Distributed mobility management for Future Internet

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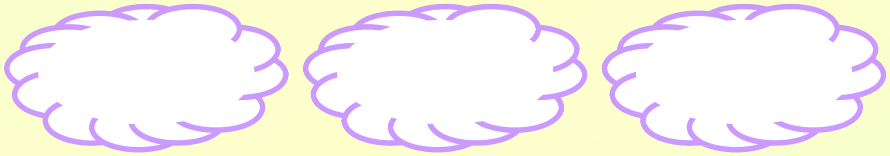
Internet

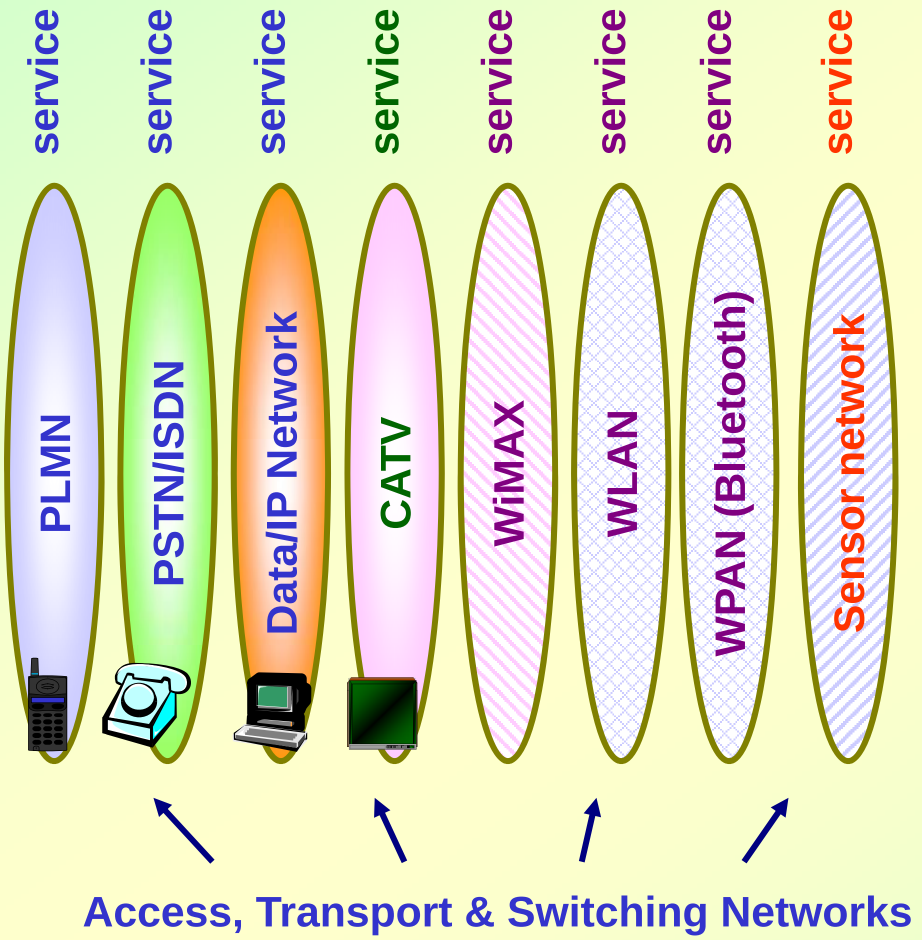
- Core network: converge (cellular and Internet – no more IPv4 blocks available)



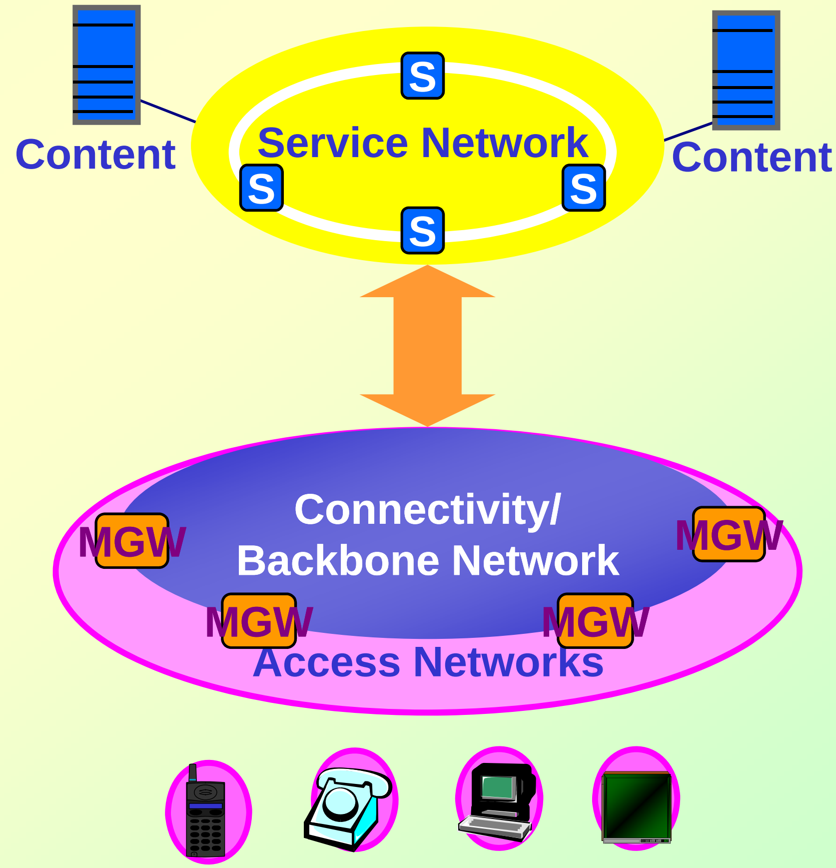
- Access networks: diverse
- Devices: multiple interfaces, multiple functions, mobile
- Traffic from Wireless device grows 3 times faster than (exceeding soon) that of wireline devices
- Internet: lack native support for mobility, multi-homing, etc.

Core network: Convergence

Single-service networks



Multi-service network



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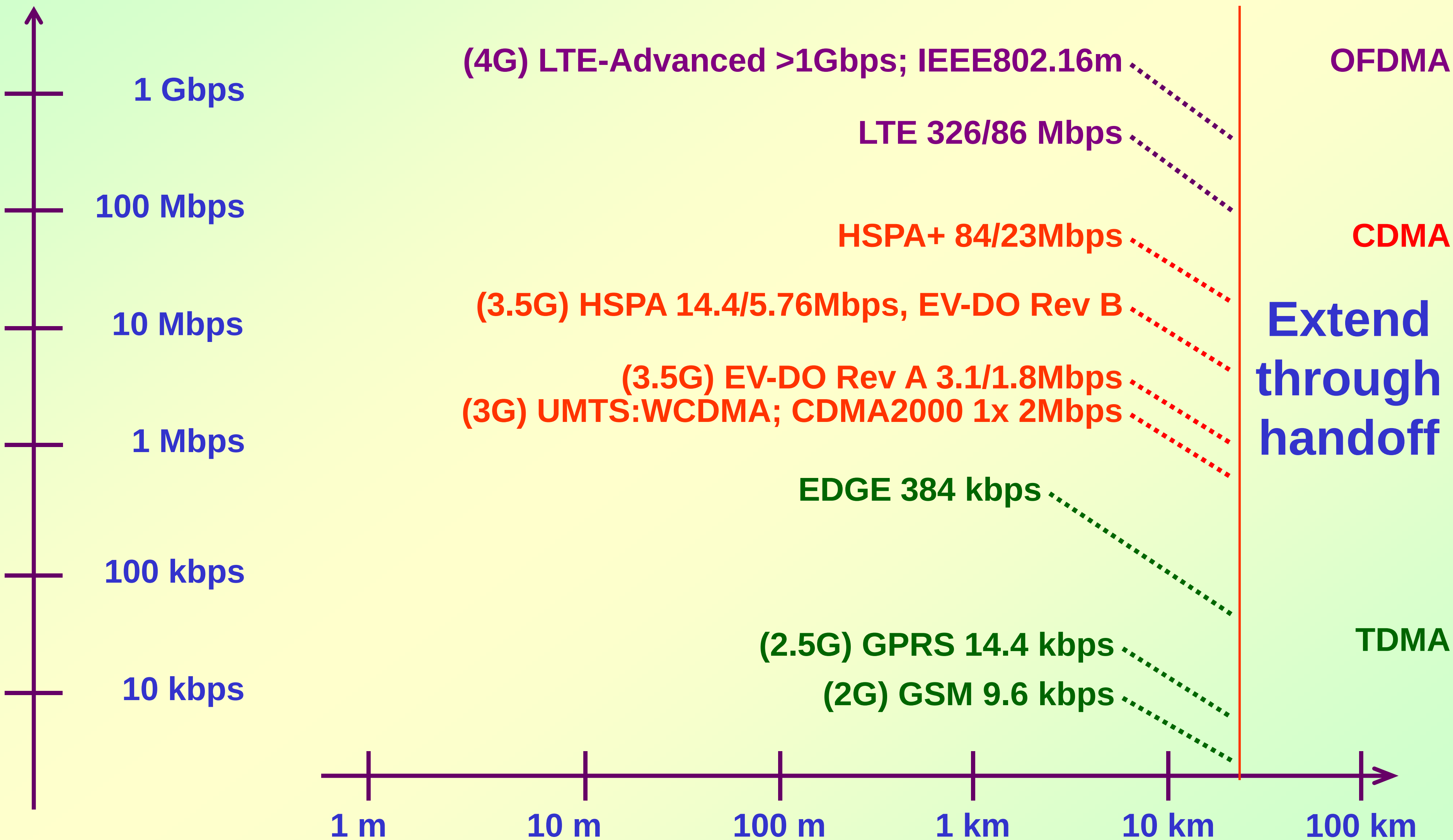
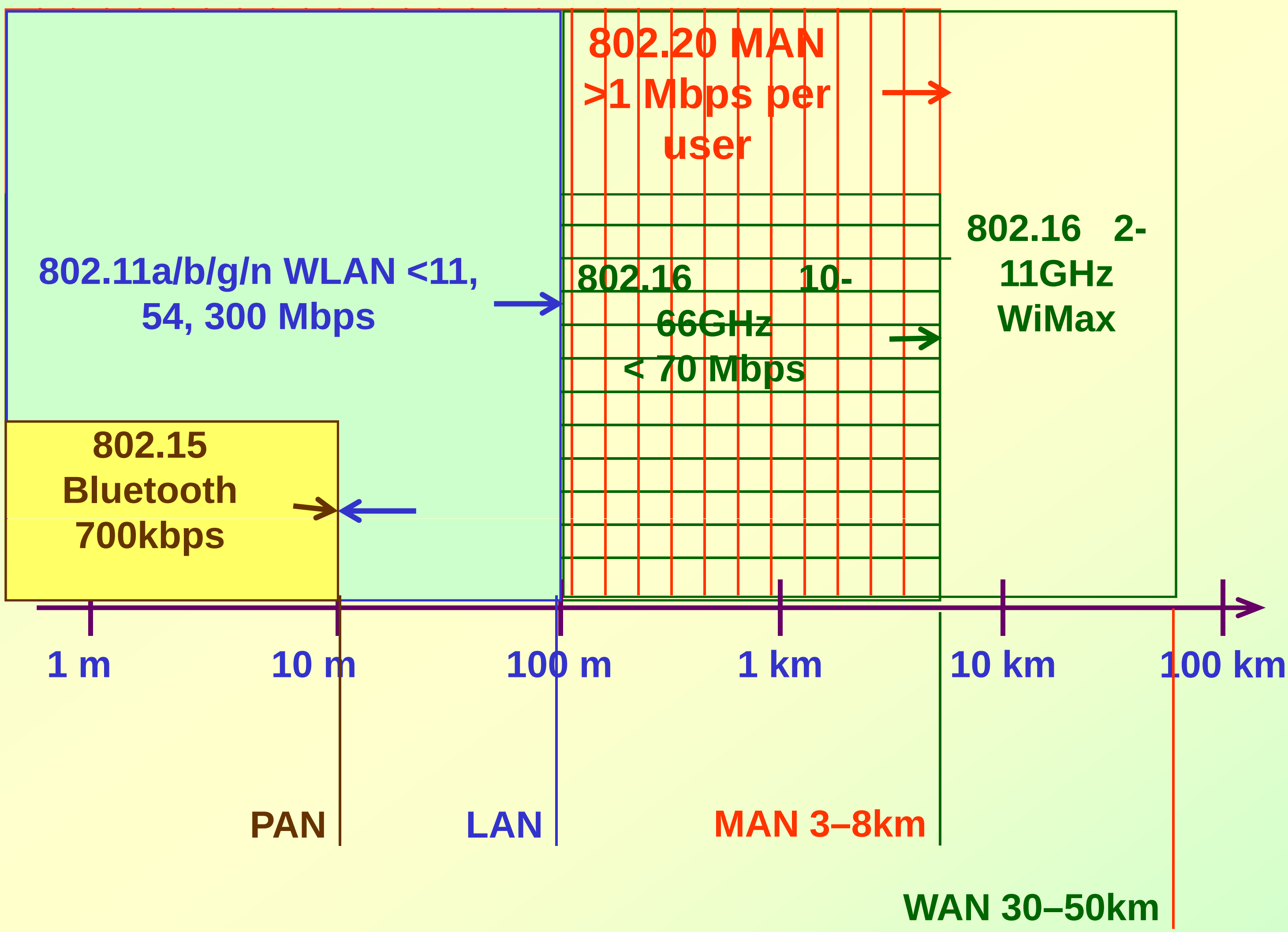
Wireless access network: Cellular



Wireless access network: 802 wireless family



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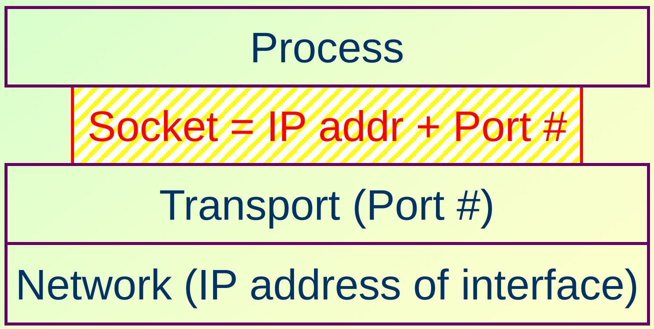
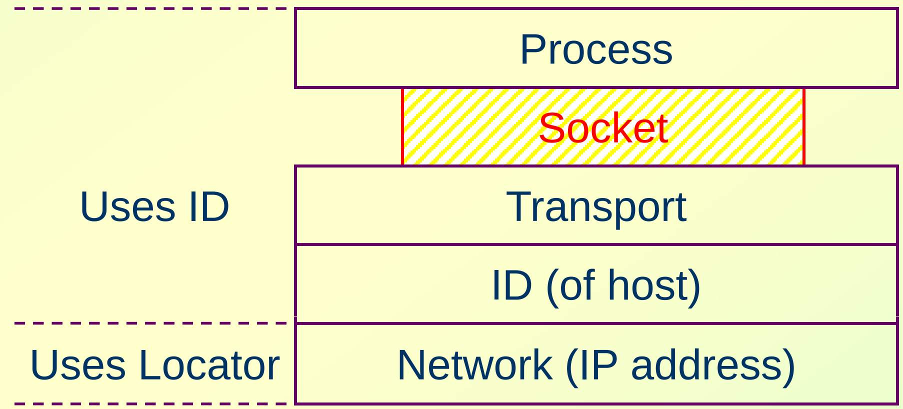
Internet: ID-Locator split problem

IP network



ID-Locator Split network



- IP address (of interface) changes when routing changes. Transport session does not survive under IP changes.

- ID (of host): Used for session, rarely changes.
- Locator (IP address): Used for network routing.
- Mapping system (control plane): maps ID with a set of locators (IP addr)

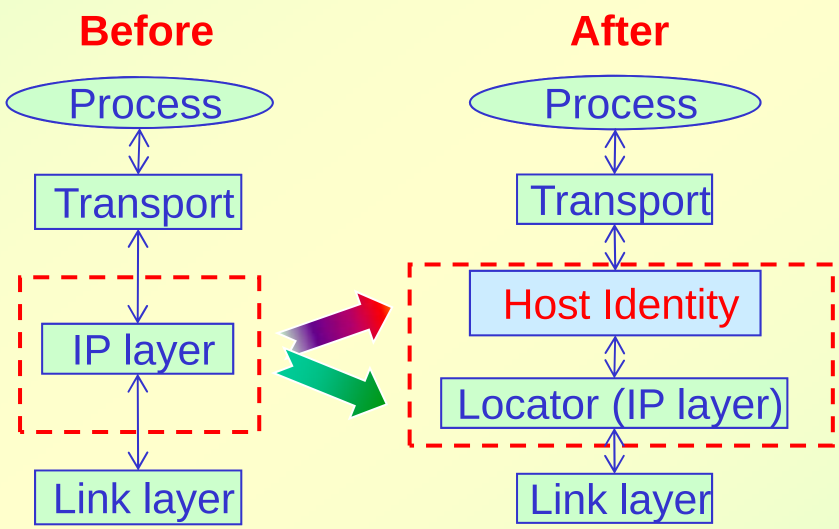
What is the ID/Locator Split Protocol?

Client based / Client-network changes

- Architectural change to the TCP/IP stack
  - A new layer between IP and transport
- Session between Host IDs not affected by locator changes

Major protocols/proposals:

- HIP (Ericsson/HIIT)
- I3 (UC Berkeley)
- Clean slate design (Stanford)
- Internet 3.0 (WashU)

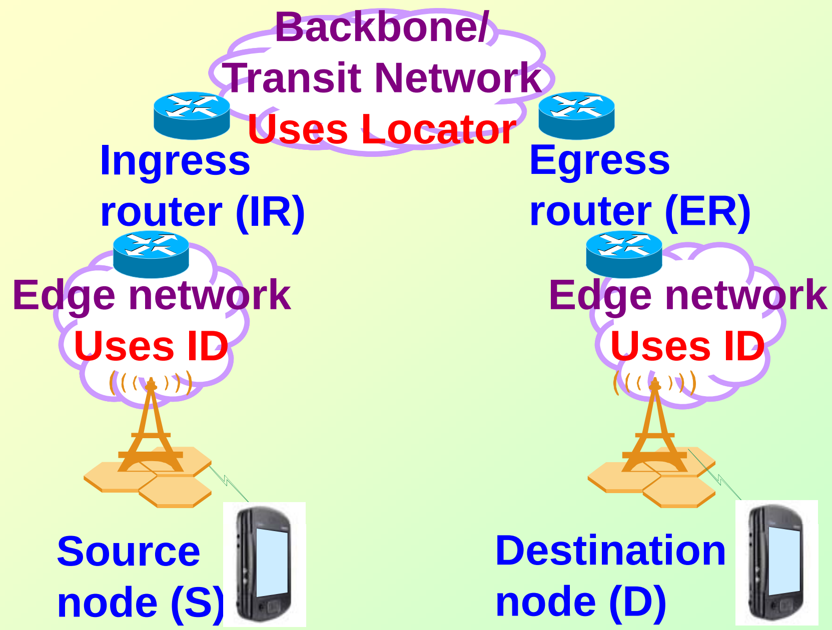


Network based: No change to client stack

- Locator = globally routable IP addr in backbone/Internet only
- ID = edge network IP addr; session not affected by locator changes in Internet.

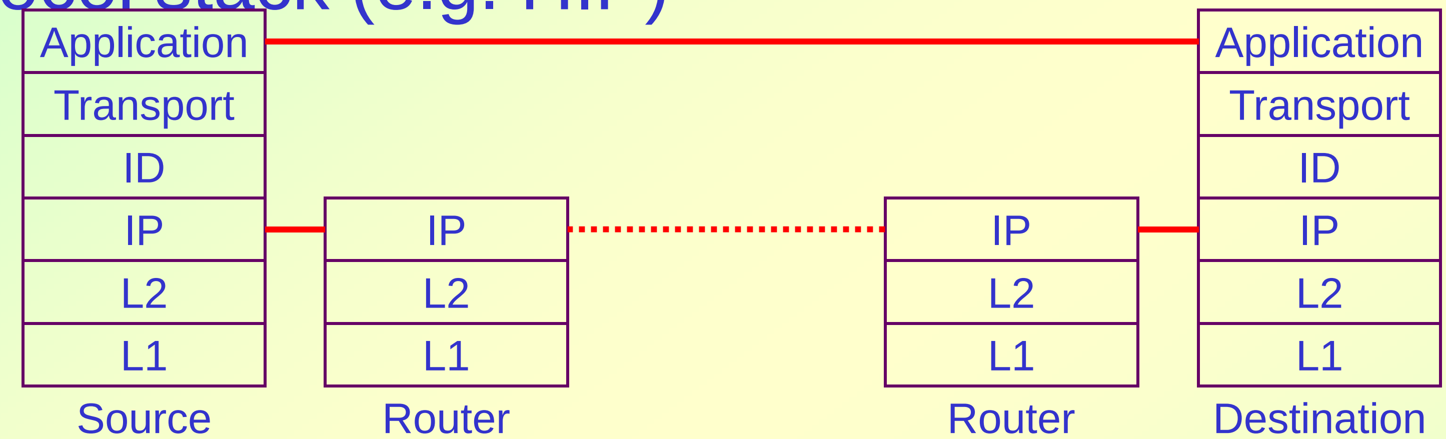
Major protocols:

- LISP (Cisco);
- APT (UCLA)

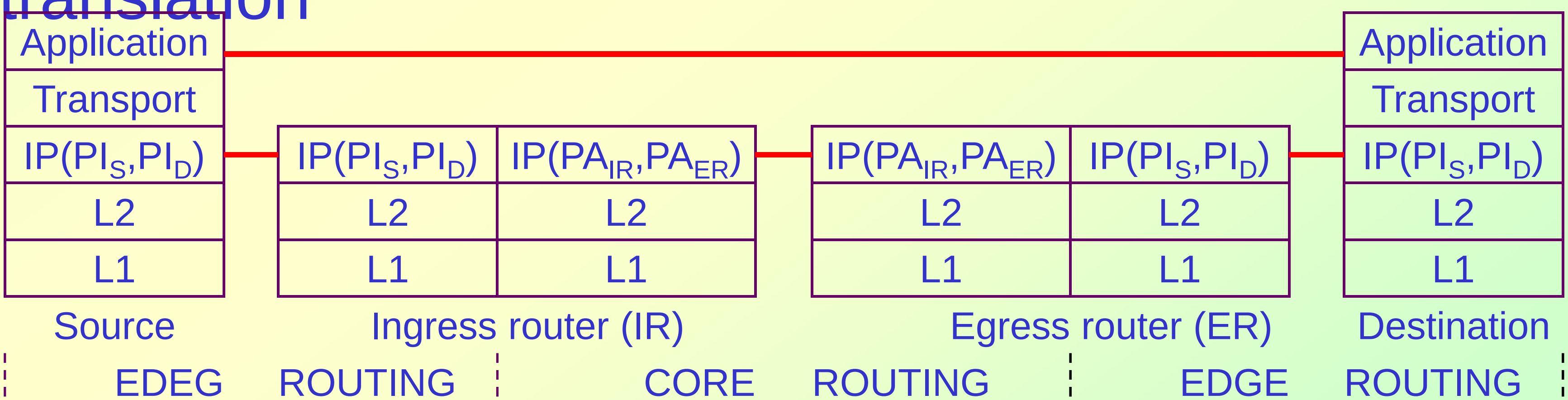


ID-Locator Split families

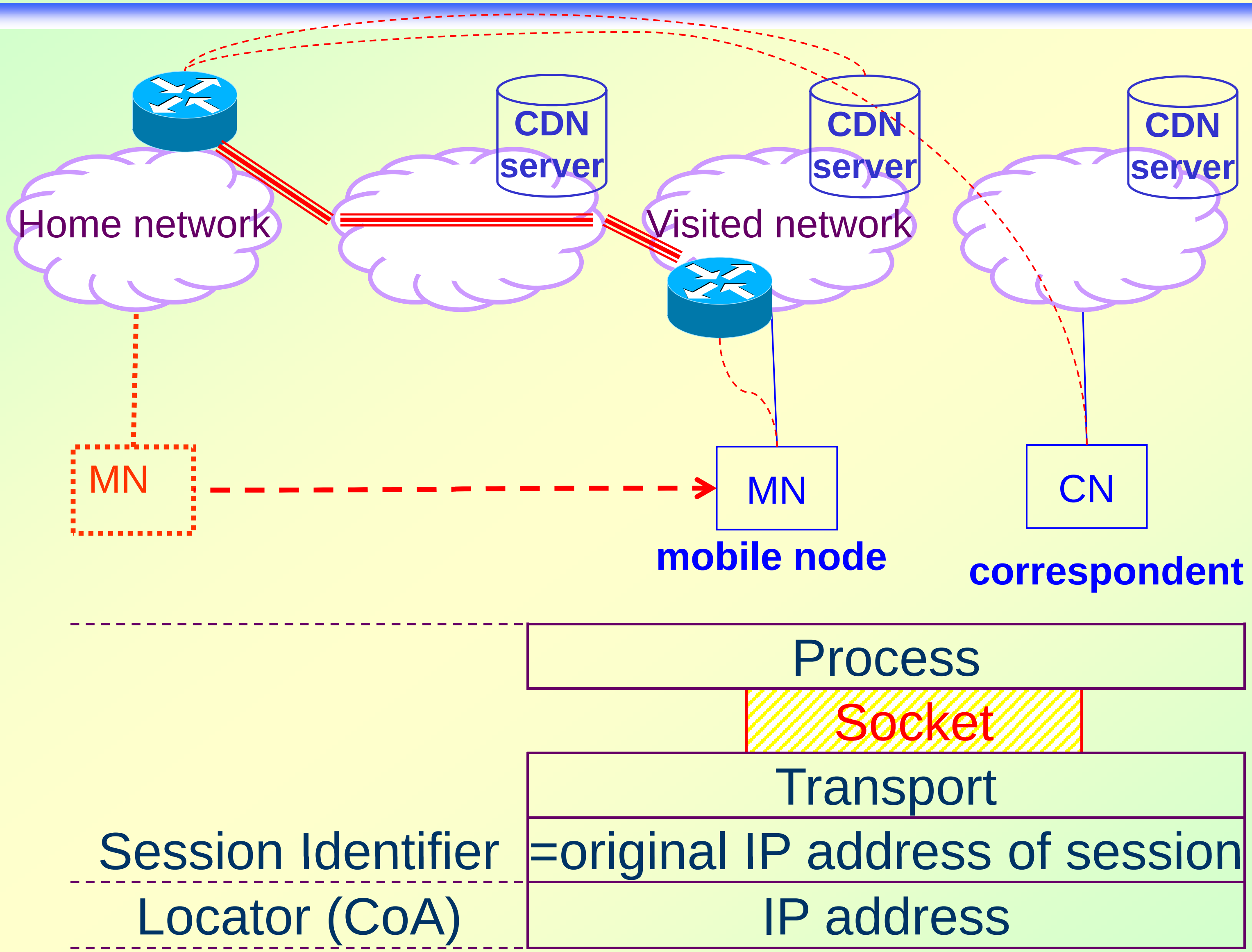
- Protocol stack (e.g. HIP)



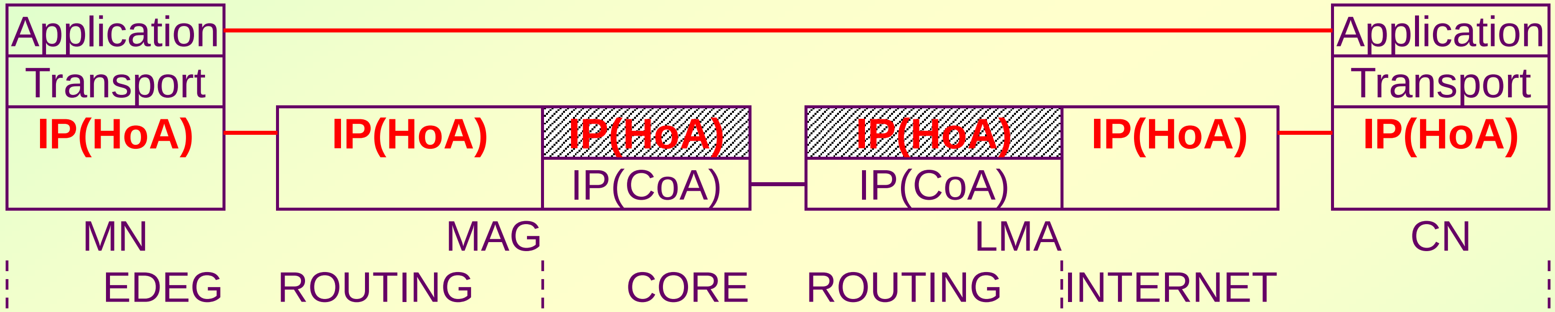
- Core-edge separation: tunneling (e.g. LISP) or translation



Mobile IP


CDN server
CDN server
CDN server
Home network
Visited network
MN
MN
CN
mobile node
correspondent node
Process
Socket
Transport
Session Identifier
=original IP address of session
Locator (CoA)
IP address

