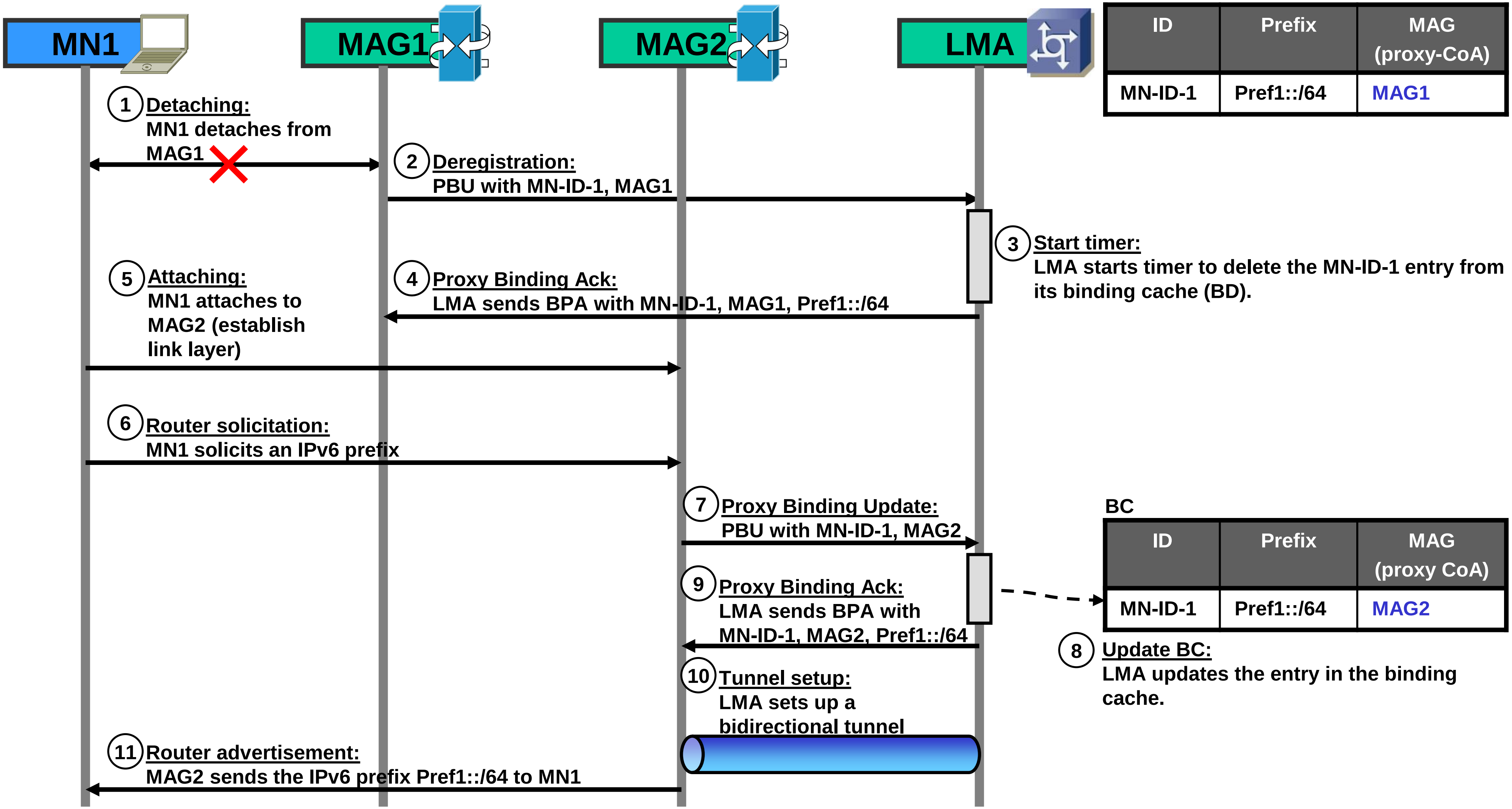
**6. Proxy binding ack (PBA):**
**The LMA sends a PBA back to MAG1. The PBA contains the information of the BPC entry created in step 5.**

**7. Tunnel setup:**
**The LMA and MAG1 establish a bidirectional IPv6-in-IPv6 tunnel that is used for tunneling packets to and from MN1. The LMA sets a route through the tunnel for traffic that is addressed to the MN.**

**8. Router advertisement:**
**MAG1 sends a router advertisement with the assigned prefix to MN1. MN1 will assign the prefix through stateless autoconfiguration. Stateful autoconfiguration would be possible as well (outside of scope of PMIPv6). MN1 creates a routing table entry for the prefix.**

