PATTERNS IN NETWORK ARCHITECTURE:

MOBILITY

MOBILITY

OUTLINE

- Roadmap
- Mobility
  - Definition of mobility
  - Discussion of “The Design Space of Network Mobility”
  - Interoperation and layering
  - A composition theorem
- Unfinished Business
  - VLANs, again
  - Architecture and trust boundaries

ROADMAP: NETWORKING REQUIREMENTS

SEARCHING OR FINDING REQUIREMENTS

The initiator of a communication must find the entity it wishes to communicate with, or the information it wishes to access.

The result of the search is a name in some network.

REACHABILITY OR PROGRESS REQUIREMENTS

Desired communication should succeed, with adequate performance, using resources efficiently, and despite failures.

SECURITY OR SAFETY REQUIREMENTS

Networks should not be used in damaging or malicious ways.

ROADMAP: NETWORK ARCHITECTURE

BASIC NETWORKING

- naming
- routing
- forwarding
- session services

LAYERING OR VERTICAL COMPOSITION

BRIDGING OR HORIZONTAL COMPOSITION

OTHER CRUCIAL TOPICS

- mobility
- middleboxes
- the granularity of change in all structures

ROADMAP: OBJECTIVES

1. To understand the relationships between requirements and architectures, so we can do a better job of meeting the requirements.

2. To formalize network architecture just enough so that solutions to problems, and how they compose, can be fully understood.

3. To encourage networking practice that exposes these formalized architectural elements, so that composition always works.

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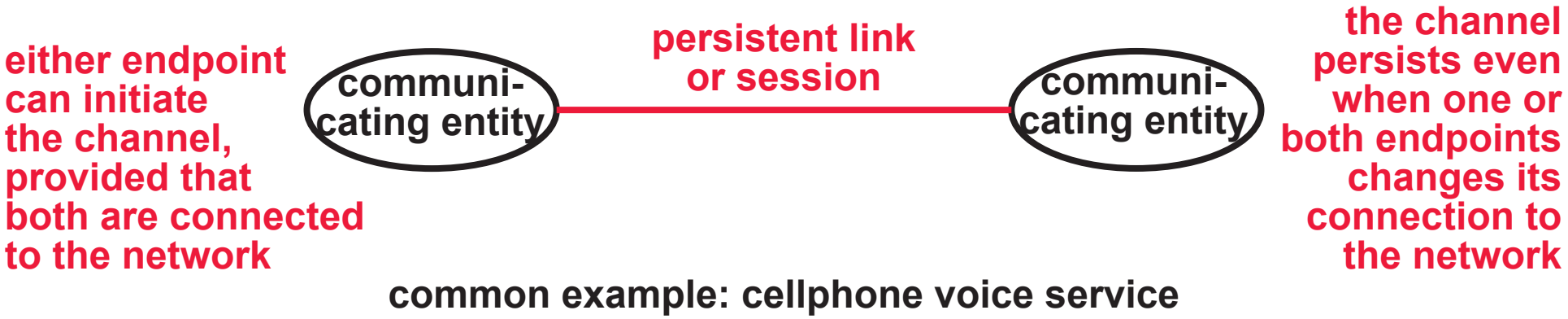
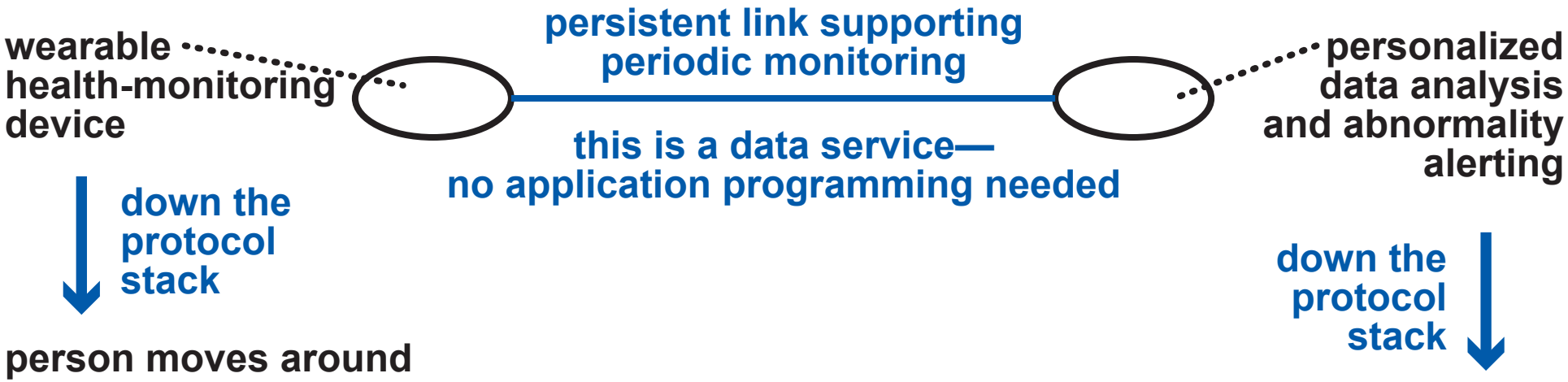
A DEFINITION OF MOBILITY



common example: cellphone voice service



person moves around

device uses both cellular and WiFi connections, alternatively or simultaneously

minimal keep-alive signaling, to reduce battery drain

virtual-machine migration

re-routing around failed links to data center

WHY DIRECTORIES?

MAP REAL-WORLD ENTITIES TO ROUTABLE NAMES

e.g., telephone book, Domain Name System

MAP NAMES IN A NETWORK TO NAMES IN AN UNDERLAY

lookup at session setup, sometimes after a mobility event

DIRECTORIES CAN BE CENTRALIZED OR DISTRIBUTED

IF DISTRIBUTED, THERE MUST BE SOME STRUCTURE FOR TARGETING LOOKUP QUERIES AND BALANCING THE LOAD

- hierarchical namespace

Domain Name System, Mobile IP home agents

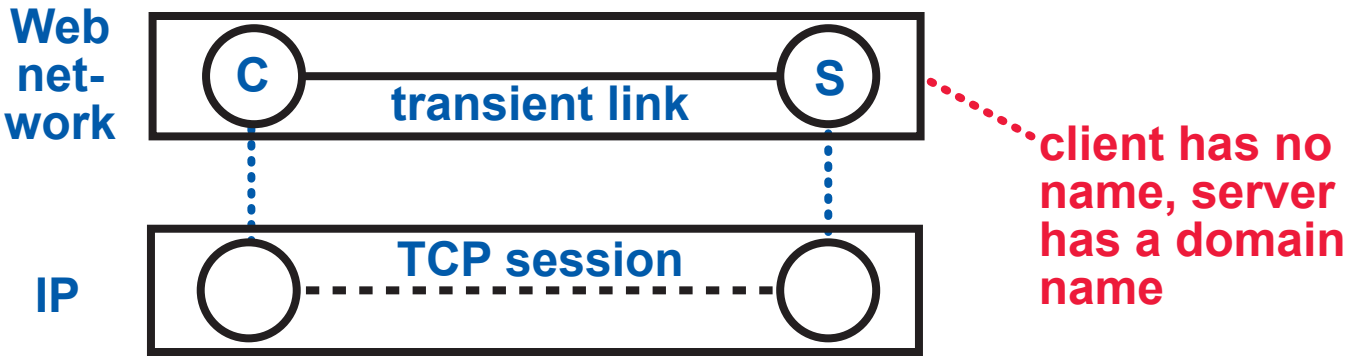
- numerical order on hash of name

distributed hash table

- simply limiting the size of the network

in ARP flooding, each member is its own directory entry

IS THIS A USEFUL PERSPECTIVE?



WHY IS MOBILITY DIFFICULT TO IMPLEMENT ON THE INTERNET?

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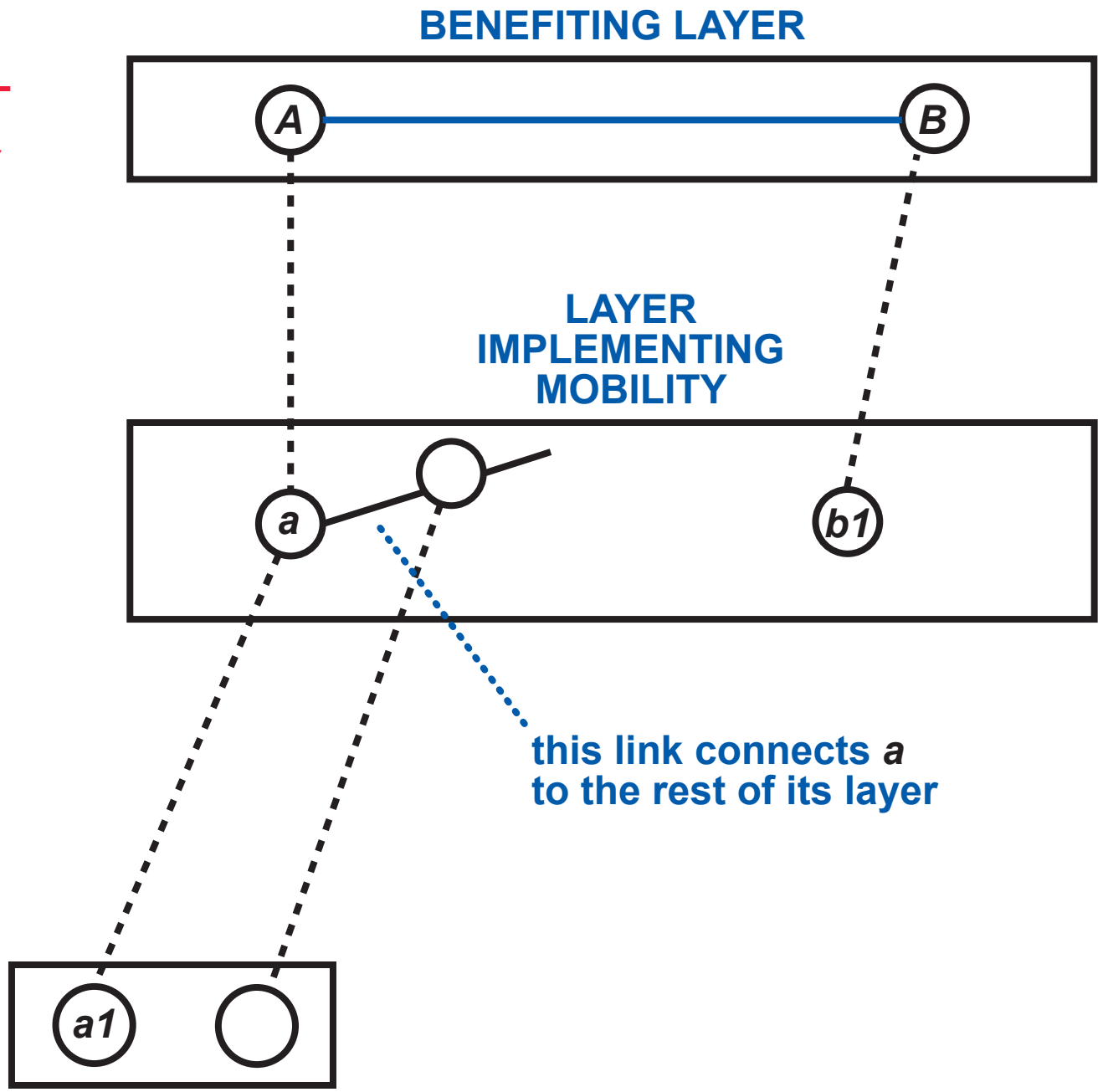
A PATTERN FOR IMPLEMENTING MOBILITY