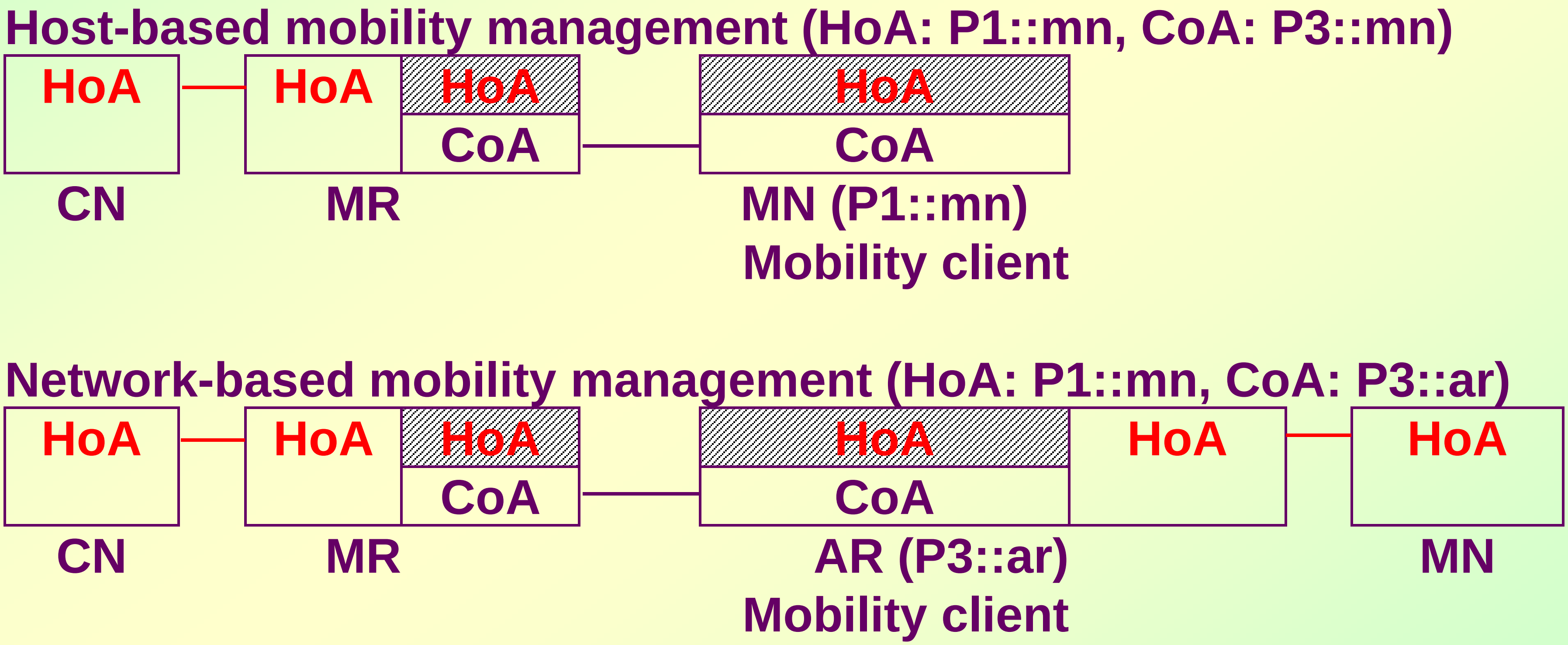
Proxy Mobile IP



MAG: Mobile access gateway

LMA: Local mobility anchor

Host-based versus Network-based mobility management



Distributed mobility anchors

- Distributed versus centralized mobility anchors
- Splitting control and data planes: Architecture
- Unified formulation of Internet mobility
- DMM Route optimization mechanism example

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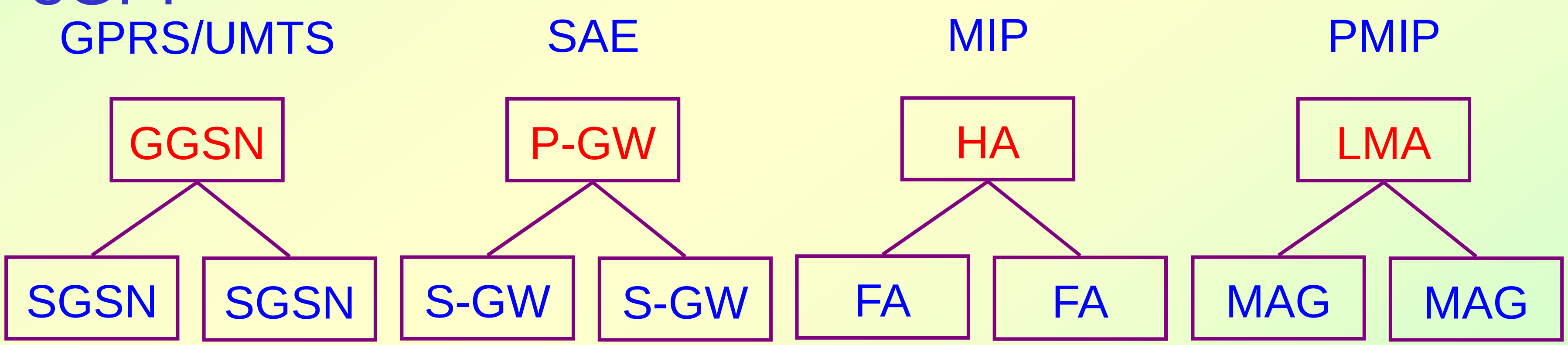
Centralized mobility anchors

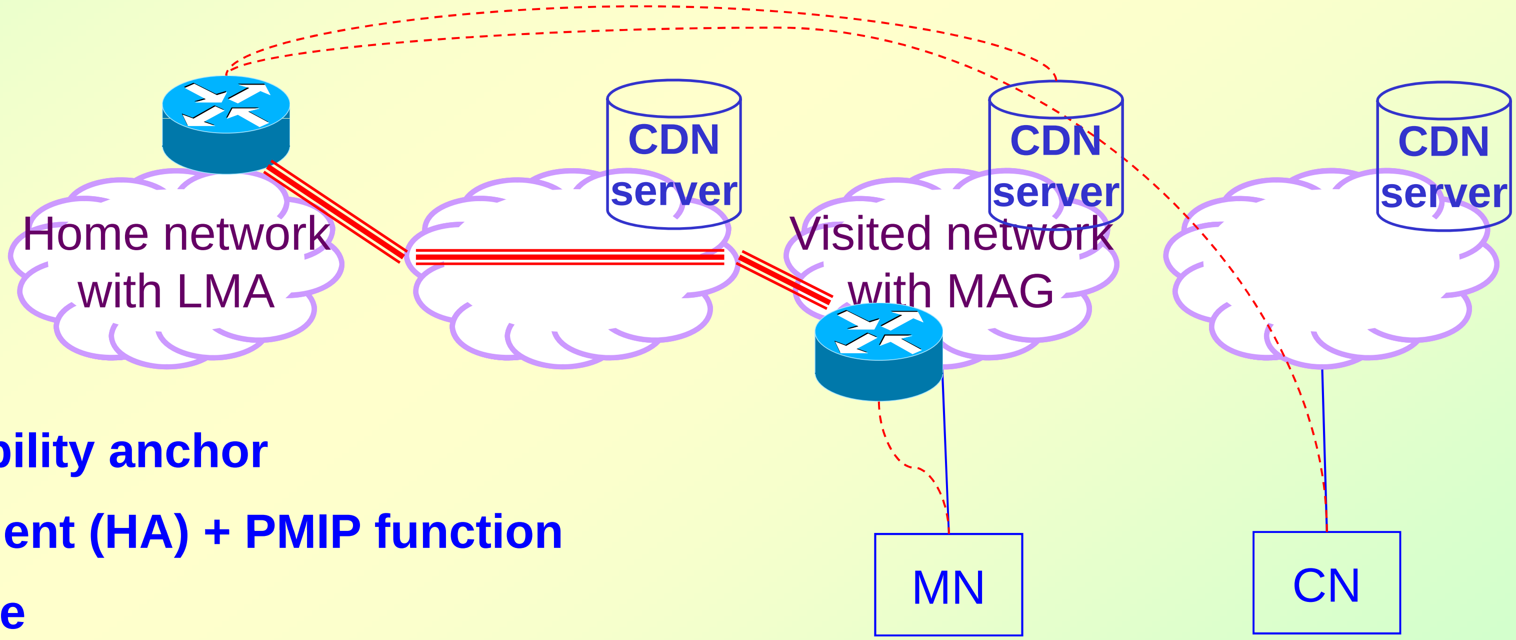
- Current mobile networks are hierarchical, and existing mobility solutions are deployed with centralized mobility anchoring
- E.g. HA in MIPv6/DSMIPv6, LMA in PMIPv6, GGSN in 3GPP



  - Network: hierarchical versus flattened
  - Mobility management: centralized versus distributed

Proxy mobile IP (PMIP) with triangle routing problem

- Packets between MN and CN need to tunnel between MAG and LMA, even when MN is far from home network but is close to CN



LMA: Local mobility anchor

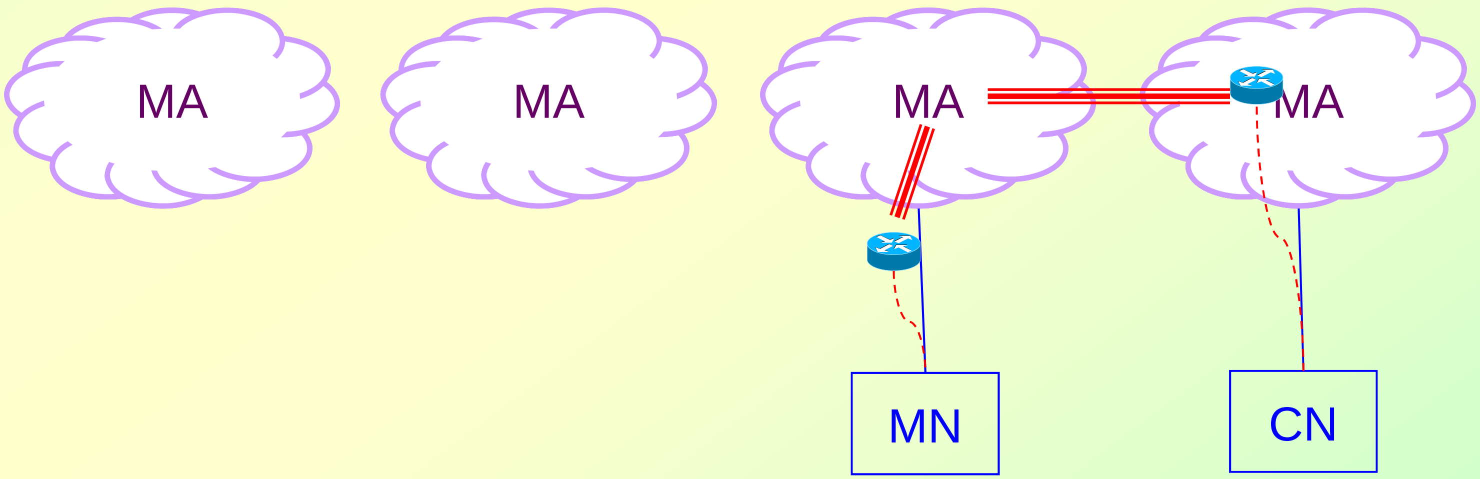
= Home agent (HA) + PMIP function

MN: mobile node

CN: correspondent node

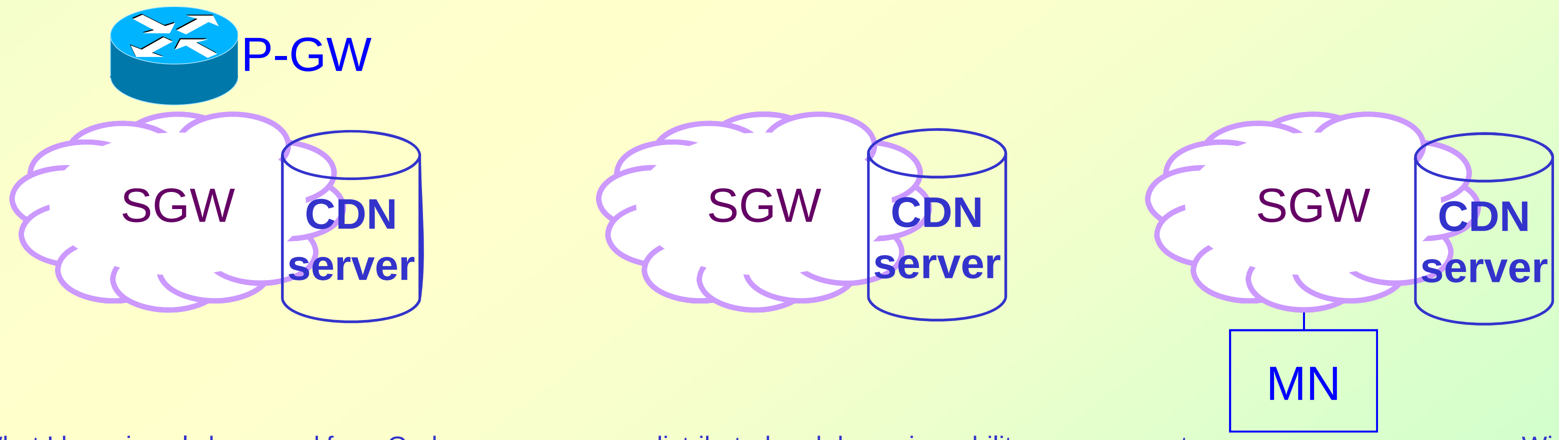
Problem statement PS1: Non-optimal routes

- (1) Routing via a centralized anchor often results in non-optimal routes, thereby increasing the end-to-end delay.



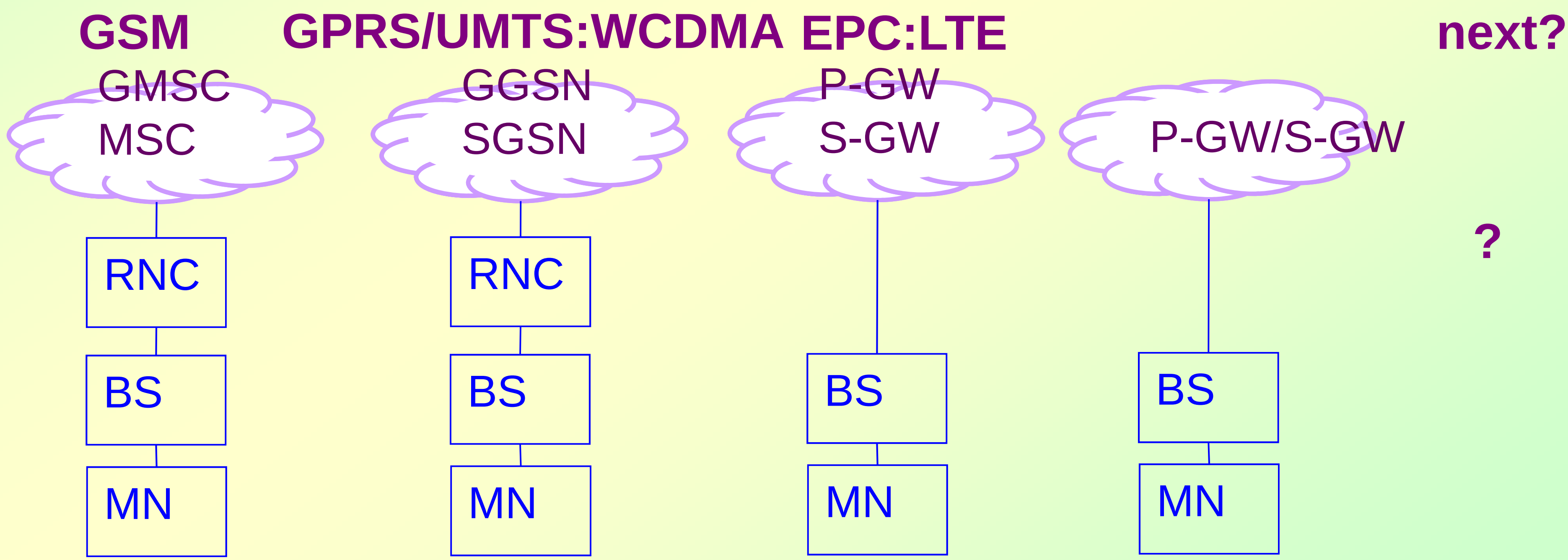
PS1: Non-optimal routes (continued)

- The problem is manifested, for example, when accessing a nearby server or servers of a Content Delivery Network (CDN).



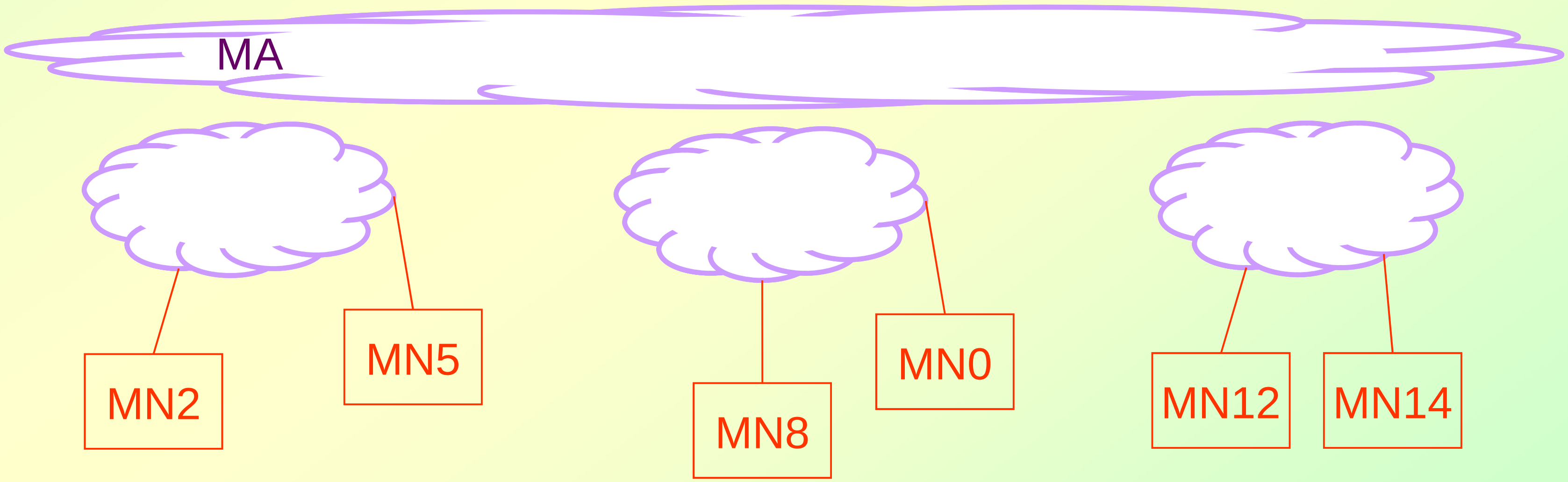
PS2: CMM does not support evolutionary trends of mobile networks towards a flat network

- In contrast, distributed mobility management can support both hierarchical network and more flattened network.



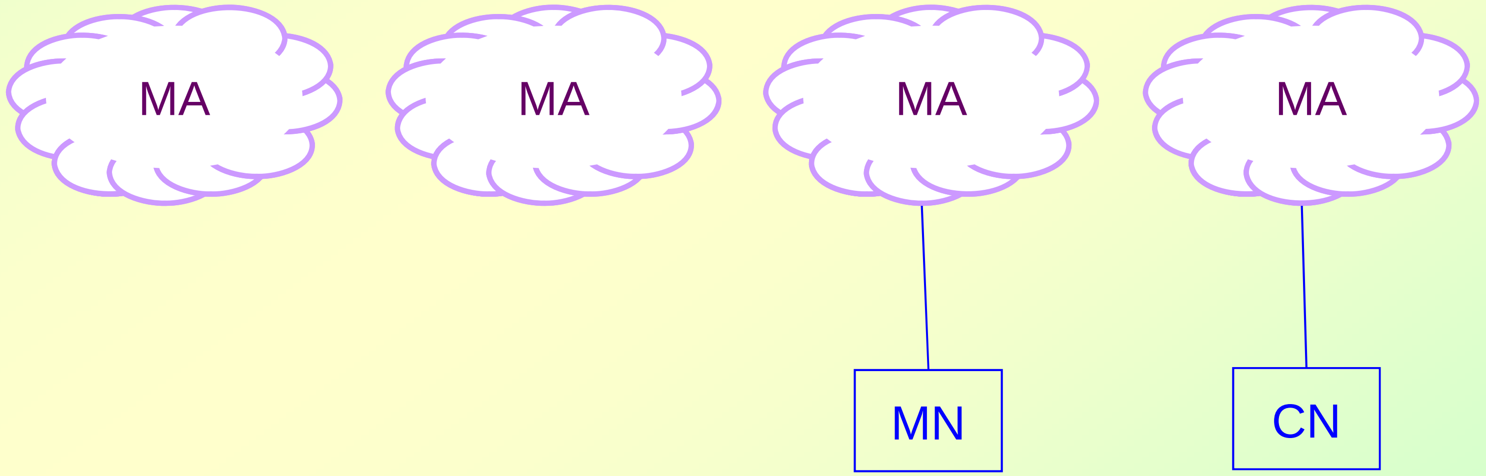
PS3: Low scalability of centralized tunnel management and mobility context maintenance

- Setting up tunnels through a central anchor and maintaining mobility context for each MN usually requires more concentrated resources in a centralized design, thus reducing scalability. Distributing the tunnel maintenance function and the mobility context maintenance function among different network entities can avoid increasing the concentrated resources..



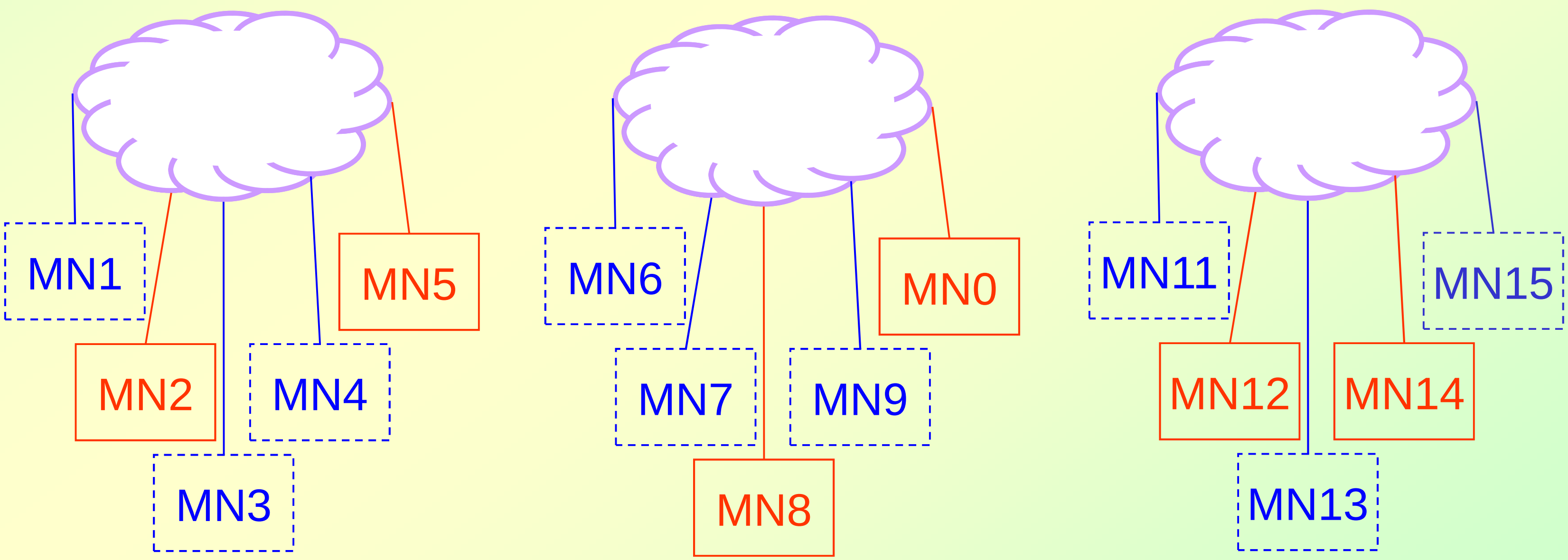
PS4: Single point of failure and attack

- Centralized anchoring designs may be more vulnerable to single points of failures and attacks than a distributed system. The impact of a successful attack on a system with centralized mobility management can be far greater as well.



PS5: Unnecessary mobility support to clients that do not need it

- IP mobility support is not always required, and not every parameter of mobility context is always used. For example, some applications do not need a stable IP address during a handover to maintain session continuity. Sometimes, the entire application session runs while the terminal does not change the point of attachment.



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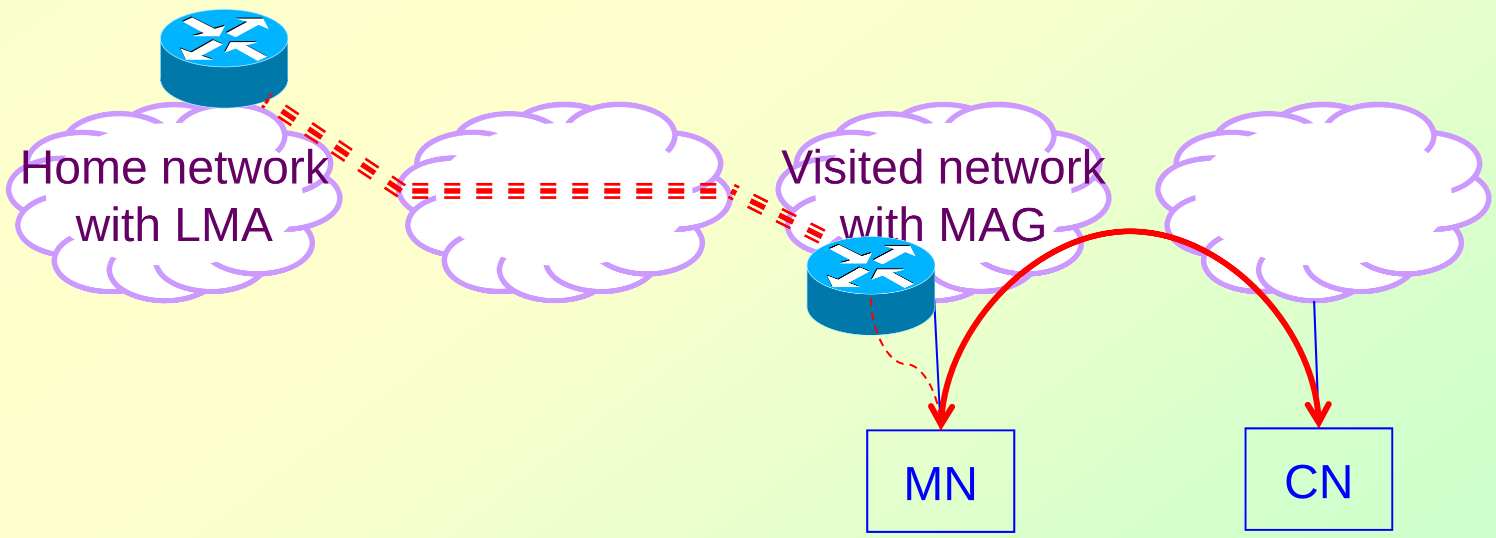
PS6 (related): Mobility signaling overhead with peer-to-peer communication

- Wasting resources when mobility signaling (e.g., maintenance of the tunnel, keep alive signaling, etc.) is not turned off for peer-to-peer communication.



PS7 (related): Deployment with multiple mobility solutions

- There are already many variants and extensions of MIP. Deployment of new mobility management solutions can be challenging, and debugging difficult, when they co-exist with solutions already deployed in the field.
- Variants: MIP, PMIP, HMIP, FMIP, DSMIP, …, etc.

PS8: Duplicate multicast traffic

- IP multicast distribution over architectures using IP mobility solutions (e.g., RFC6224) may lead to convergence of duplicated multicast subscriptions towards the downstream tunnel entity (e.g. MAG in PMIPv6). Concretely, when multicast subscription for individual mobile nodes is coupled with mobility tunnels (e.g. PMIPv6 tunnel), duplicate multicast subscription(s) is prone to be received through different upstream paths. This problem may also exist or be more severe in a distributed mobility environment.

IETF dmm WG charter work items

- Solution Requirements: Define precisely the problem of distributed mobility management and identity the requirements for a distributed mobility management solution.
- Practices: Document practices for the deployment of existing mobility protocols in a distributed mobility management environment.
- Gap Analysis and extensions: identify the limitations in the current practices with respect to providing the expected functionality.
- If limitations are identified as part of the above deliverable, specify extensions to existing protocols that removes these limitations within a distributed mobility management environment.

REQ1: Distributed processing

- IP mobility, network access and routing solutions provided by DMM MUST enable distributed processing for mobility management so that traffic can avoid traversing single mobility anchor far from the optimal route.

- Addresses PS1, PS2, PS3, and PS4

REQ2: Transparency to Upper Layers when needed

- DMM solutions MUST provide transparent mobility support above the IP layer when needed. Such transparency is needed, for example, when, upon change of point of attachment to the network, an application flow cannot cope with a change in the IP address. However, it is not always necessary to maintain a stable home IP address or prefix for every application or at all times for a mobile node.

- Addresses PS5, and PS6

REQ3: IPv6 deployment

- DMM solutions SHOULD target IPv6 as the primary deployment environment and SHOULD NOT be tailored specifically to support IPv4, in particular in situations where private IPv4 addresses and/or NATs are used.

- This requirement avoids the unnecessarily complexity in solving the problems in Section 4 for IPv4, which will not be able to use some of the IPv6-specific features..

REQ4: Existing mobility protocols

- A DMM solution SHOULD first consider reusing and extending IETF-standardized protocols before specifying new protocols.

- This requirement attempts to avoid the need of new protocols development and therefore their potential problems of being time-consuming and error-prone.

