Locator/ID Separation Protocol (LISP)

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* special thanks to Olivier Bonaventure, Luigi Iannone and Dino Farinacci

Disclaimer

- Not a vendor
- Not an operator
- LISP will not solve all the problems

➡ try to stay with the facts (now)

Agenda

- Why Separating Identifiers from Locators?
- Locator/ID Separation Protocol (LISP)
- LISP Use Case
- Open Questions

Why Separating Identifiers from Locators?

Bad Traffic Engineering

- Outgoing TE is ok
- Incoming TE is not can be hard, only tricks (BGP, DNS, NAT)
- Scalability issues
  - Table size (Memory)
  - Churn (CPU)

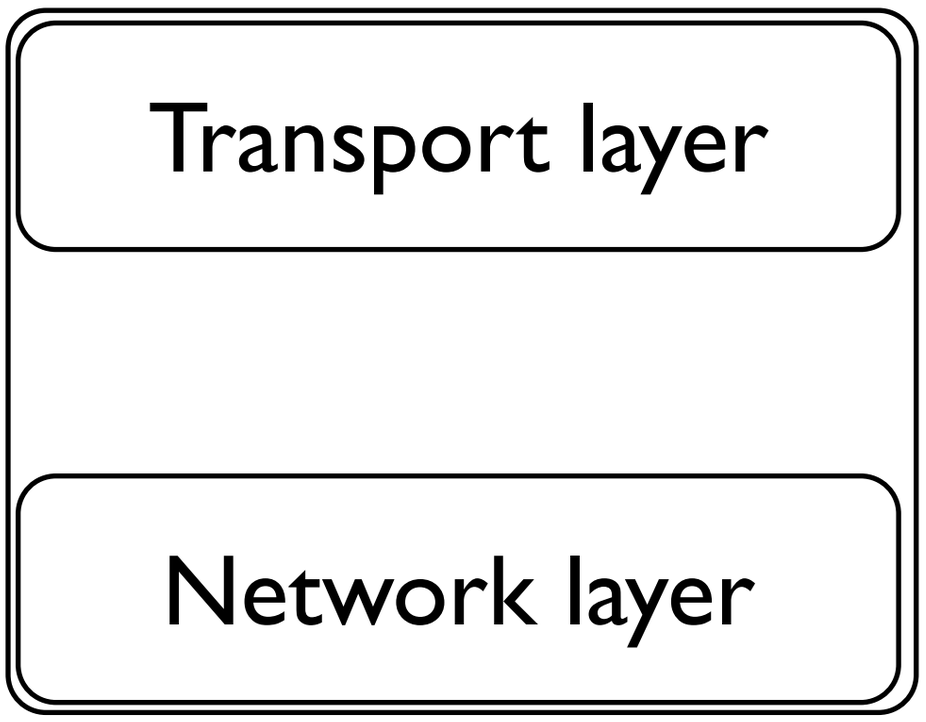
The IP Schizophrenia

- The IP addresses currently used by endhosts play two complementary roles
  - **Identifier role**: the IP address identifies (with port) the endpoint of transport flows
  - **Locator role**: the IP address indicates the paths used to reach the endhost
    - these paths are updated by routing protocols after each topology change

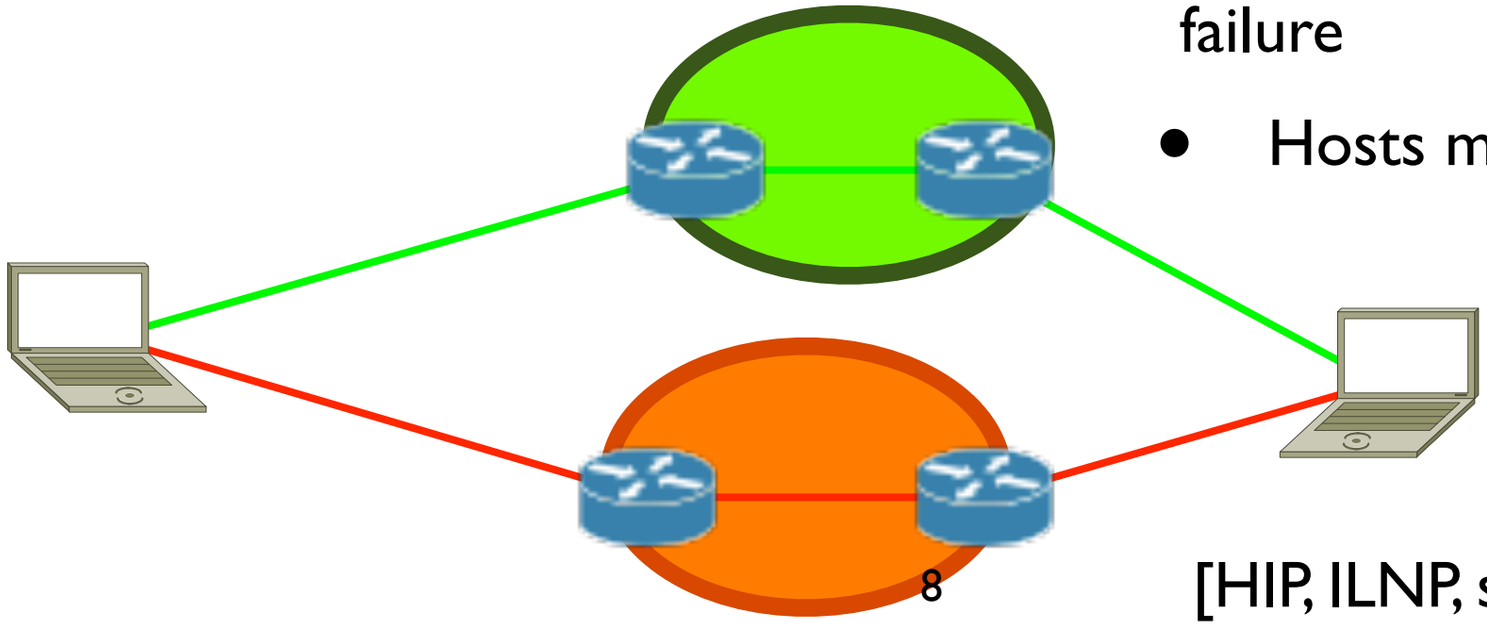
The Locator/Identifier Separation

- Today, changing the locator means changing the identifier, breaking the pending flows
- Separating the locator and the identifier roles to avoid breaking the flows
  - Host-based approach
  - Network-based approach

Host-based Loc/ID split



- Roles
  - Translates the packets so that
    - Transport layer only sees the host identifier
    - Network layer only sees locators
  - Manages the set of locators
  - Switches from one locator to another upon move or after link failure
    - Hosts maintain flow state



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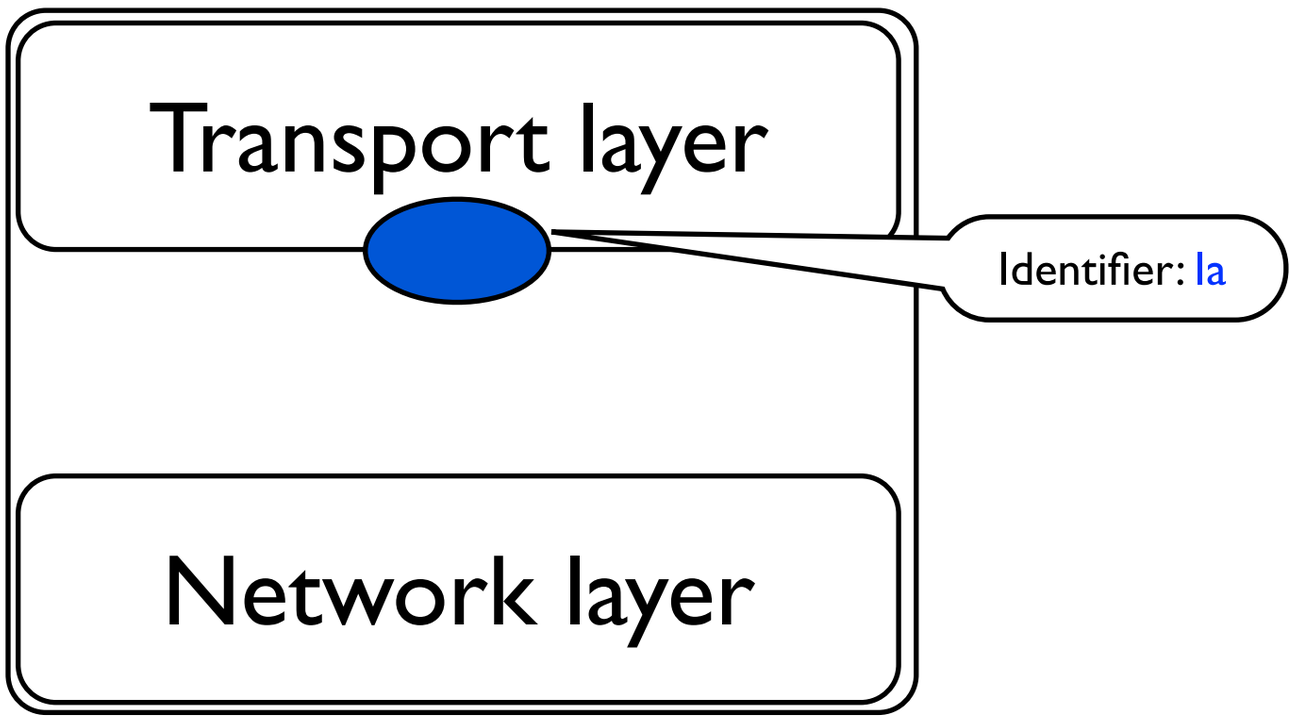

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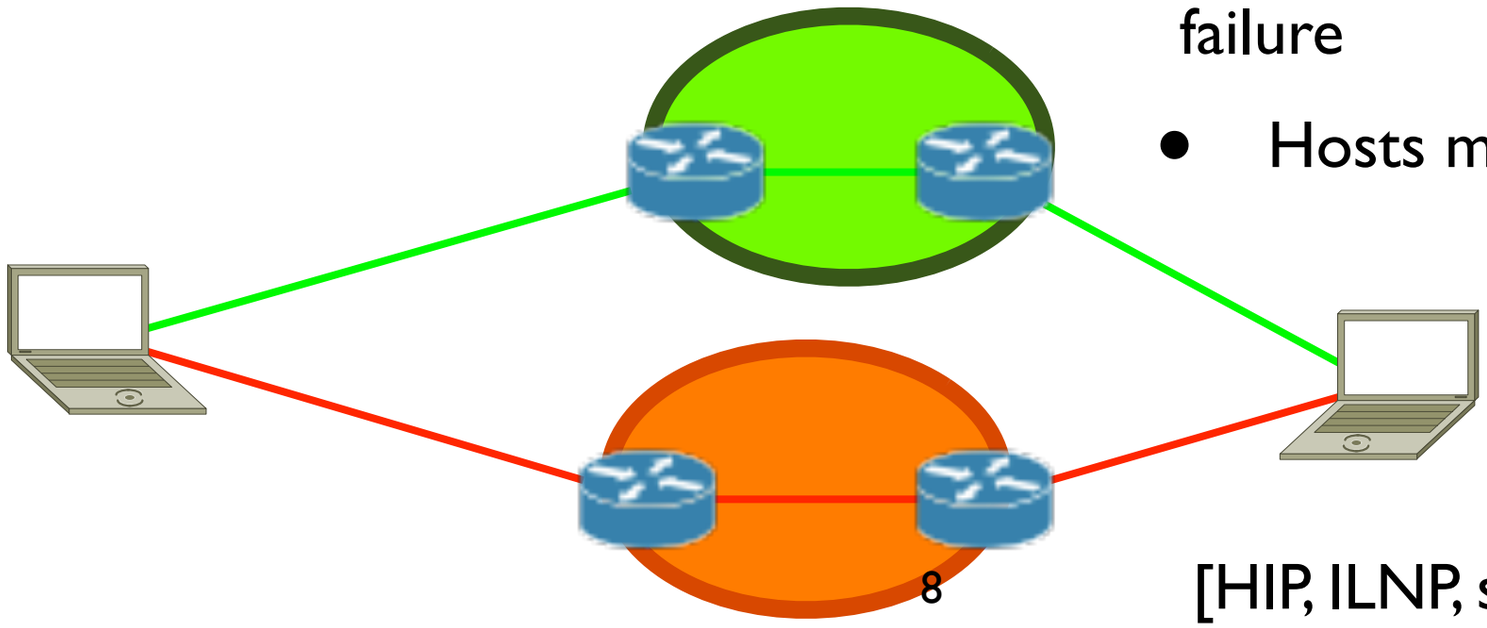

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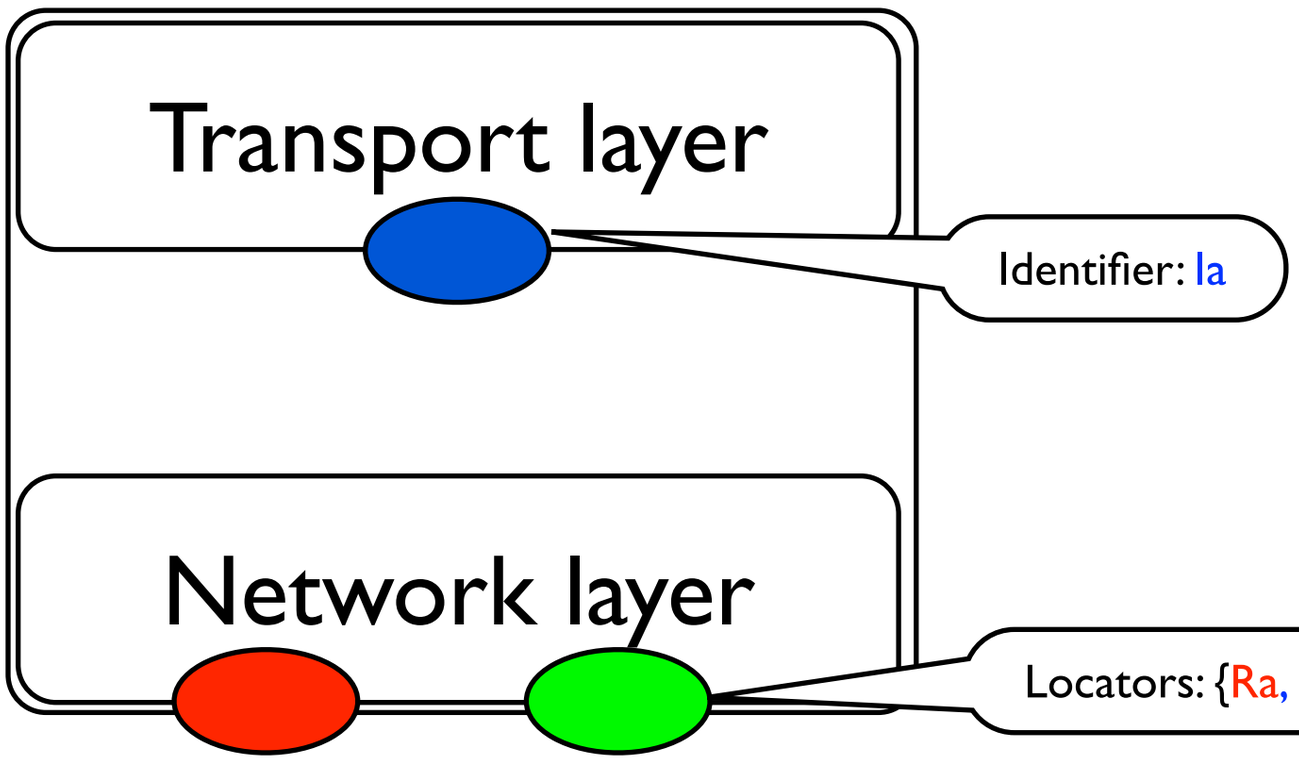

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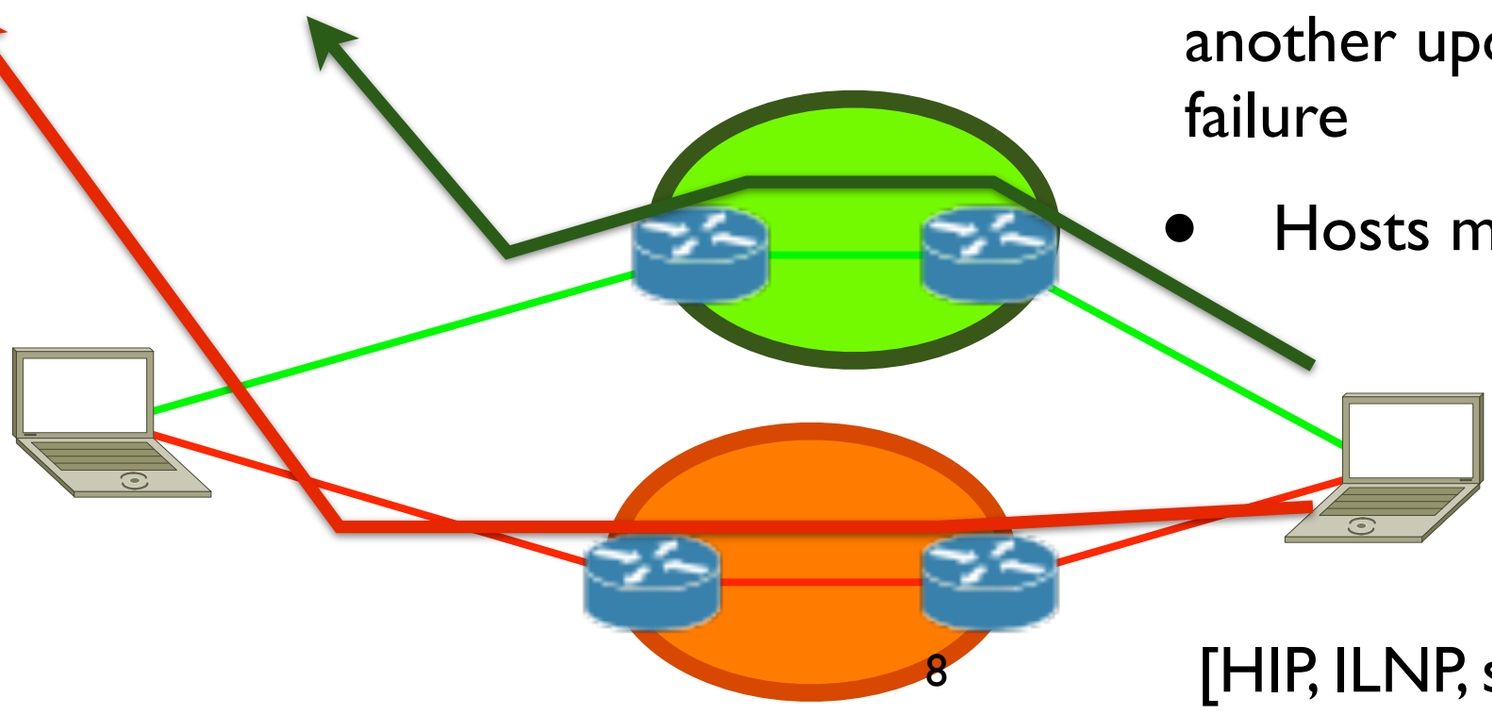

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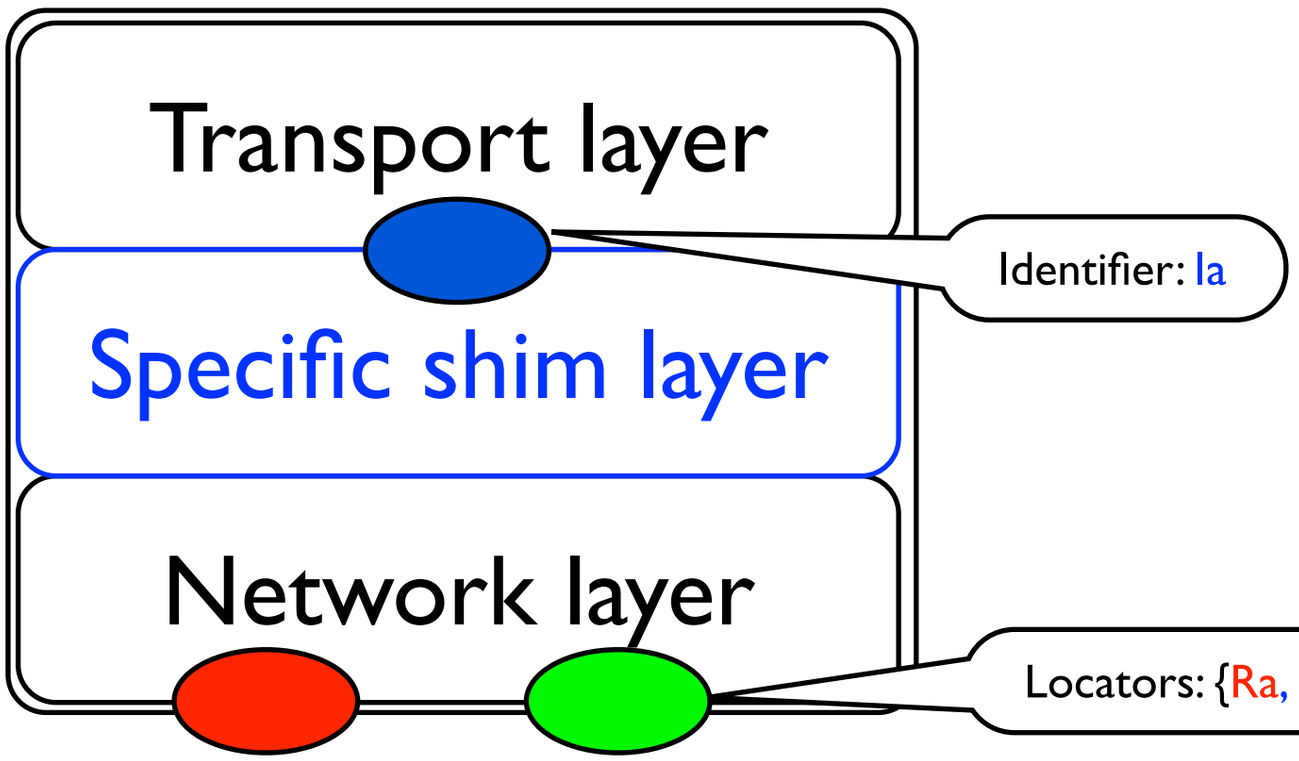

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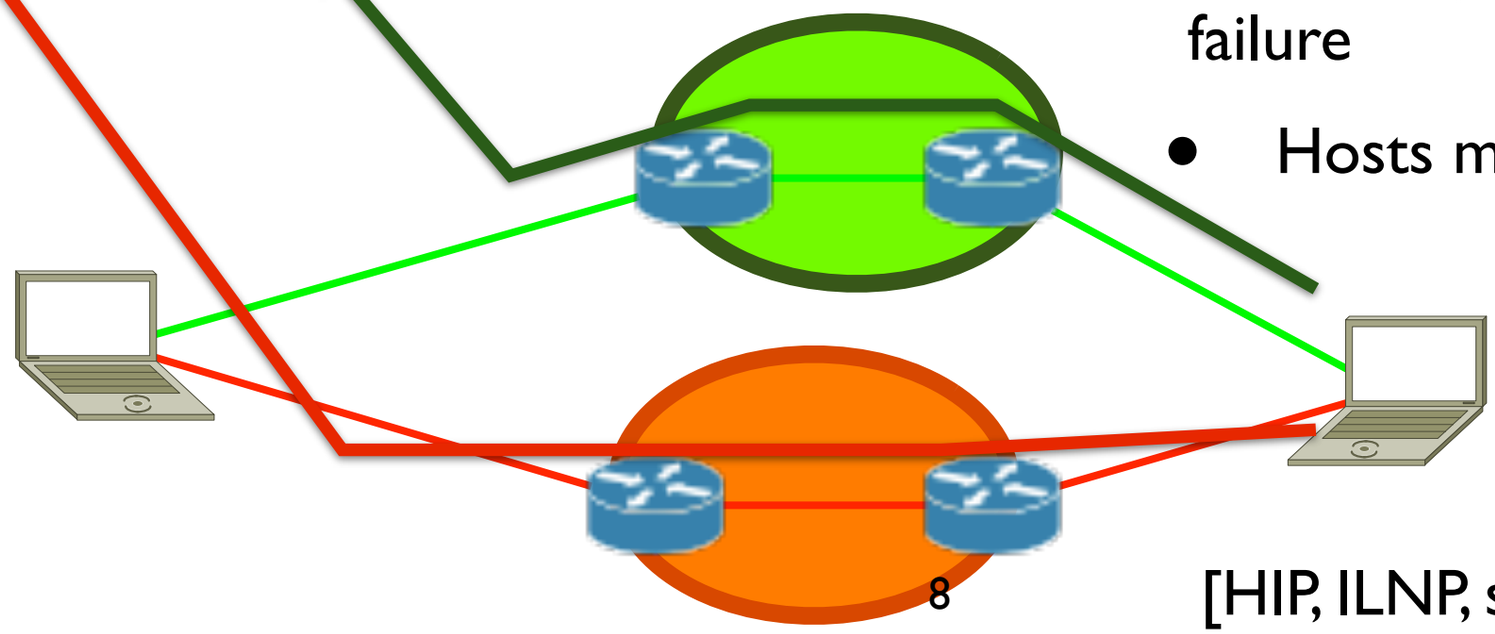

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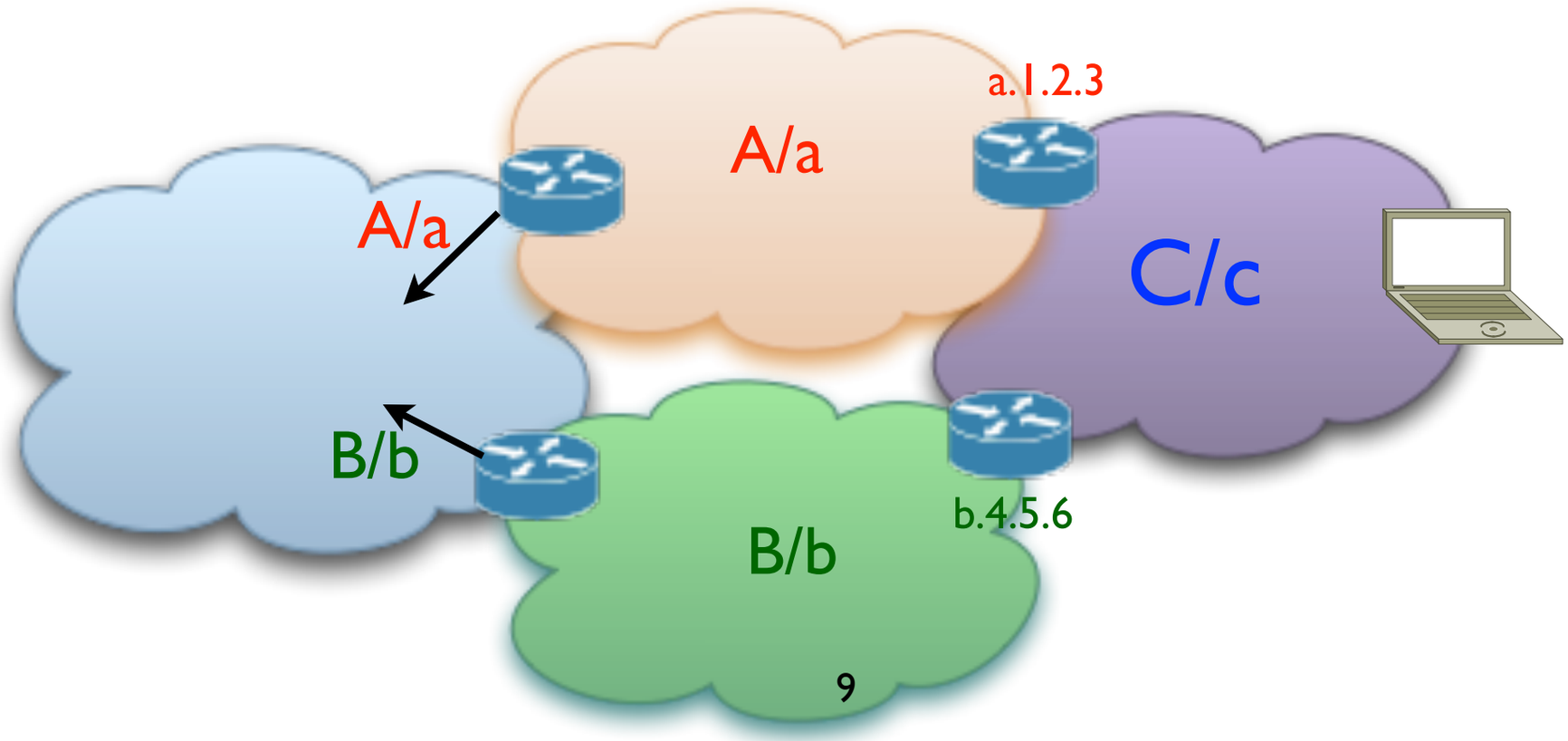
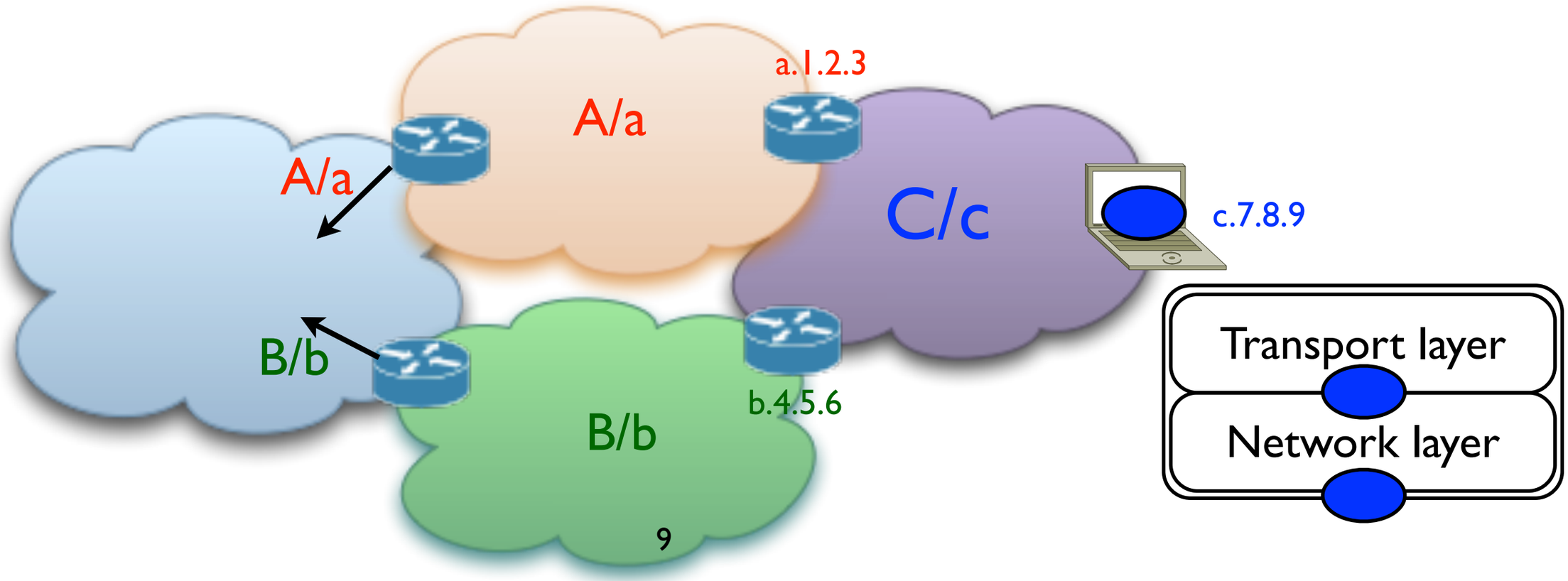


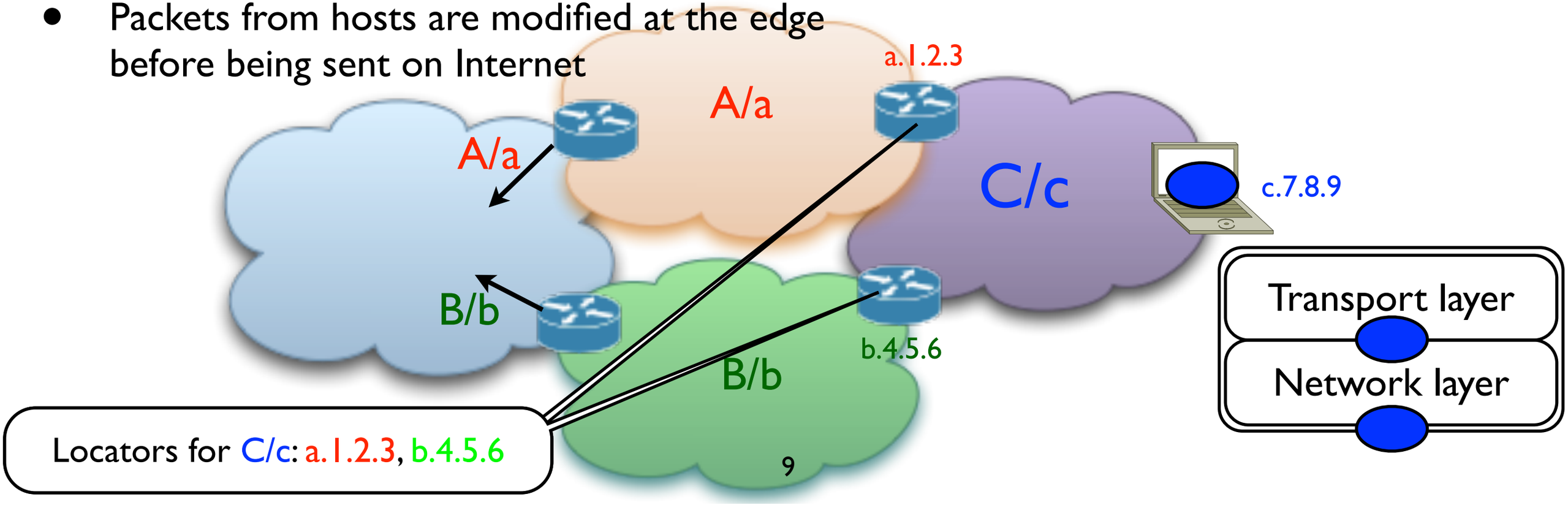
Network-based Loc/ID split

- Host's IP stack unchanged
  - Each host has one stable IP address
  - Used as identifier
  - **Not globally routable**



Network-based Loc/ID split

- Each edge router owns
  - Globally routable addresses
  - Used as locators
- **Mapping mechanism** is used to find locators associated to one identifier
- Packets from hosts are modified at the edge before being sent on Internet
- Host's IP stack unchanged
  - Each host has one stable IP address
  - Used as identifier
  - **Not globally routable**



Benefits of Identifier and Locator separation*

- Reduction of the DFZ routing table size
- No provider lock-in
- More traffic control and cost-effective multihoming
- Mobility

* in theory

Locator/ID Separation Protocol (LISP)

Design Goals*

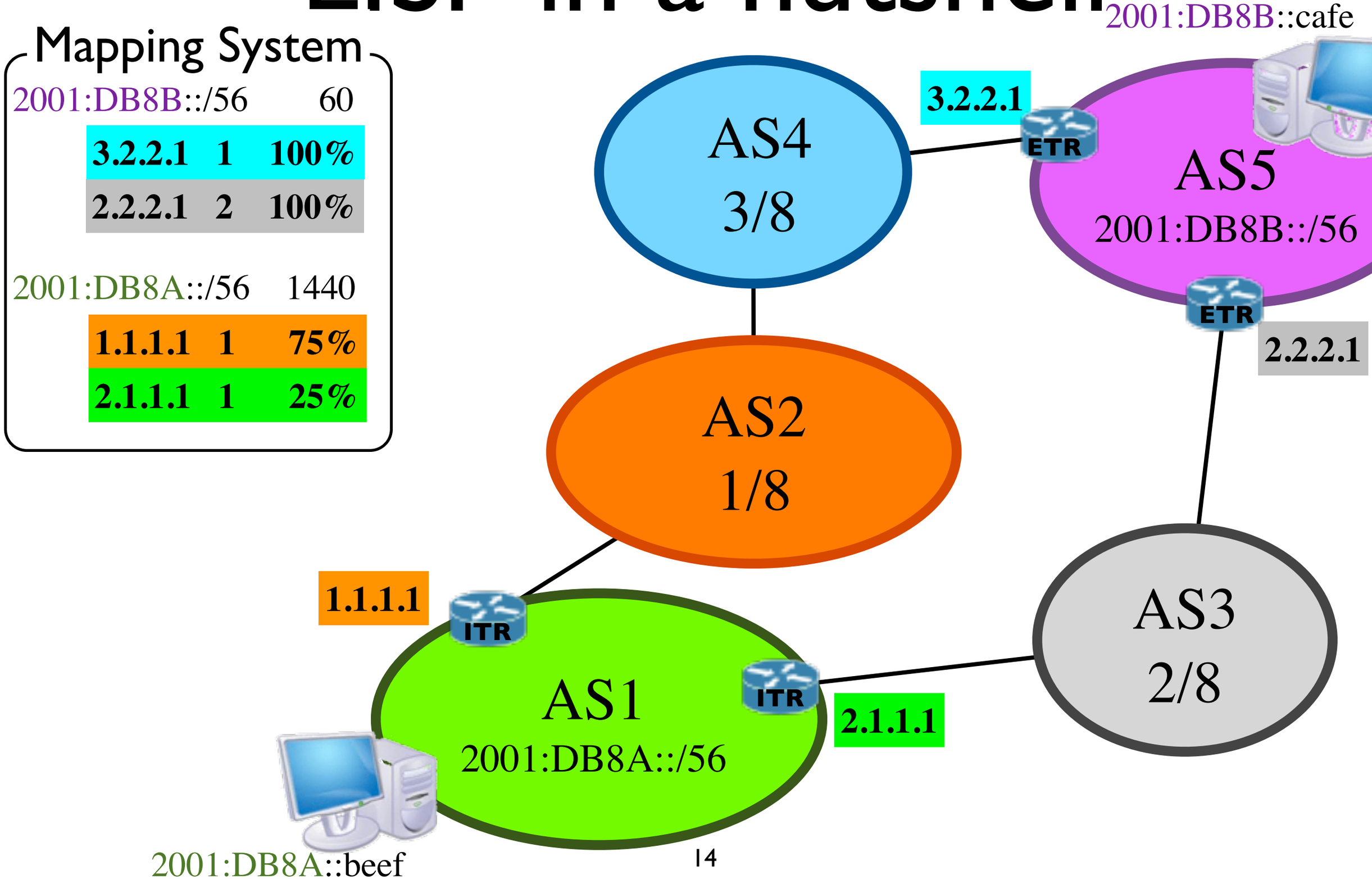
- No end-systems (hosts) changes (1)
- Minimize required changes to the Internet infrastructure (2) and the number of routers which have to be modified (5)
- Avoid or minimize packet loss when EID-to-RLOC mappings need to be performed (7)
- Be incrementally deployable (3)
- No router hardware change (4) and minimize router software changes (6)

*explicitly stated until -08

LISP Philosophy

- Split the IP address space in two at the border routers
  - **Endpoint IDentifiers (EID)**
    - identify end-systems and edge routers
    - non-globally routable
    - end systems in a site share the same EID prefix
  - **Routing LOCators (RLOC)**
    - attached to core routers (router interfaces)
    - globally routable
- Use **Map-and-Encap** to glue the two spaces

LISP in a nutshell



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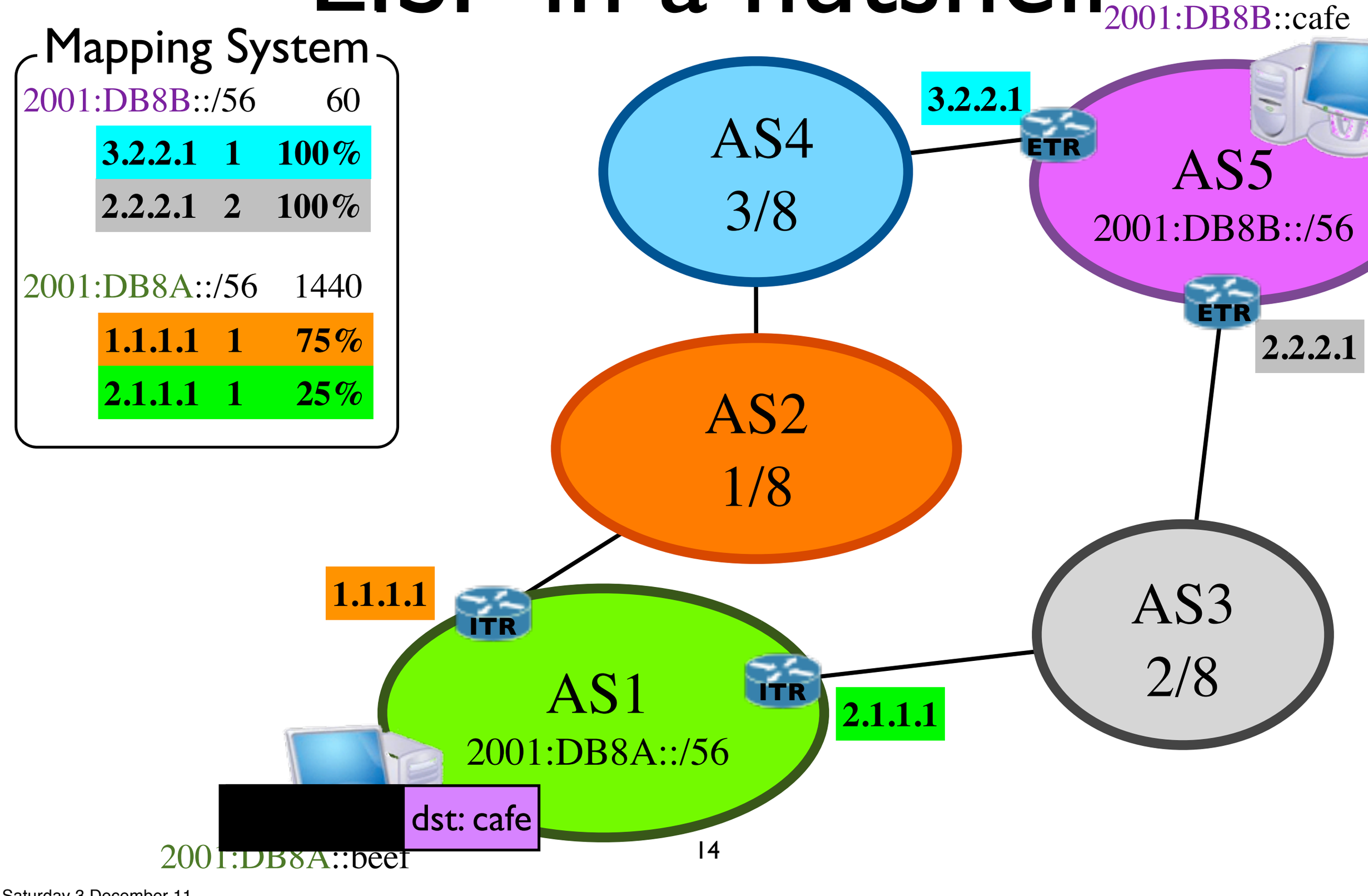

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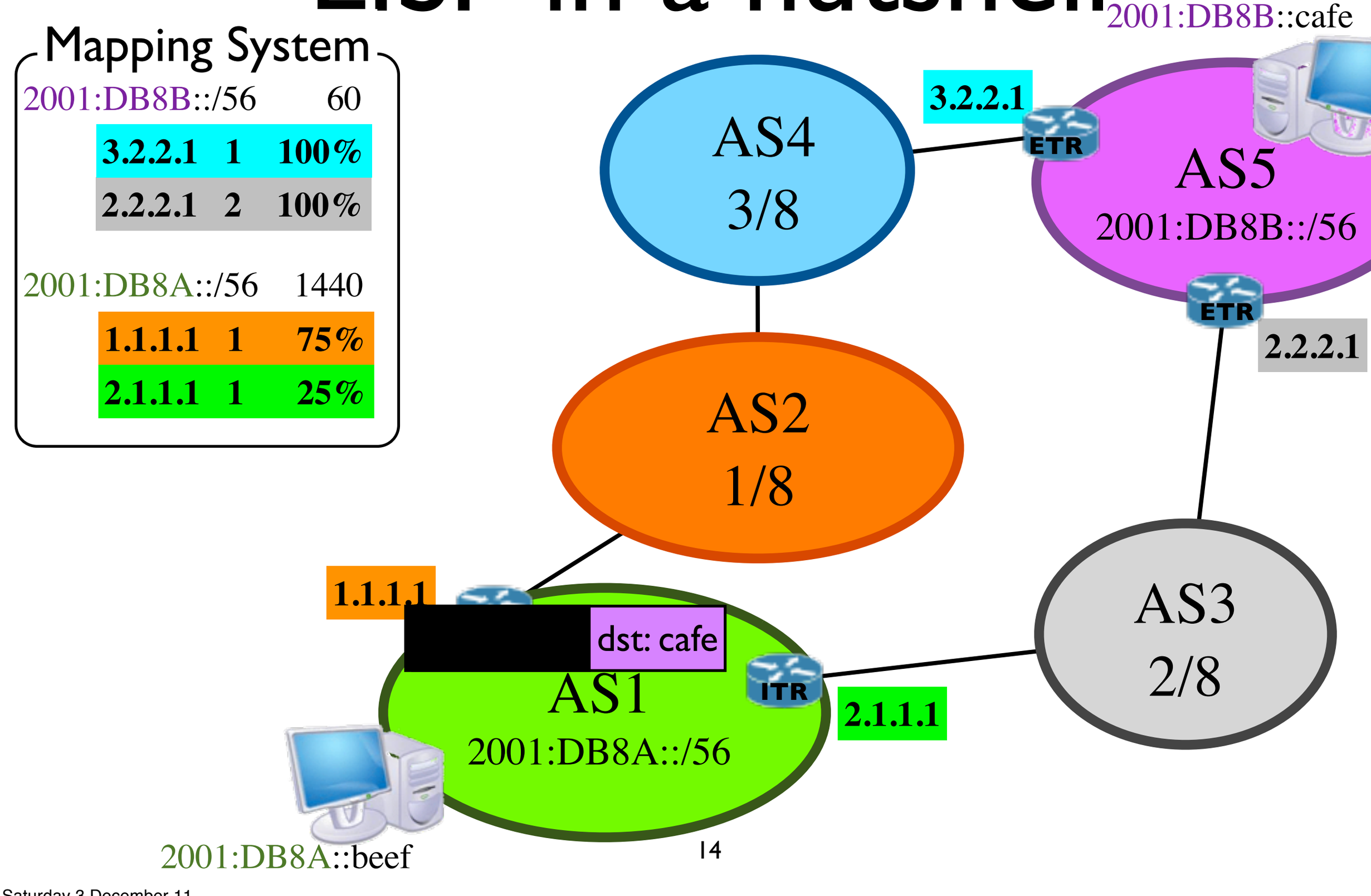

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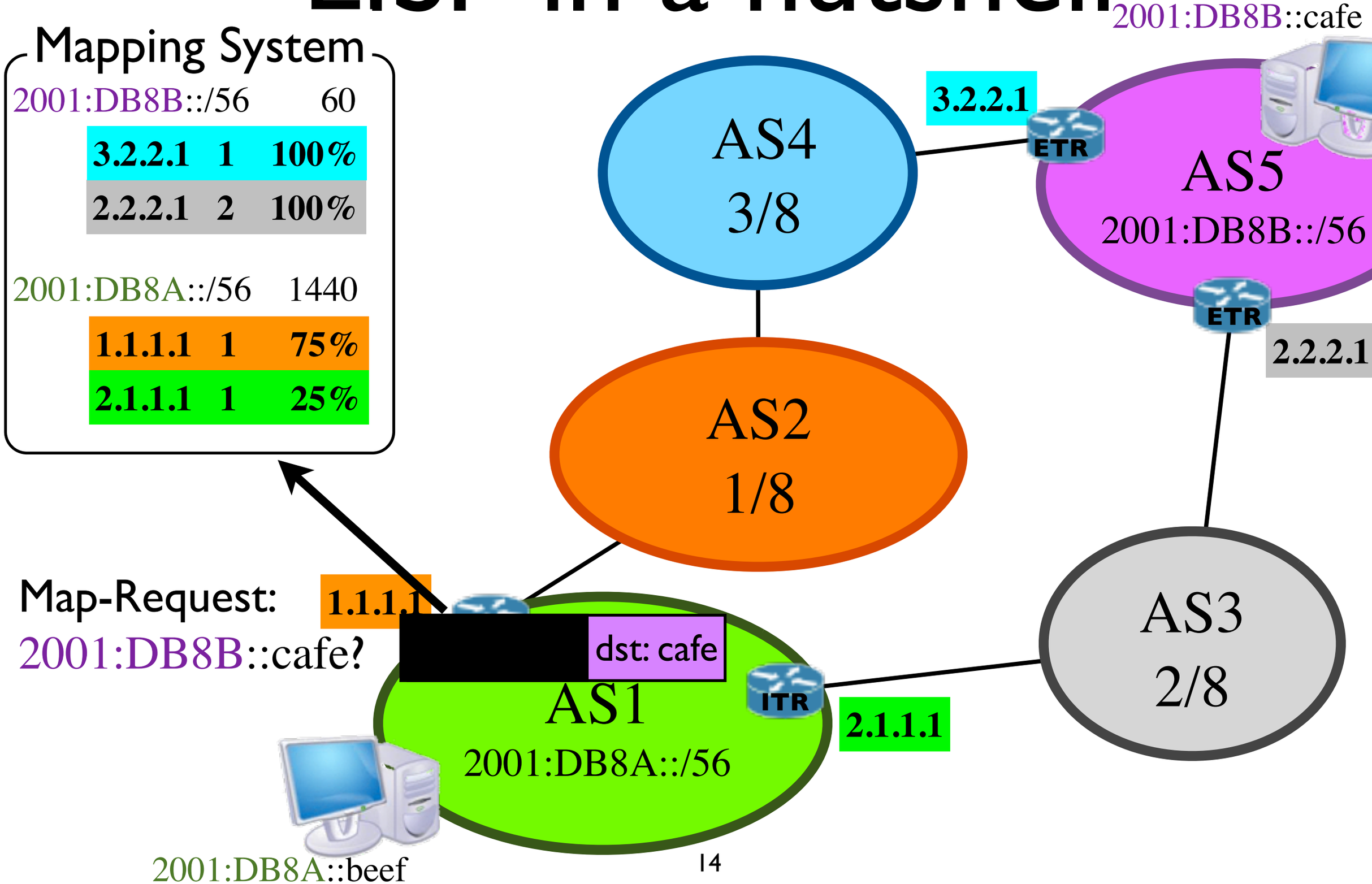

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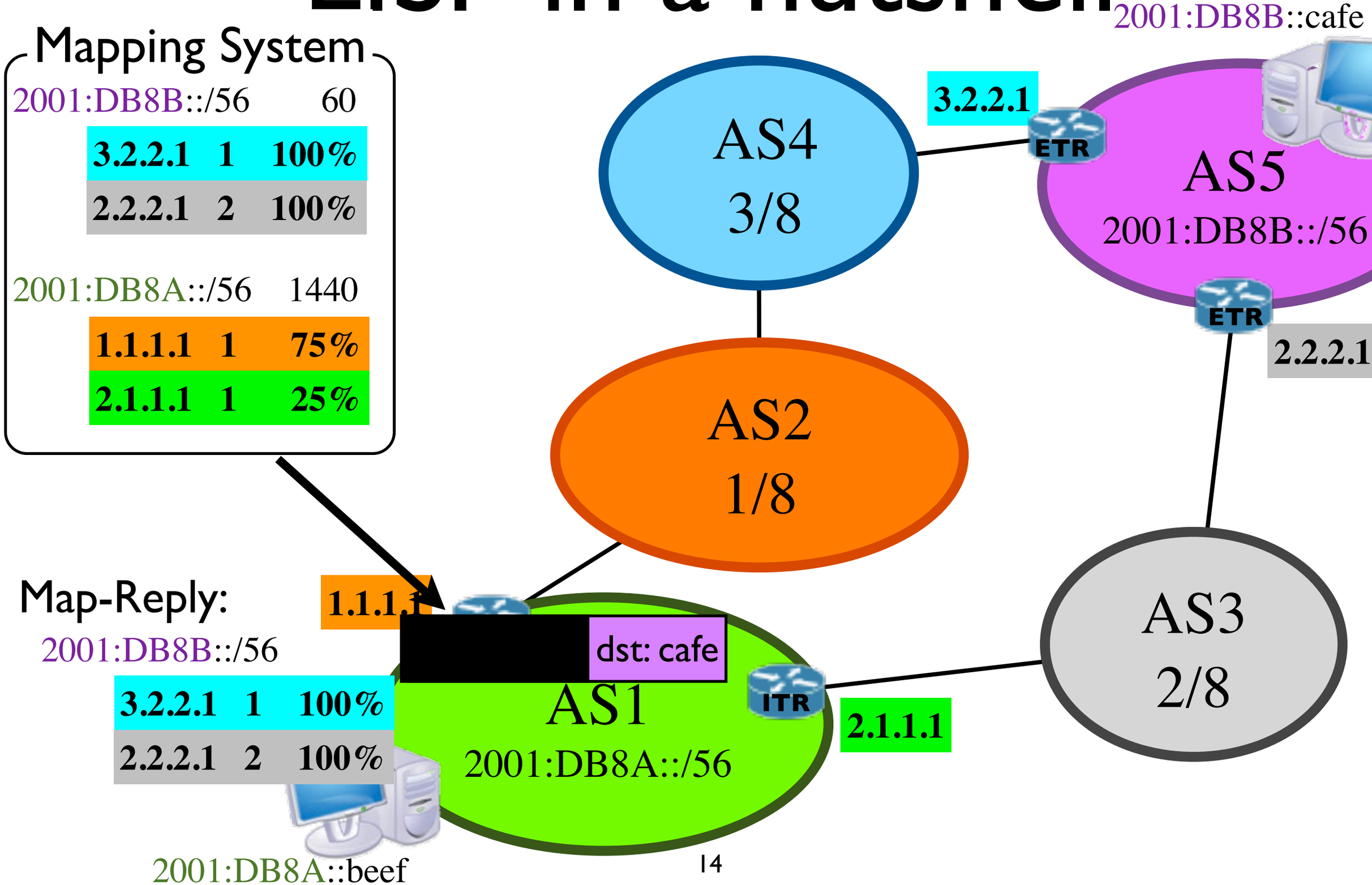