DYNAMIC-ROUTING MOBILITY



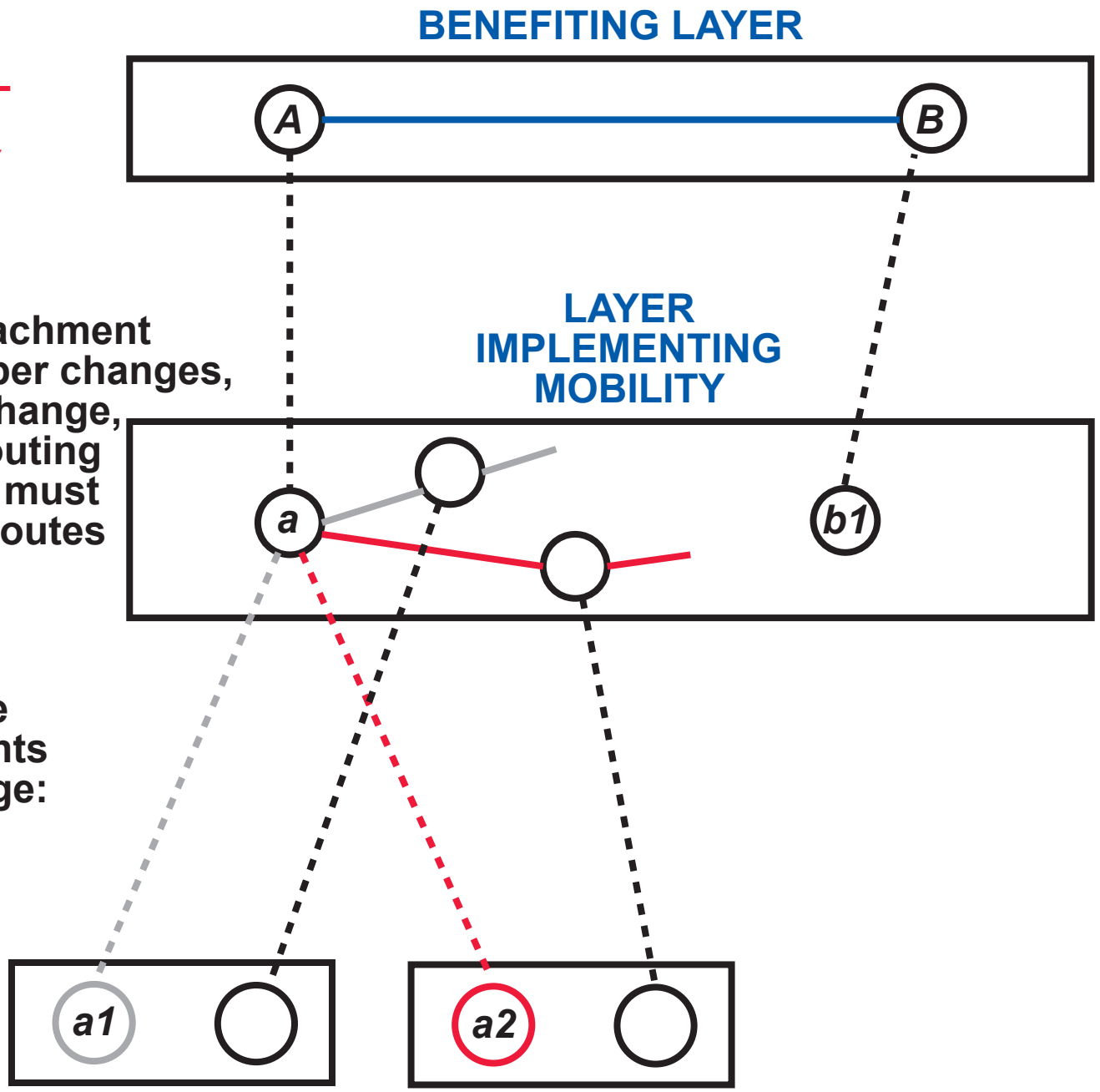
A PATTERN FOR IMPLEMENTING MOBILITY

DYNAMIC-ROUTING MOBILITY

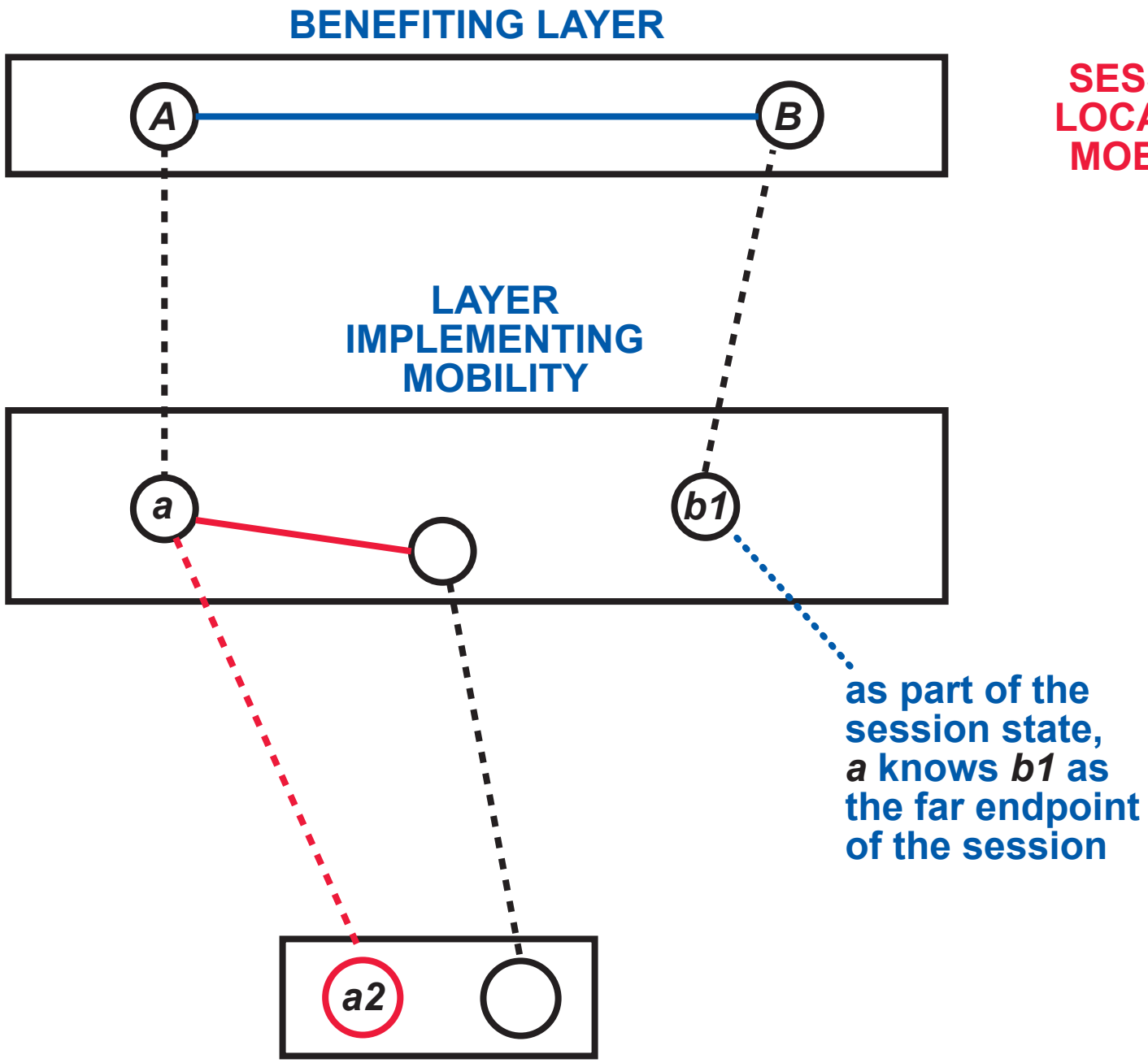
as the attachment of a member changes, its links change, and the routing algorithm must find new routes to it

layer state components that change:

locations
links
routes



ANOTHER PATTERN FOR IMPLEMENTING MOBILITY



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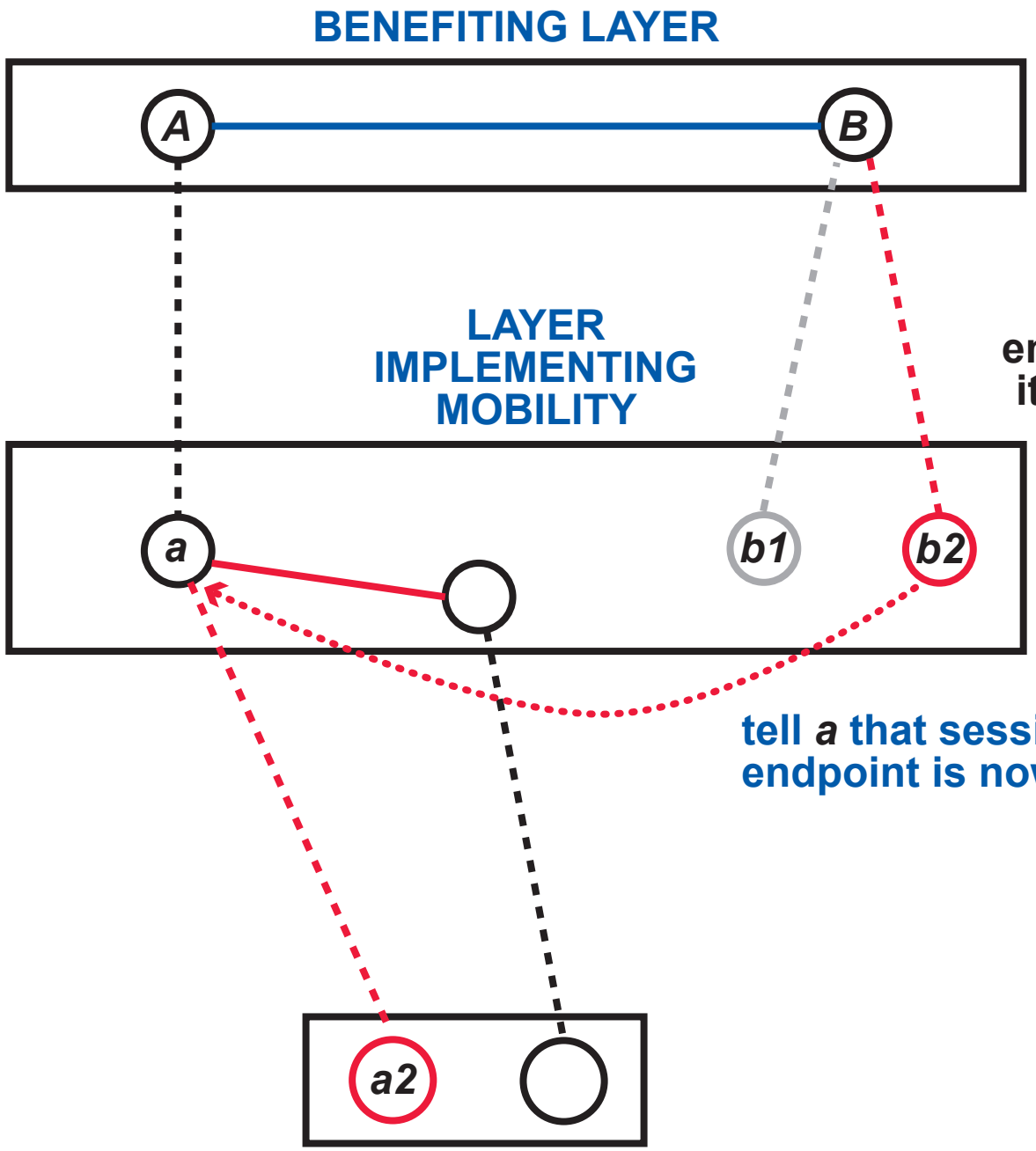