# 7. MN handoff sequence (1/4)

## Handoff from MAG1 (PMAG – Previous MAG) to MAG2 (NMAG – New MAG):




BC

| ID | Prefix | MAG (proxy-CoA) |
|---|---|---|
| MN-ID-1 | Pref1::/64 | MAG1 |

BC

| ID | Prefix | MAG (proxy CoA) |
|---|---|---|
| MN-ID-1 | Pref1::/64 | MAG2 |

# 7. MN handoff sequence (2/4)

**1. Detaching:**
**MN1 detaches from MAG1 (PMAG – Previous MAG). MAG1 detects this event through some mechanism outside of the scope of PMIPv6, e.g. through link layer events (link down) or through an *IPv6 Neighbor Unreachability Detection* event.**

**2. Deregistration:**
**MAG1 sends a PBU with a deregistration request for MN1 (MN-ID-1).**

**3. Start timer:**
**LMA starts a timer for the MN1 proxy binding cache entry. During the timer period the LMA drops any packets received for MN1. If the LMA does not receive a PBU from the new MAG within the timer period, it can drop the entry for MN1 from its binding cache. Thus the timer allows the LMA deleting binding cache entries in case the MN1 leaves the LMD for good.**

**4. Proxy binding ack (PBA):**
**The LMA sends a PBA back to MAG1. The PBA contains the information of the BPC entry created in the join phase.**

**5. Attaching to MAG2 (NMAG – New MAG):**
**MN1 now attaches to MAG2 the same way as it did to MAG1 in the LMD join phase. MN1 and MAG2 will establish the link layer (PPP, PPPoE).**

**6. Router solicitation:**
**MN1 sends a router solicitation to obtain an IPv6 prefix. MAG2 will not send a router advertisement until it obtained a prefix for MN1 from the LMA.**

**7. Proxy binding update (PBU):**
**MAG2 sends a proxy binding update to the LMA. This PBU associates the MAG2 address with the identity of the MN.**

**8. Update of the binding cache entry (BCE):**
**The LMA detects that MN1 already has an entry in the binding cache and therefore updates the entry for MN1. MN1 is now associated with MAG2. The prefix for MN1 remains the same (address transparency for MN1).**

# 7. MN handoff sequence (3/4)

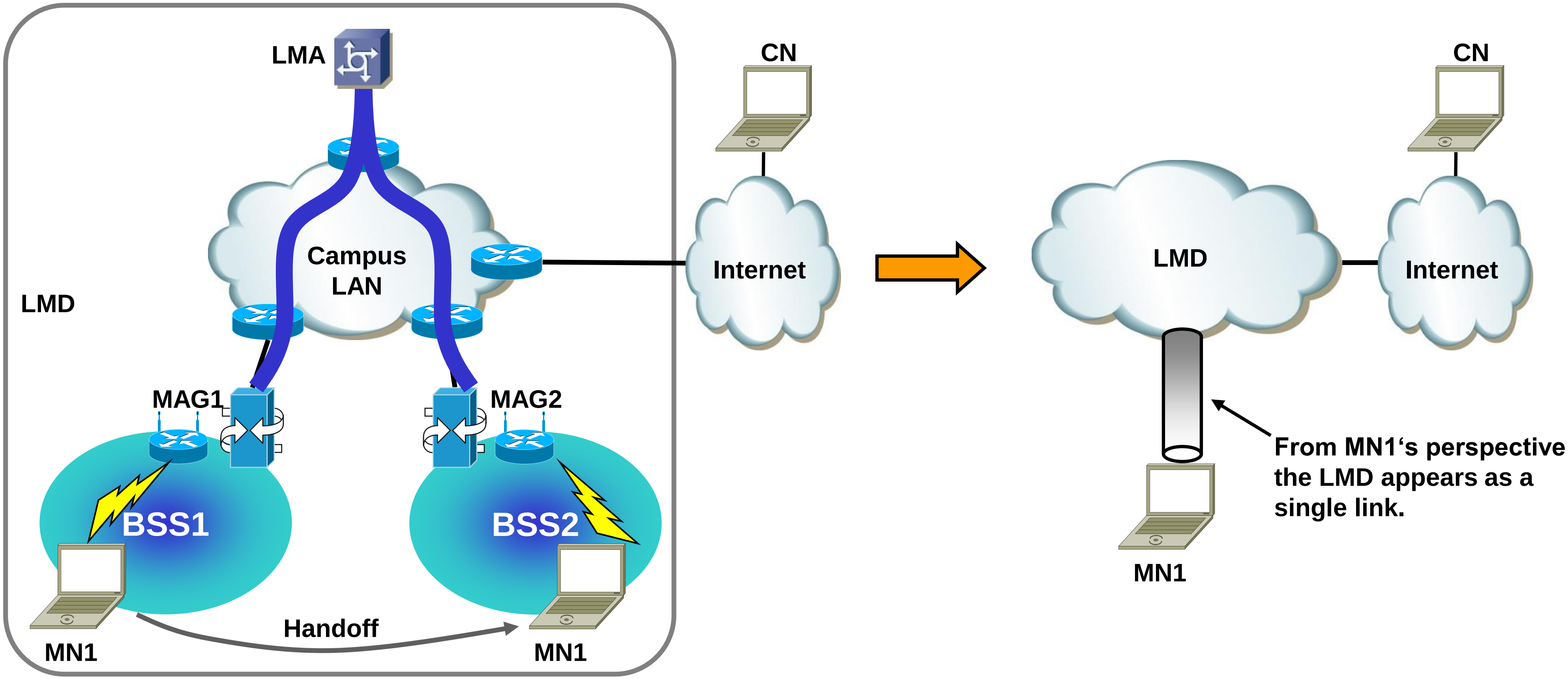
**9. Proxy binding ack (PBA):**
**The LMA sends a PBA back to MAG2. The PBA contains the information of the BPC entry updated in step 8.**