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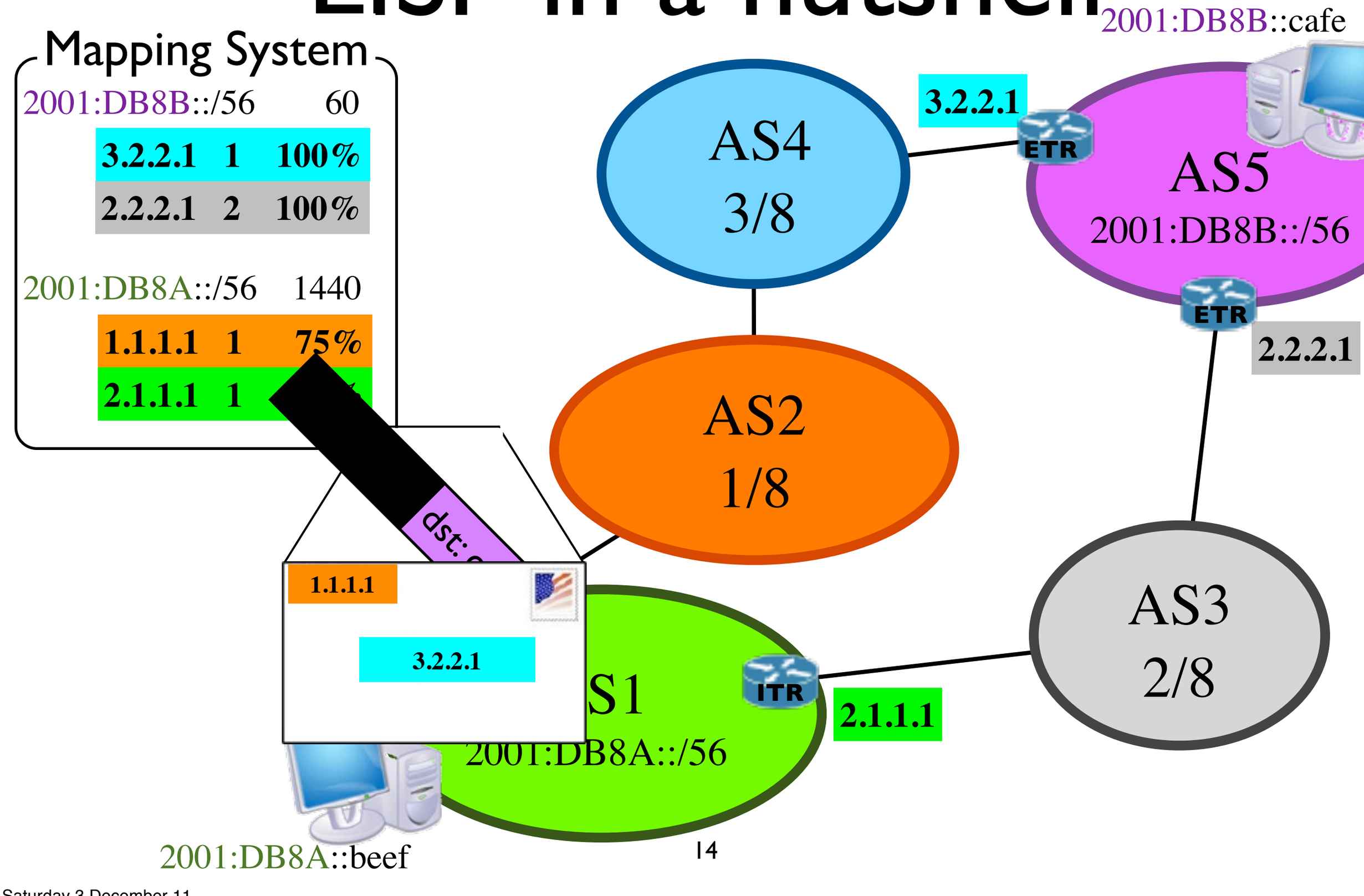

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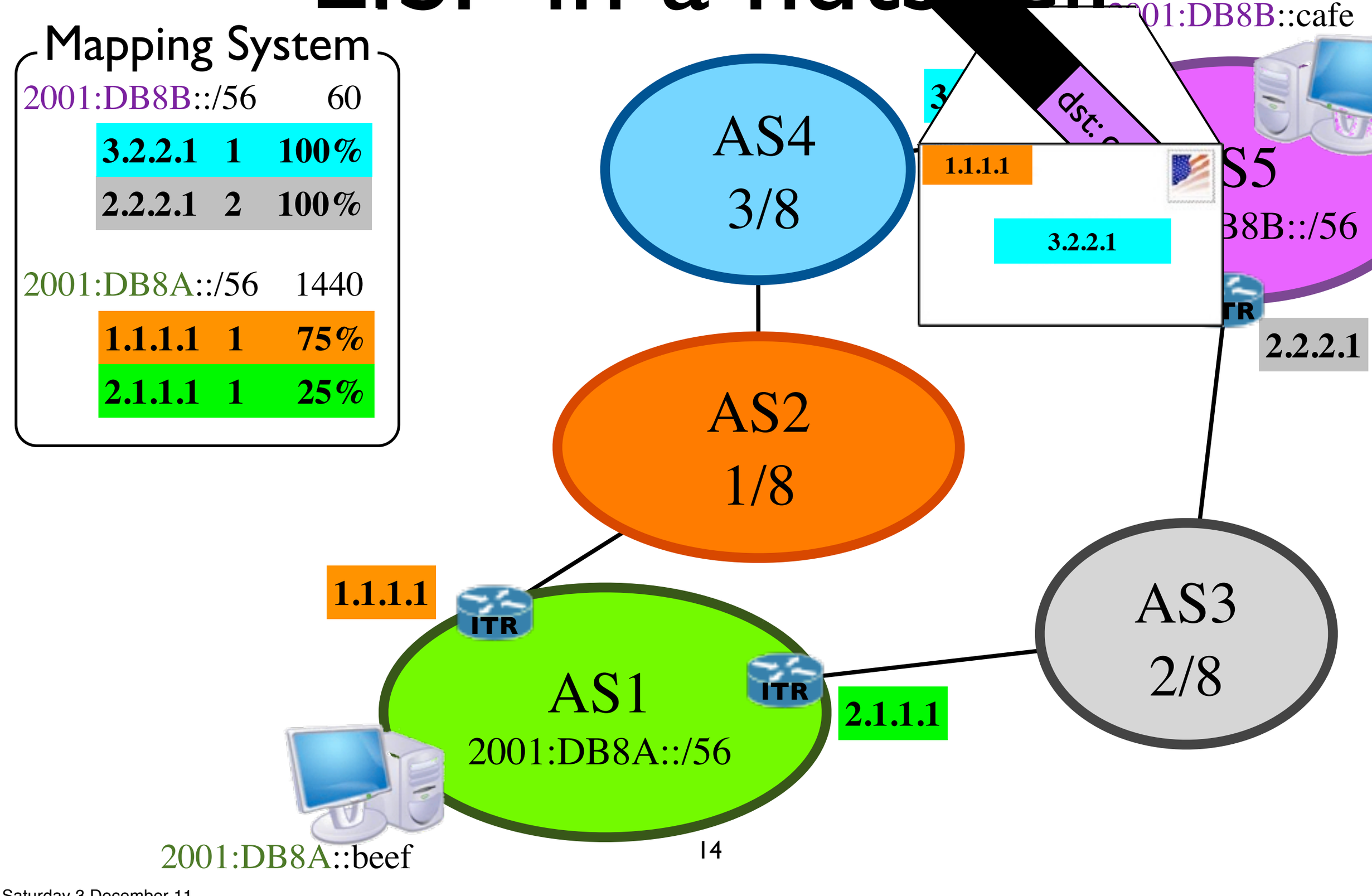

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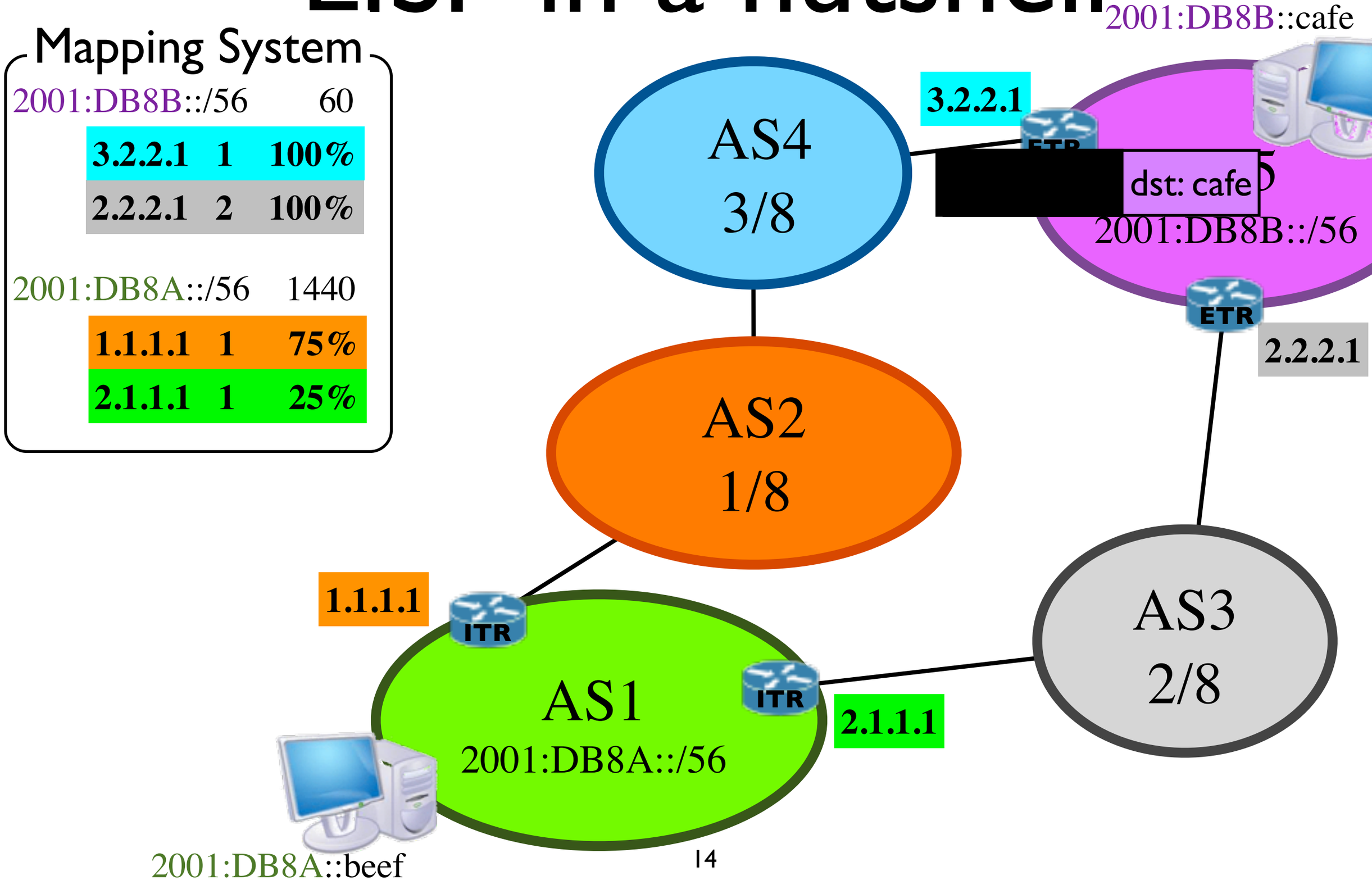

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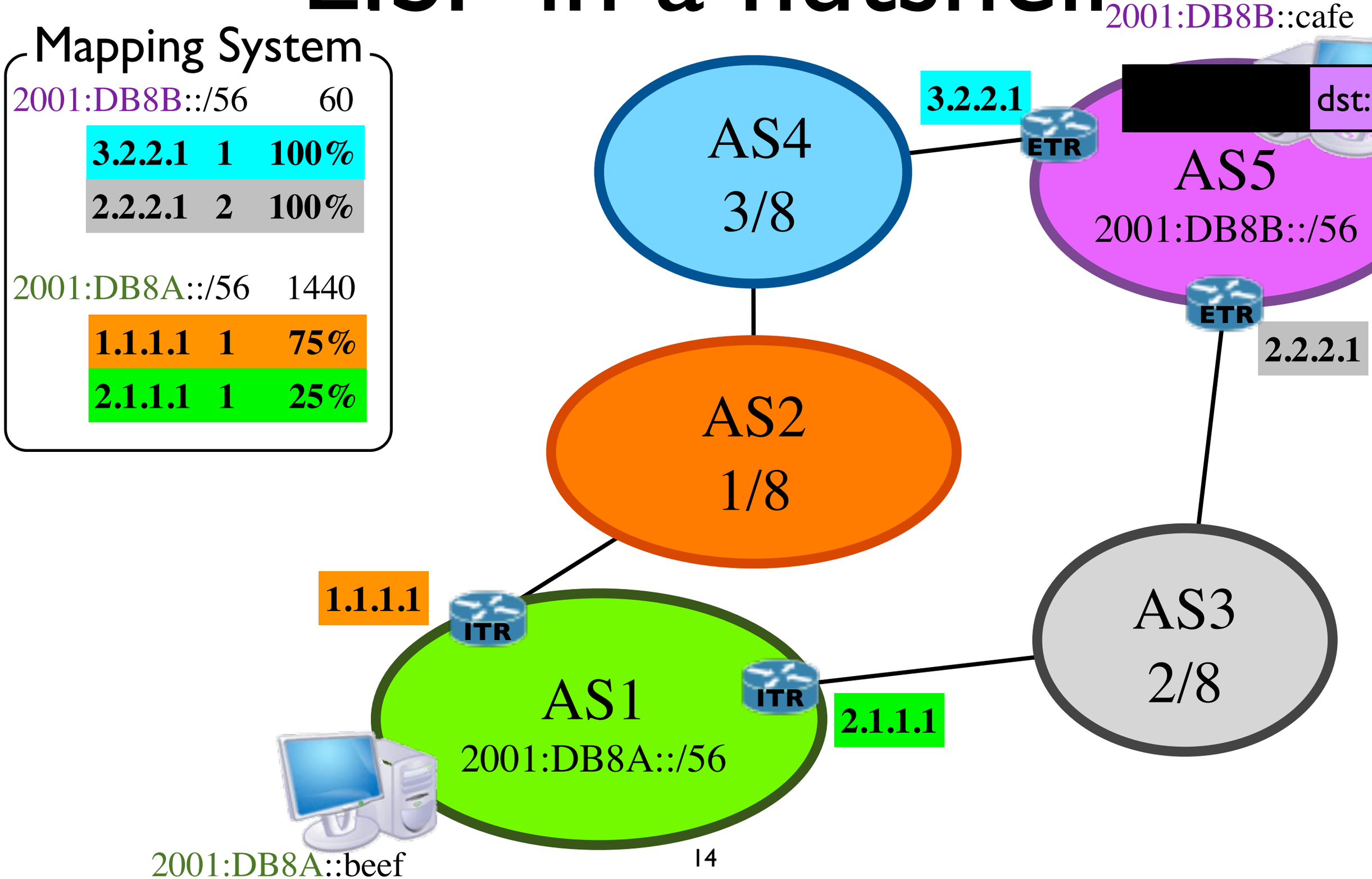

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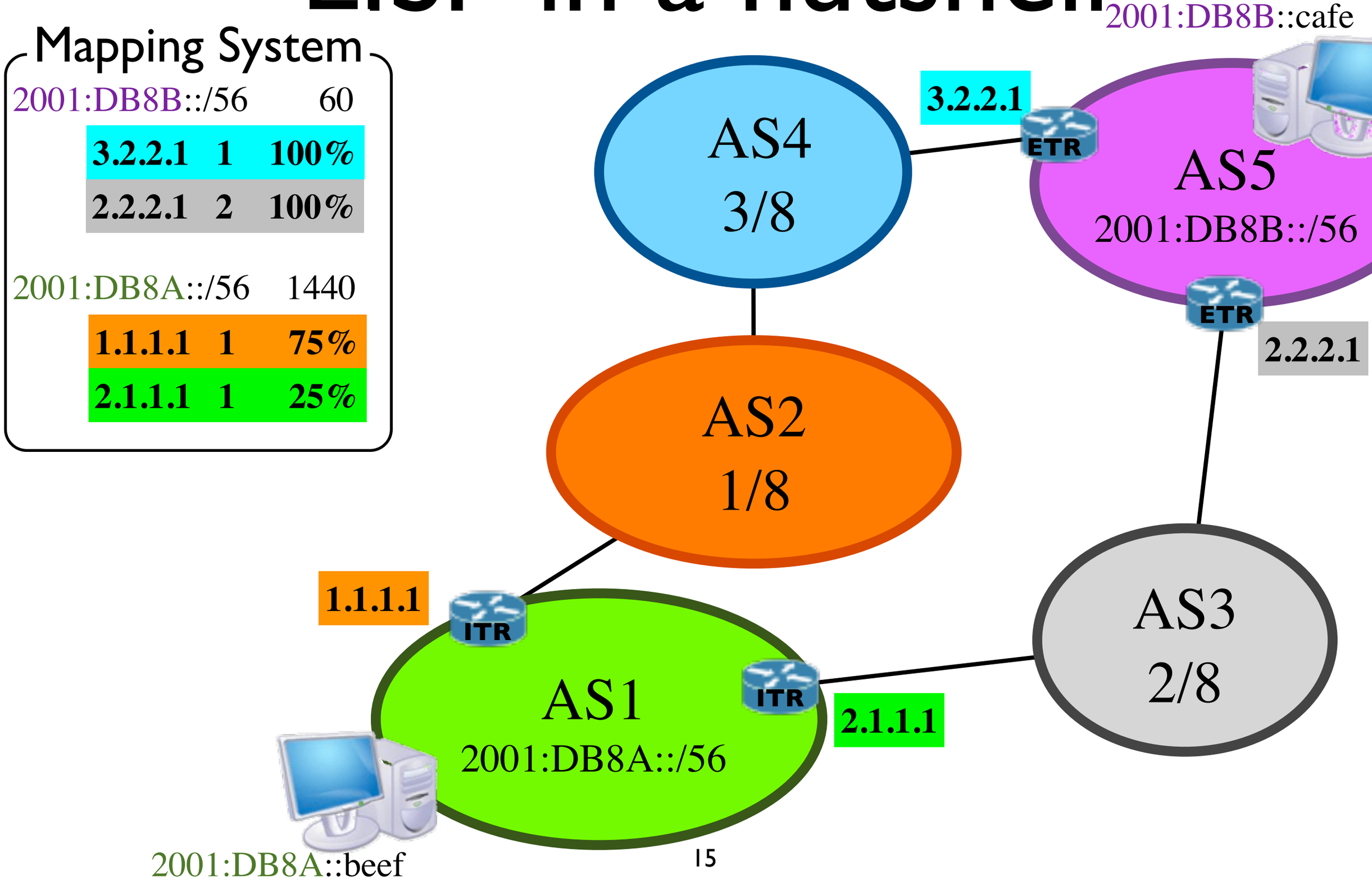

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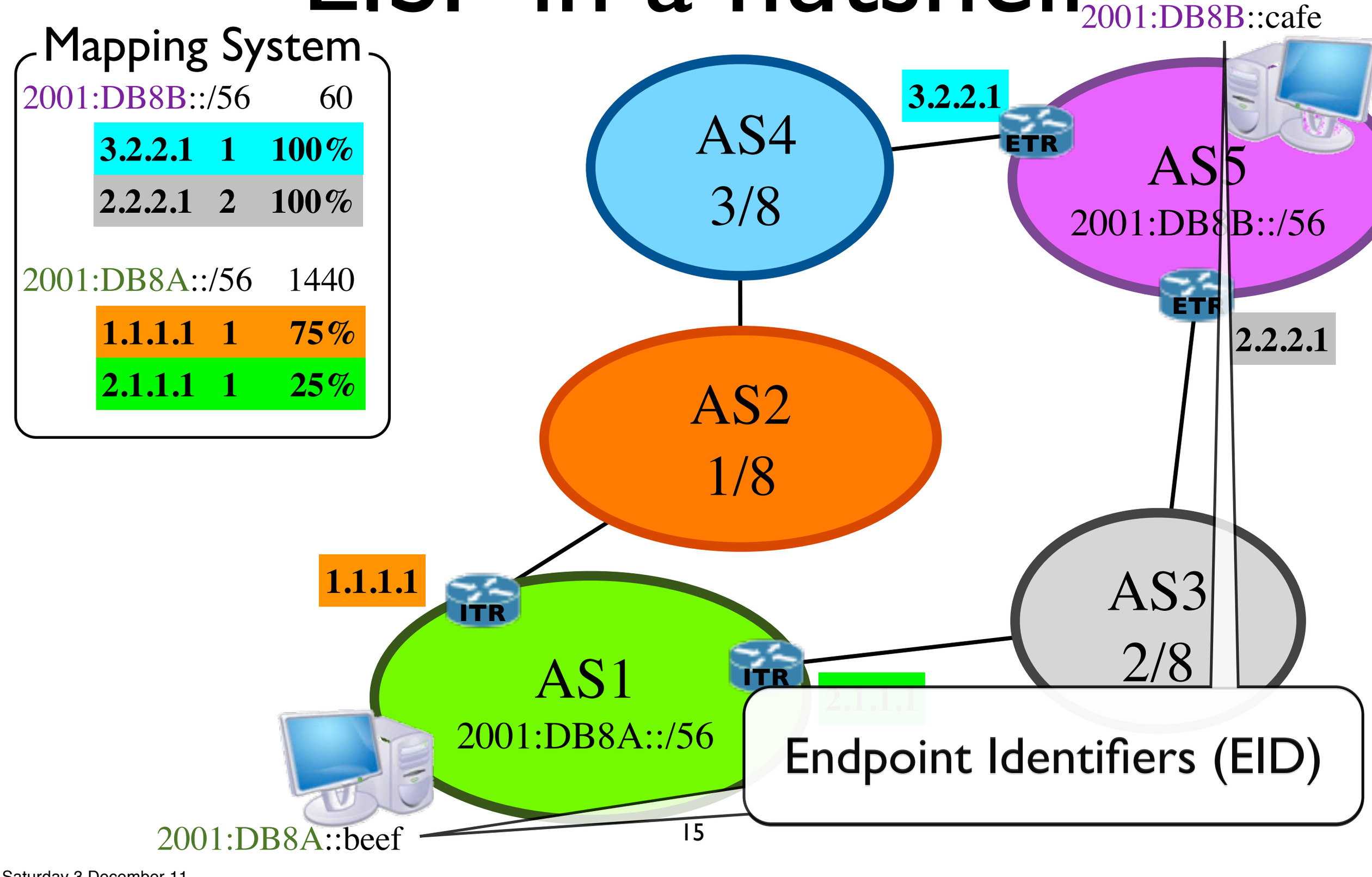

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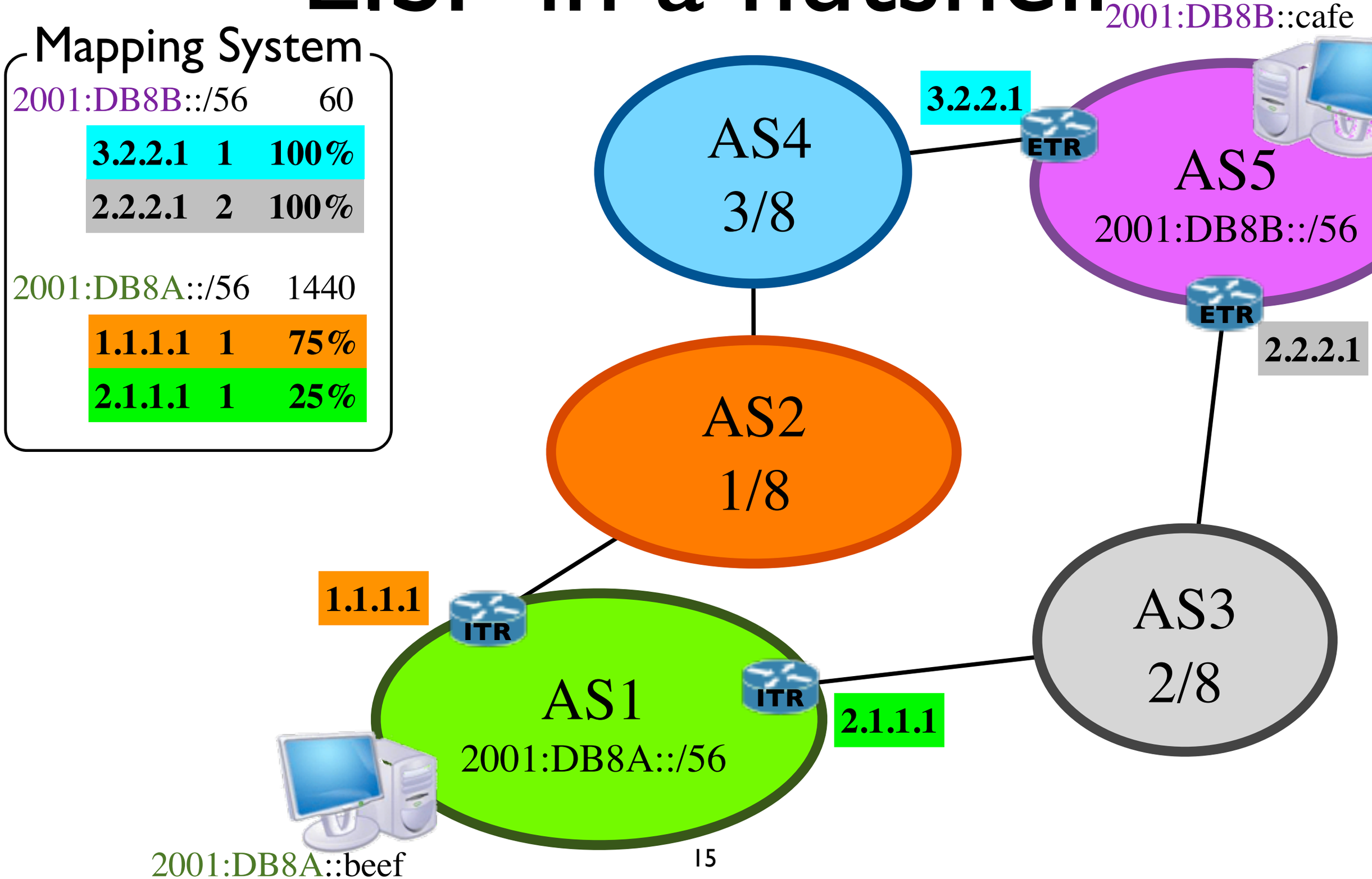

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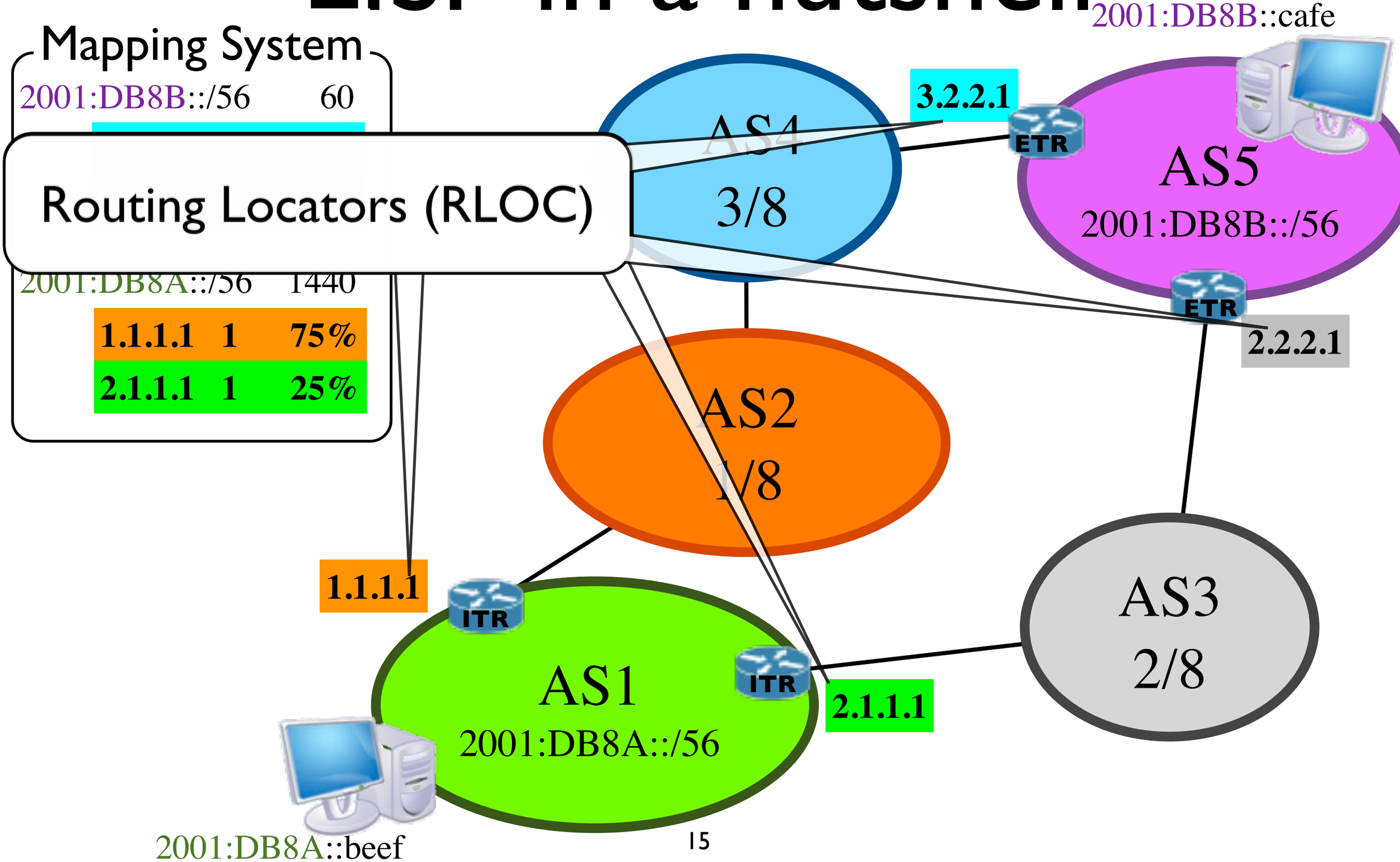

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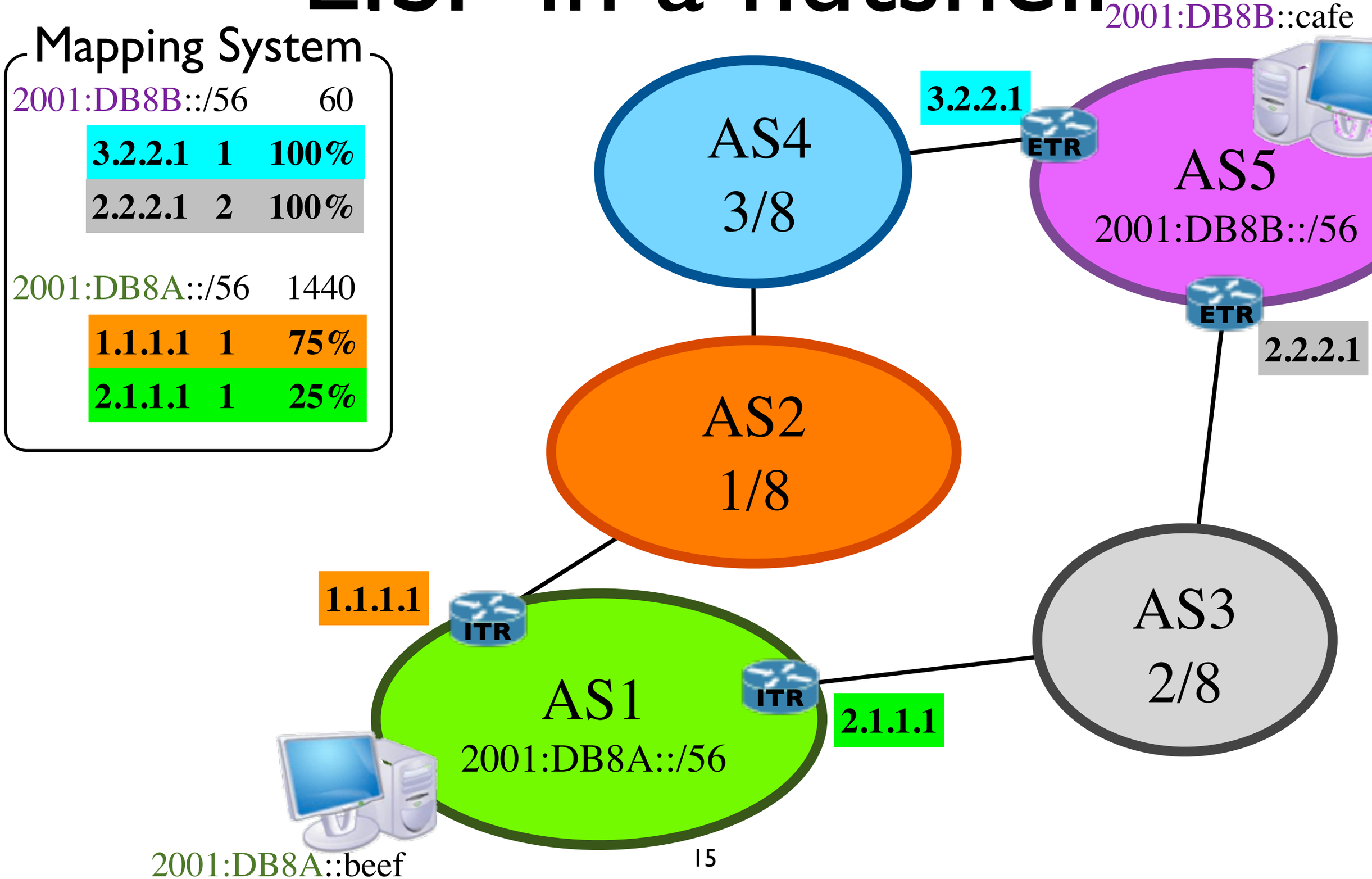

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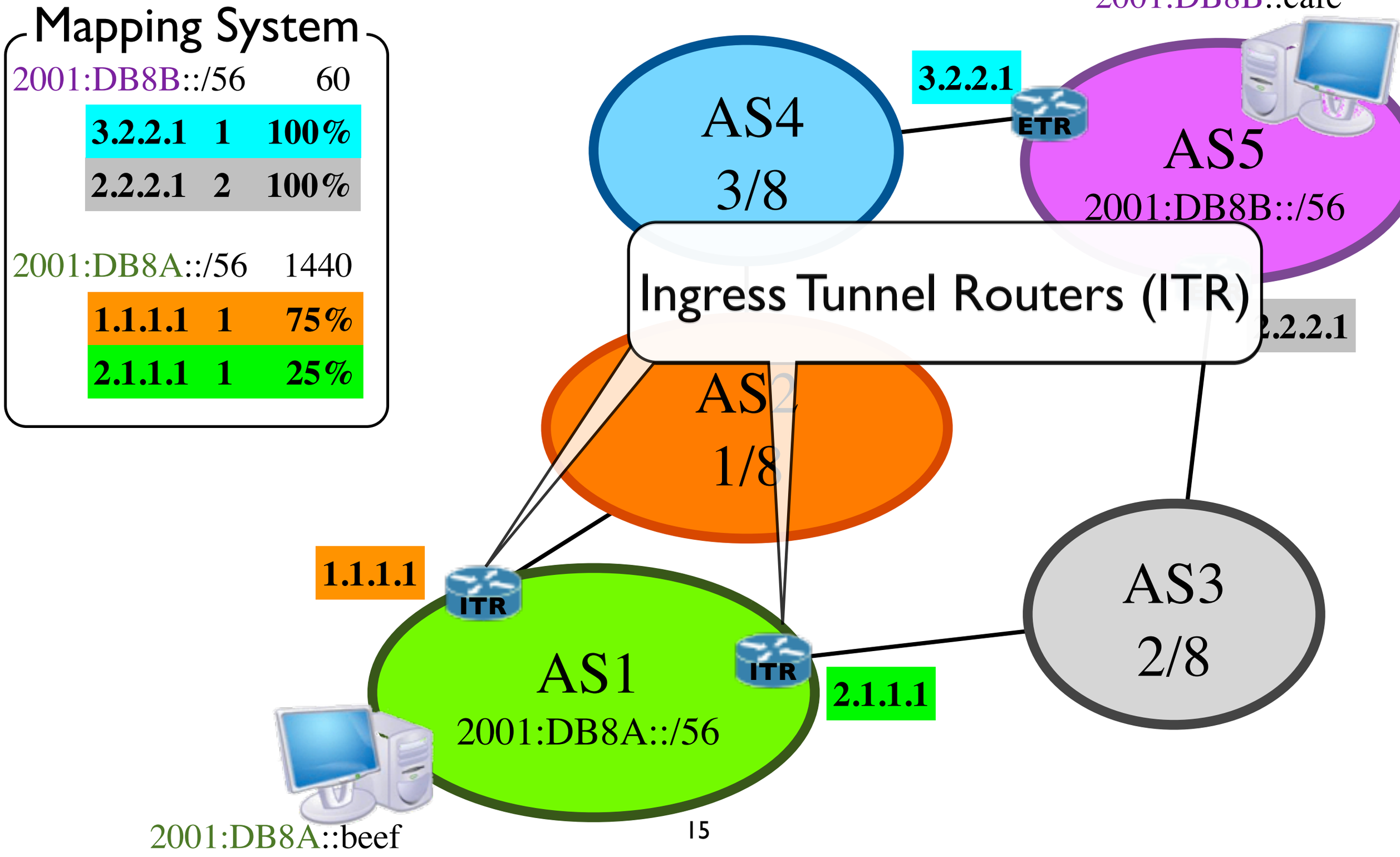

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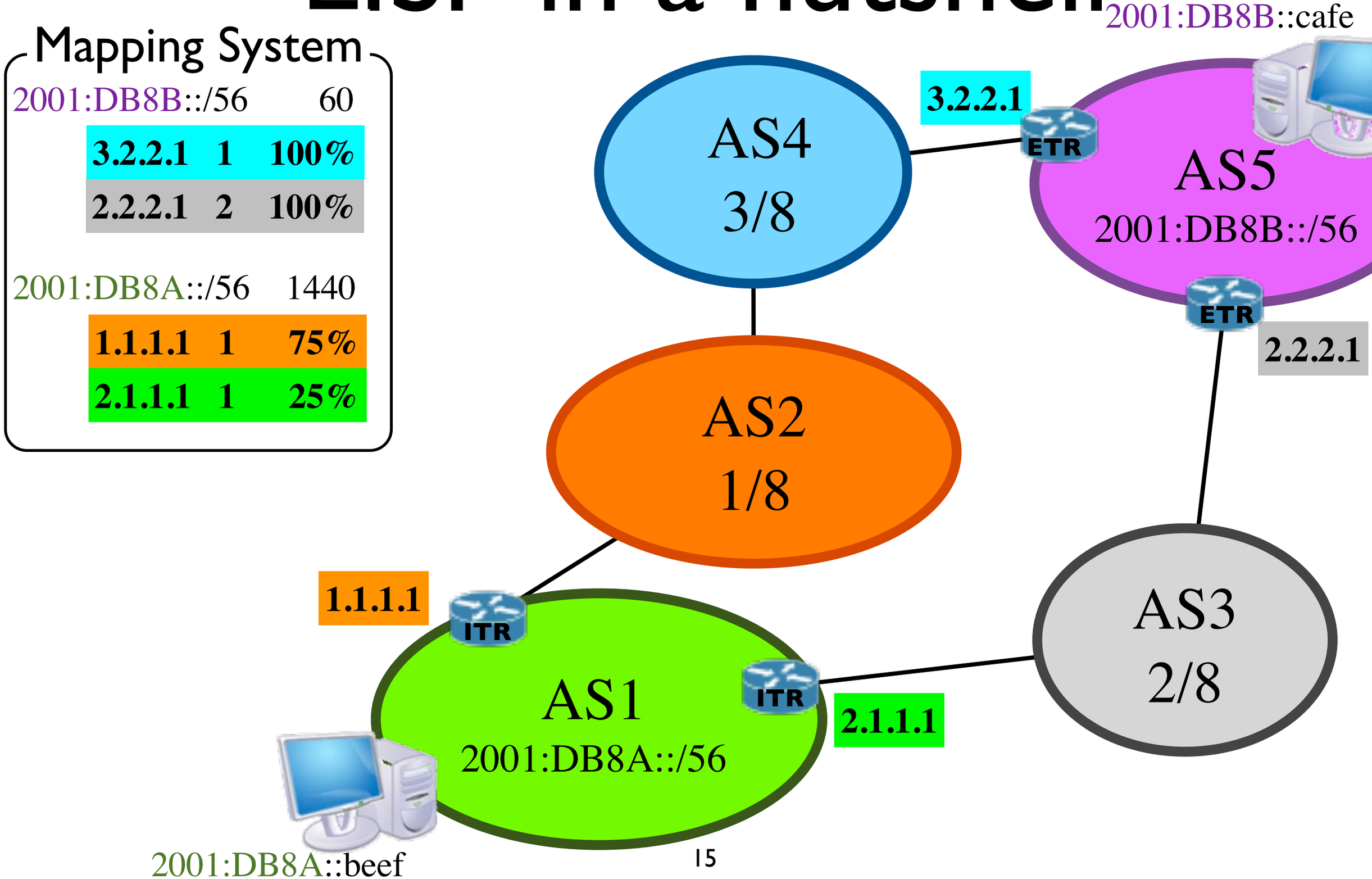

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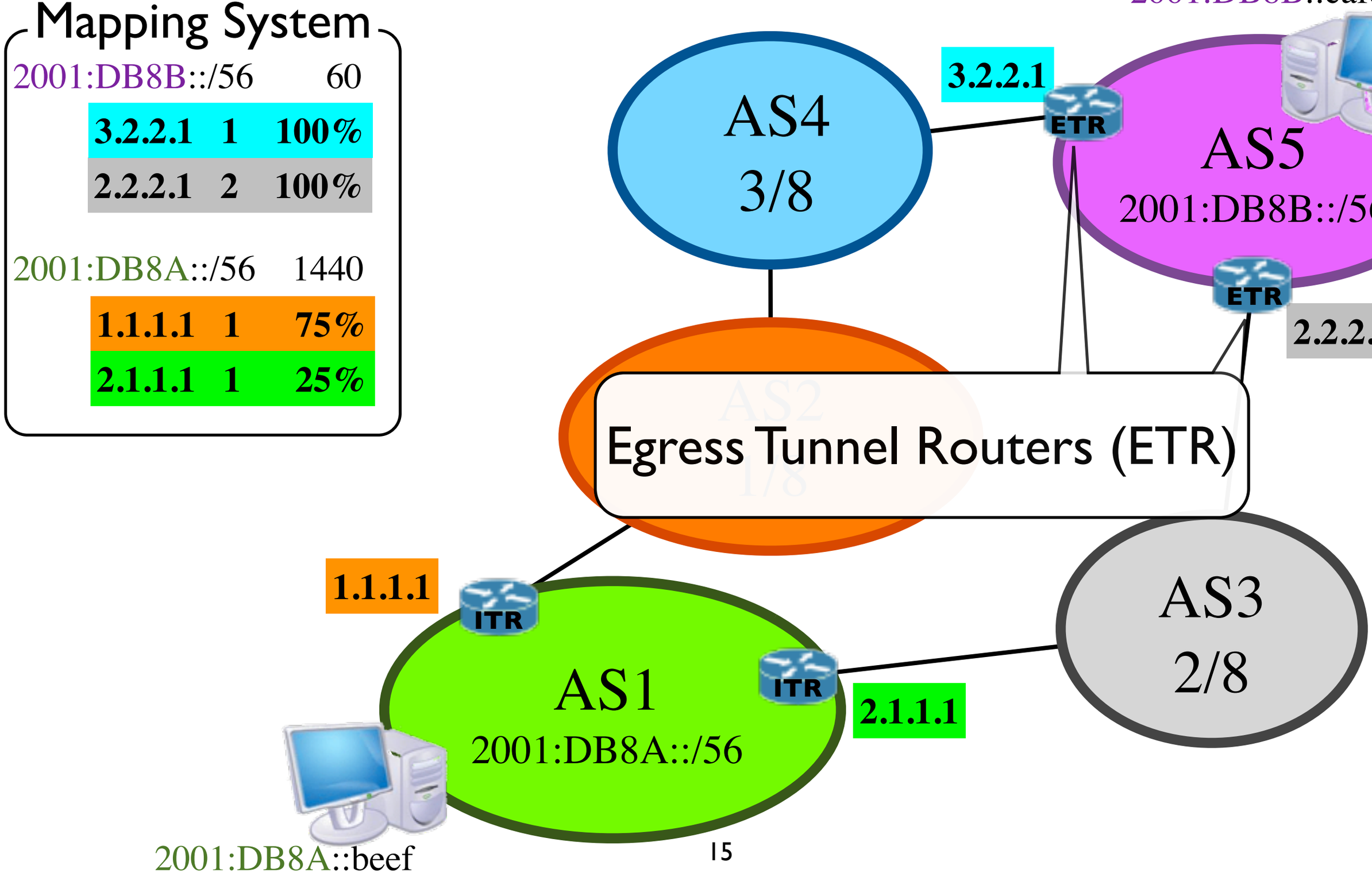

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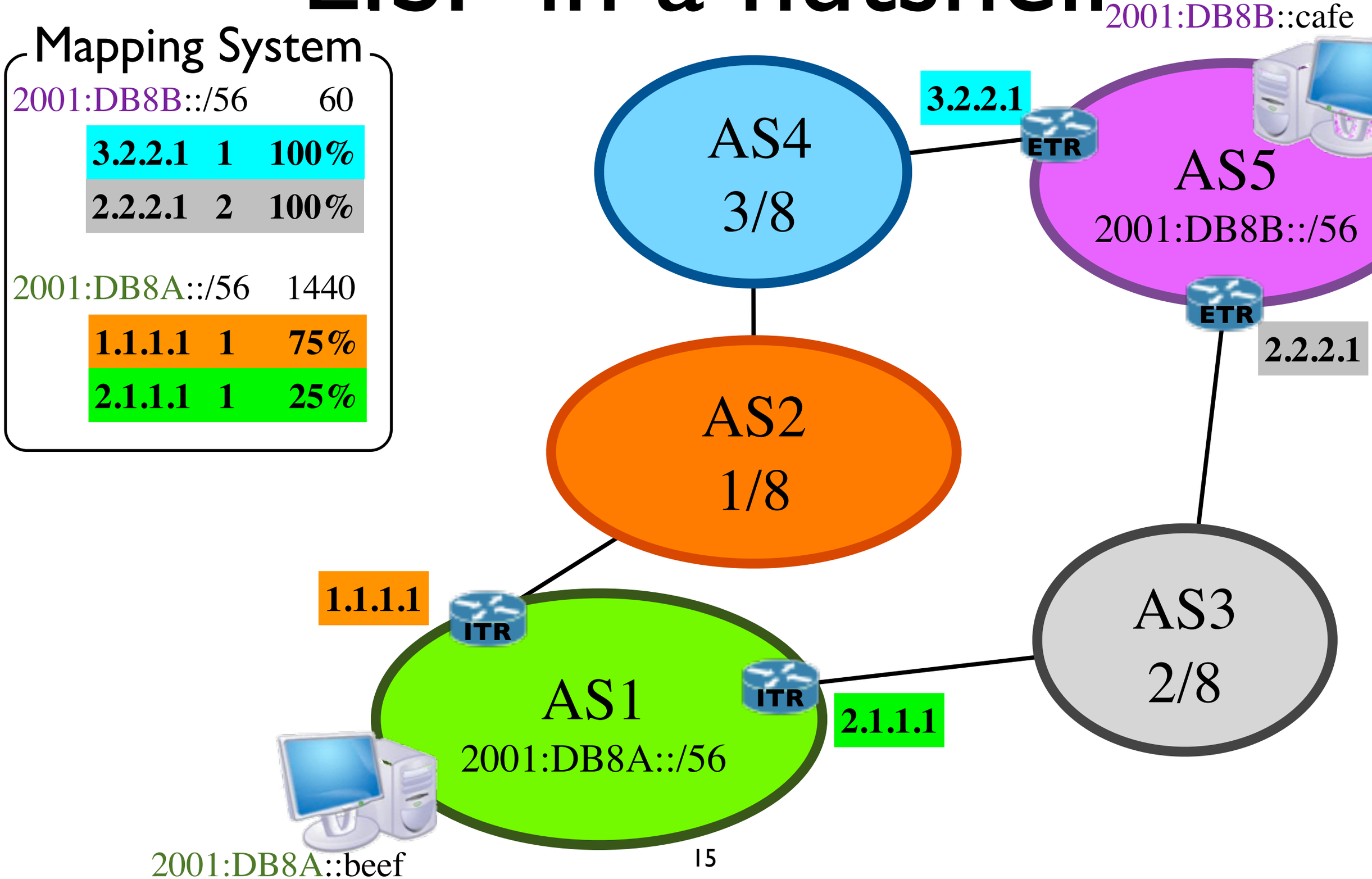

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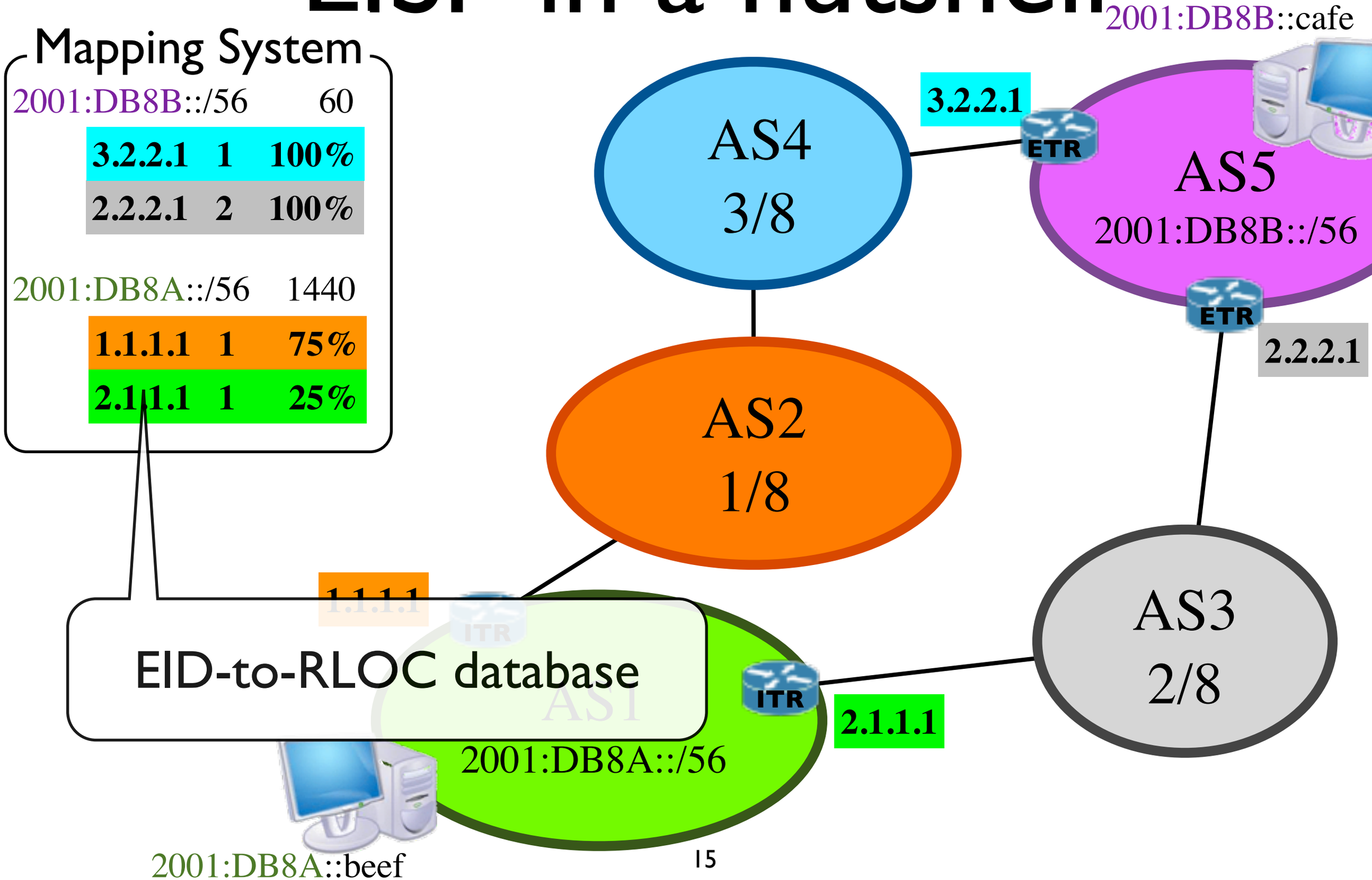

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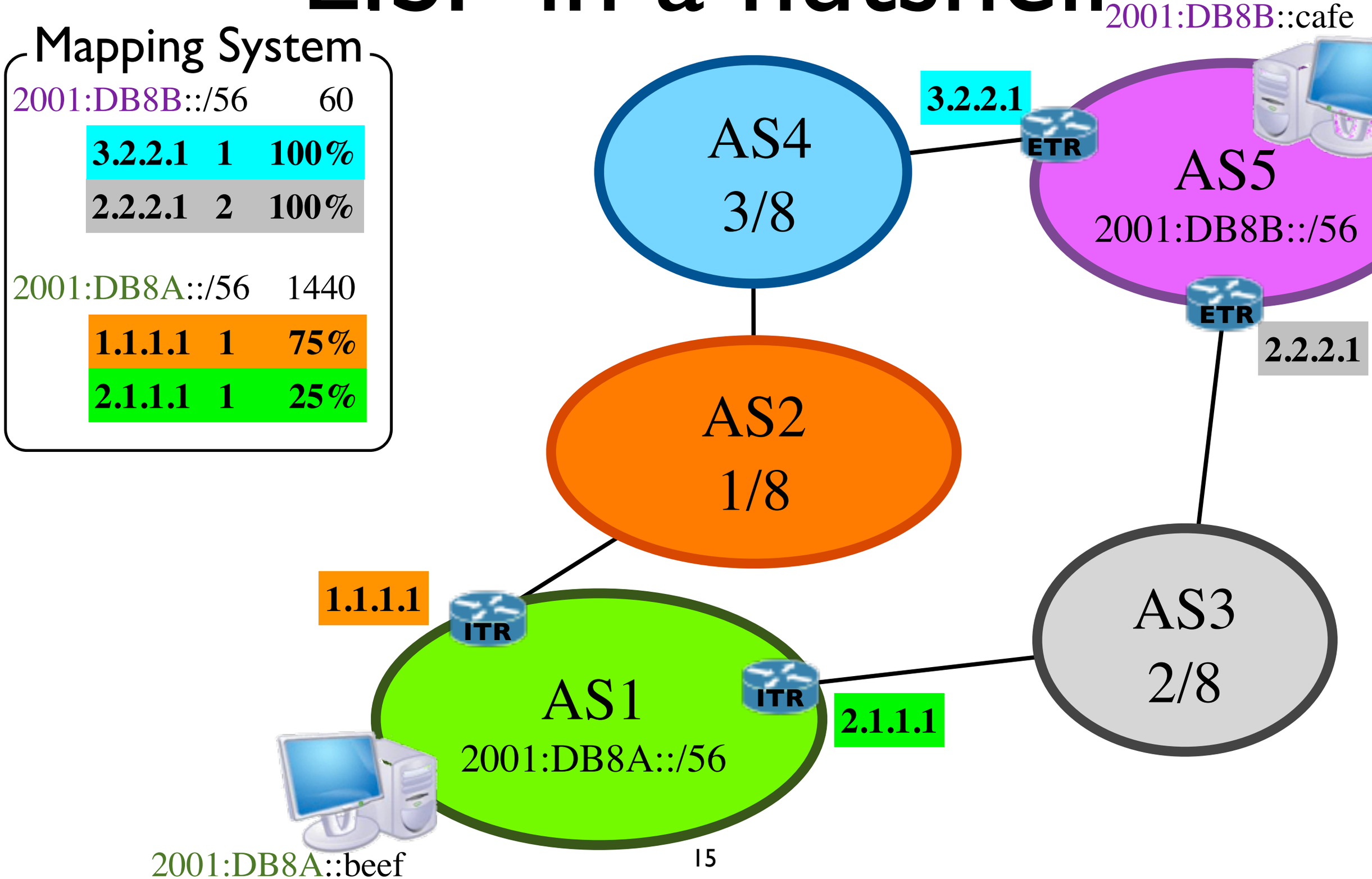


