Improving network agility with seamless BGP reconfigurations

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Based on joint work with

Stefano Vissicchio, Luca Cittadini, Cristel Pelsser, Pierre François and Olivier Bonaventure

“ When you are changing
the tires of a moving car

--Vijay Gill

“ When you are changing
the tires of a moving car

make sure one wheel is
on the ground at all time ”

--Vijay Gill

Why does seamless BGP reconfigurations matter?

BGP is critical for ISPs

enforce business relationship, responsible for most of traffic

BGP configuration is often changed

On average, 400+ changes accounted per month in a Tier1

Changing a BGP configuration can impact availability

even if the initial and final configurations are safe

Improving network agility with seamless BGP reconfigurations

1 **BGP reconfiguration**
A crash course

2 **Finding an ordering**
Is it easy? Does it exist?

3 **Reconfiguration framework**
Overcome complexity

Improving network agility with seamless BGP reconfigurations

1 BGP reconfiguration

A crash course

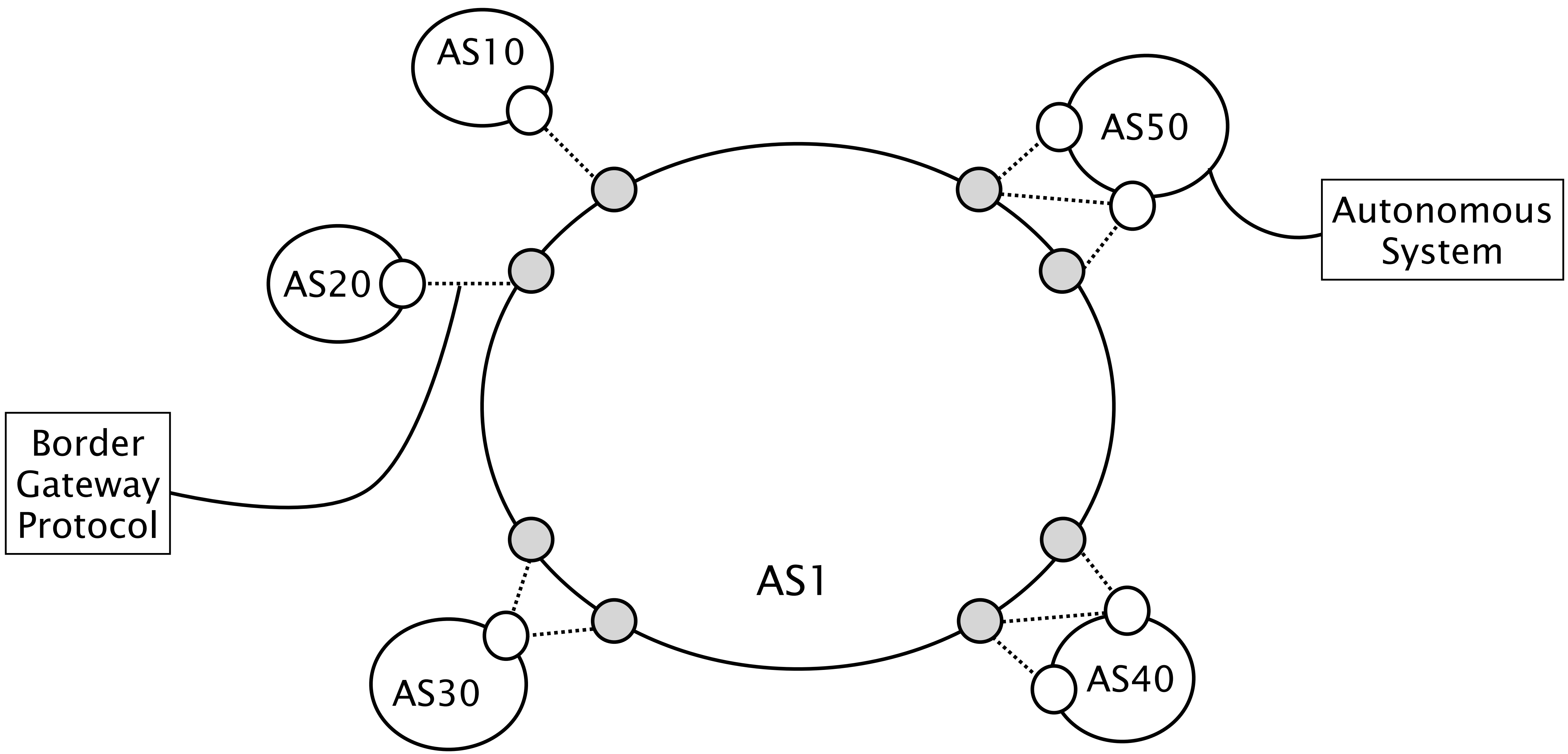
Finding an ordering

Is it easy? Does it exist?

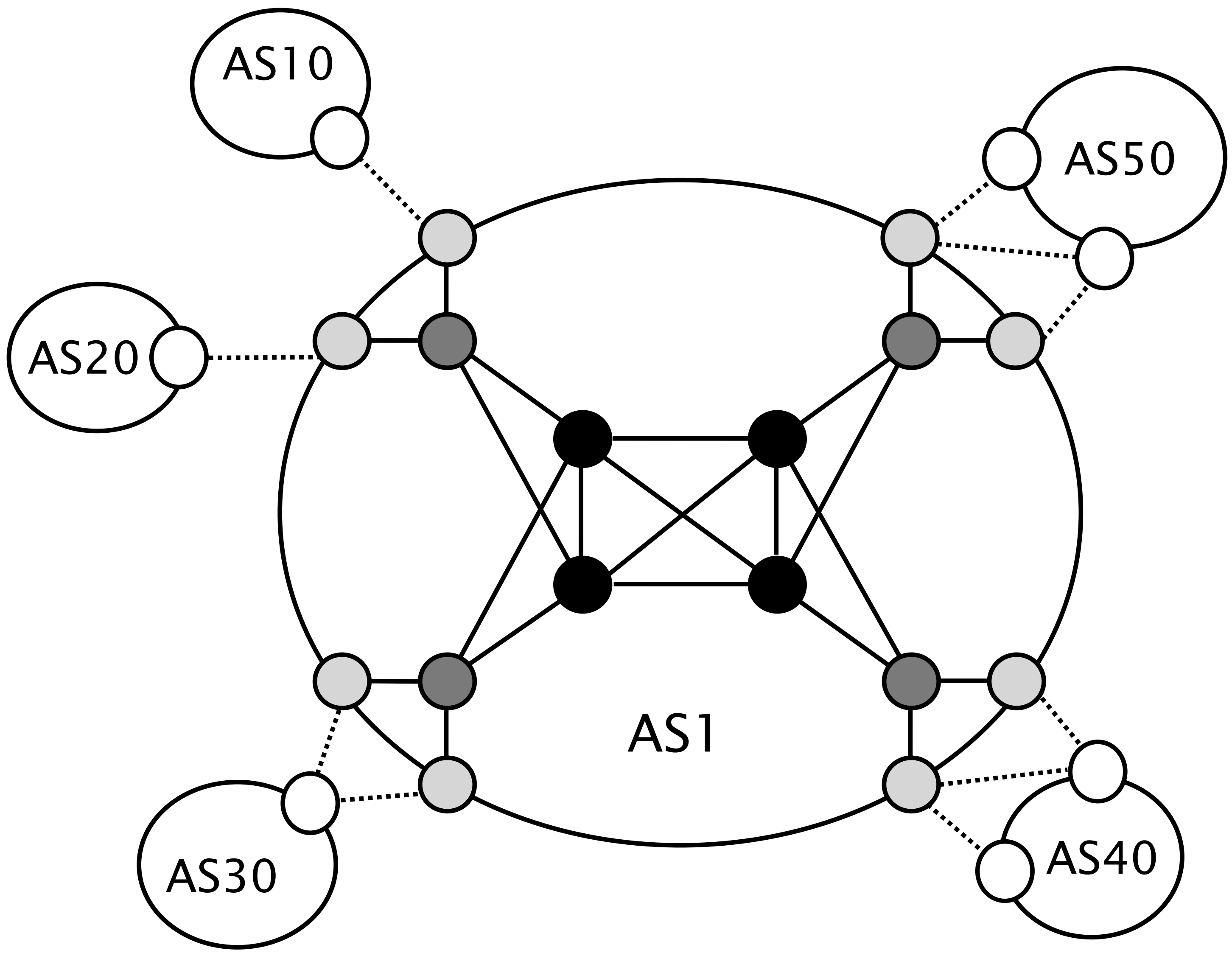
Reconfiguration framework

Overcome complexity

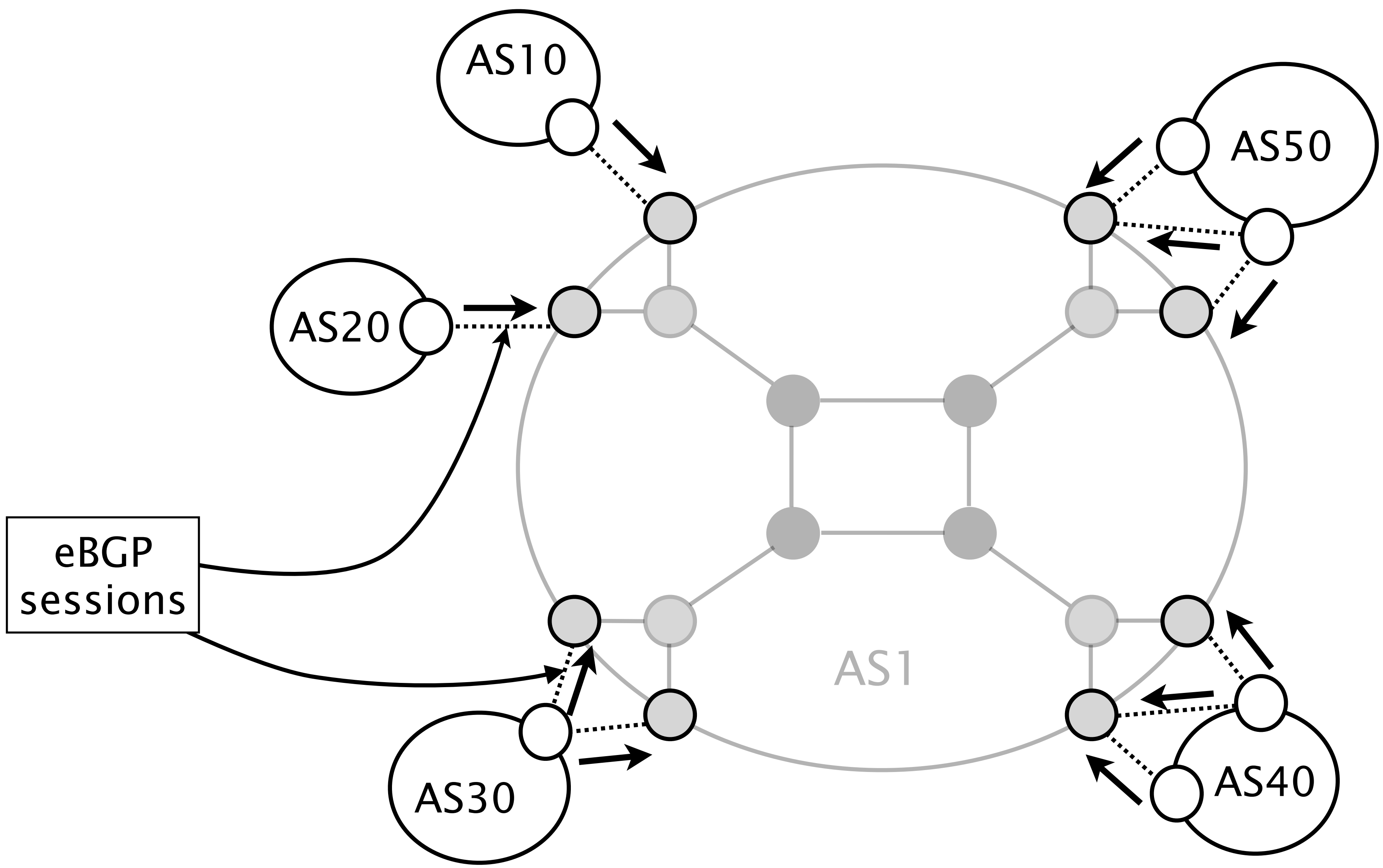
BGP is the only inter-domain routing protocol used today