REQ5: Co-existence with deployed networks and hosts

- The DMM solution MUST be able to co-exist with existing network deployments and end hosts. For example, depending on the environment in which DMM is deployed, DMM solutions may need to be compatible with other deployed mobility protocols or may need to co-exist with a network or mobile hosts/routers that do not support DMM protocols. The mobile node may also move between different access networks, where some of them may support neither DMM nor another mobility protocol. Furthermore, a DMM solution SHOULD work across different networks, possibly operated as separate administrative domains, when allowed by the trust relationship between them.
- This requirement address PS7

REQ6: Security considerations

- A DMM solution MUST NOT introduce new security risks or amplify existing security risks against which the existing security mechanisms/protocols cannot offer sufficient protection.

- This requirement prevents a DMM solution from introducing uncontrollable problems of potentially insecure mobility management protocols which make deployment infeasible because platforms conforming to the protocols are at risk for data loss and numerous other dangers, including financial harm to the users.

REQ7: Multicast considerations

- DMM SHOULD enable multicast solutions to be developed to avoid network inefficiency in multicast traffic delivery.

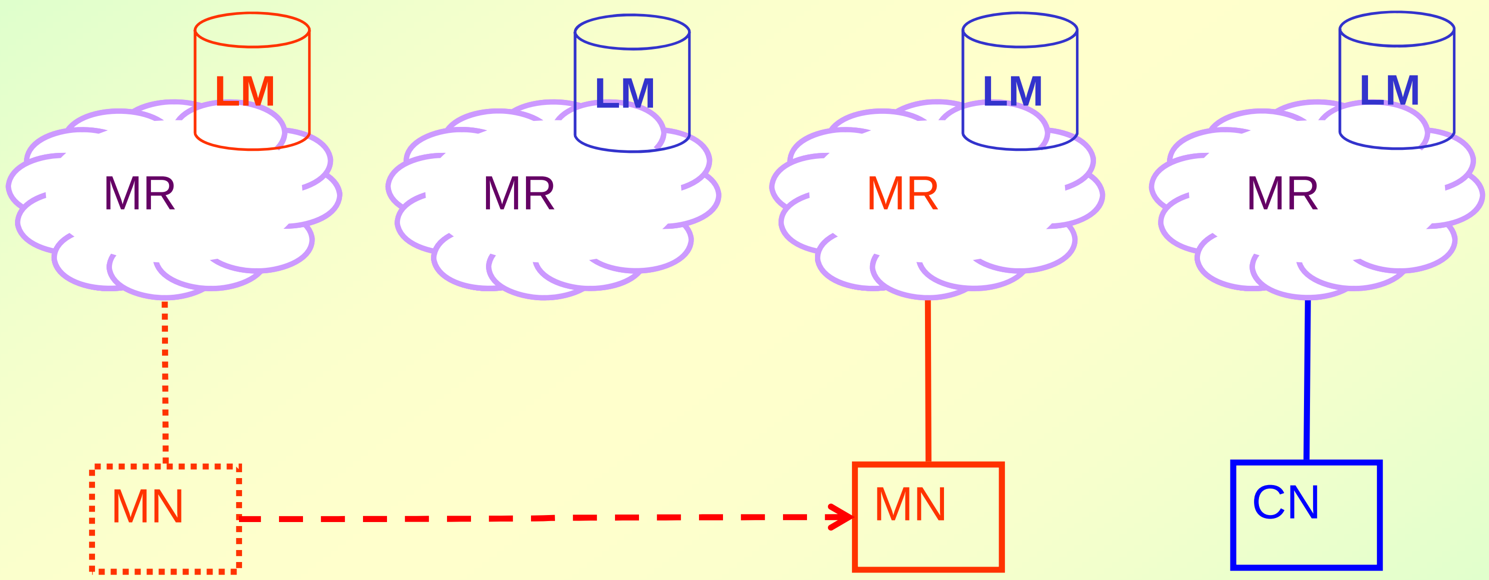
- This requirement addresses the problems PS1 and PS8.

Distributed mobility anchors

- Distributed versus centralized mobility anchors
- Splitting control and data planes: Architecture
- Unified formulation of Internet mobility
- DMM Route optimization mechanism example

Distributed mobility anchors-Architecture

- LMA functions: mobility routing + location management + HoA allocation.

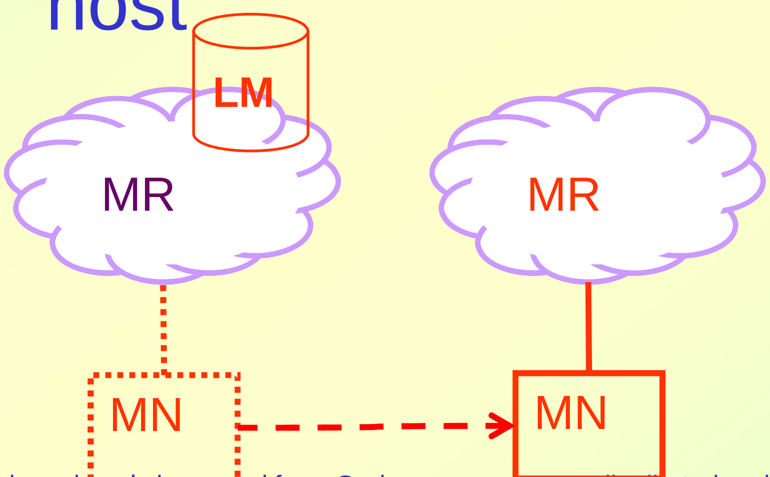


LM: Location management (control plane)
MR: Mobility routing (data plane)

Distributed mobility anchors-Architecture

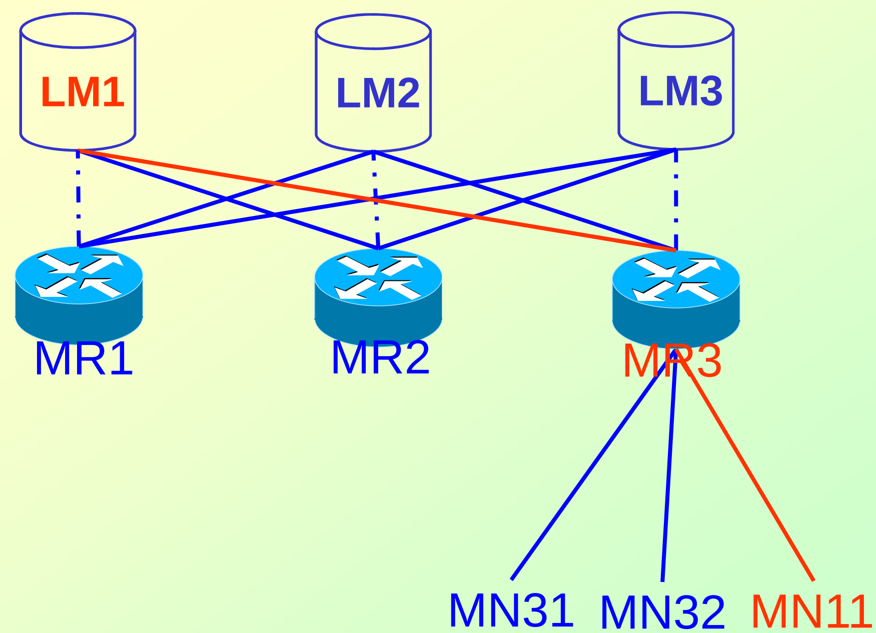
MR: Mobility routing function (data plane)

- ♦ Network-based: MR in every network, at GW which may move down to AR in flat net
- ♦ Host-based: MR at host



Location Management function (control plane)

- ♦ LM is supported by distributed database



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Unified formulation of Internet mobility standards

3 Basic Internet Functions

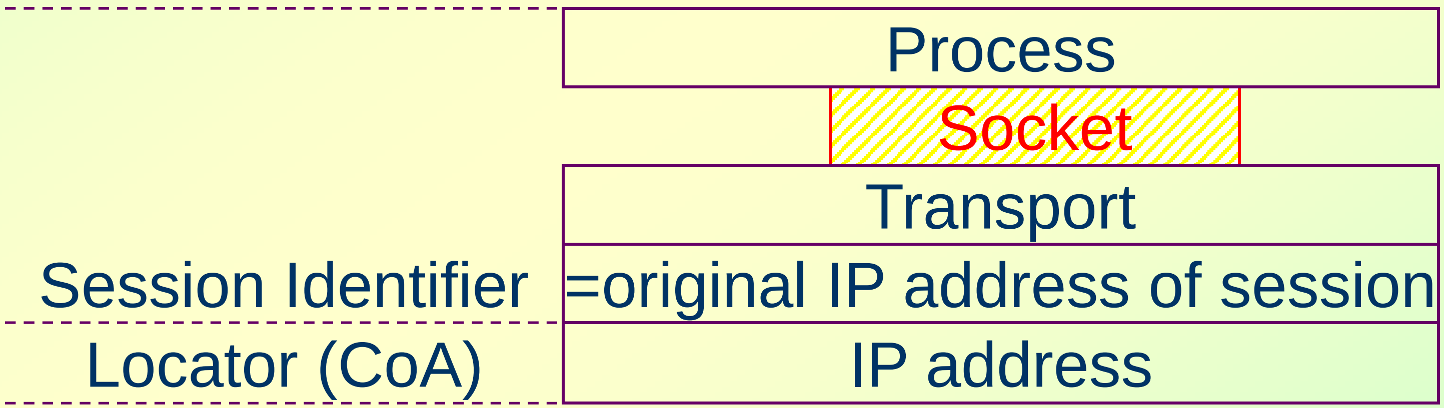
- 1. allocates IP prefixes or addresses are to the hosts.
- 2. manages information such as in maintaining DNS database system and in exchanging routing information between routers.
- 3. Router forwards packets using appropriate information in the routing table

3 Basic Mobility Management Functions

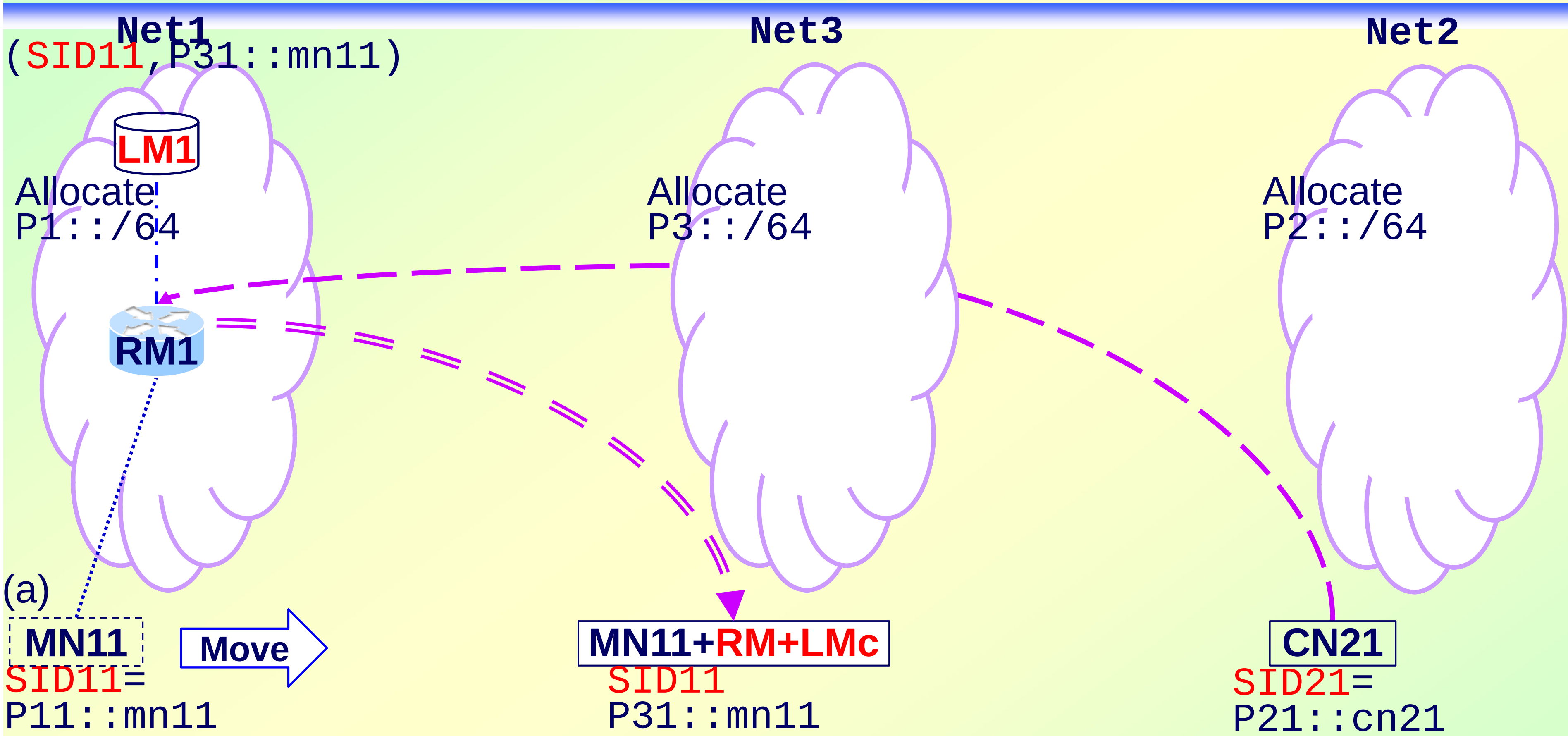
- 1. Session identification
- 2. Location management (LM)
- 3. Mobility routing (MR)

Session continuity

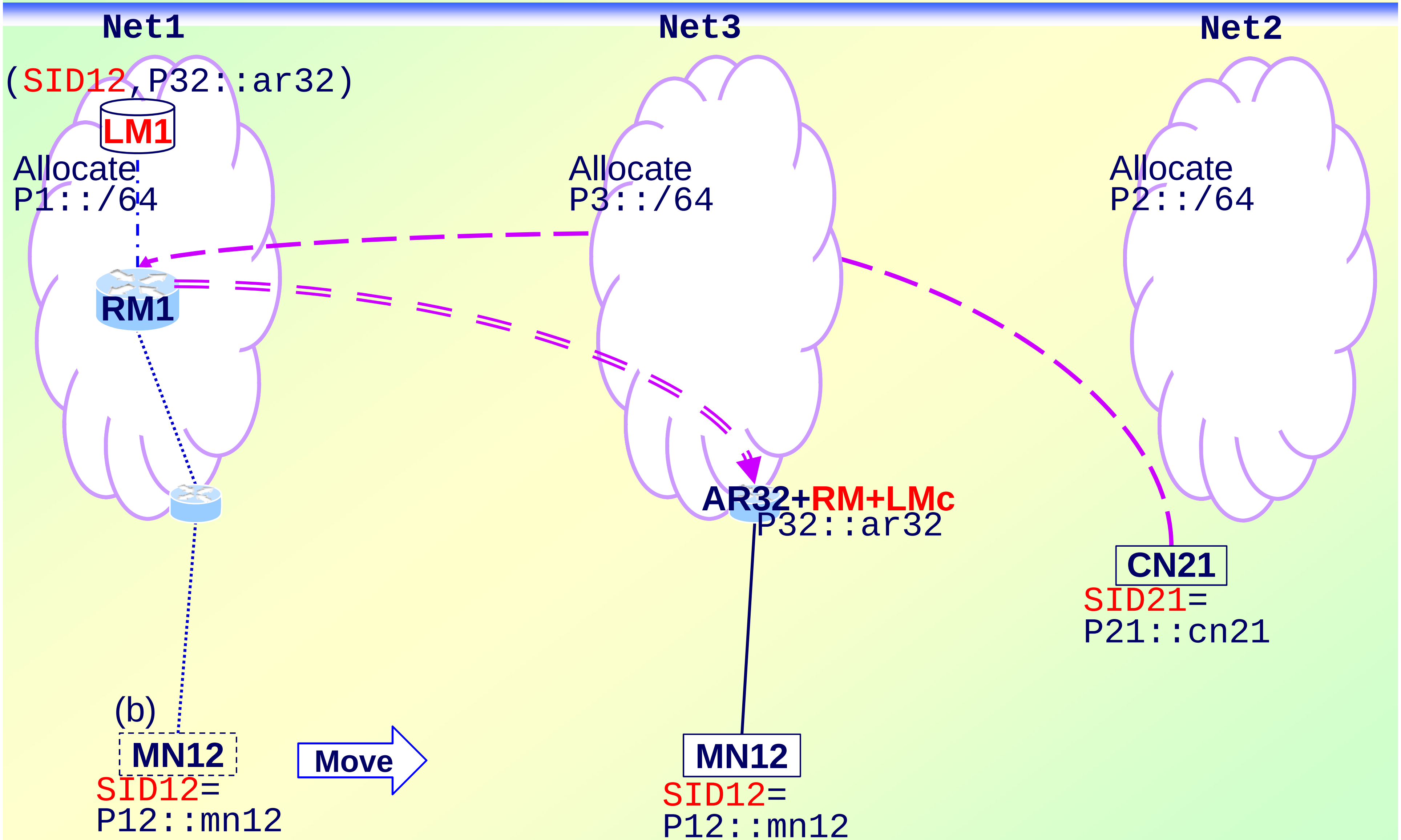
- Session may continue when Session Identifier (original IP address) does not change.



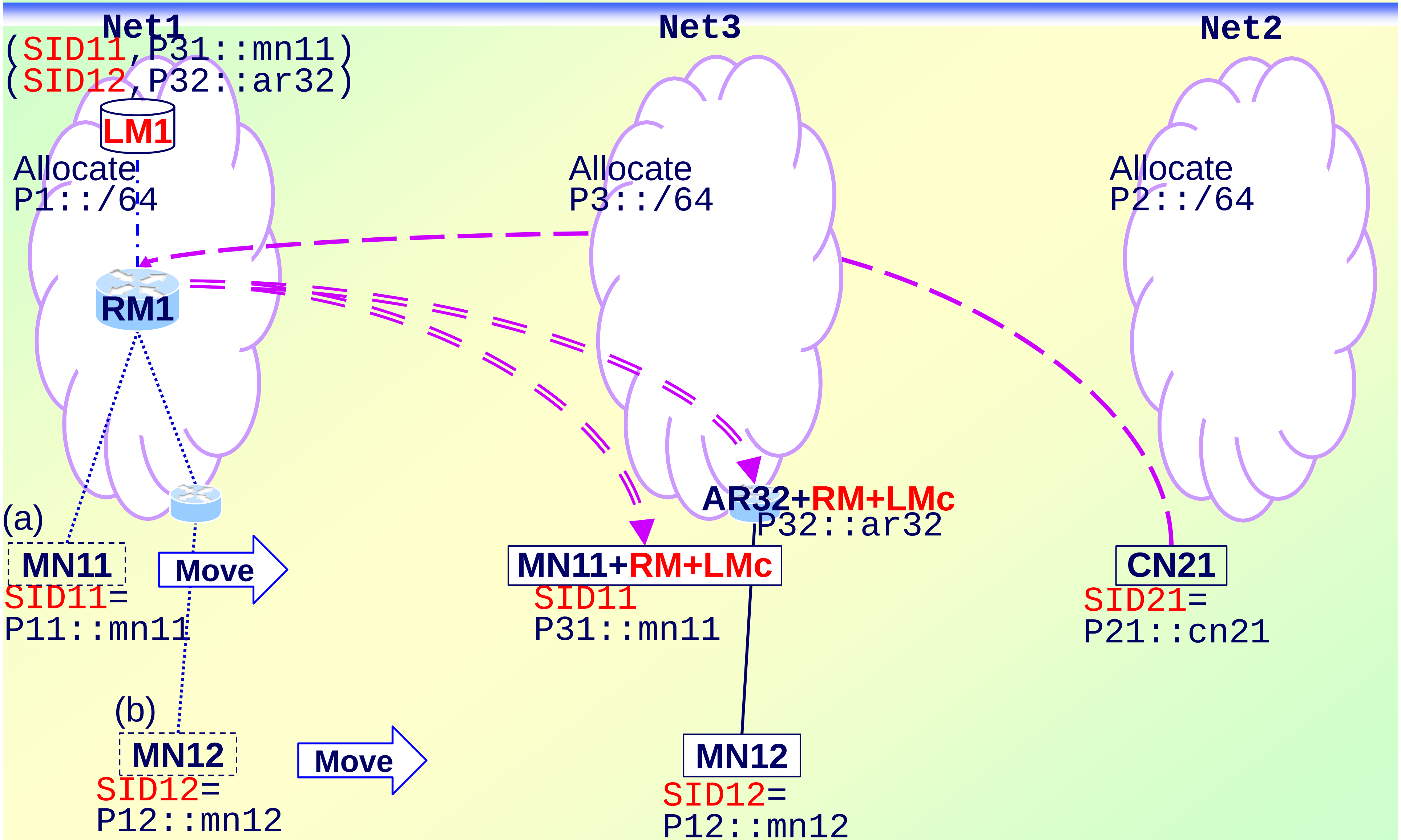
Existing protocol: MIPv6



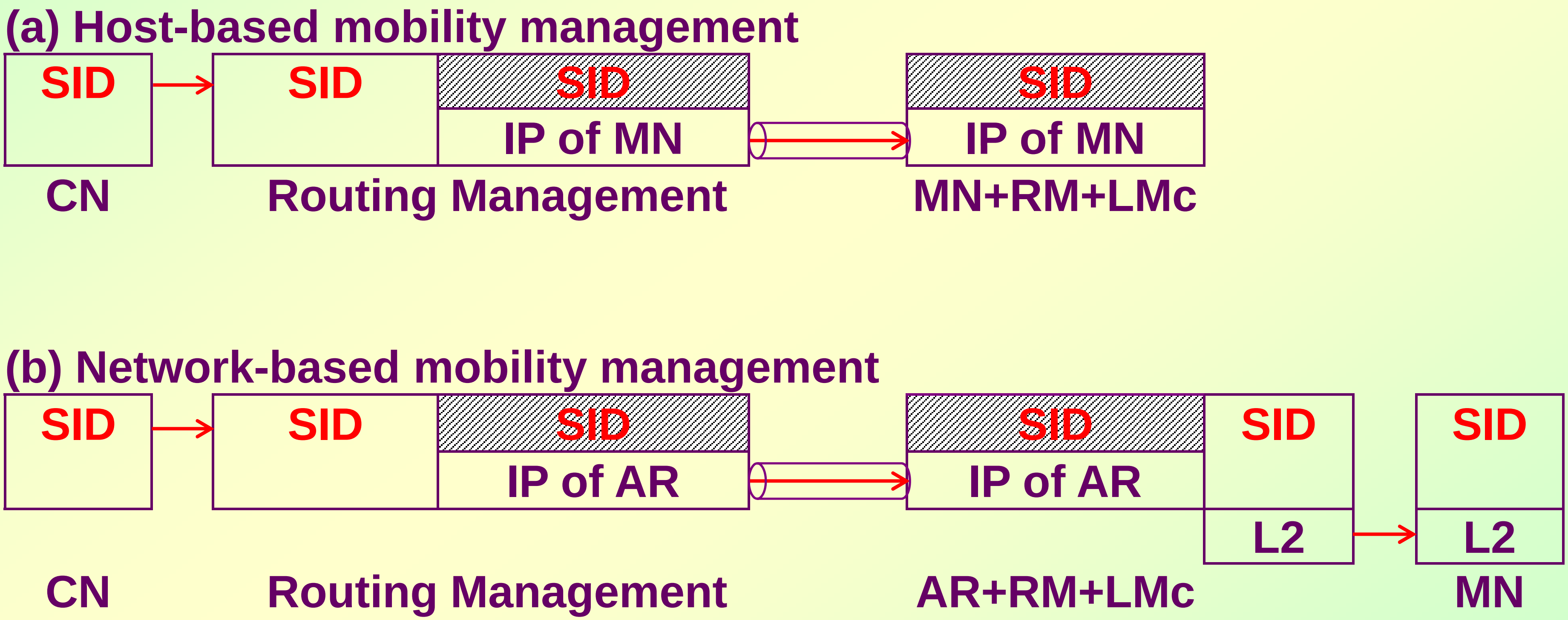
Existing protocol: PMIPv6



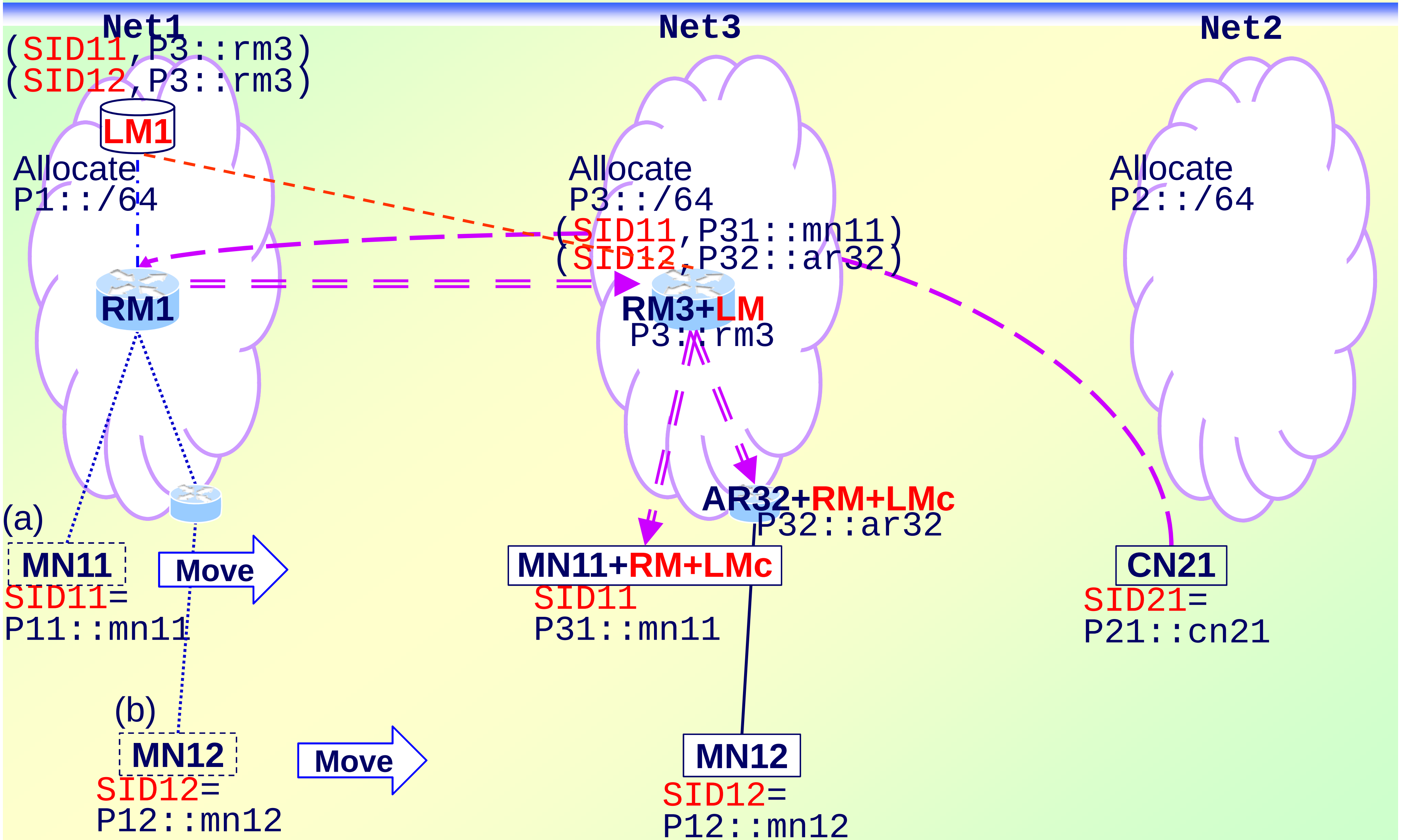
MIPv6/PMIPv6



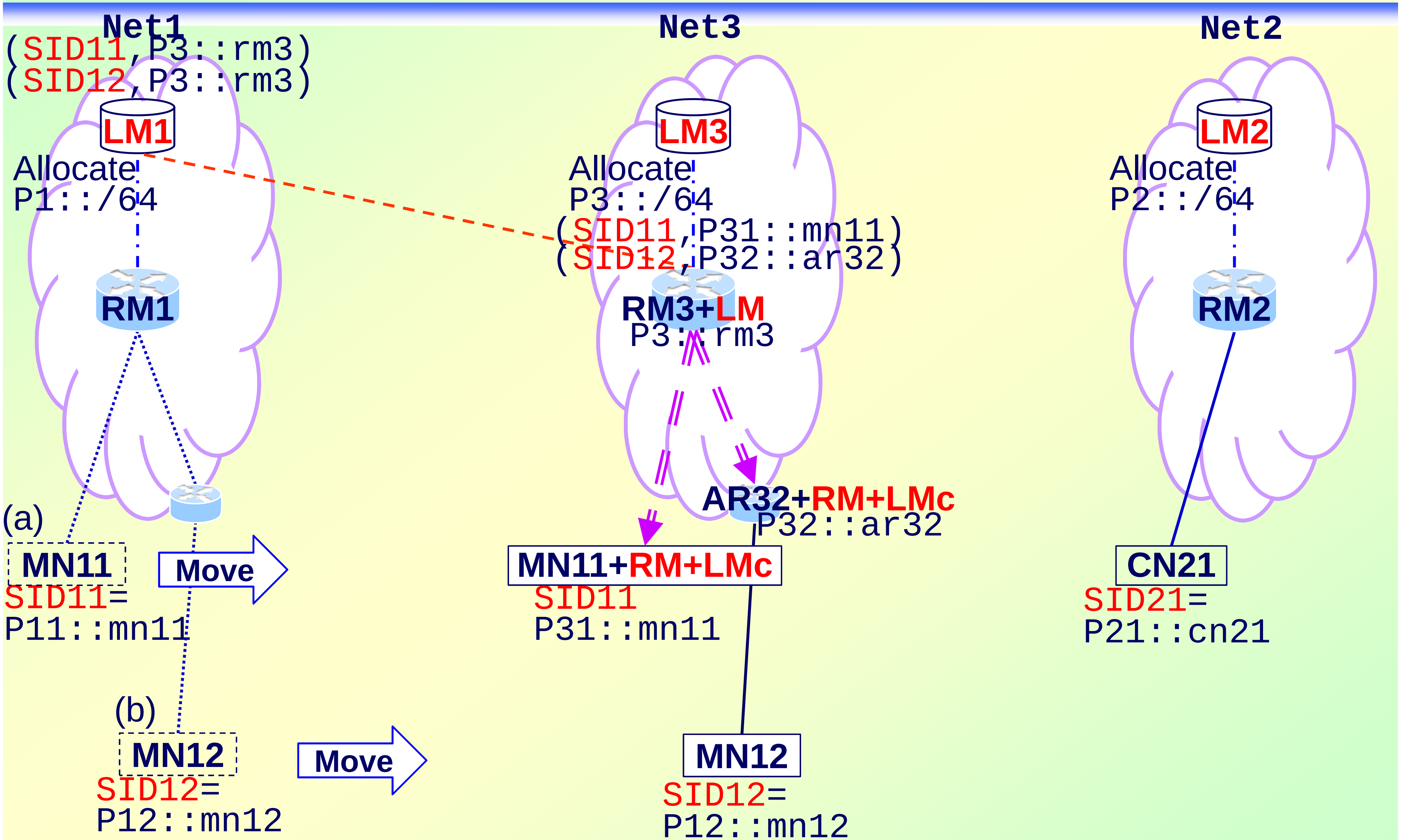
Host-based versus Network-based mobility management