SESSION-LOCATION MOBILITY

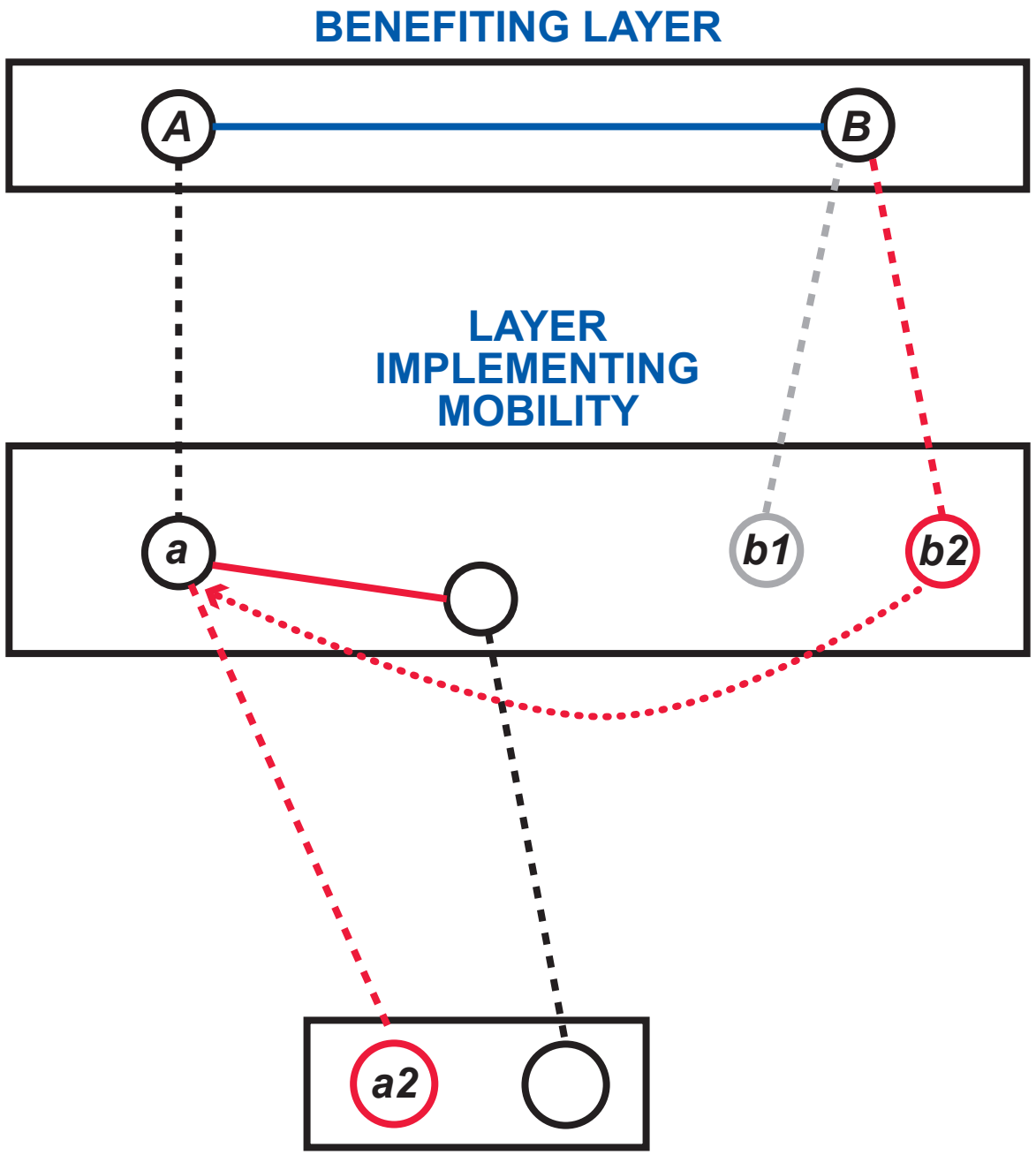
as the link endpoint changes its location in the implementing layer, the session state changes to match it

tell *a* that session endpoint is now *b2*

layer state components that change:

members attachedTo sessions

BOTH PATTERNS FOR IMPLEMENTING MOBILITY



DYNAMIC-ROUTING MOBILITY

SESSION-LOCATION MOBILITY

layer state components that change:

locations
links
routes

layer state components that change:

members
attachedTo
sessions

STRENGTHS AND WEAKNESSES OF THE PATTERNS

DYNAMIC-ROUTING MOBILITY

Strengths

Works well in a network with a smaller scope and a flat name space—usually dynamic routing for mobility is no different from "normal" routing.

e.g., Ethernet

Implemented by routers, which are more trusted.

Weaknesses

In a larger network with a hierarchical name space, costs for dynamic routing to individual members are high.

How many routers know where to find a mobile member?

trade-off:
- if many, storage and update costs are high
- if few, path costs are high

SESSION-LOCATION MOBILITY

Strengths

Low storage and update costs.

No path costs.

Weaknesses

Implemented by endpoints, which are less trusted, and harder to update with network software.

Packet losses during handover may be disruptive.

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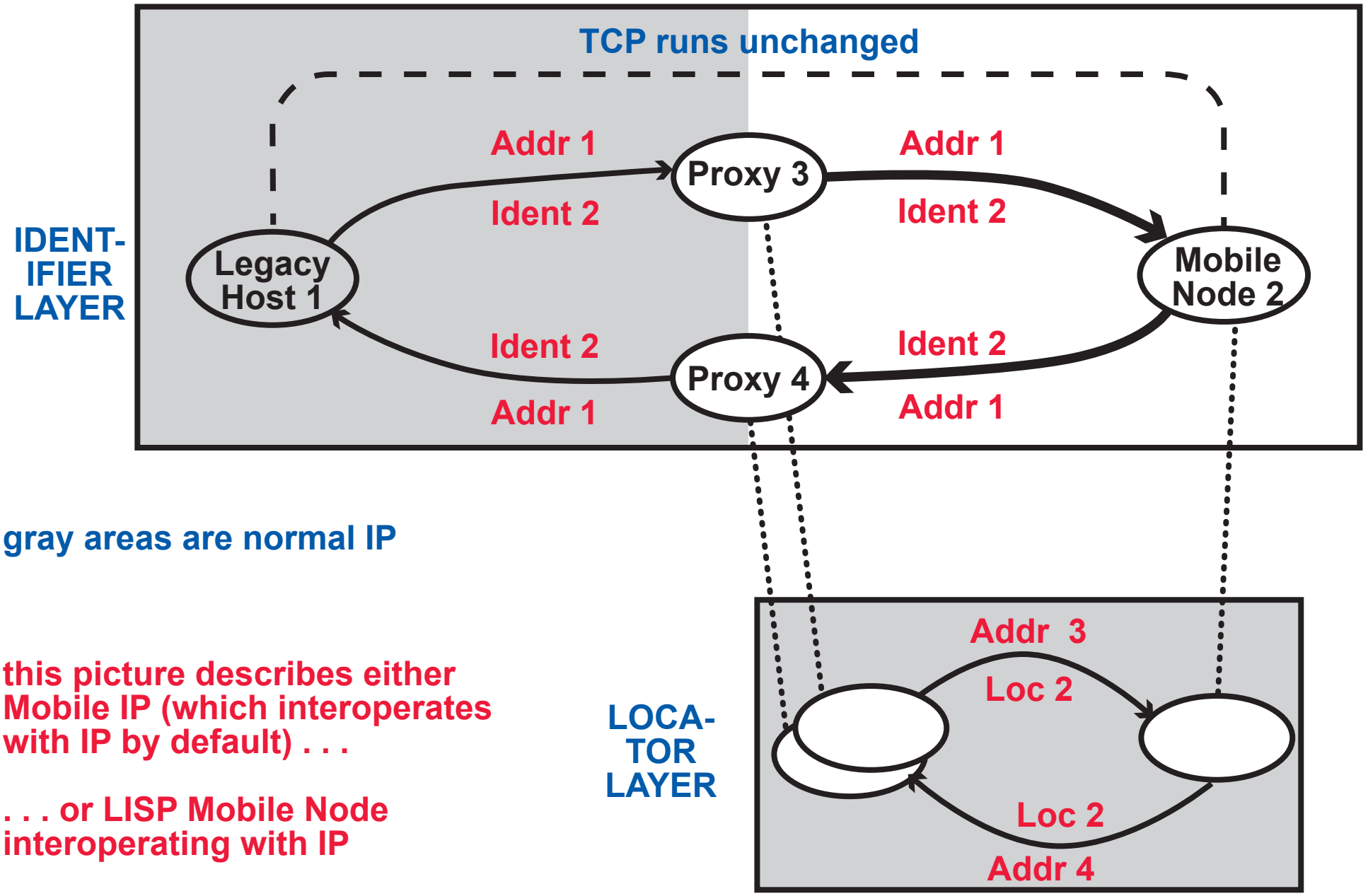
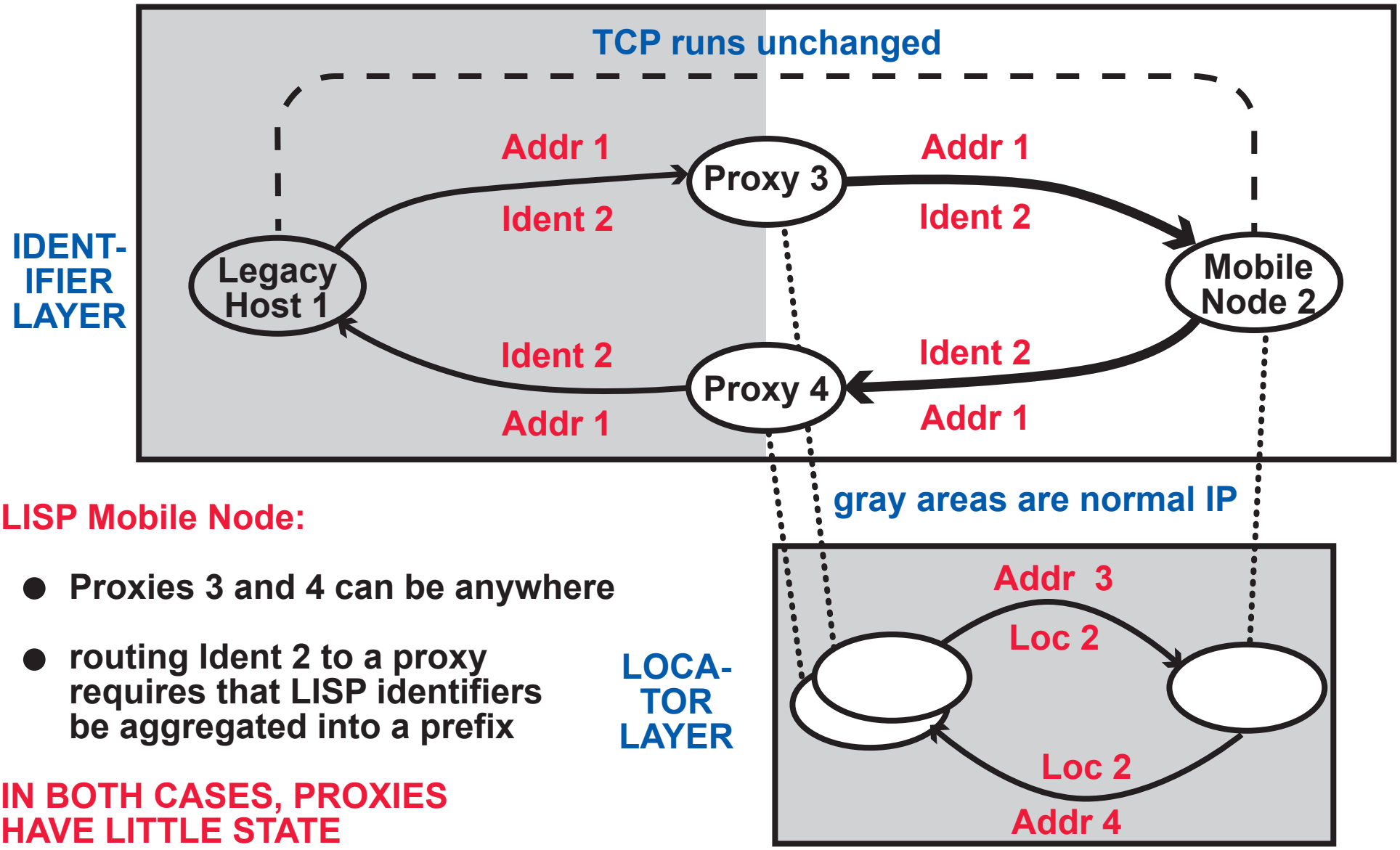
INTEROPERATION BRINGS THE TWO PATTERNS CLOSER



Mobile IPv6 without route optimization:

- Proxies 3 and 4 are both the Home Agent of Ident 2, in a fixed location
- HA routes to Ident 2 either locally or on a “special link”



LISP Mobile Node:

- Proxies 3 and 4 can be anywhere
- routing Ident 2 to a proxy requires that LISP identifiers be aggregated into a prefix

IN BOTH CASES, PROXIES HAVE LITTLE STATE

PURPOSES FOR LAYERING

TO BUILD A NETWORK WITH A LARGER SPAN OUT OF SMALLER, HETEROGENEOUS NETWORKS

IP over LANs and WANs

TO BUILD A NETWORK WITH BETTER PERFORMANCE OR RELIABILITY ON TOP OF AN EXISTING NETWORK

Resilient Overlay Networks over IP

TO SHARE THE RESOURCES OF AN EXISTING NETWORK IN A DISCIPLINED WAY

Virtual LANs over LANs

application networks over IP

TO BUILD A NETWORK WITH LINKS THAT OFFER A SUPERIOR COMMUNICATION SERVICE

Virtual Private Networks over IP

TO MAINTAIN A PERSISTENT, ROUTABLE IDENTIFIER FOR A MOBILE ENDPOINT

Mobile IP, LISP Mobile Node, and many other examples over IP

how do these compose?