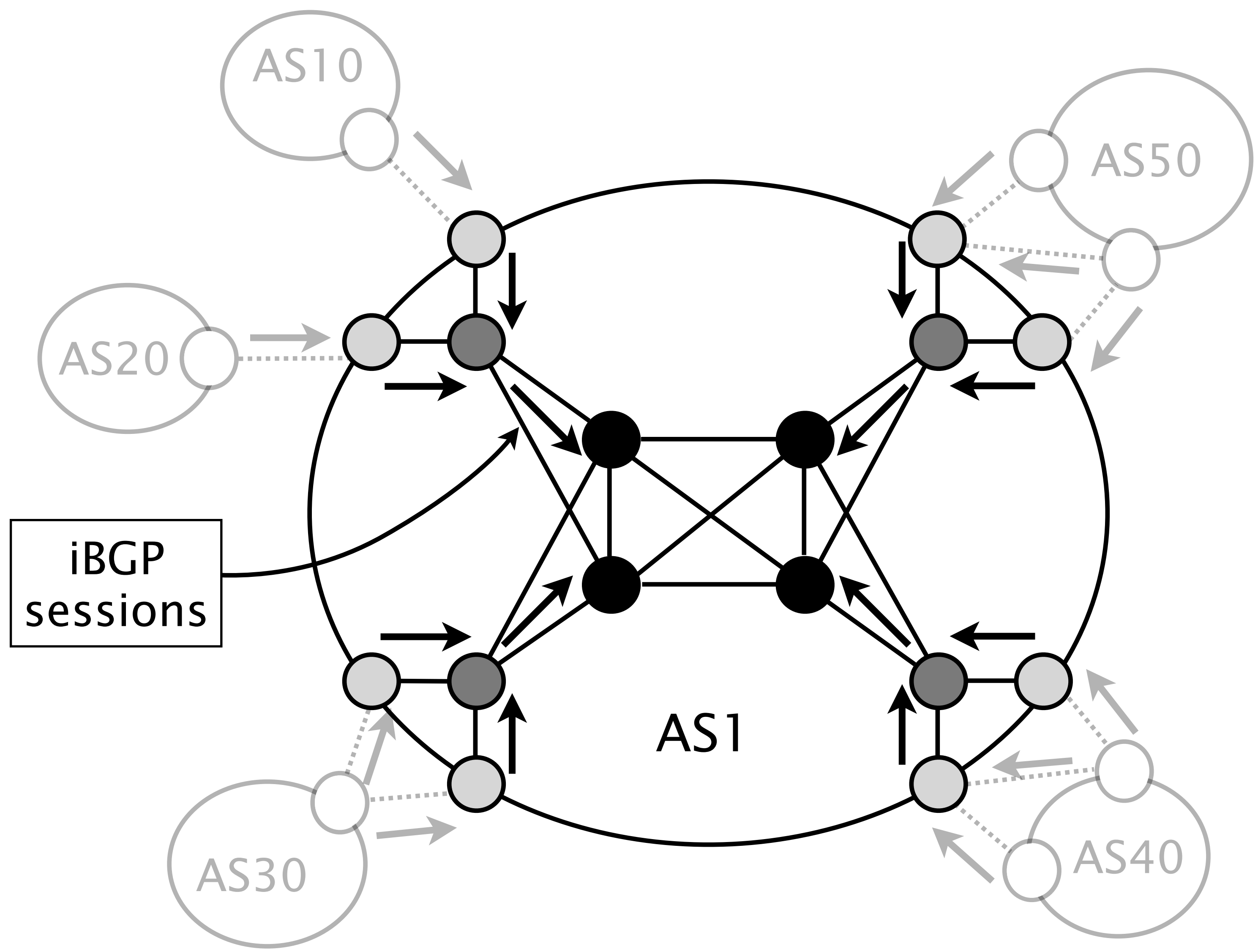
BGP comes in two flavors



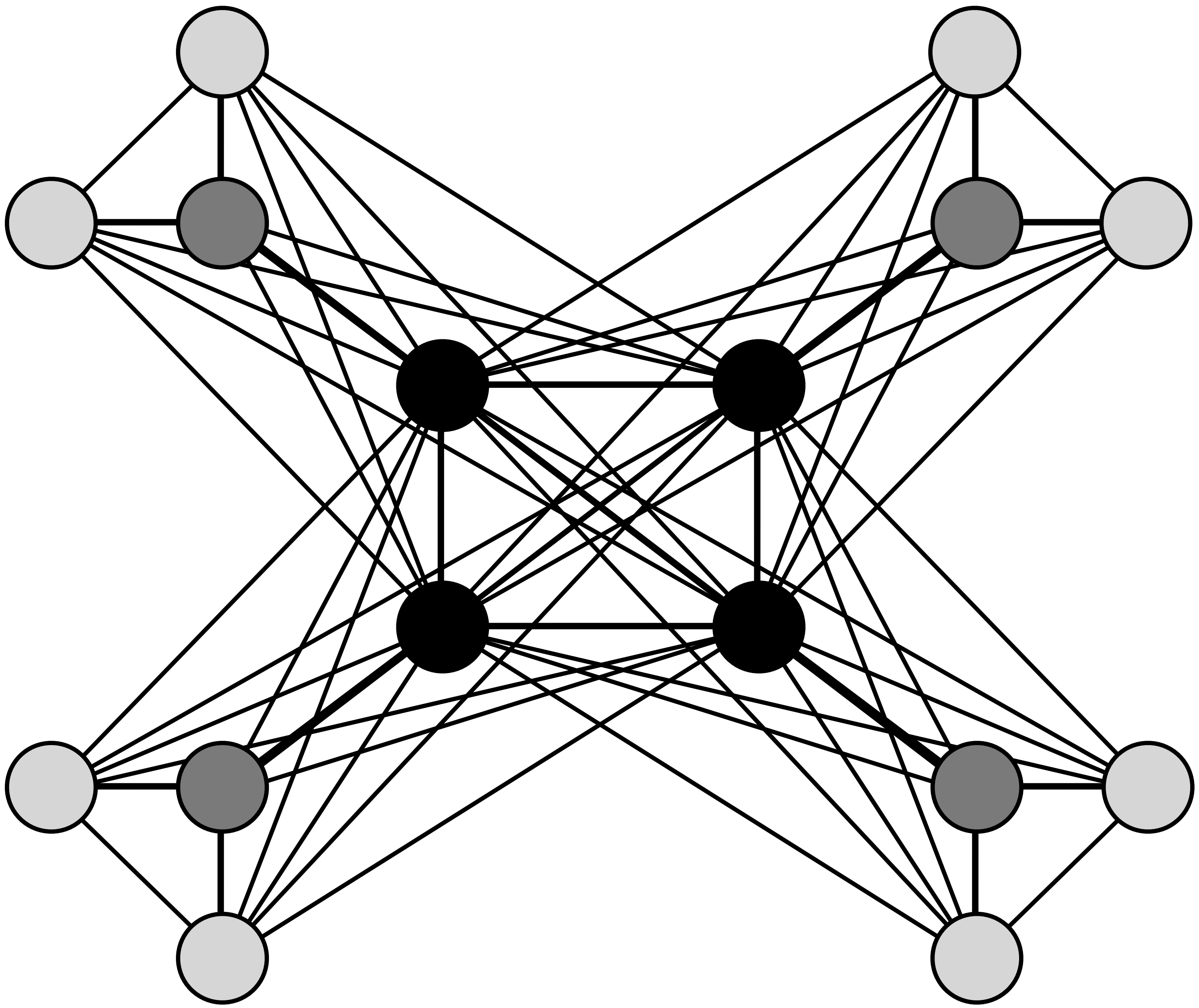
external BGP (eBGP) exchanges reachability information between ASes