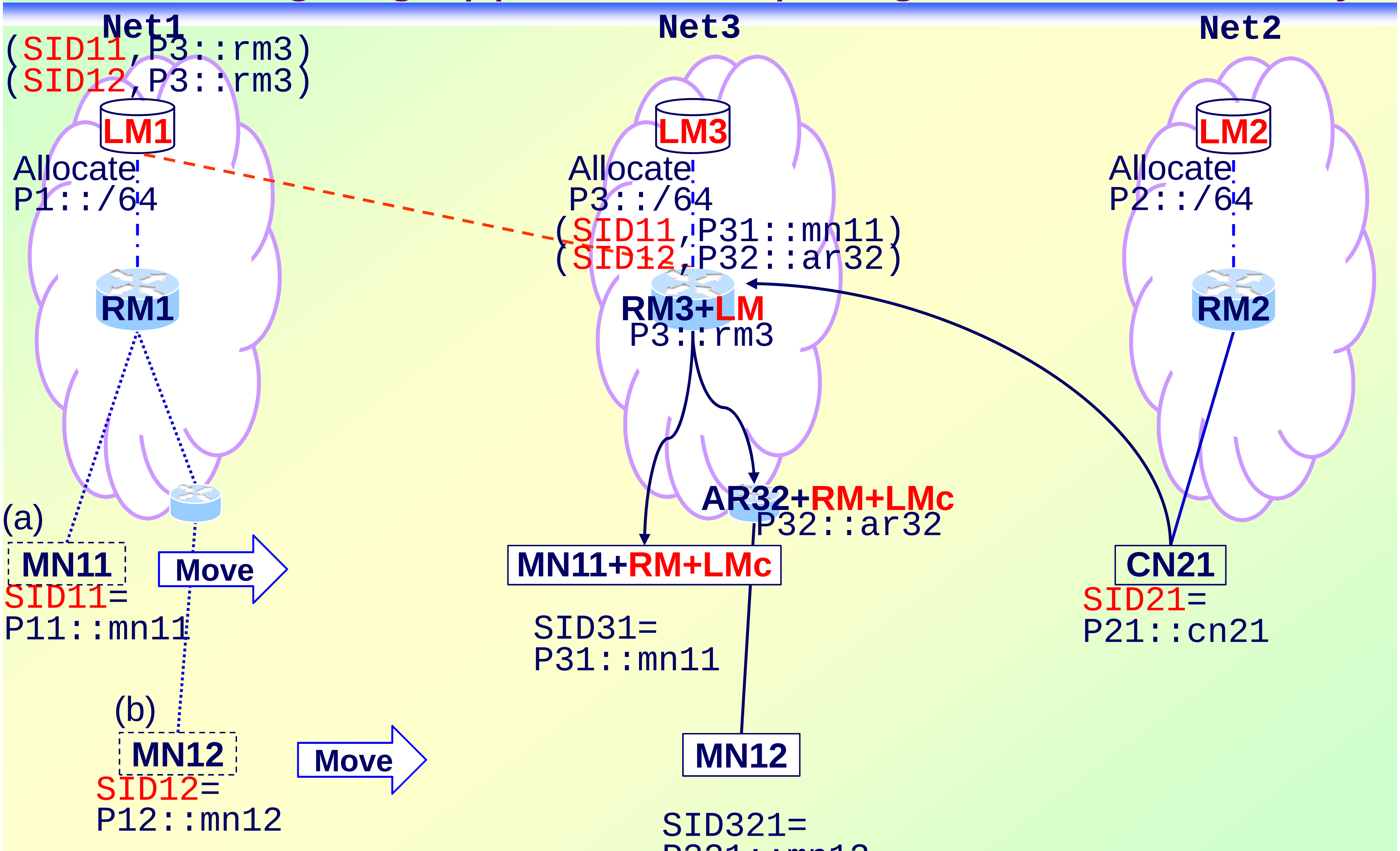
Hierarchical



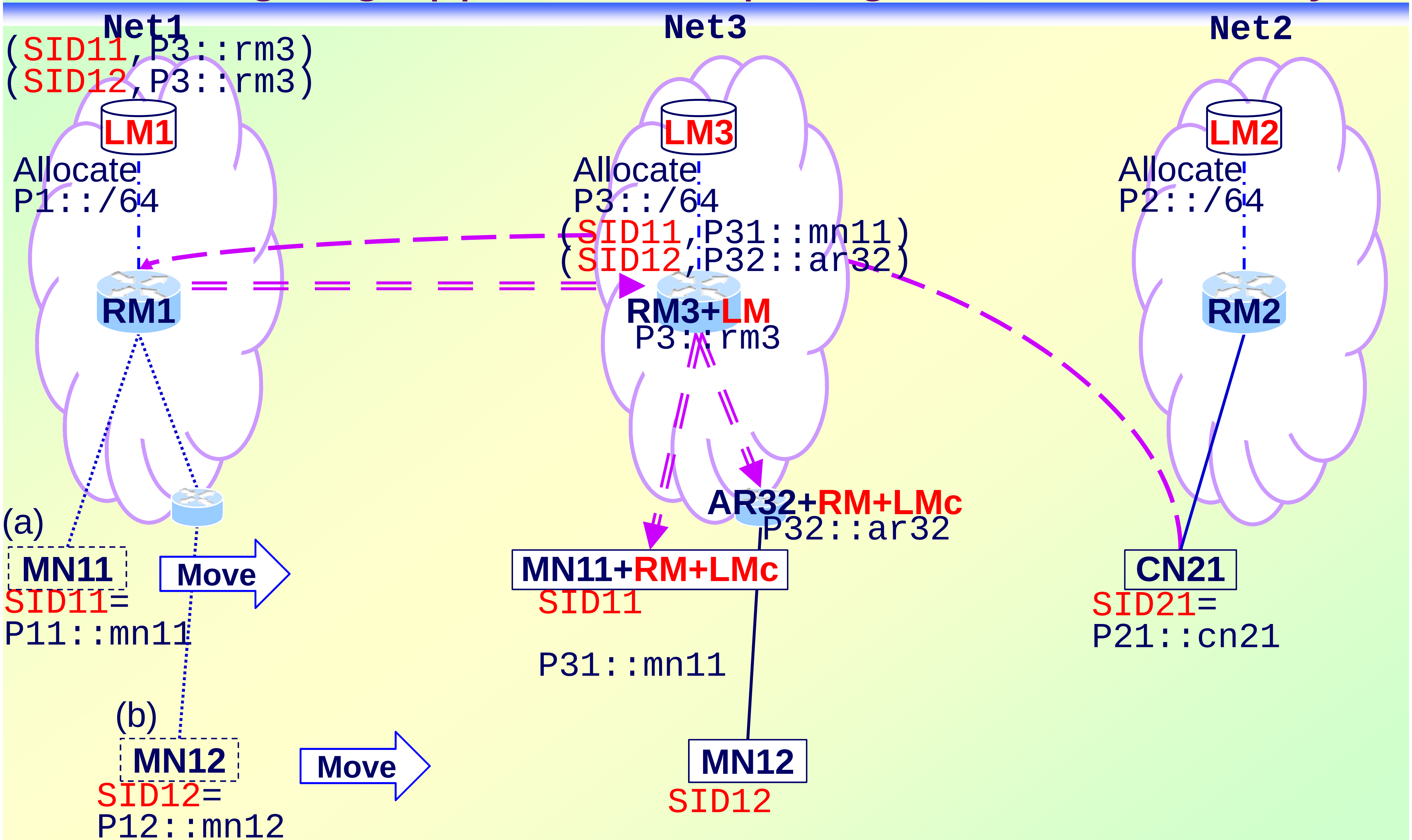
Deploying MM in each network



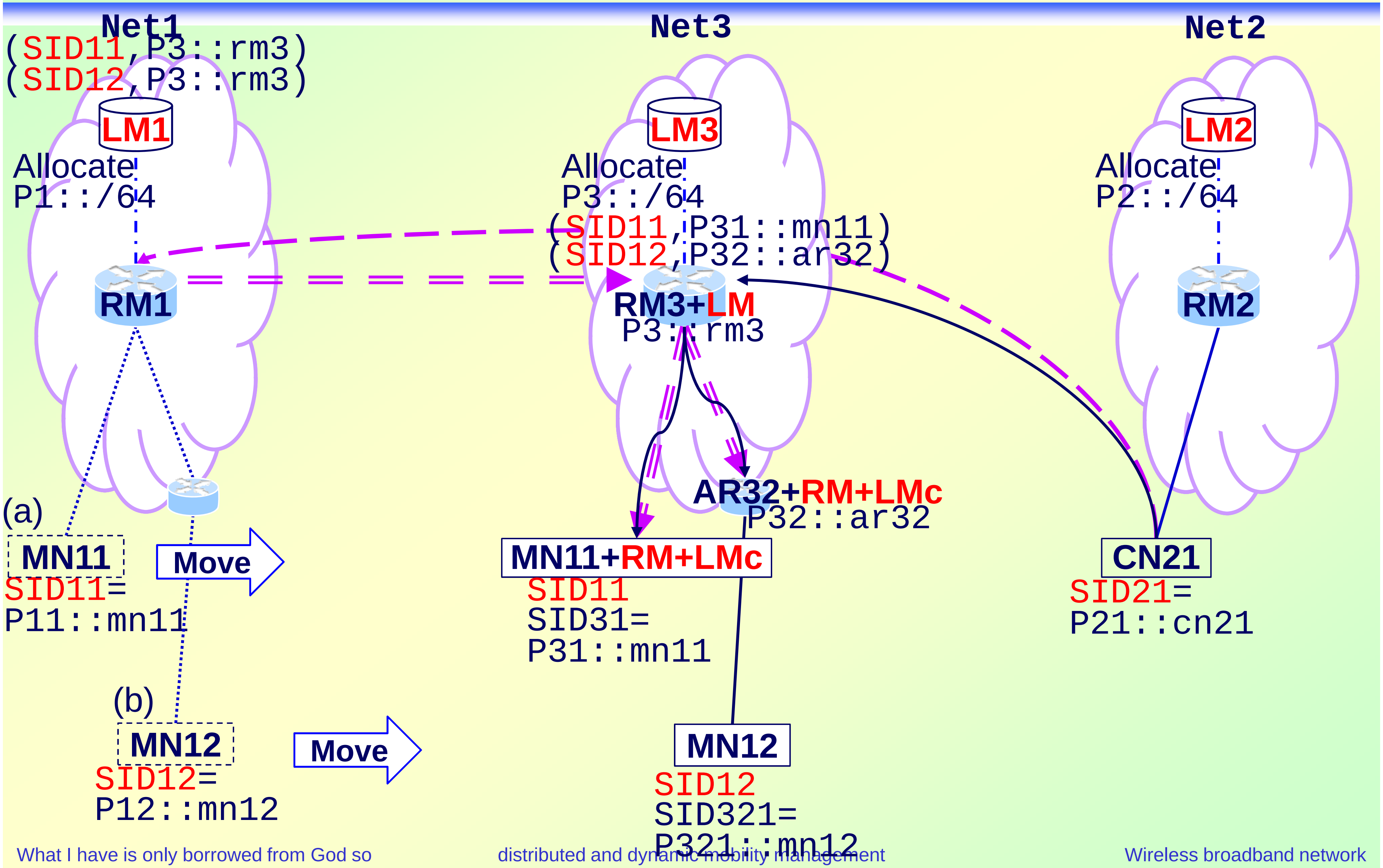
Selective mobility support
without ongoing application requiring session continuity



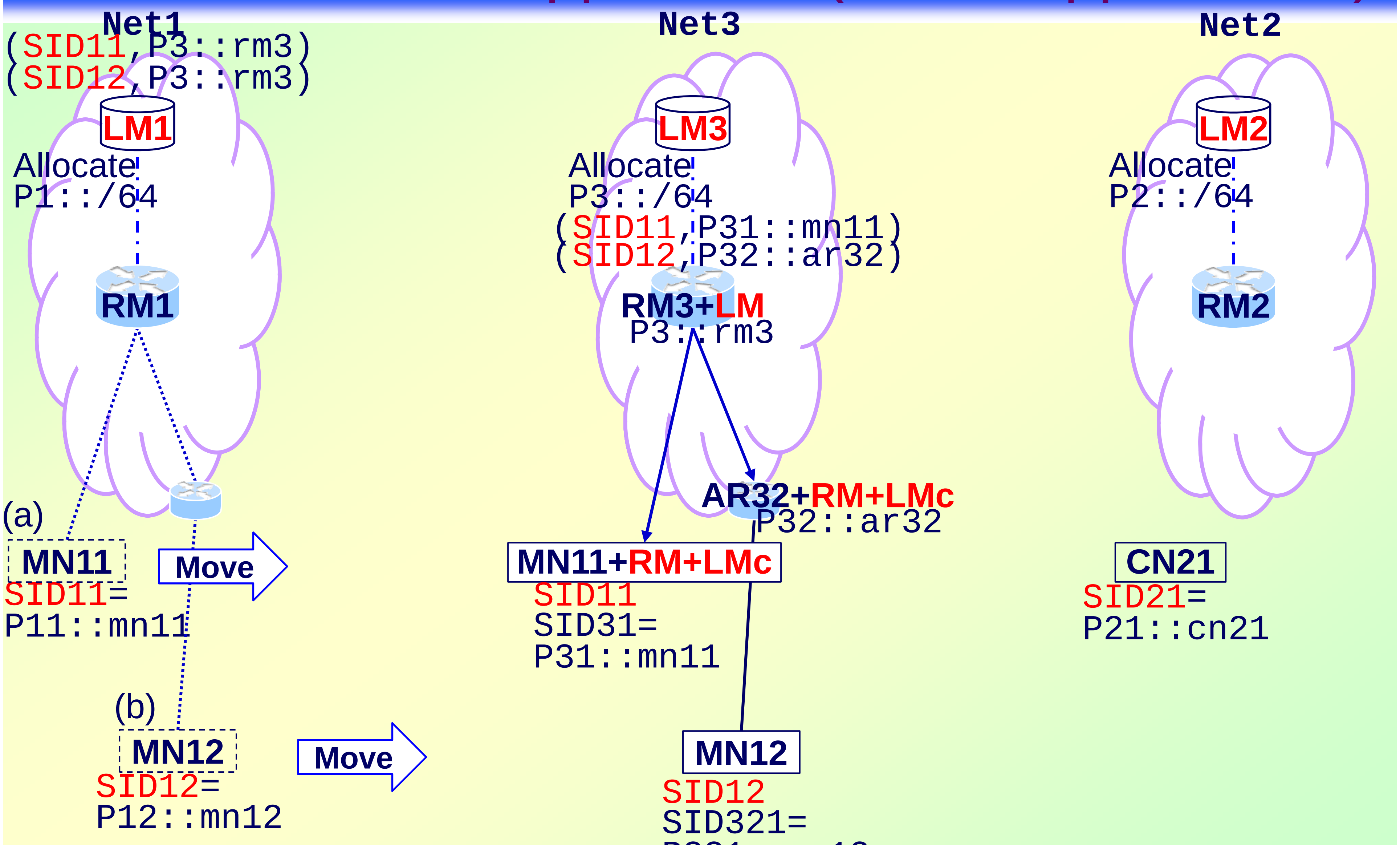
Selective mobility support
with ongoing application requiring session continuity



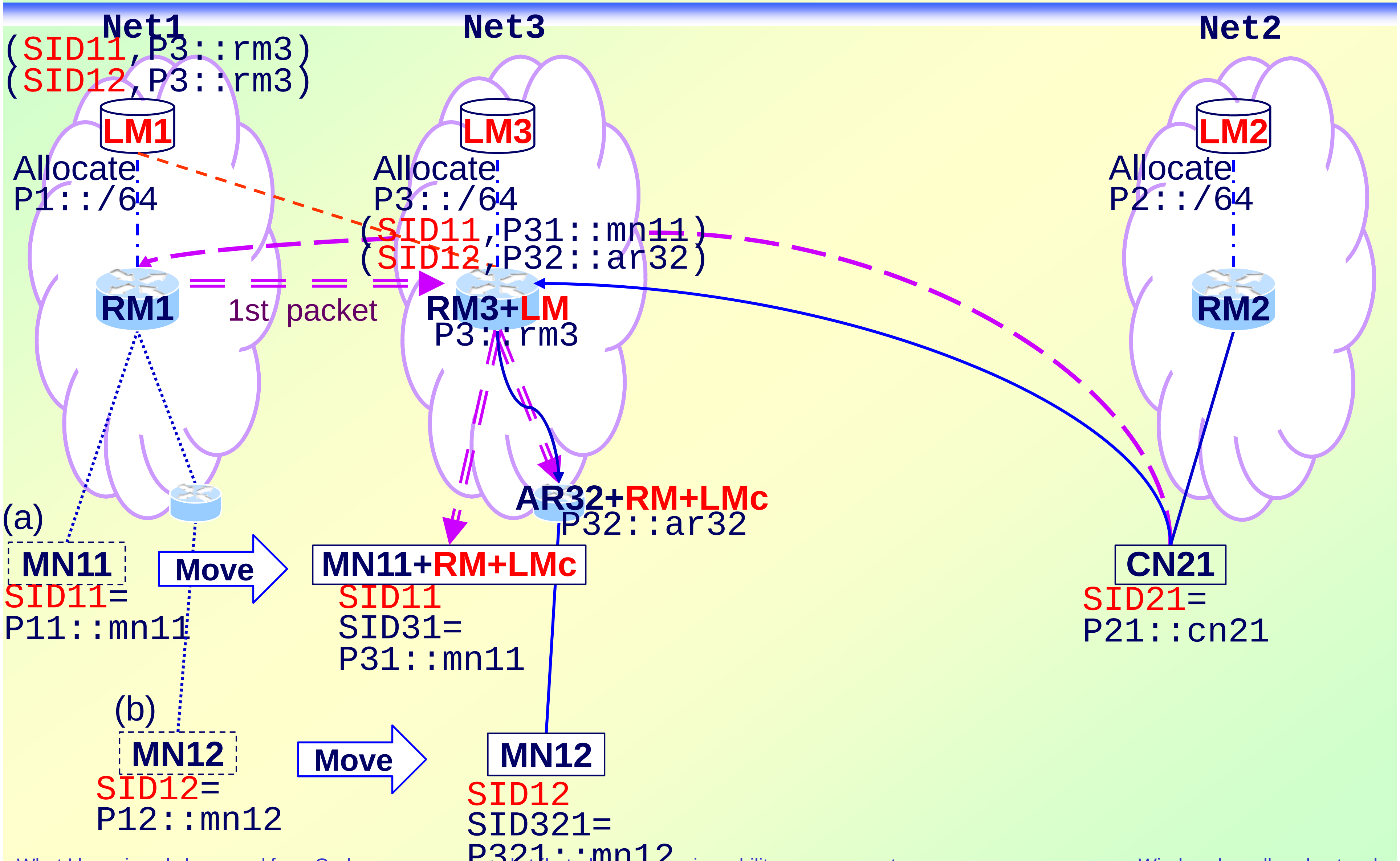
Selective mobility support



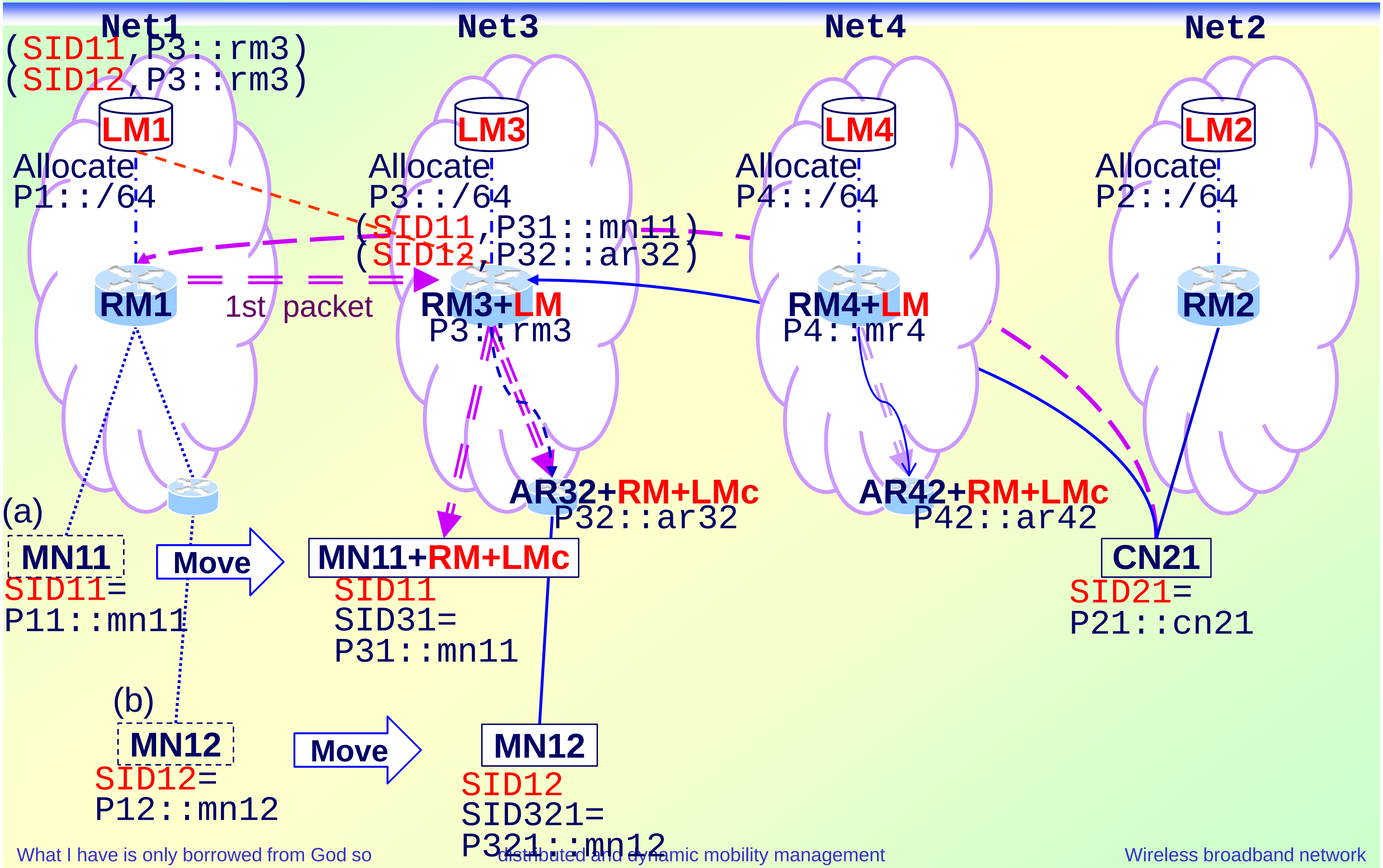
Mobility Management Framework: Home network of application (where appl started)