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COMPOSITIONAL NETWORK MOBILITY

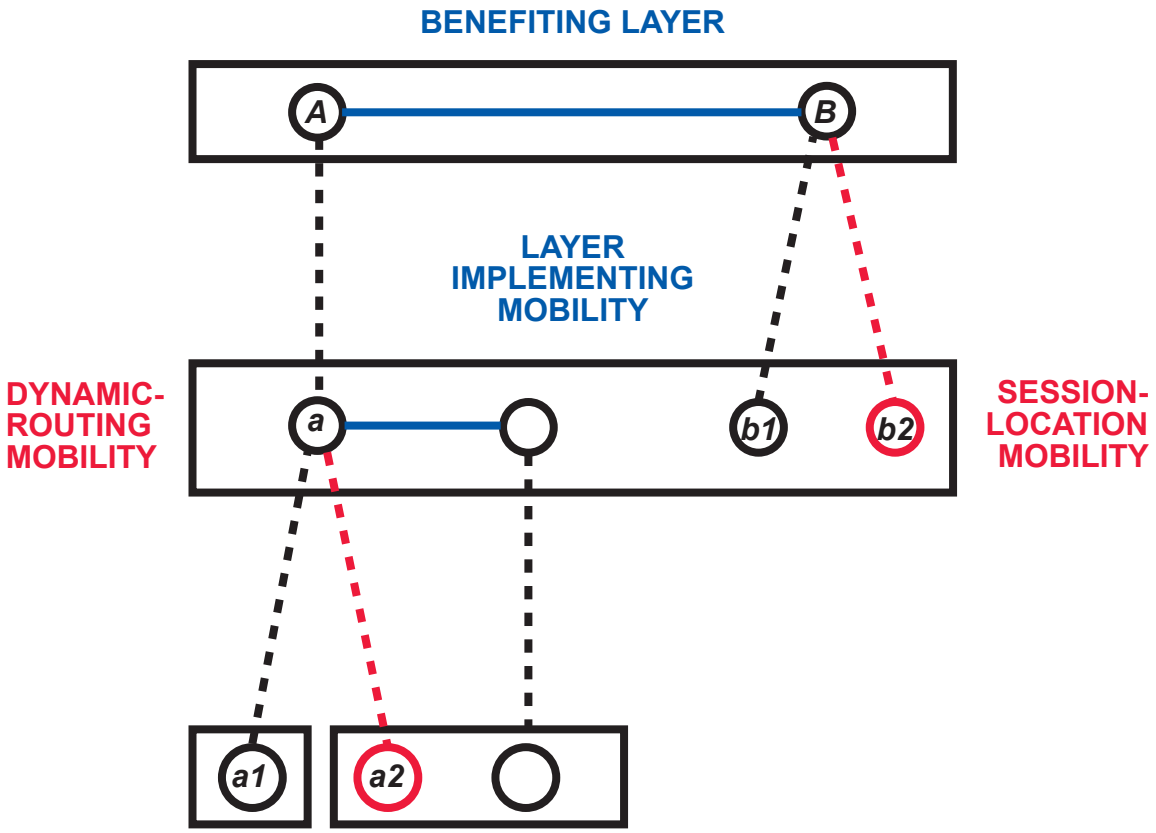
- every mobility mechanism specializes one of these patterns, or is a composition of the two

with enough design freedom, instances of mobility can be moved up and down the levels

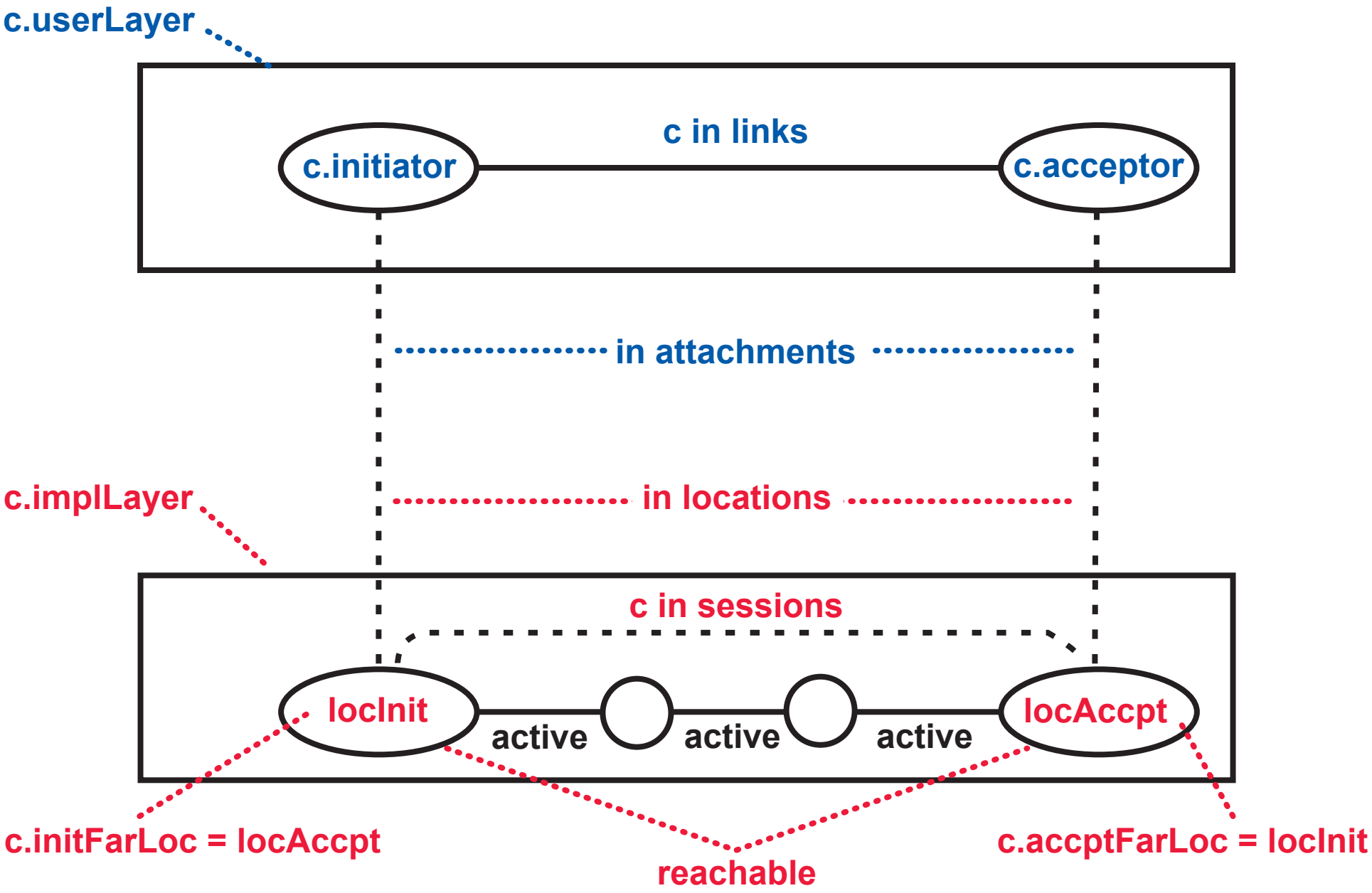
- in principle, each instance of mobility could be handled with either of these patterns at any level below the benefiting layer —so mobility mechanisms could be everywhere

there is a large design space, much of it unexplored

- an interesting question: how do implementations of both patterns in the same layer compose?