**10. Tunnel setup:**
**The LMA and MAG2 establish a bidirectional IPv6-in-IPv6 tunnel that is used for tunneling packets to and from MN1. The LMA sets a route through the tunnel for traffic that is addressed to the MN.**

**11. Router advertisement:**
**MAG2 sends a router advertisement with the same prefix assigned to MN1. MN1 will not 'see' an address change and therefore all open transport connections (TCP, UDP) remain open.**

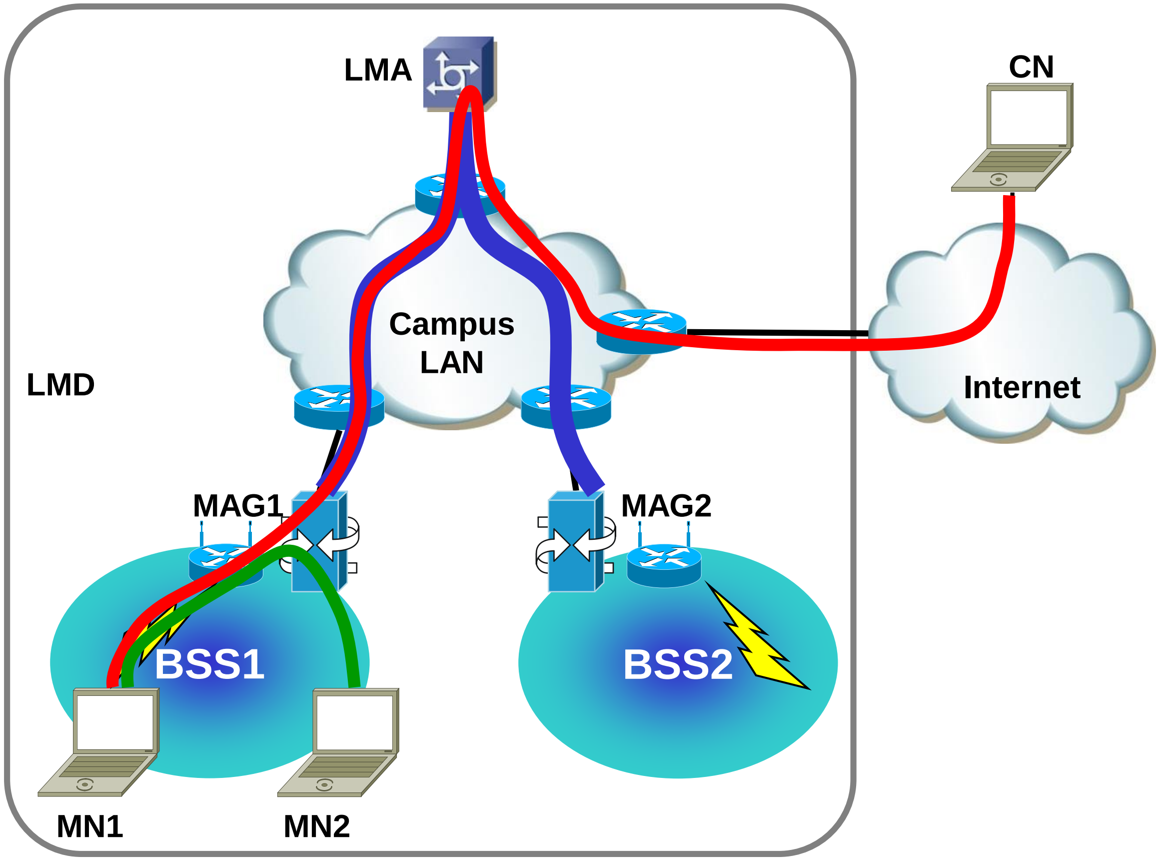
# 7. MN handoff sequence (4/4)

**From the perspective of the MN the LMD appears as a single link. The handoff is fully transparent to the MN.**



# 8. Routing / packet forwarding from and to MN through LMD

**The LMA is the anchor point for packets to and from the MN.**




**A. Routing MN←→MAG←→LMA←→CN:**

**All traffic is routed through the LMA (=anchor point for routing).**

**B. MN←→MAG←→MN:**

**If 2 MNs are attached to the same MAG, the traffic may be routed directly through the MAG without the detour through the LMA (short-circuit routing).**