Terminology

- **Ingress Tunnel Router (ITR)**: a router which accepts a packet which addresses are identifiers. The router maps the destination address of the packet to an RLOC and prepends a LISP header before forwarding the encapsulated packet.
- **Egress Tunnel Router (ETR)**: a router which accepts a LISP encapsulated packet. The router strips the LISP header and forwards the packet based on the next header

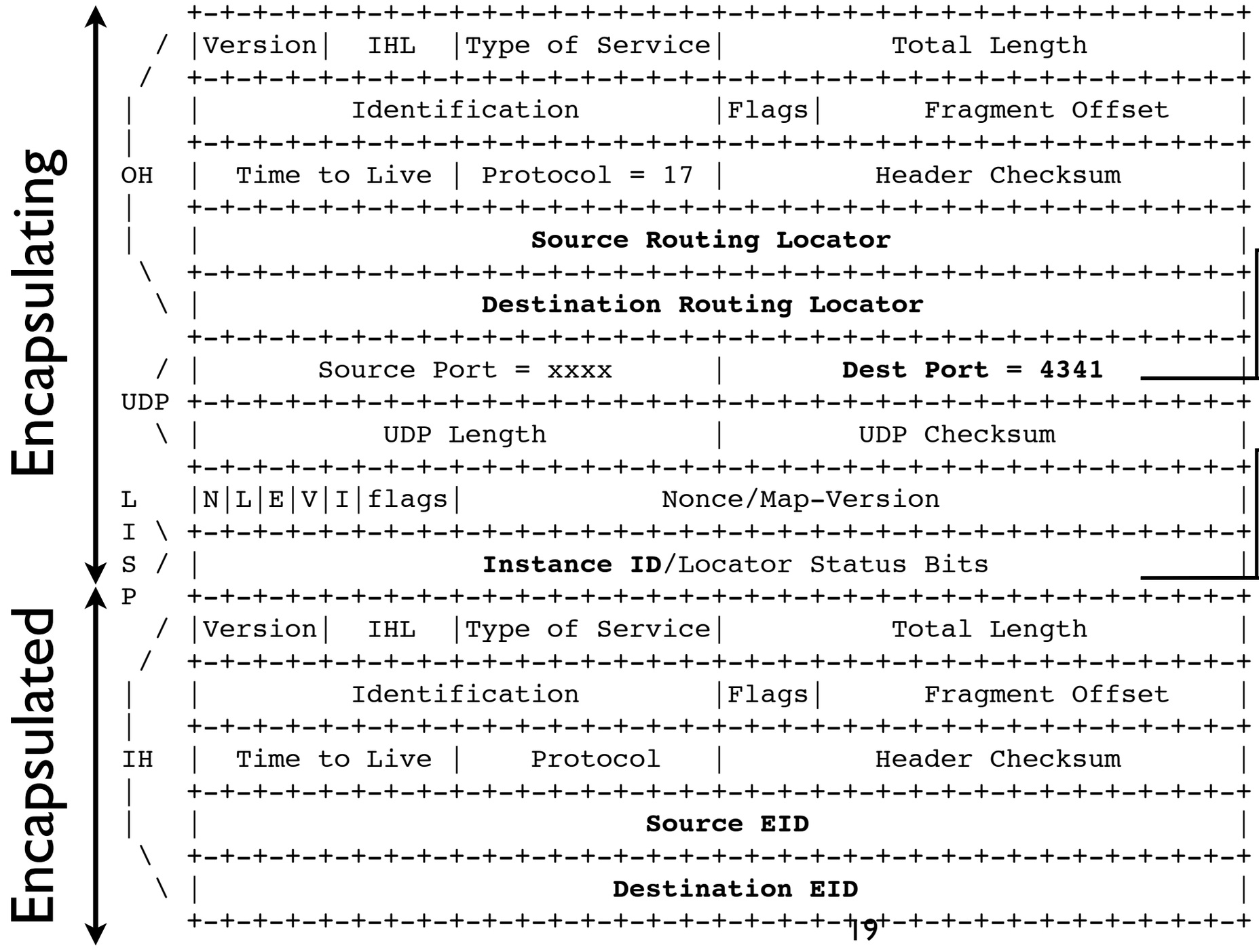
Terminology

- **EID-to-RLOC Database**: a globally distributed database that contains all known EID-prefix to RLOC mappings
- **LISP Cache**: EID-to-RLOC Database stored at the ITR
- **LISP Database**: EID-to-RLOC Database stored at the ETR

Under the hood

Data-plane packets

(IP(UDP:4341(LISP(XXX))))



Fixed Destination Port: 4341

Possible virtualization with Instance ID

Data-plane packets

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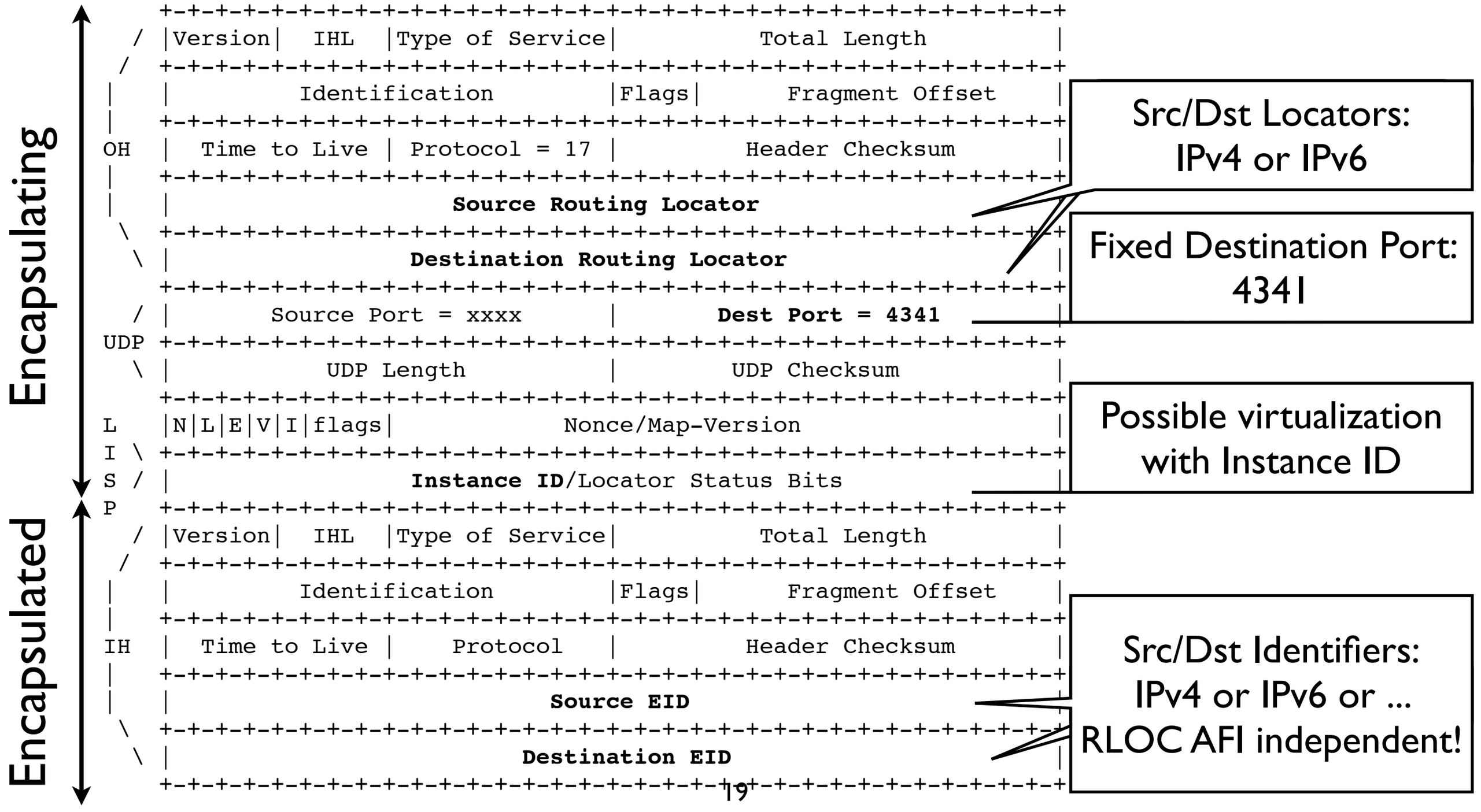
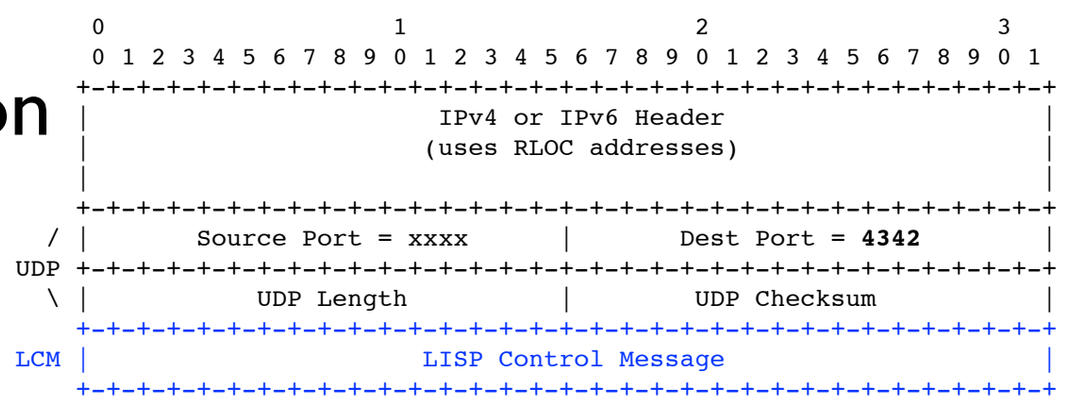


Control Plane Packets

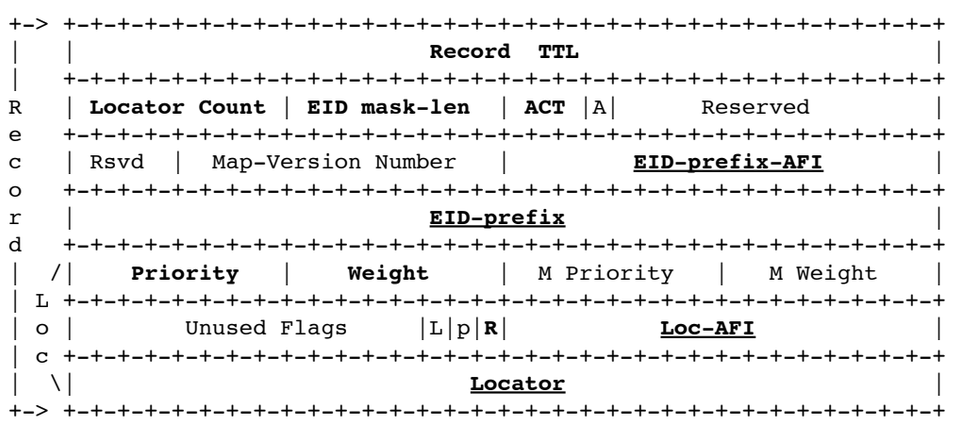
(IP(UDP:4342(LISP_control)))

- Map-Request (ITR => MR/ETR)
  - request for a mapping
- Map-Reply (ETR/MS => ITR)
  - provides the mapping requested by a Map-Request
- Map-Register (ETR => MS)
  - register a mapping to the mapping system
- Map-Notify (MS => ETR)
  - confirm a mapping registration



What is in a mapping?

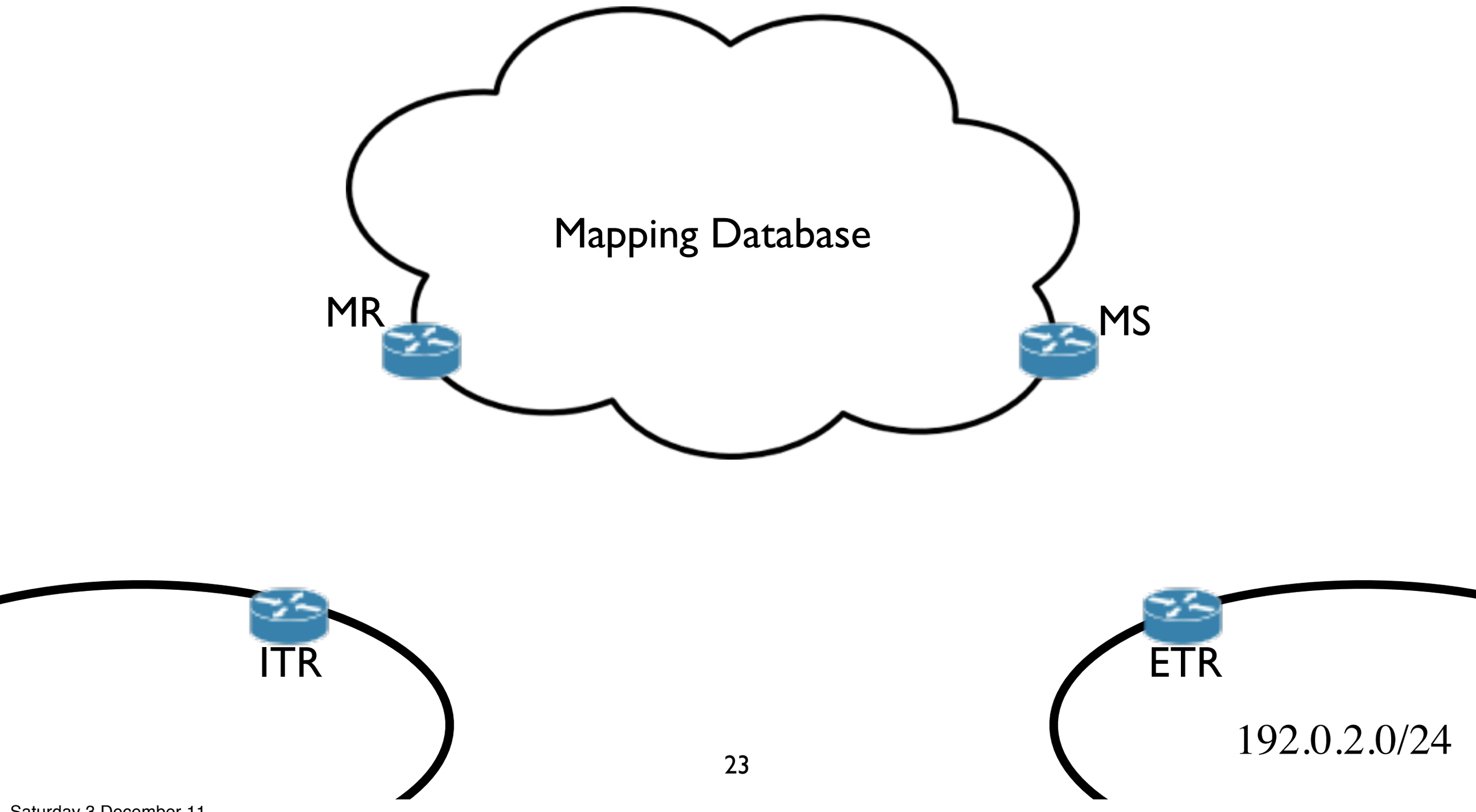
- A mapping associates an EID prefix to a list of RLOC of arbitrary AFI
  - Each RLOC receives a priority and a weight
    - L4-flows are balanced between RLOCs of same priority, proportionally to the weight
- Mappings can be empty to announce holes
- Mappings are time limited



Infrastructure

- Mapping Database modularity
- Interworking of LISP and non LISP networks

Mapping Database modularity



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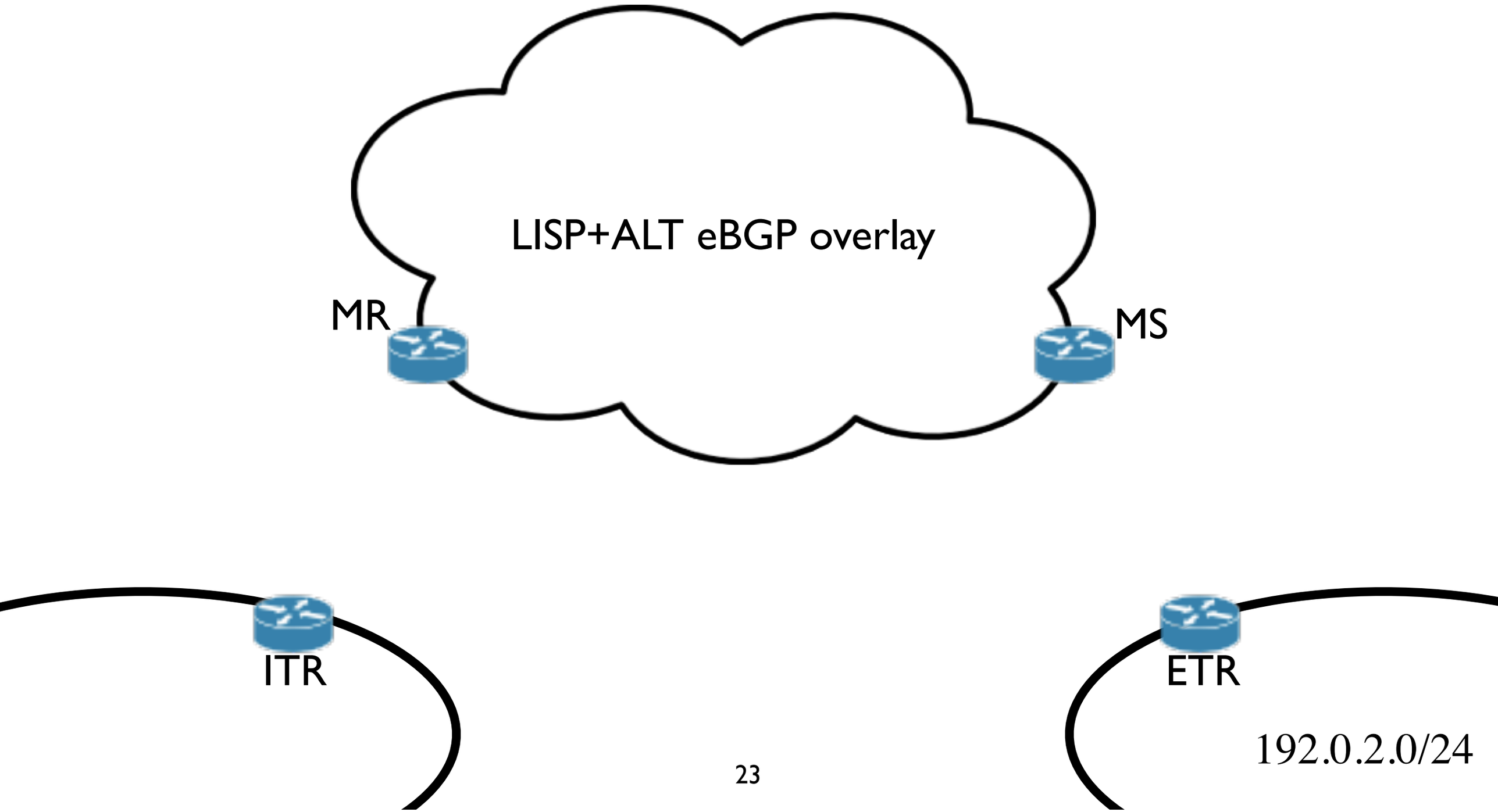

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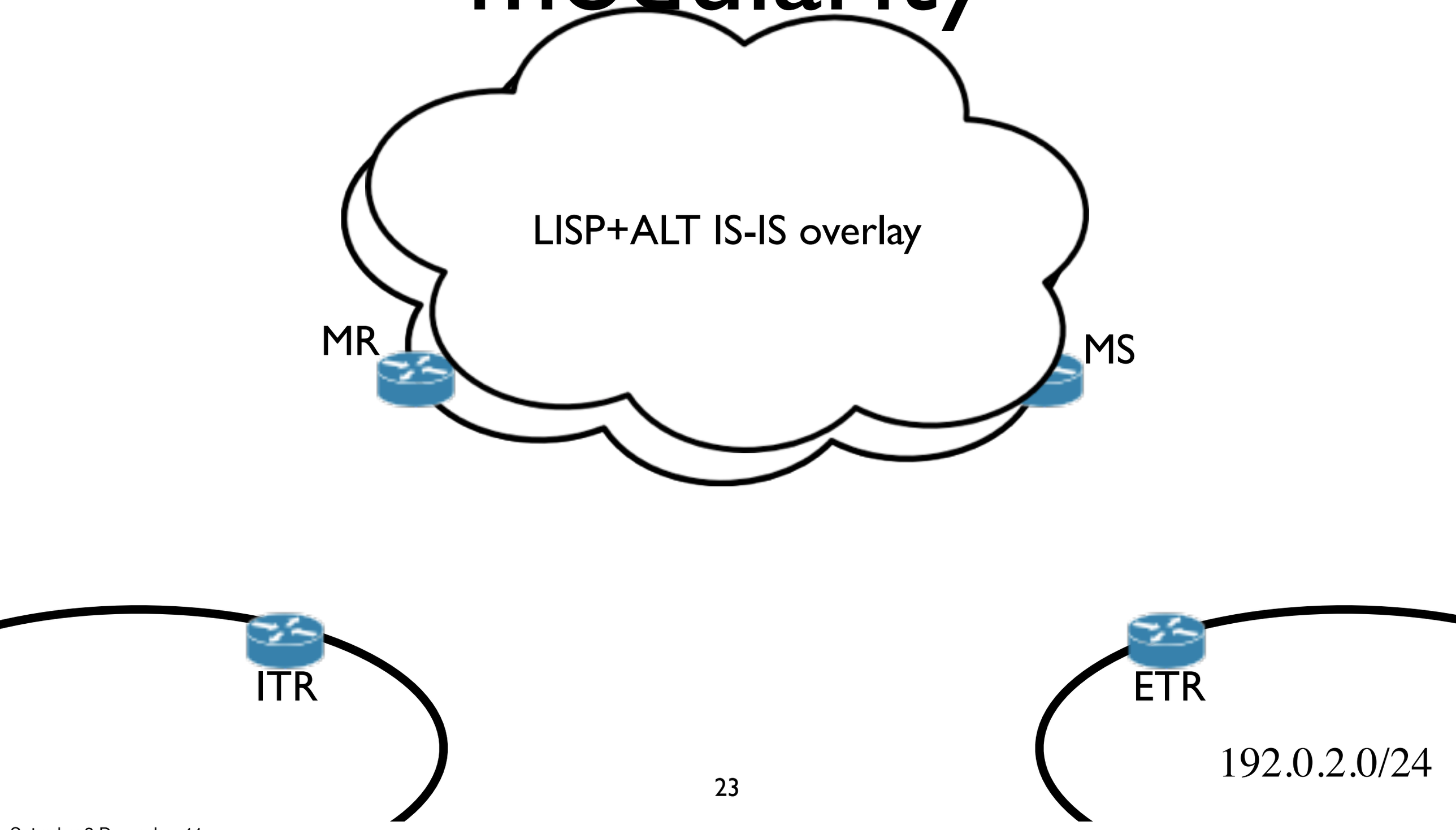

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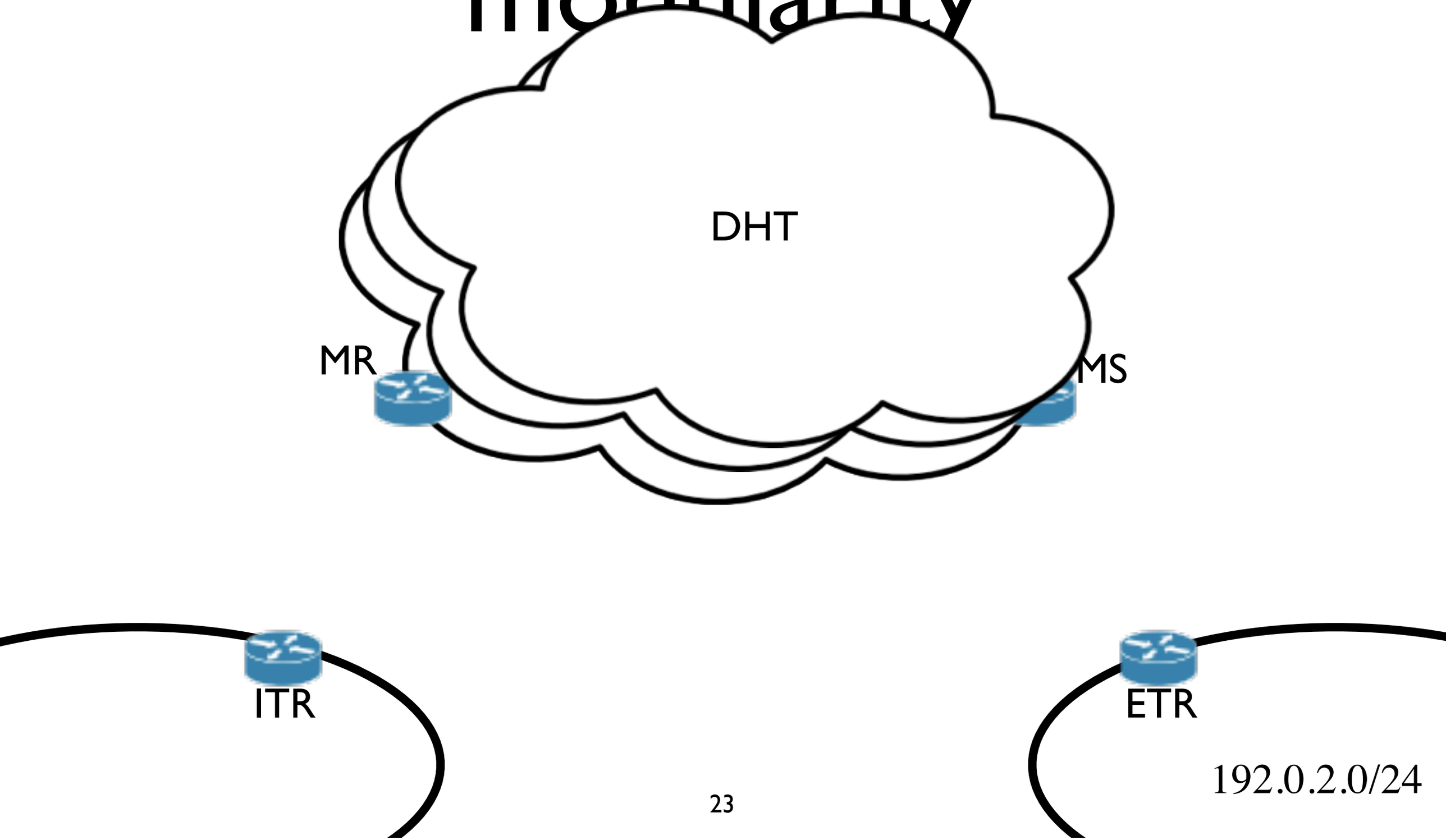

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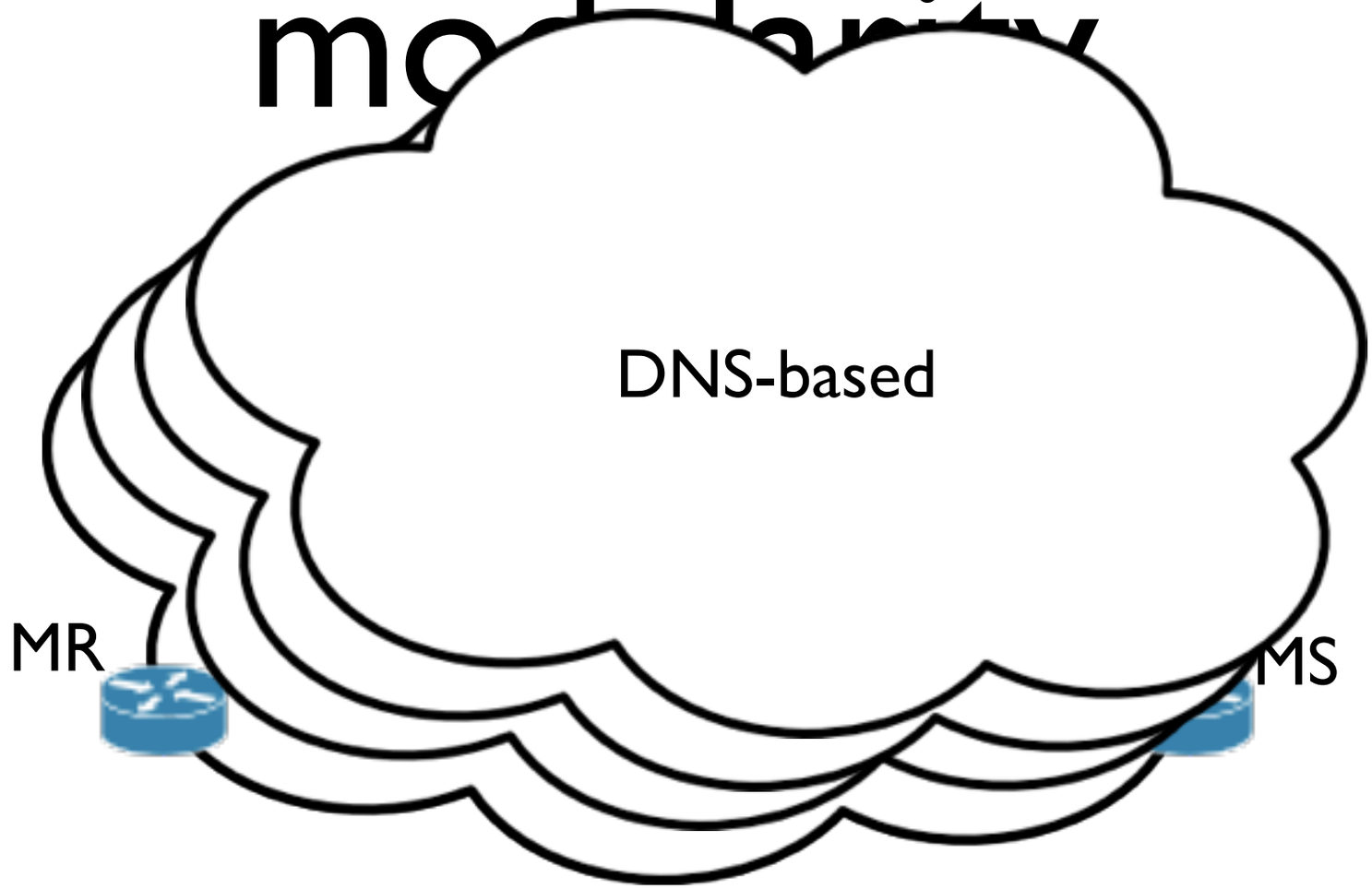

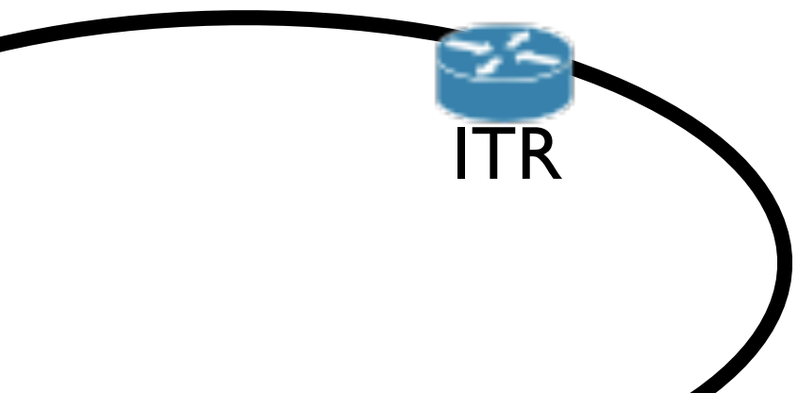

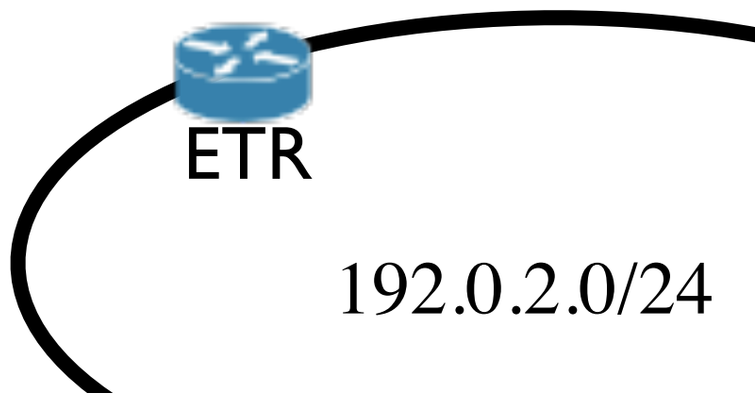

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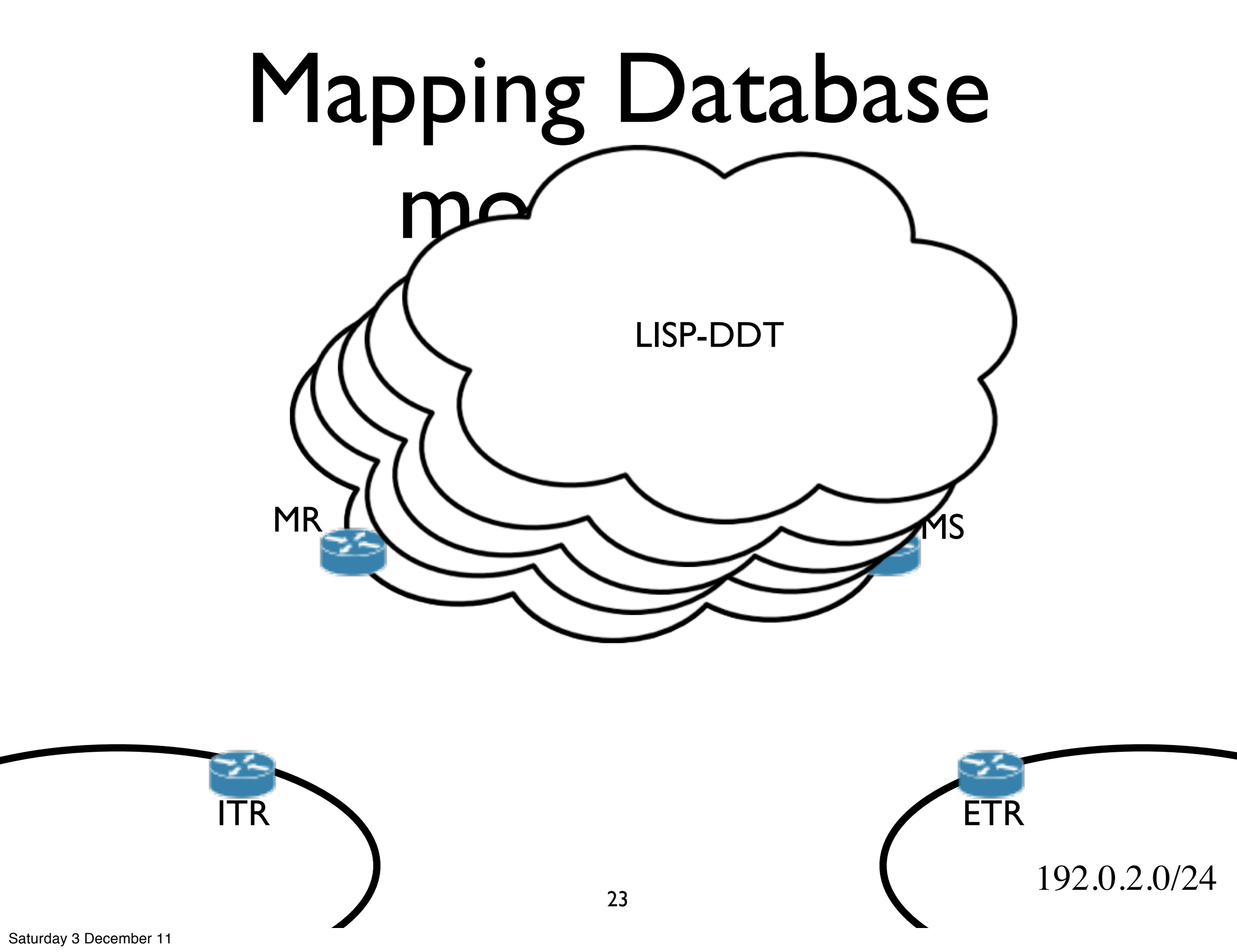

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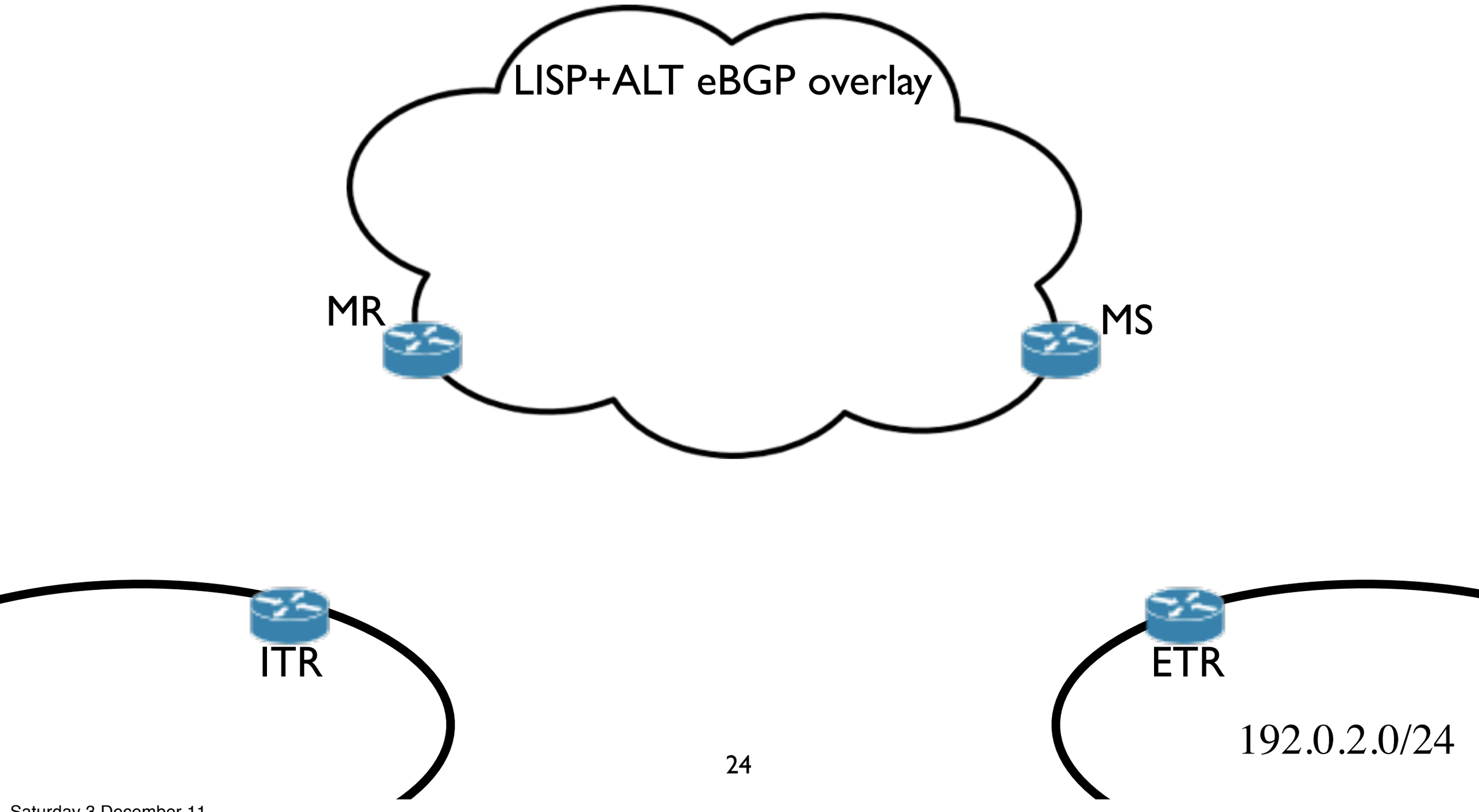

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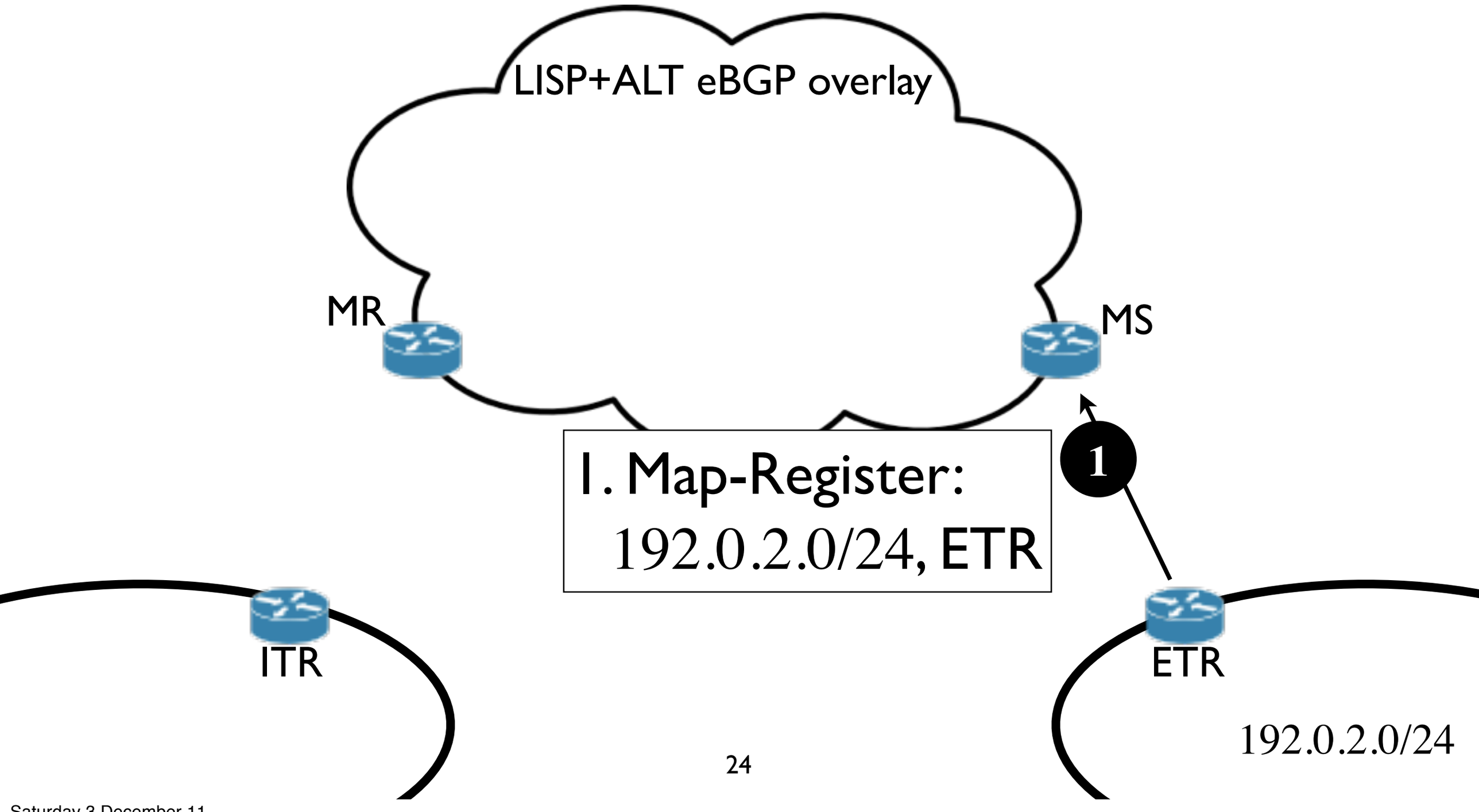

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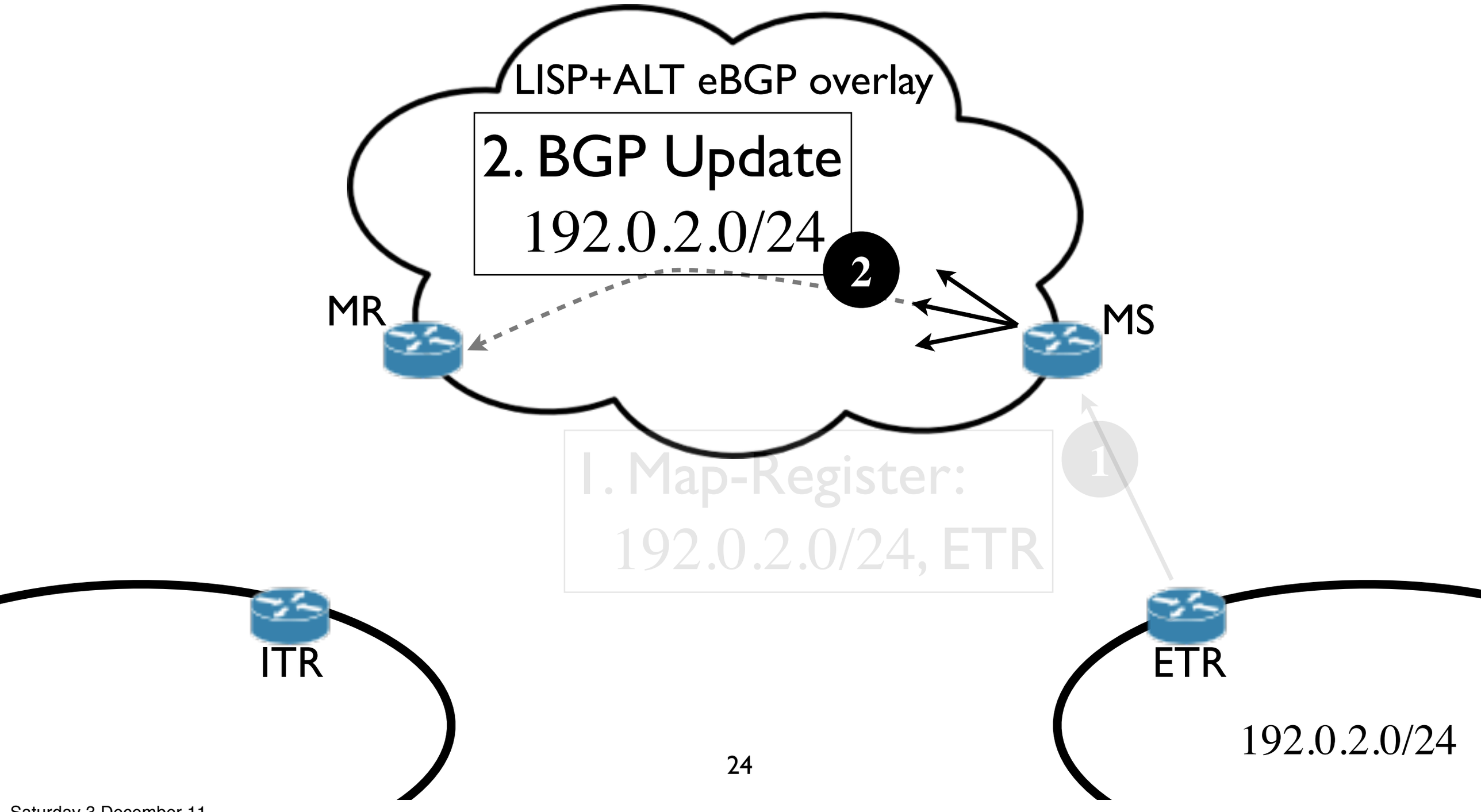

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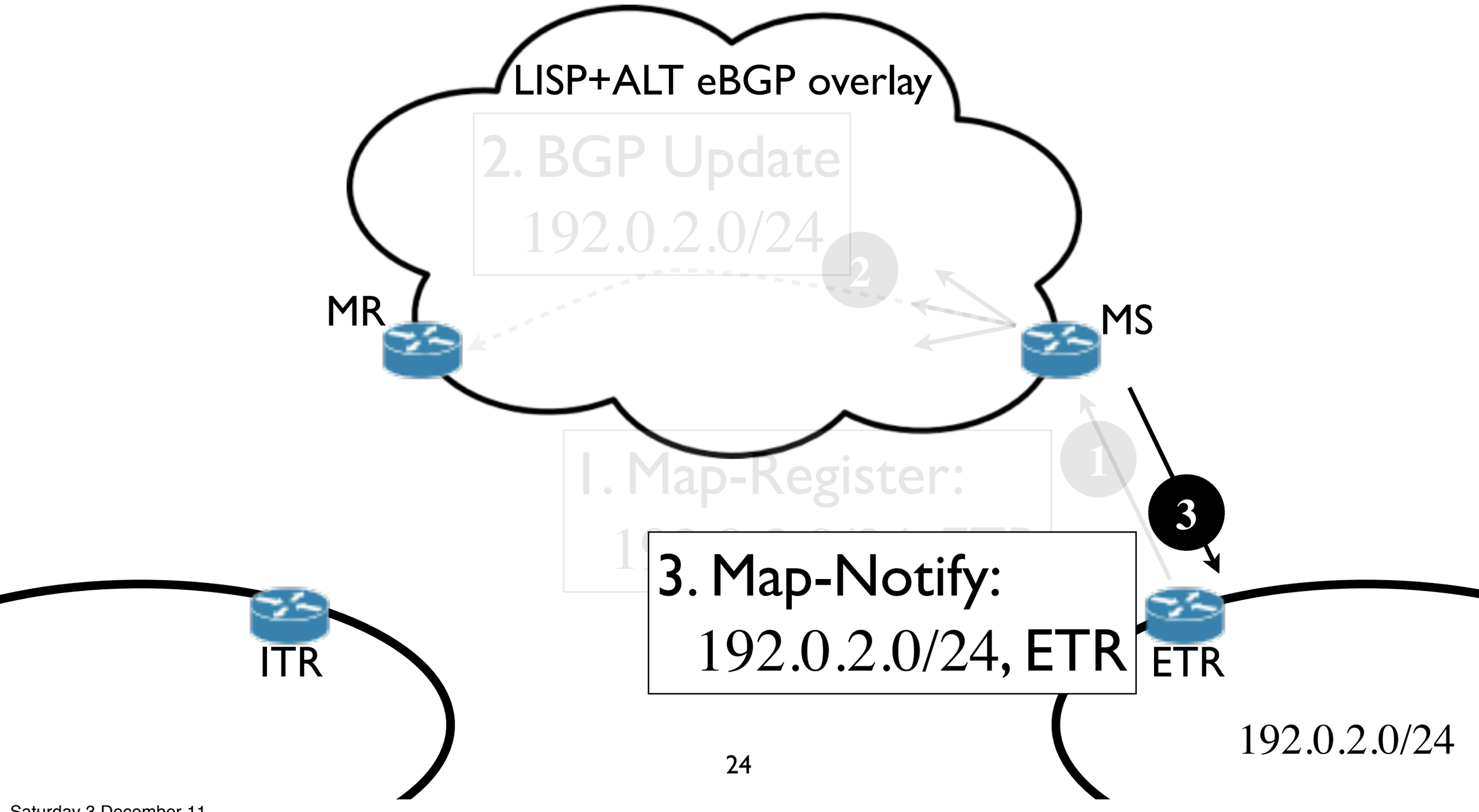