internal BGP (iBGP) distributes externally learned routes within the AS



Plain iBGP mandates a full-mesh of iBGP sessions

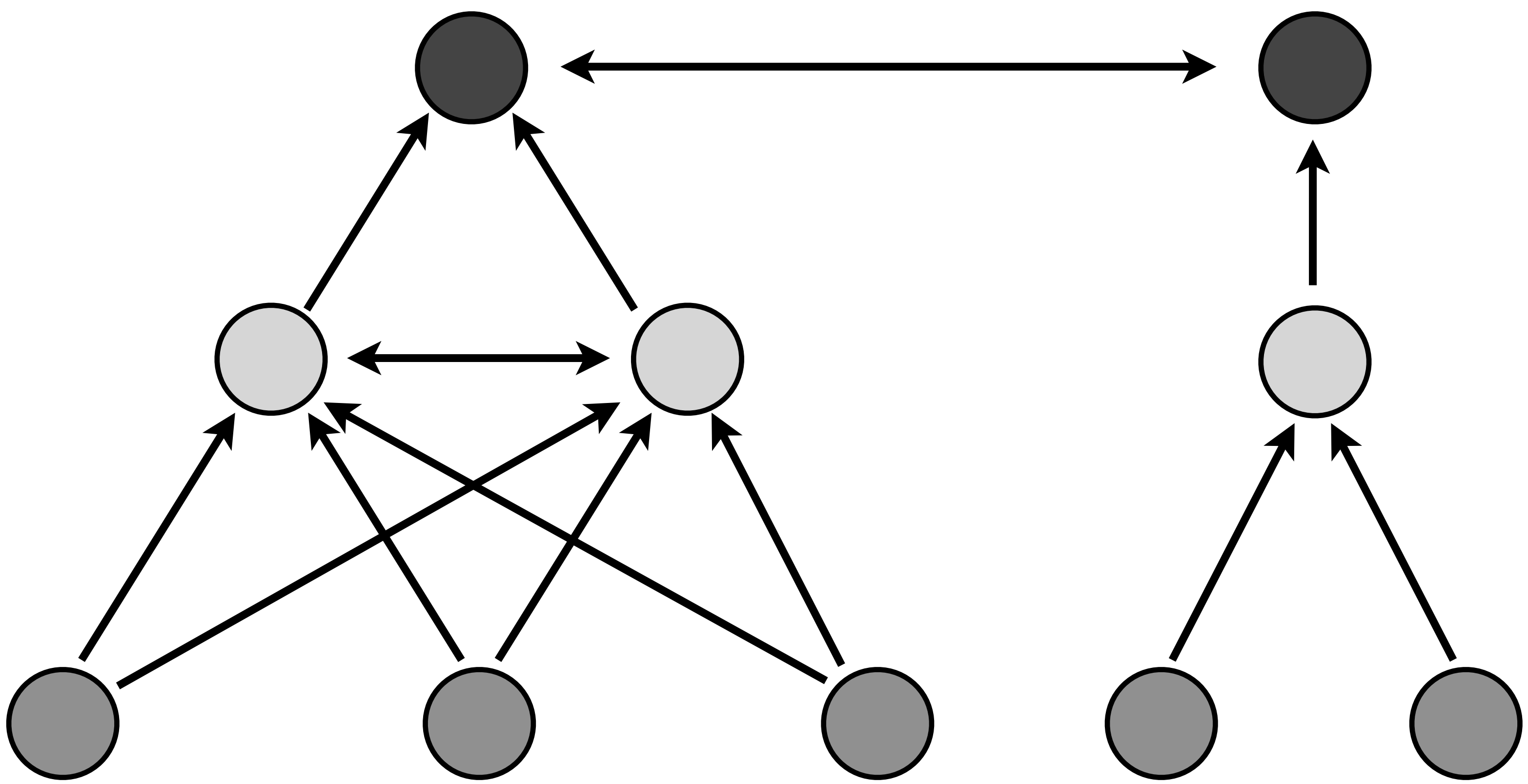


$O(n^2)$ iBGP sessions where *n* is the number of routers

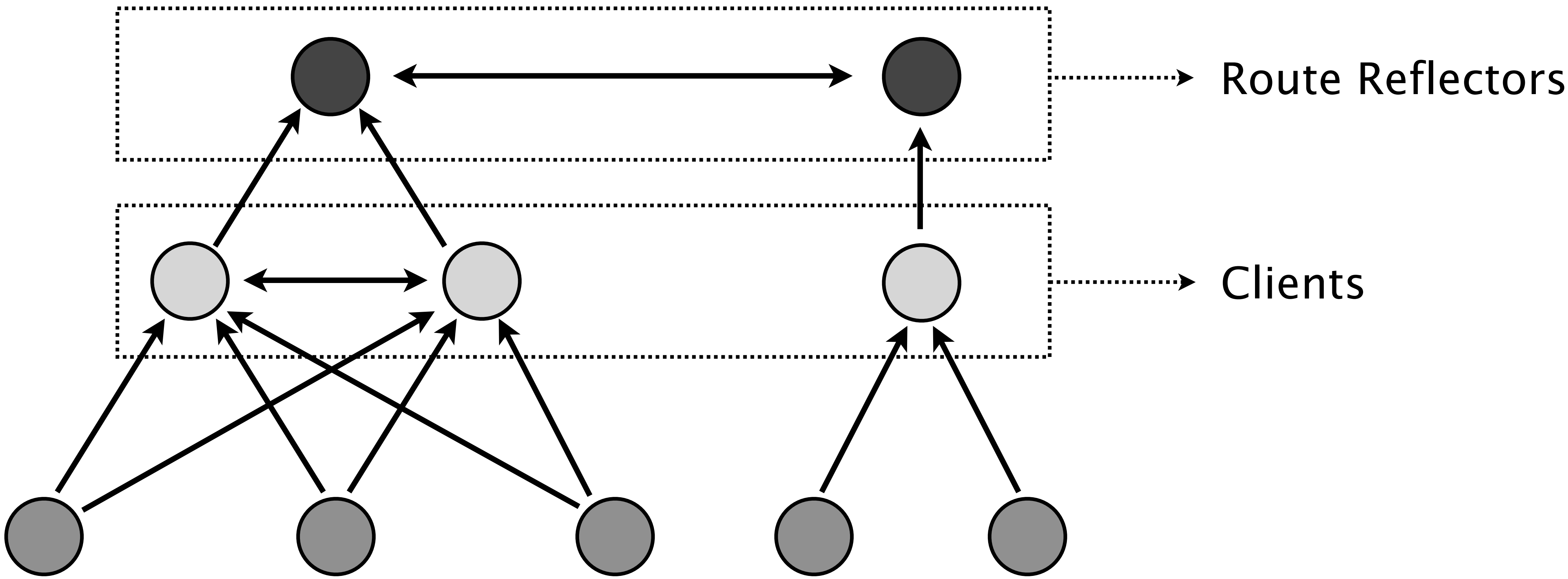
... quickly becomes totally *unmanageable*

Fair warning: some sessions are missing

With Route Reflection, iBGP routers are hierarchically organized



Route Reflectors relay route updates between iBGP neighbors



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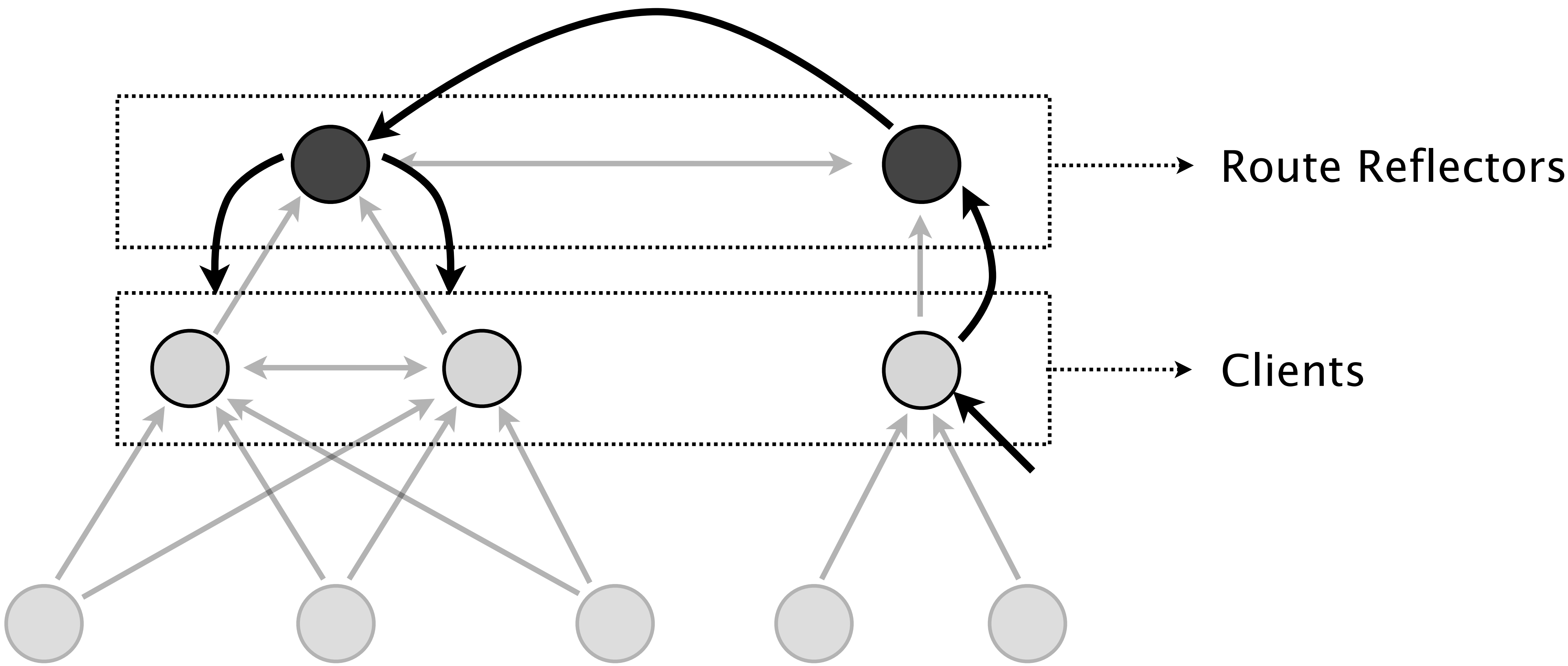


Lower layers rely on upper layers to learn and propagate routing informations

iBGP and eBGP need to be carefully configured

A BGP configuration is composed of

iBGP	Clients sessions
	Route-reflector sessions
	Peer sessions
eBGP	External sessions
	Routing policies

Each part of a BGP configuration can be changed

Typical reconfiguration scenarios consist in

iBGP	Clients sessions	▶	Add sessions
	Route-reflector sessions		Remove sessions
	Peer sessions		Change type
eBGP	External sessions		
	Routing policies		

Each part of a BGP configuration can be changed

Typical reconfiguration scenarios consist in

iBGP	Clients sessions	▶	Add sessions
	Route-reflector sessions		Remove sessions
	Peer sessions		Change type
eBGP	External sessions	▶	Add sessions
	Routing policies		Remove sessions
			Modify policies