## 9. Use of link-local and link addresses by MAGs

**Problem:**

**Emulation of a virtual link requires that router advertisements sent by MAGs to a particular MN have**
**a. the same prefix assigned to the MN,**
**a. the same source IPv6 link-local address (IPv6 source address of ICMPv6 packet) and**
**b. the same source link layer address (source link layer option within ICMPv6 packet).**

**PMIPv6 proposes the following solutions:**

**A. Fixed address configuration:**

**Configuration of a fixed link-local and fixed link layer address to be used by all MAGs in the LMD. However, the use of a fixed link-local address to be used in all access links in an PMIPv6 domain may lead to collisions. As PMIPv6 requires that the link-local address used by the different MAGs for a particular MN be the same, these collisions can only happen when an MN enters a PMIPv6 domain. PMIPv6 requires that the MN perform DAD (Duplicate Address Detection) so that the MAG can defend its link-local address.**

**B. Dynamic address generation, signalling through LMA:**

**The LMA generates a link-local address to be used by all MAGs with a particular MN and signals this address to all serving MAGs. This signalling must be completed before the MN performs DAD.**

## 10. Proxy Based Fast Handover for MIPv6 (PFMIPv6) with RFC5949 (1/8)

**The handover sequence defined by RFC5213 is not optimized for fast handovers.
During handover from one radio access network to another network, packets cannot be delivered to and from the mobile node. The handover delay essentially leads to packet loss thus degrading the quality of service in mobility scenarios.**

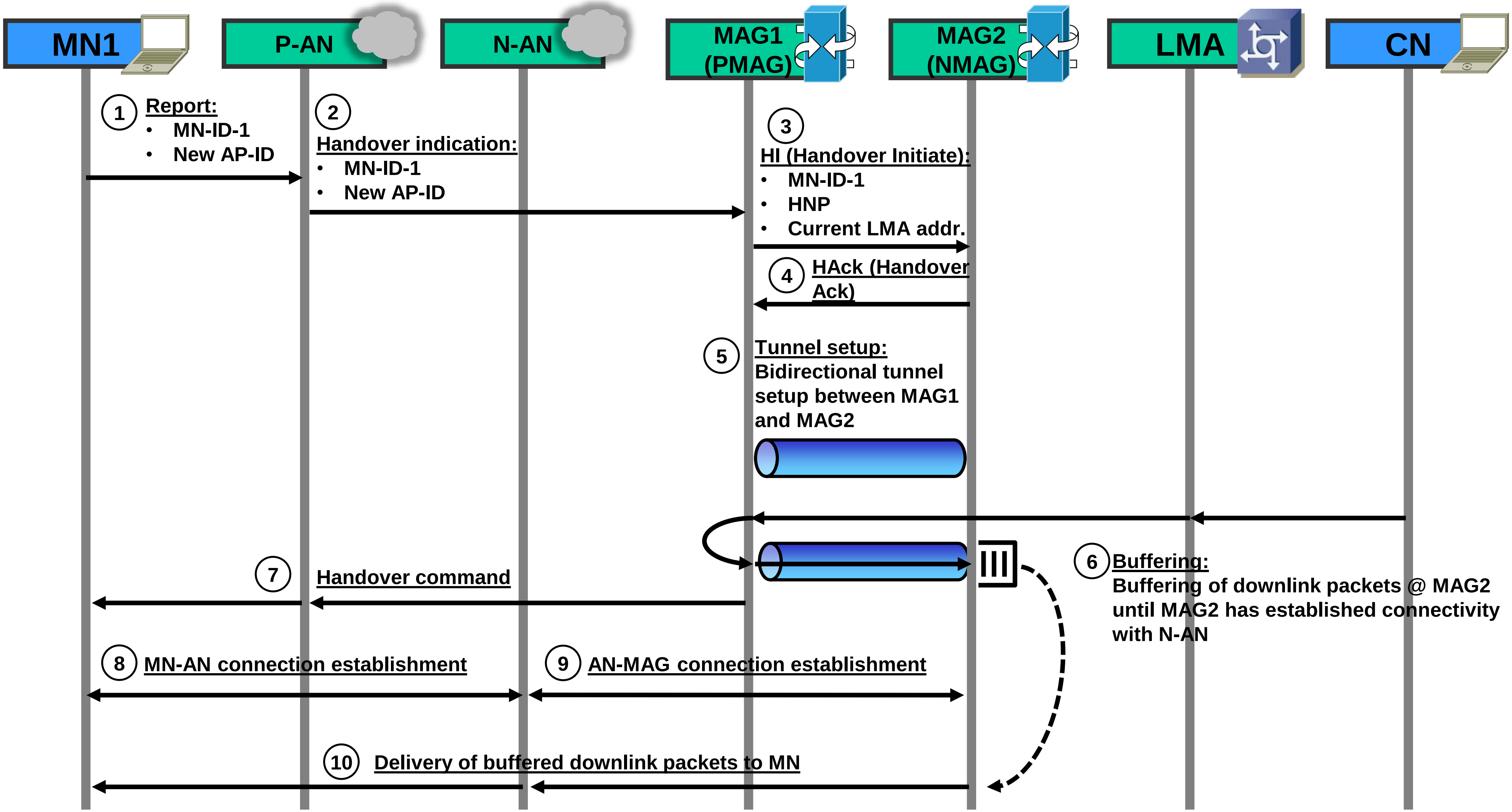
**RFC5949 defines a fast handover procedure to be used in conjunction with PMIPv6. It defines 2 modes, *predective fast handover* (MAG1 initiates handover before MN establishes connectivity with the new access network) and *reactive fast handover* (MAG2 initiates handover after MN has established connectivity with the new access network).**