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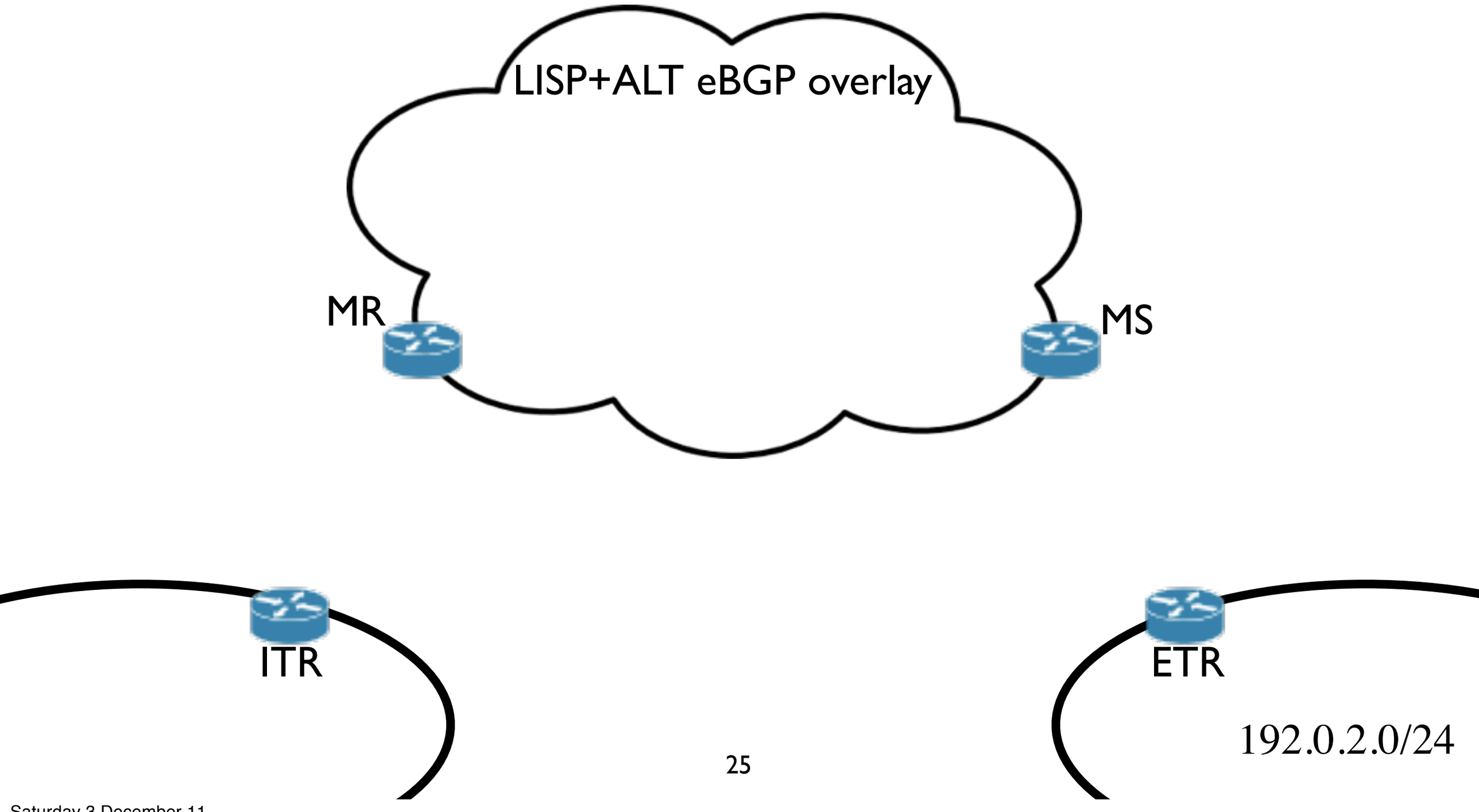

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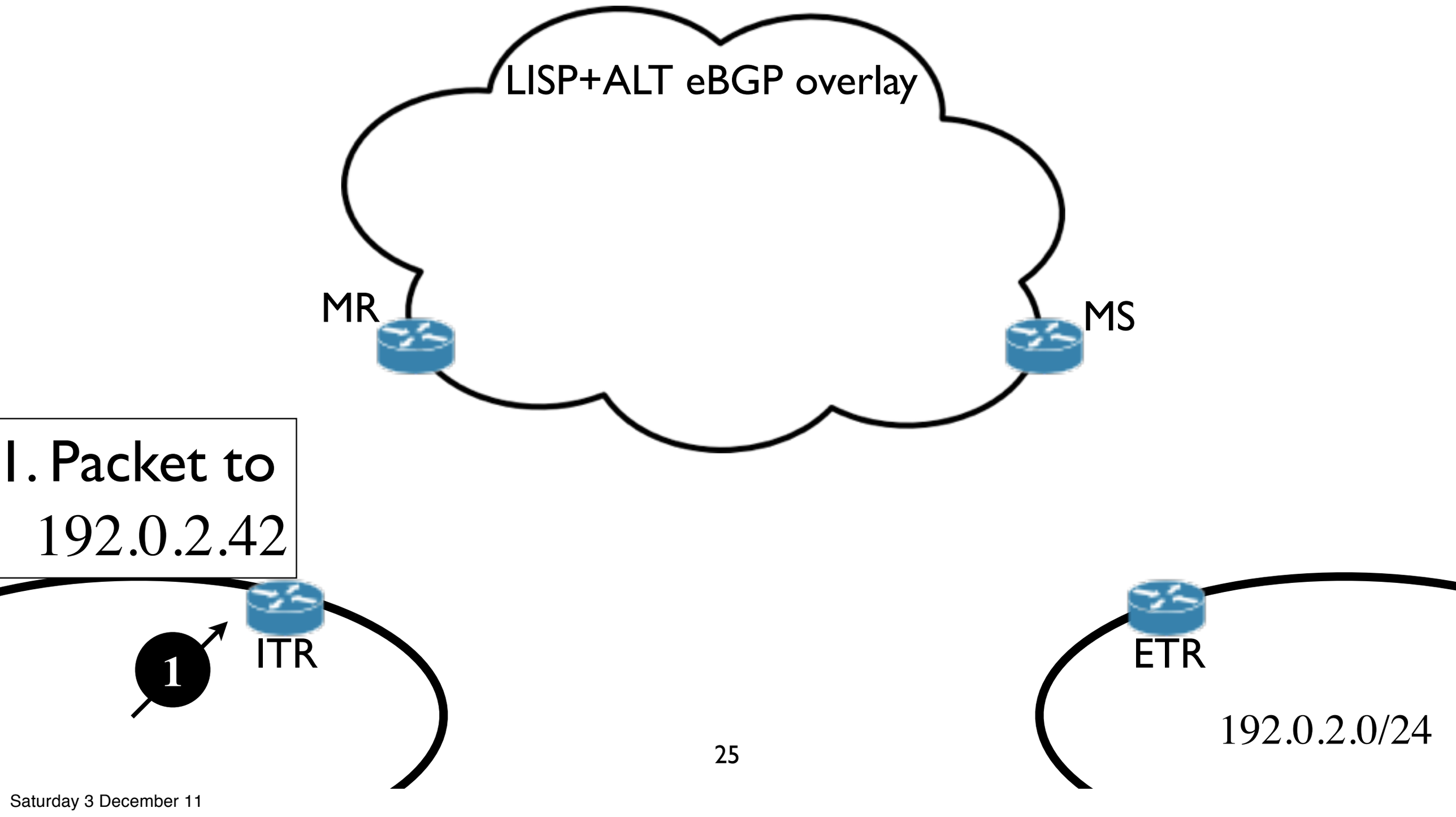
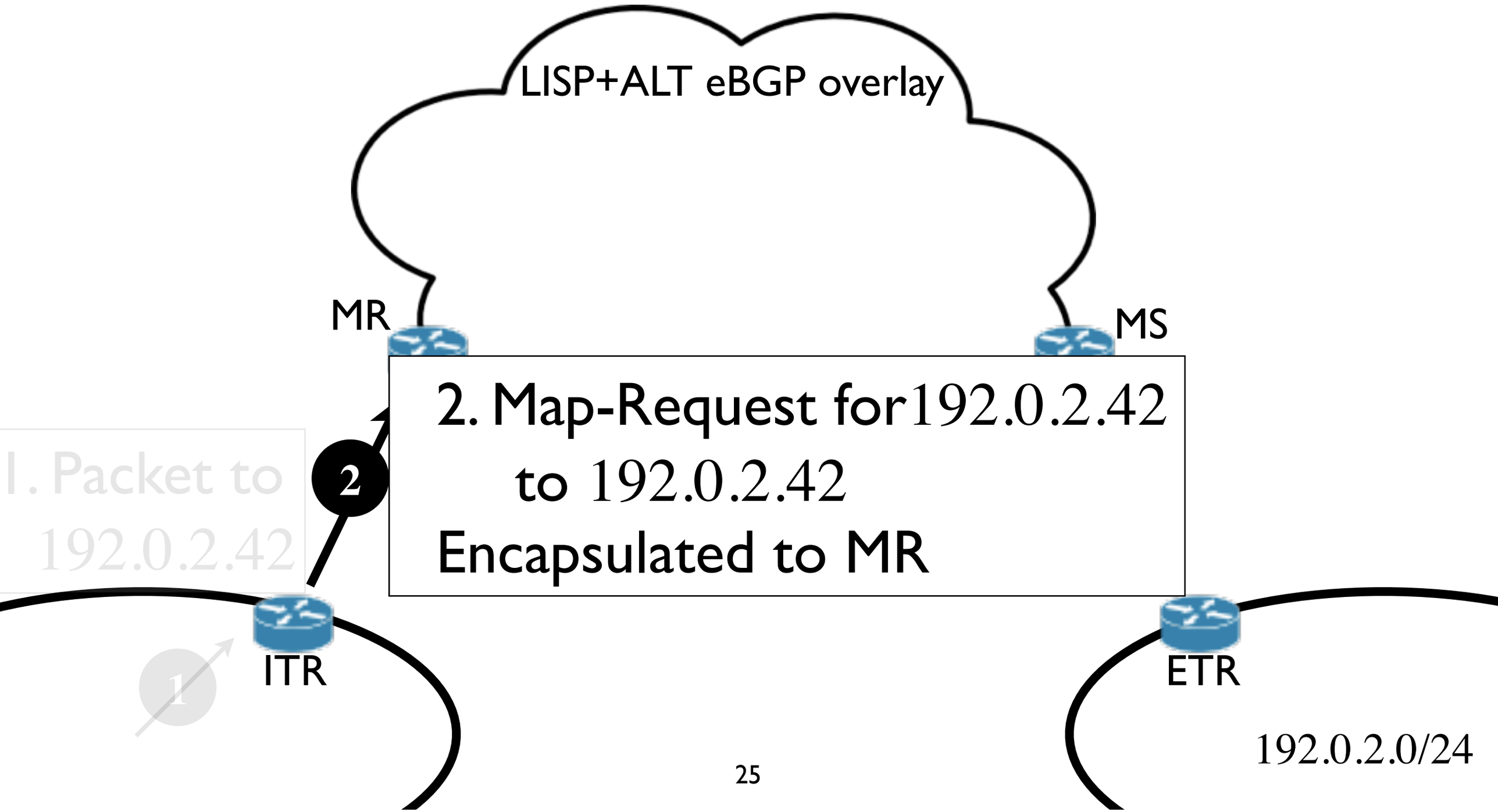
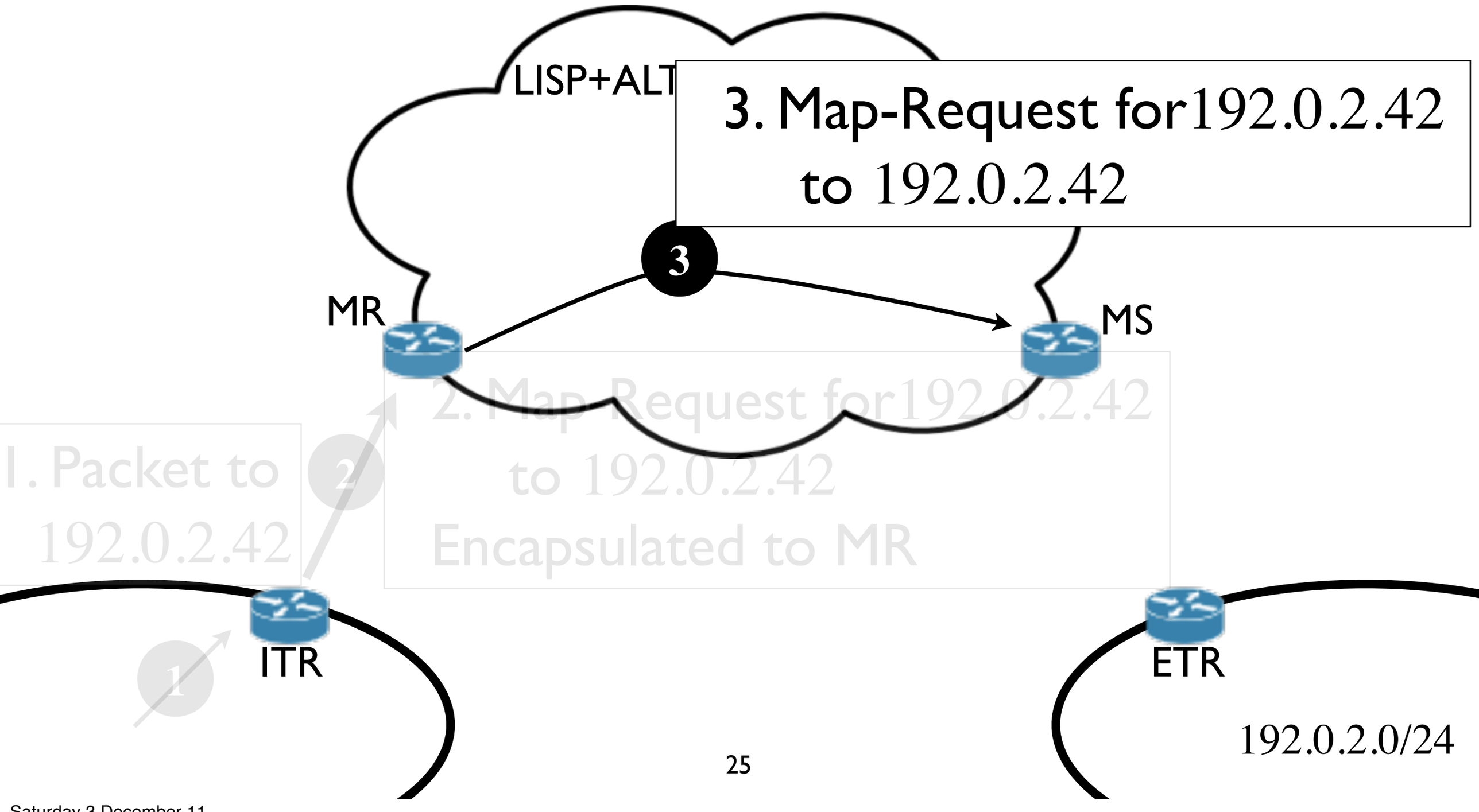


Mapping retrieval



Mapping retrieval



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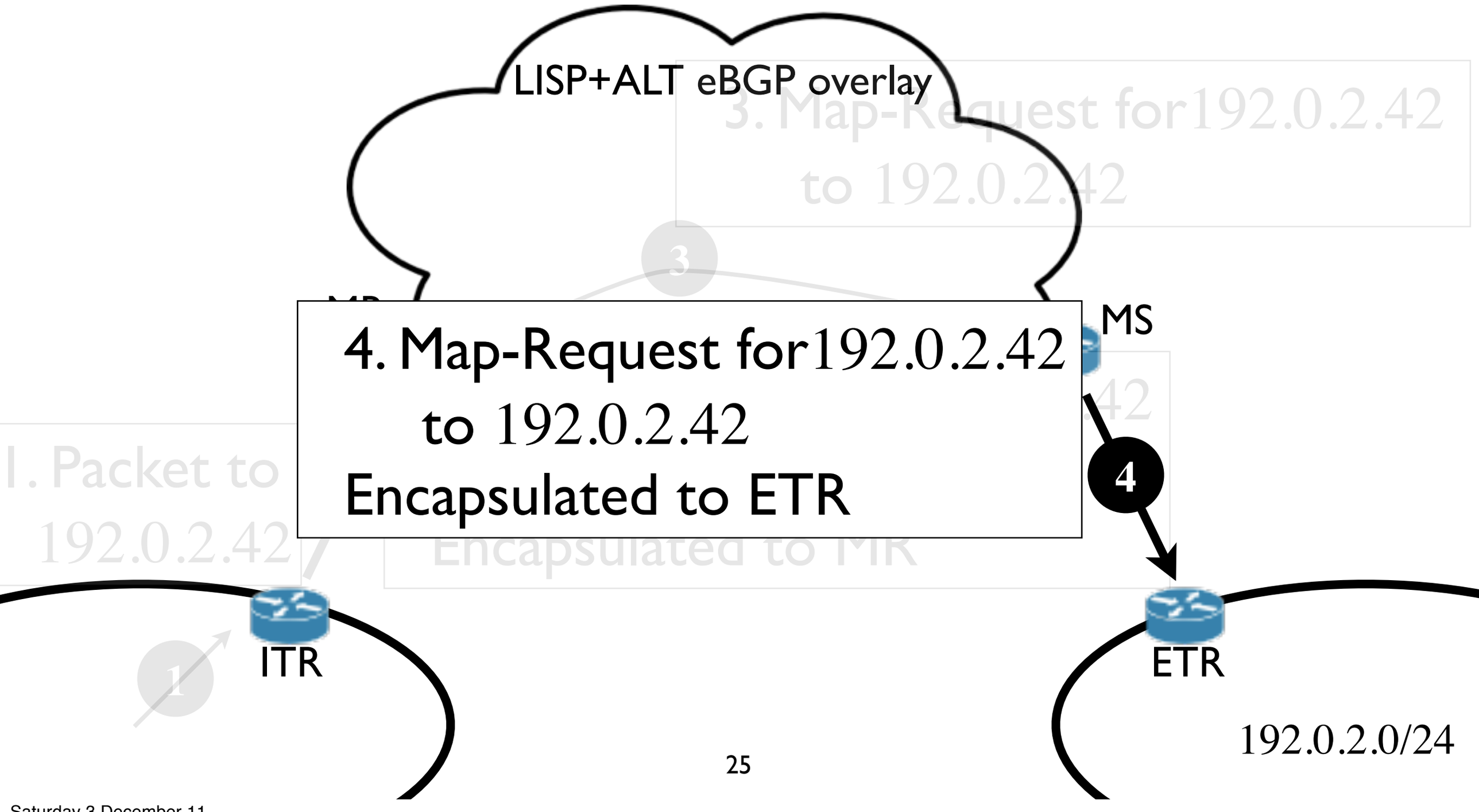
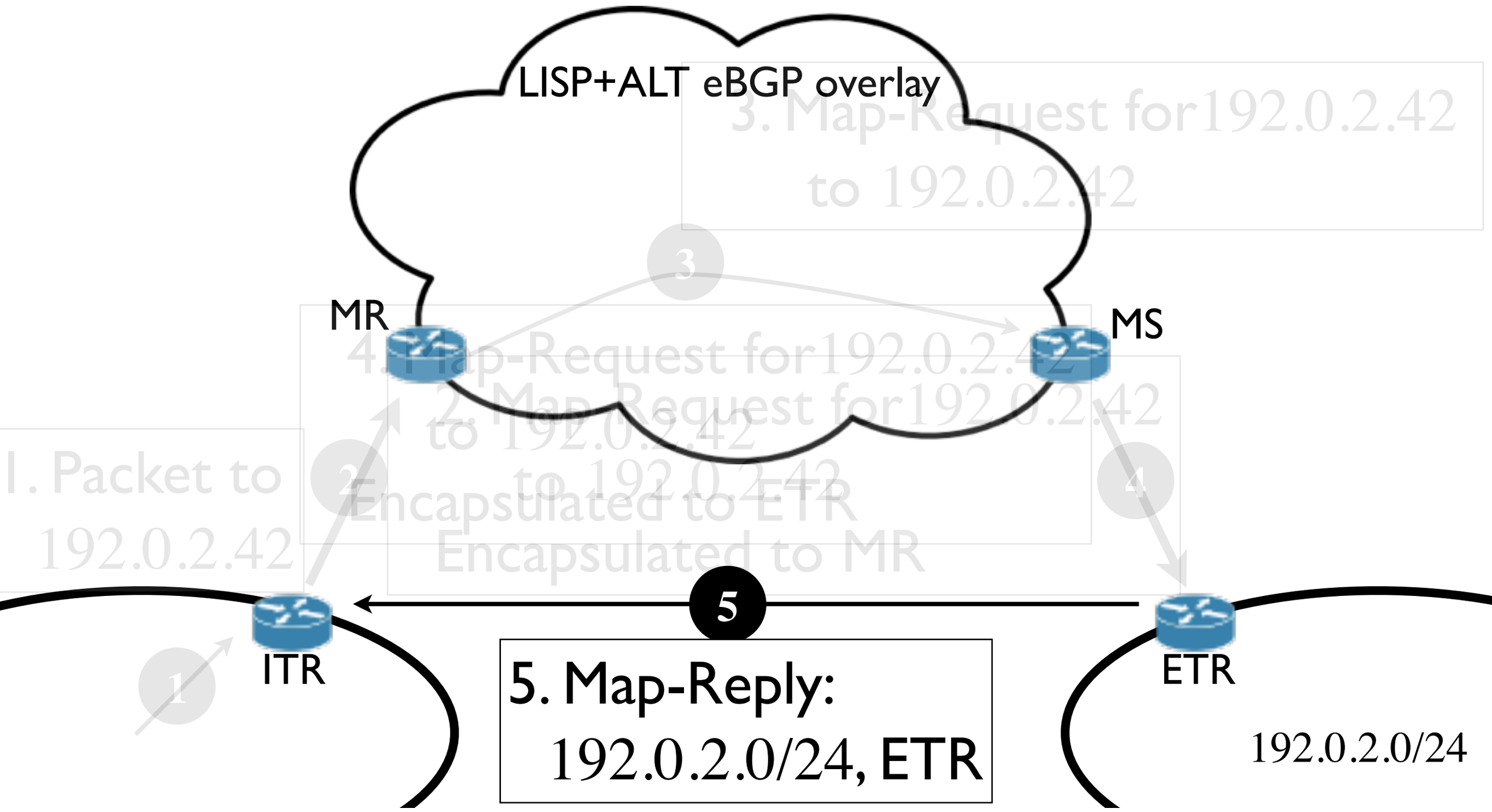
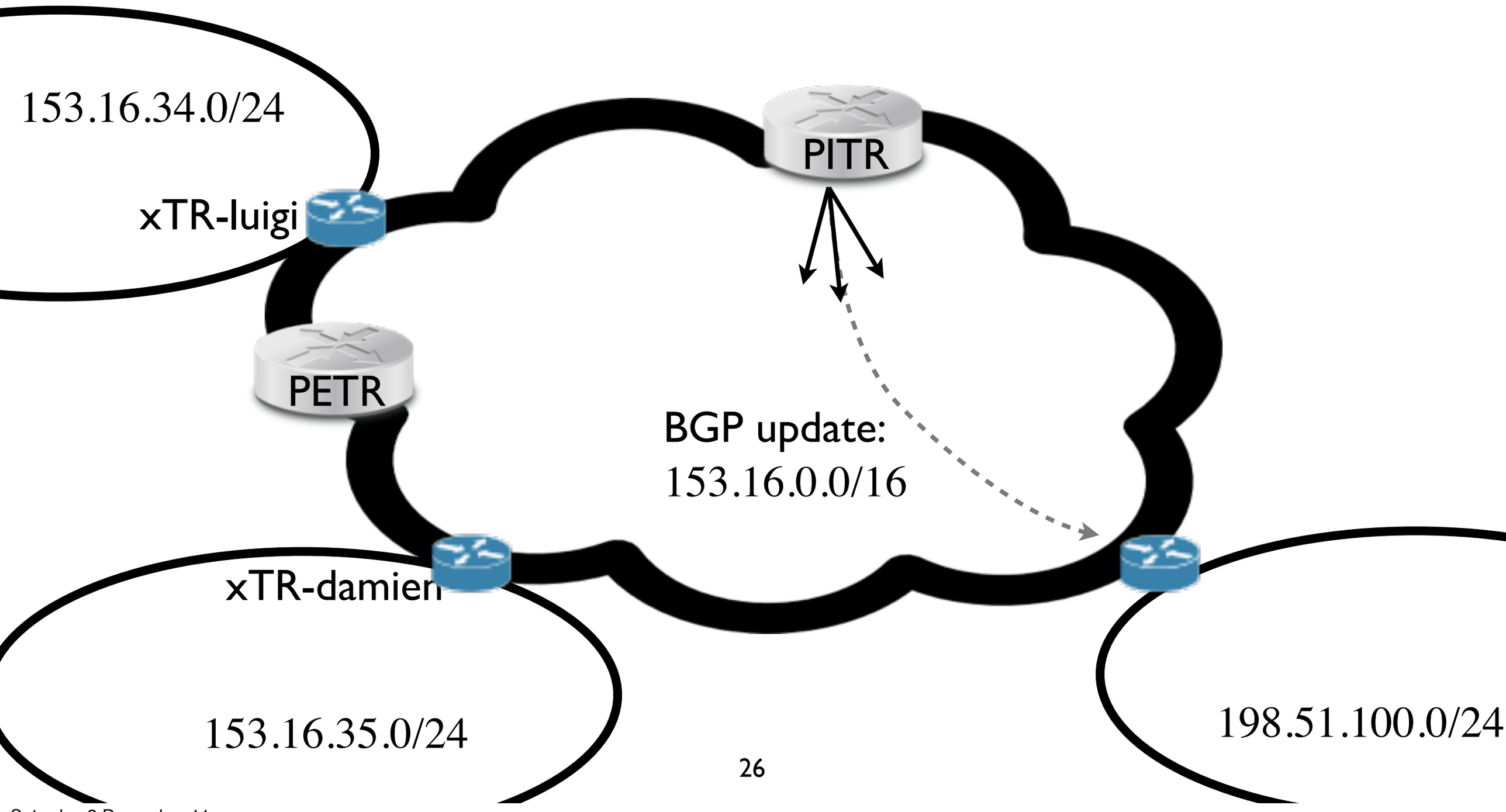


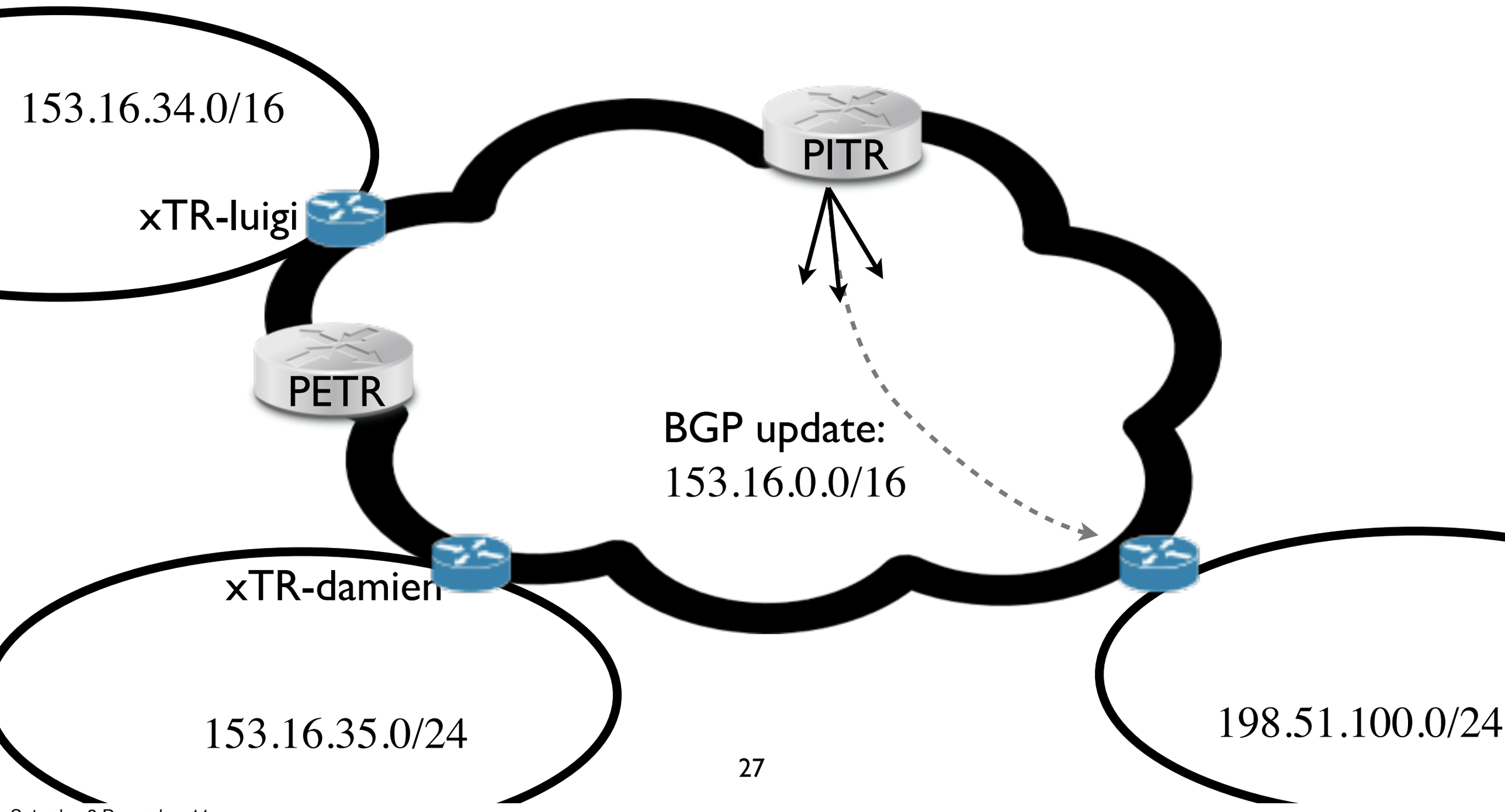
Mapping retrieval



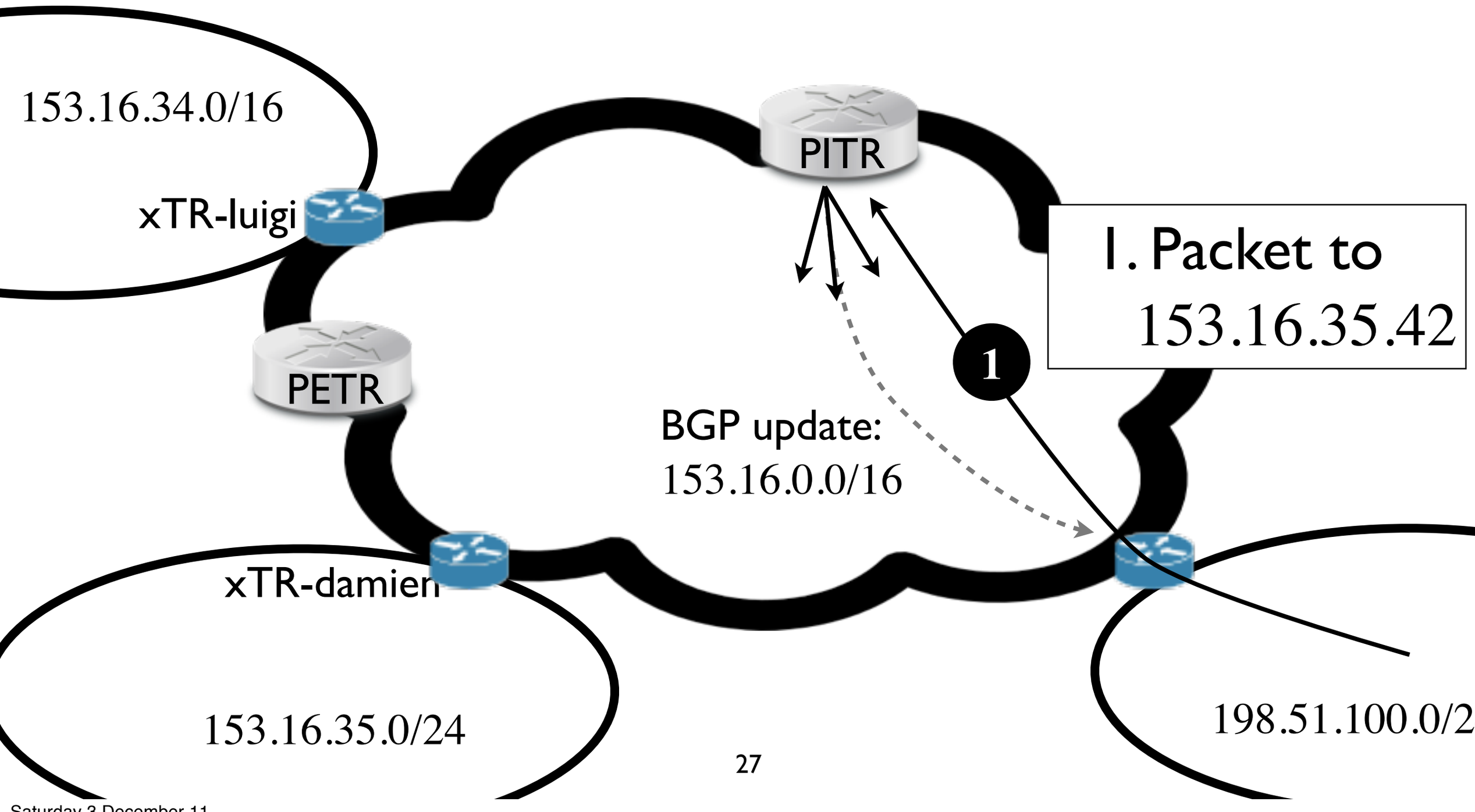
Interworking LISP



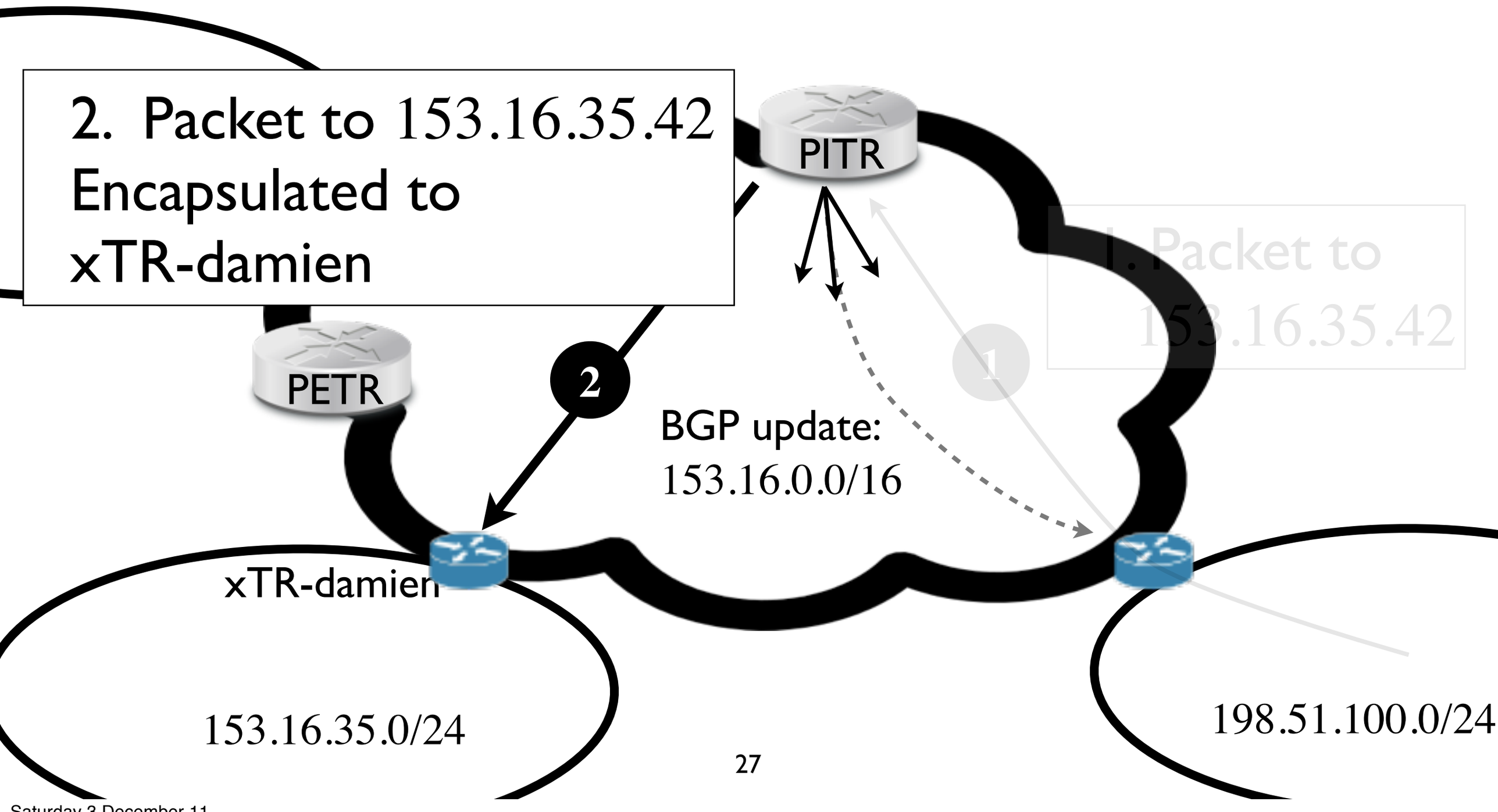
Non-LISP to LISP



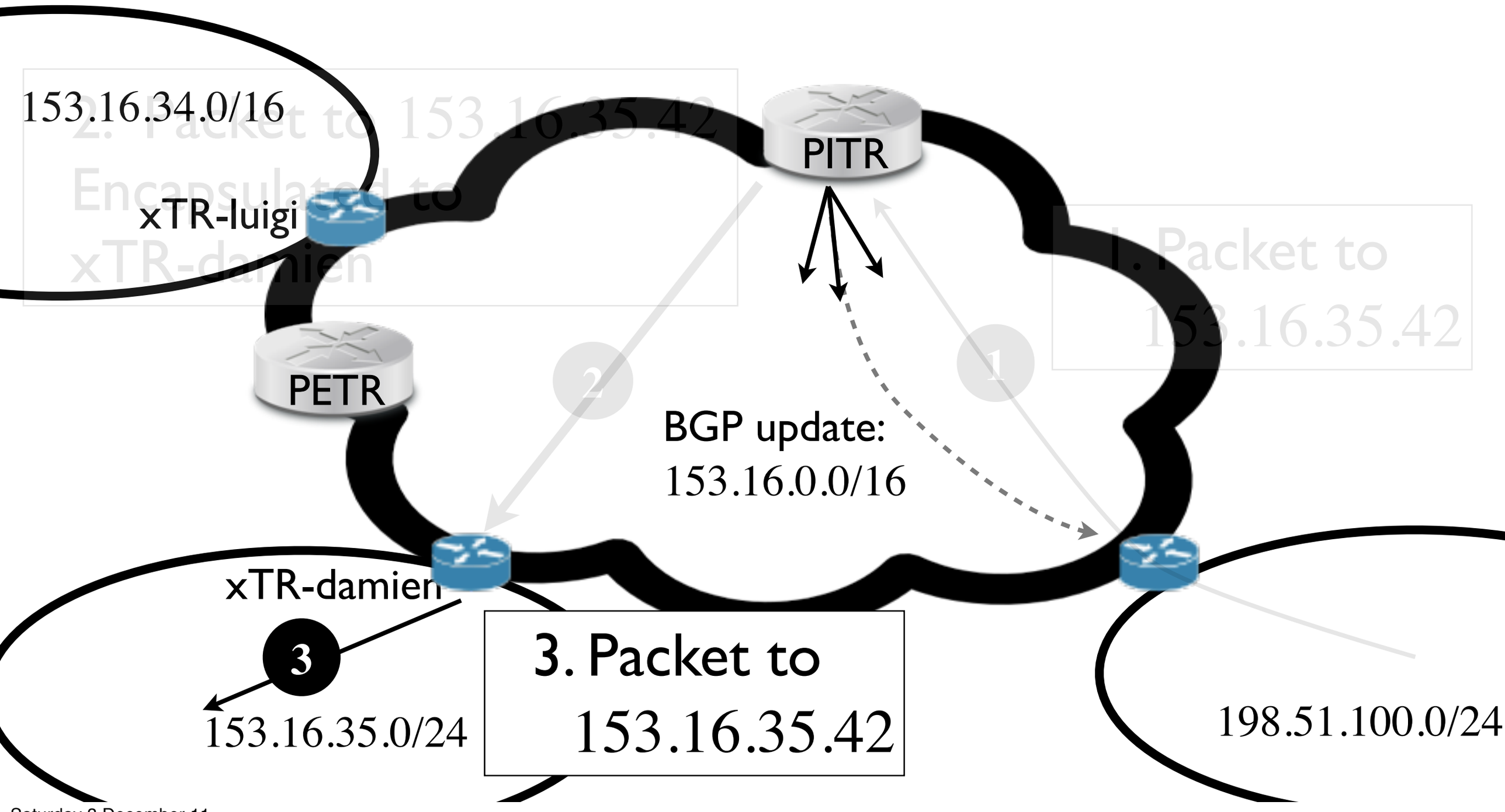
Non-LISP to LISP



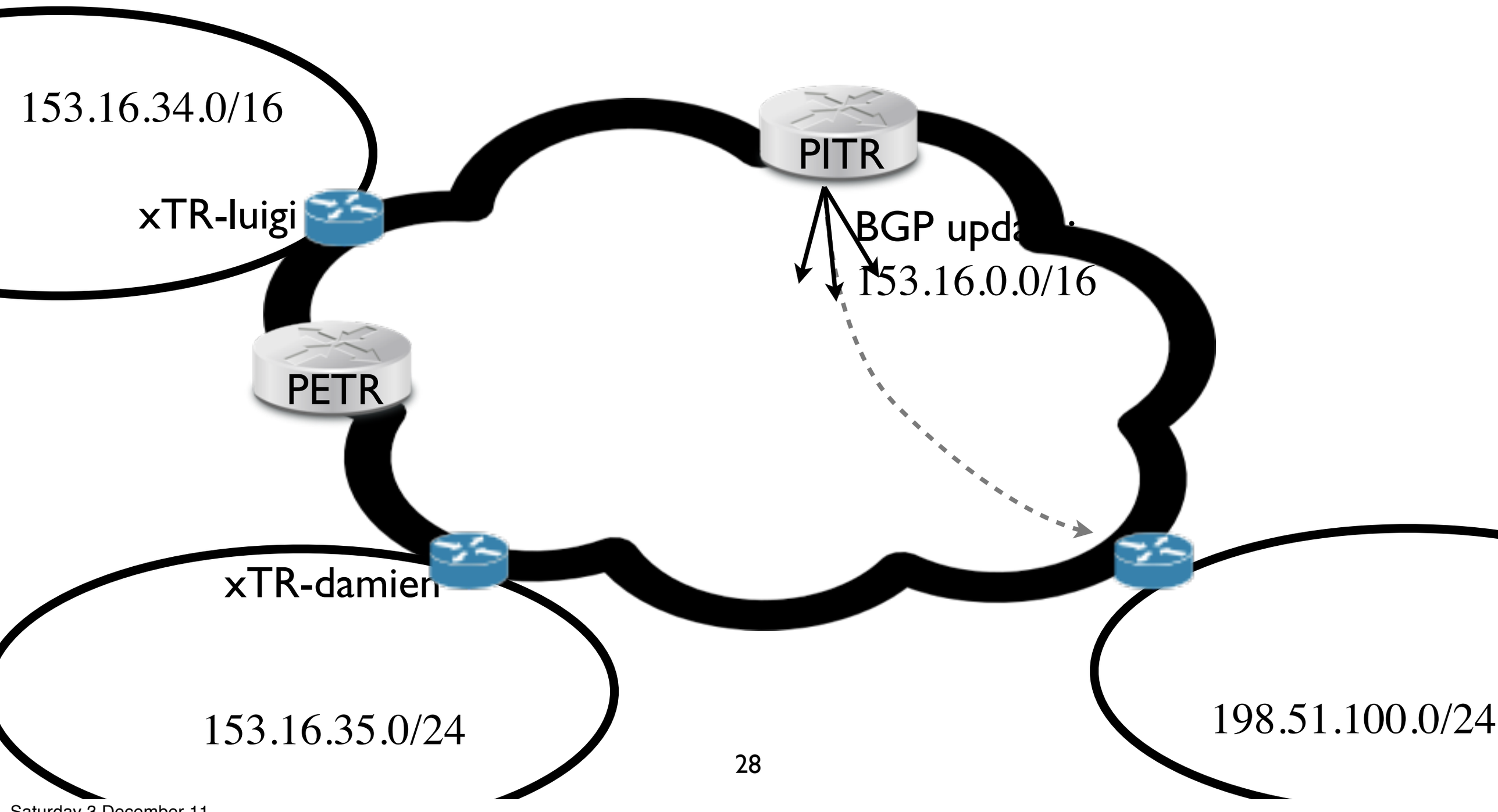
Non-LISP to LISP



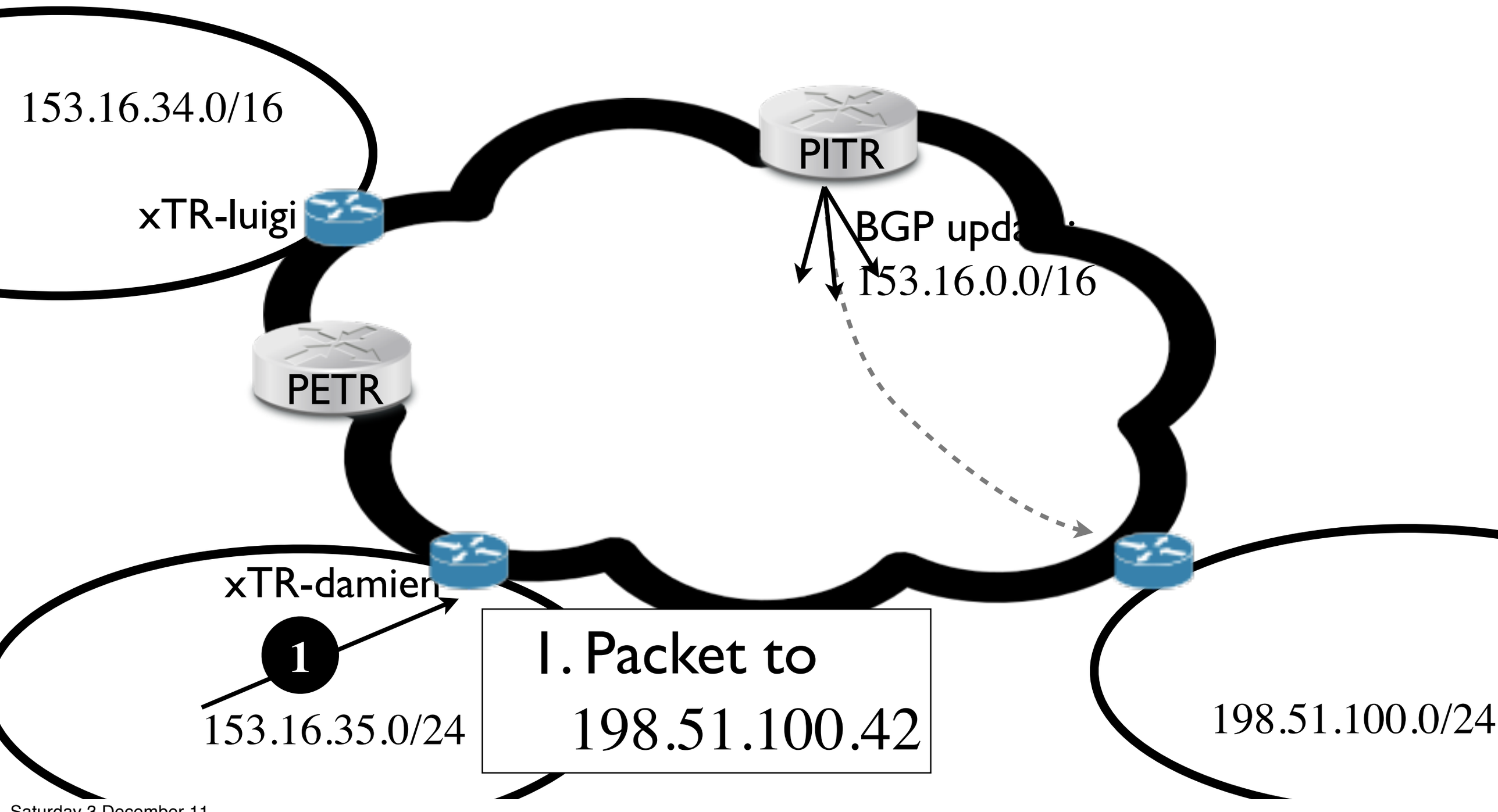
Non-LISP to LISP



LISP to non-LISP

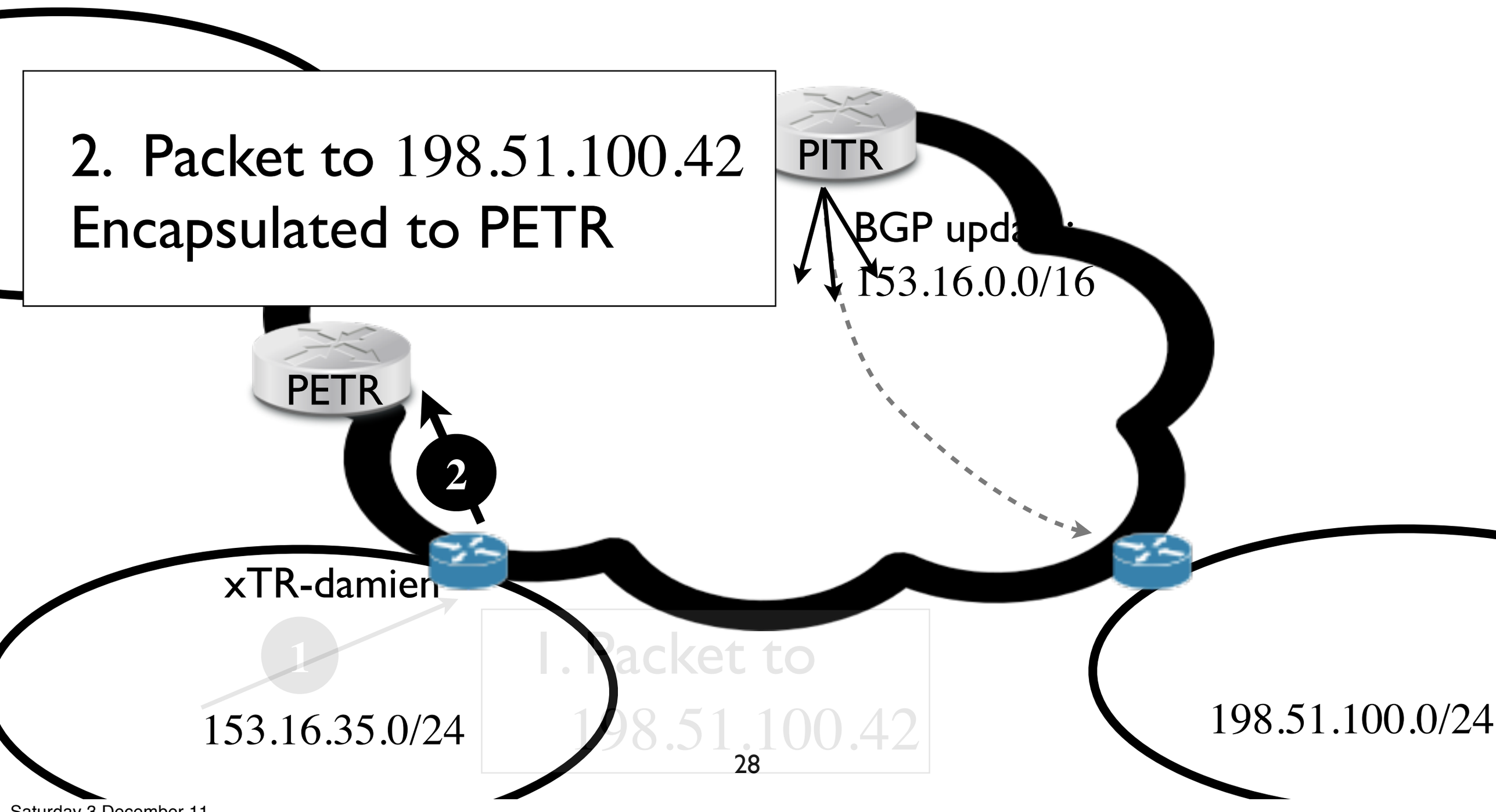


LISP to non-LISP

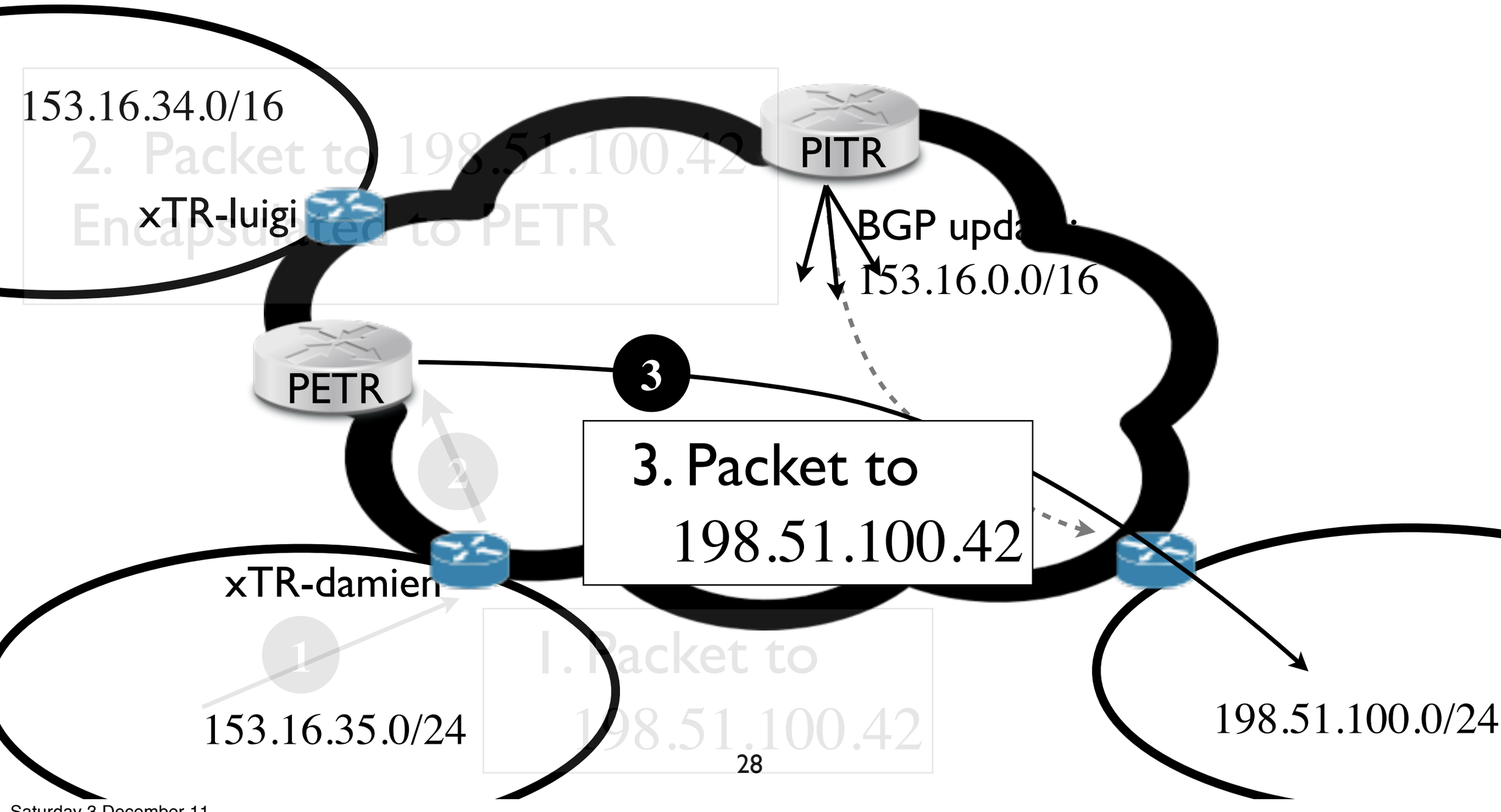


LISP to non-LISP

2. Packet to 198.51.100.42 Encapsulated to PETR

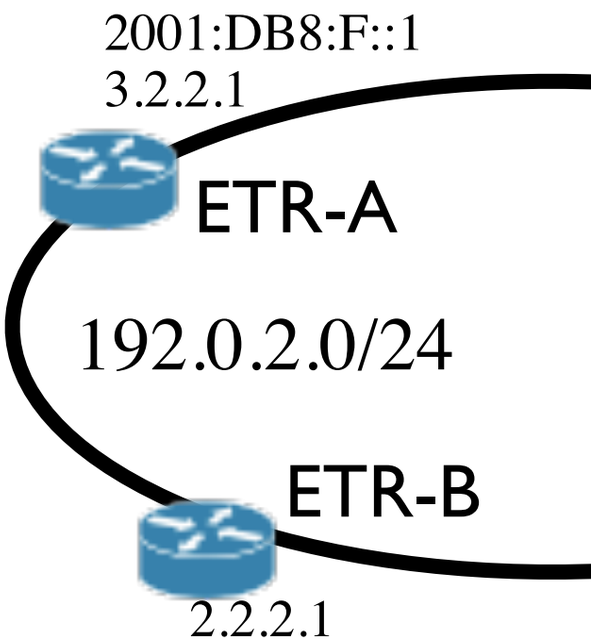


LISP to non-LISP



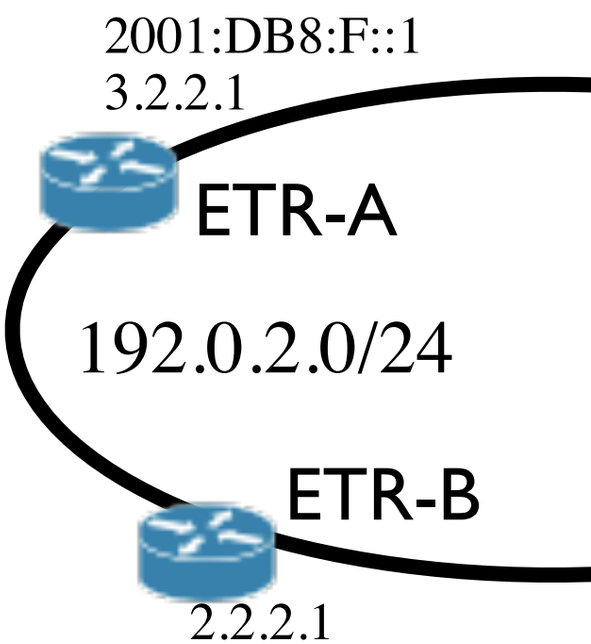
LISP Use Cases

Low OpEx site multihoming



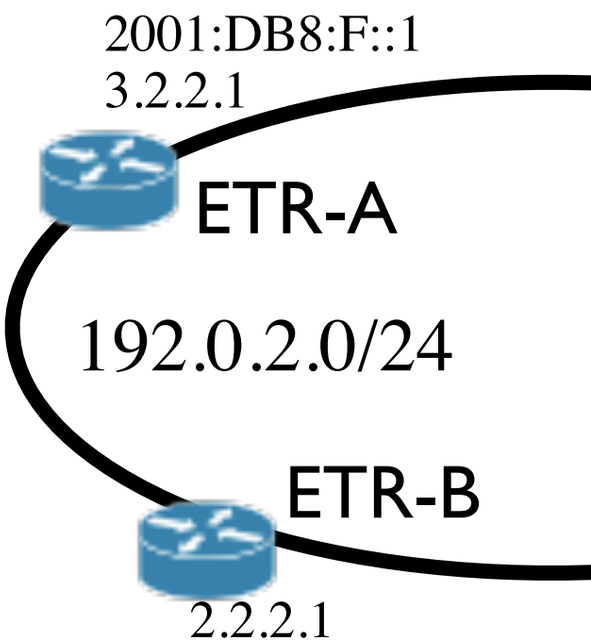
Low OpEx site multihoming

- Basic LISP feature



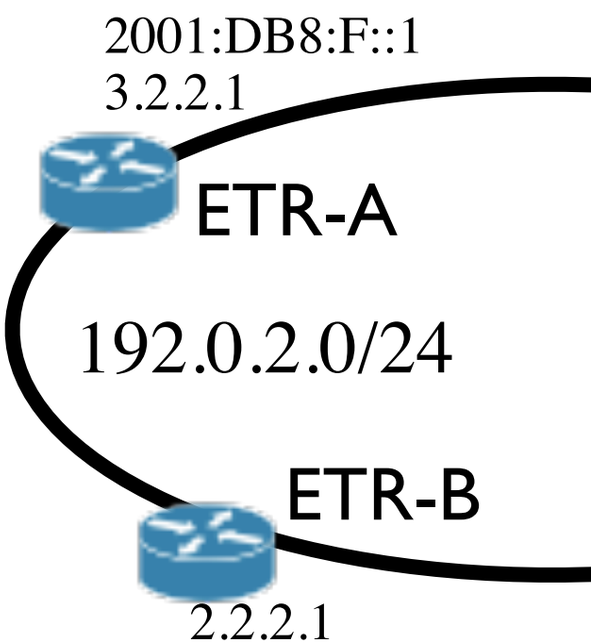
Low OpEx site multihoming

- Basic LISP feature
- ETR-A Primary, ETR-B Backup (IPv6 just in case...)
  - 3.2.2.1, prio: 1, weight: 100
  - 2.2.2.1, prio: 10, weight: 100
  - 2001:DB8:F:11, prio 100, weight: 100