Reconfiguring BGP can be disruptive

BGP reconfigurations can create

- signaling anomalies [Griffin, SIGCOMM02]
- dissemination anomalies [Vissicchio, INFOCOM12]
- forwarding anomalies [Griffin, SIGCOMM02]

or any combination of those

Reconfiguring BGP can be disruptive

BGP reconfigurations can create

- signaling anomalies	routing oscillations
- dissemination anomalies	black holes
- forwarding anomalies	forwarding loops traffic shifts

or any combination of those

Reconfiguring BGP can be disruptive

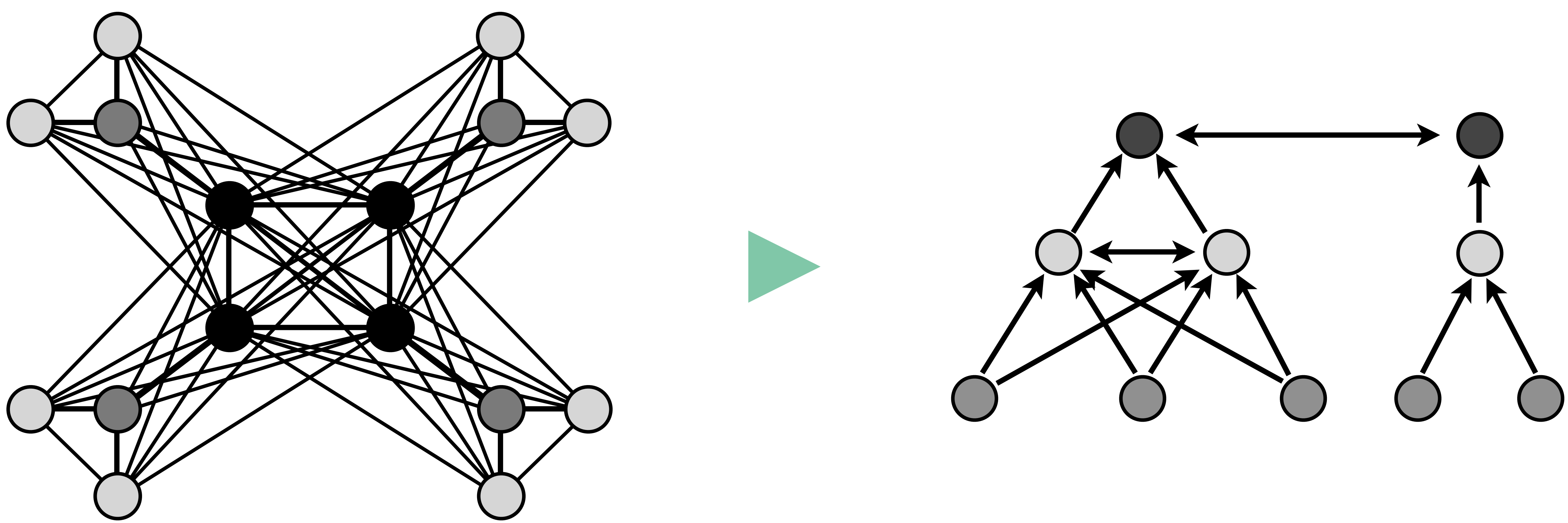
BGP reconfigurations can create

- signaling anomalies
- dissemination anomalies
- forwarding anomalies

How much ?

or any combination of those

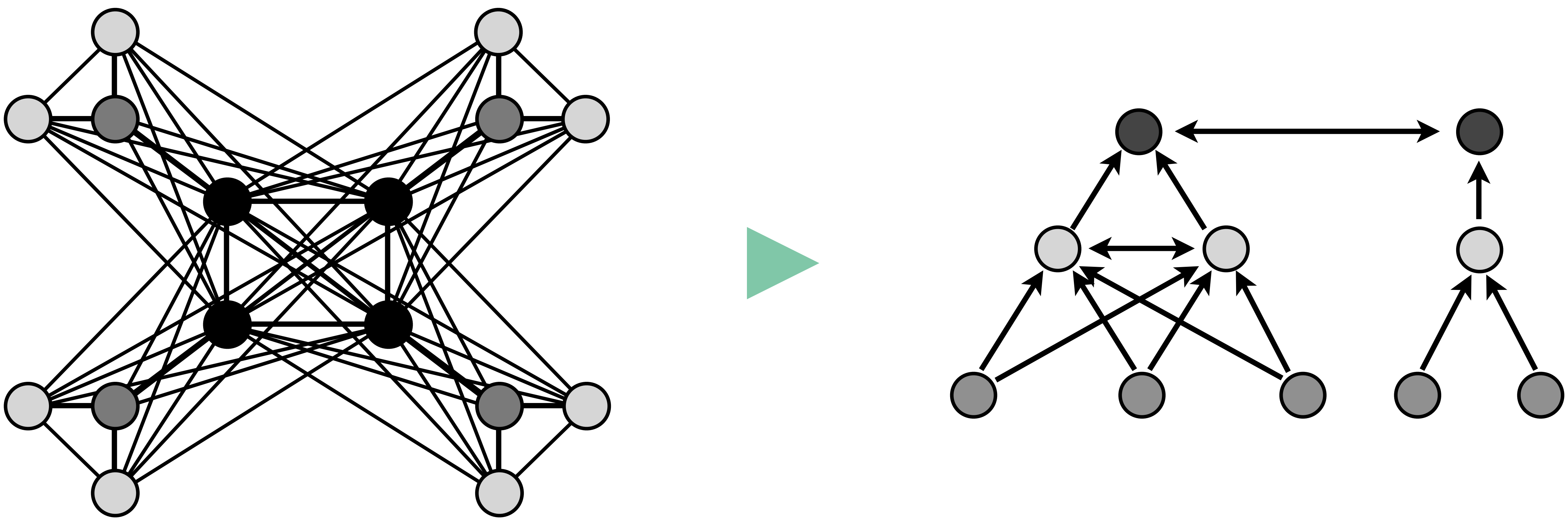
Let’s migrate from a full-mesh to a RR topology



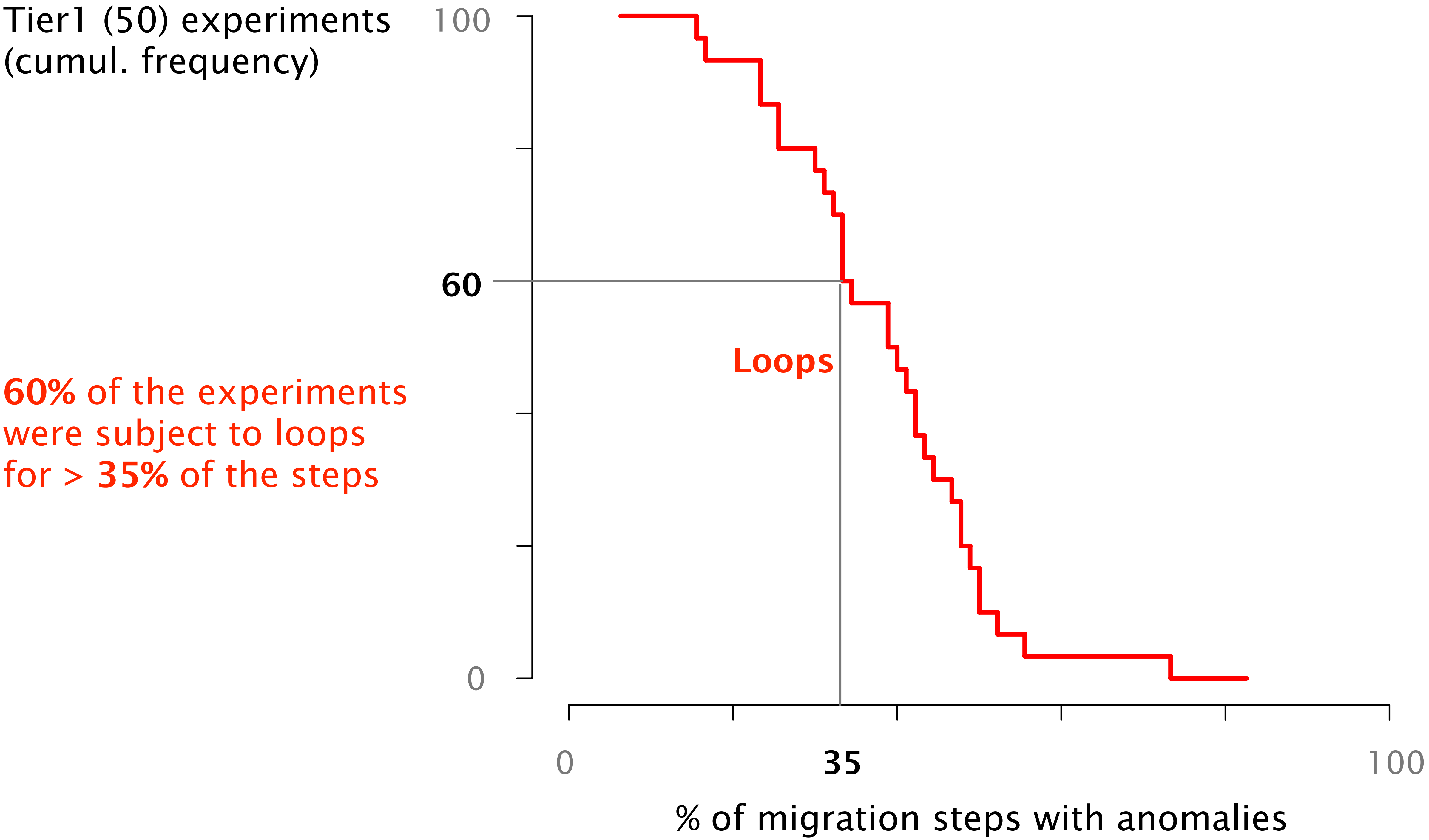
Let's migrate from a full-mesh to a RR topology, following best practices

Establish the RR sessions in a bottom-up manner, then remove the full-mesh sessions

[Herrero10]