**Other mobility protocols have their specific fast handover protocol as shown in the following table:**

| Mobility Protocol | Corresponding Fast Handover Protocol |
|---|---|
| RFC6275<br>Mobile IPv6 | RFC5568<br>Mobile IPv6 Fast Handovers (FMIPv6) |
| RFC5944 (obsoletes RFC3344)<br>Mobile IPv4 | RFC4988<br>Mobile IPv4 Fast Handovers (FMIPv4) |
| RFC5213<br>Proxy Mobile IPv6 | RFC5949<br>Proxy Based Fast Handover for MIPv6 (PFMIPv6), extends RFC5568 |
| RFC5844<br>IPv4 Support for PMIPv6 | RFC5949<br>Proxy Based Fast Handover for MIPv6 (PFMIPv6), extends RFC5568 |

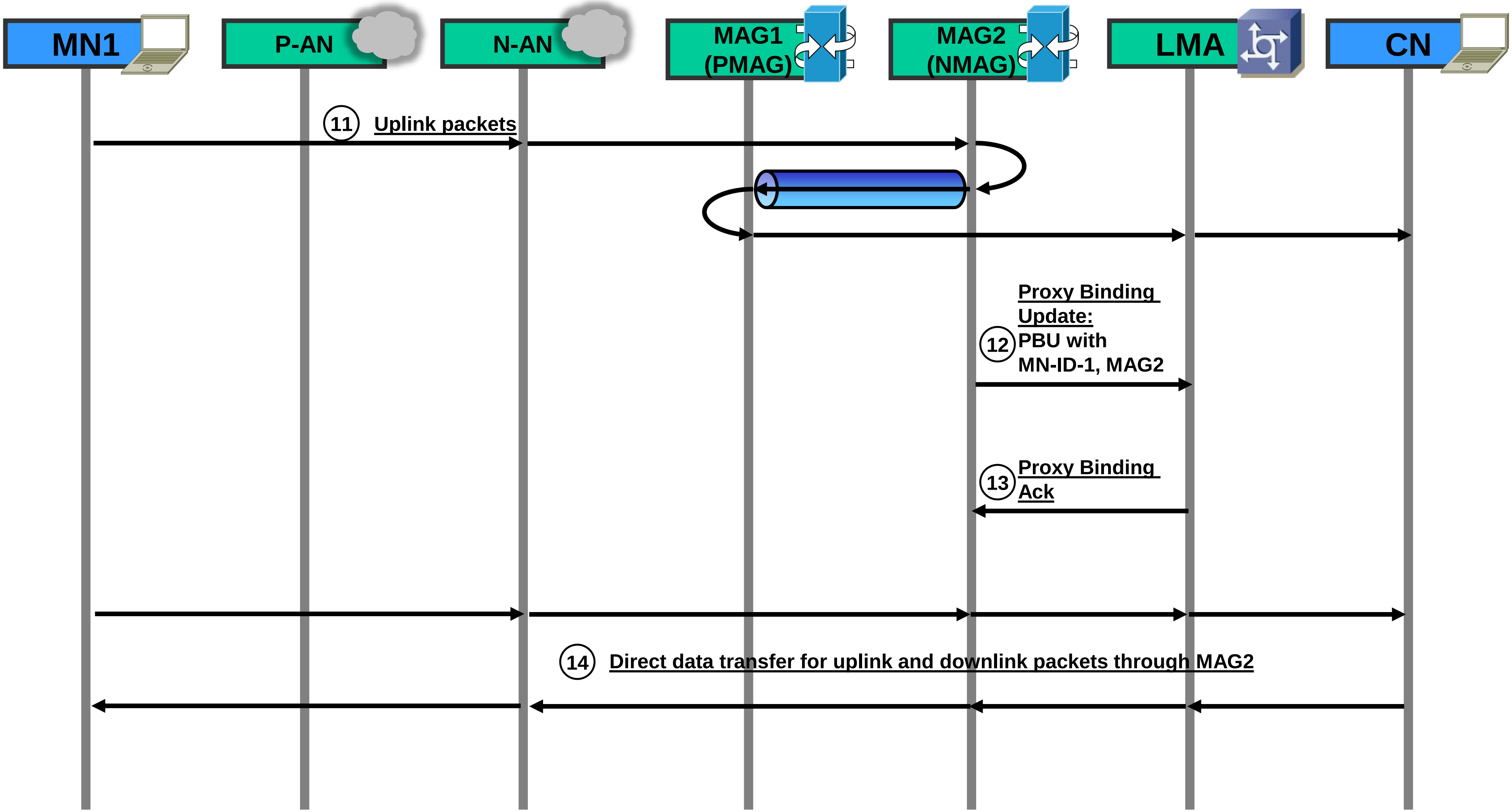
# 10. Proxy Based Fast Handover for MIPv6 (PFMIPv6) with RFC5949 (2/8)