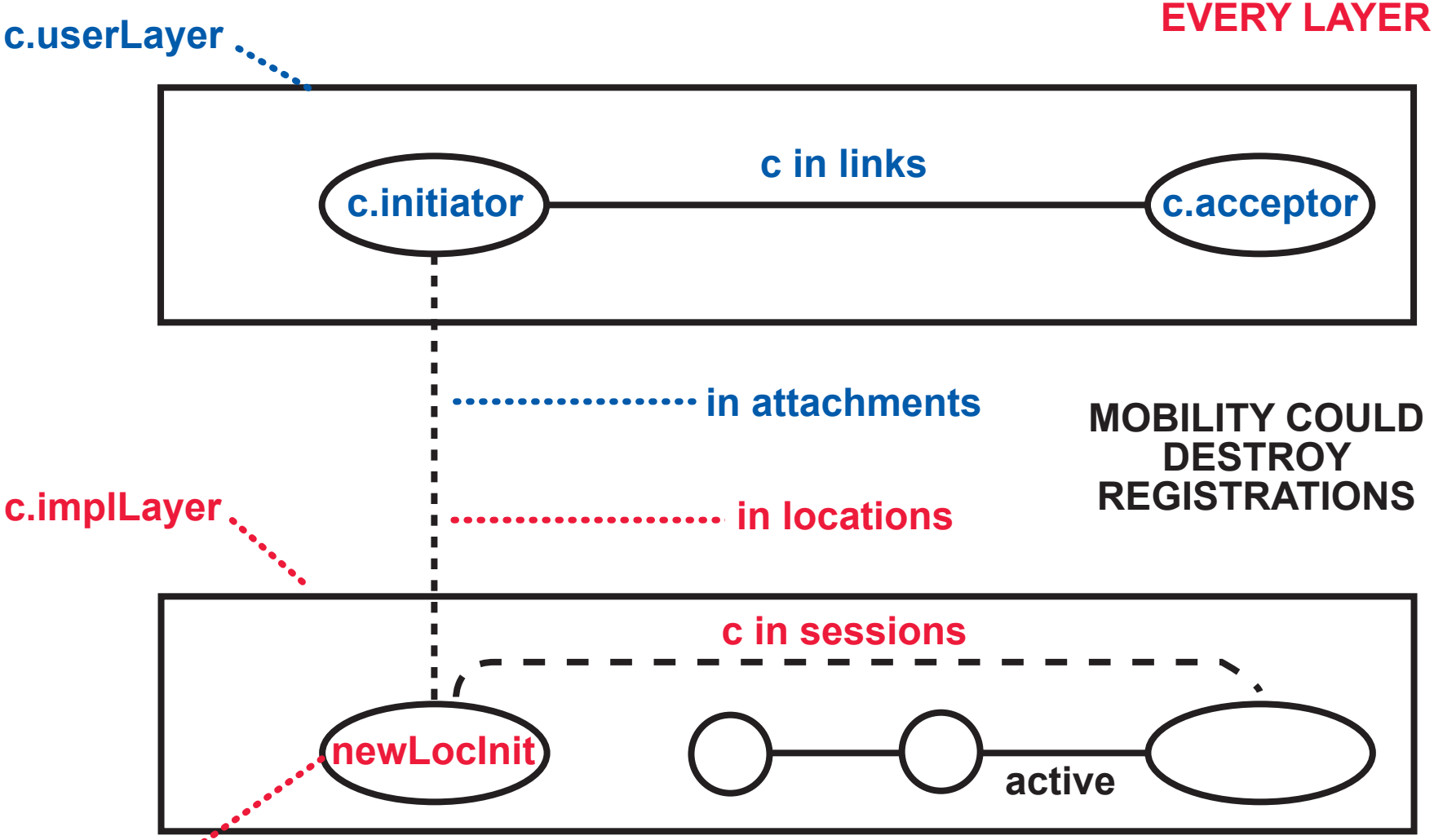


AN ACTIVE IMPLEMENTED CHANNEL



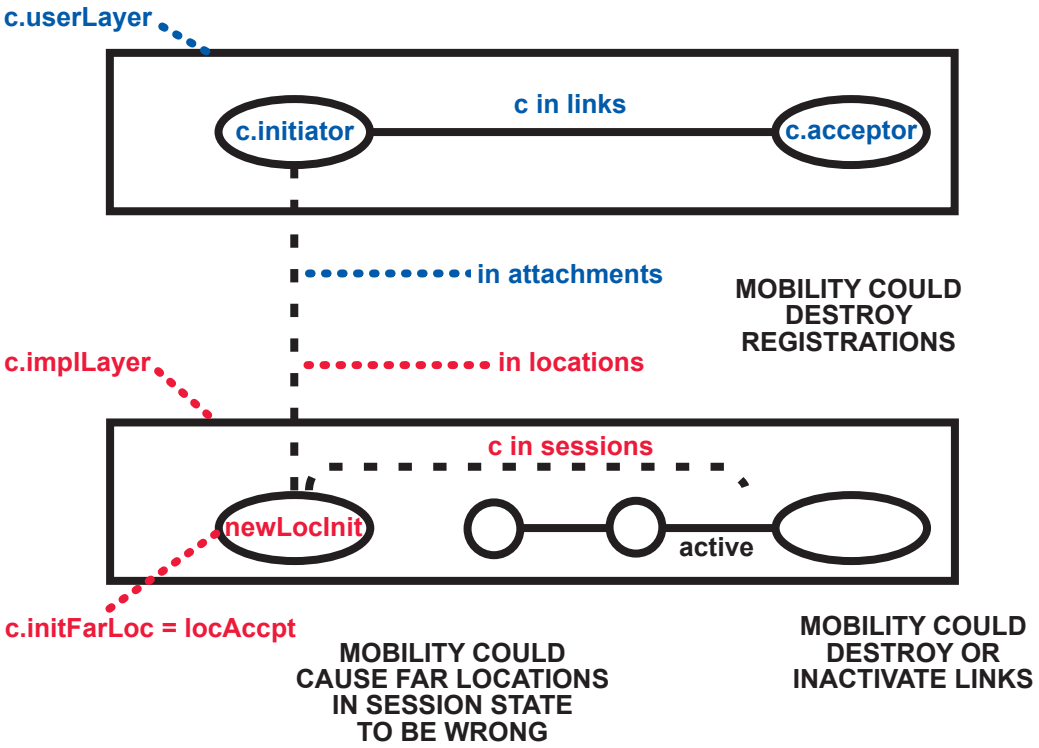
AN INACTIVE IMPLEMENTED CHANNEL

MODEL IMPLEMENTS BOTH PATTERNS IN EVERY LAYER



PROOF THAT MOBILITY MECHANISMS IN A LAYER COMPOSE WITHOUT INTERFERENCE

We cannot assume that mobile devices and network elements will perform all the requisite actions (to prove a true progress property).



We do assume that a mobile device can always become a member of a layer of its choice.

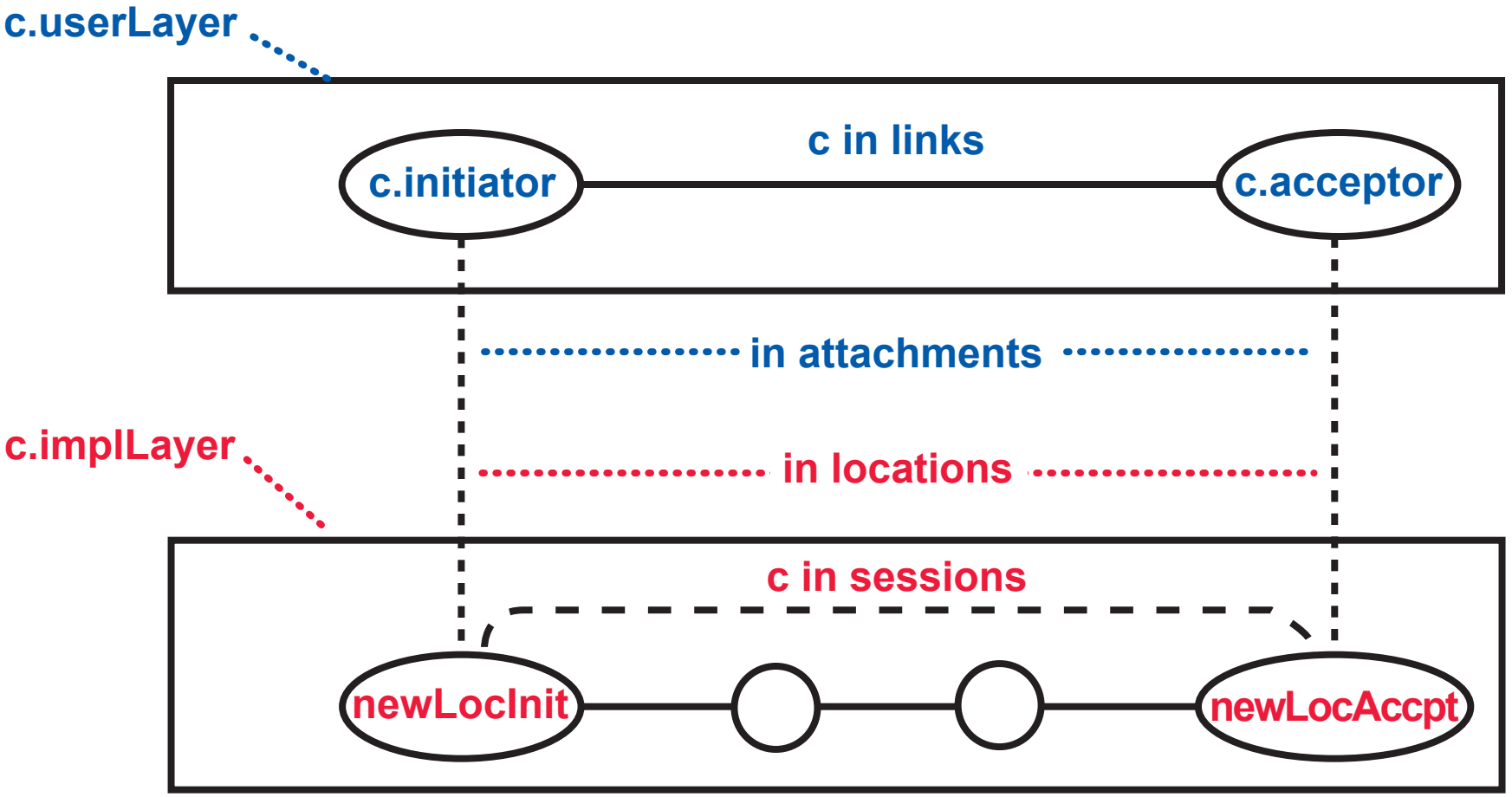
Theorem:

In any state in which an implemented link is inactive, some event is enabled whose execution will make progress toward making the link active (a safety property).

Proof at one level:

Manual enumeration of possible event sequences, automated checking of their preconditions with the Alloy Analyzer (verification over small domains).

WHAT COULD GO WRONG?