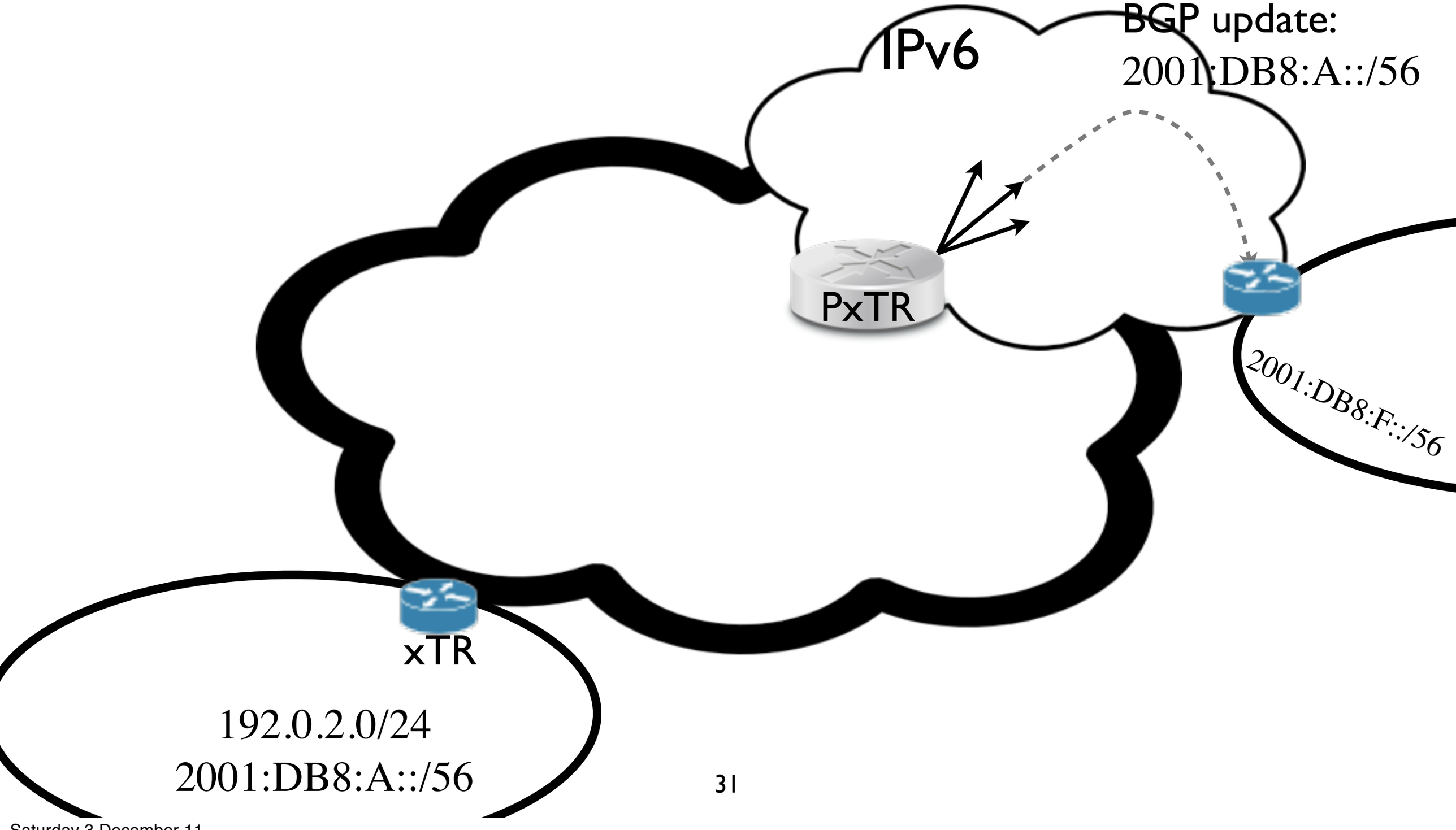


Low OpEx site multihoming

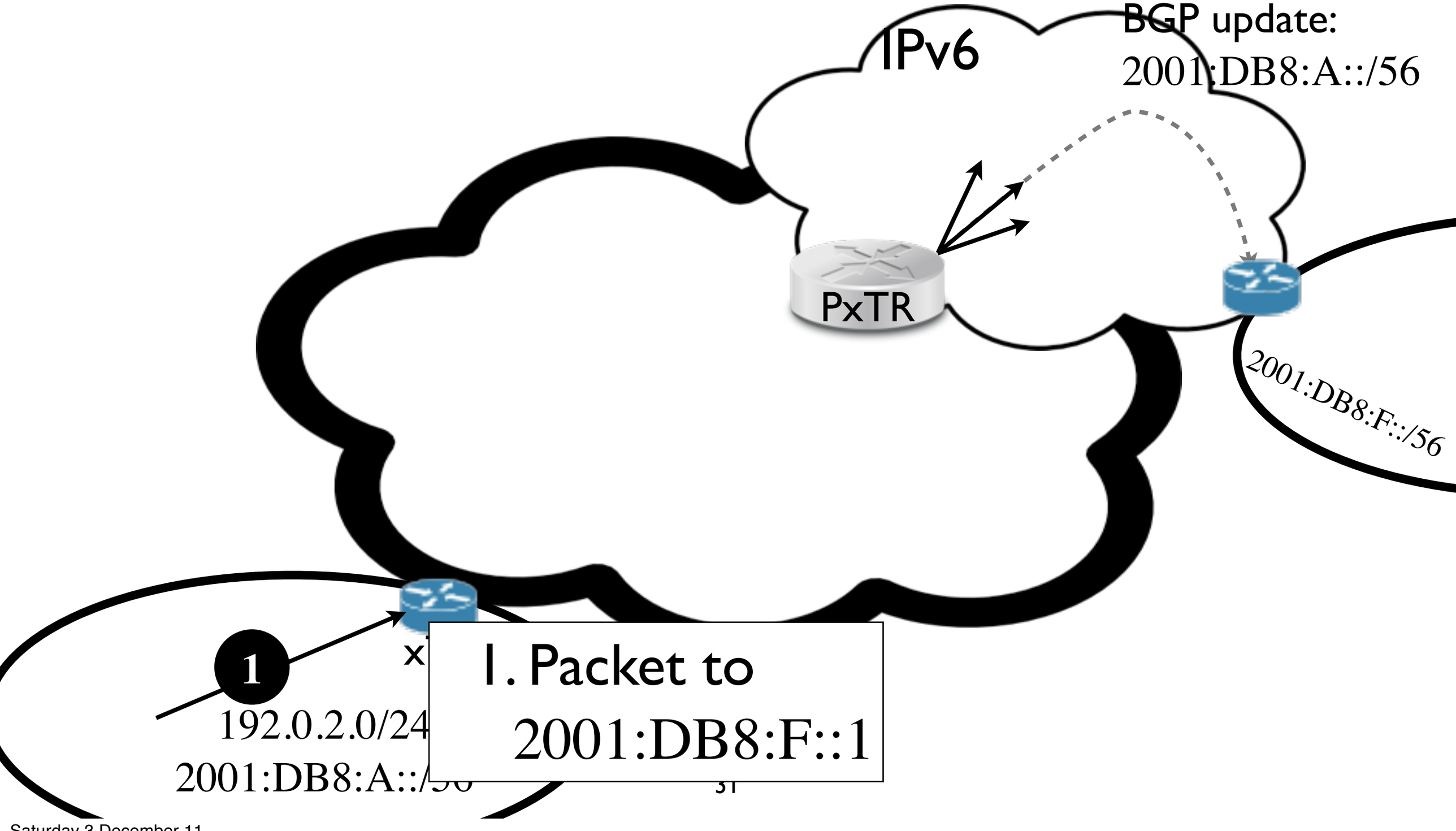
- Basic LISP feature
- ETR-A Primary, ETR-B Backup (IPv6 just in case...)
  - 3.2.2.1, prio: 1, weight: 100
  - 2.2.2.1, prio: 10, weight: 100
  - 2001:DB8:F:11, prio 100, weight: 100
- ETR-A: 60%, ETR-B: 40% (IPv6 just in case...)
  - 3.2.2.1, prio: 1, weight: 60
  - 2.2.2.1, prio: 1, weight: 40
  - 2001:DB8:F:11, prio 99, weight: 100



IPv6/IPv4 coexistence

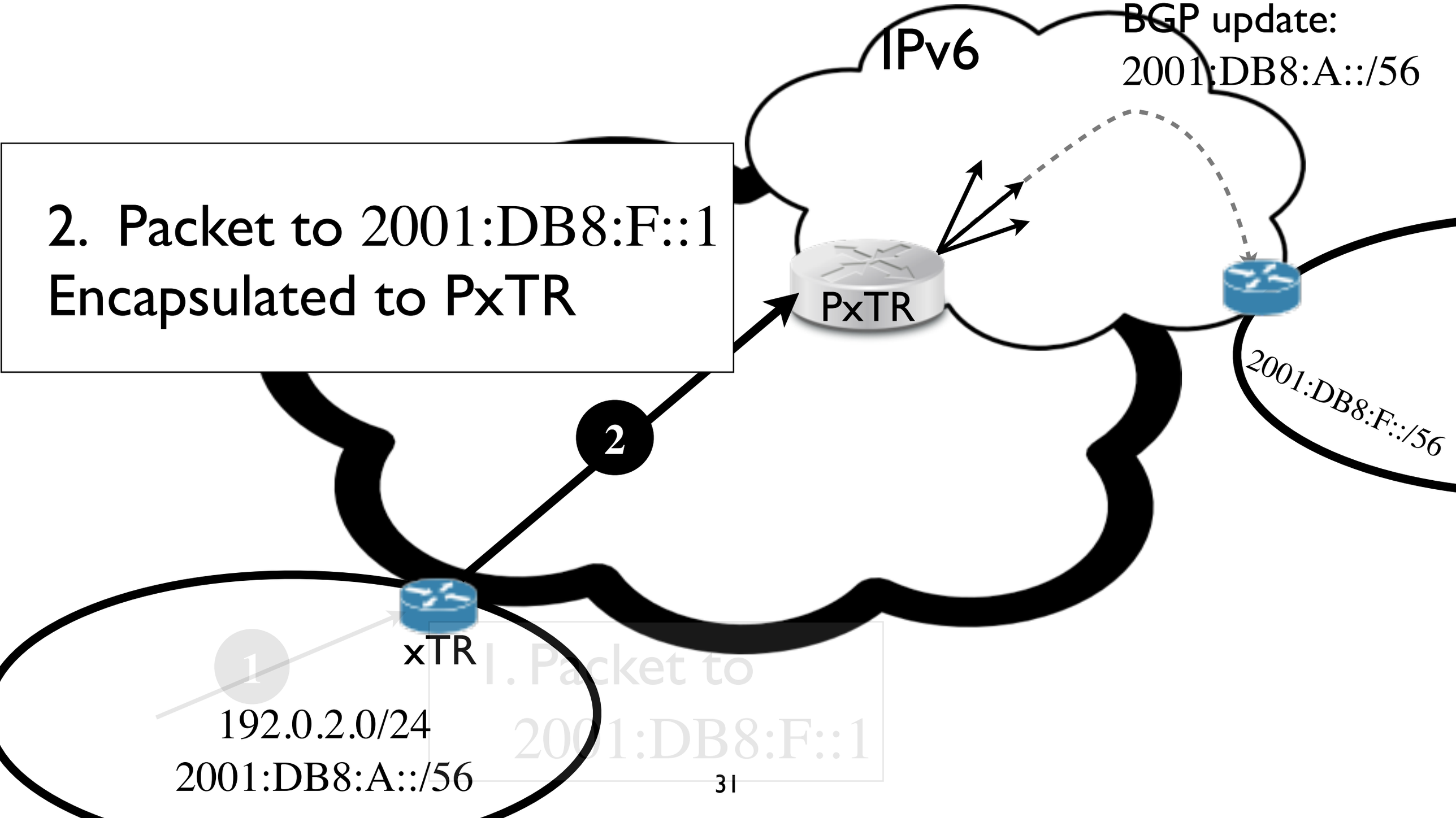


IPv6/IPv4 coexistence

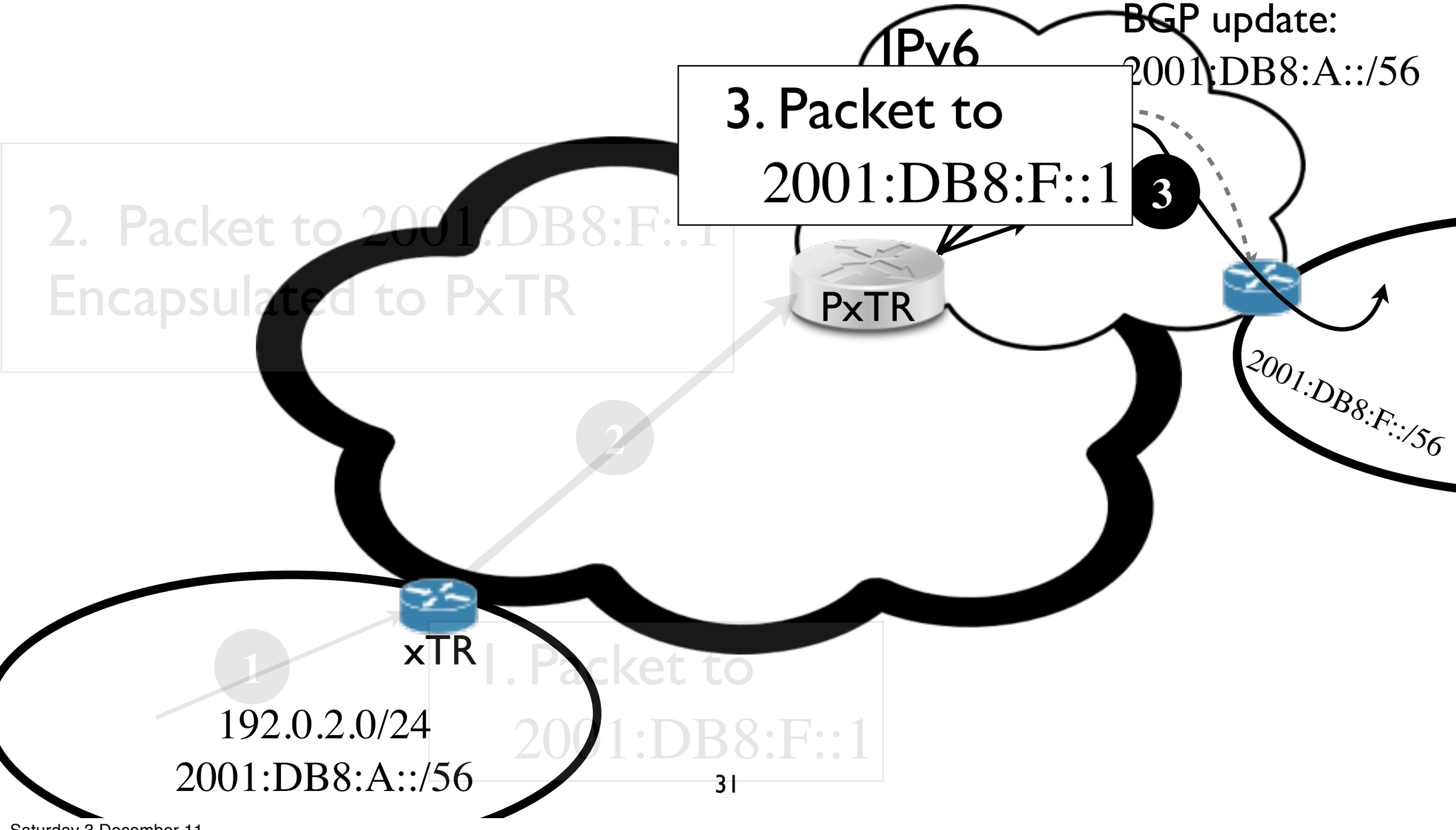


IPv6/IPv4 coexistence

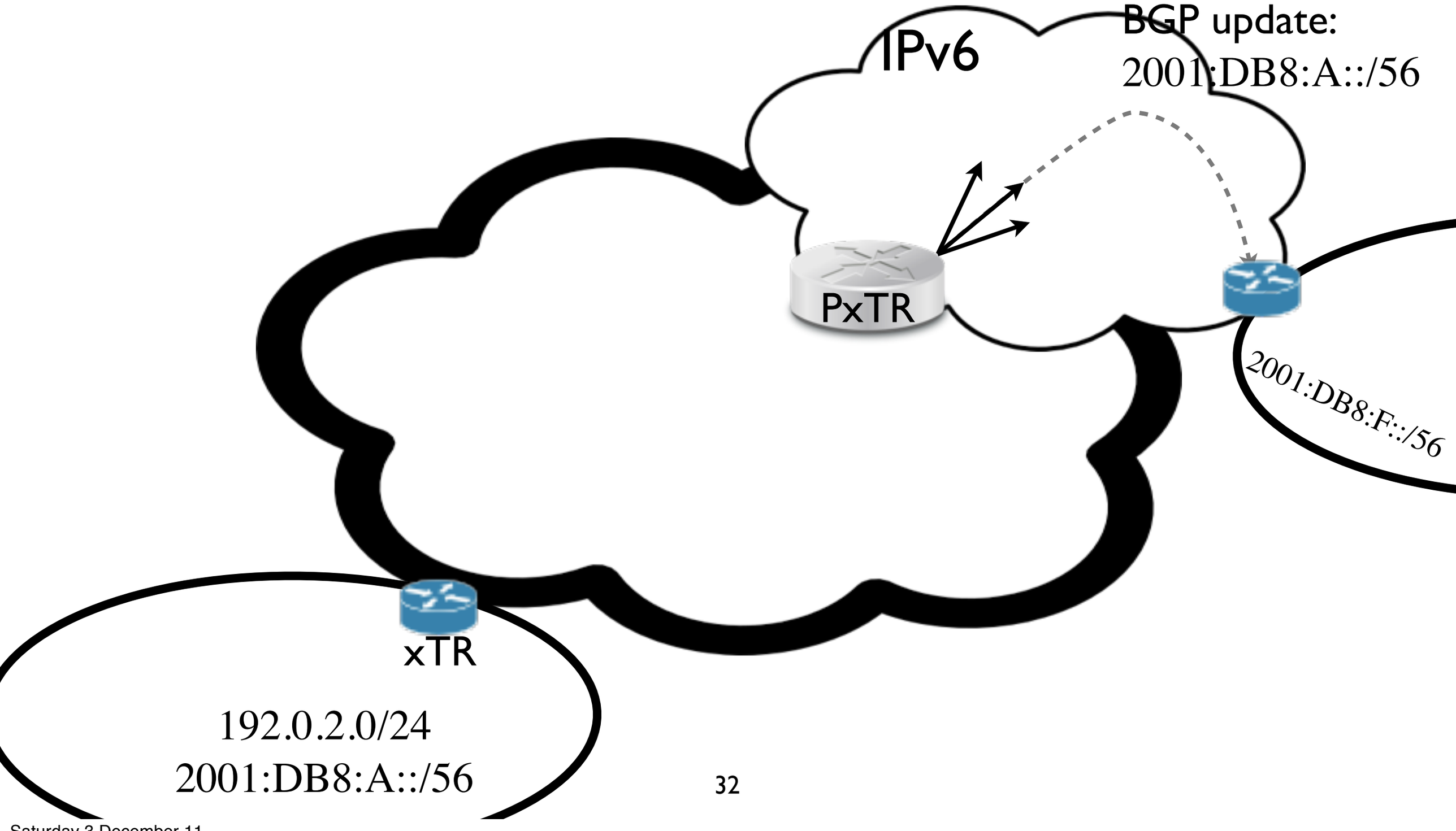
2. Packet to 2001:DB8:F::1 Encapsulated to PxTR



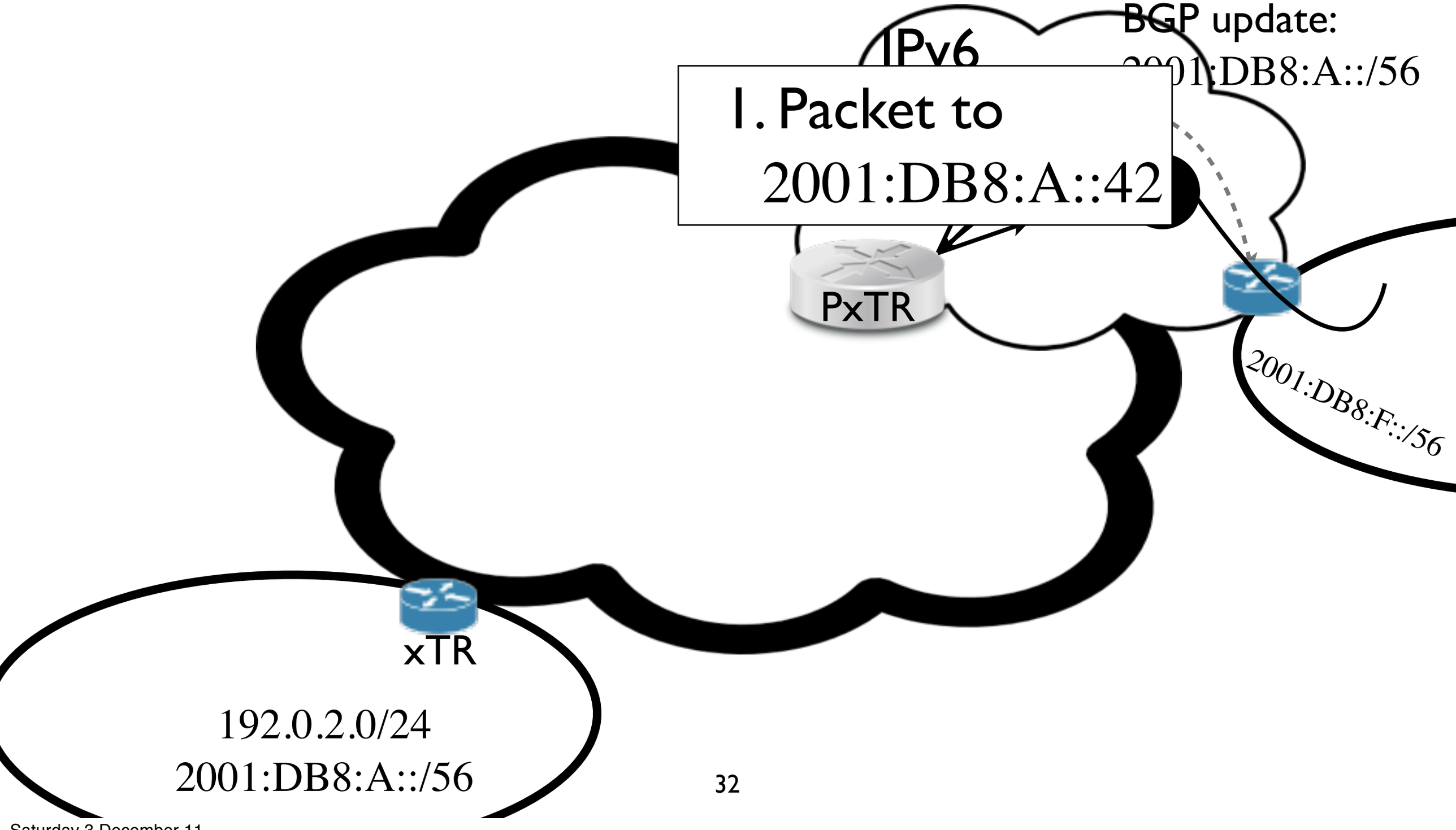
IPv6/IPv4 coexistence



IPv6/IPv4 coexistence

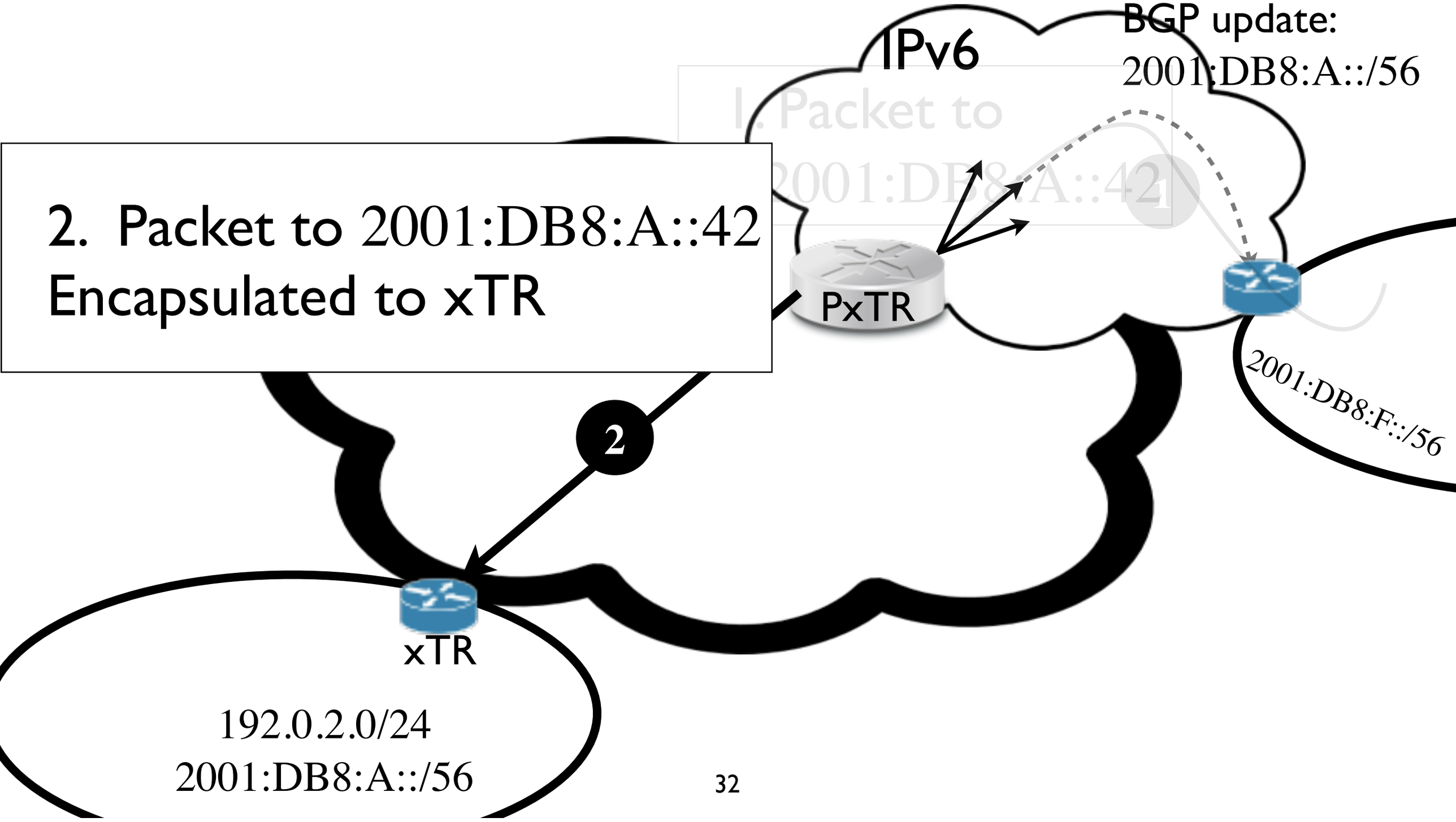


IPv6/IPv4 coexistence

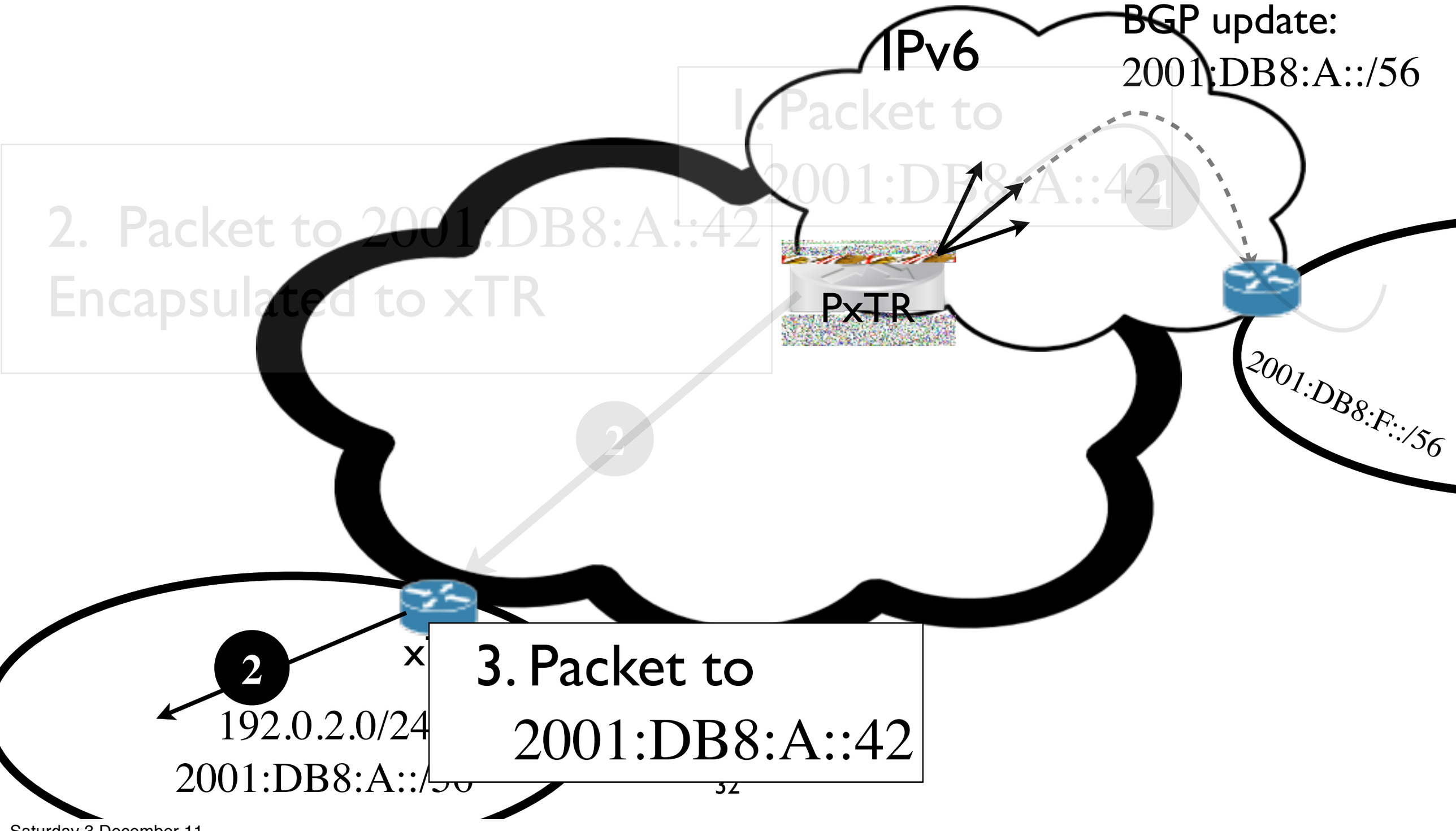


IPv6/IPv4 coexistence

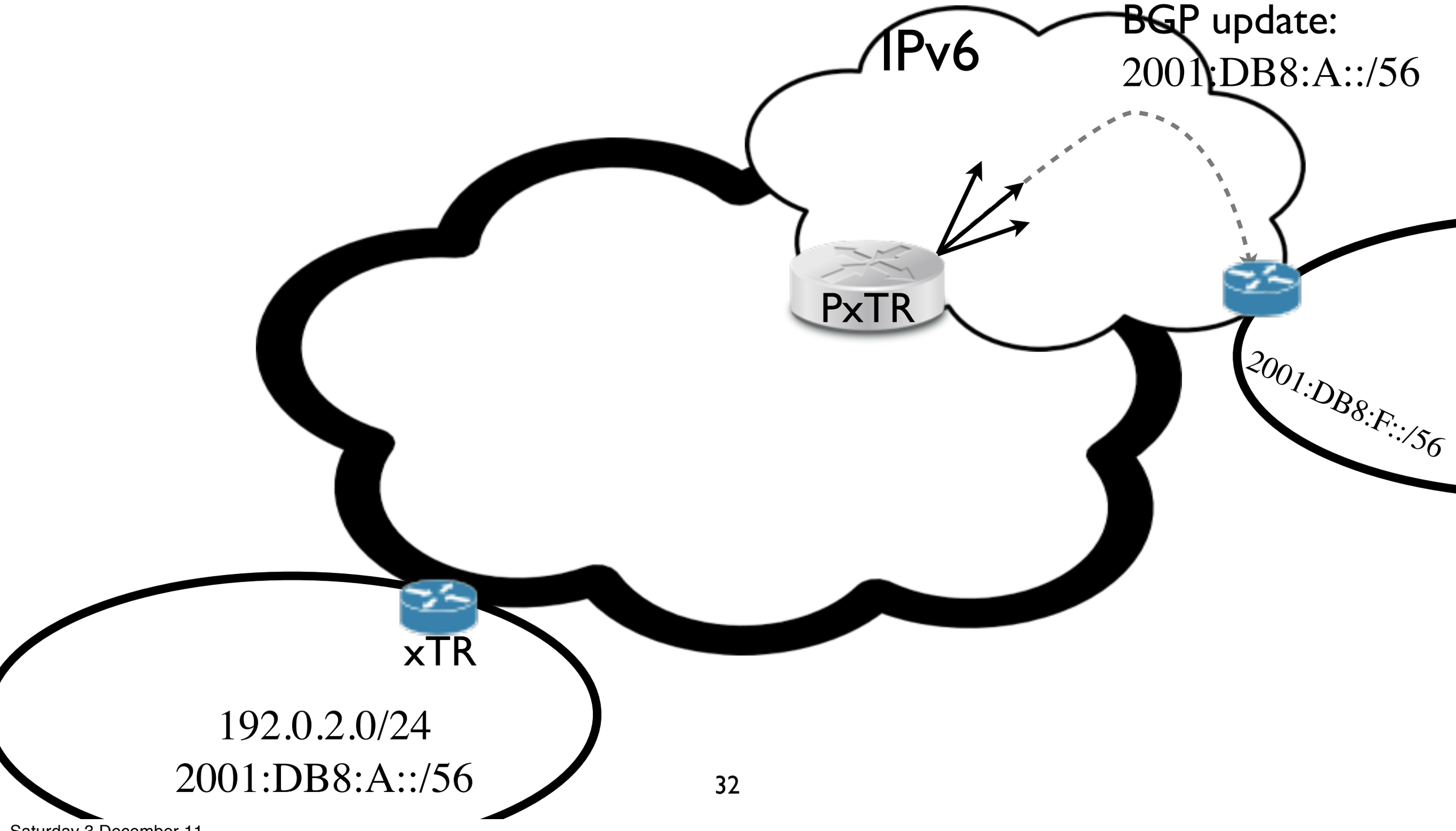
2. Packet to 2001:DB8:A::42 Encapsulated to xTR



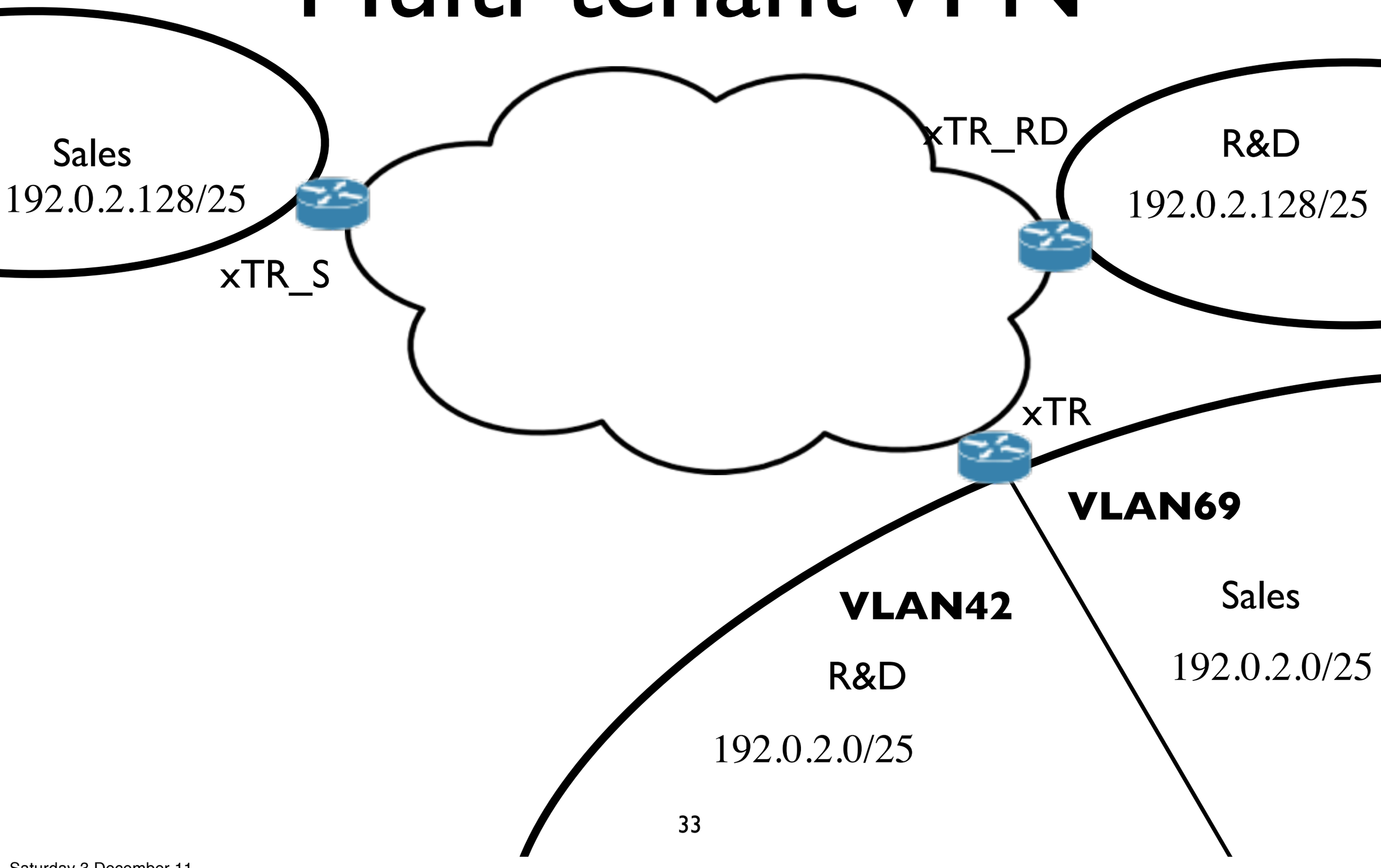
IPv6/IPv4 coexistence



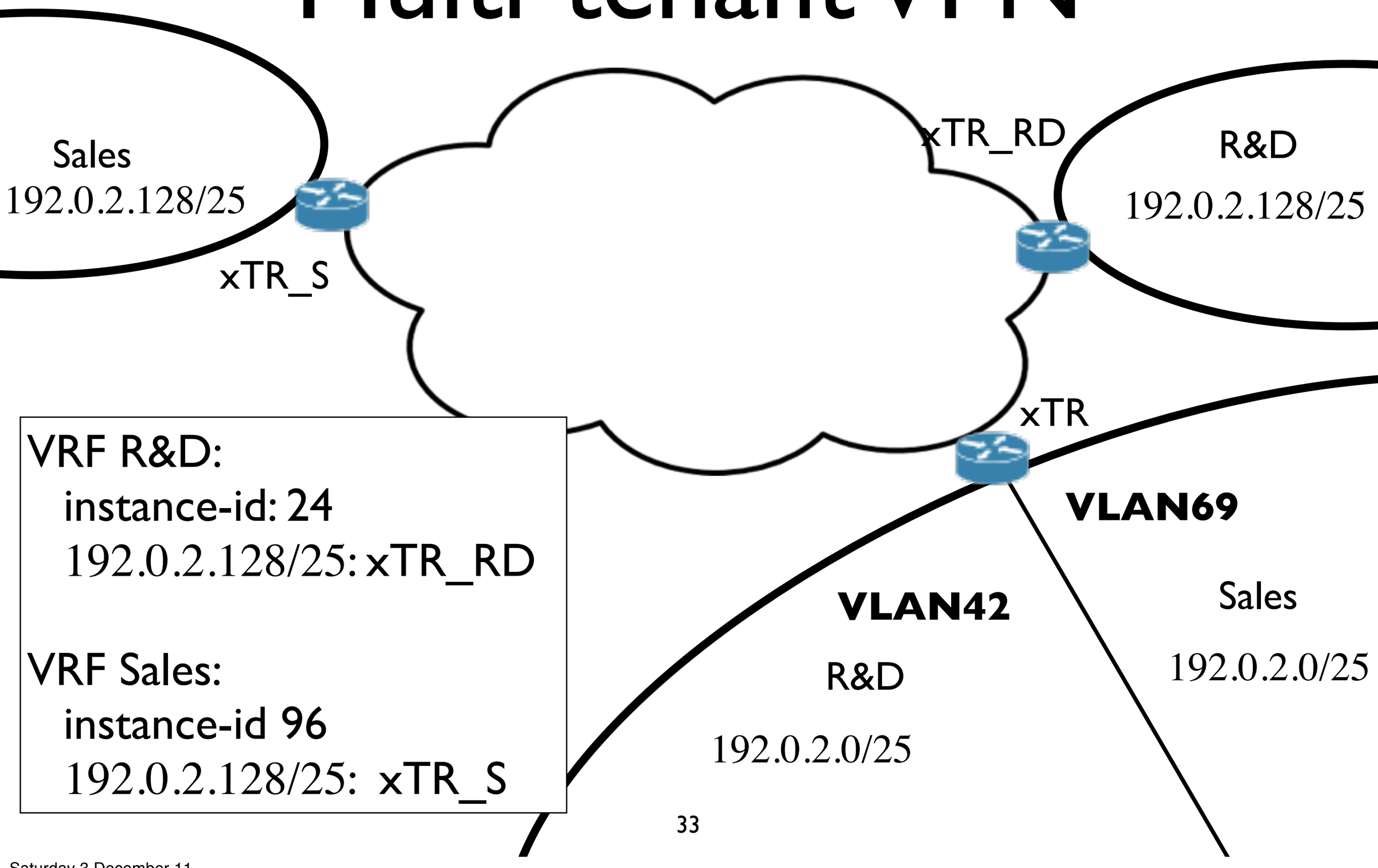
IPv6/IPv4 coexistence



Multi-tenant VPN



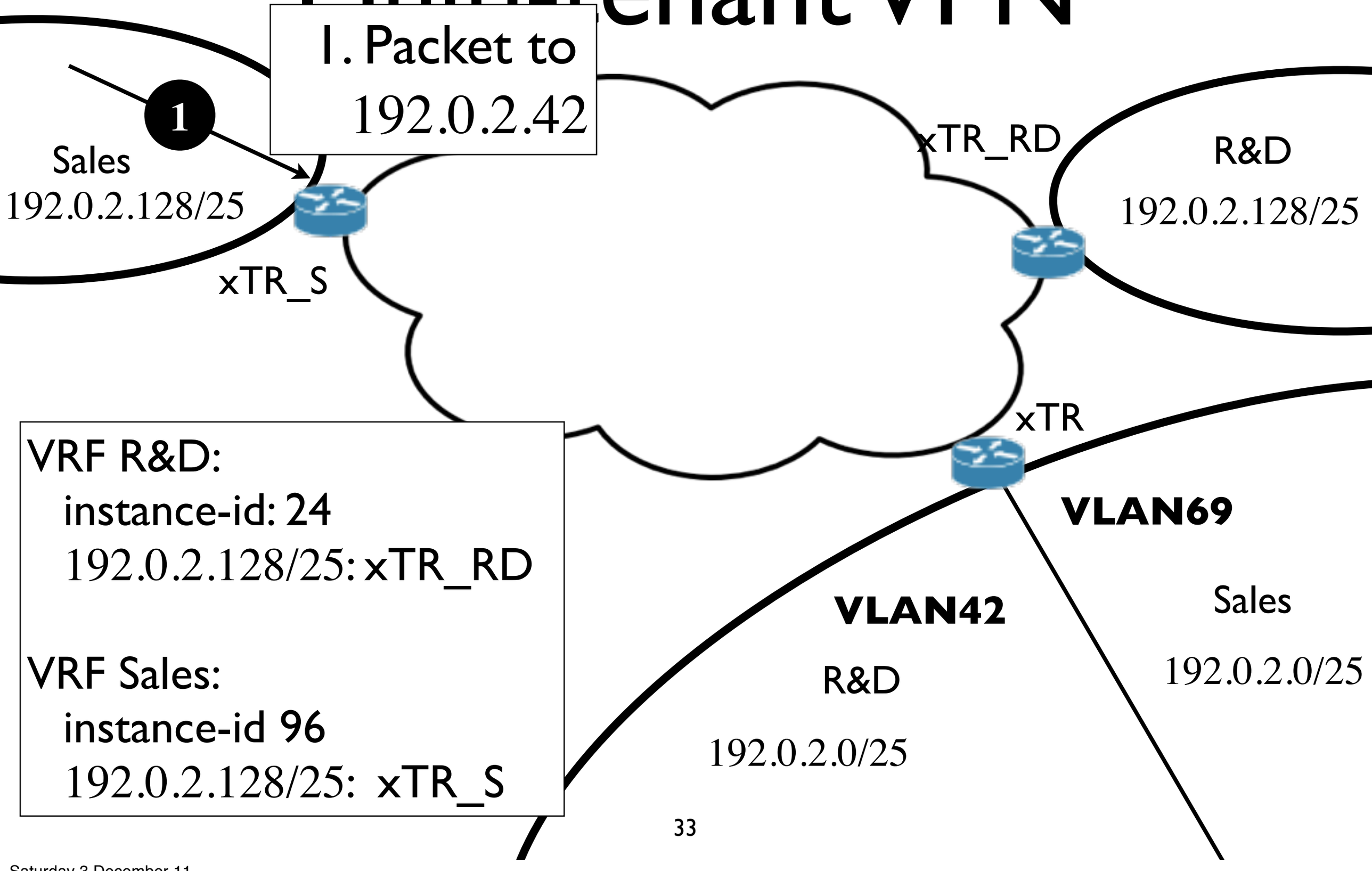
Multi-tenant VPN



VRF R&D:
- instance-id: 24
- 192.0.2.128/25: xTR_RD

VRF Sales:
- instance-id 96
- 192.0.2.128/25: xTR_S

Multi-tenant VPN



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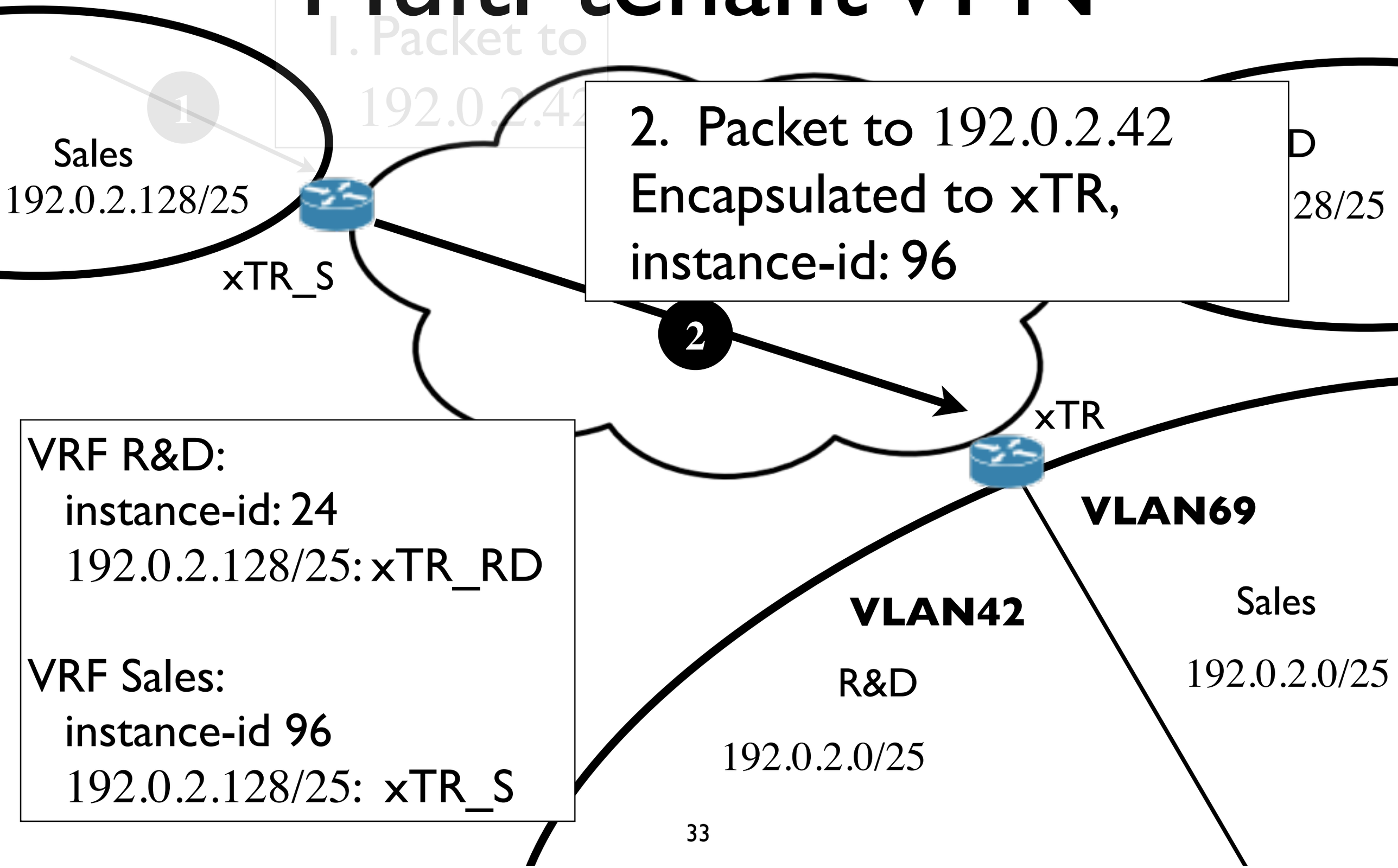