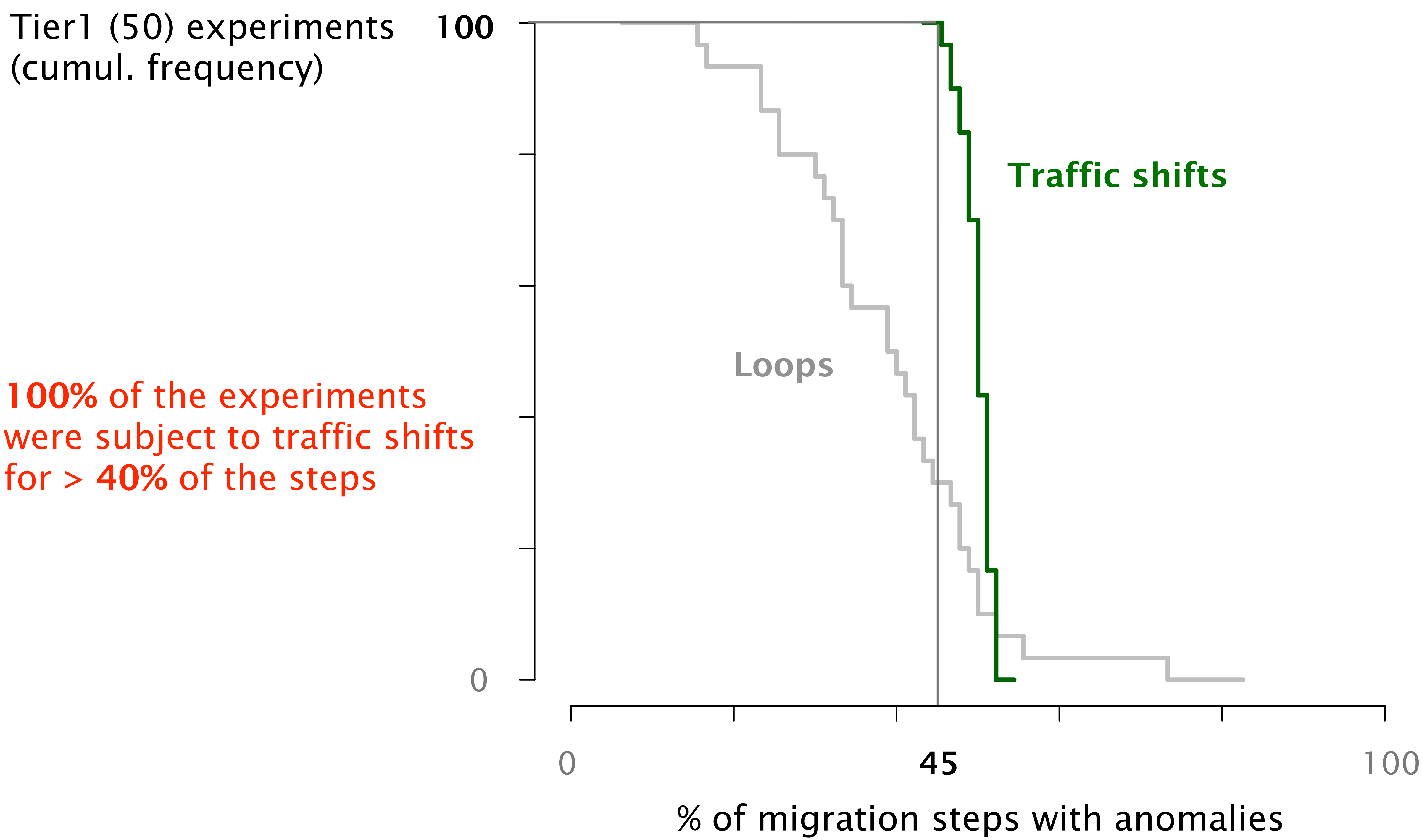


Best practices do not work



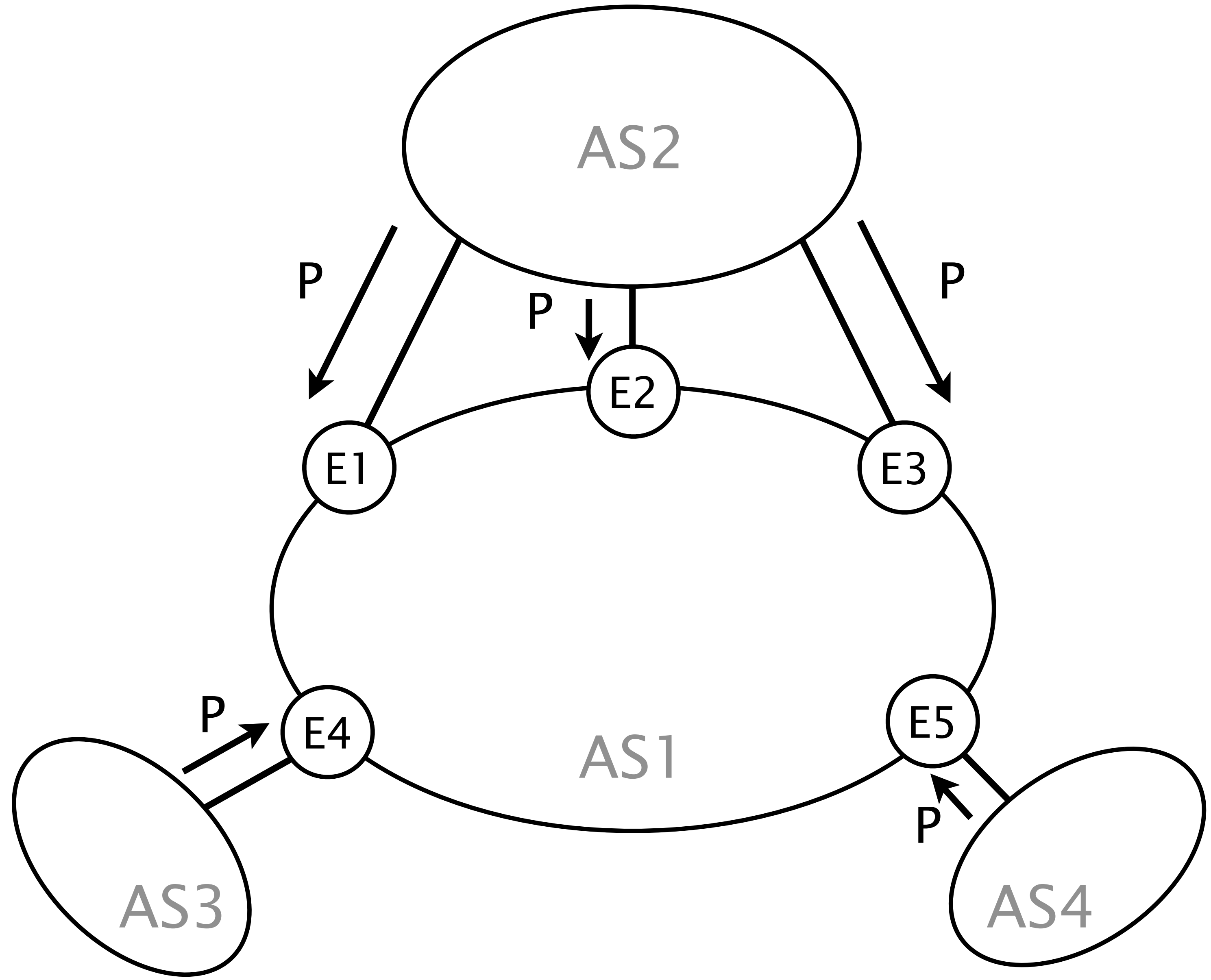
60% of the experiments were subject to loops for > **35%** of the steps

Best practices do not work

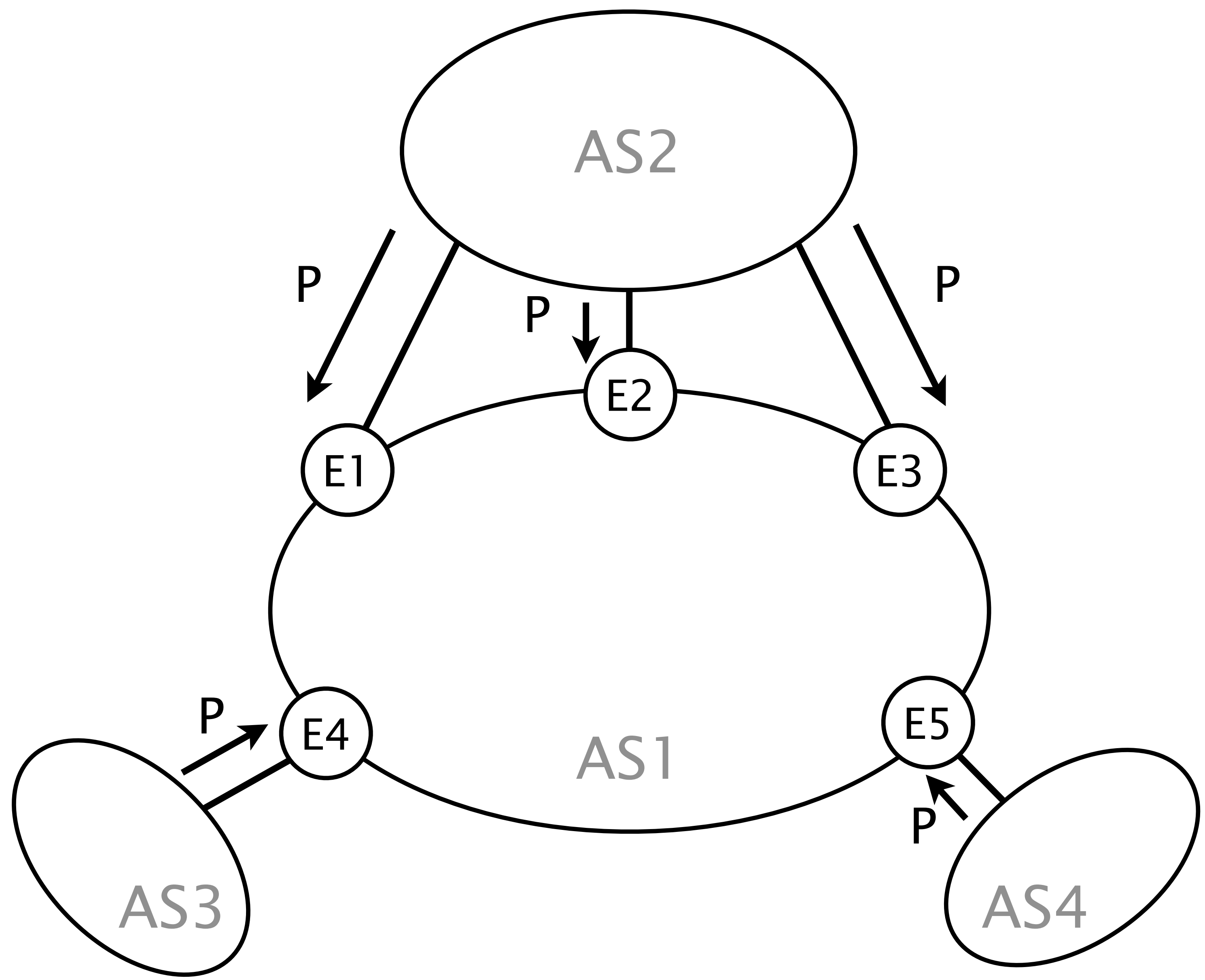


100% of the experiments were subject to traffic shifts for > **40%** of the steps