c.initFarLoc = locAccpt

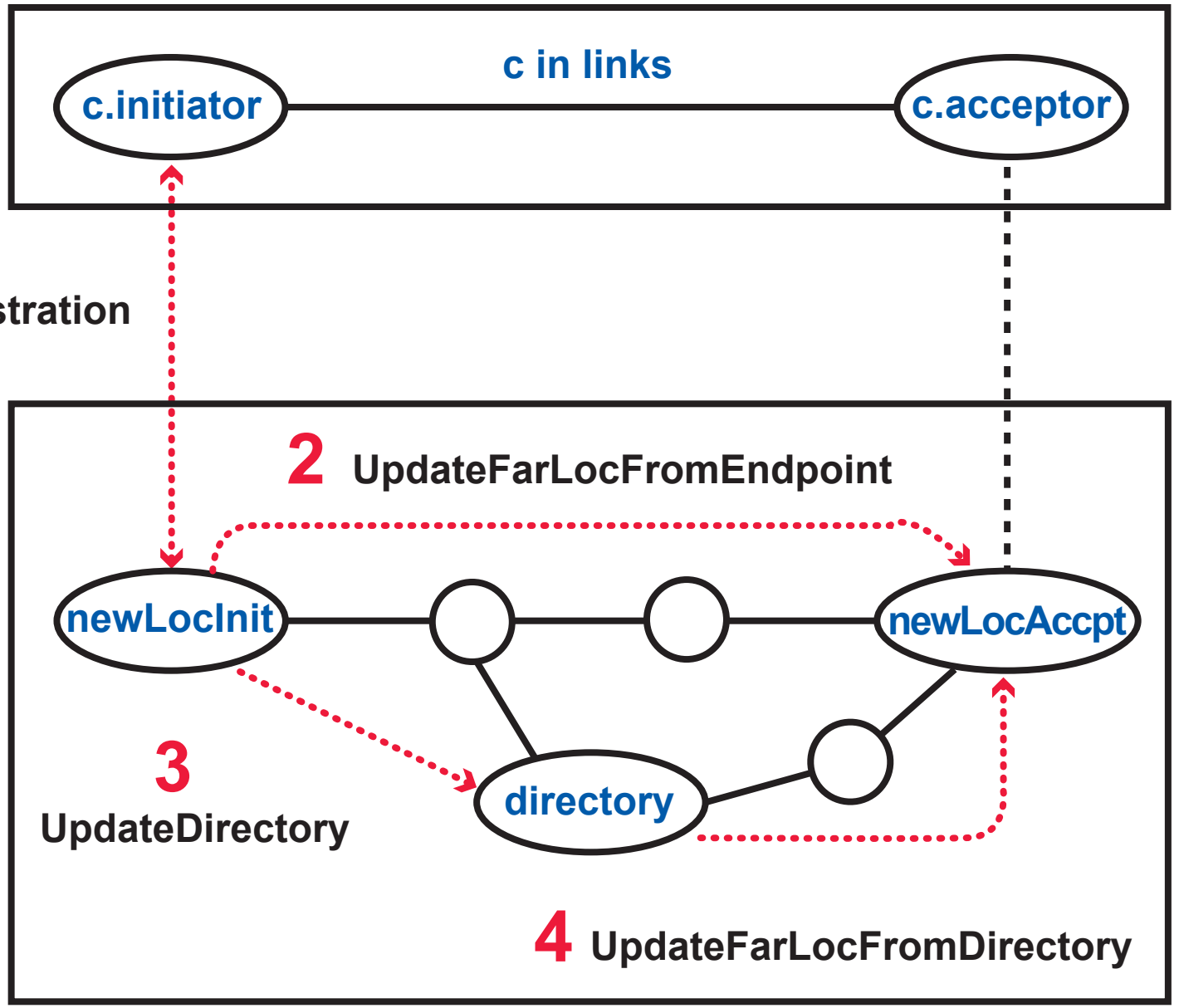
both endpoints have moved

c.accptFarLoc = locInit

both endpoints have the wrong far location

neither can send an update message to the other

SOME EVENT SEQUENCES



in the double-handoff scenario,

1, 2, 3 and 1, 3, 2

do not work, but

1, 3, 4 does

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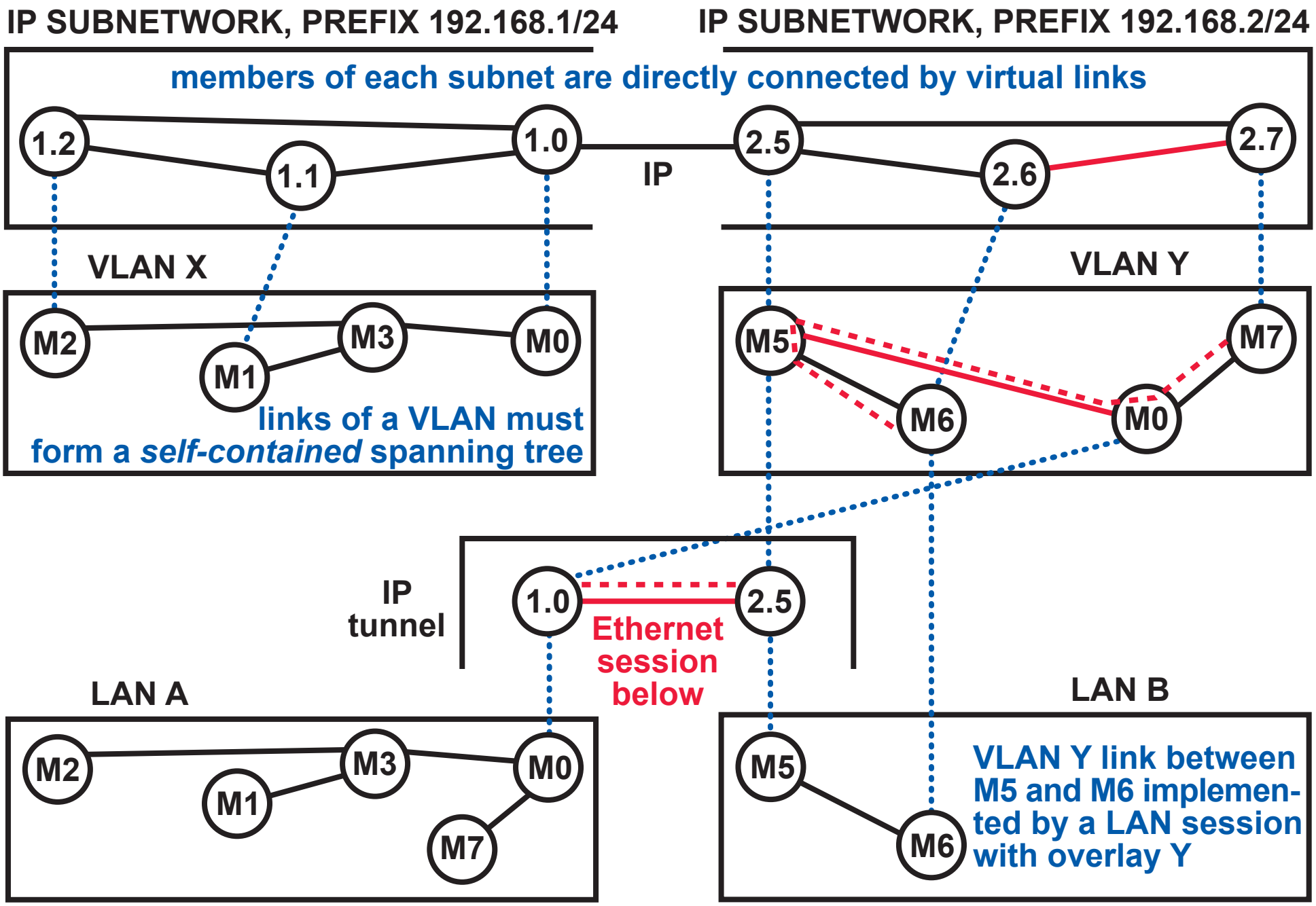
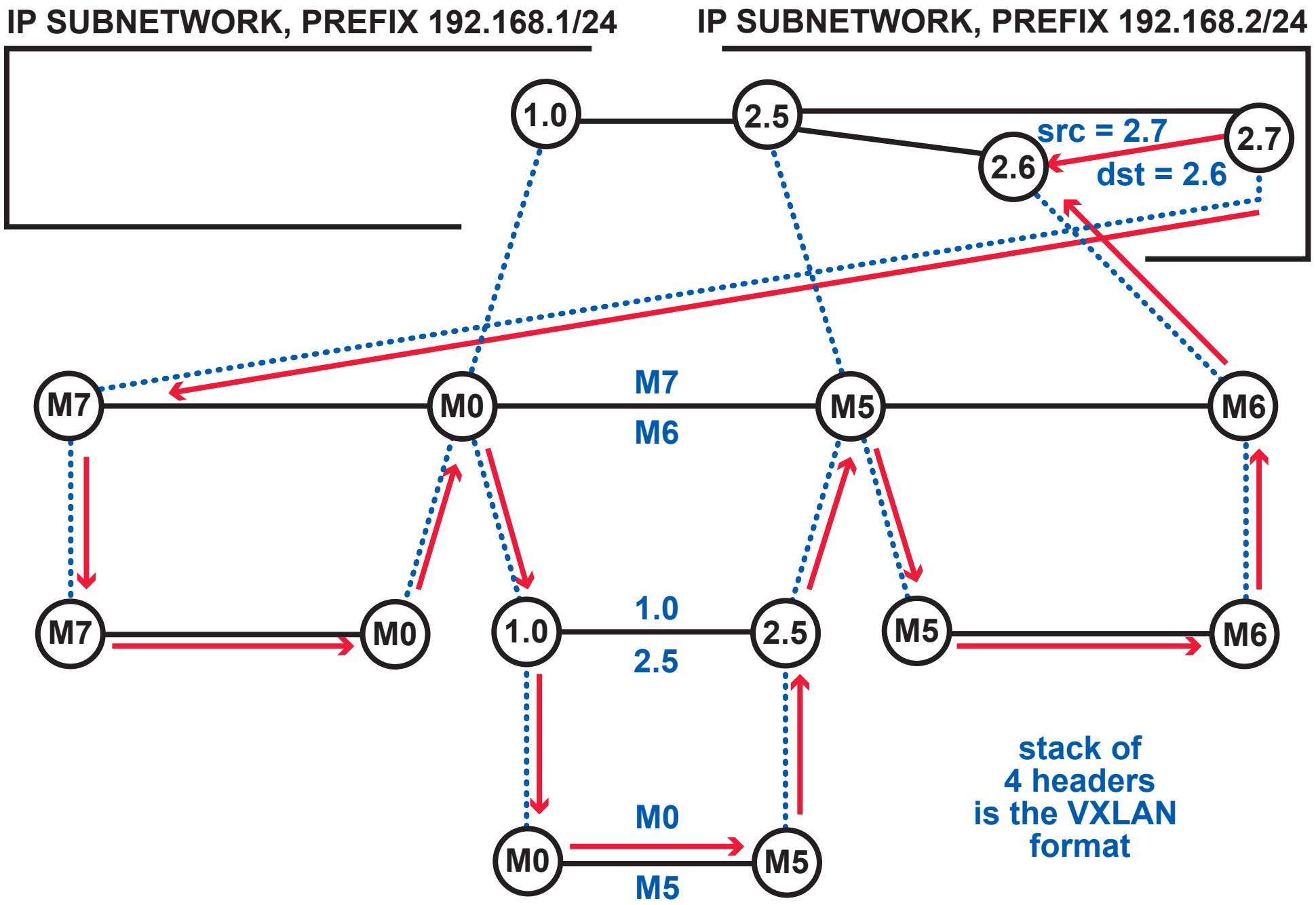
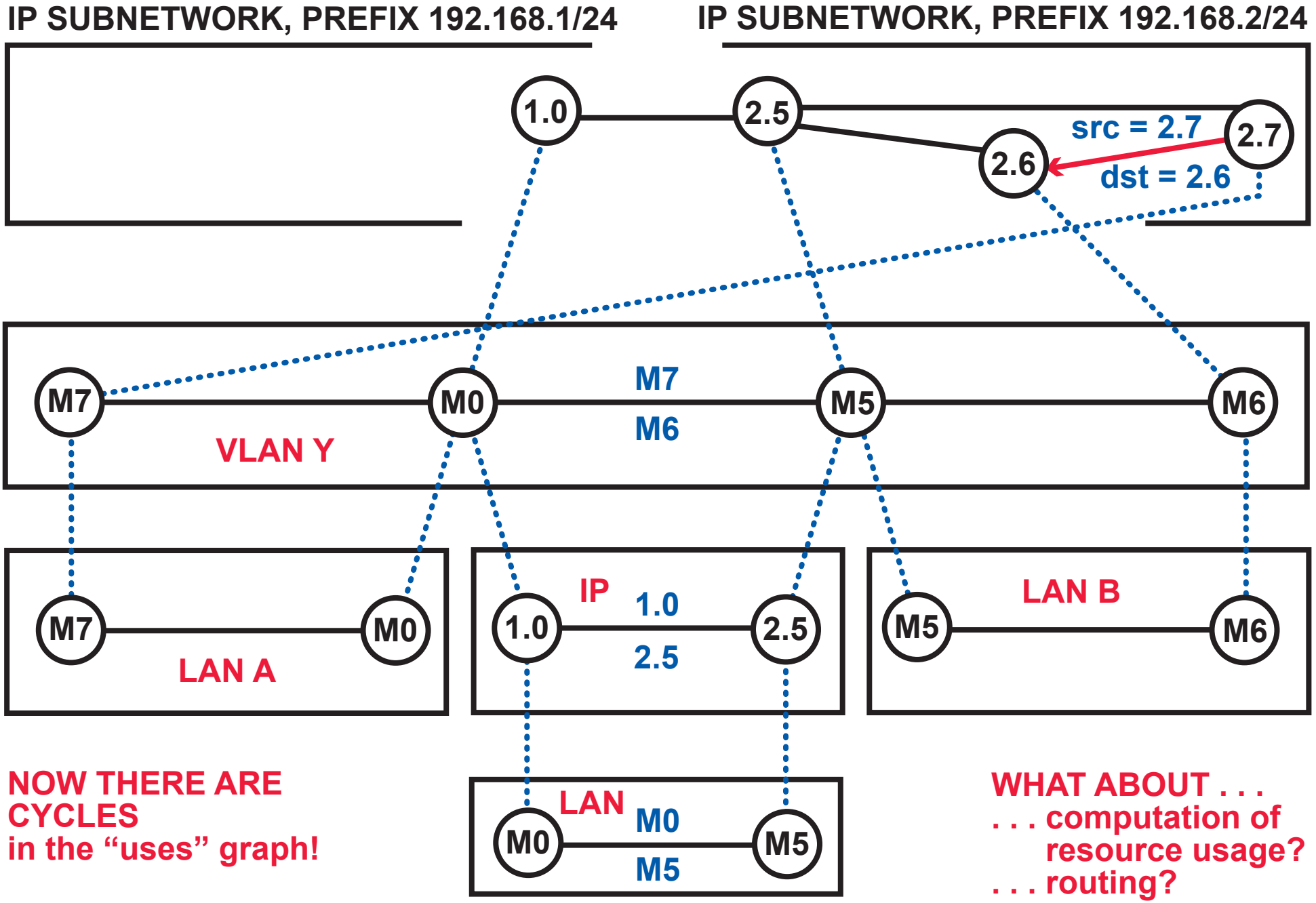
VLAN TECHNOLOGY



VXLAN TECHNOLOGY

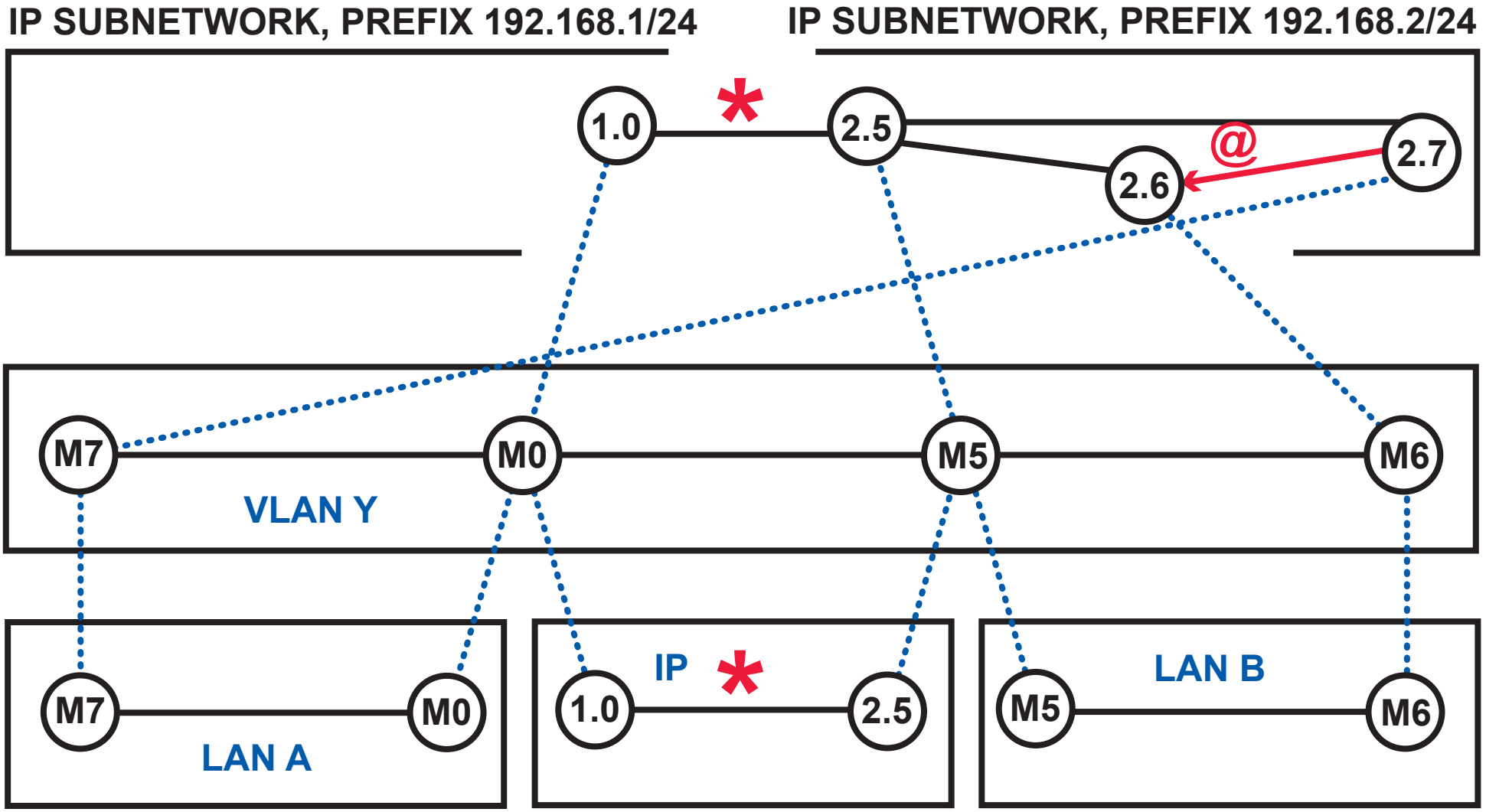


UNDERSTANDING THE COMPOSITION



COMPUTATION OF RESOURCE USAGE

There can be usage cycles among networks, but not among links!