***Predictive Fast Handover*** **from MAG1 to MAG2 (initiated by MAG1=PMAG):**



# 10. Proxy Based Fast Handover for MIPv6 (PFMIPv6) with RFC5949 (3/8)

***Predictive Fast Handover*** **from MAG1 to MAG2 (initiated by MAG1=PMAG):**



# 10. Proxy Based Fast Handover for MIPv6 (PFMIPv6) with RFC5949 (4/8)

## *Predictive Fast Handover* from MAG1 to MAG2 (initiated by MAG1=PMAG):

**1. Report:**
The MN1 detects that handover is imminent (waning radio signal strength in the radio access network where it is attached to) and signals its MN-ID-1 and the ID of the radio access network ID (new AP-ID) to the current radio access network (P-AN for Previous Access Network).
The way this is accomplished is outside the scope of PFMIPv6. Addtionally, it may be the access network itself (P-AN, Previous Access Network) detecting an imminent handover and acting on behalf of MN1.

**2. Handover indication:**
The P-AN indicates the imminent handover along with the MN-ID-1 and new AP-ID to the current MAG (PMAG – Previous MAG).
MN-ID-1 may be the MAC address of its radio interface.
The new AP-ID may be the MAC address or SSID (Service Set ID) of a WLAN access point.

**3. Handover Initiate:**
MAG1 derives the address of MAG2 (NMAG – New MAG) from the new AP-ID (see RFC5568 for details).
The HI packet contains MN-ID-1, HNP (Home Network Prefix = MN1's persistent IP address prefix) and MN1's current LMA address.

**4. Handover Acknowledge:**
MAG2 acknowledges the handover.

**5. Bidirectional tunnel setup between MAG1 and MAG2:**
MAG1 and MAG2 set up a bidirectional tunnel for temporarily tunneling data packets bound for MN1.

**6. Buffering downlink data packets at MAG2:**
Downlink packets destined for MN1 are forwarded by MAG1 (previous MAG) to MAG2 (new MAG) where they are queued for delivery until MN1 has established connectivity with the new access network. When NM1 has established connectivity with N-AN (New Access Network), MAG2 delivers the queued downlink packets to MN1 over N-AN.

# 10. Proxy Based Fast Handover for MIPv6 (PFMIPv6) with RFC5949 (5/8)

## *Predictive Fast Handover* from MAG1 to MAG2 (initiated by MAG1=PMAG):

**7. Handover command:**
**MAG1 sends a handover command to MN1 telling it that everything is set up and that it now may switch to N-AN. Again, the way this is accomplished is outside of scope of PFMIPv6.**

**8. MN-AN connection establishment:**
**MN1 establishes layer 2 connectivity with the N-AN through some means outside the scope of PFMIPv6.**

**9. AN-MAG connection establishment:**
**Likewise, MAG2 establishes layer 2 connectivity with N-AN if not done so before. When connectivity is established, the access network (N-AN) becomes responsible for buffering downlink packets. The specifics are again outside the scope of PFMIPv6. From now on, MN1 uplink packets can be forwarded to CN without buffering.**

**10. Delivery of buffered downlink packets to MN1:**
**After having established N-AN connectivity, MAG2 deliveres the queued packets to MN1.**

**11. MN1 uplink packet forwarding:**
**All MN1 uplink packets between step 8./9. and 12. follow the forwarding path MN1→MAG2→MAG1 (through tunnel)→LMA.**