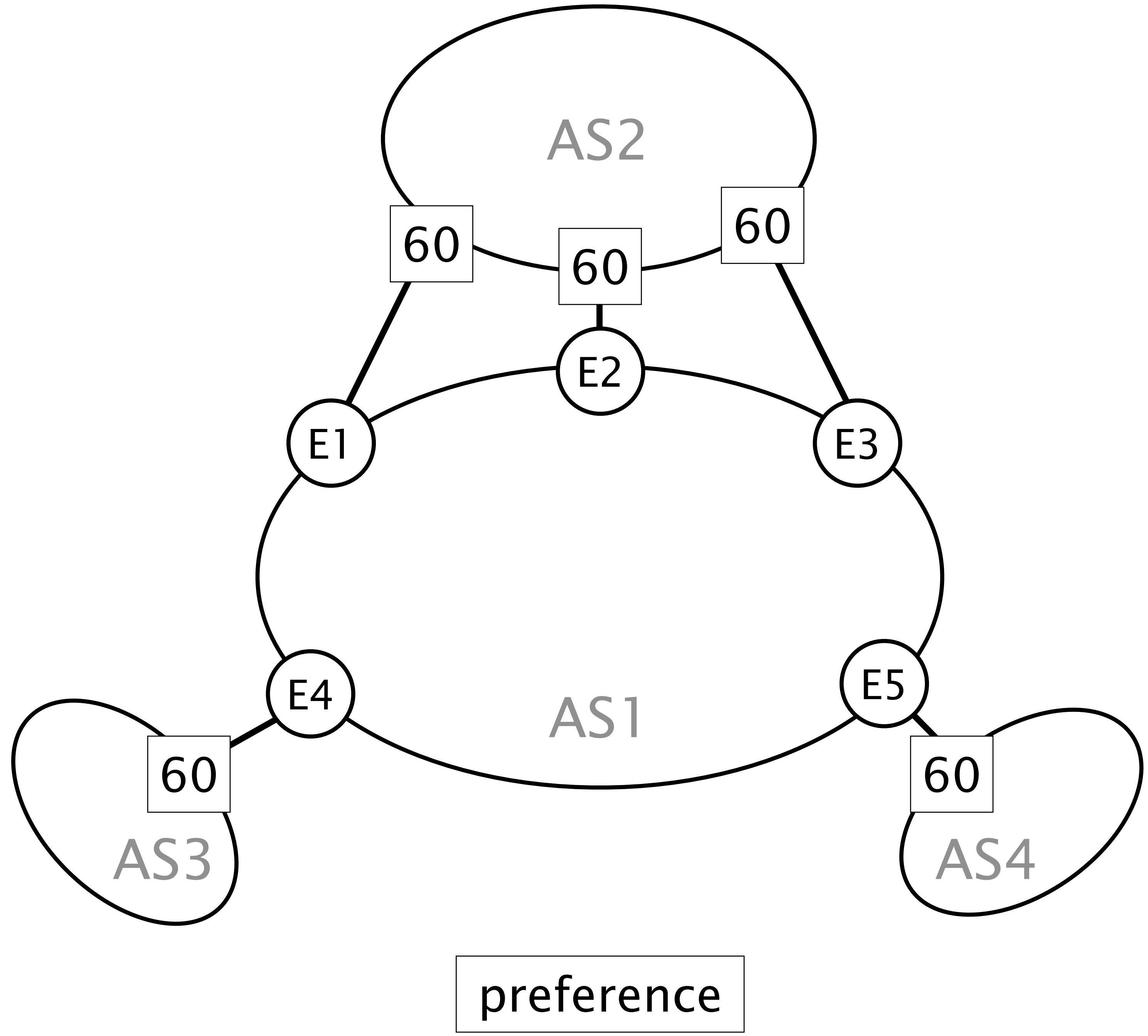
Let's tune BGP policies



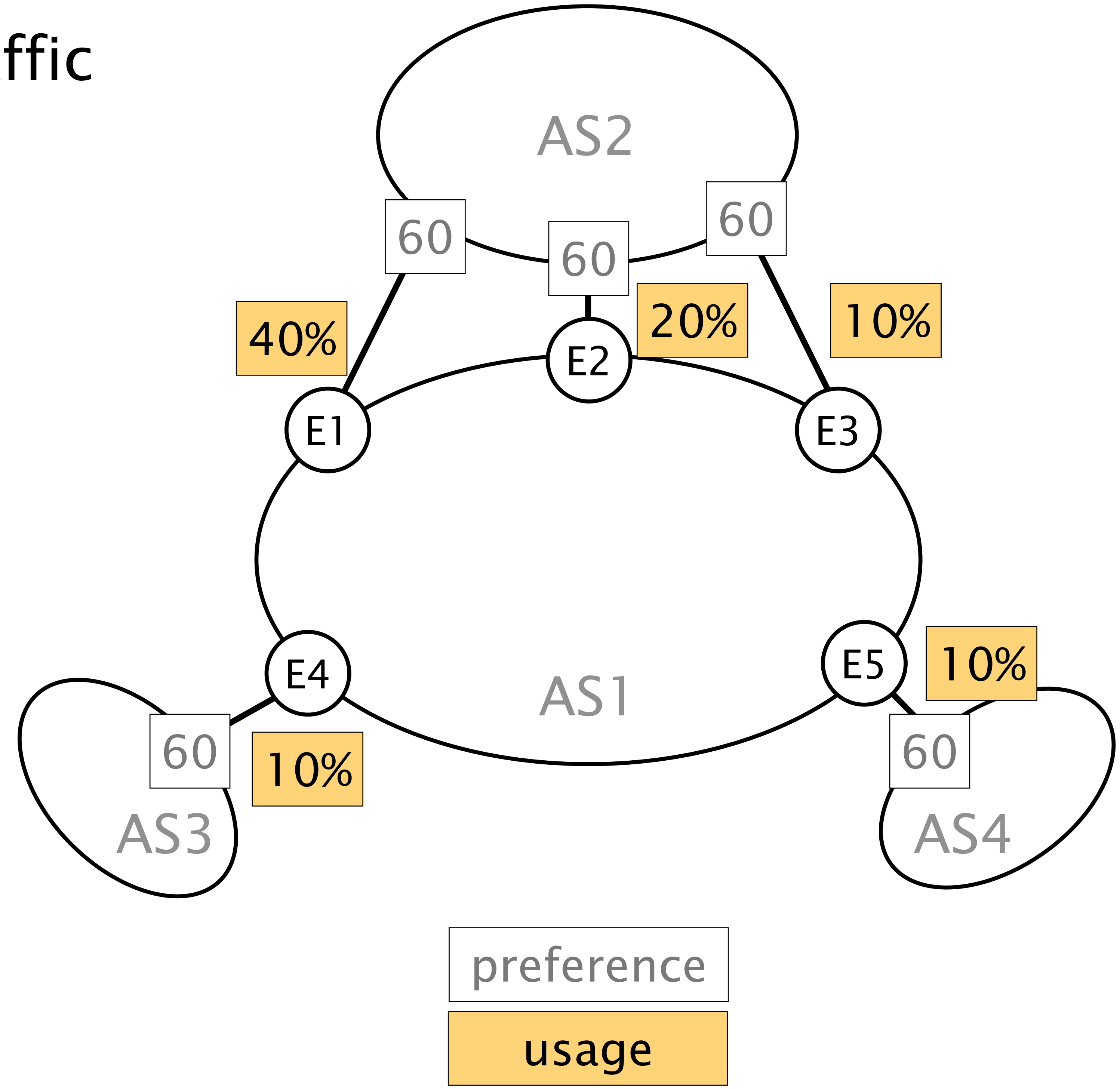
AS1 learns a destination
P via 5 egress points



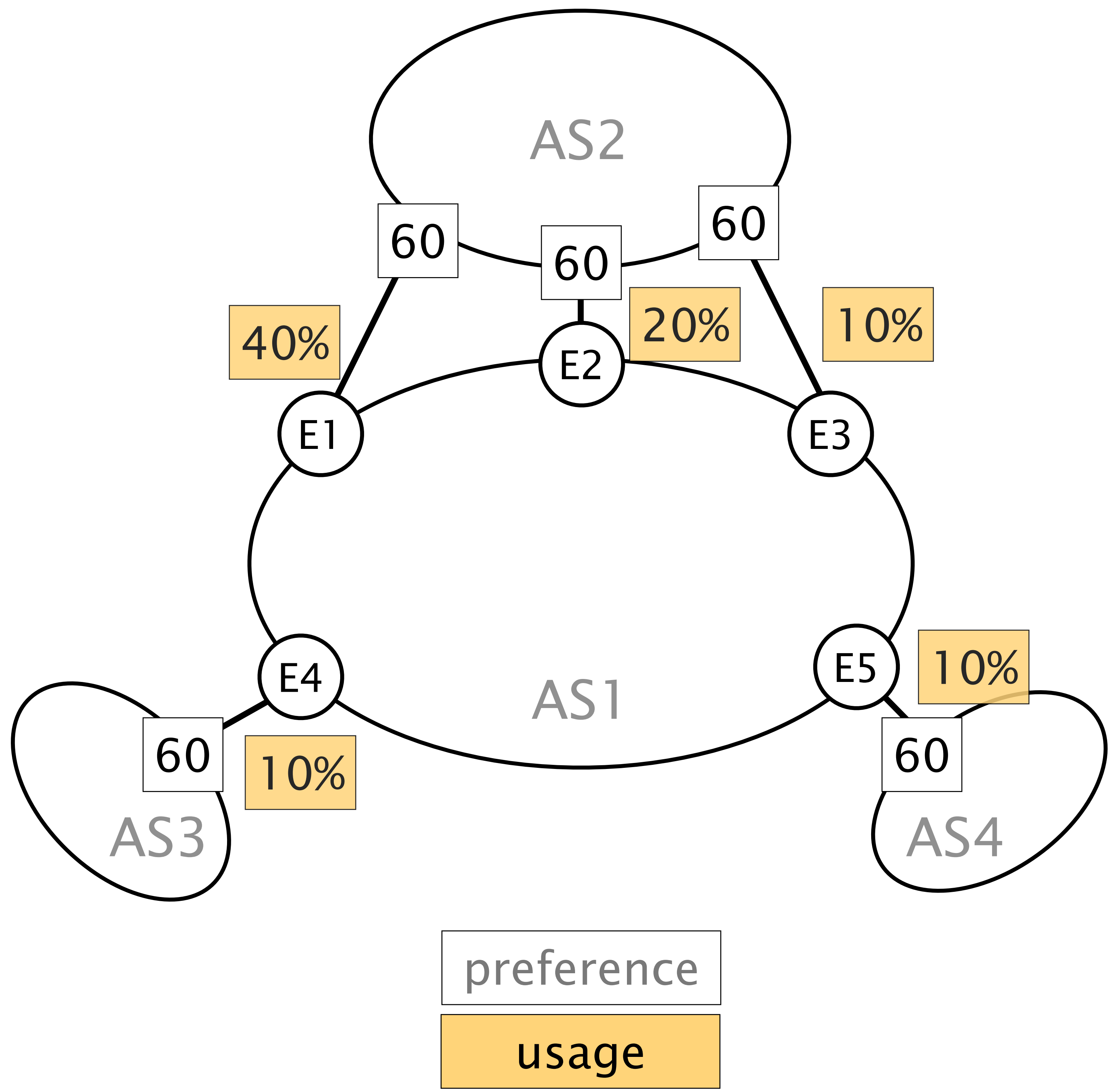
Initially, each egress point is equally preferred