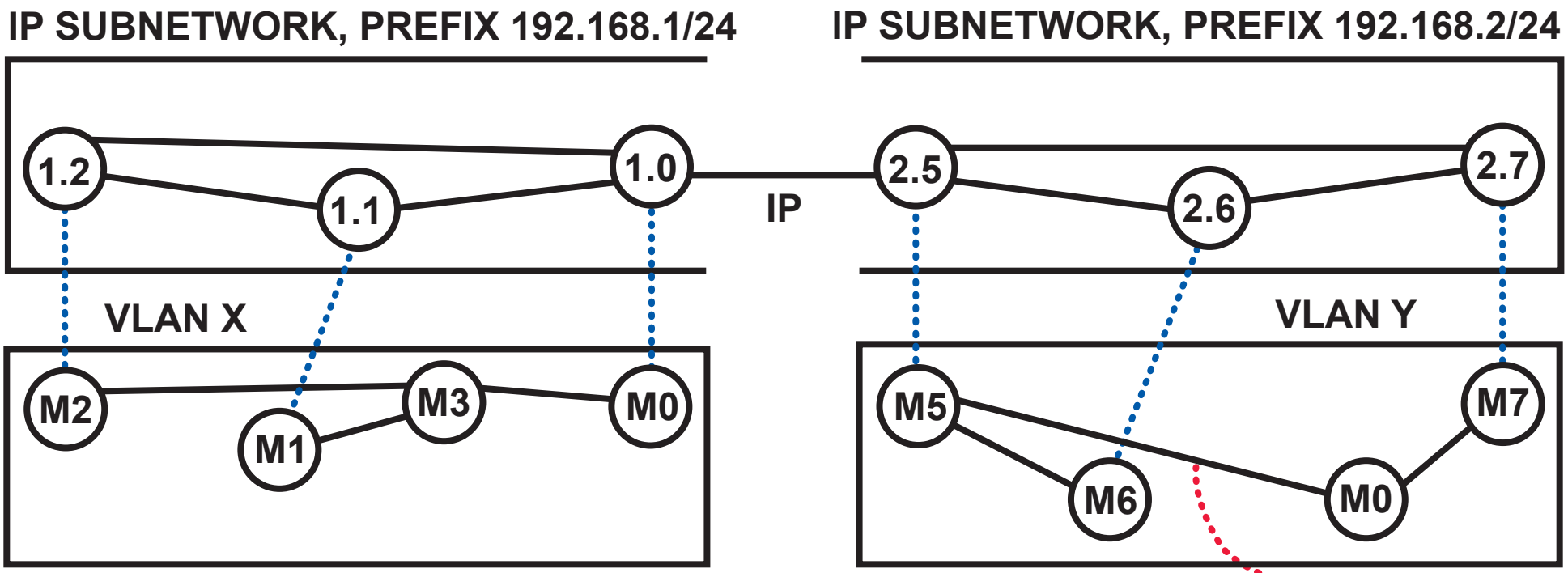


@ USES *

* does not use anything but an isolated Ethernet link

ROUTING

WITH THE VXLAN ARCHITECTURE, ROUTING IN EVERY NETWORK IS NORMAL

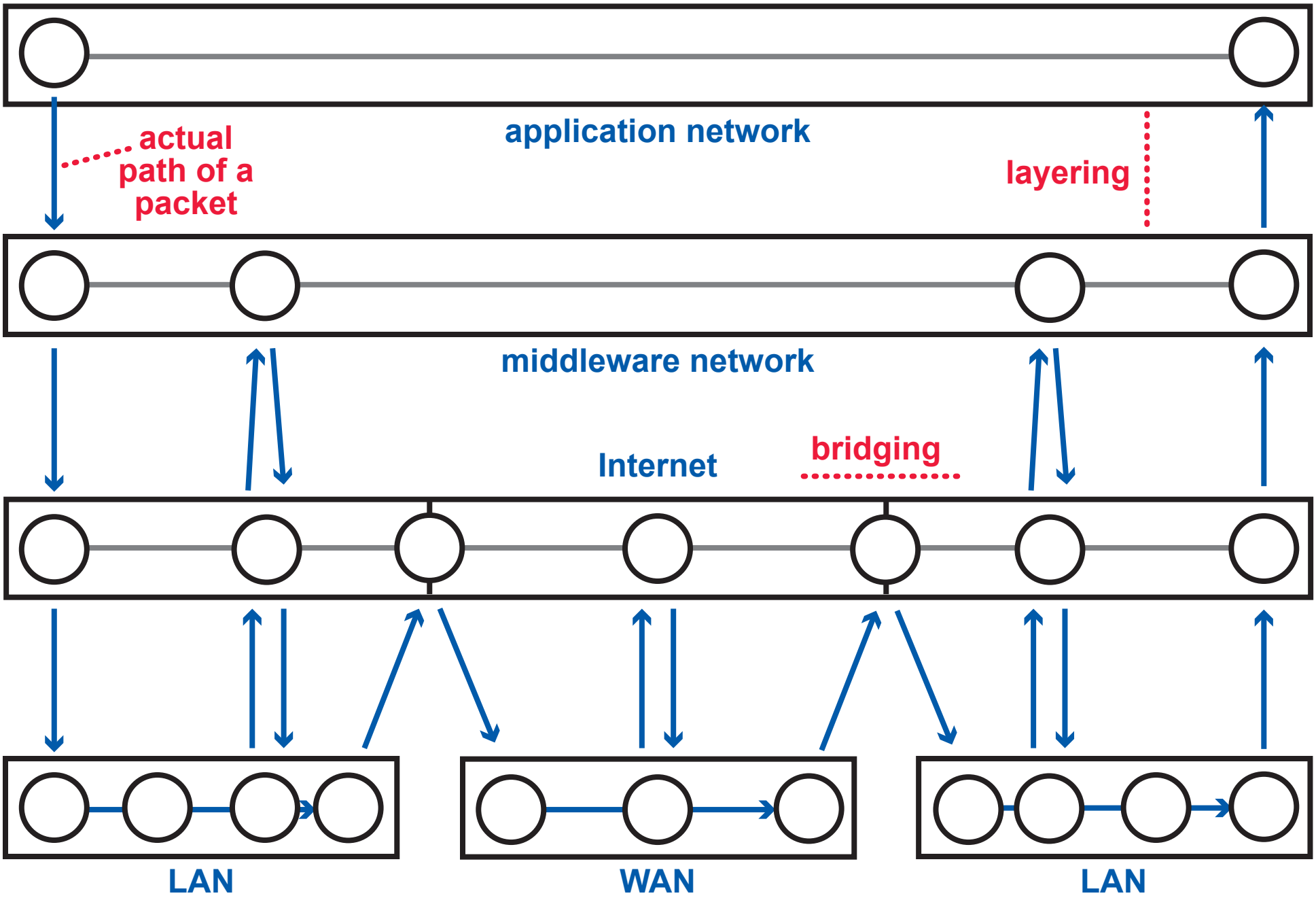


note that switches and links can belong to multiple VLANs, although hosts cannot

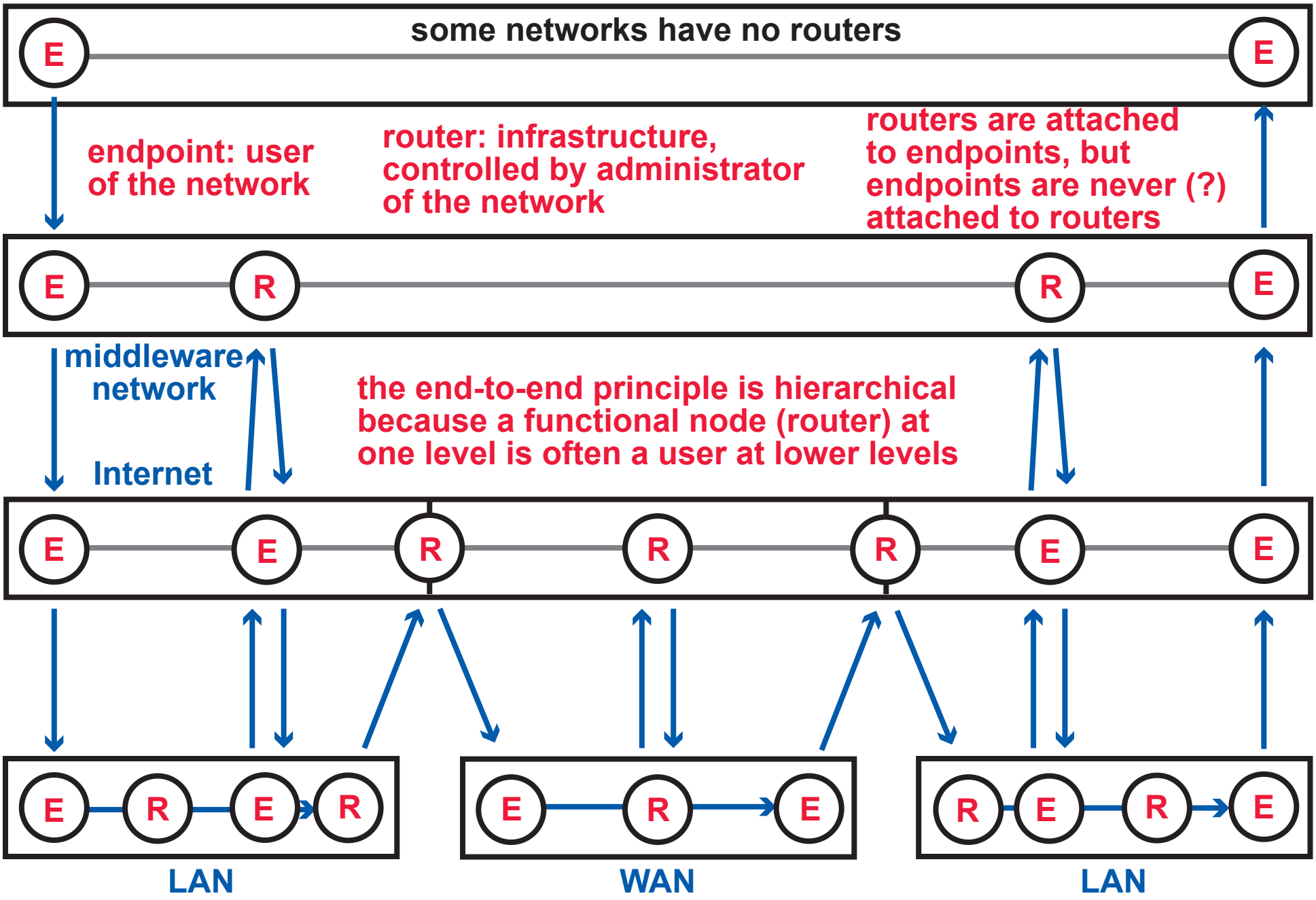
this causes no confusion because VLANS are isolated, both for security and to limit broadcast domains

it does not matter to VLAN routing that M0 and M5 are physically connected through the IP backbone, which is used here