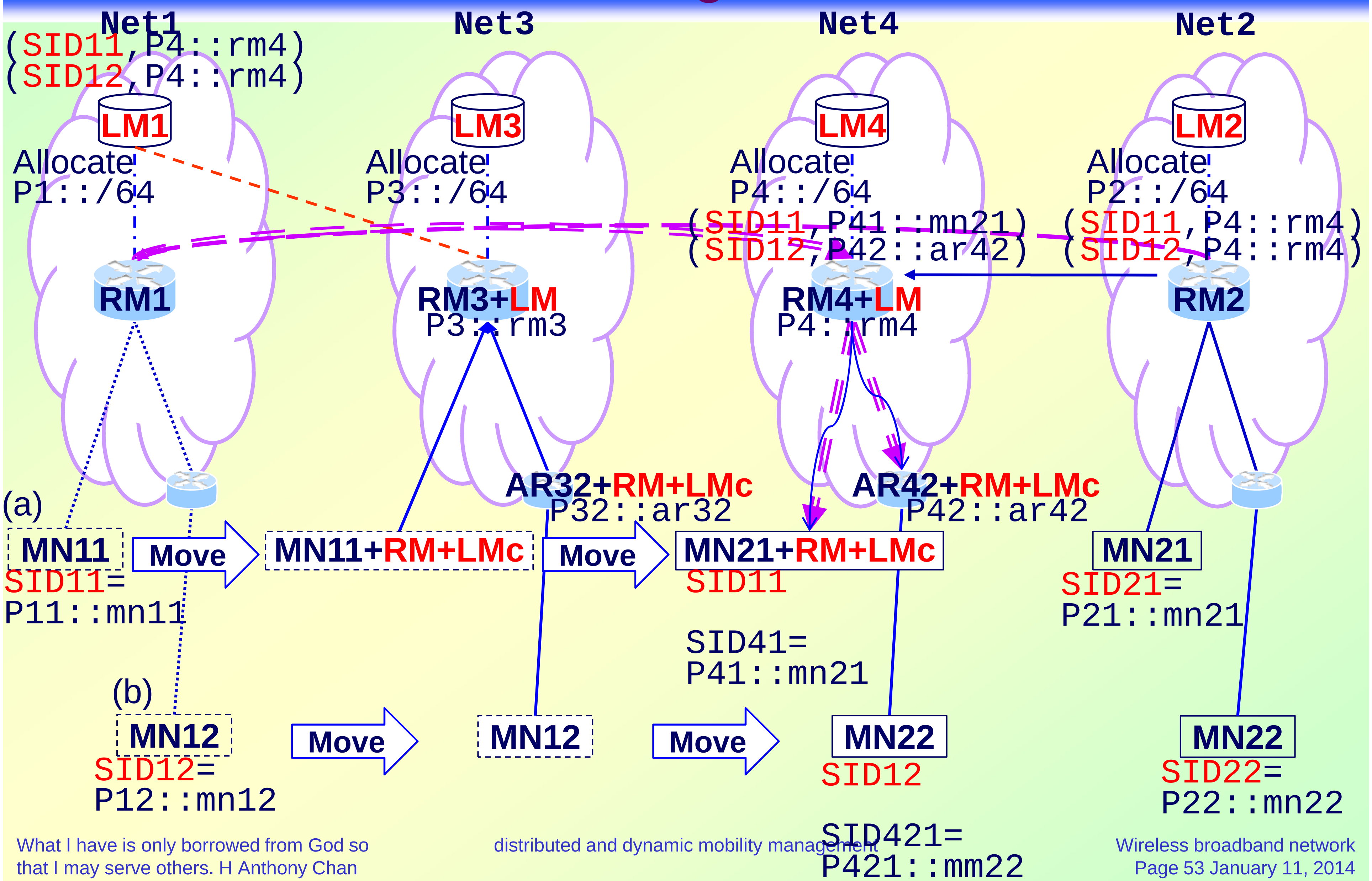
Selective mobility management



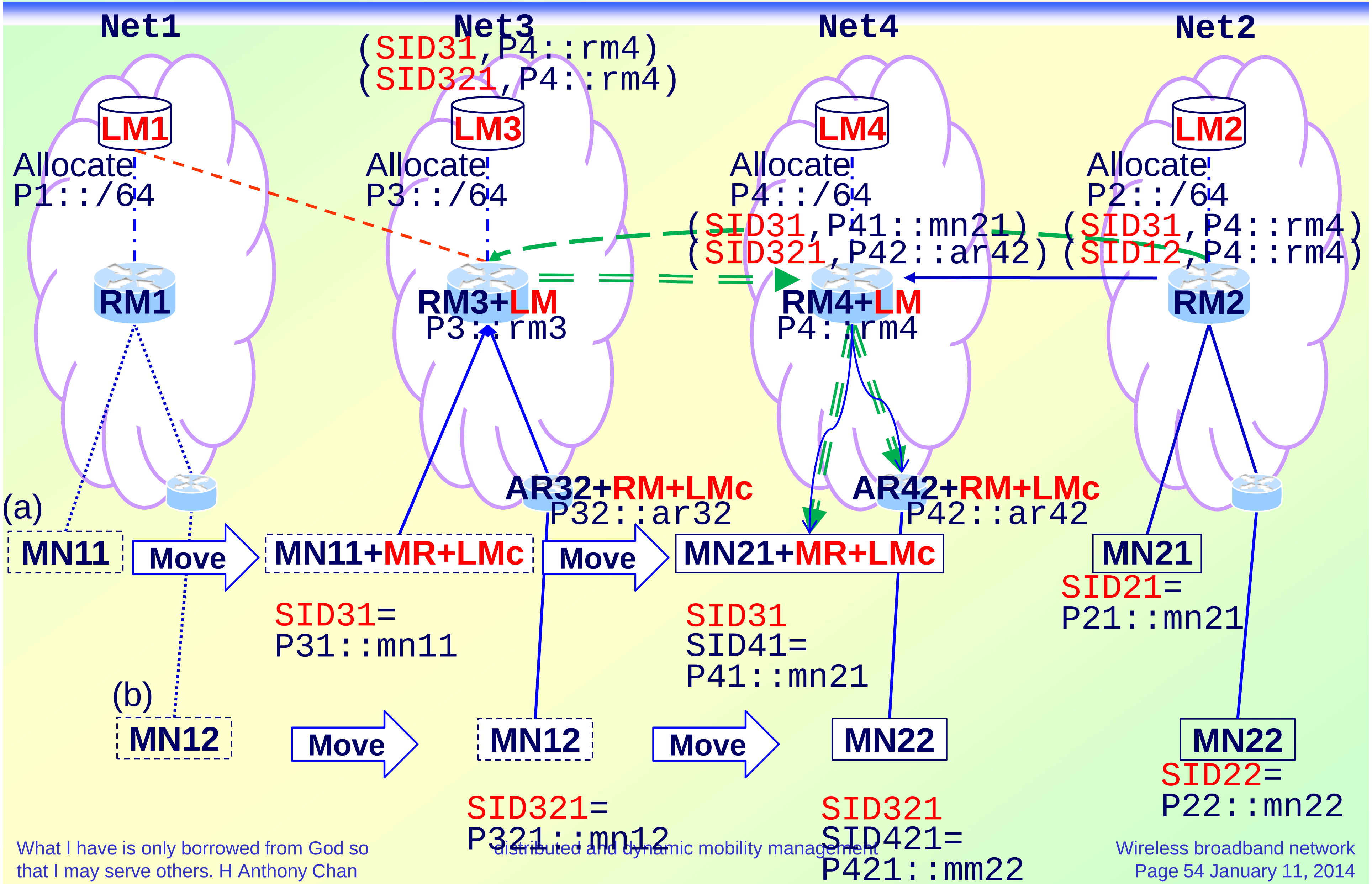
Selective mobility management



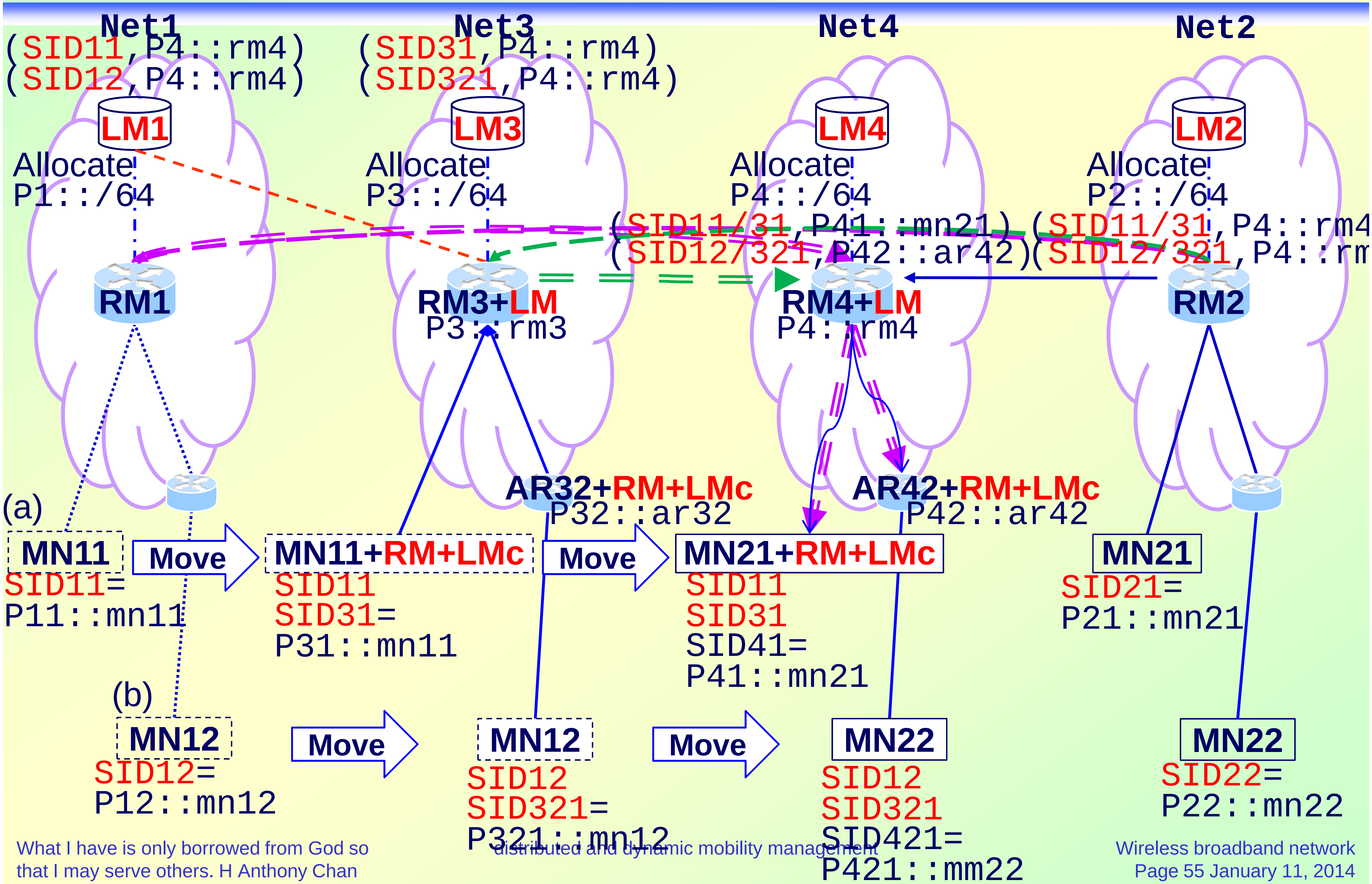
Successive move
MN moves again to Net4



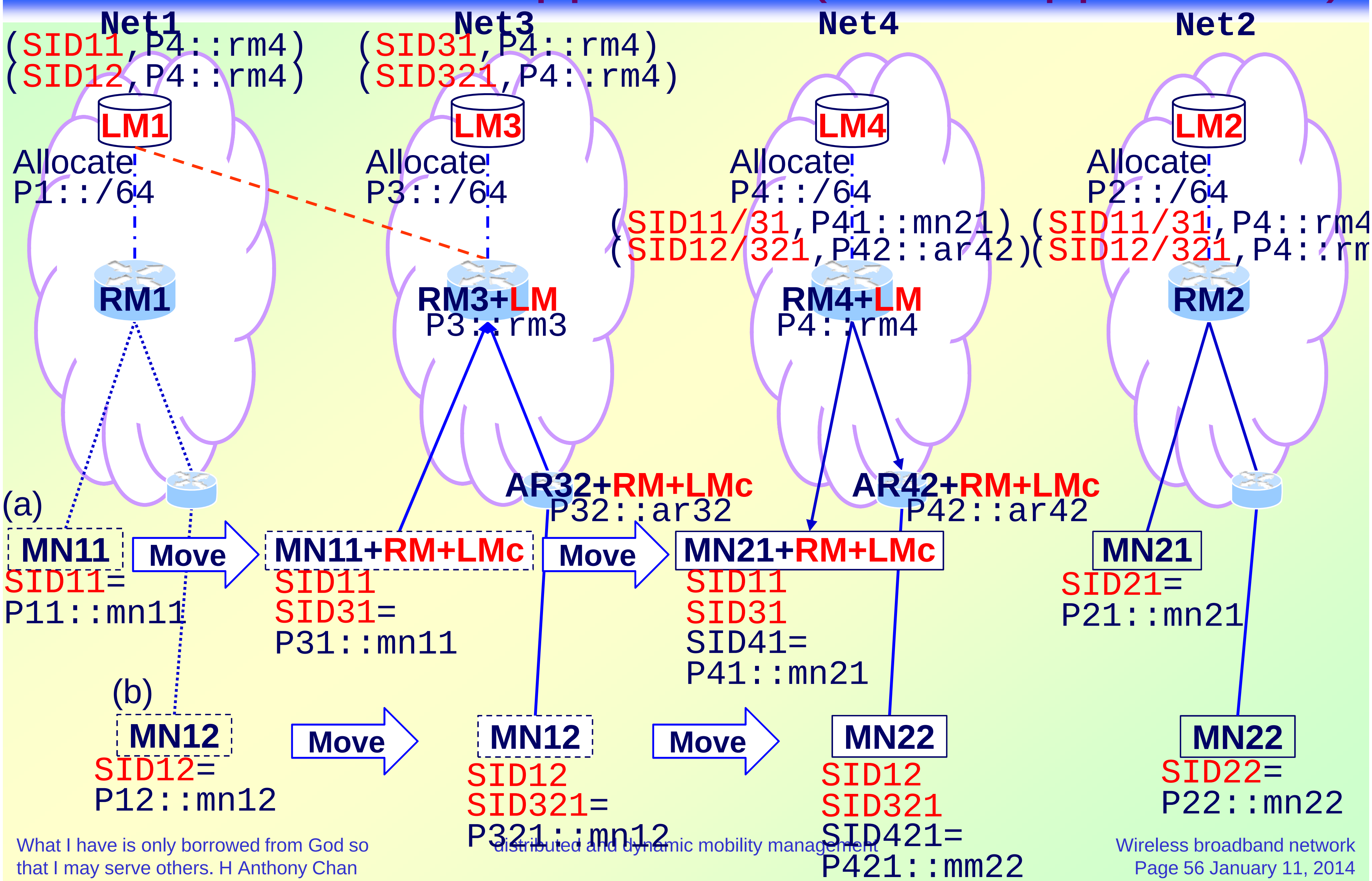
Successive move
MN's session initiated at Net3



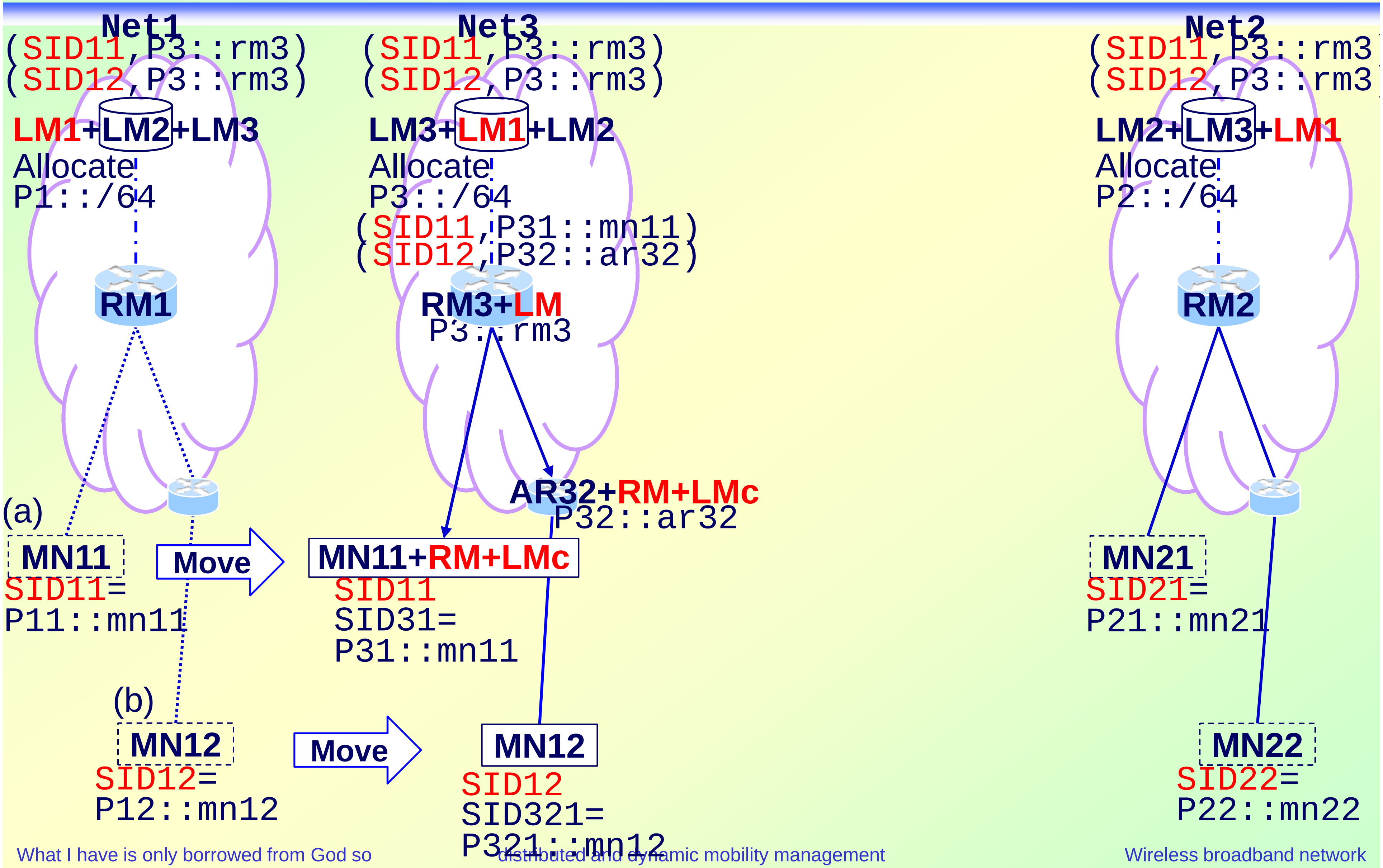
Successive move
MN's sessions initiated at Net1 and Net3



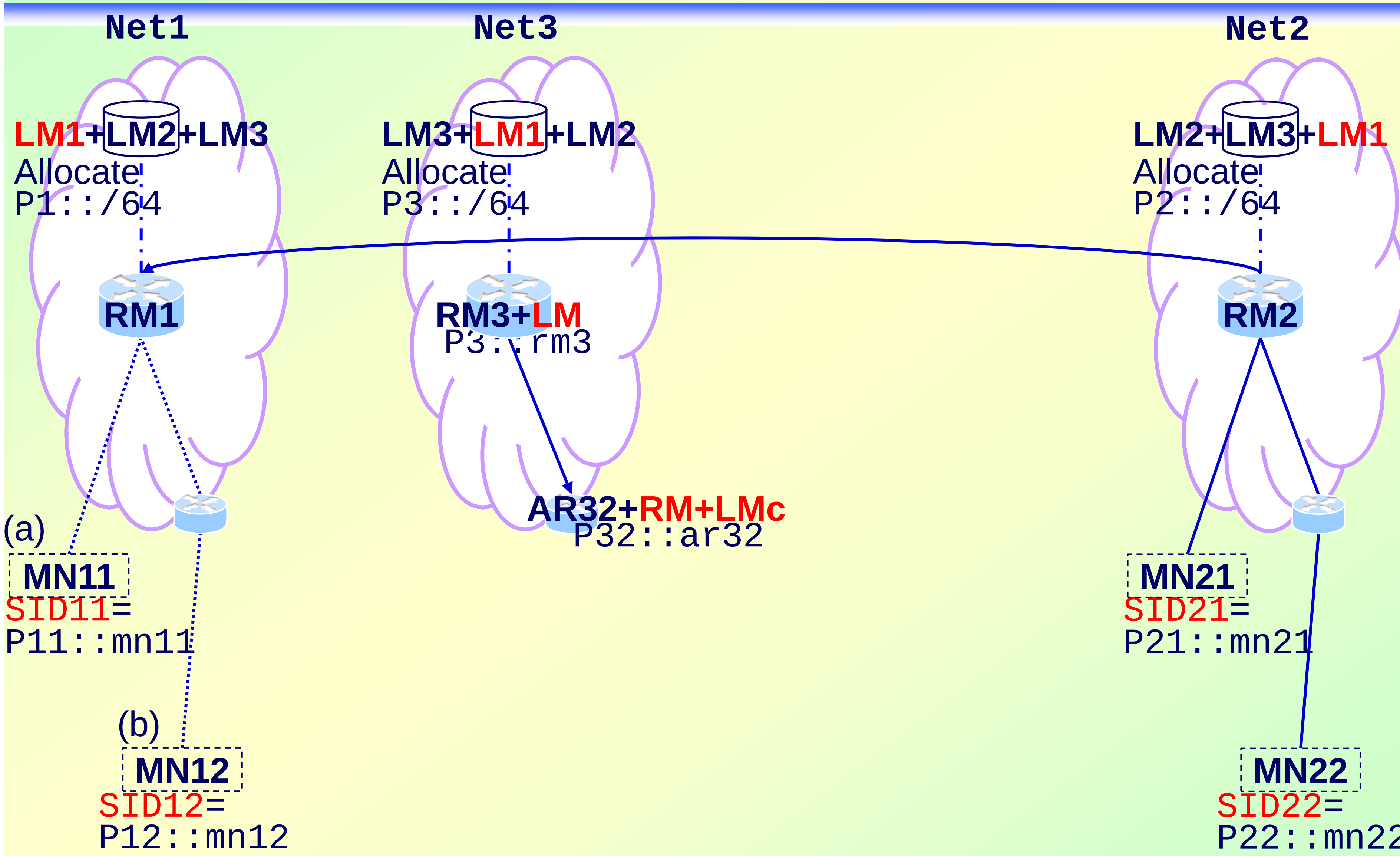
Mobility Management Framework: Home network of application (where appl started)



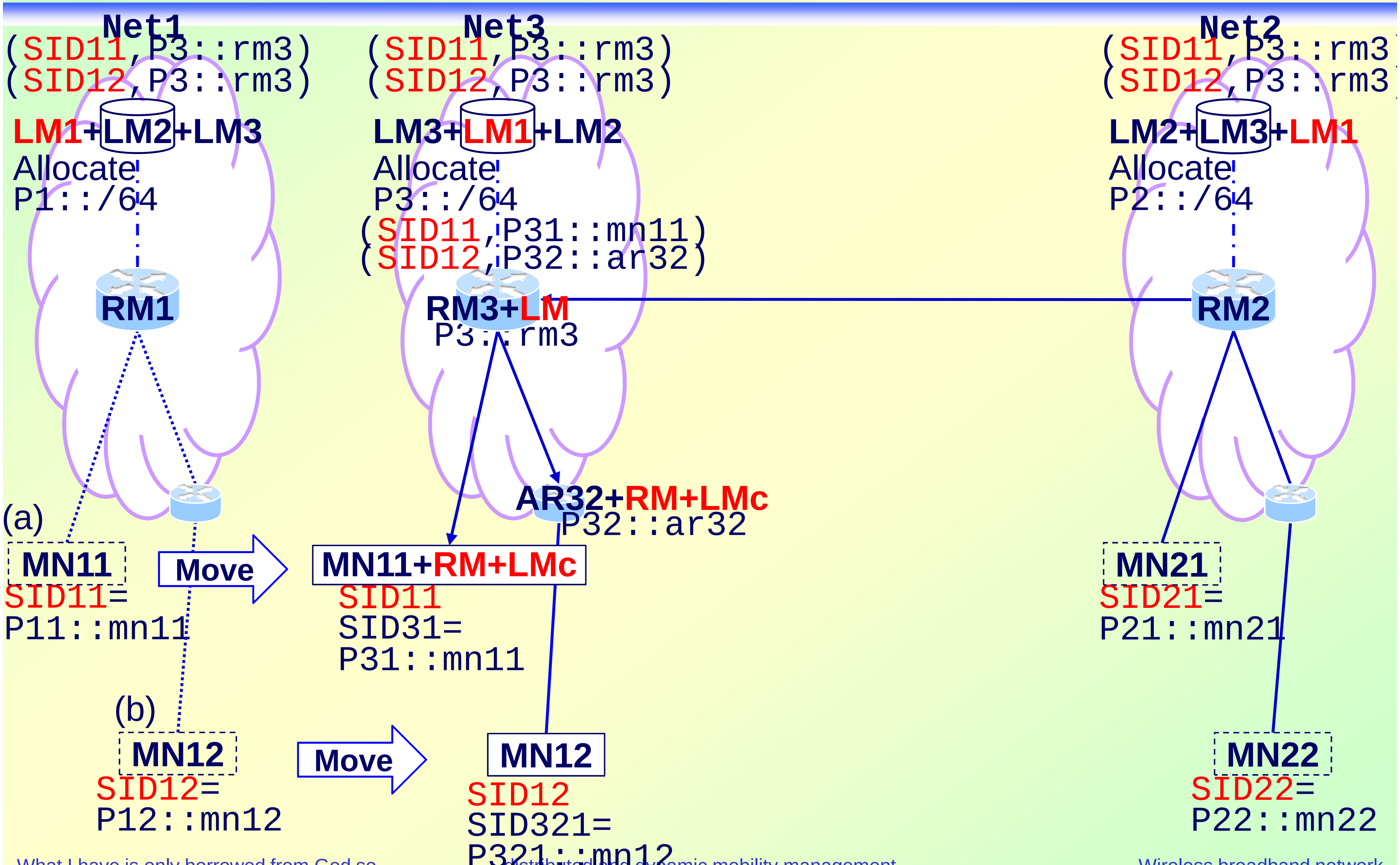
Copying LM info to all networks



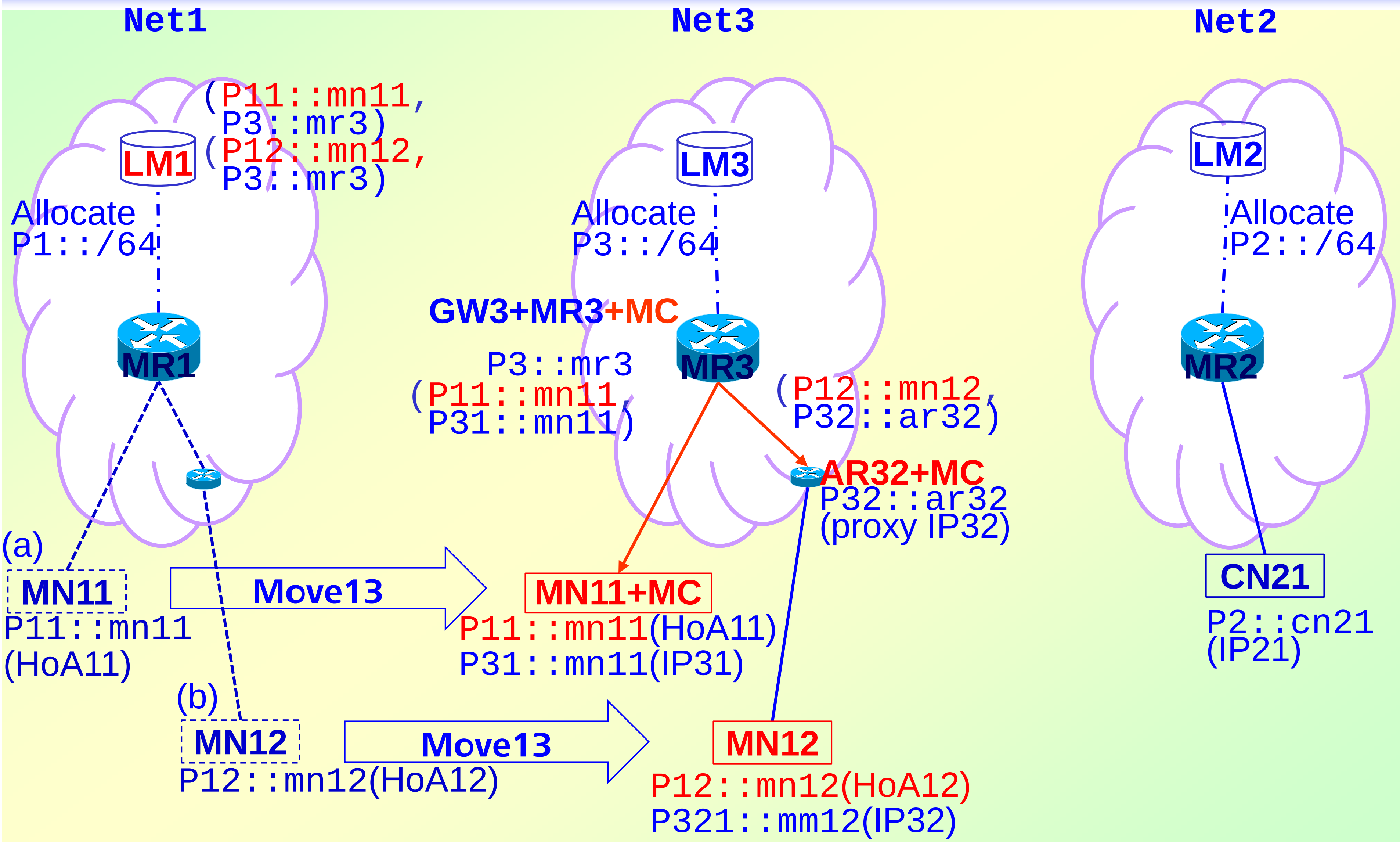
Copying LM info to all networks before handover



Copying LM info to all networks



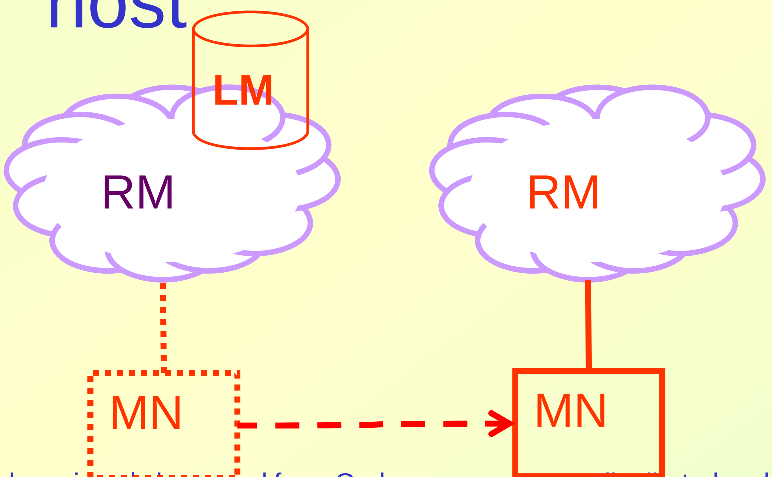
Mobility Management Framework:
HoA of application (in network where appl started)



Distributed mobility anchors-Architecture

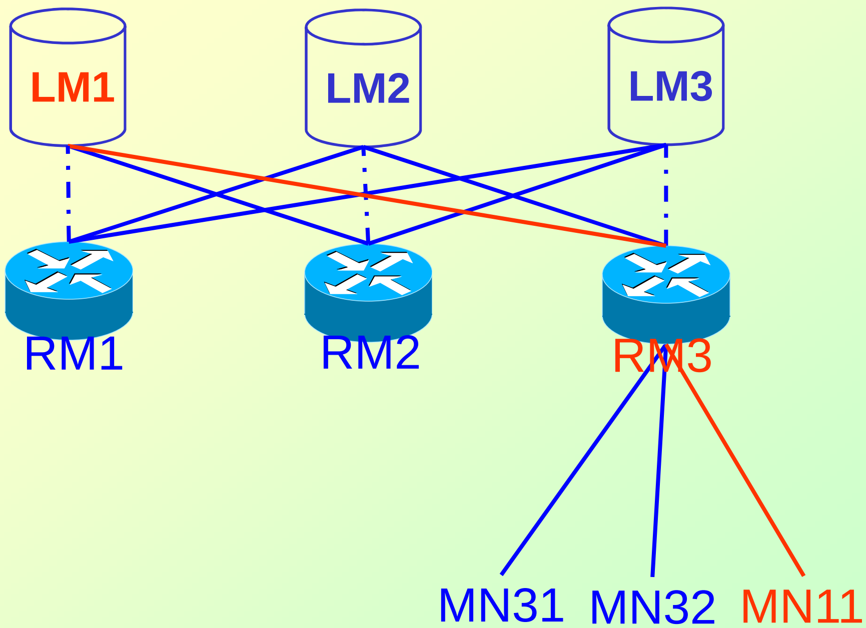
RM: Routing Management function (data plane)

- Network-based: RM in every network, at GW which may move down to AR in flat net
- Host-based: MR at host