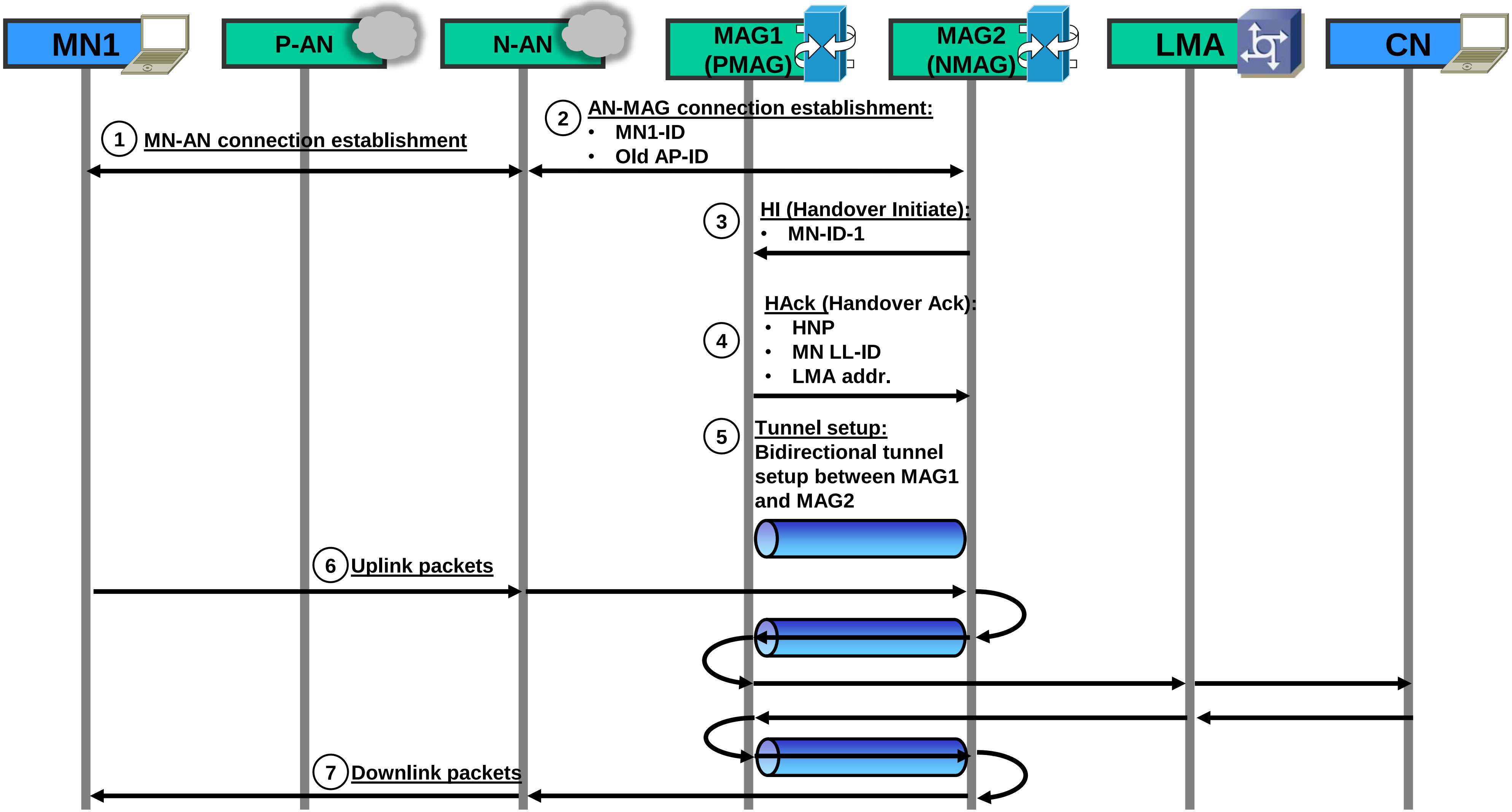
**12. Proxy binding update (PBU):**
**MAG2 sends a proxy binding update to the LMA. This PBU associates the MAG2 address with the identity of MN1 (MN-ID-1). The LMA updates the BCE (Binding Cache Entry) for MN1. MN1 is now associated with MAG2. The prefix (HNP) for MN1 remains the same (address transparency for MN1).**

**13. Proxy binding ack (PBA):**
**The LMA sends back a PBA packet to MAG2.**

**14. Uplink and downlink data transfer through MAG2:**
**Uplink and downlink packets are now forwarded through MAG2 and the tunnel between MAG2 and LMA.**