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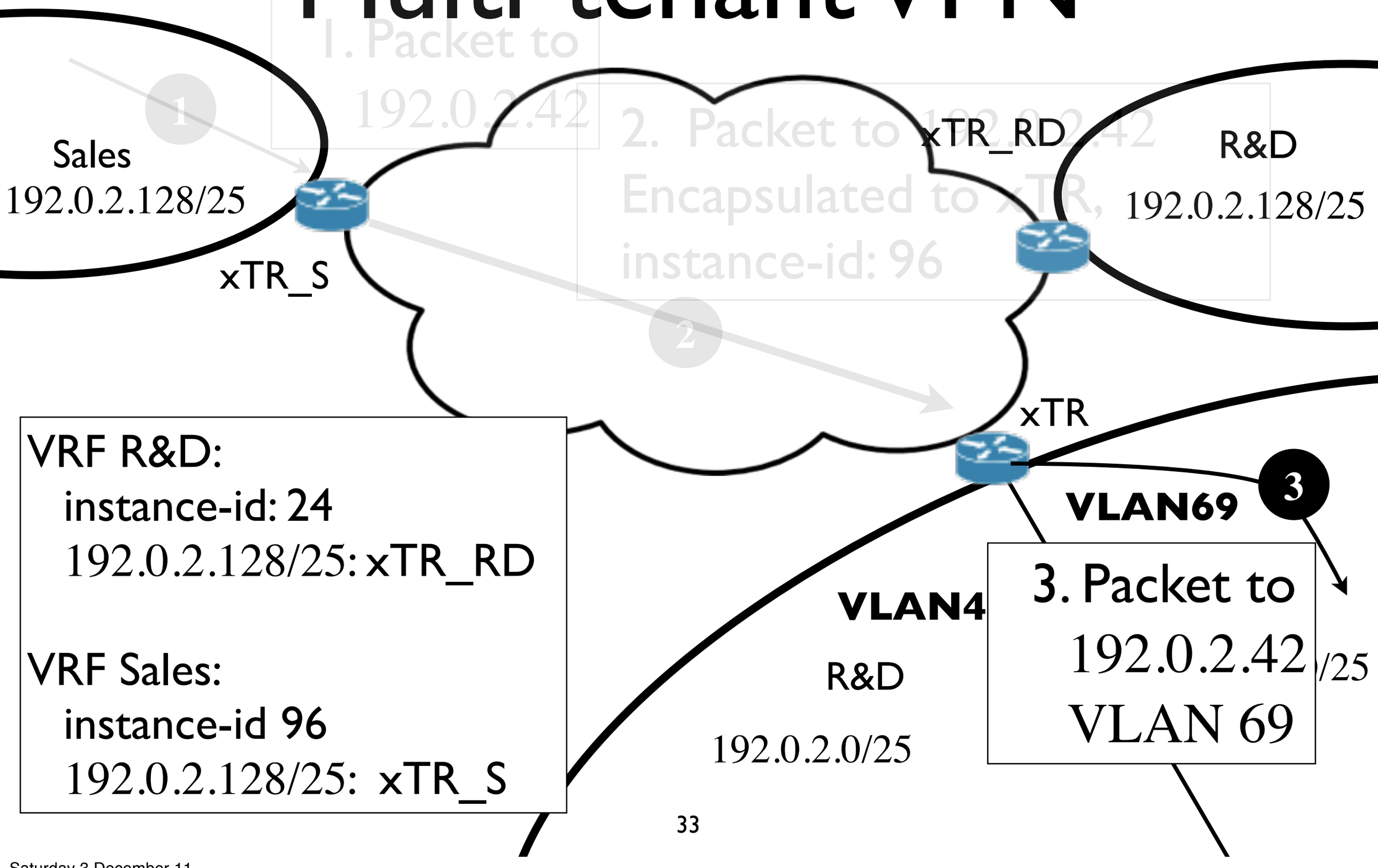

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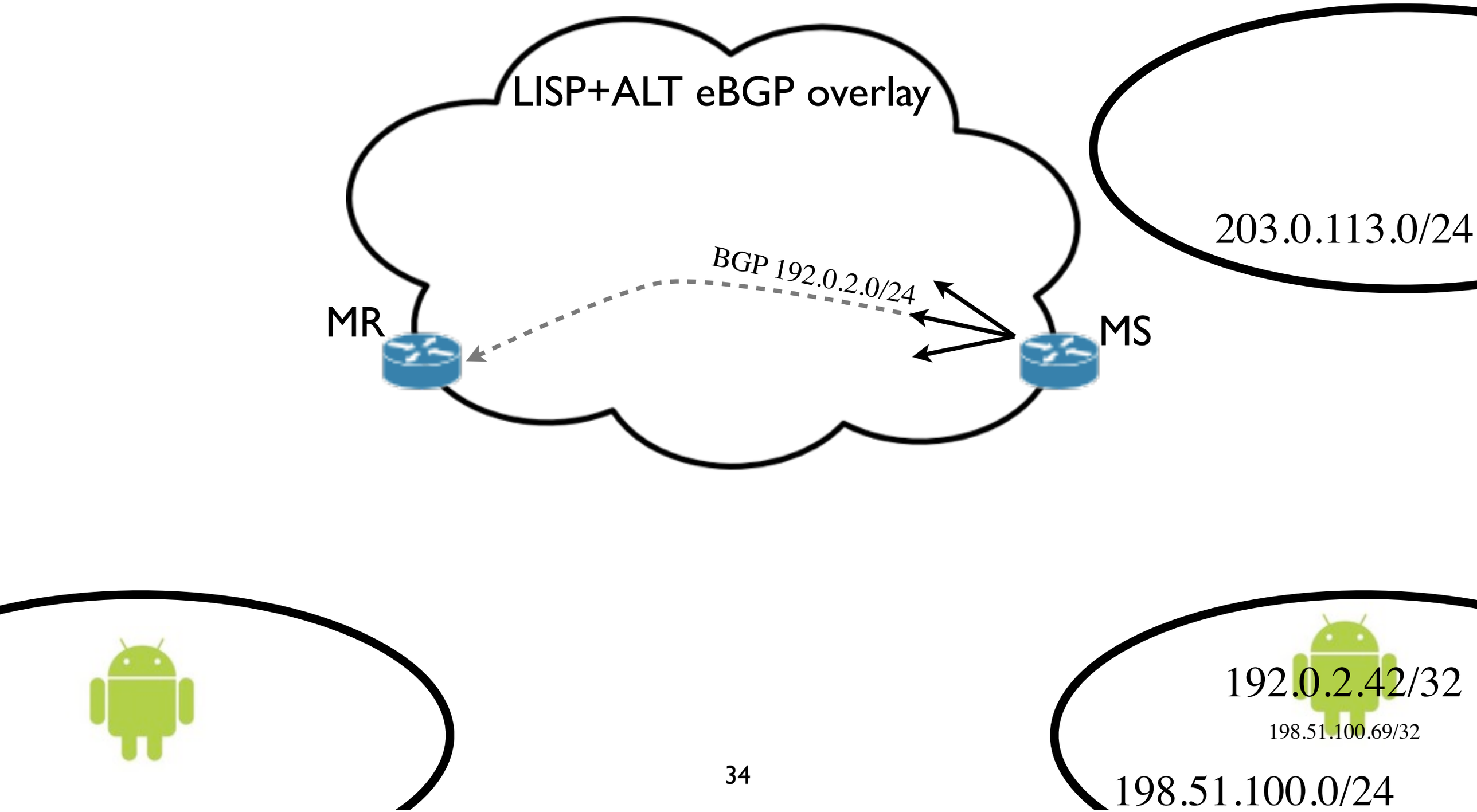
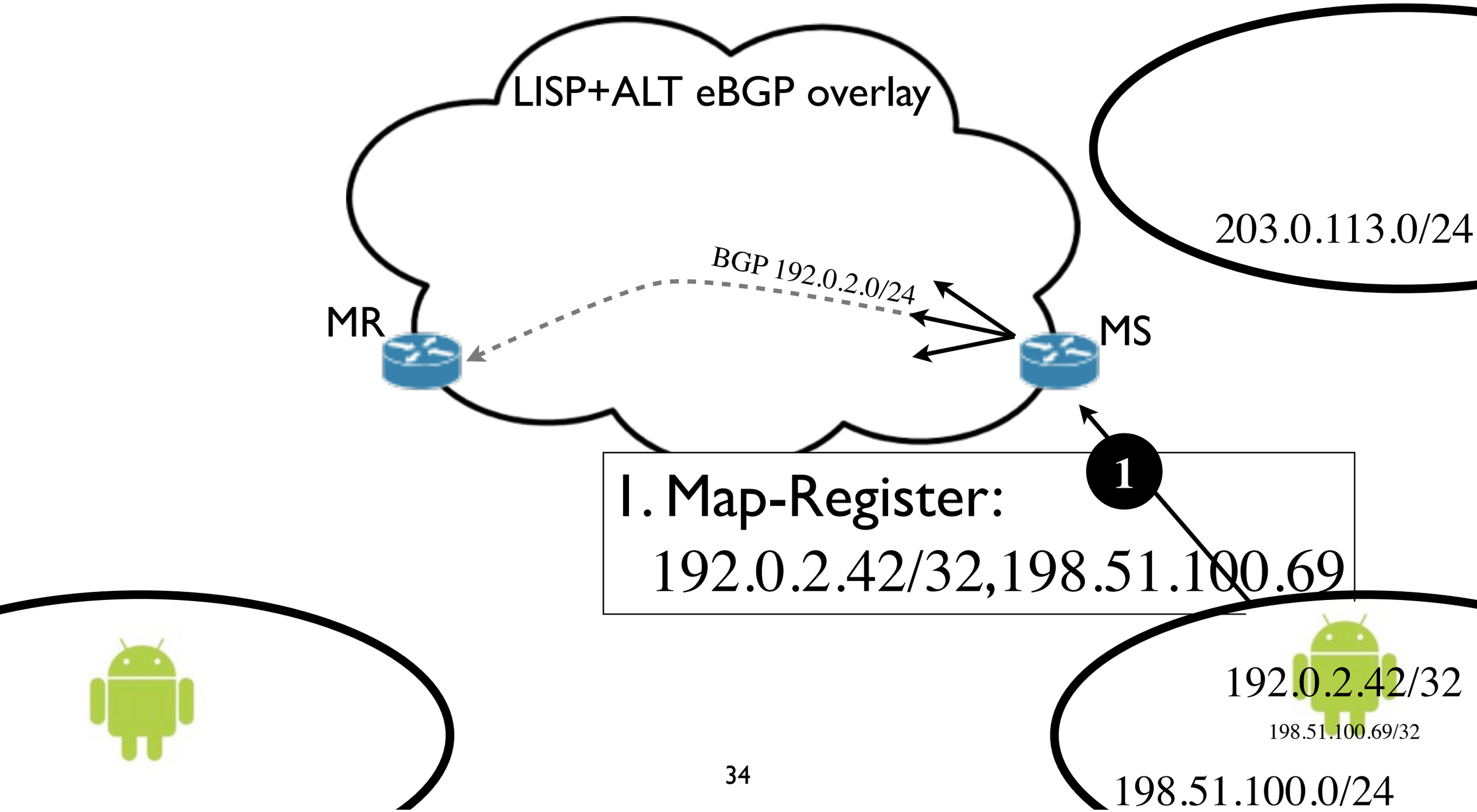
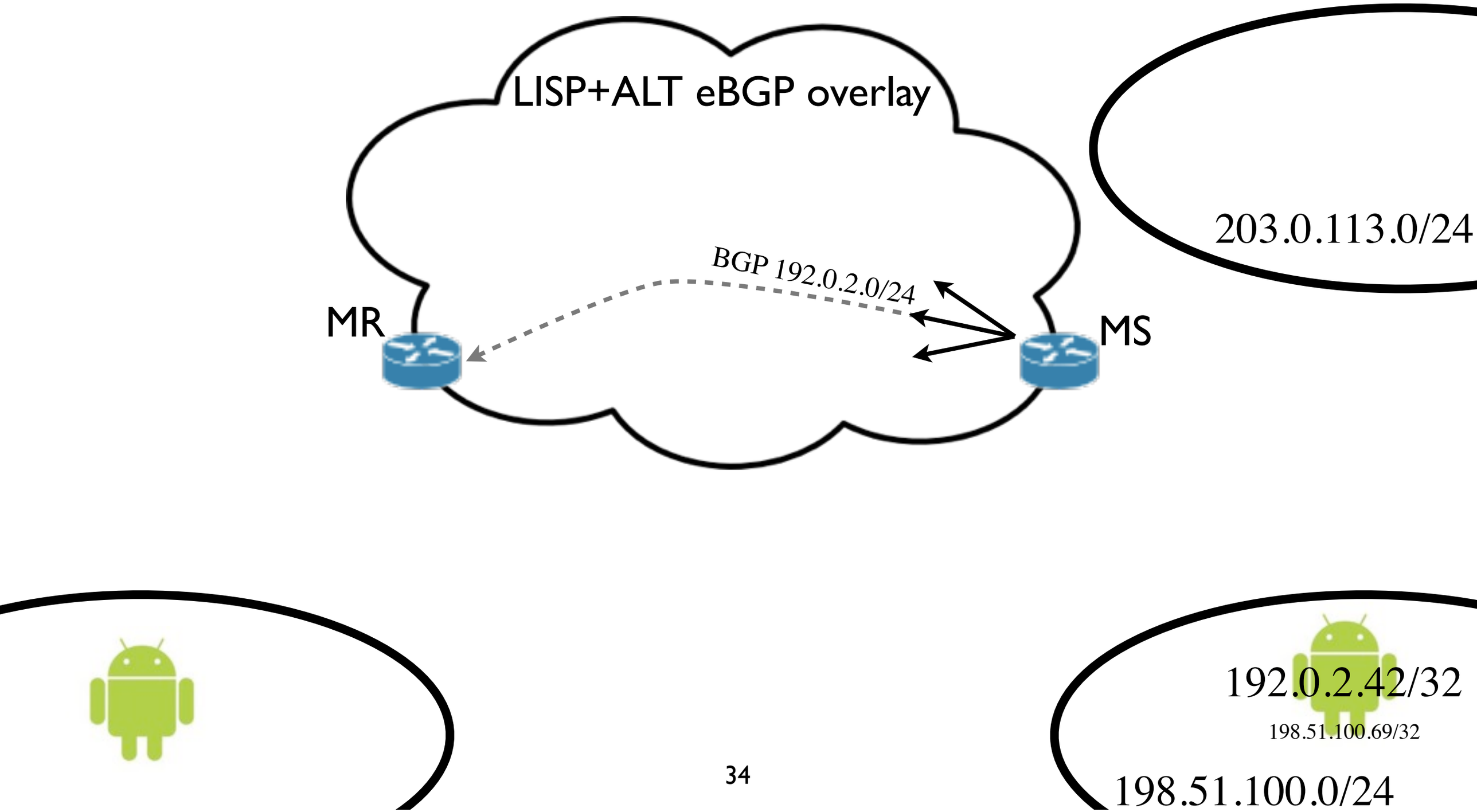
LISP Mobile Nodes



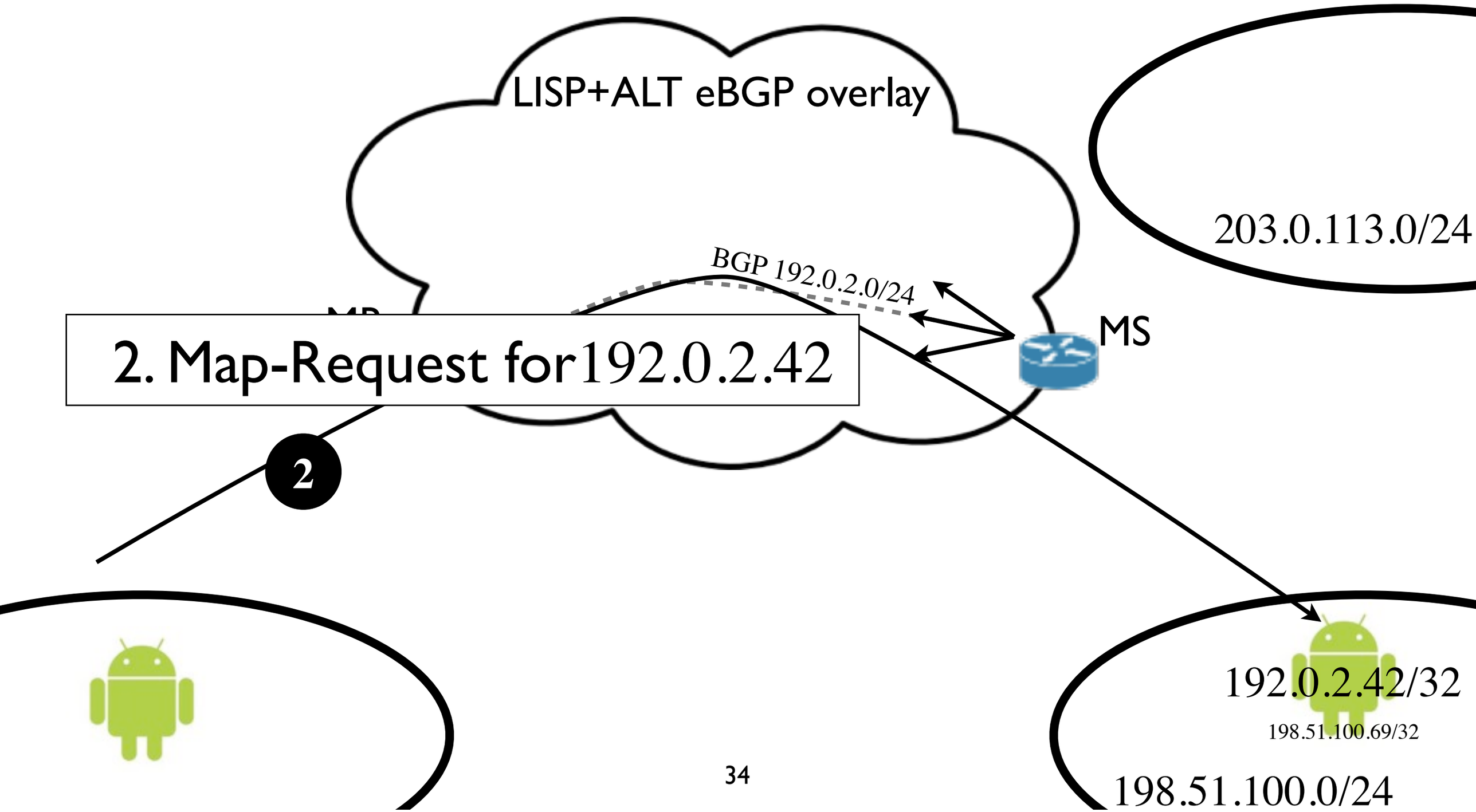
LISP Mobile Nodes



LISP Mobile Nodes



LISP Mobile Nodes



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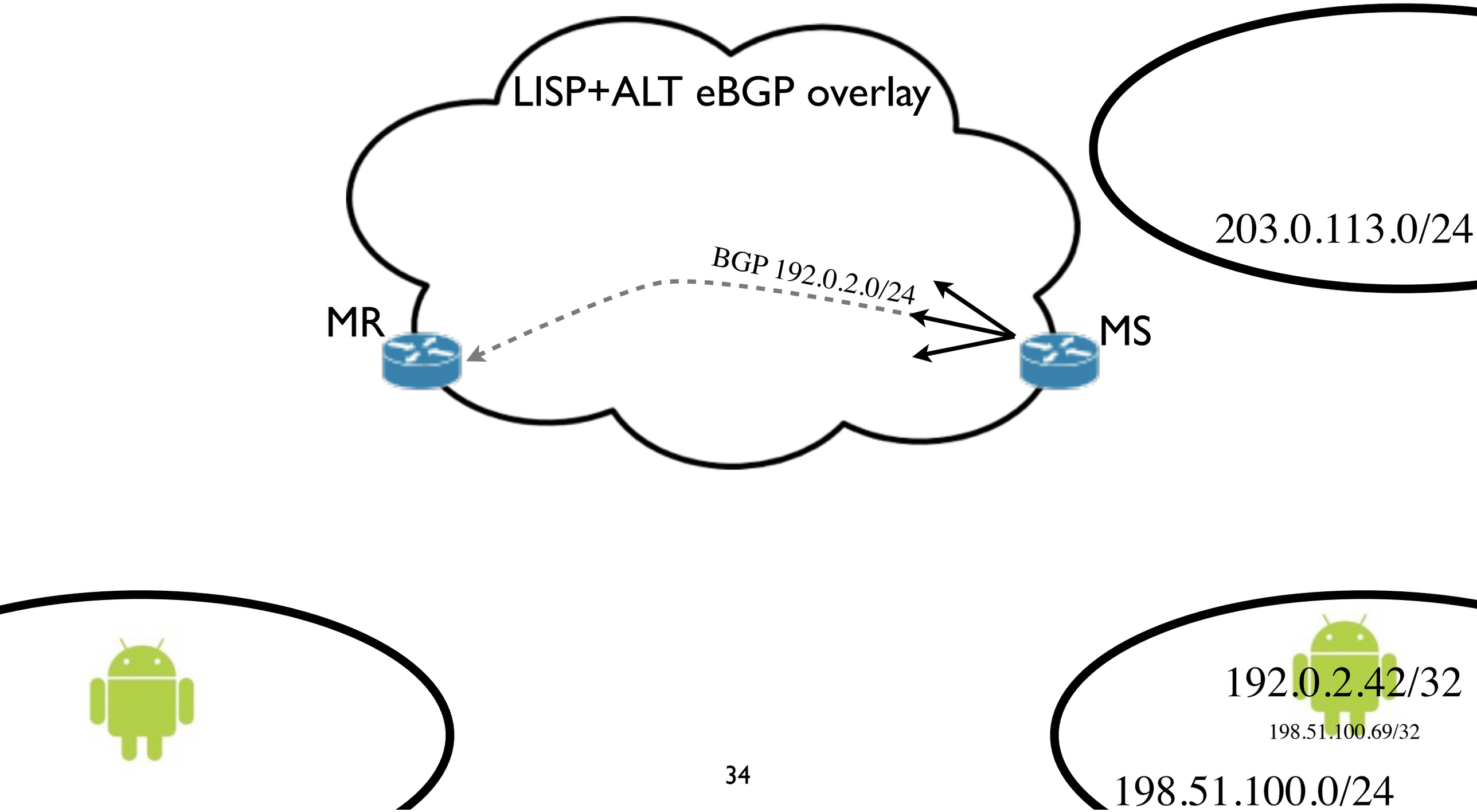

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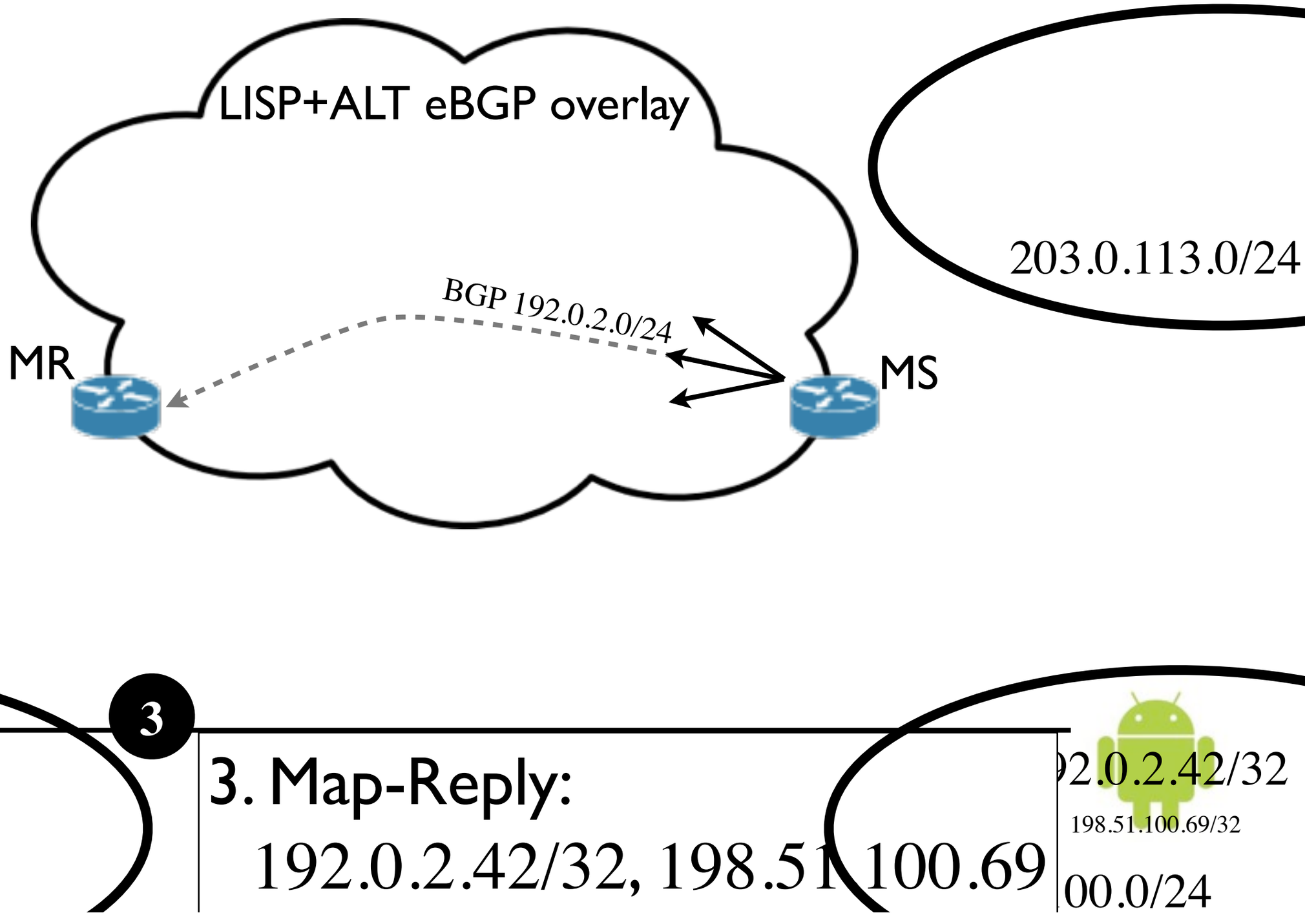

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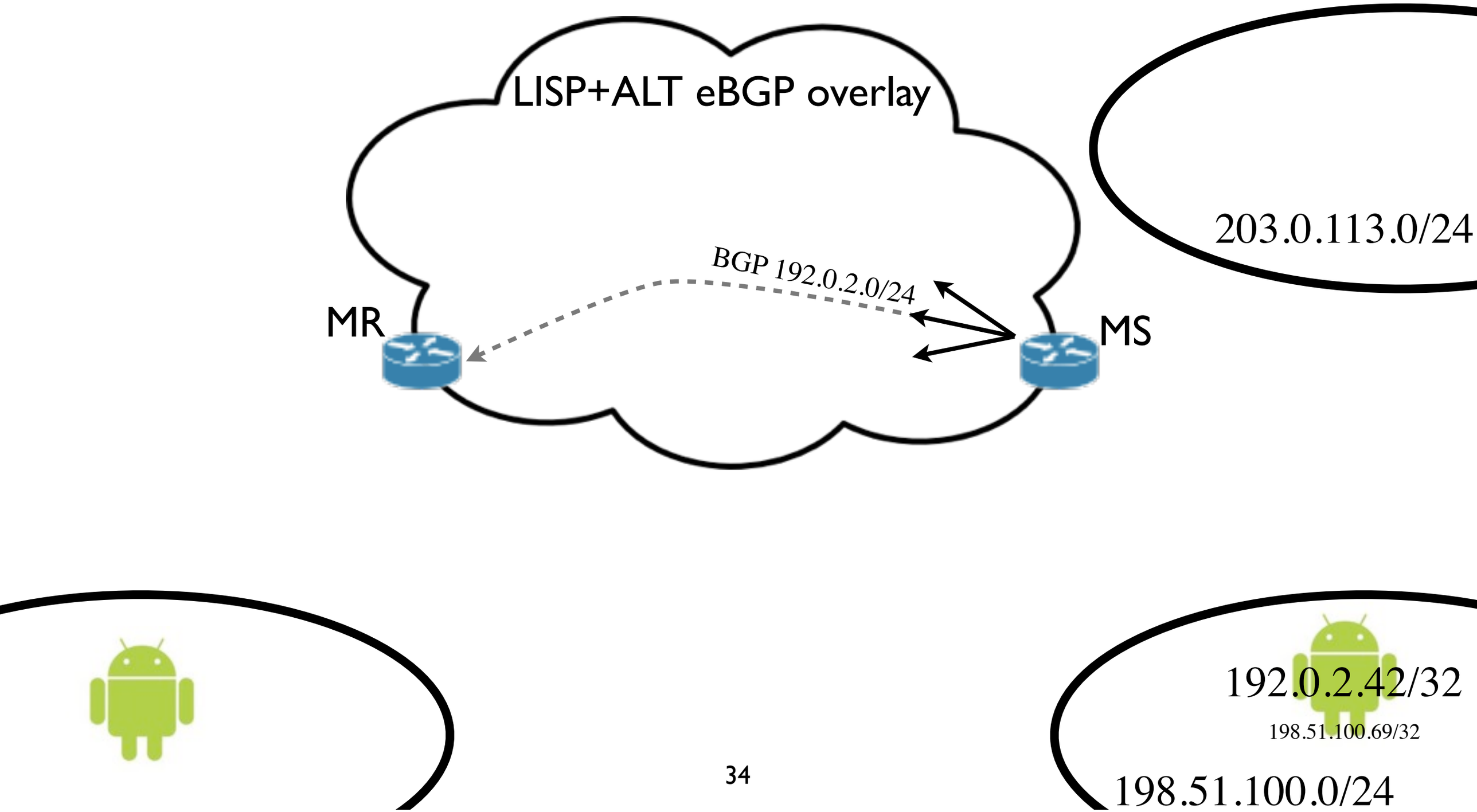
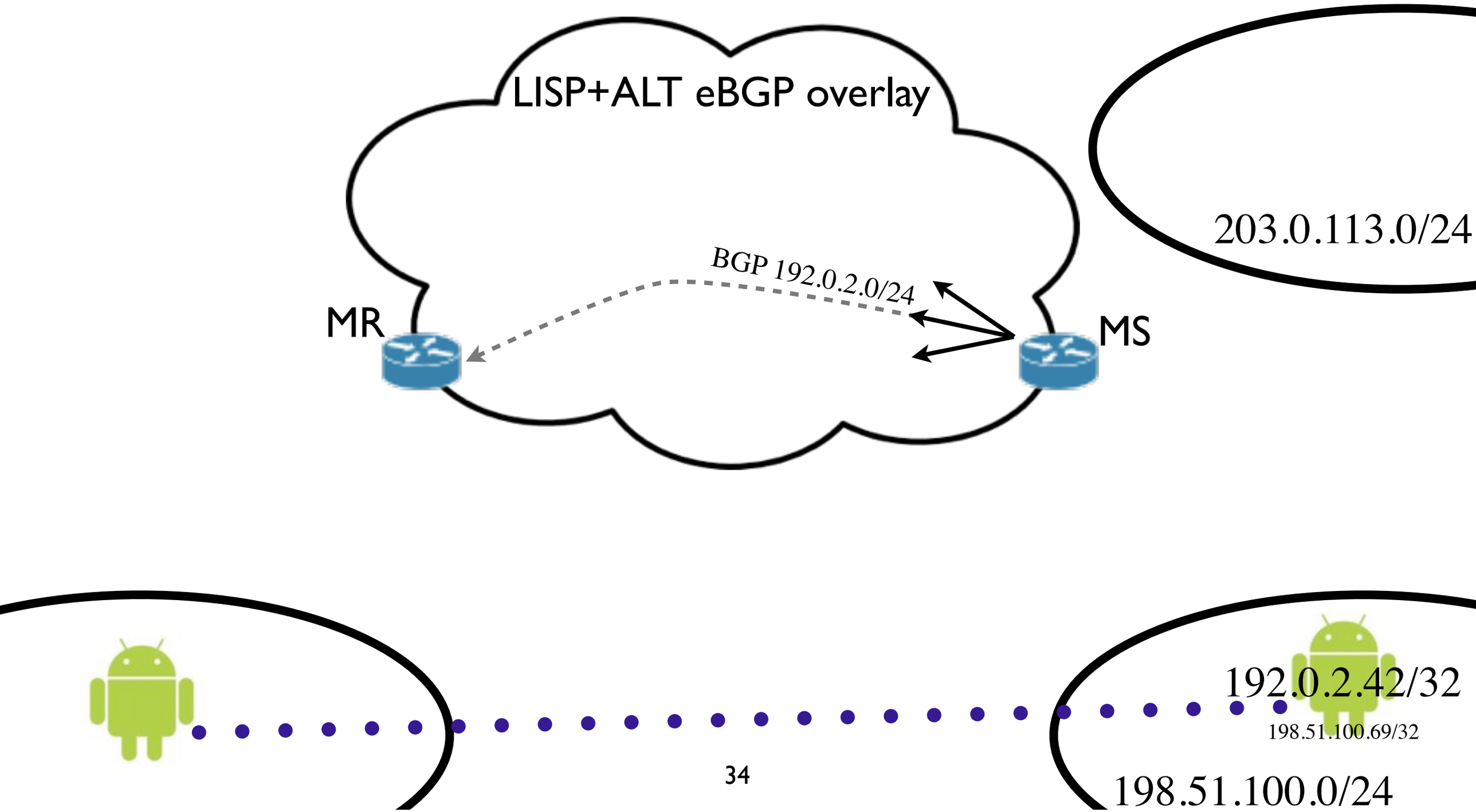


LISP Mobile Nodes



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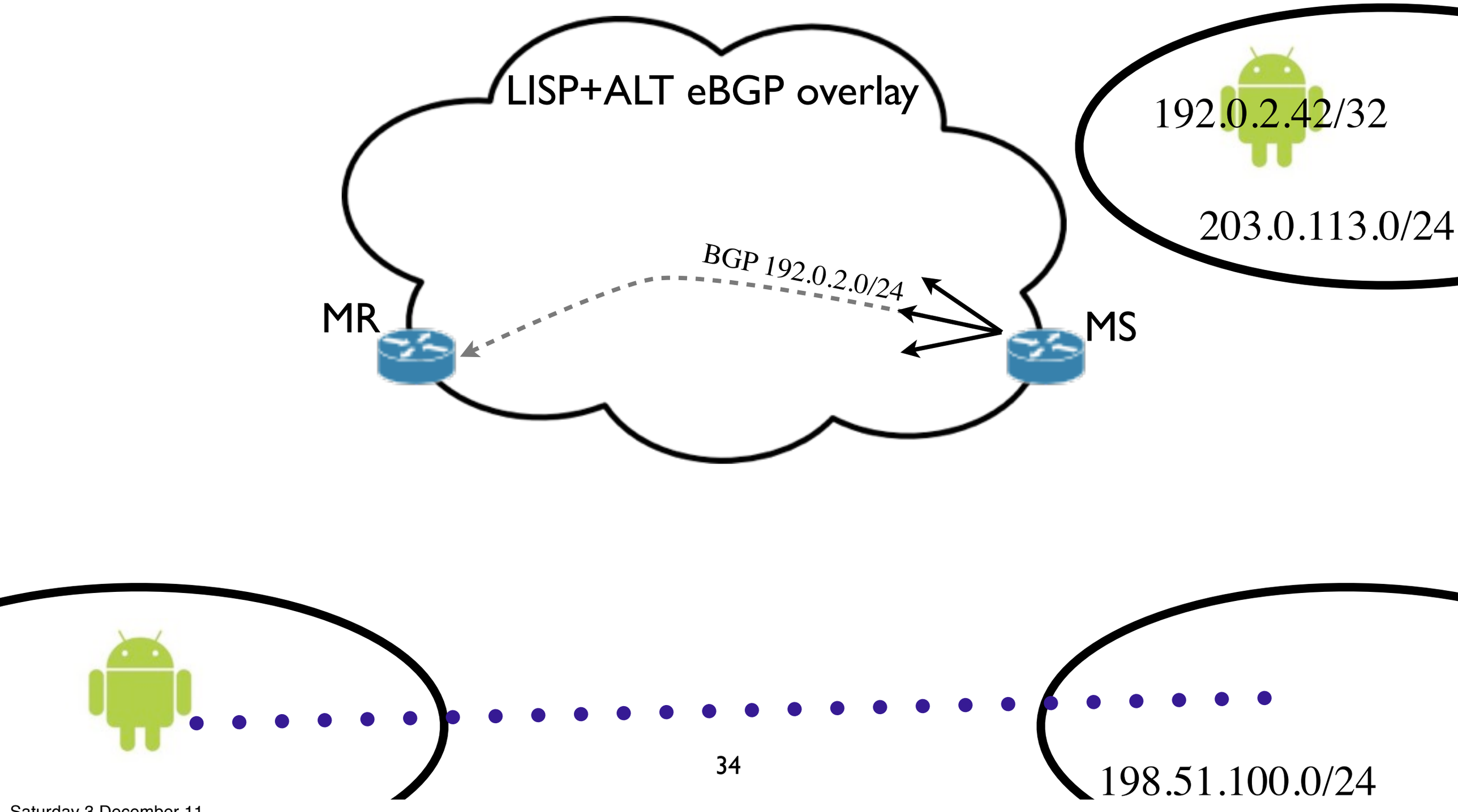
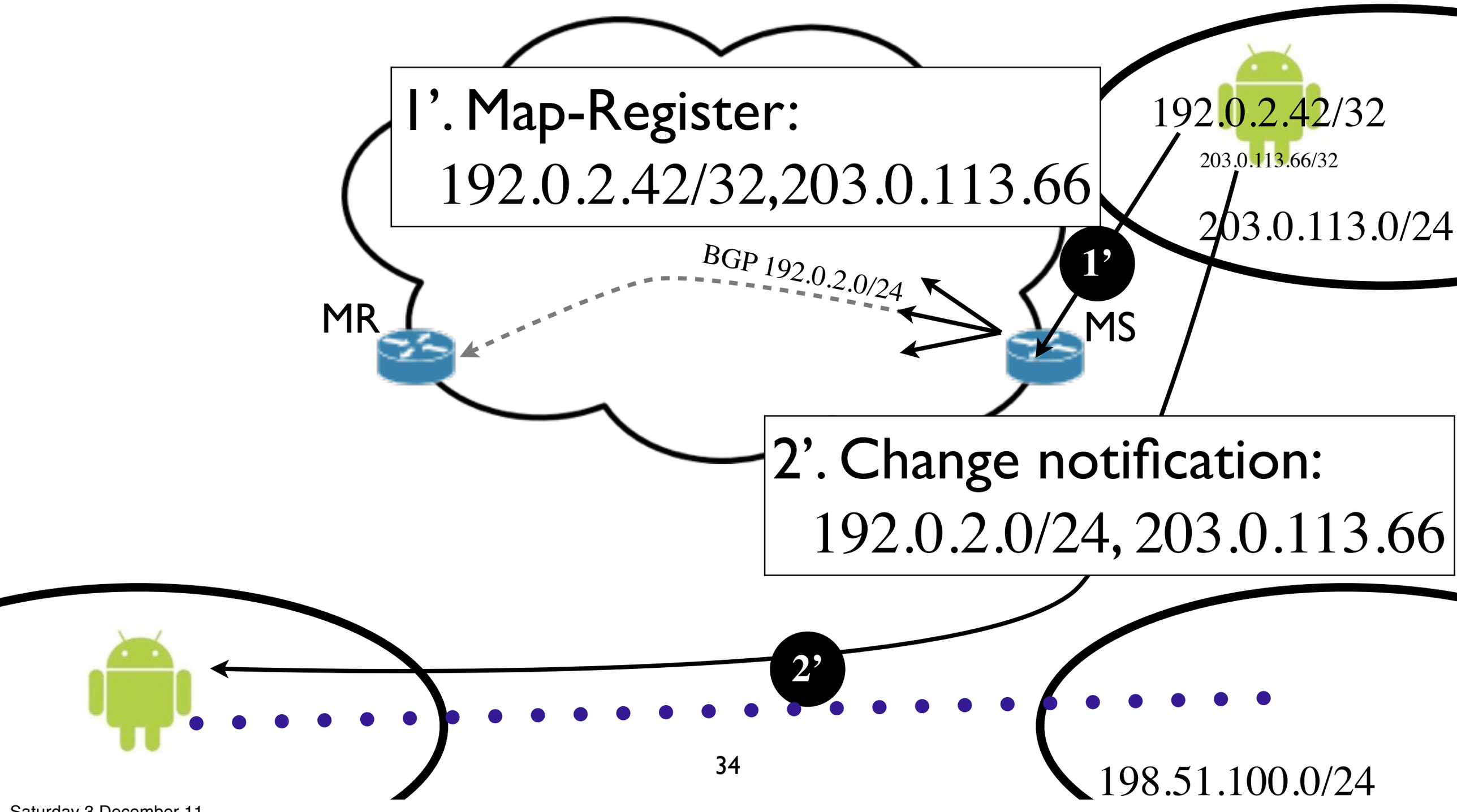
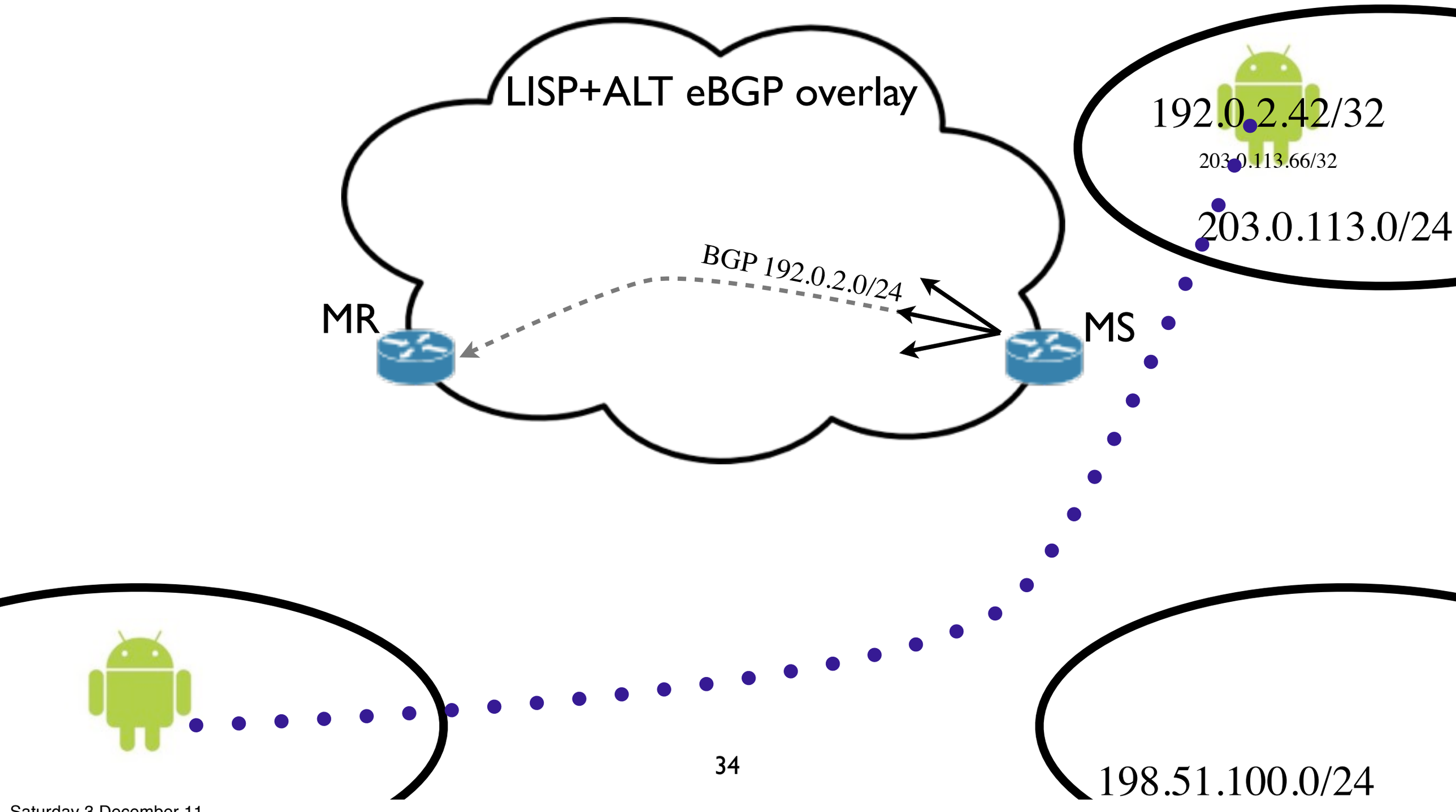


LISP Mobile Nodes



LISP Mobile Nodes



Open Questions

Network Resiliency

- Today, preserving the prefixes reachability is mainly performed locally
- In LISP, the legacy Internet is EID agnostic
  - Recovery only once ITR discover ETR failure
    - ITR periodically probes RLOCs
- Important part of LISP WG' new charter

Network Security

- Who control the mappings control the traffic
  - Denial of service
  - Eavesdropping
  - ...
- Firewalls? DPI?
- Important part of LISP WG' new charter

Conclusion

Summary

- LISP uses map-and-encap to separate IP's ID and locator roles
  - Improve network multi-homing
  - Transparent for the end-users
  - Incrementally deployable
  - Mobility support
- **See you @ 5:55 pm for a configuration hands on (possible to play with live routers)**

Bibliography

- draft-ietf-lisp
- draft-ietf-lisp-alt
- draft-fuller-ddt
- draft-ietf-lisp-ms
- draft-ietf-lisp-map-versioning
- draft-ietf-lisp-mn
- draft-ietf-lisp-lig
- draft-ietf-lisp-threats
- draft-ietf-lisp-sec
- draft-farinacci-lisp-lcaf
- Jackab et al., *LISP-TREE: A DNS Hierarchy to Support the LISP Mapping System*
- Iannone and Bonaventure, *On the cost of caching locacor/ID mappings*
- Kim et al, *A Deep Dive into the LISP Cache and What ISPs Should Know about It*
- Ohmori et al, *Analyses on First Packet Drops of LISP in End-to-End Bidirectional Communications*
- www.lisp4.net

```
?? || /**/
```

Backup

LISP Philosophy 2/2

- Follows the **Map-and-Encap** principle
  - a **mapping system** maps EID prefixes onto site router's RLOCs
  - ITR routers **encapsulate** the packets received from end systems before sending them toward the destination RLOC
  - ETR routers **decapsulate** the packets received from the Internet before sending them towards the destination end system

LISP is over UDP

- UDP to traverse firewalls/NAT, limit the impact of ECMP hashing on reordering...
- Source port is random
  - but per-flow source port is recommended
- Destination port is fixed to 4341
- Checksum is important if IPv6 RLOCs

Locator Status Bits

- A vector of 32 bits (L bit set to 1 if LSB is present)
- Each **source** locator is mapped to one position in the vector

```
if locator_status_bit[i] = 1
    RLOC i is reachable
else
    RLOC i is not reachable
```

- Each RLOC has an implicit position in the LSB
- How to set the bit? What is her meaning?

Mapping Systems

NERD: A Not-so-novel EID to RLOC Database

NERD

- The only proposed push model
  - Composed of 4 parts
    - a network database format;
    - a change distribution format;
    - a database retrieval/bootstrapping method;
    - a change distribution method

- Principles
  - An authority computes the mapping database based on the stored registrations
  - The database signed by the authority is stored on servers
  - ITR poll regularly the database servers to update their own mapping database

LISP+ALT

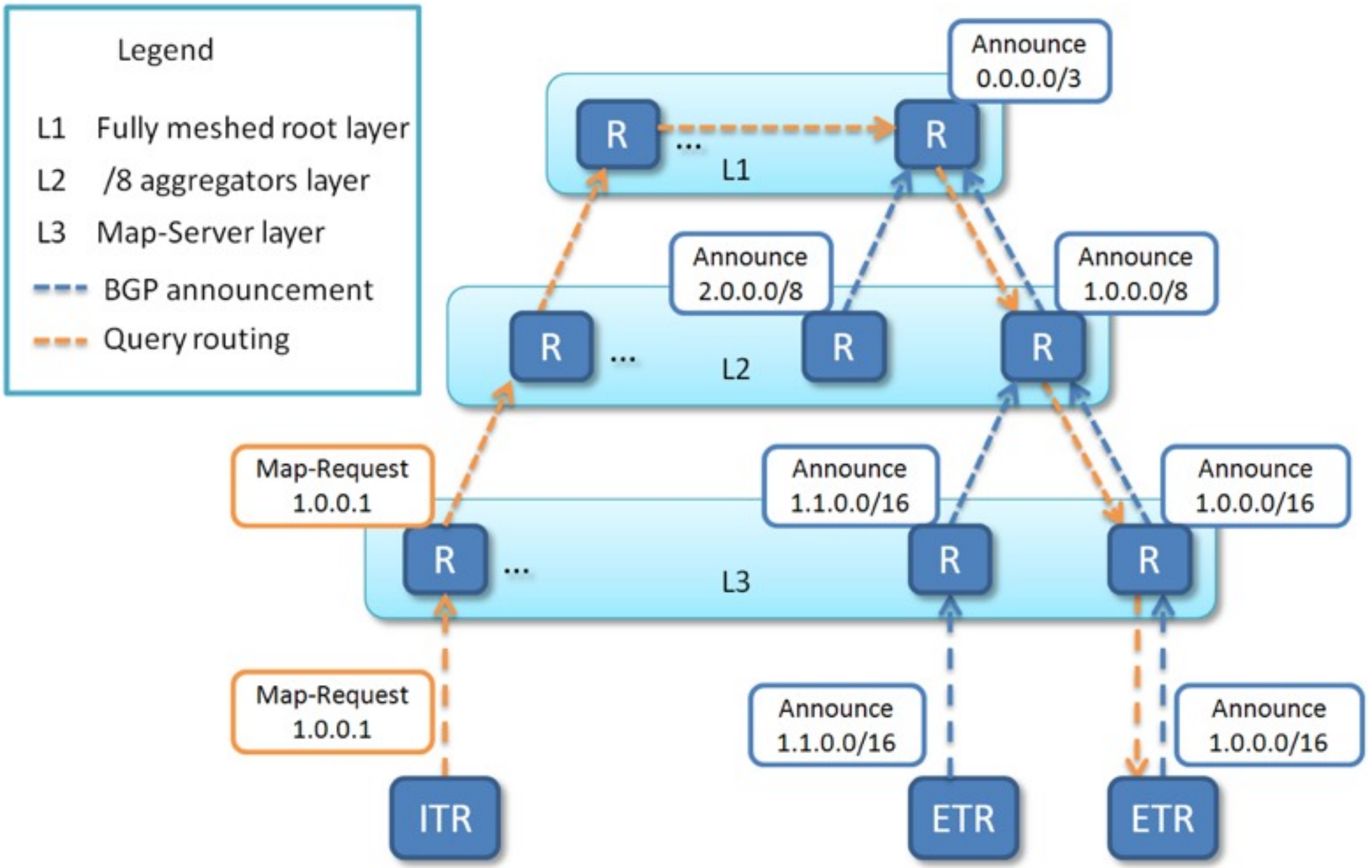
LISP+ALT

- An pull model mapping system
- A mapping mechanism that relies on an alternate topology to distribute mapping requests to mapping servers
  - LISP ITR routers sending mapping request messages to ALT routers
  - ALT routers forward those mapping messages between themselves on an overlay topology built by using GRE tunnels

LISP+ALT

- BGP announces **where** the mappings can be found
- Map-Requests are forwarded on the ALT
- Map-Replies are forwarded on the legacy Internet (directly sent to the ITRs' RLOC)
- ! BGP does not give the mappings !