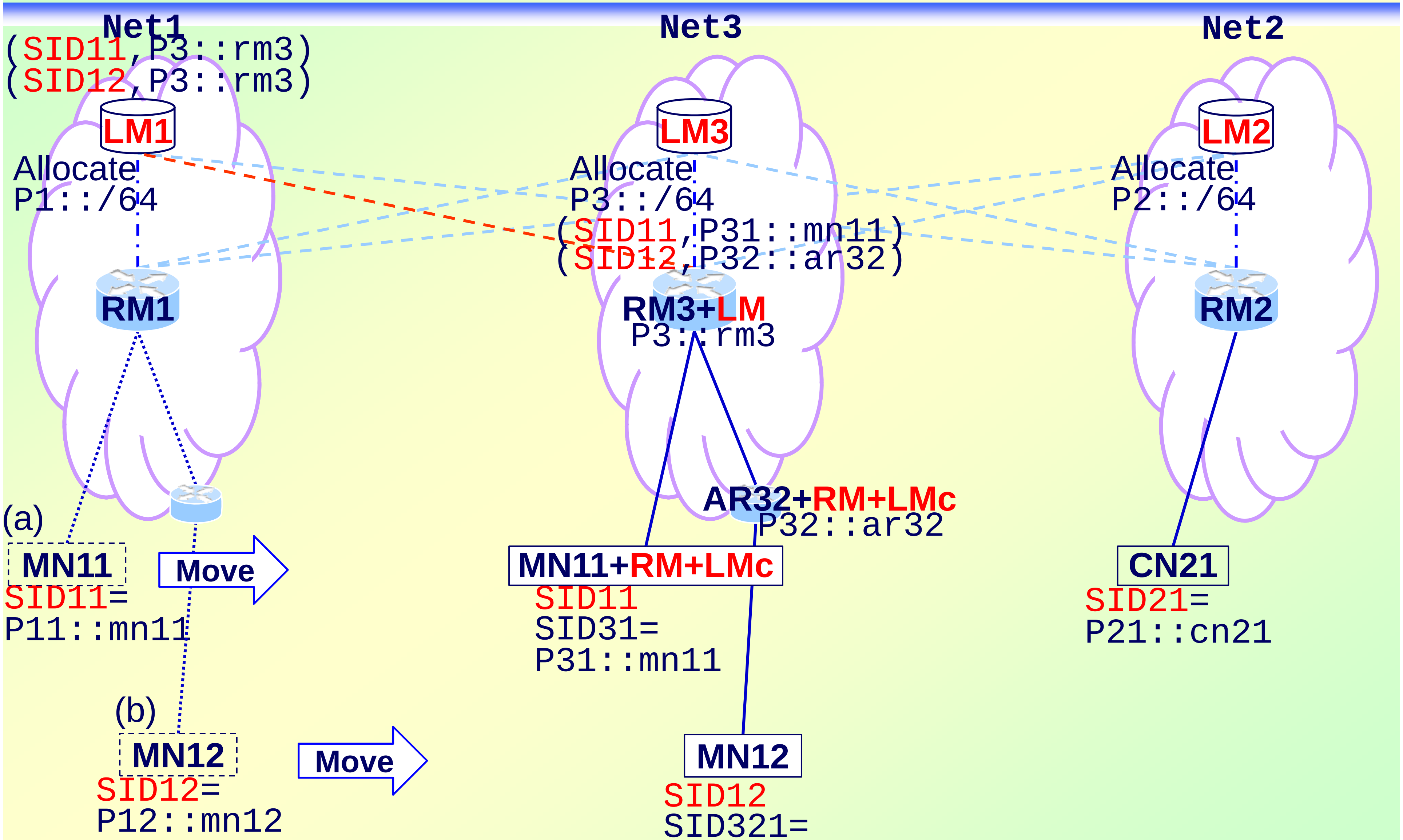


Location Management function (control plane)

- LM is supported by distributed database

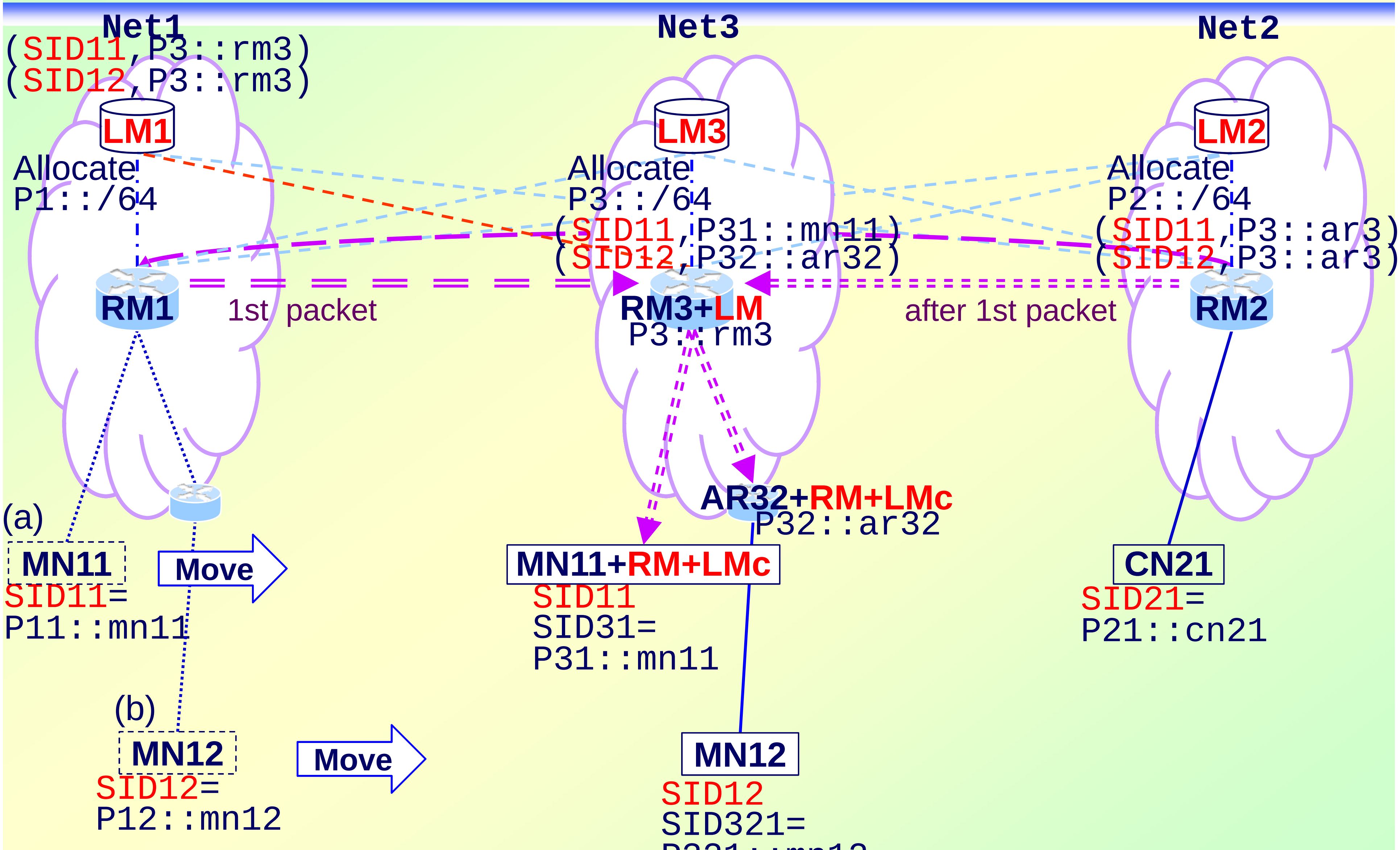


DMM



Net1
(SID11,P3::rm3)
(SID12,P3::rm3)
LM1
Allocate
P1::/64
RM1
(a)
MN11
SID11=
P11::mn11
Move
(b)
MN12
SID12=
P12::mn12
Move
Net3
LM3
Allocate
P3::/64
(SID11,P31::mn11)
(SID12,P32::ar32)
RM3+LM
P3::rm3
AR32+RM+LMc
P32::ar32
MN11+RM+LMc
SID11
SID31=
P31::mn11
MN12
SID12
SID321=
P321::mn12
Net2
LM2
Allocate
P2::/64
RM2
CN21
SID21=
P21::cn21

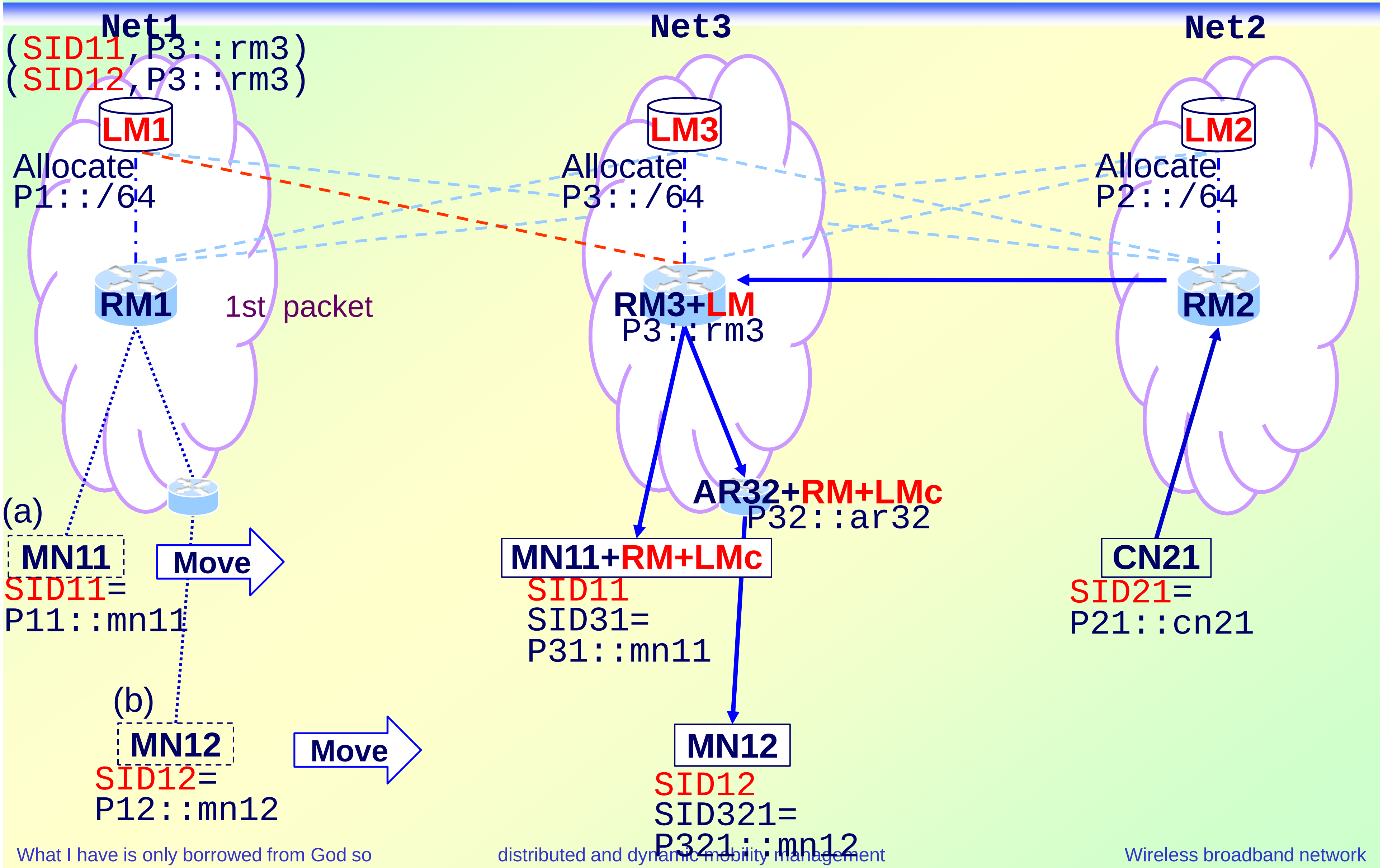
DMM


Net1
(SID11,P3::rm3)
(SID12,P3::rm3)
LM1
Allocate
P1::/64
RM1
1st packet
(a)
MN11
SID11=
P11::mn11
Move
(b)
MN12
SID12=
P12::mn12
Move
Net3
LM3
Allocate
P3::/64
(SID11,P31::mn11)
(SID12,P32::ar32)
RM3+LM
P3::rm3
AR32+RM+LMc
P32::ar32
MN11+RM+LMc
SID11
SID31=
P31::mn11
MN12
SID12
SID321=
P321::mn12
Net2
LM2
Allocate
P2::/64
(SID11,P3::ar3)
(SID12,P3::ar3)
RM2
after 1st packet
CN21
SID21=
P21::cn21

Distributed mobility anchors

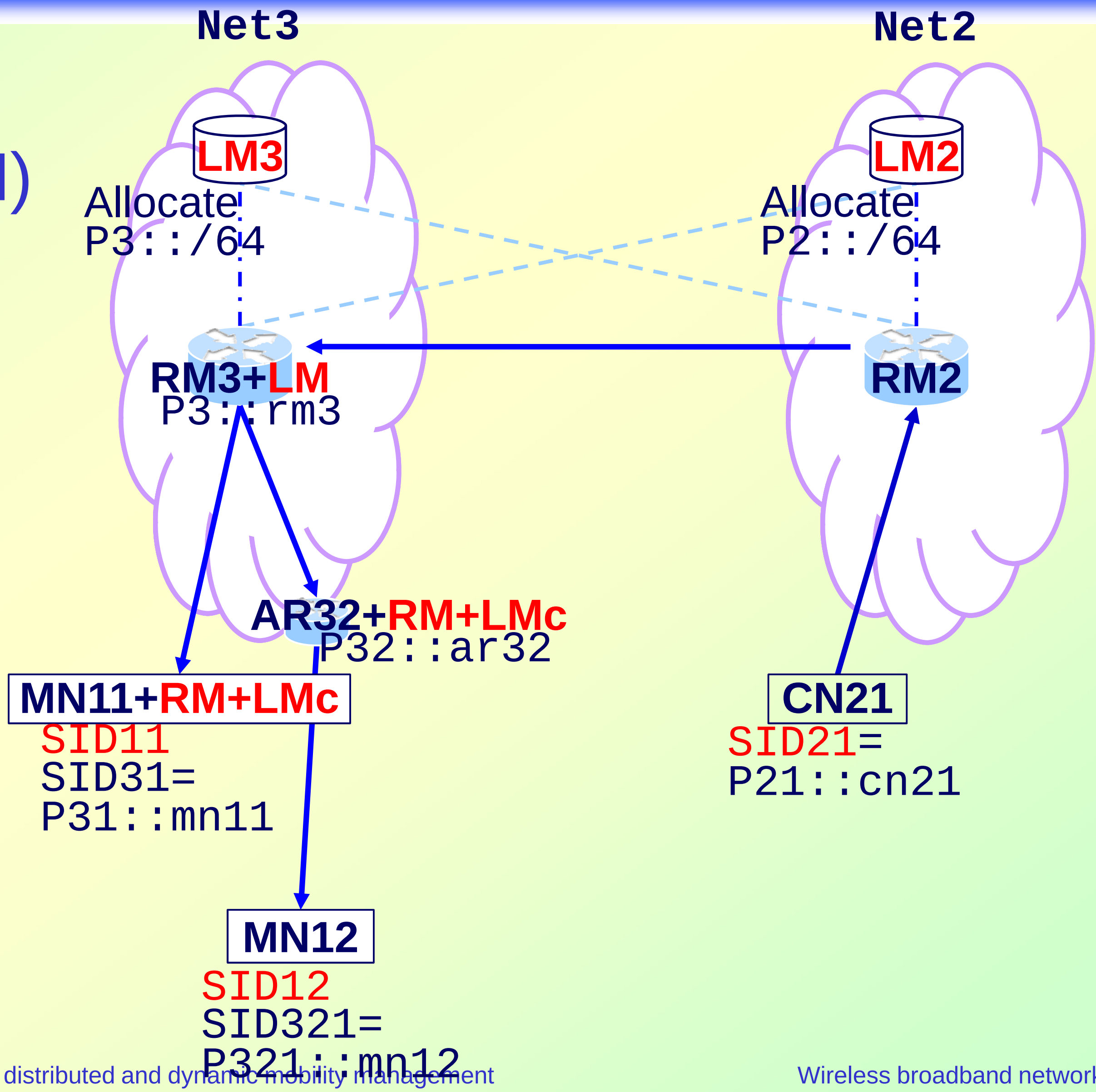
- ♦ Distributed versus centralized mobility anchors
- ♦ Splitting control and data planes: Architecture
- ♦ Unified formulation of Internet mobility
- ♦ DMM Route optimization mechanism example

DMM
direct route



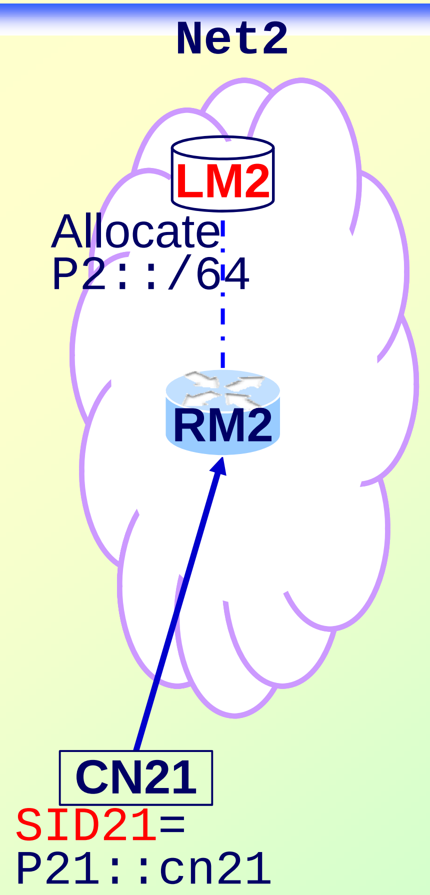
DMM route segments

- CN—MR(CN)
- MR(CN)—MR(MN)
- MR(MN)—MN



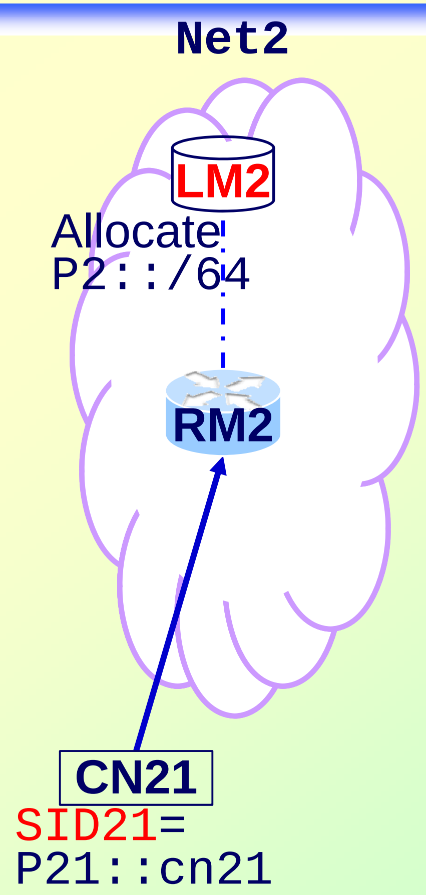
DMM
CN—MR(CN)

- CN—MR(CN)
- MR(CN)—MR(MN)
- MR(MN)—MN



DMM
CN—MR(CN)

- Co-locate the MR function at a convenient location to which the packets will always pass. Such locations may be a gateway (GW) or an AR.
- Use anycast to route the packets to the nearest MR function.



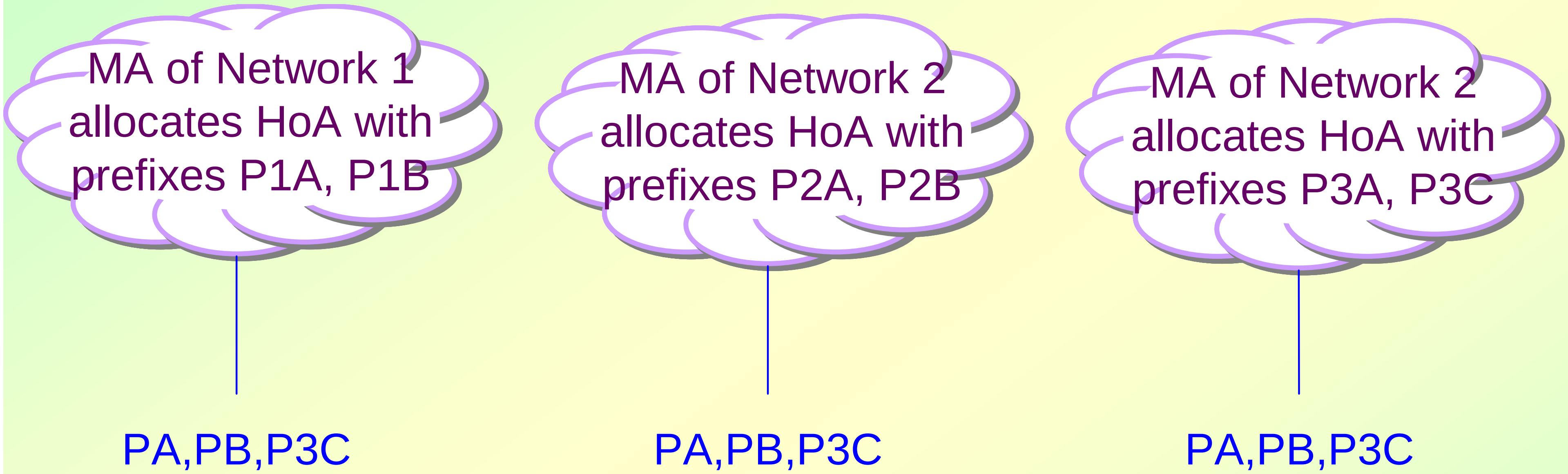
Anycast

- Use anycast to route the packets to the nearest MR function.
- Each MR includes all the HoAs in its route announcements as if each of them is the destination for the HoA. Such route announcements affect routing tables such that the packets destined to a HoA will be routed to the nearest MR.

Anycast

- Use anycast to route the packets to the nearest MR function.
- Each MA in its network owns a unique set of IP prefixes to allocate home network prefixes or HoAs to the MNs registered to that network. The HoA prefixes of all the MAs form a superset of HoA prefixes. Some prefixes in this superset may be aggregatable, but some may not. Each MA advertises the superset of these HoA prefixes using anycast so that an IP packet sent to any HoA will be intercepted by the MA nearest to the sender.

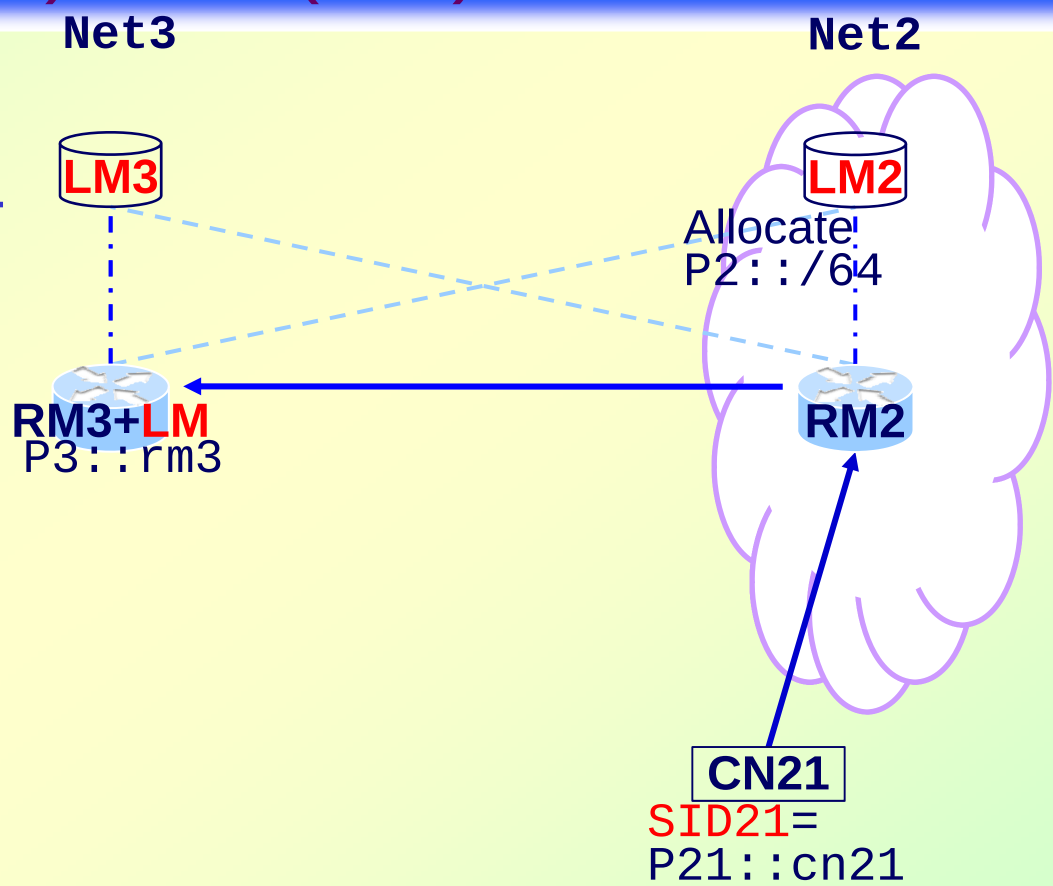
Example of Anycast of HoA Prefixes



- The MR in each network broadcasts the superset of prefixes PA, PB, P3C, where PA is the aggregate of P1A, P2A and P3A, and PB is the aggregate of P1B and P2B.

DMM
MR(CN)—MR(MN)

- MR(CN) pulls the LM information from LM1
- LM information is pushed to MR(CN)



DMM
MR(CN)—MR(MN)

- MR(CN) pulls the needed internetwork location information by querying the LM database and uses the result to tunnel the packets to MR(MN).
- Optionally the first packet or the first few packets may be forwarded using MIPv6 or PMIPv6 while the database query is perform in the meantime. Then, the first packet may incur a non-optimal route rather than wait for the query reply. After receiving the reply, subsequent packets are tunneled directly to MR(MN). The query result may be cached for forwarding future packets.

DMM
MR(CN)—MR(MN)

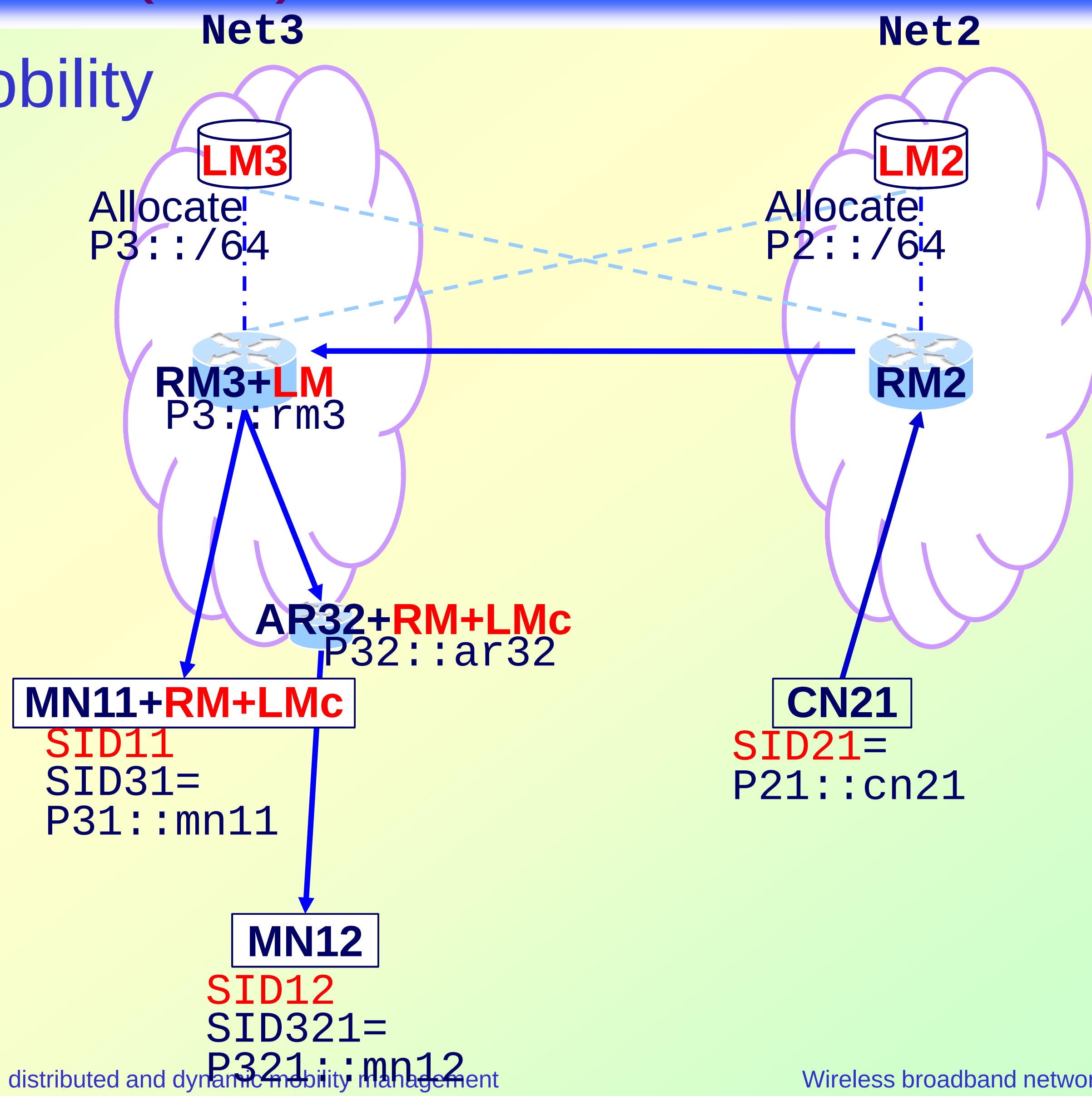
- MR(HoA) pushes the LM information of MN to MR(CN) which may then cache this LM binding and use this information to tunnel such future packets directly to MR(MN).