Depending on its position, each egress receives a percentage of the traffic



Let's say that AS2 becomes more preferred



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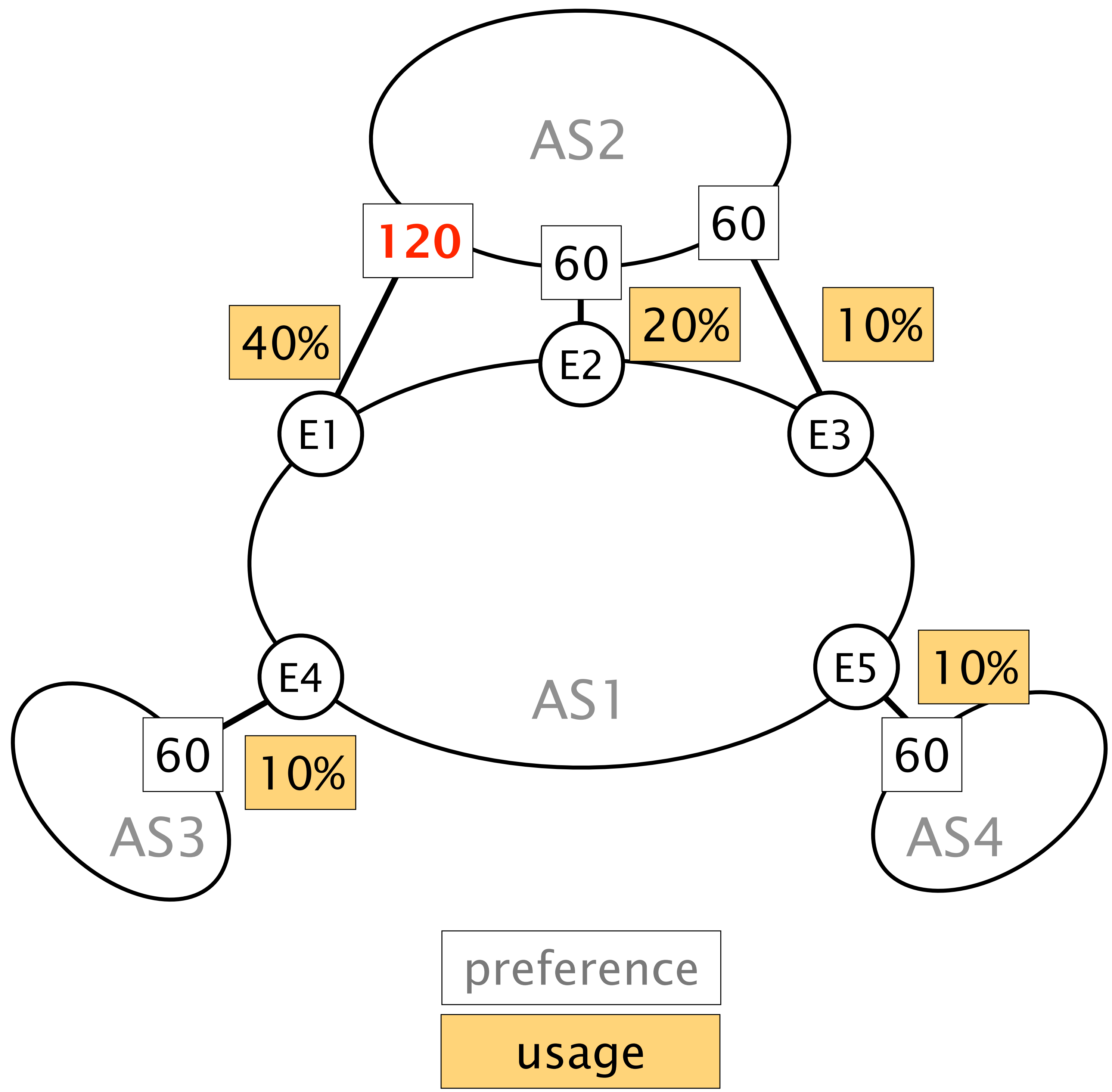
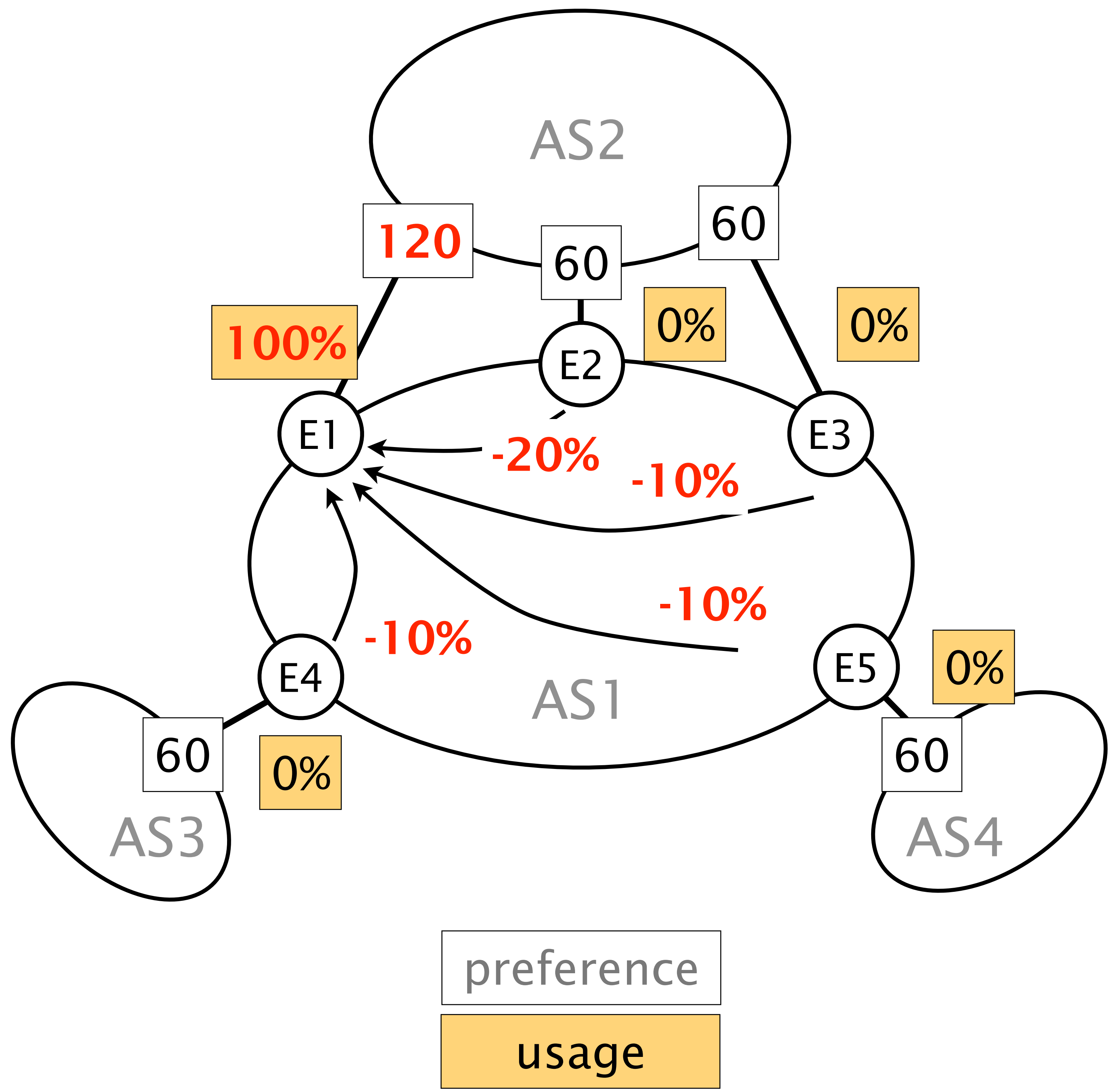


Let's say that AS2 becomes more preferred

60% of the traffic
experience a traffic shift



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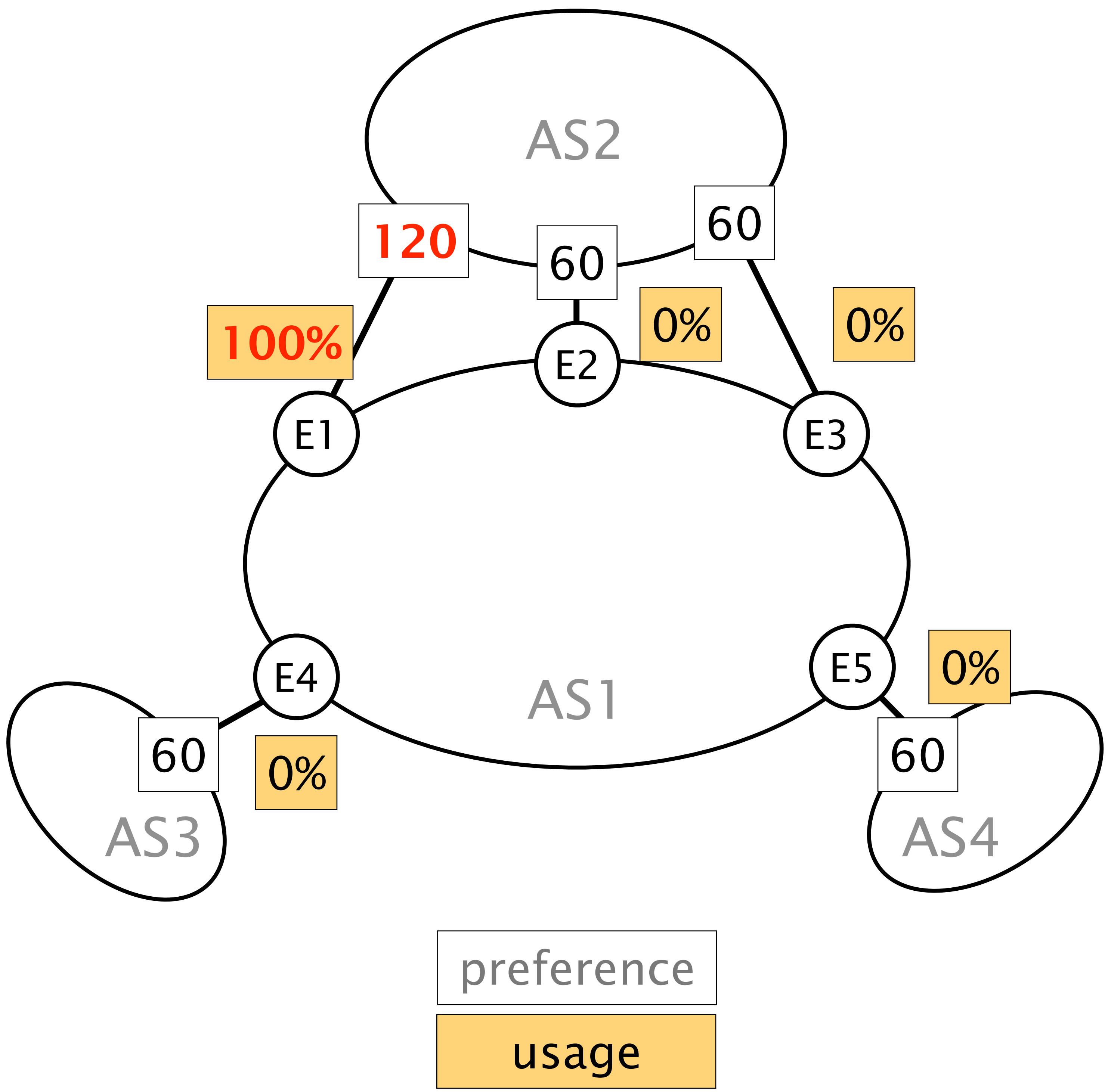