LISP+ALT


Legend
L1 Fully meshed root layer
L2 /8 aggregators layer
L3 Map-Server layer
BGP announcement
Query routing
Announce 0.0.0.0/3
R
...
L1
R
Announce 2.0.0.0/8
Announce 1.0.0.0/8
R
...
L2
R
R
Map-Request 1.0.0.1
Announce 1.1.0.0/16
Announce 1.0.0.0/16
R
...
L3
R
R
Map-Request 1.0.0.1
Announce 1.1.0.0/16
Announce 1.0.0.0/16
ITR
ETR
ETR

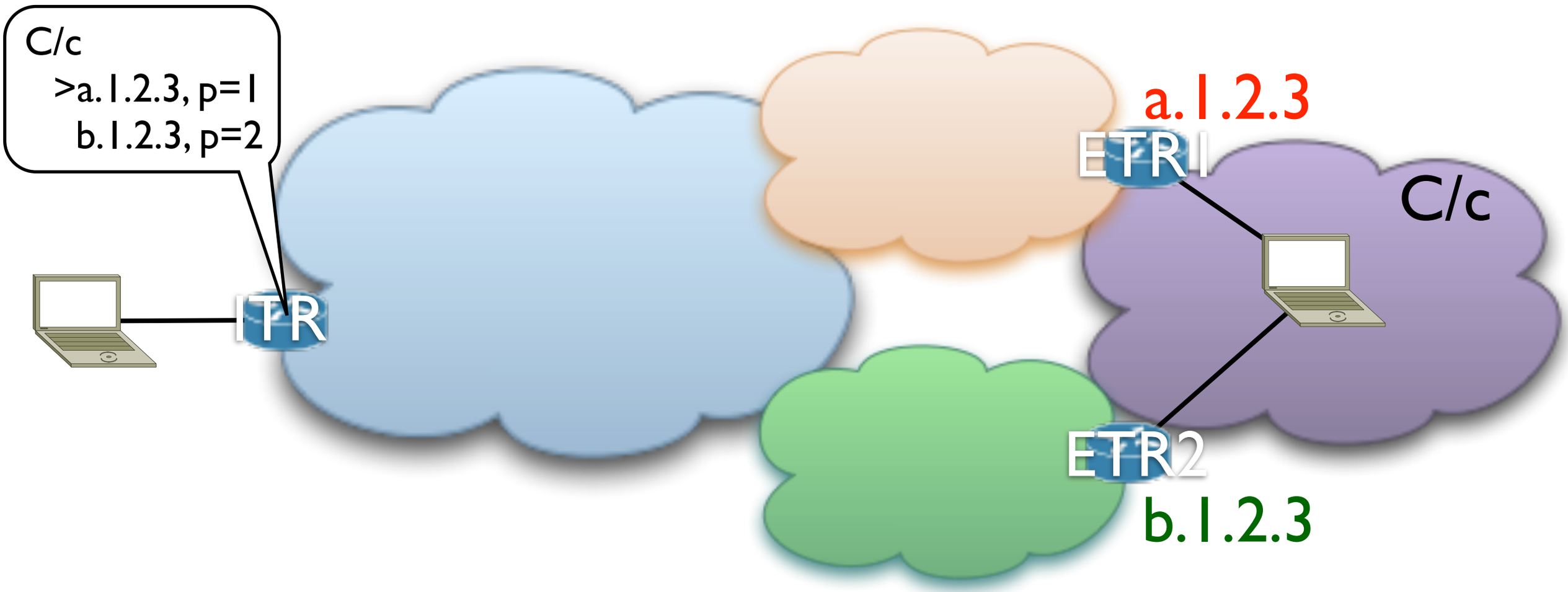
LISP+ALT issues

- Complex system with tunnels, BGP protocol (no discussion about policies), ...
- Still relies on lots of error-prone manual configuration
- Scalability will depend on whether aggregation will be possible
- If mapping requests are lost due to congestion, difficult to diagnose the problem or send them via another path
- Security needs to be studied

LISP+ALT, big question

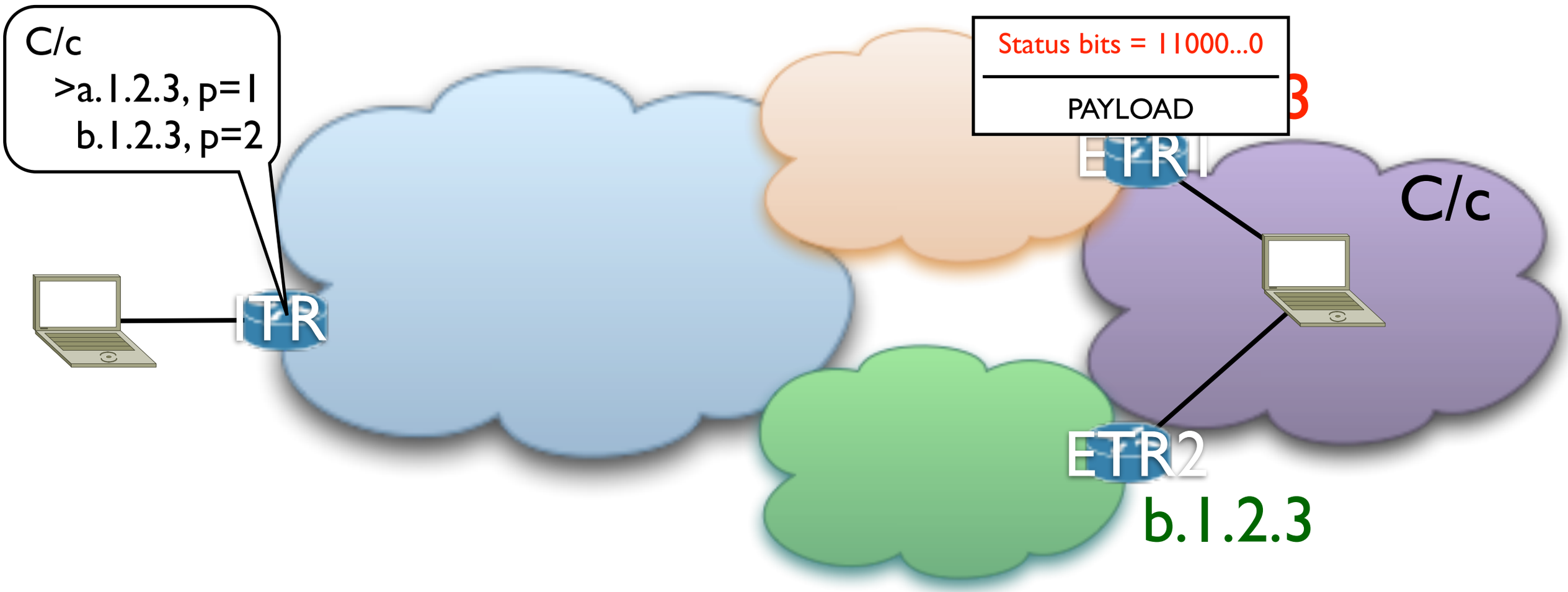
- How to deploy it?
- aggregation vs recovery vs TE
- how to cache the mappings?

Solving the reachability problem with the locator status bits



- ETR2 notices the failure and informs all ITRs to which it is sending LISP encapsulated packets by setting the reachability bit of ETR1 to 0

Solving the reachability problem with the locator status bits



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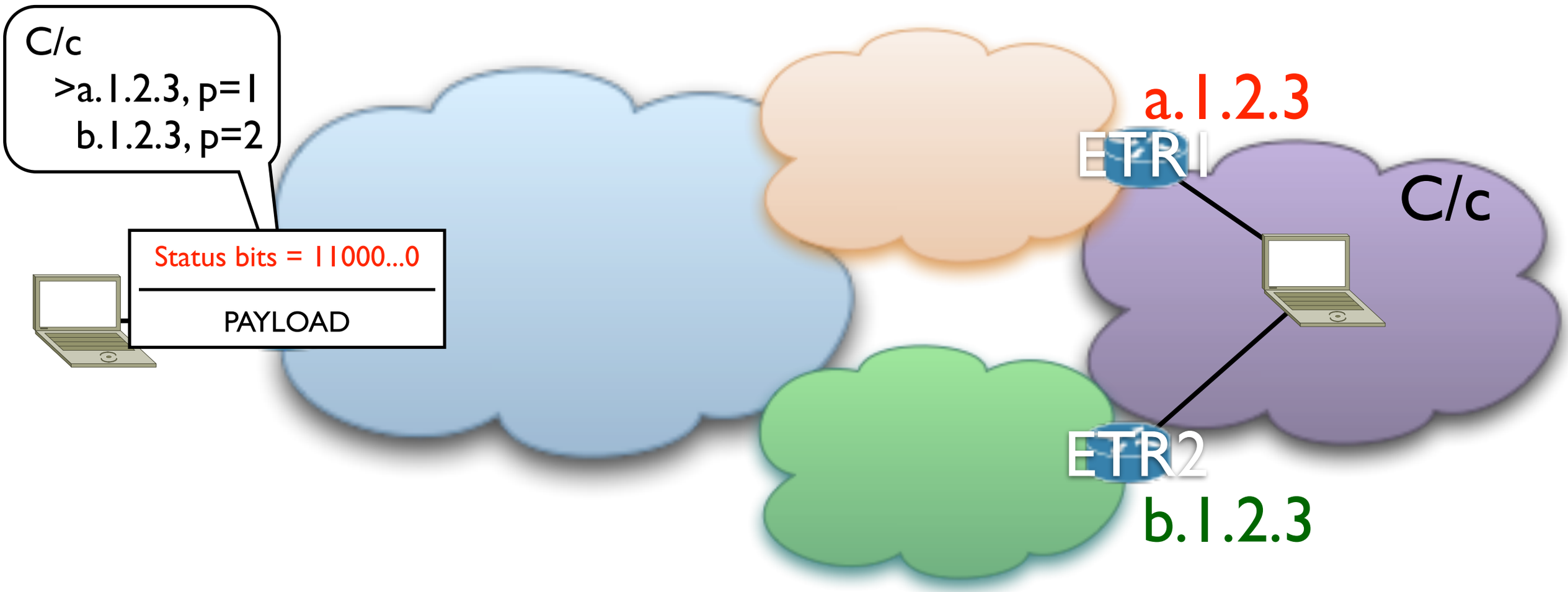

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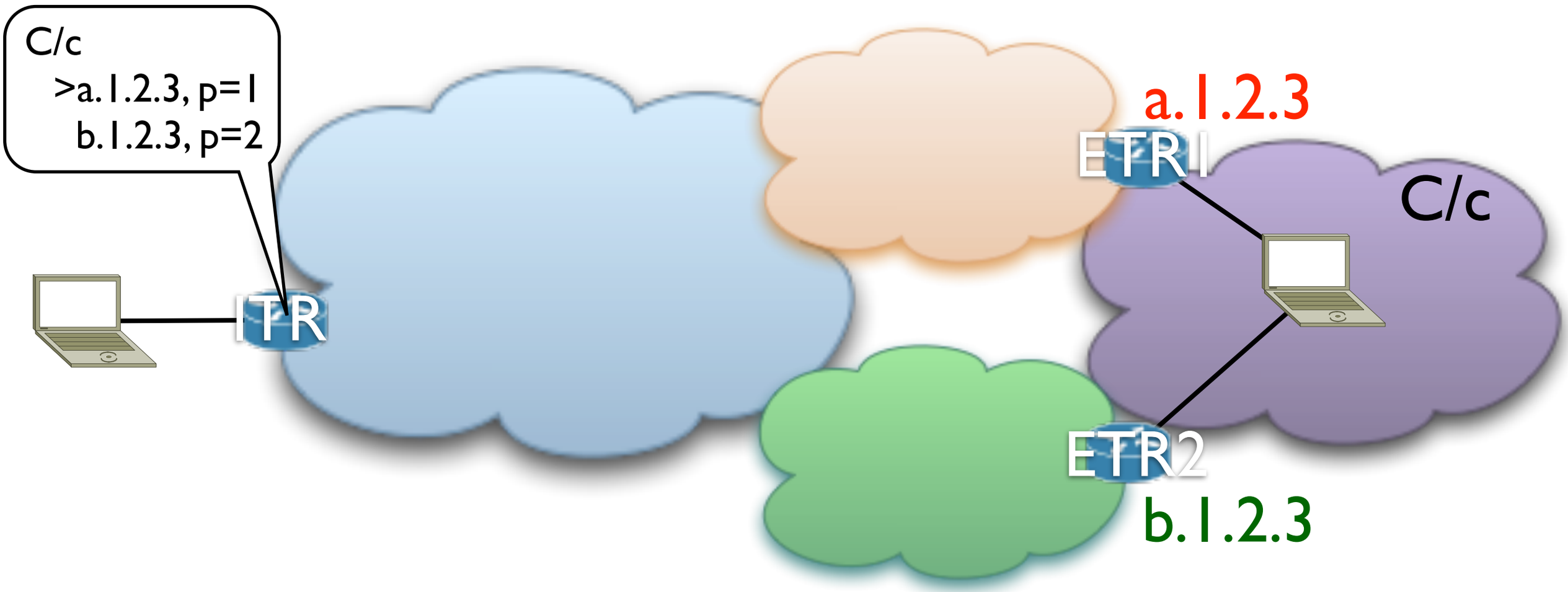

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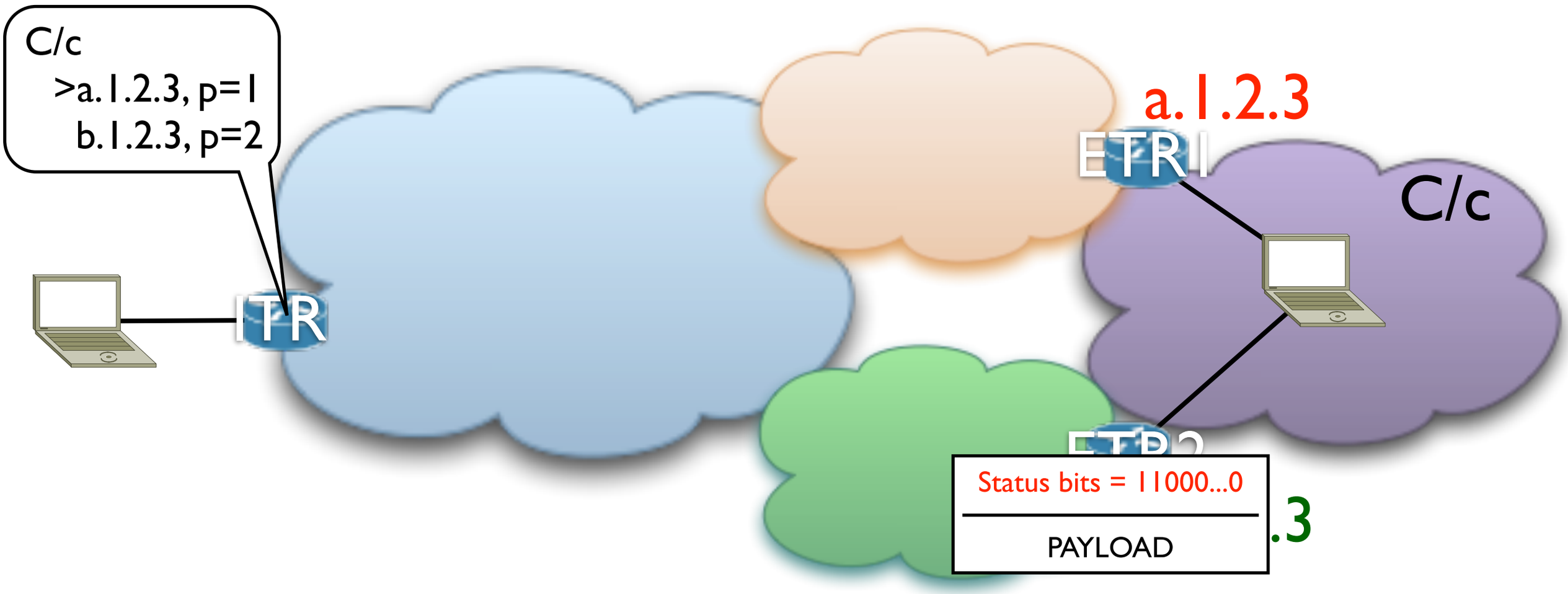

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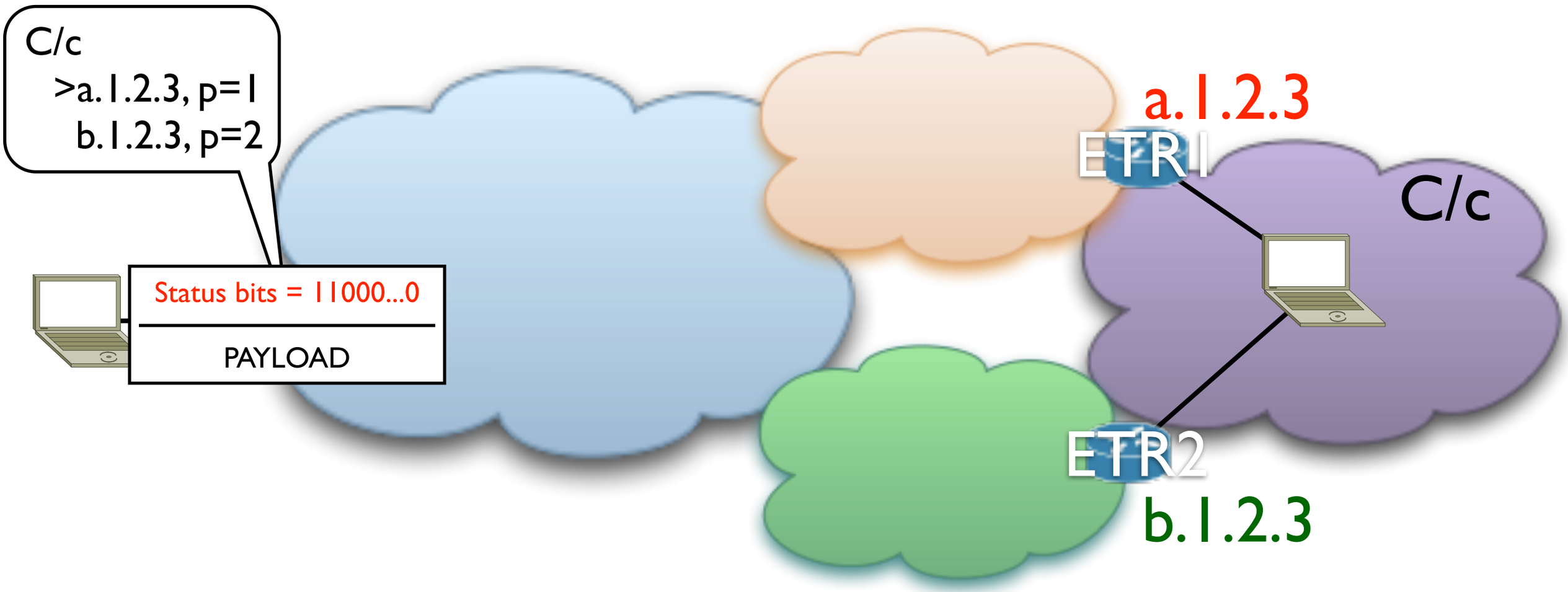

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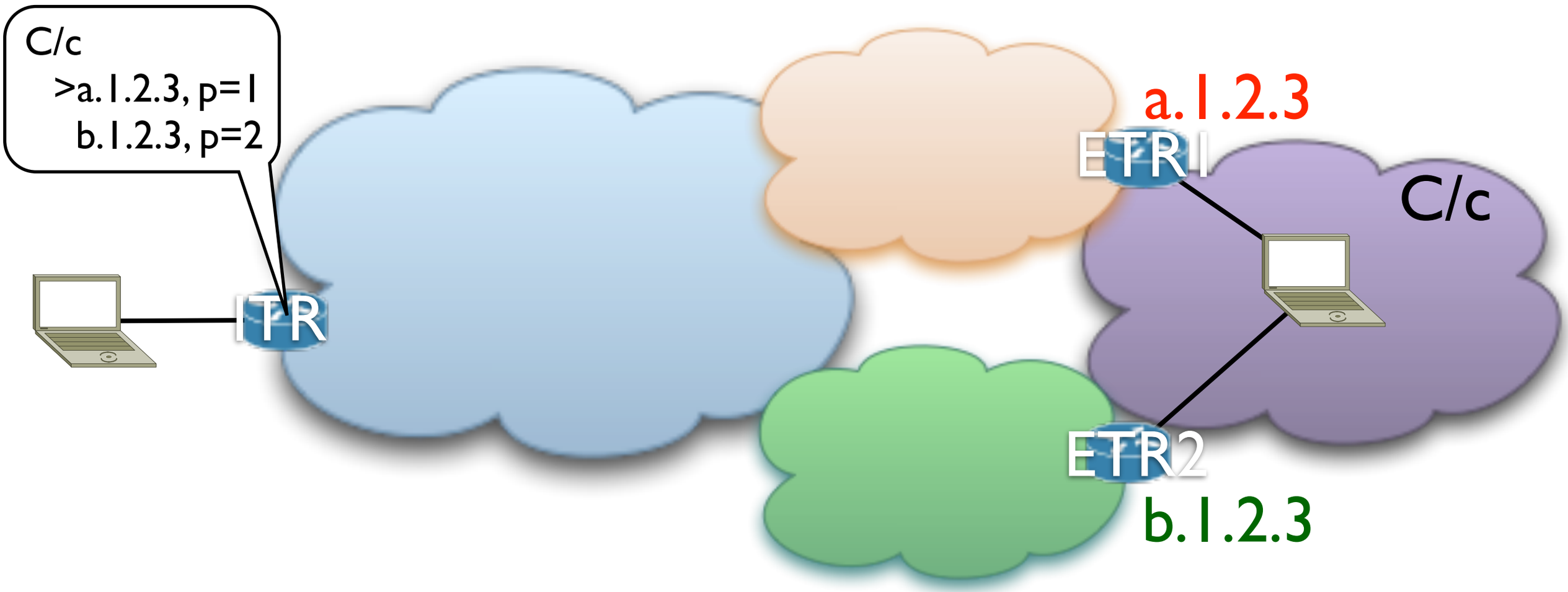

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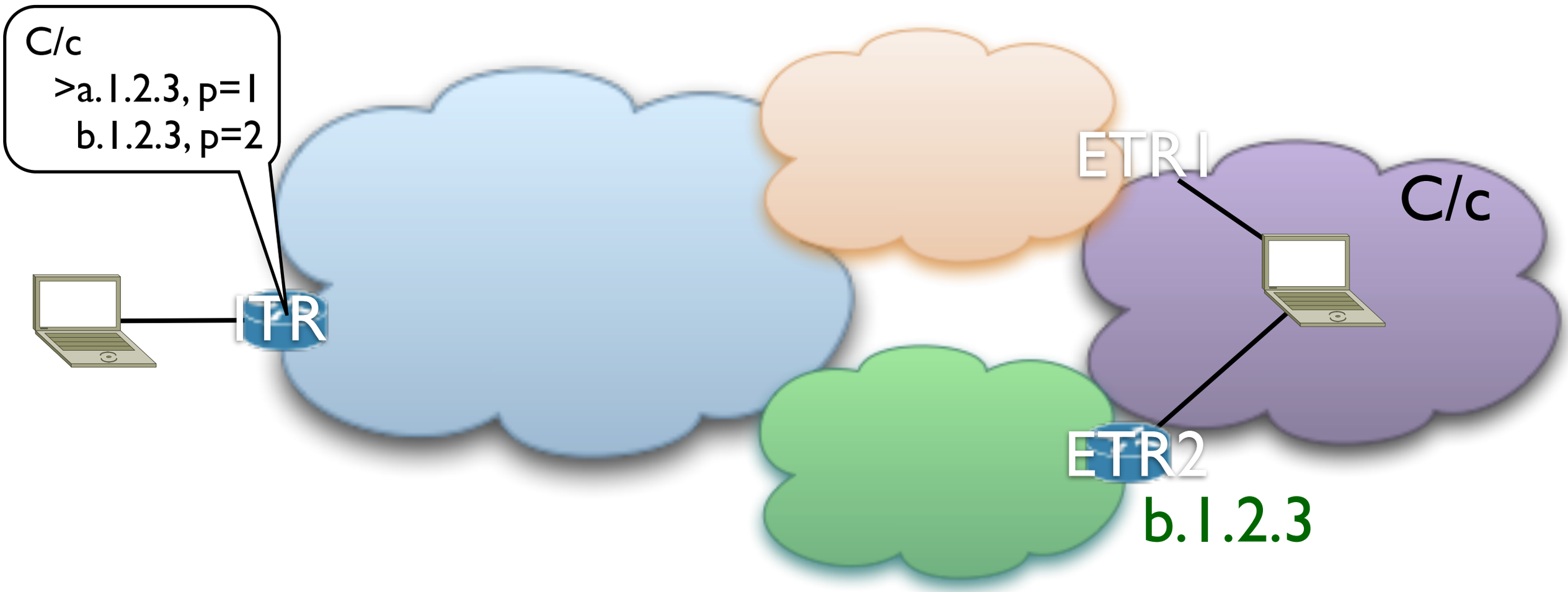

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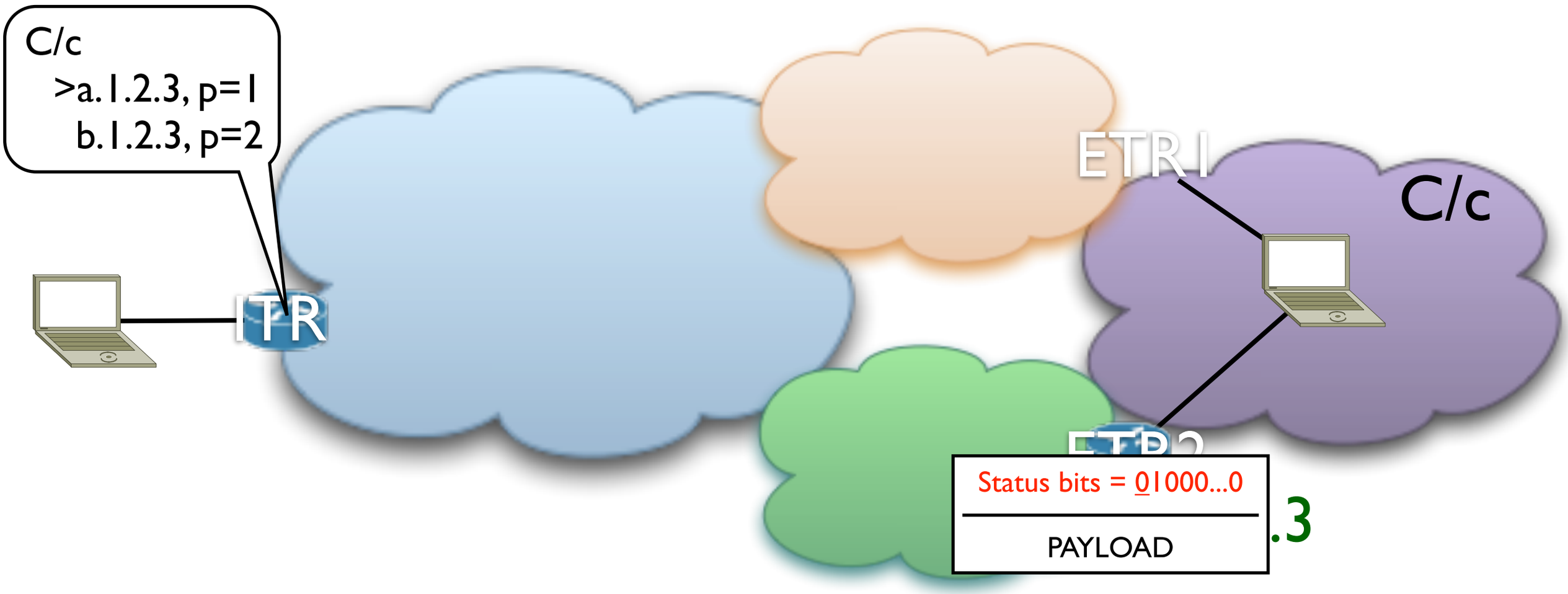

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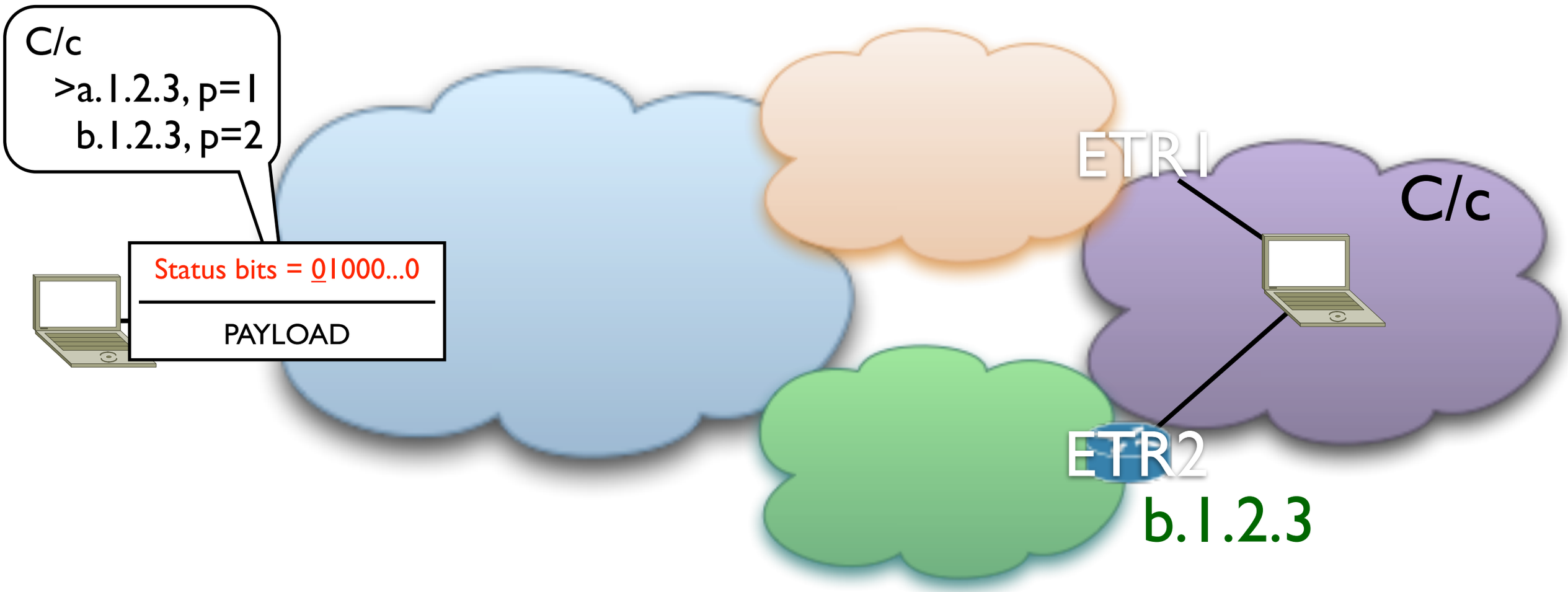

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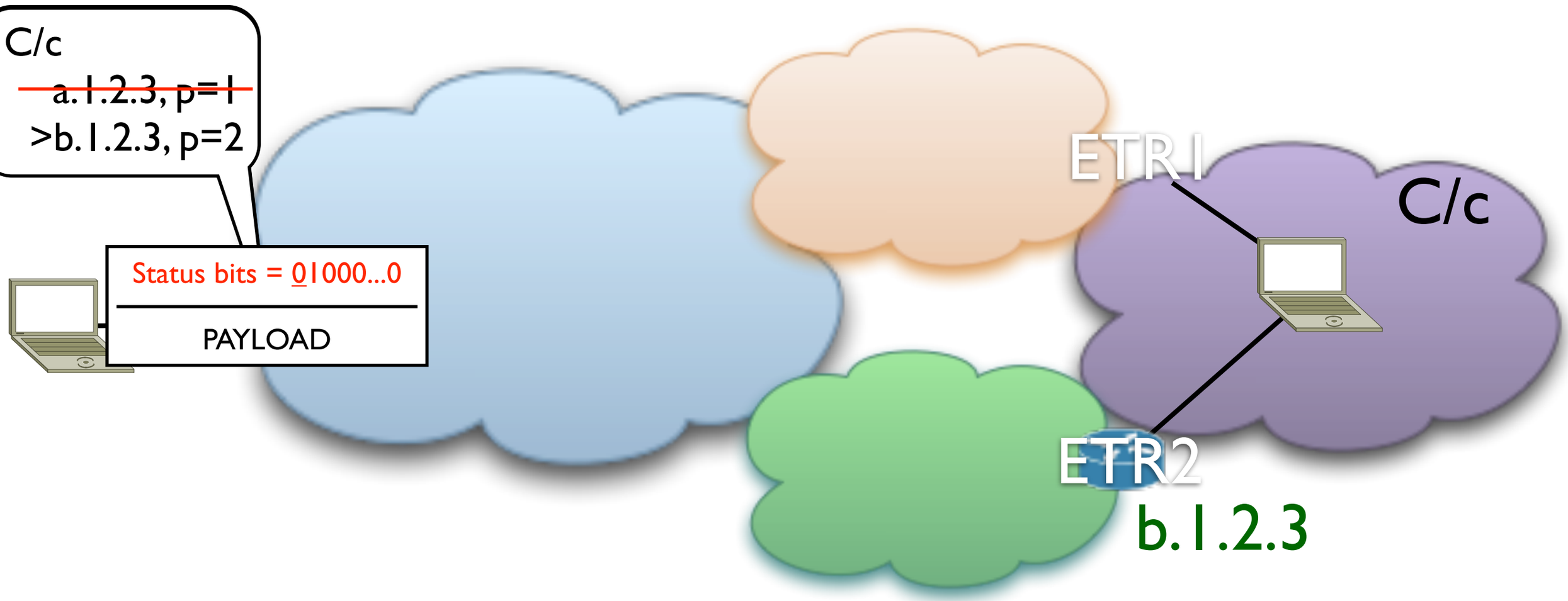

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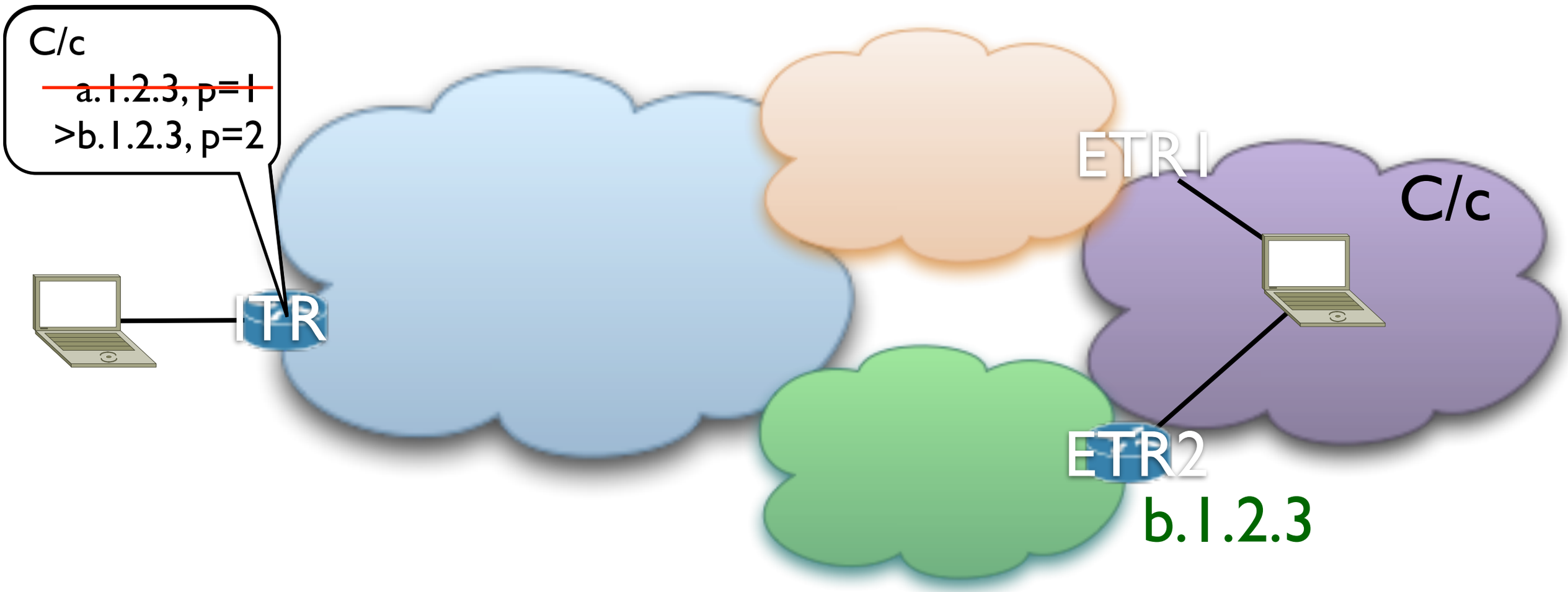

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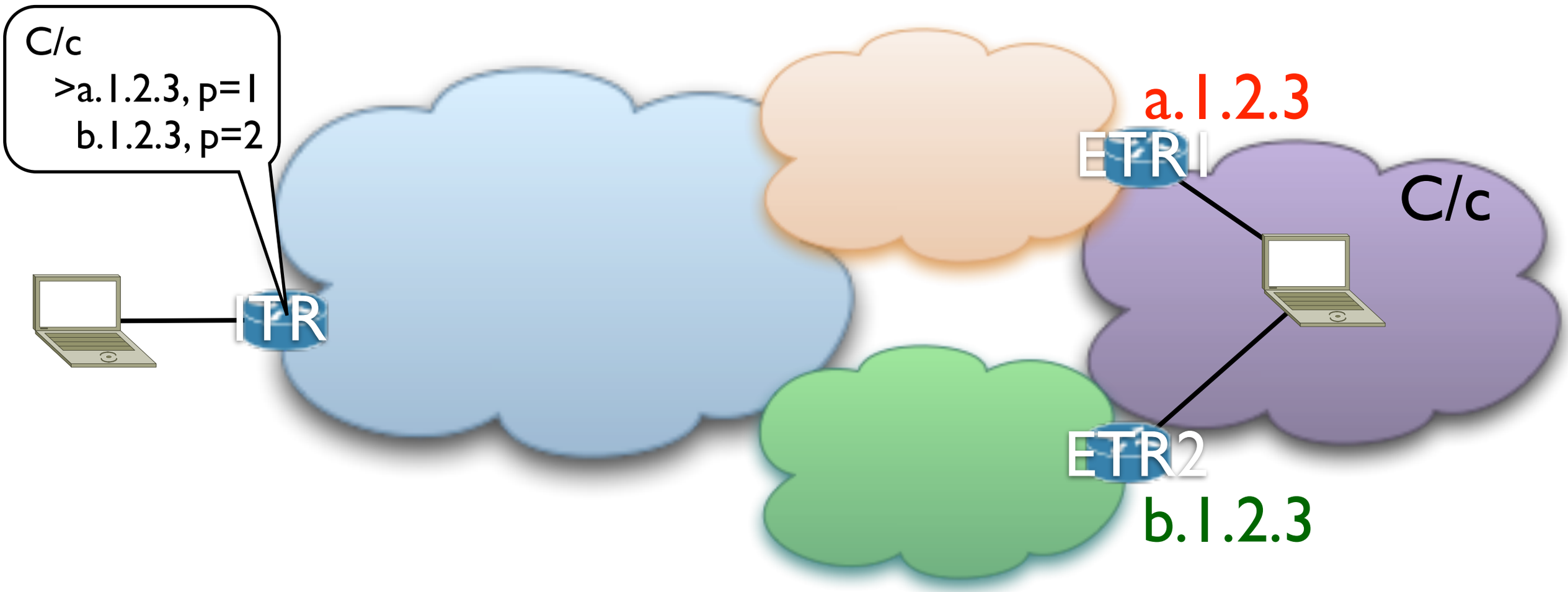
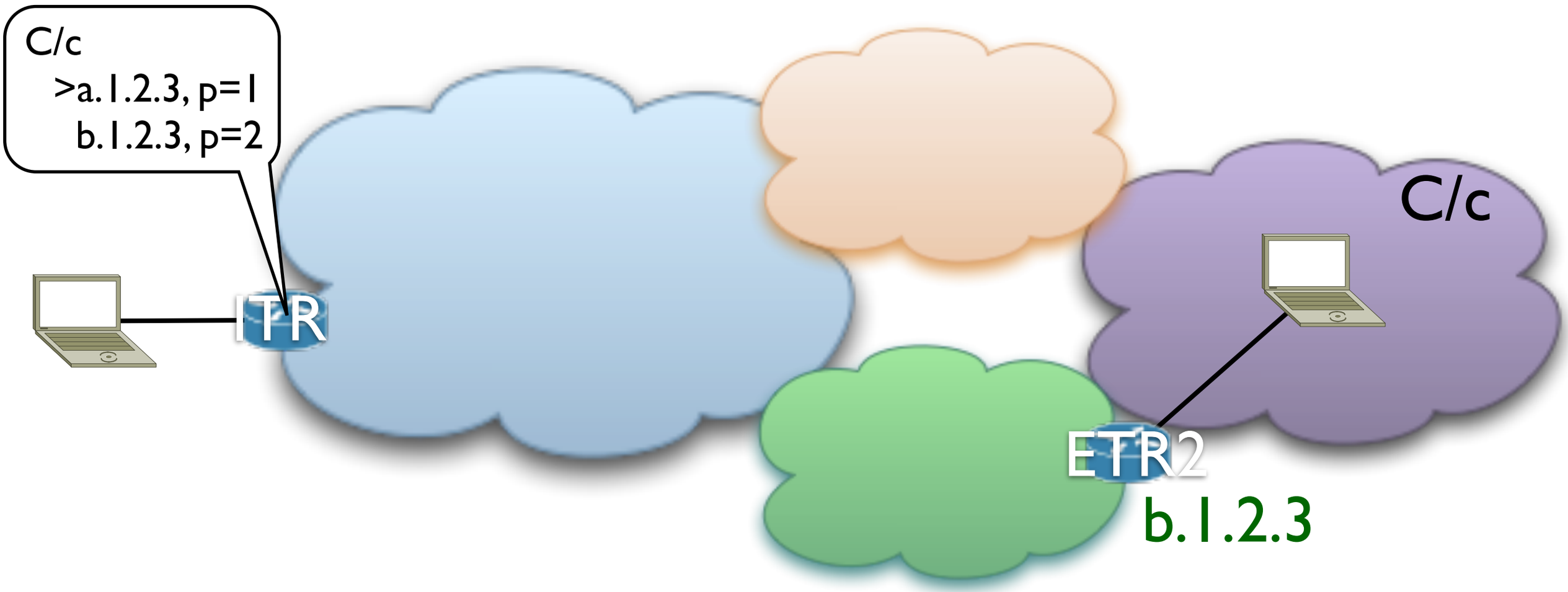
Solving the reachability problem with the SMR bit



- ETR1 has been decommissioned and ETR2 wants that all the sites currently sending encapsulated data to itself update the mapping

Solving the reachability problem with the SMR bit



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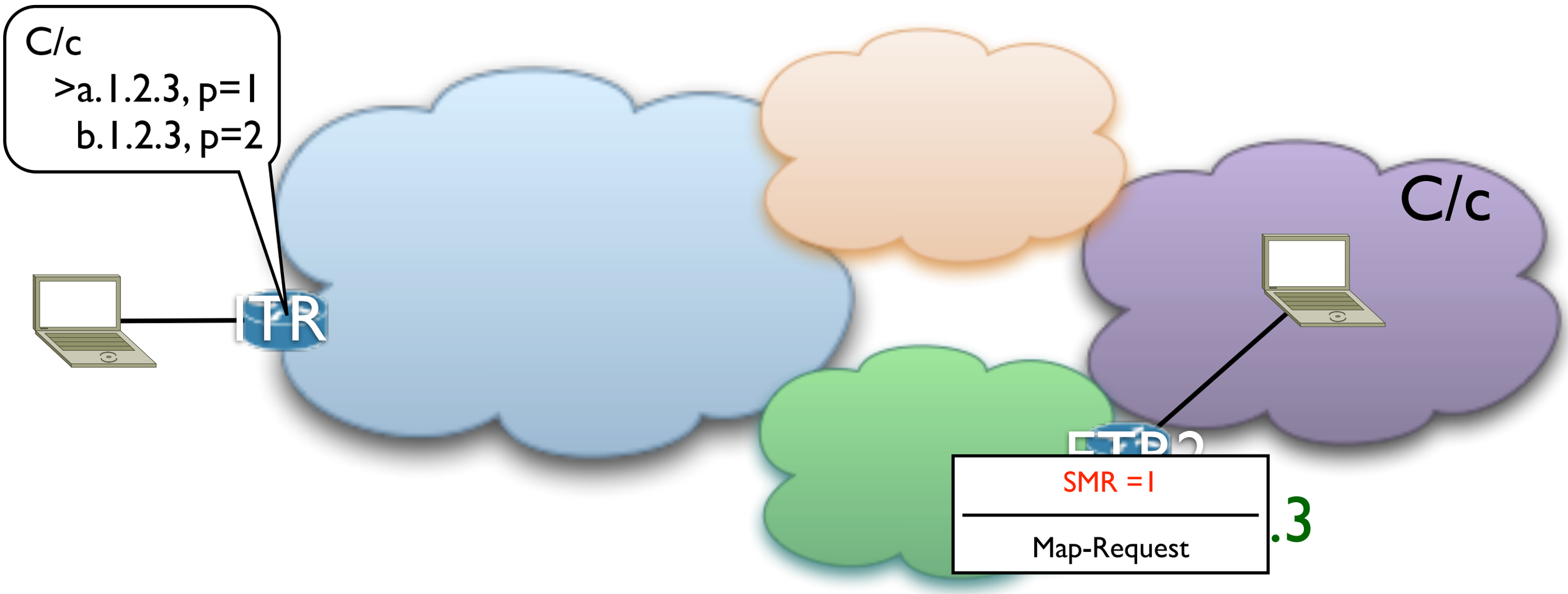

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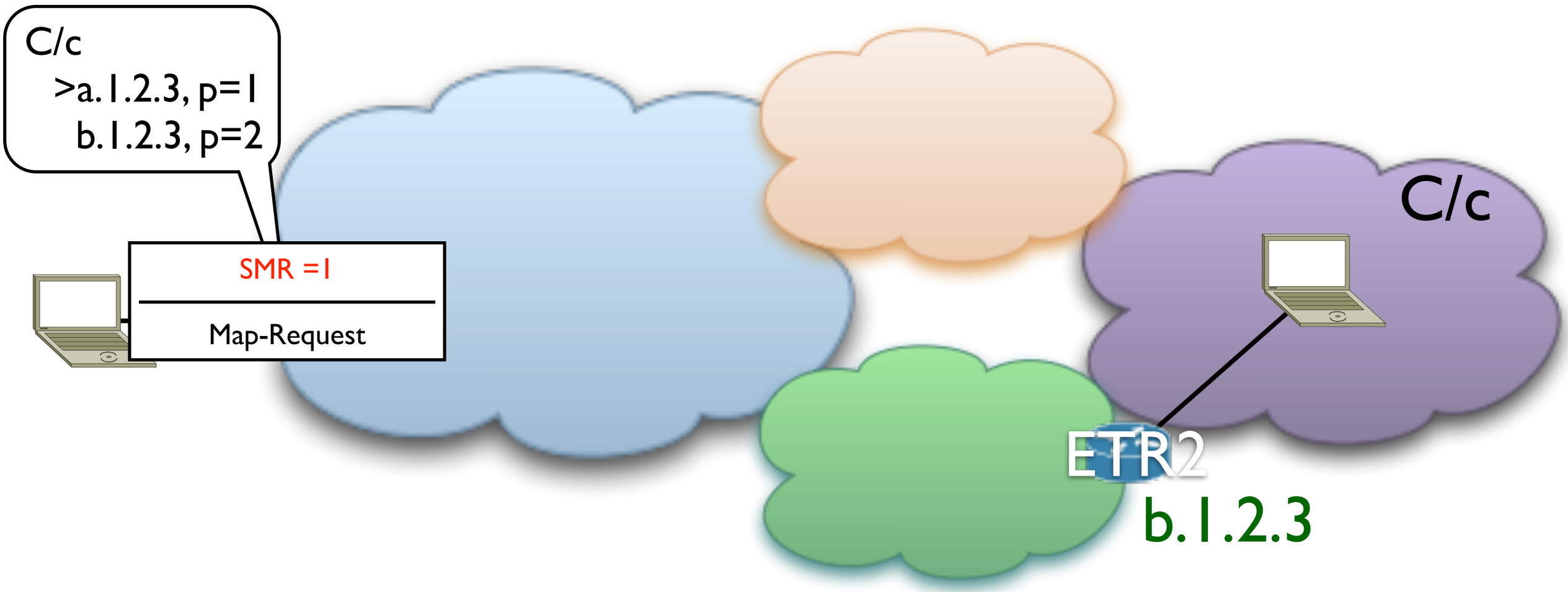

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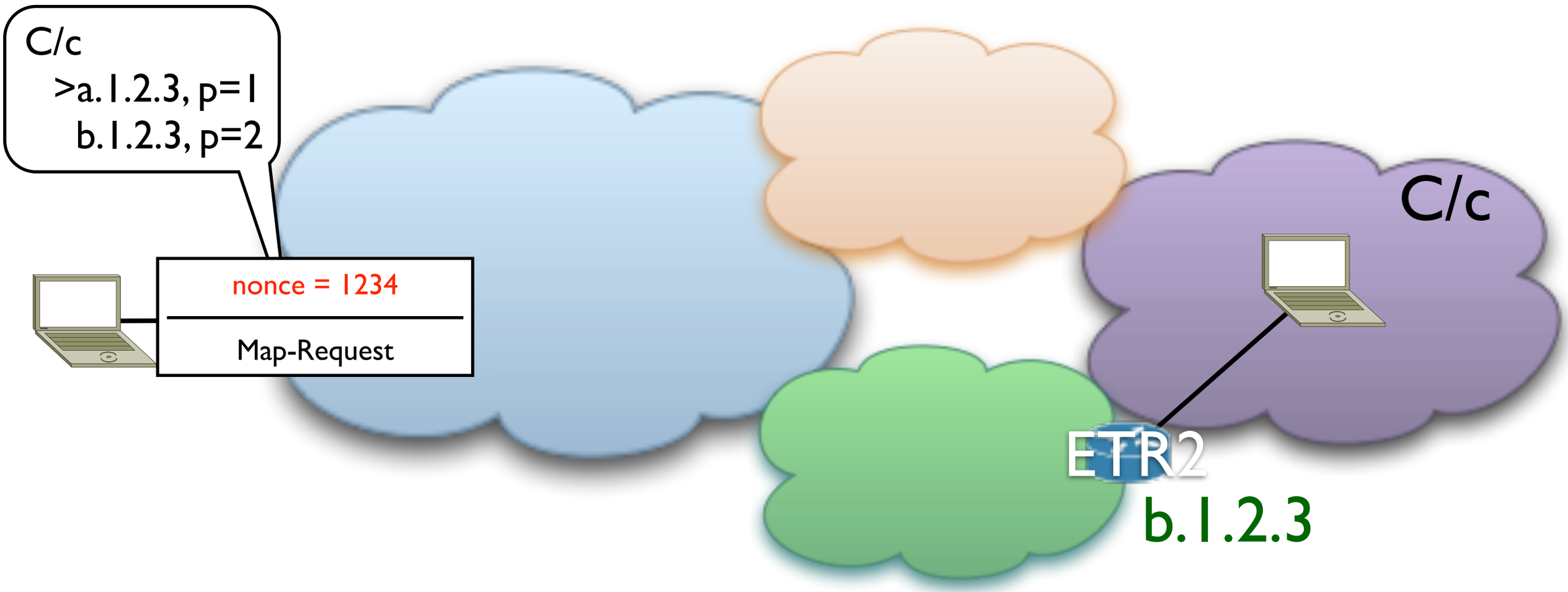

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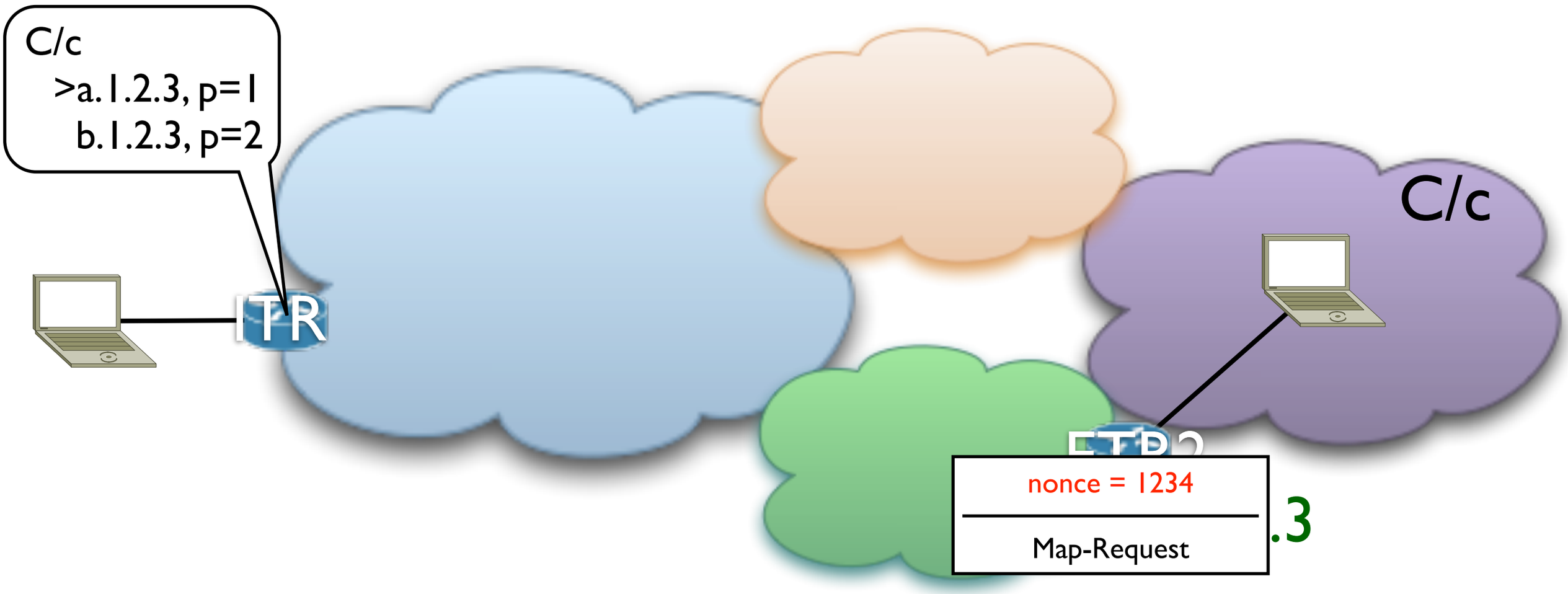

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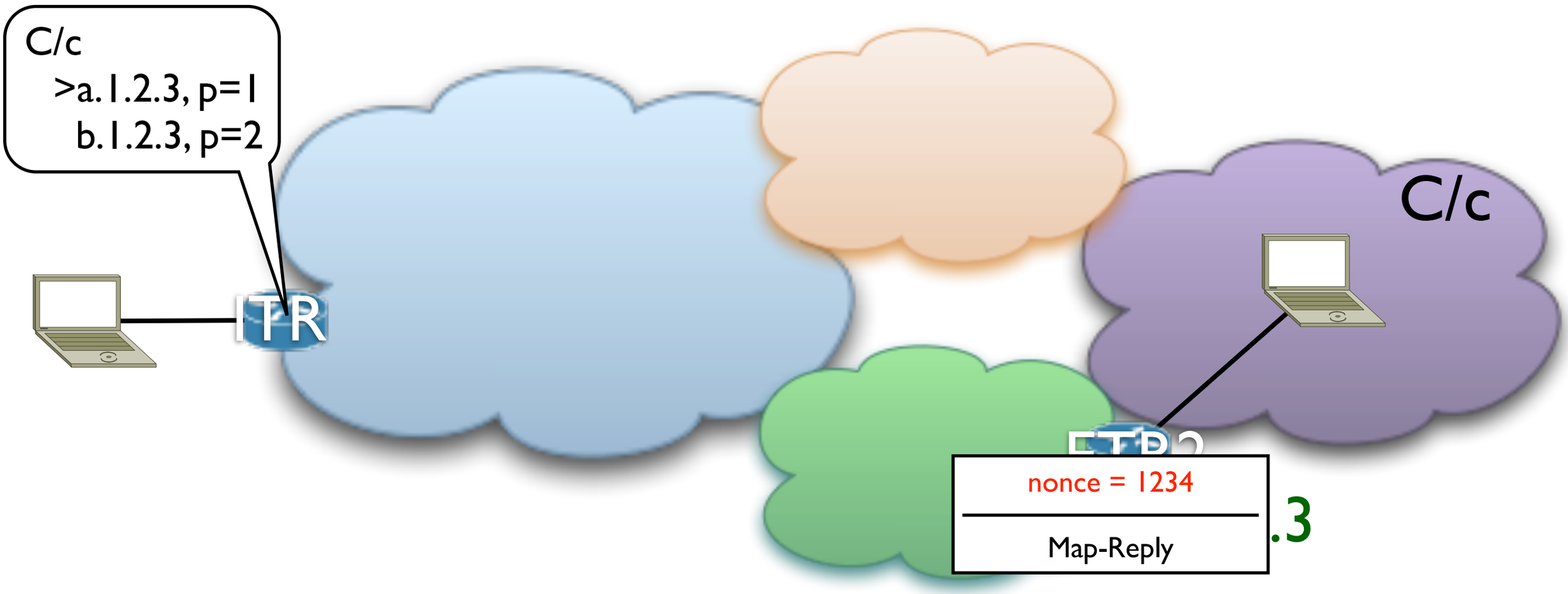