DMM
MR(CN)—MR(MN)

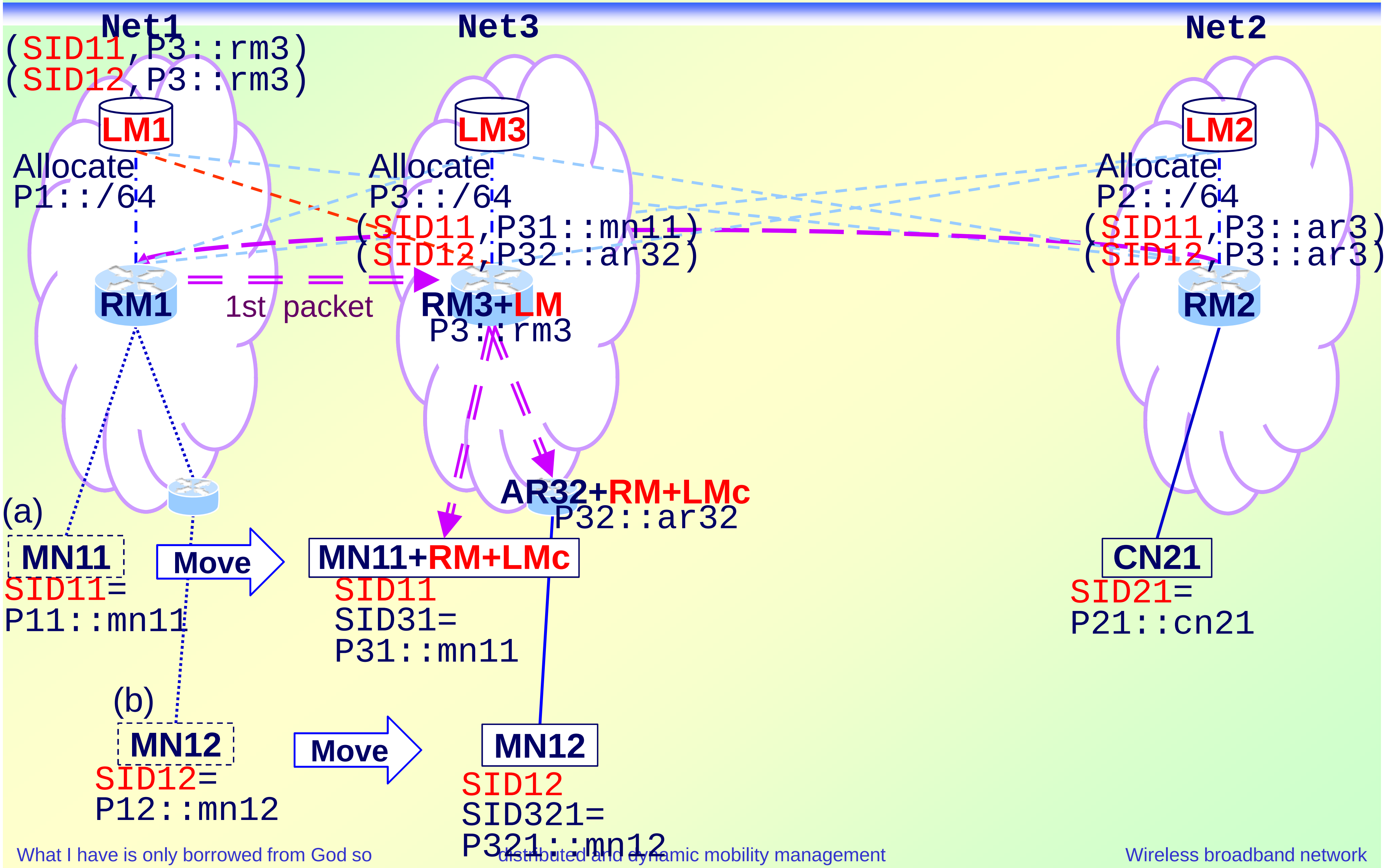
- MR(CN) routes the first packet to the home network using MIPv6 or PMIPv6. The MR at the home network, MR(HoA), intercepts this packet and, with the help its LM server, knows whether the MN has moved to a different network and uses the LM mapping to tunnel the packet to MR(MN). Meanwhile
- MR(HoA) pushes the LM information of MN to MR(CN) which may then cache this LM binding and use this information to tunnel such future packets directly to MR(MN).

DMM
MR(MN)—MN

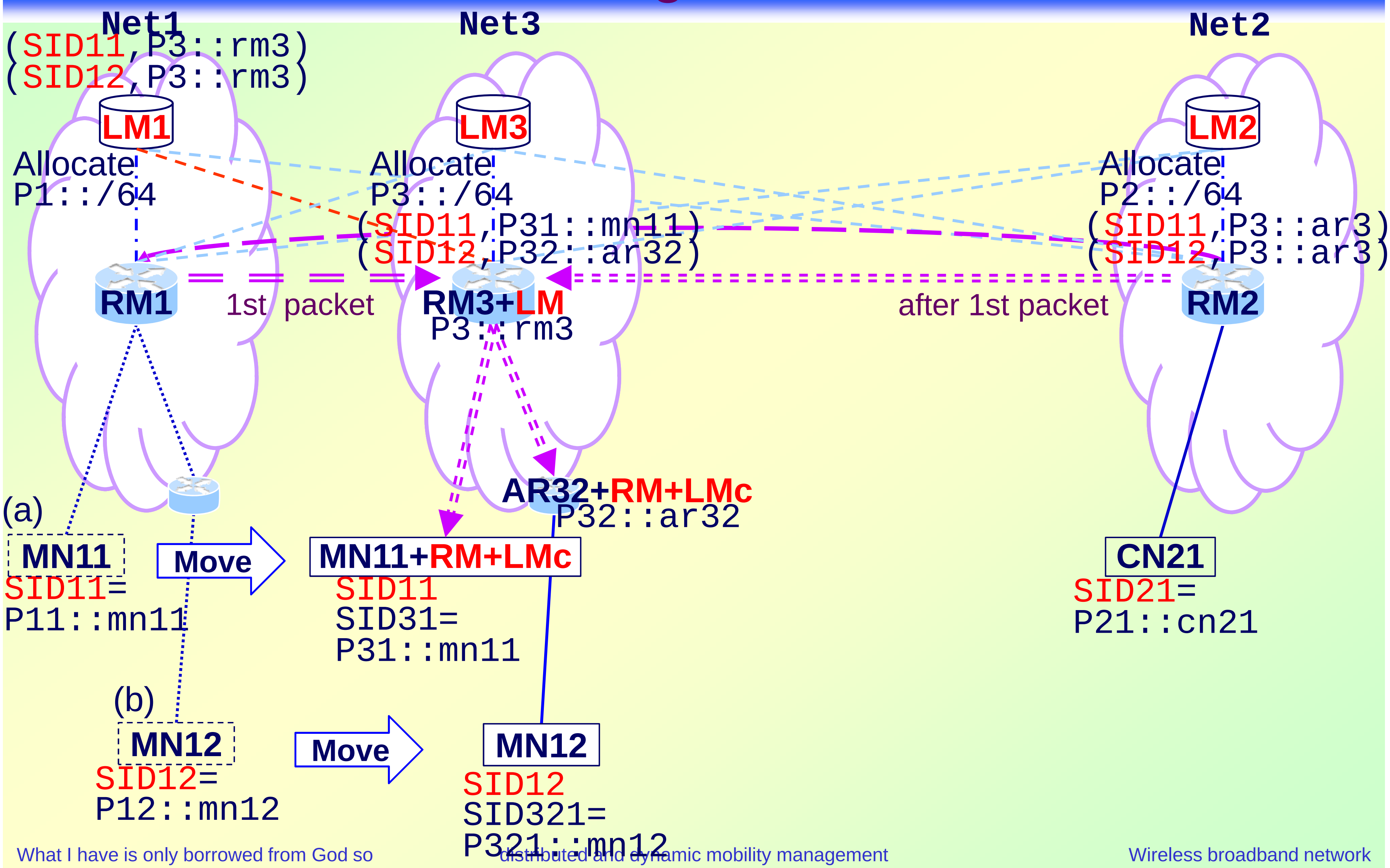
- Intra-network mobility management



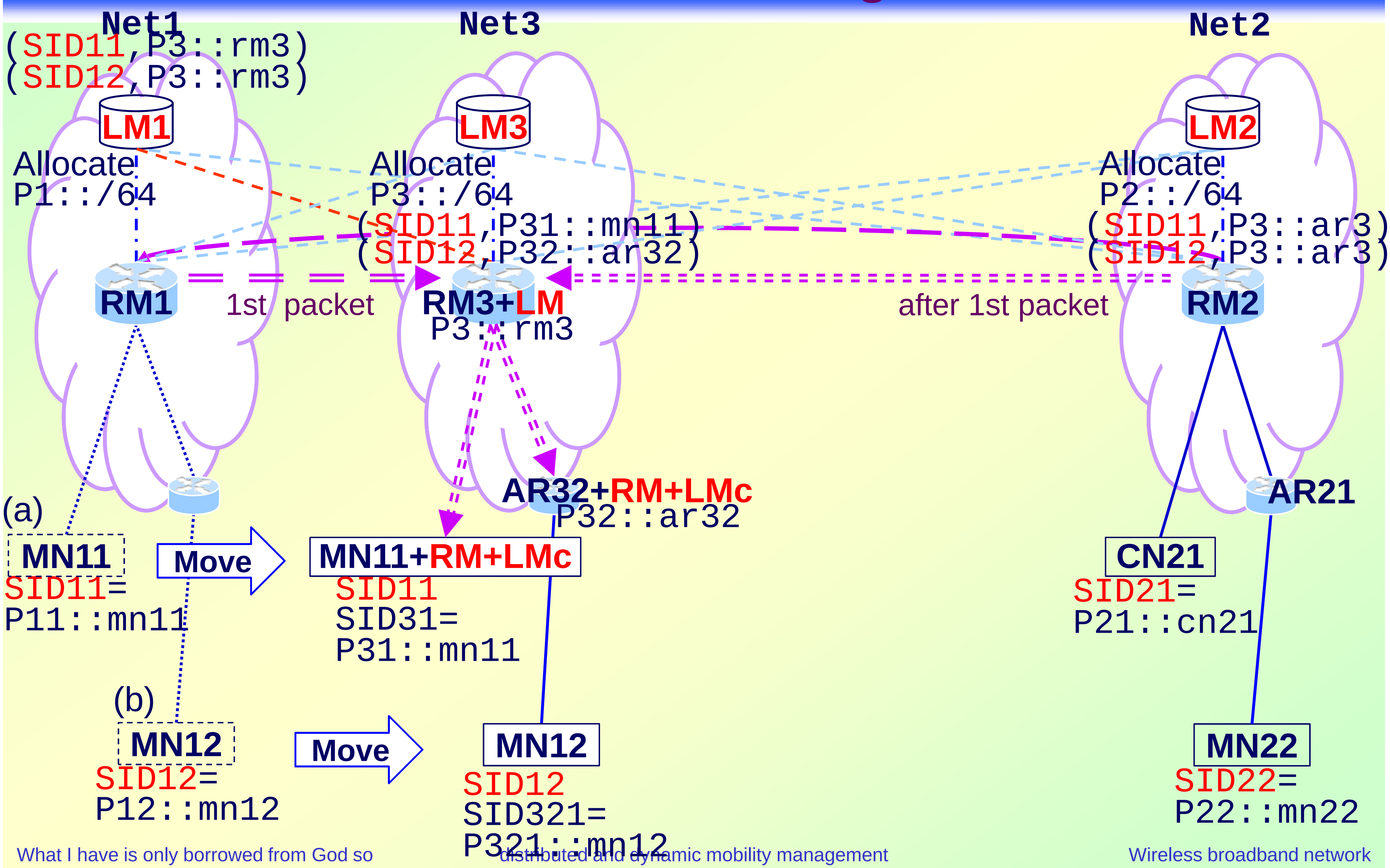
Receiving 1st packet



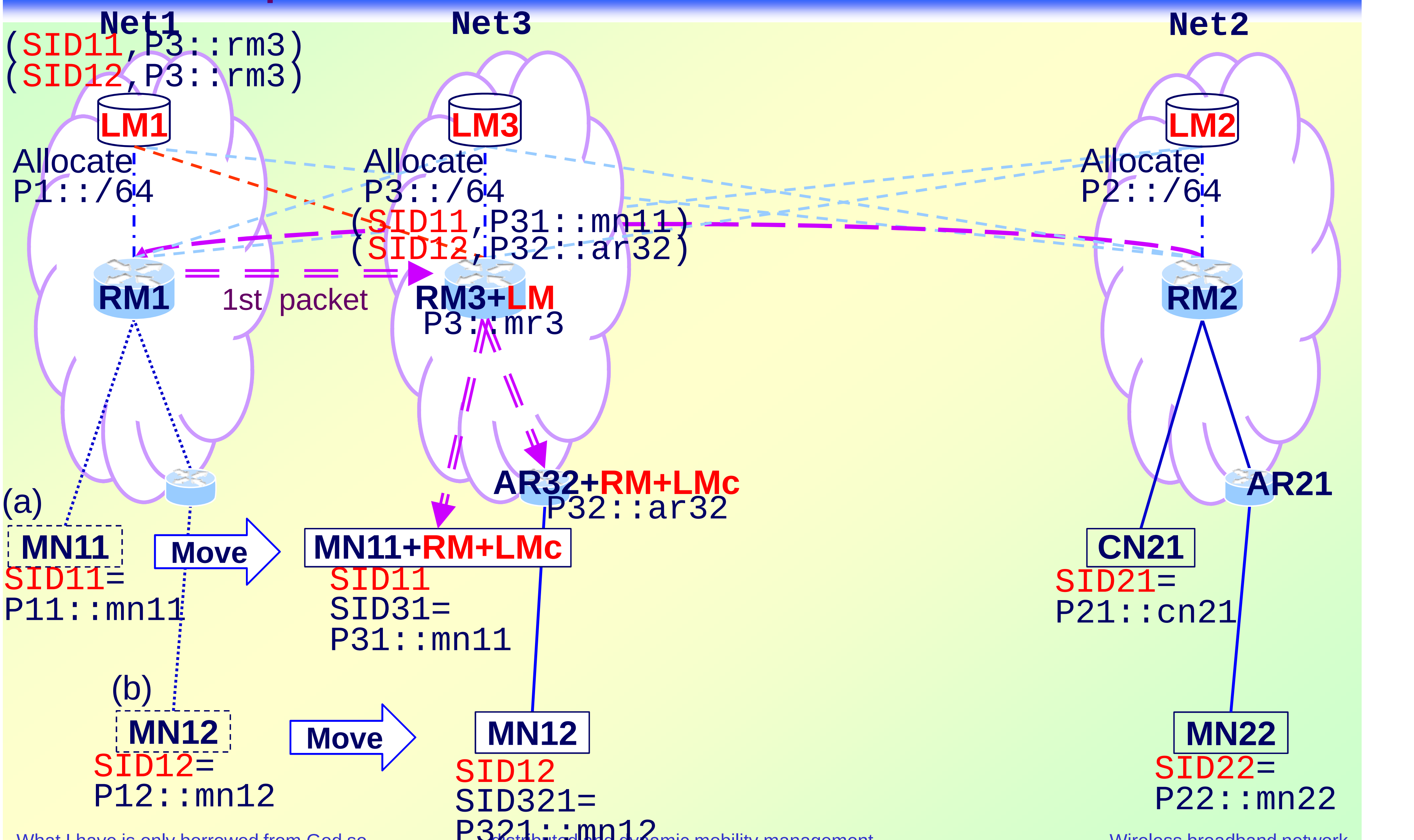
Receiving subsequent packets using cache binding at MR2



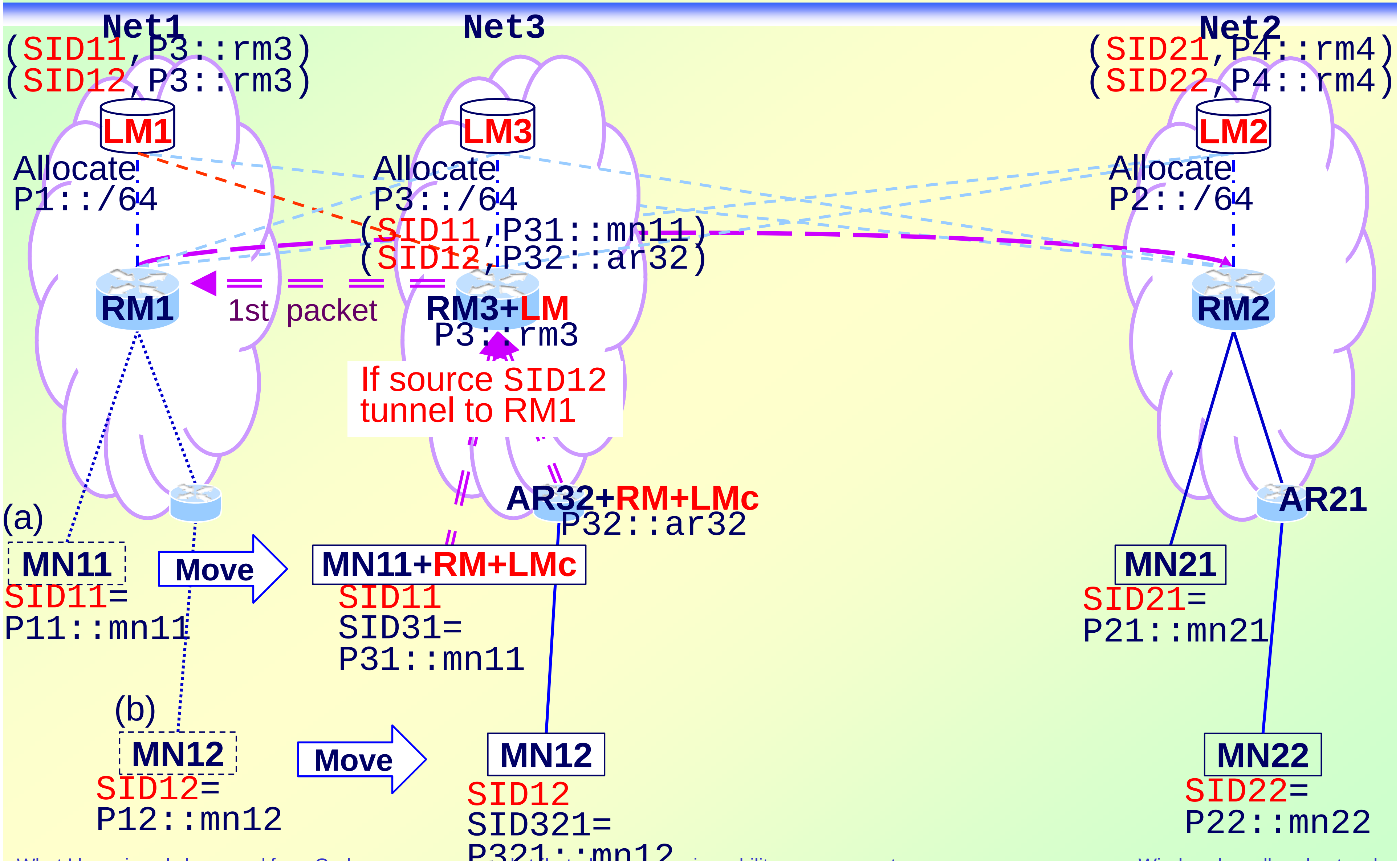
Other packets from GW2 may also use this Cache binding



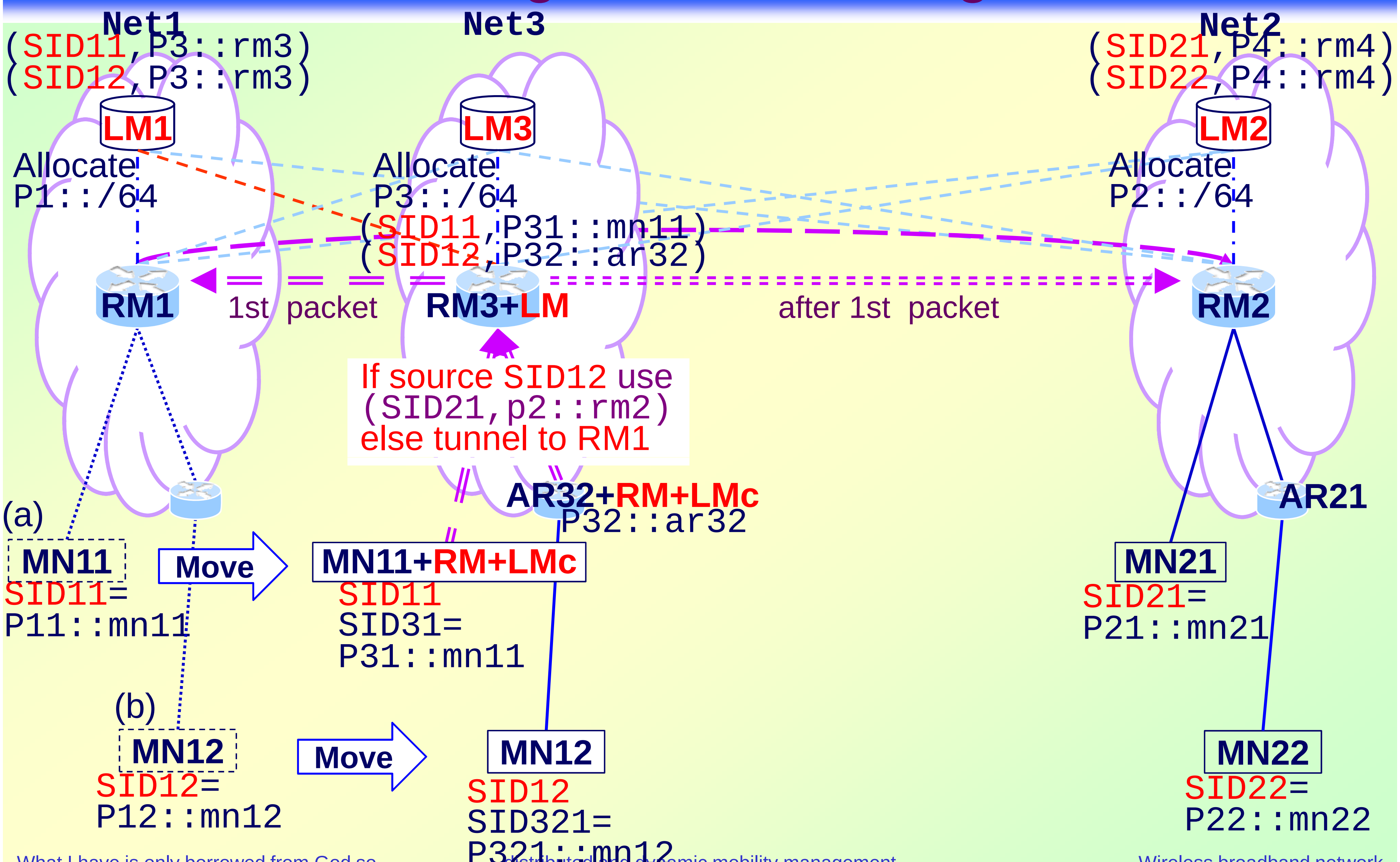
Cache binding at MR2 timeout when no more packets are received from MR2



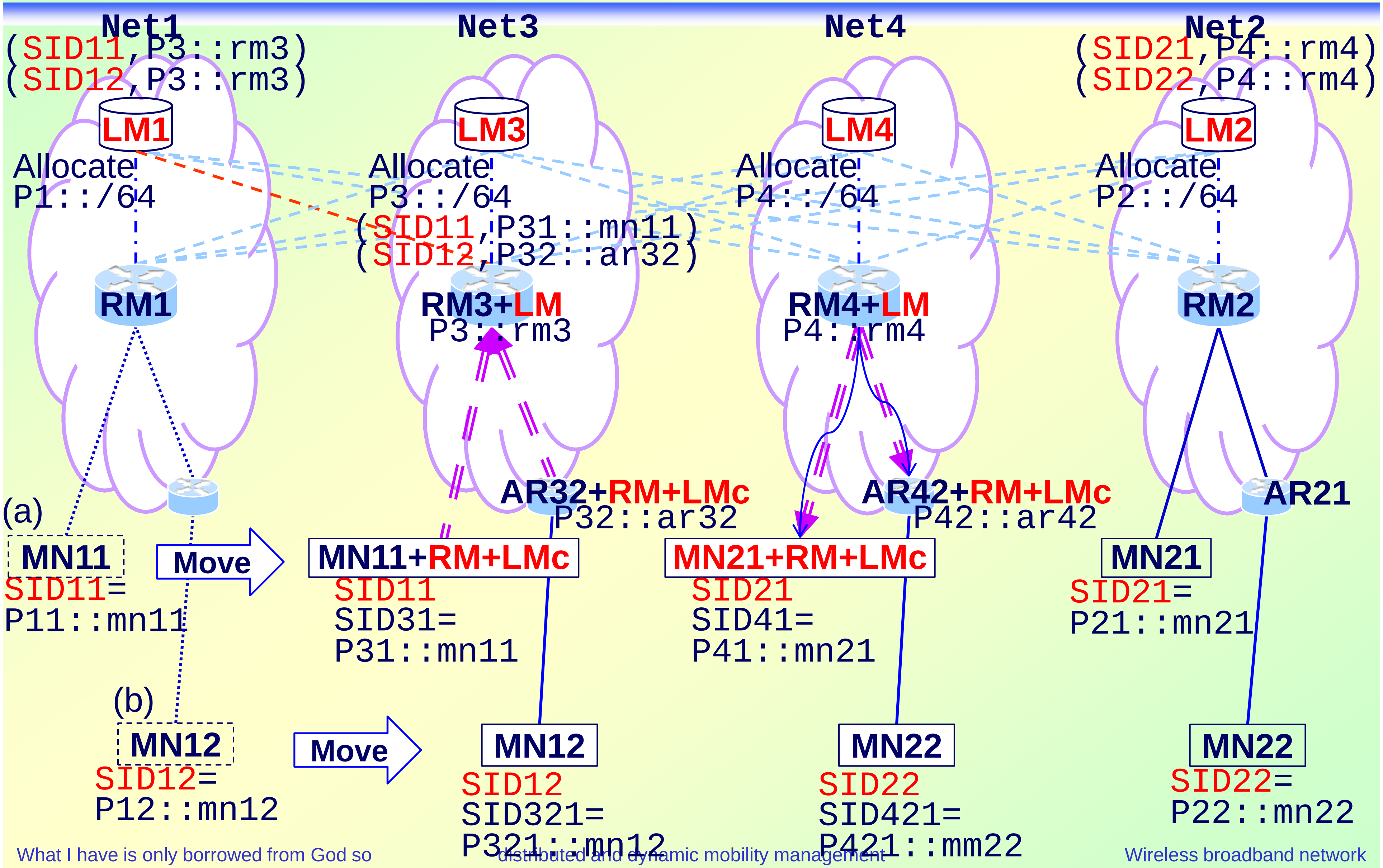
Sending 1st packets by tunneling back to MR1



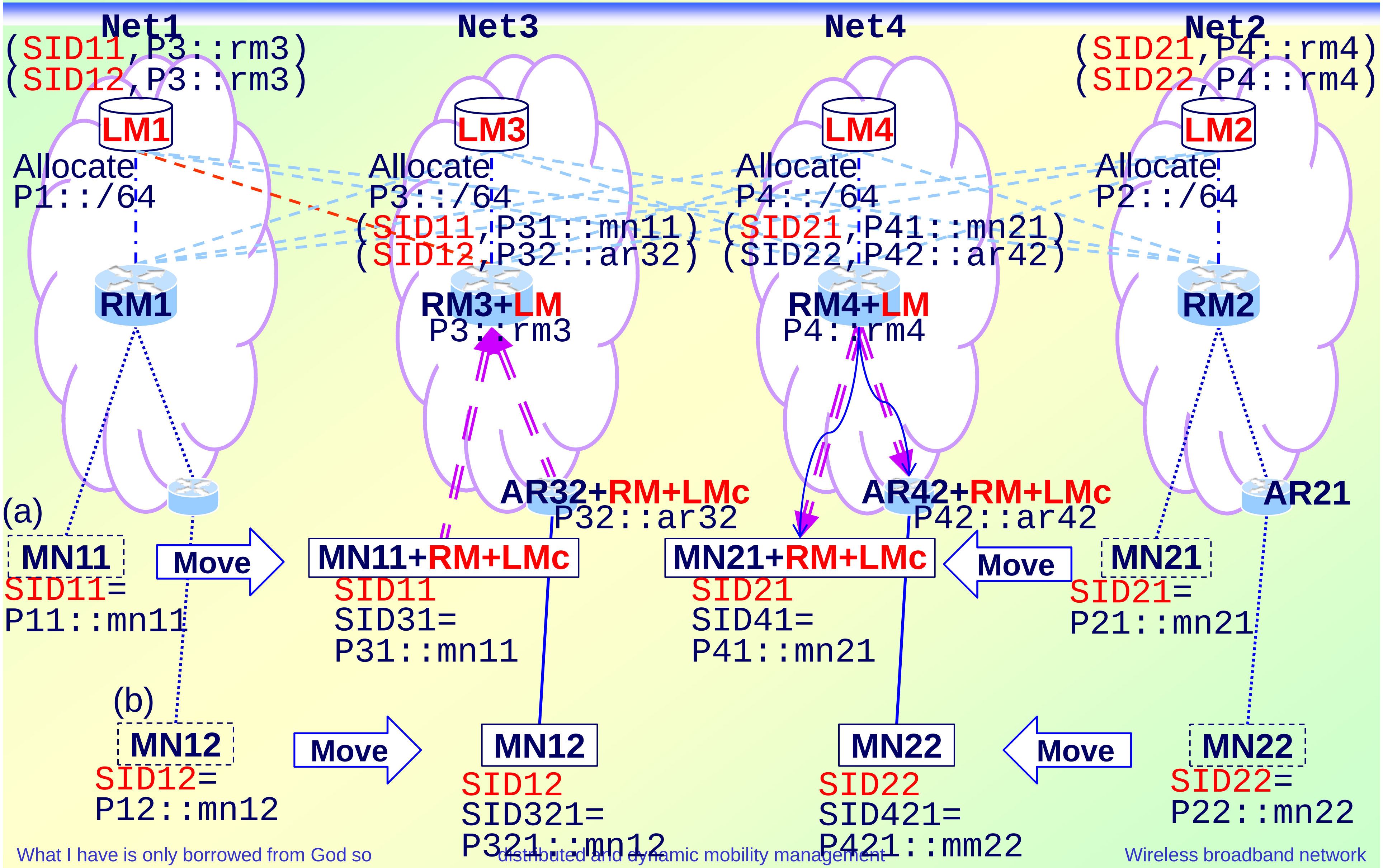
Sending subsequent packets using cached binding