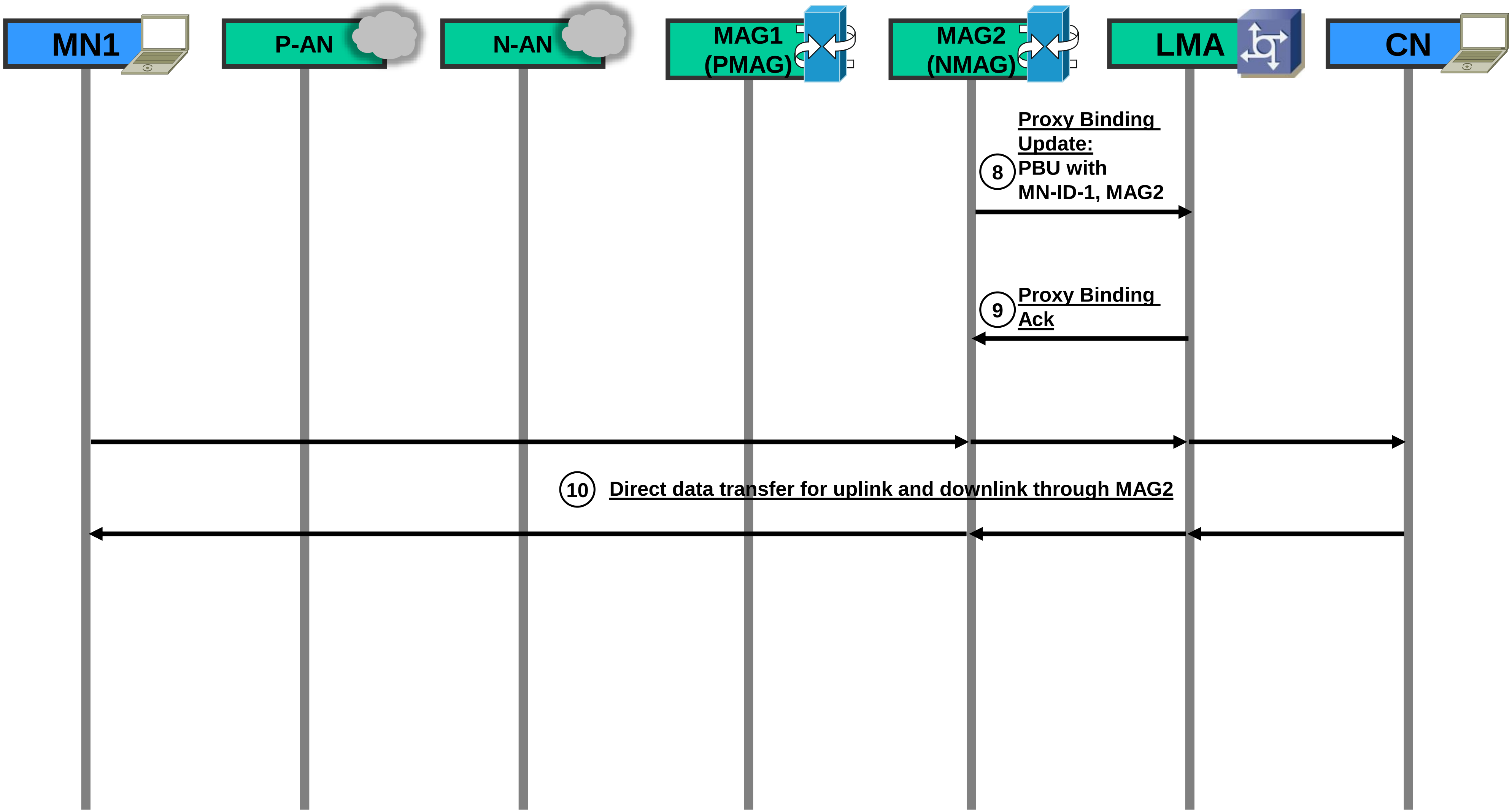
# 10. Proxy Based Fast Handover for MIPv6 (PFMIPv6) with RFC5949 (6/8)

***Reactive Fast Handover*** **from MAG1 to MAG2 (initiated by MAG2=NMAG):**



# 10. Proxy Based Fast Handover for MIPv6 (PFMIPv6) with RFC5949 (7/8)

*Reactive Fast Handover* **from MAG1 to MAG2 (initiated by MAG2=NMAG):**



# 10. Proxy Based Fast Handover for MIPv6 (PFMIPv6) with RFC5949 (8/8)

## *Reactive Fast Handover* from MAG1 to MAG2 (initiated by MAG2=NMAG):

**1. MN-AN connection establishment:**
**MN1 establishes layer 2 connectivity with the N-AN through some means outside the scope of PFMIPv6.**

**2. AN-MAG connection establishment:**
**Likewise, MAG2 establishes layer 2 connectivity with N-AN if not done so before. When connectivity is established, the access network (N-AN) becomes responsible for buffering downlink packets. The specifics of all that is again outside the scope of PFMIPv6.**

**3. Handover Initiate:**
**MAG2 derives the address of MAG1 from the old AP-ID and sends a HI (Handover Initiate) packet that contains MN-ID-1.**

**4. Handover Acknowledge:**
**MAG1 acknowledges the handover. The acknowledge packet contains MN1's link layer ID (MN LL-ID), HNP (Home Network Prefix) and MN1's current LMA address.**

**5. Bidirectional tunnel setup between MAG1 and MAG2:**
**MAG1 and MAG2 set up a bidirectional tunnel for temporarily tunneling data packets bound for MN1.**

**6. & 7. Uplink and downlink packets:**
**Up- and downlink packets are relayed through MAG1.**

**12. & 13. Proxy binding update (PBU) and Proxy binding ack (PBA):**
**MAG2 sends a proxy binding update to the LMA. This PBU associates the MAG2 address with the identity of MN1 (MN-ID-1). The LMA updates the BCE (Binding Cache Entry) for MN1. MN1 is now associated with MAG2. The prefix (HNP) for MN1 remains the same (address transparency for MN1). The LMA sends back a PBA packet to MAG2.**

**14. Uplink and downlink data transfer through MAG2:**
**Uplink and downlink packets are now forwarded through MAG2 and the tunnel between MAG2 and LMA.**