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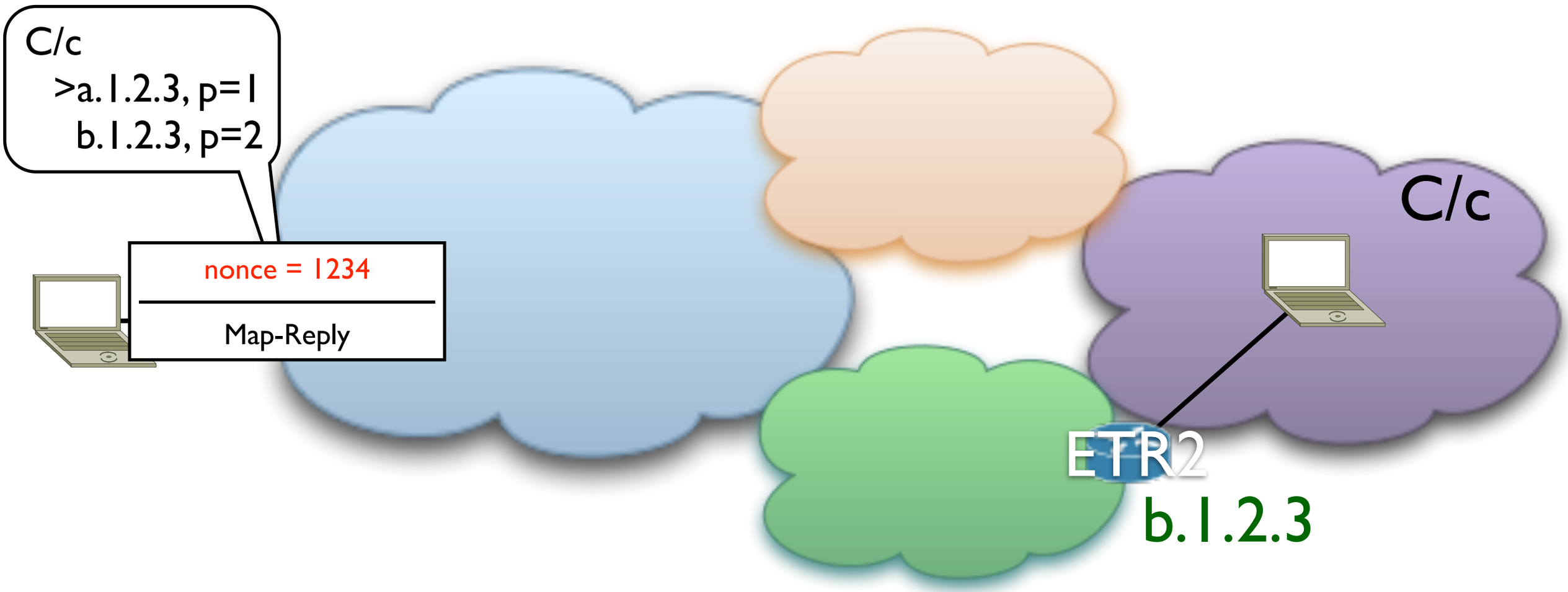

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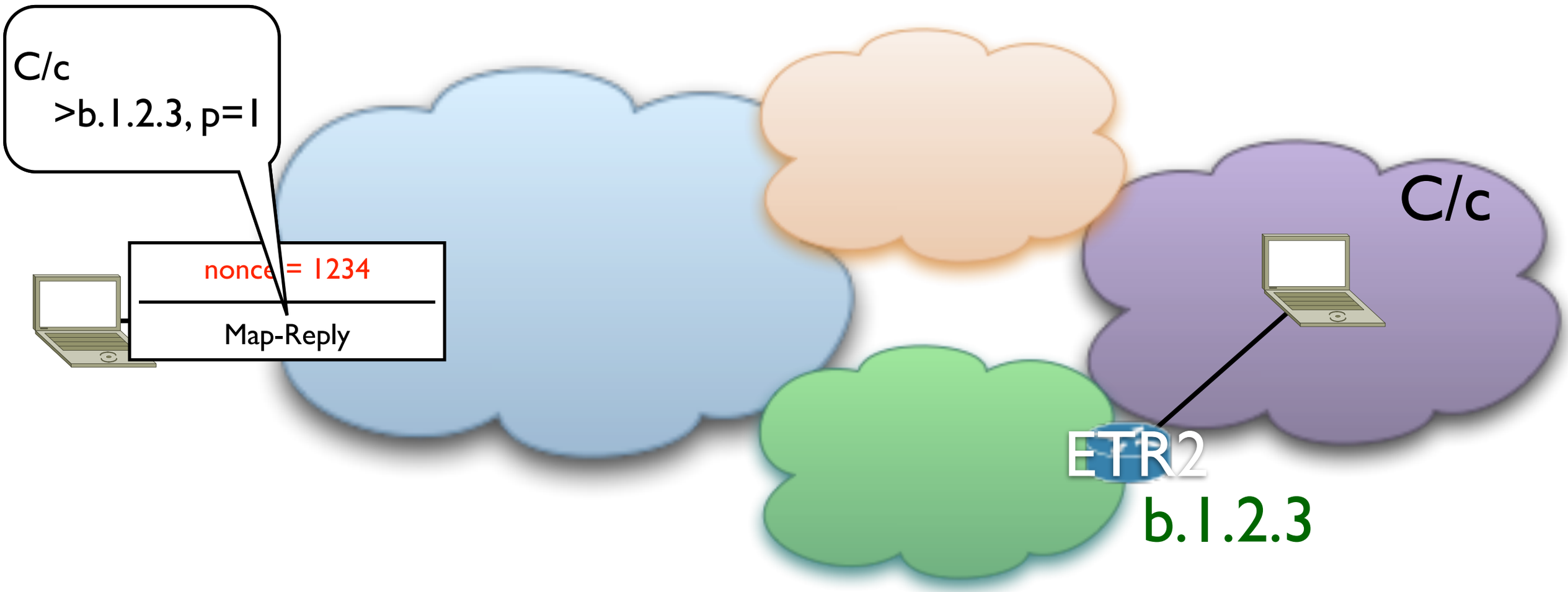

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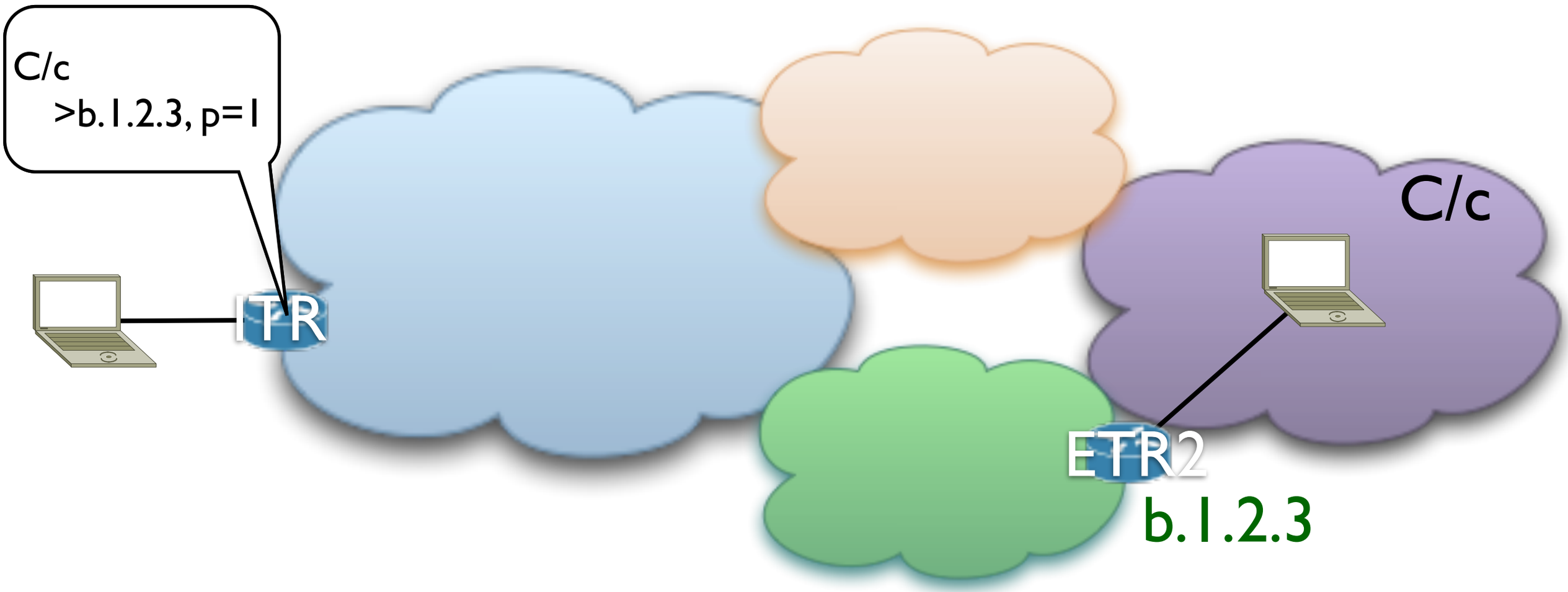

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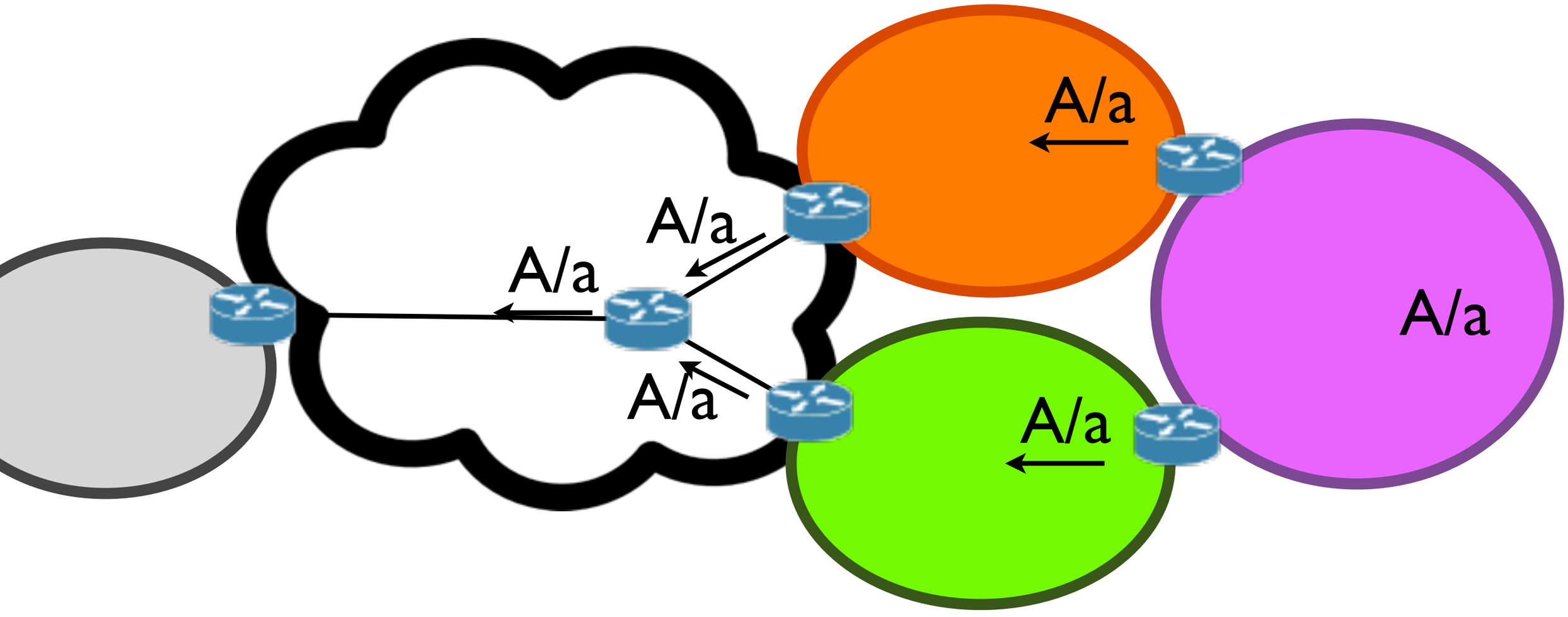
Solving the reachability problem with the Echo-Nonce Algorithm

- xTR *I* wants to know if the RLOC she uses to reach ETR *E* is reachable:
  - generate a nonce *n* when encap to *E*
  - set E=1
- Next time *E* sends a packet to *I*, she sets the nonce to *n*
- If *I* receives the nonce within a given time, she considers the RLOC reachable, otherwise *E* is considered unreachable

The reachability problem

- Today, preserving the prefixes reachability is mainly performed locally
- In LISP, the legacy Internet is EID agnostic
-

The reachability problem in today's Internet



- In today's Internet, routing protocols converge after a link failure to ensure that multihomed prefixes such as *A/a* remain reachable

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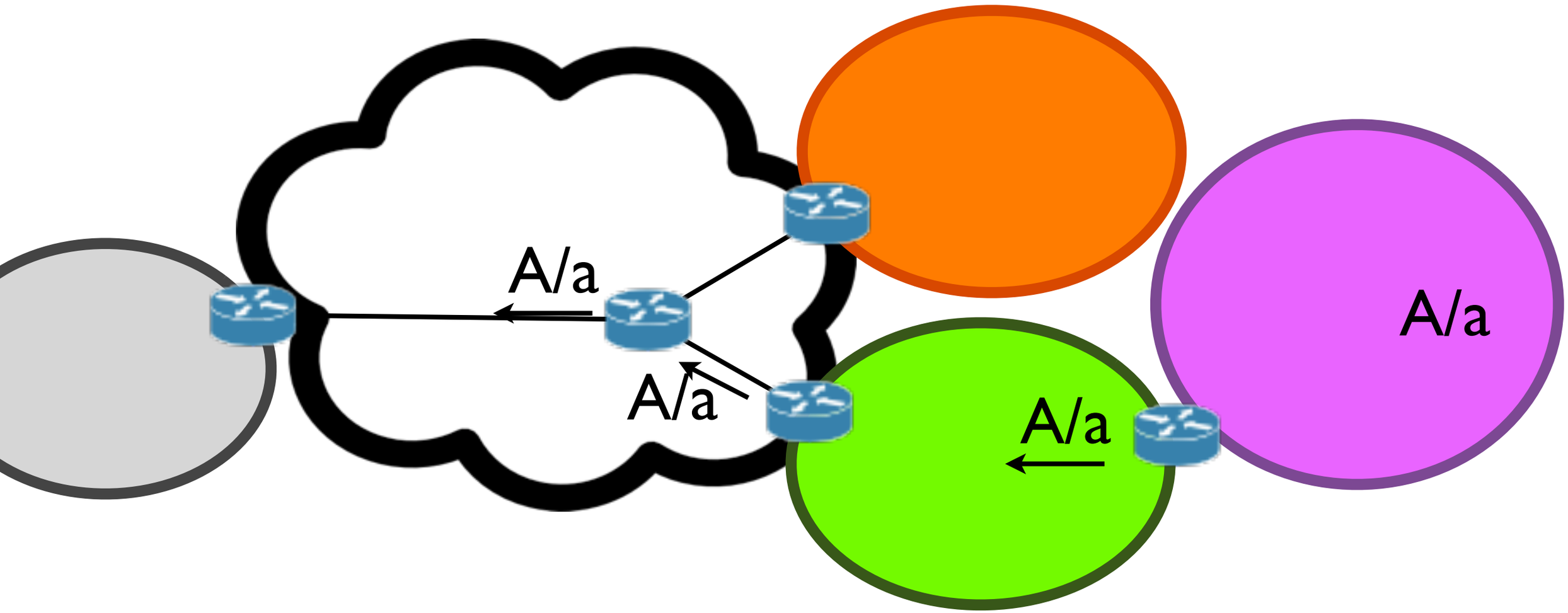

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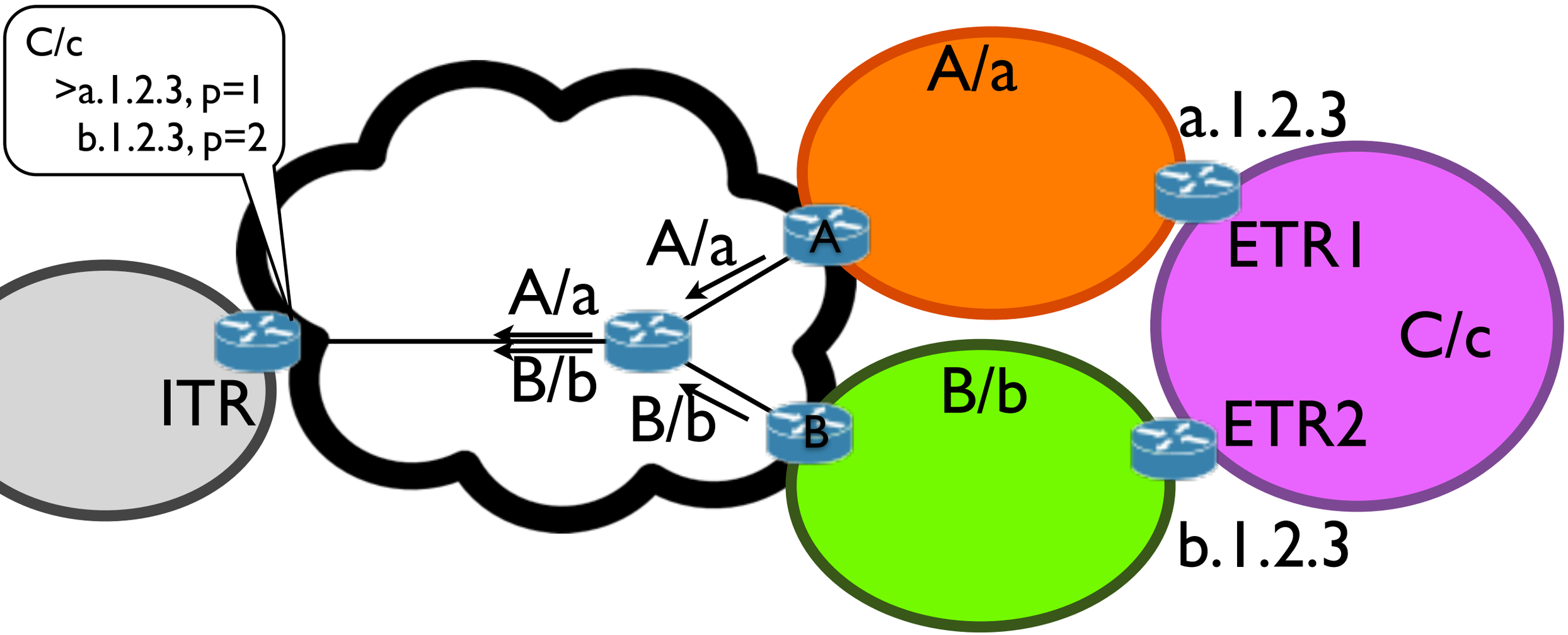
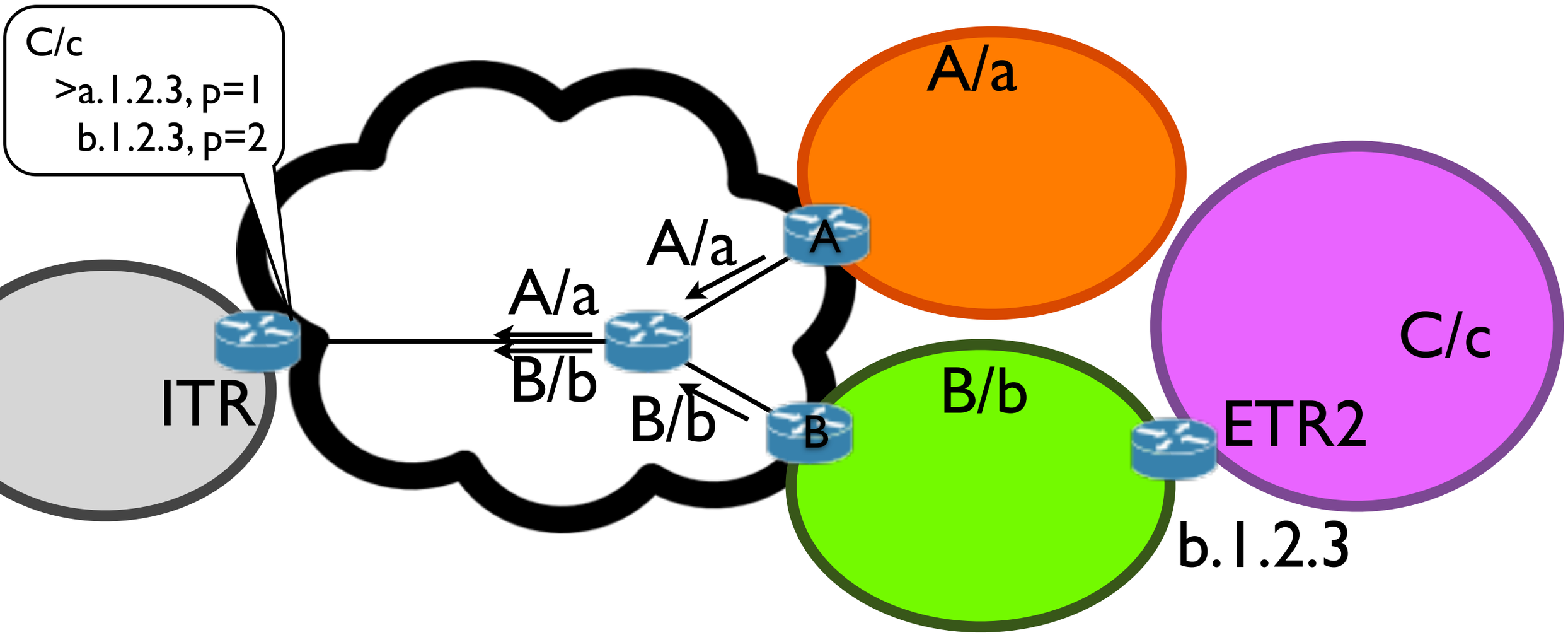
The reachability problem in a LISP-based Internet



- Upon failure of ETR1, A continues to advertise A/a via BGP
- How can ITR notice that ETR1 failed and that ETR2 should be used instead?

The reachability problem in a LISP-based Internet



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- How can ITR notice that ETR1 failed and that ETR2 should be used instead?

Solving the reachability problem with RLOC Probing

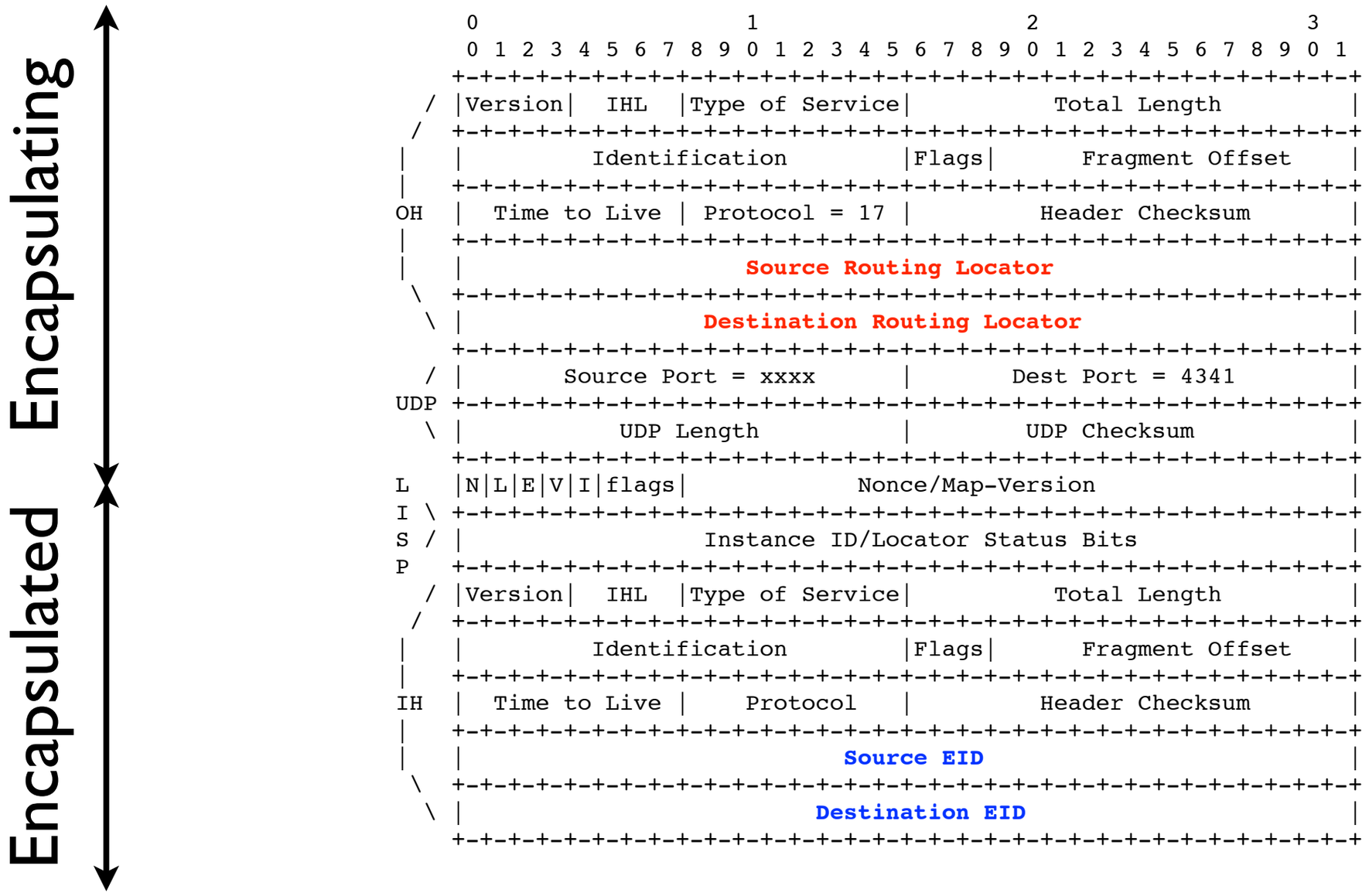
- Periodically probe the RLOCs to check their reachability

Host vs Network-based Loc/ID split

- Both can coexist
- At home, connected directly to the wall
  - Let my ISP do the stuff for me
- In the street, calling with Skype over WIFI&3G
  - Prefer WIFI to 3G when possible

Header details

(IP(UDP(LISP(IP))))



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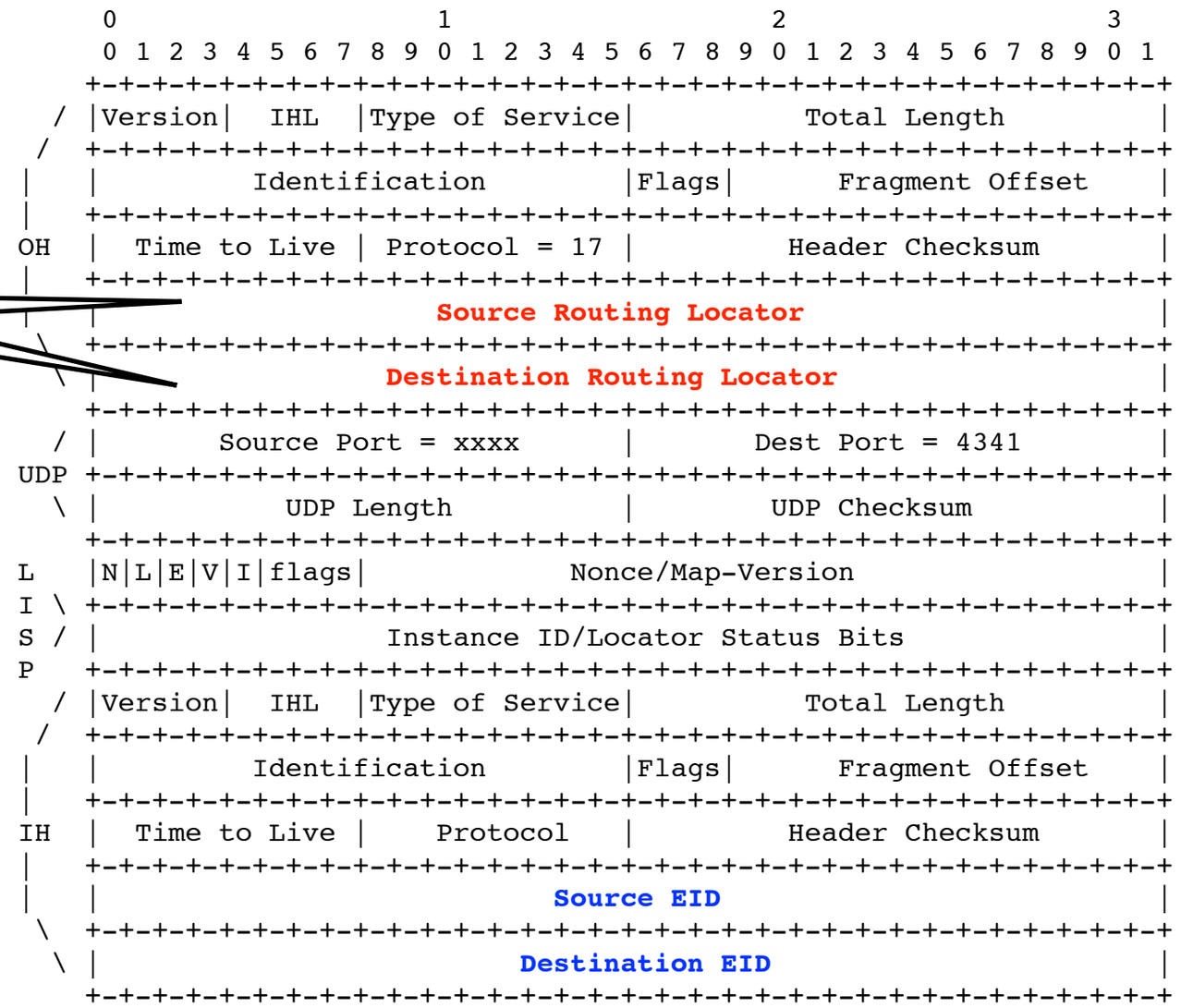
Encapsulating / Encapsulated

Source/Destination Locators



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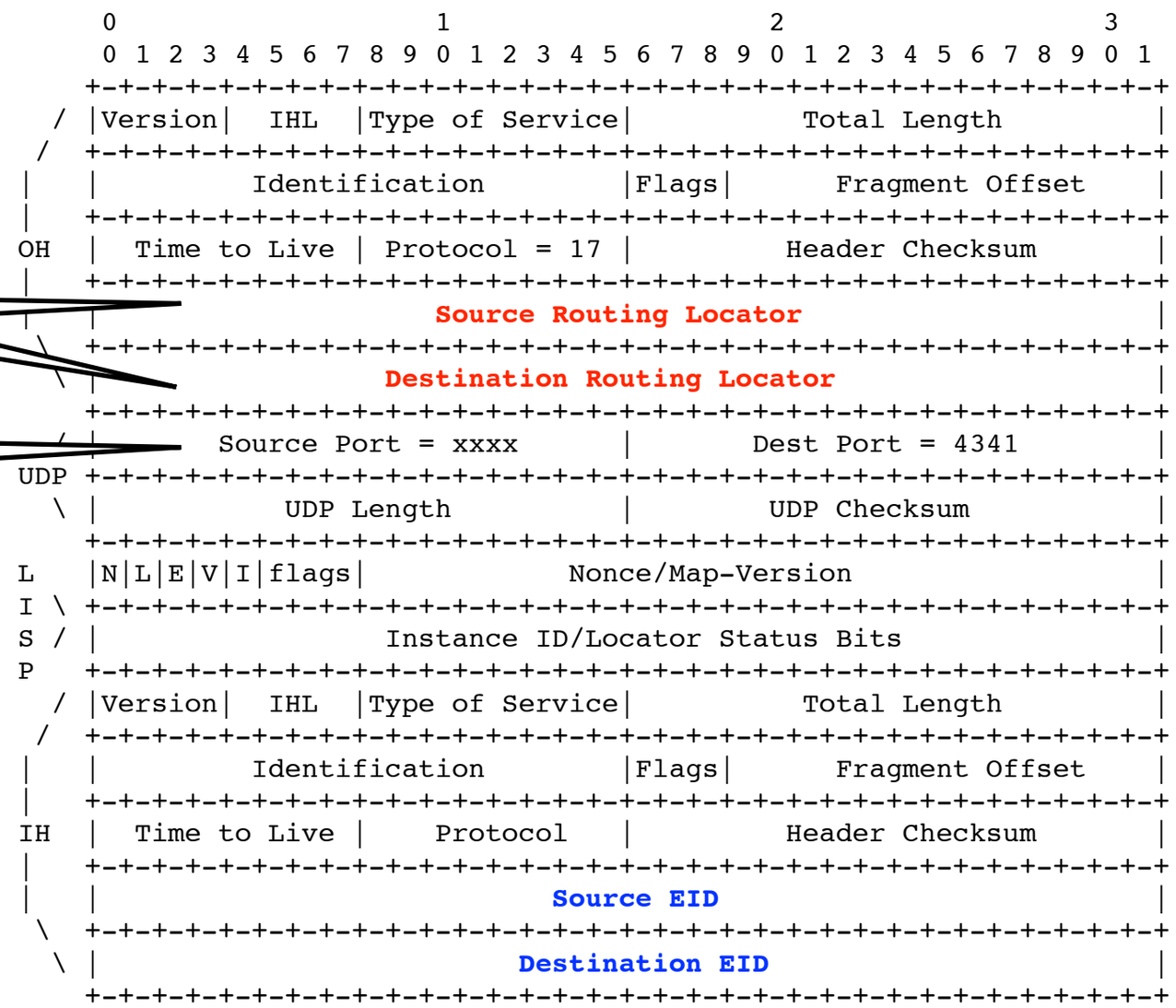
Source/Destination Locators

Hash based Source Port



Header details

(IP(UDP(LISP(IP))))

```
                 0                   1                   2                   3
                 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
              / |Version|  IHL  |Type of Service|          Total Length         |
             /  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
            |   |         Identification        |Flags|      Fragment Offset    |
            |   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
            OH  |  Time to Live | Protocol = 17 |         Header Checksum       |
            |   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
            |   |                    Source Routing Locator                     |
             \  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
              \ |                 Destination Routing Locator                   |
                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
              / |       Source Port = xxxx      |       Dest Port = 4341        |
            UDP +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
              \ |           UDP Length          |        UDP Checksum           |
                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
            L   |N|L|E|V|I|flags|            Nonce/Map-Version                  |
            I \ +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
            S / |                 Instance ID/Locator Status Bits               |
            P   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
              / |Version|  IHL  |Type of Service|          Total Length         |
             /  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
            |   |         Identification        |Flags|      Fragment Offset    |
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            IH  |  Time to Live |    Protocol   |         Header Checksum       |
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            |   |                           Source EID                          |
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              \ |                         Destination EID                       |
                +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
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Encapsulating

Encapsulated

Source/Destination Locators

Hash based Source Port

Fixed Destination port

Header details

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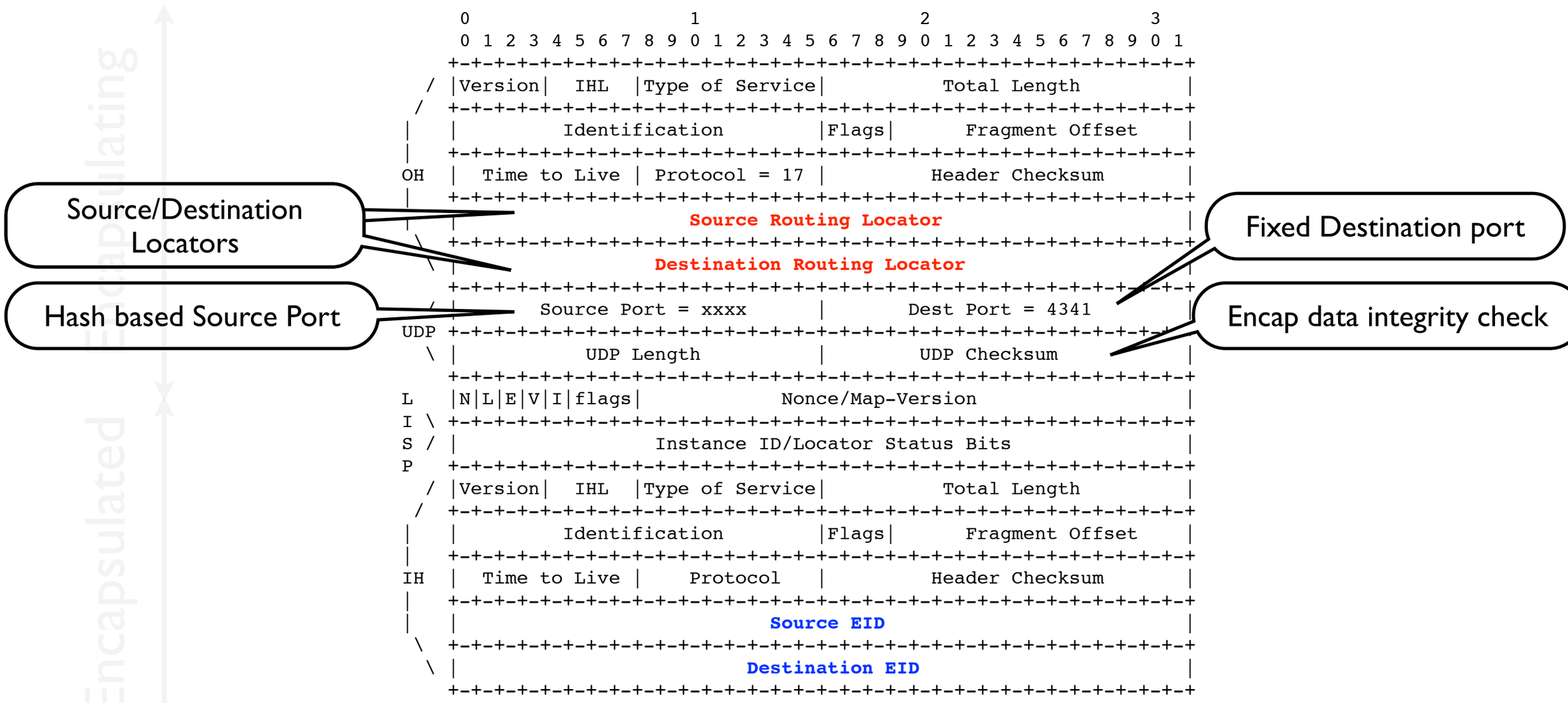

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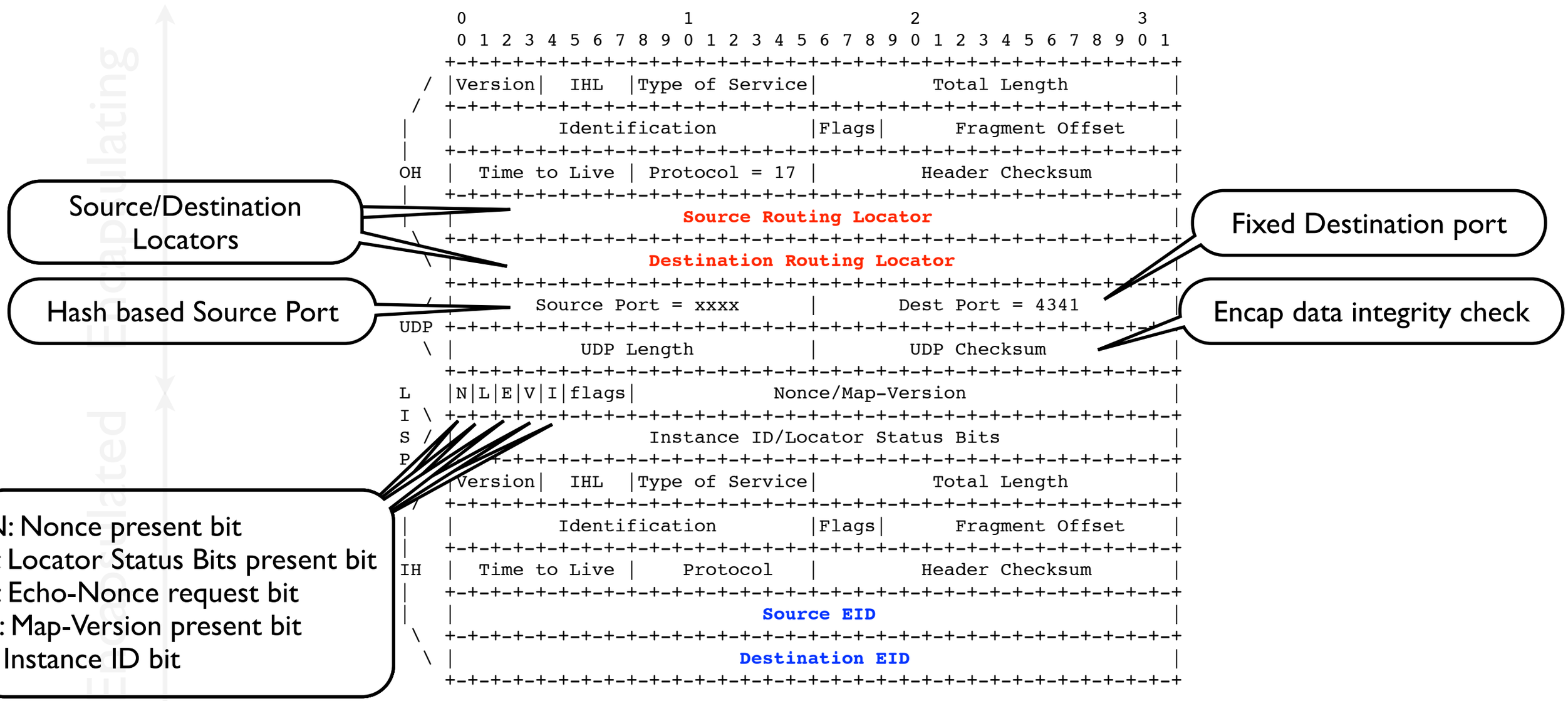

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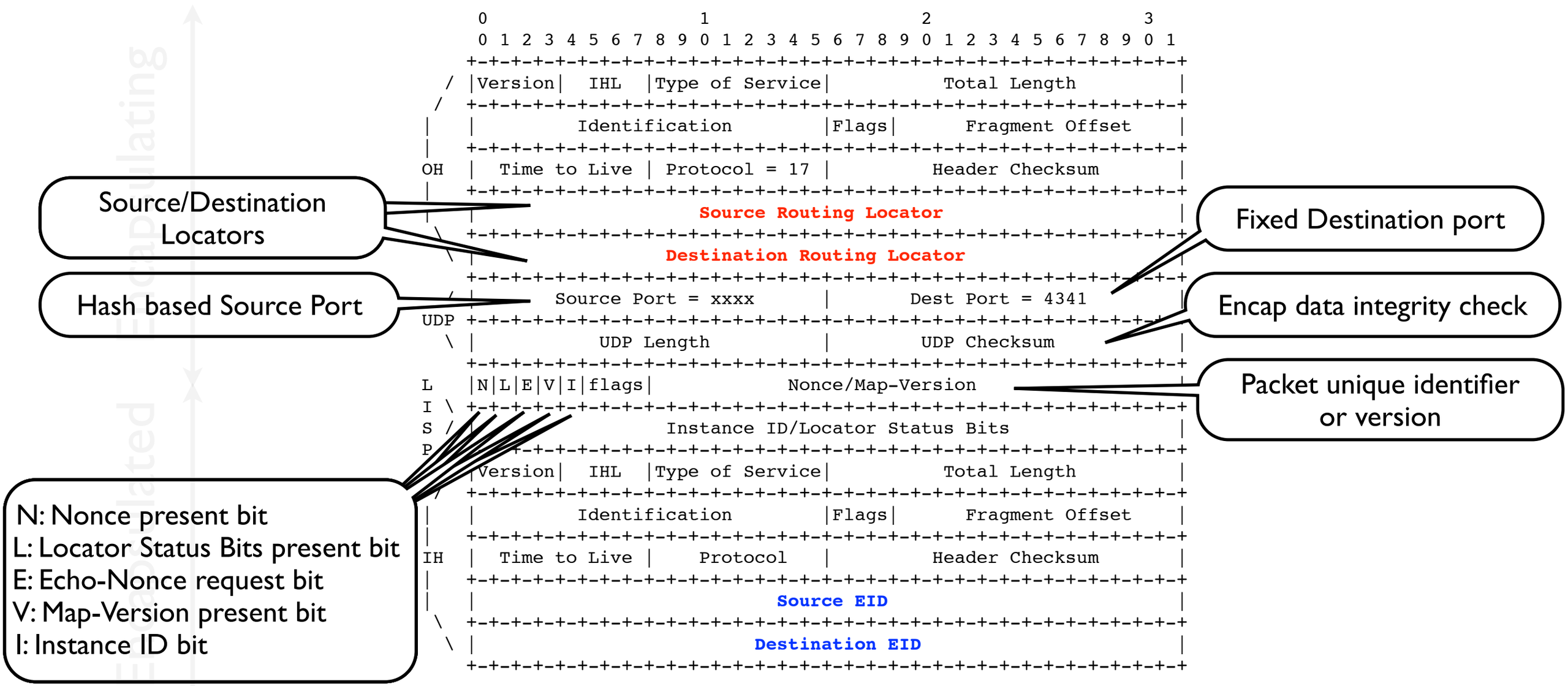

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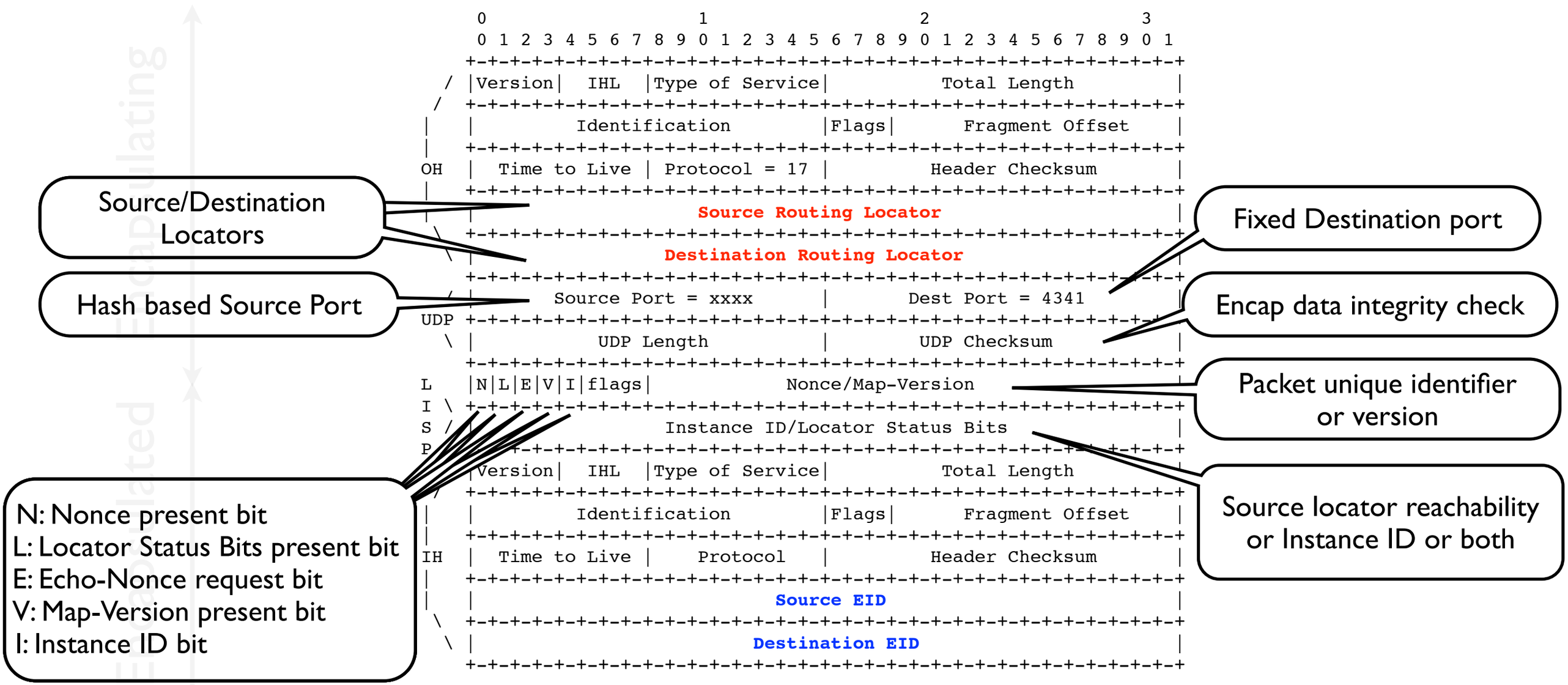

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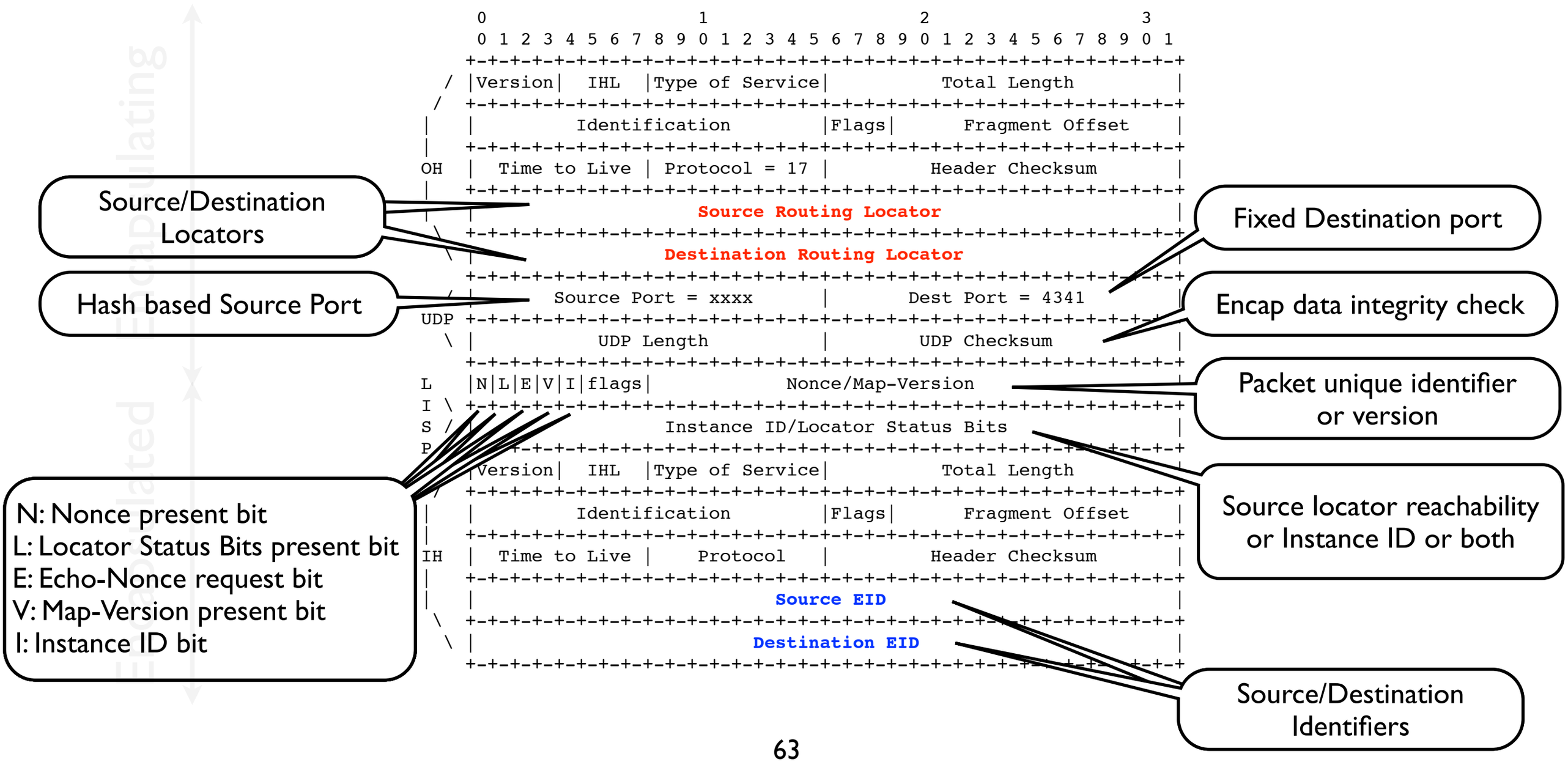

Src/Dst Locators

- Source locator: IP address of the ITR that performed the encapsulation
- Destination locator: IP address of one ETR responsible for the destination EID's prefix
- Locators can be in **IPv4 or IPv6**

Src/Dst EID

- Source EID: IP address of the source end-host
- Destination EID: IP address of destination end-hosts
- EIDs can be in **IPv4 or IPv6**
  - or even L2 with LCAF (WiP)
- *AFI*(RLOC) can be different *AFI*(EID)
  - LISP can be an IPv4/IPv6 transition mechanism (but does not support xAFI)

Interworking of LISP and non LISP networks

- Introduce transition devices
  - Consider the legacy Internet as a big LISP site
- **Proxy-ITR**, encapsulates packets, whatever their source address
  - Advertises coarse-aggregated EID prefixes to BGP
- **Proxy ETR**, decapsulates packets, whatever their destination EID
- **LISP-NAT**, rewriting instead of encapsulation
  - ITR replaces source EID by one of its RLOCs