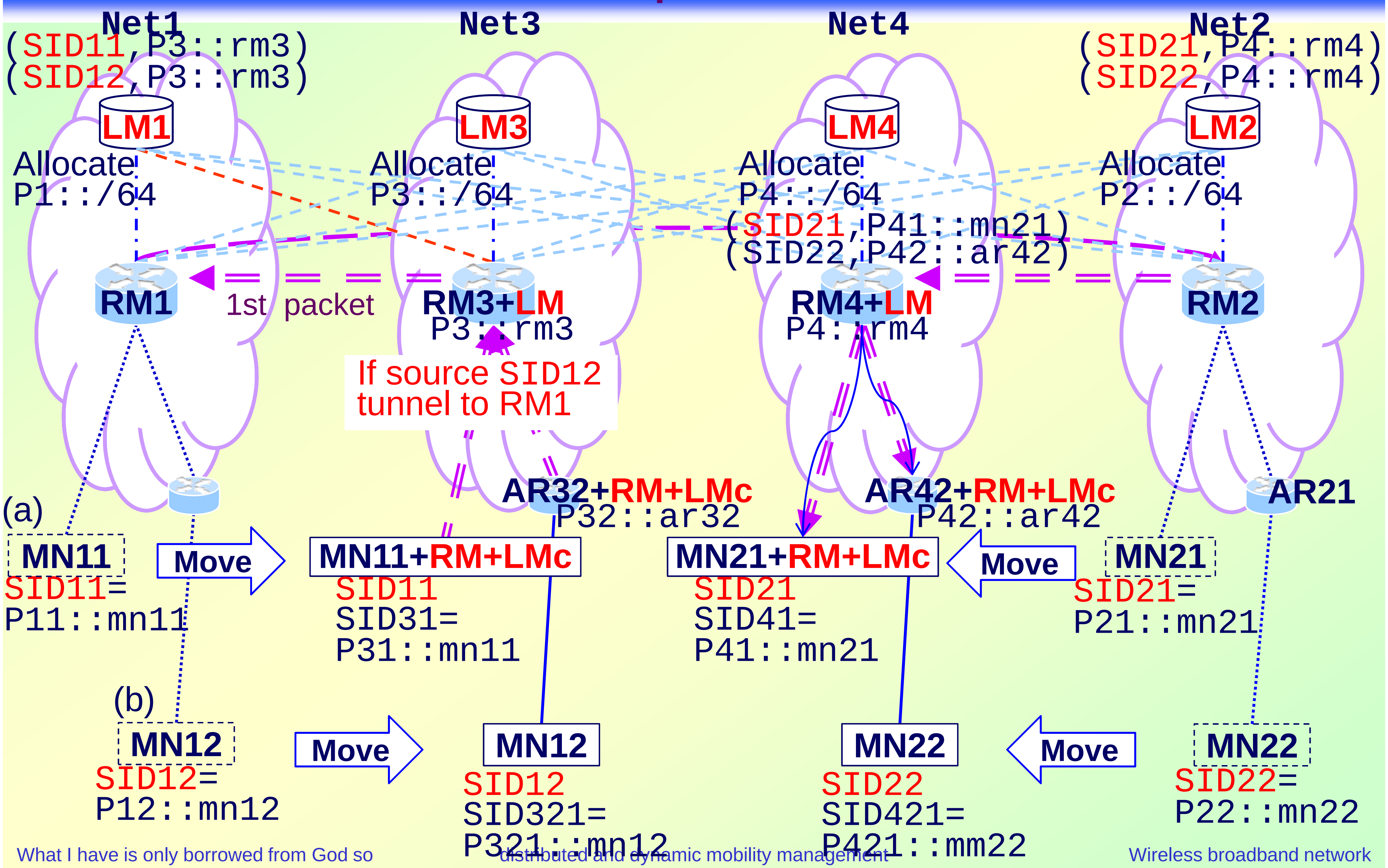
DMM with 4 networks



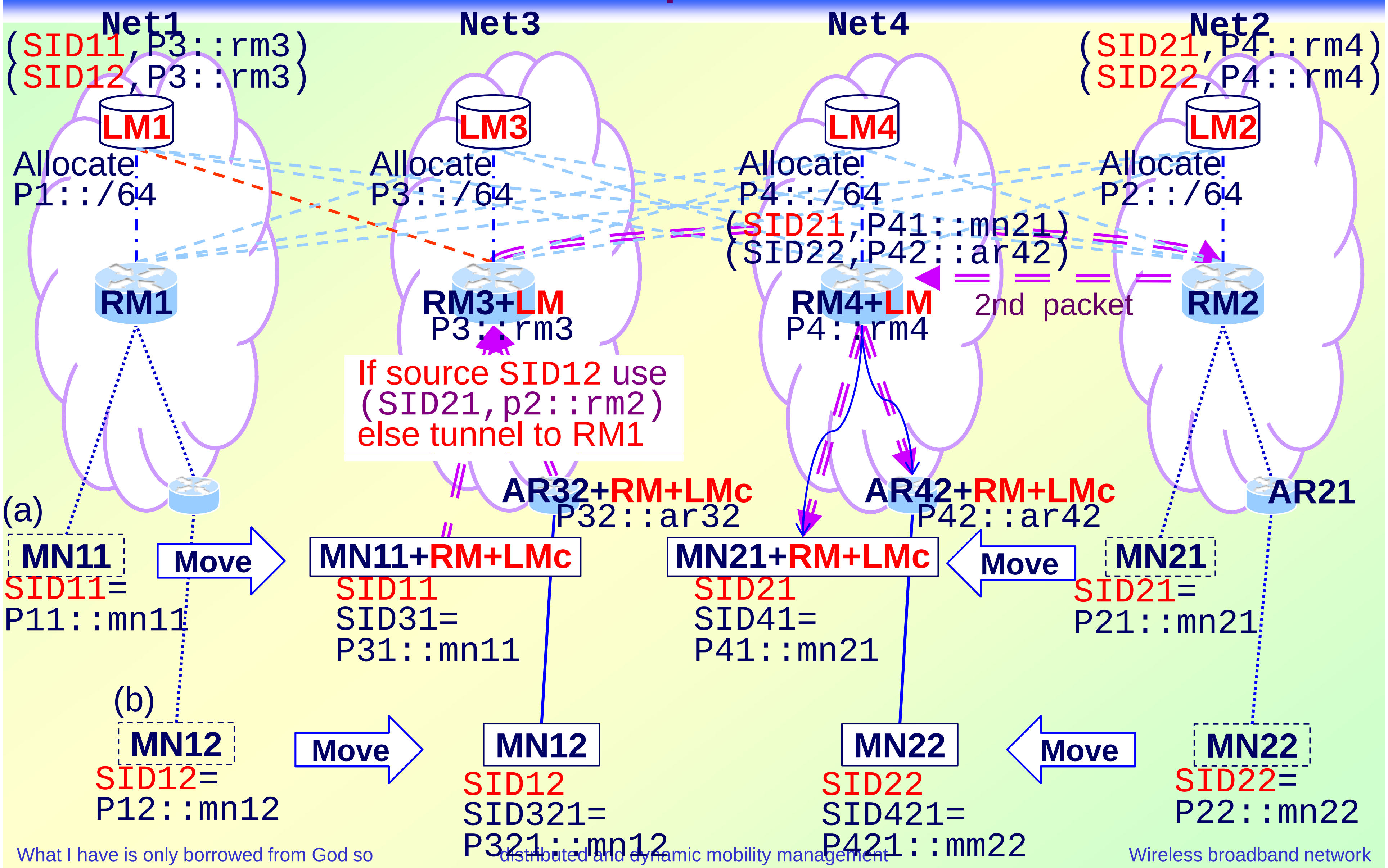
Both nodes move



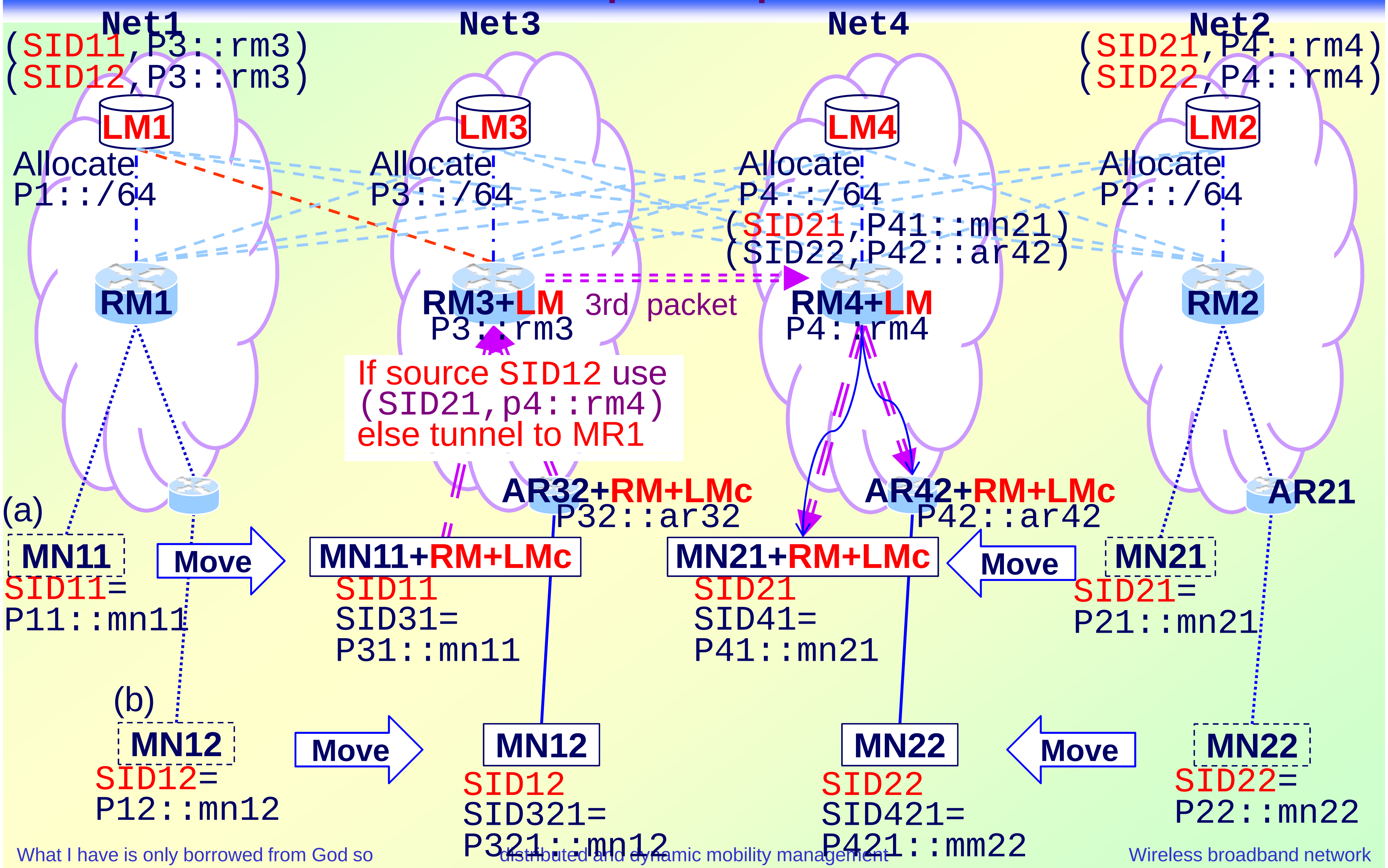
Both nodes move
1st packet



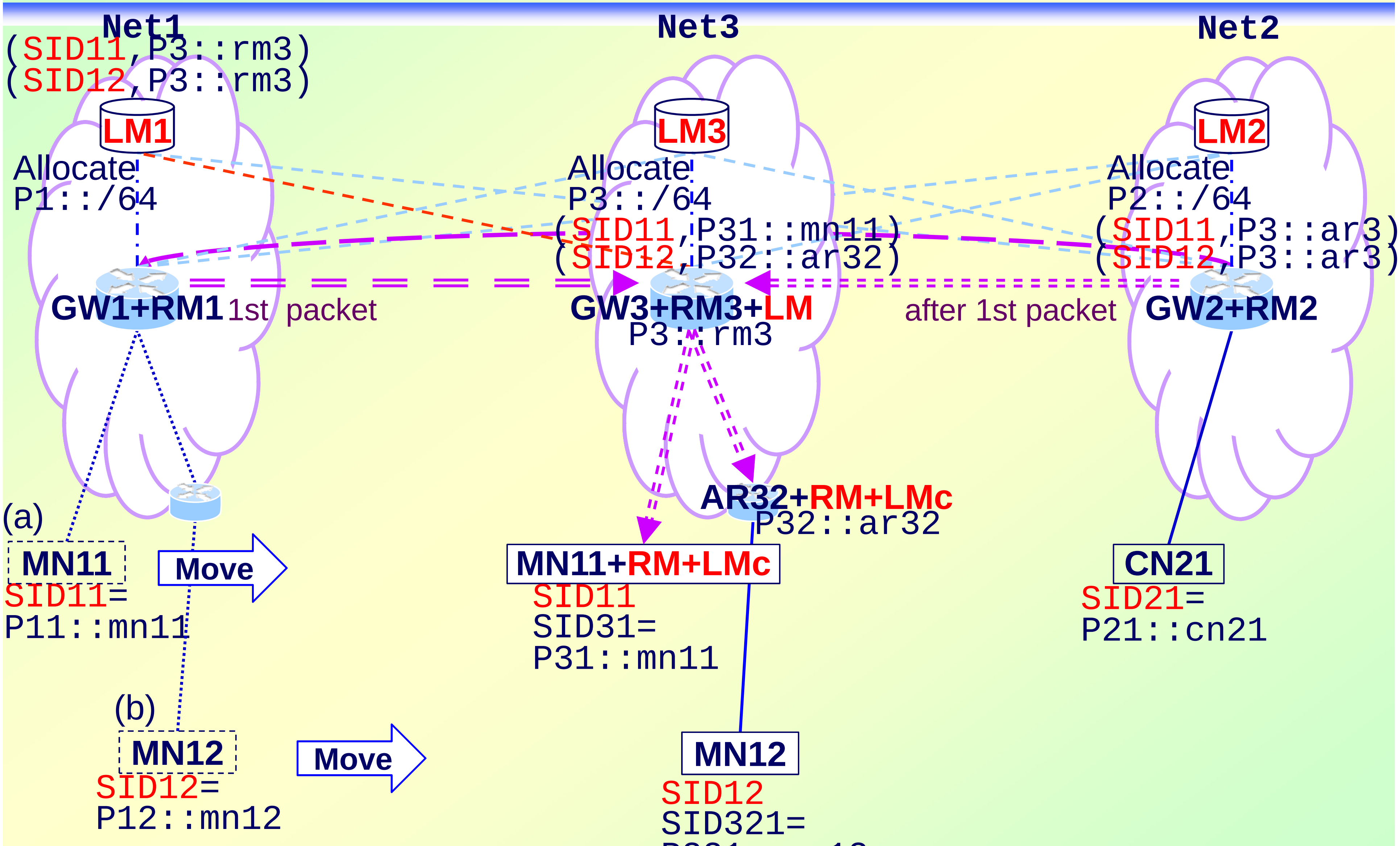
Both nodes move
2nd packet



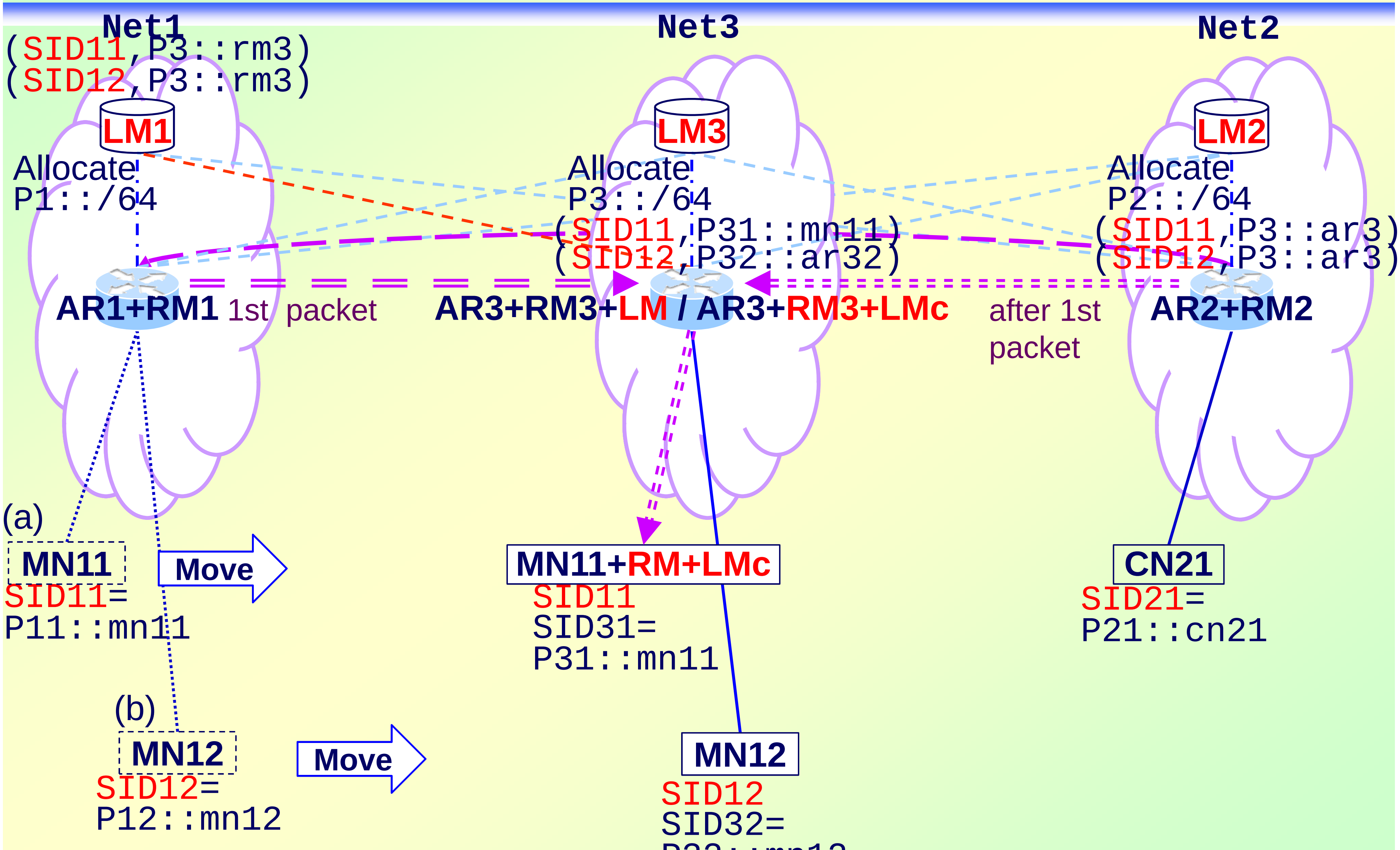
Both nodes move subsequent packets



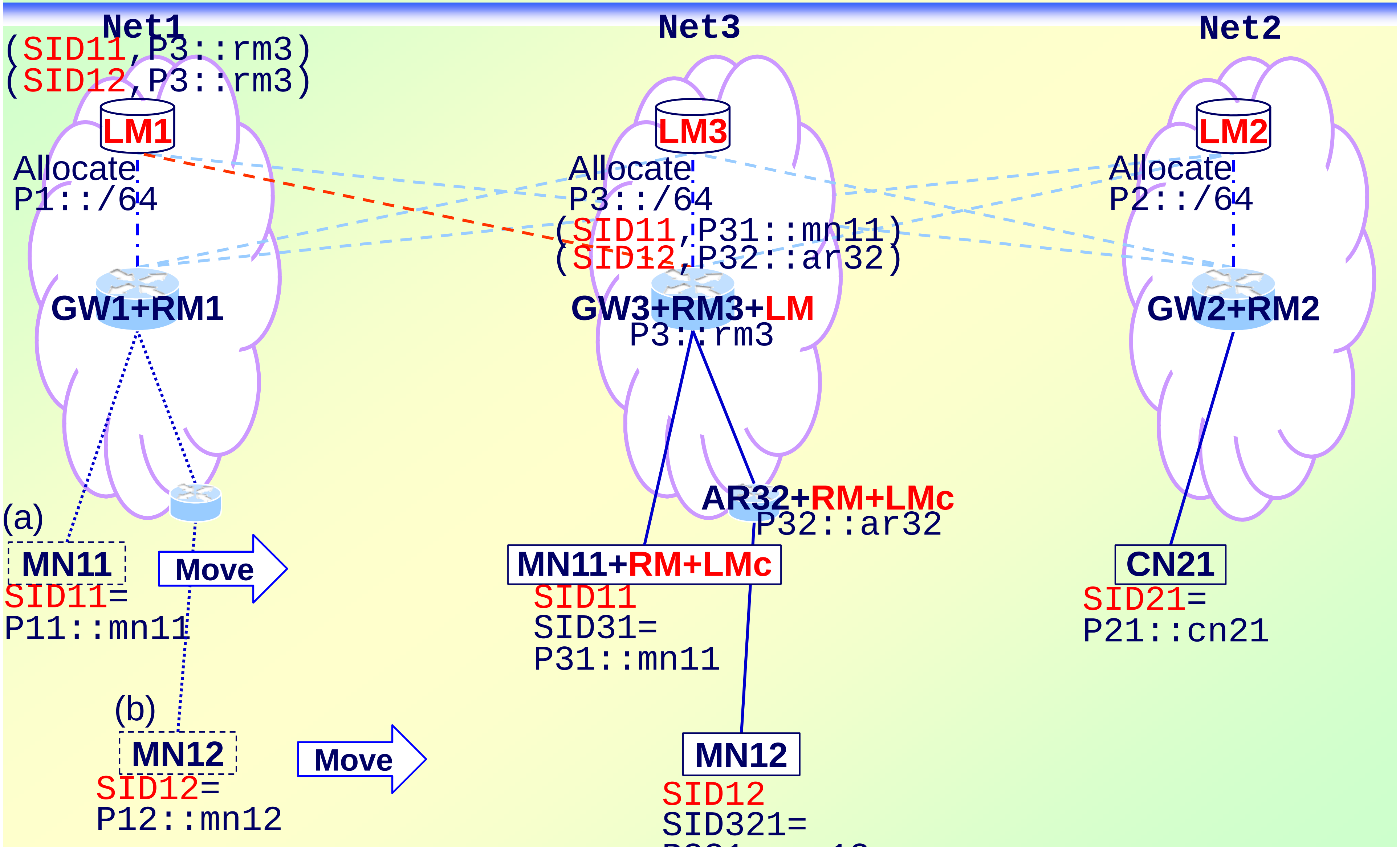
DMM networks with Access GW and AR



DMM with flat networks

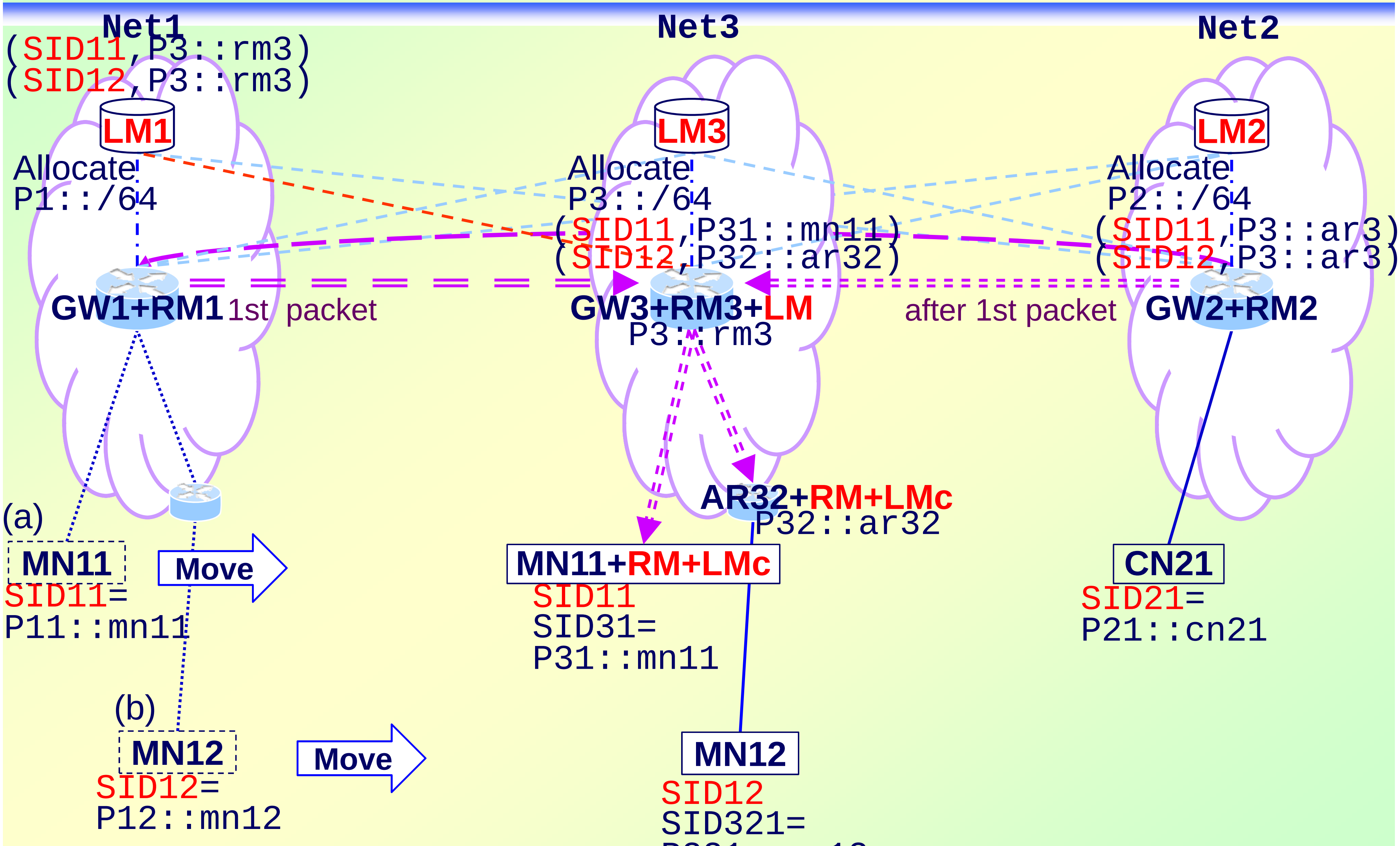


DMM



Net1
(SID11,P3::rm3)
(SID12,P3::rm3)
LM1
Allocate
P1::/64
GW1+RM1
(a)
MN11
SID11=
P11::mn11
Move
(b)
MN12
SID12=
P12::mn12
Move
Net3
LM3
Allocate
P3::/64
(SID11,P31::mn11)
(SID12,P32::ar32)
GW3+RM3+LM
P3::rm3
AR32+RM+LMc
P32::ar32
MN11+RM+LMc
SID11
SID31=
P31::mn11
MN12
SID12
SID321=
P321::mn12
Net2
LM2
Allocate
P2::/64
GW2+RM2
CN21
SID21=
P21::cn21

DMM



Net1
(SID11,P3::rm3)
(SID12,P3::rm3)
LM1
Allocate
P1::/64
GW1+RM1
1st packet
(a)
MN11
SID11=
P11::mn11
Move
(b)
MN12
SID12=
P12::mn12
Move
Net3
LM3
Allocate
P3::/64
(SID11,P31::mn11)
(SID12,P32::ar32)
GW3+RM3+LM
P3::rm3
AR32+RM+LMc
P32::ar32
MN11+RM+LMc
SID11
SID31=
P31::mn11
MN12
SID12
SID321=
P321::mn12
Net2
LM2
Allocate
P2::/64
(SID11,P3::ar3)
(SID12,P3::ar3)
after 1st packet
GW2+RM2
CN21
SID21=
P21::cn21

Related papers

- H. Anthony Chan, “Proxy Mobile IP with Distributed Mobility Anchors,” Proceedings of GLOBECOM 2010 Workshop on Seamless Wireless Mobility, Miami, USA, 6-10 December 2010.
- H. Chan, H. Yokota, J. Xie, P. Seite, and D. Liu, “Distributed and Dynamic Mobility Management in Mobile Internet: Current Approaches and Issues,” Journal of Communications, 2011.
- H. Chan and A. Dutta, “IP-based mobility and handover optimization,” Half-day tutorial at IEEE WCNC Conference, March 2011.
- H. Chan, “Distributed Mobility Management with Mobile IP,” Proceedings of IEEE International Communication Conference (ICC) Workshop on Telecommunications: from Research to Standards, Ottawa, Canada, 10-11 June 2012.
- Petro P. Ernest, H. Anthony Chan, Jiang Xie, and Olabisi E. Falowo, “Mobility Management with Distributed Mobility Routing Functions,” Paper accepted at Springer Telecommunication Systems Journal, to appear in 2013.

Thank you

H. Anthony Chan

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What I have is only borrowed from God so that I may serve others.