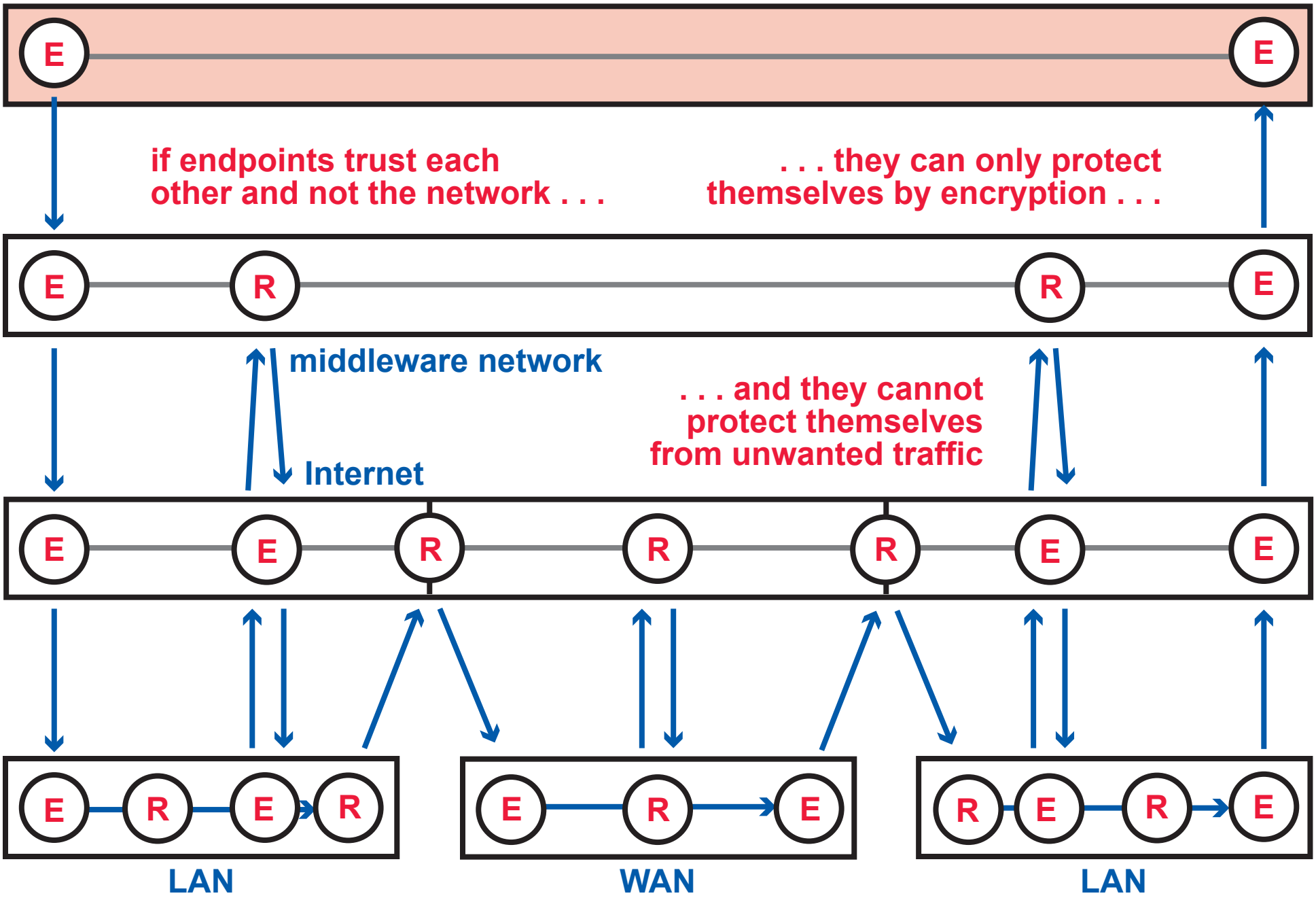
ARCHITECTURE AND TRUST



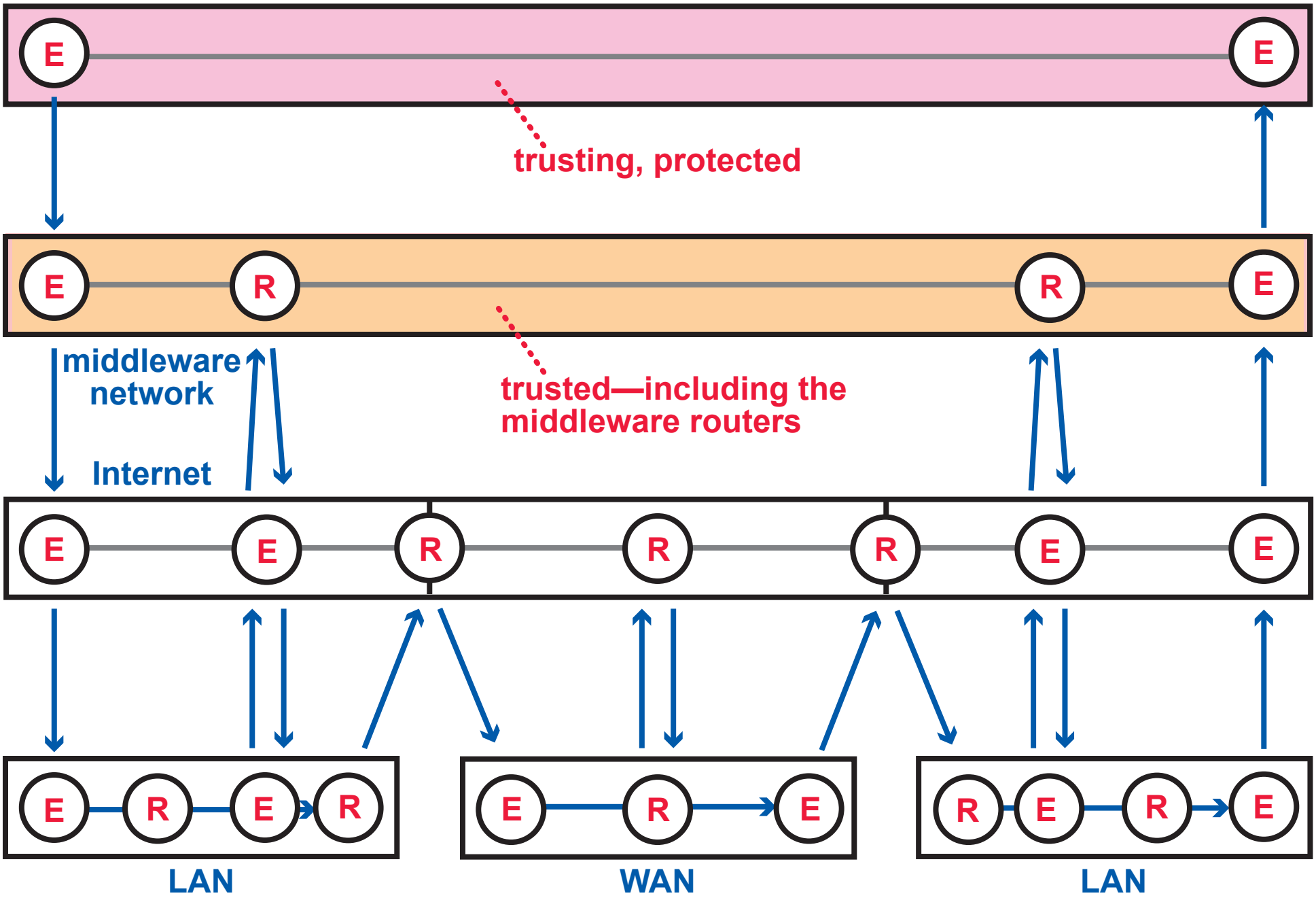
ARCHITECTURE AND TRUST: ENDPOINTS AND ROUTERS



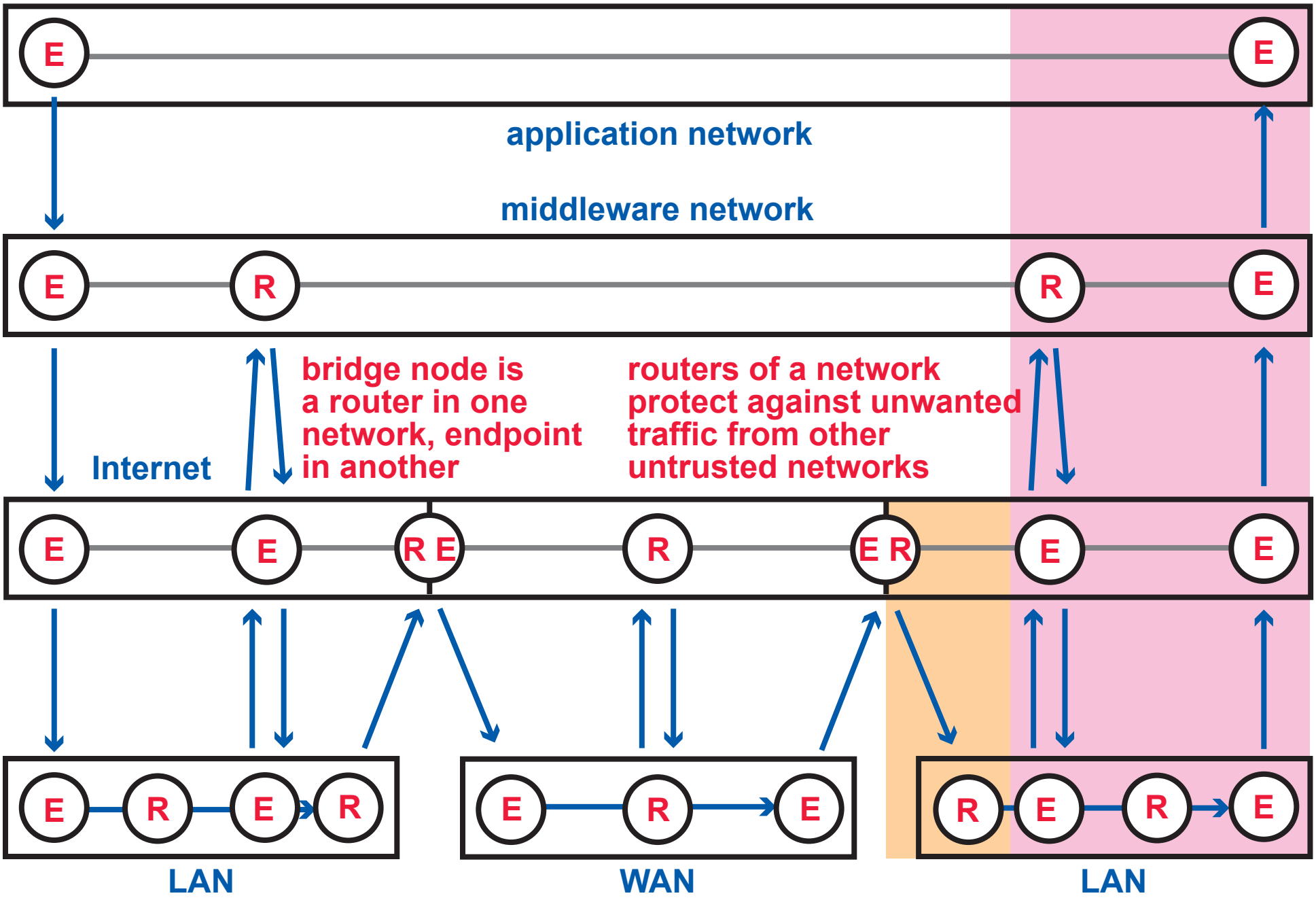
ARCHITECTURE AND TRUST: ENDPOINT TRUST



ARCHITECTURE AND TRUST: ENDPOINT TRUST



ARCHITECTURE AND TRUST: NETWORK VS. NETWORK



ARCHITECTURE AND TRUST: ROUTERS VS. ENDPOINTS