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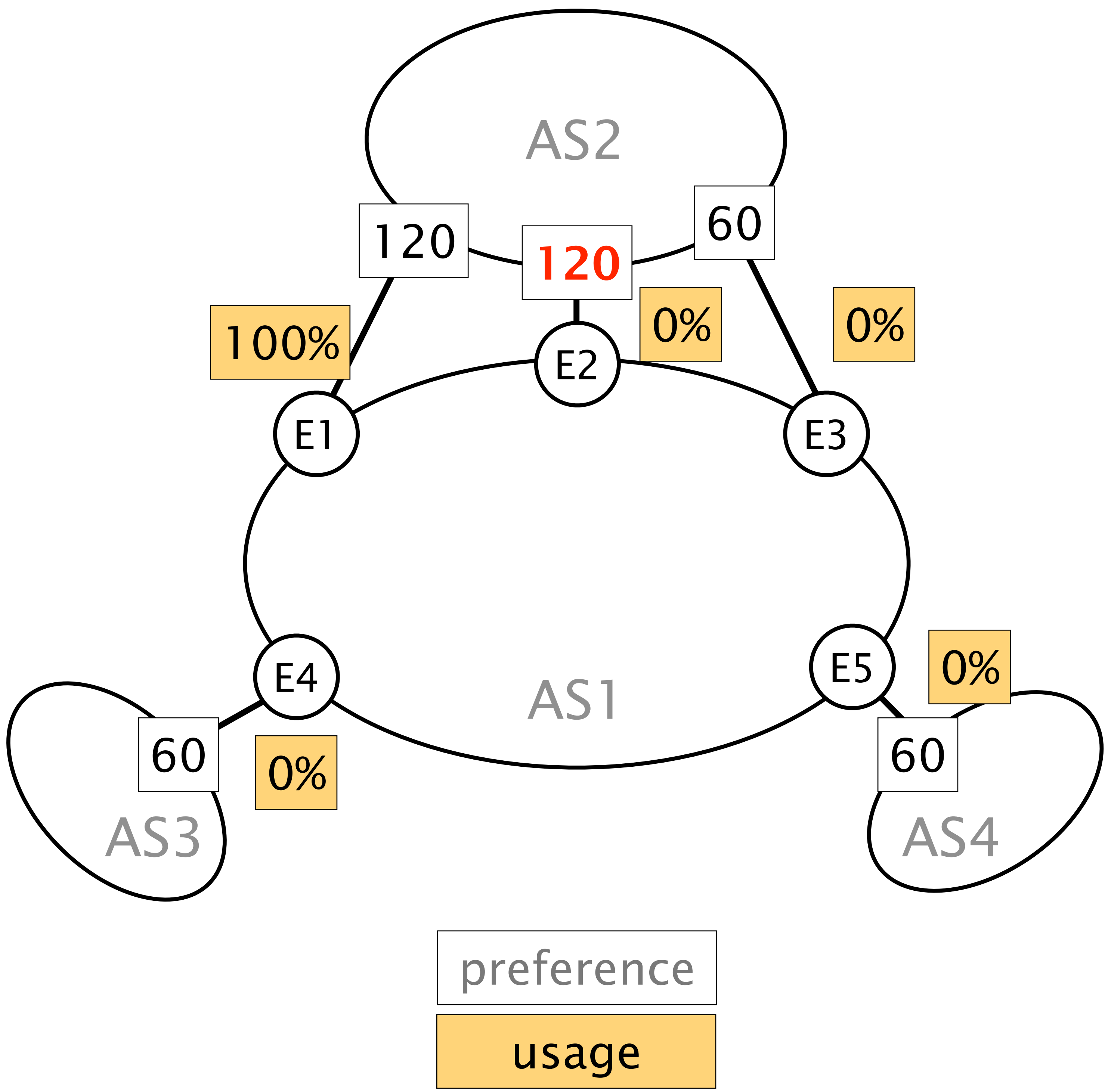
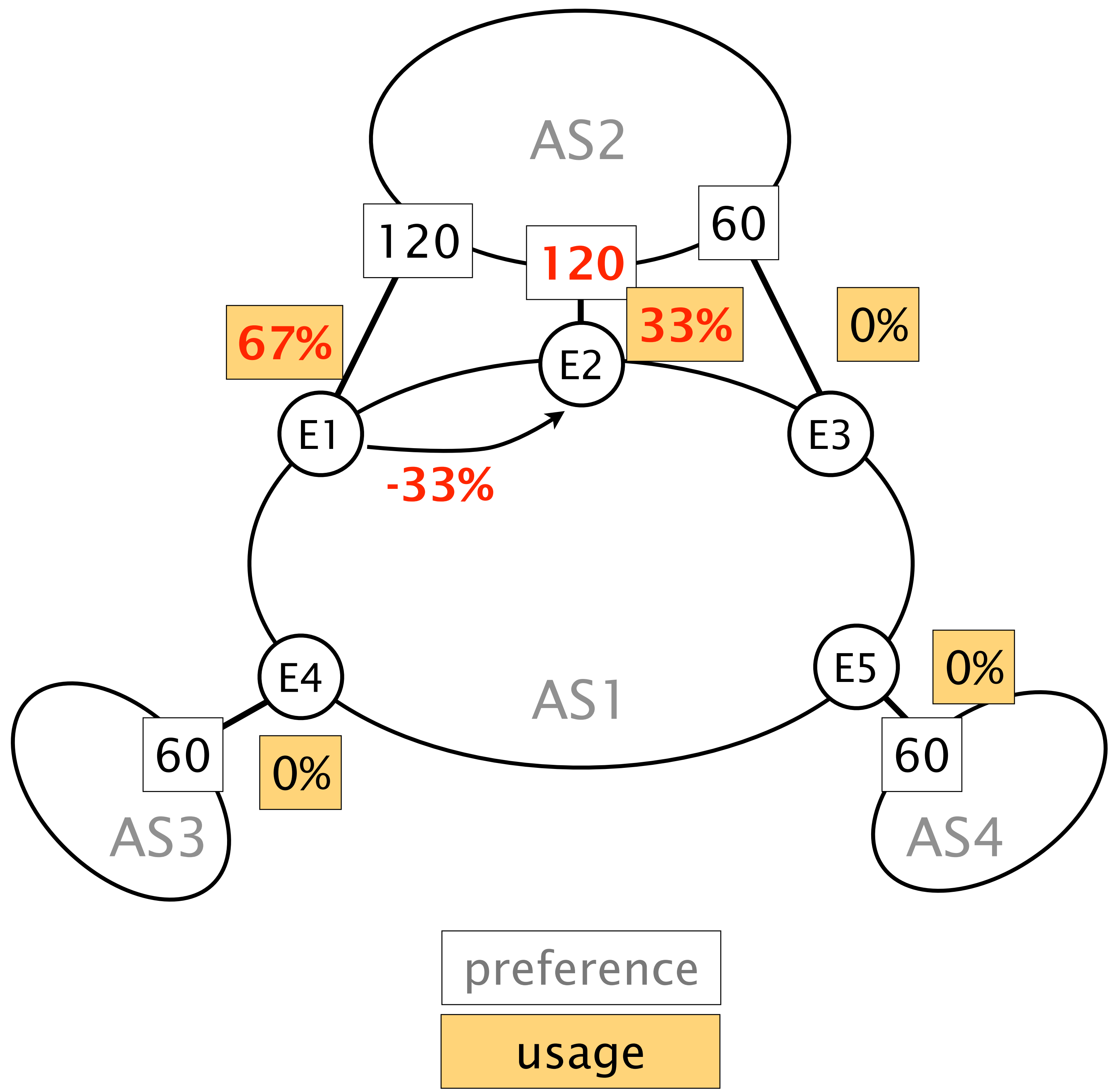


Let's say that AS2 becomes more preferred

60% of the traffic experience a traffic shift

33% of the traffic experience a traffic shift



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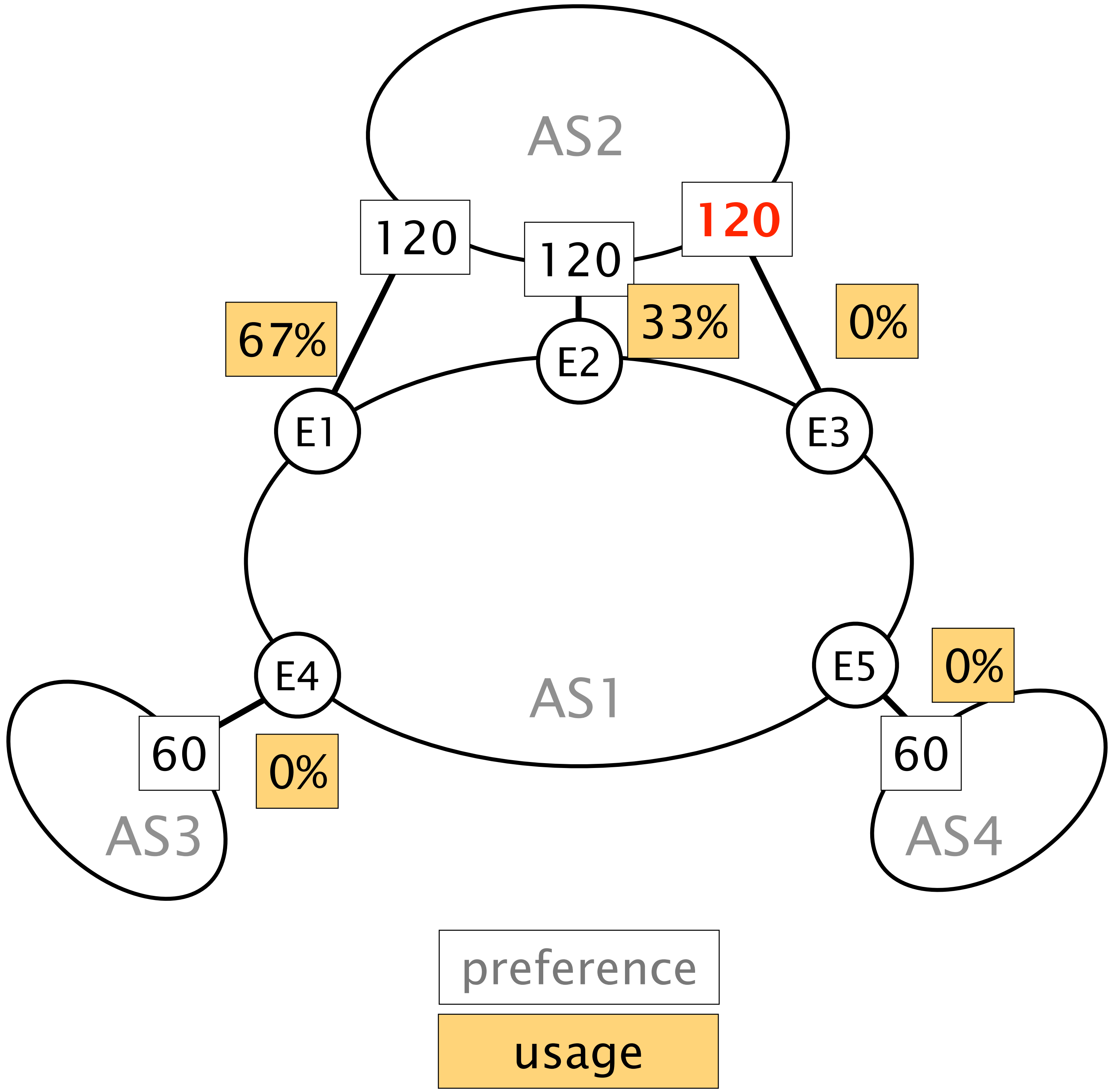
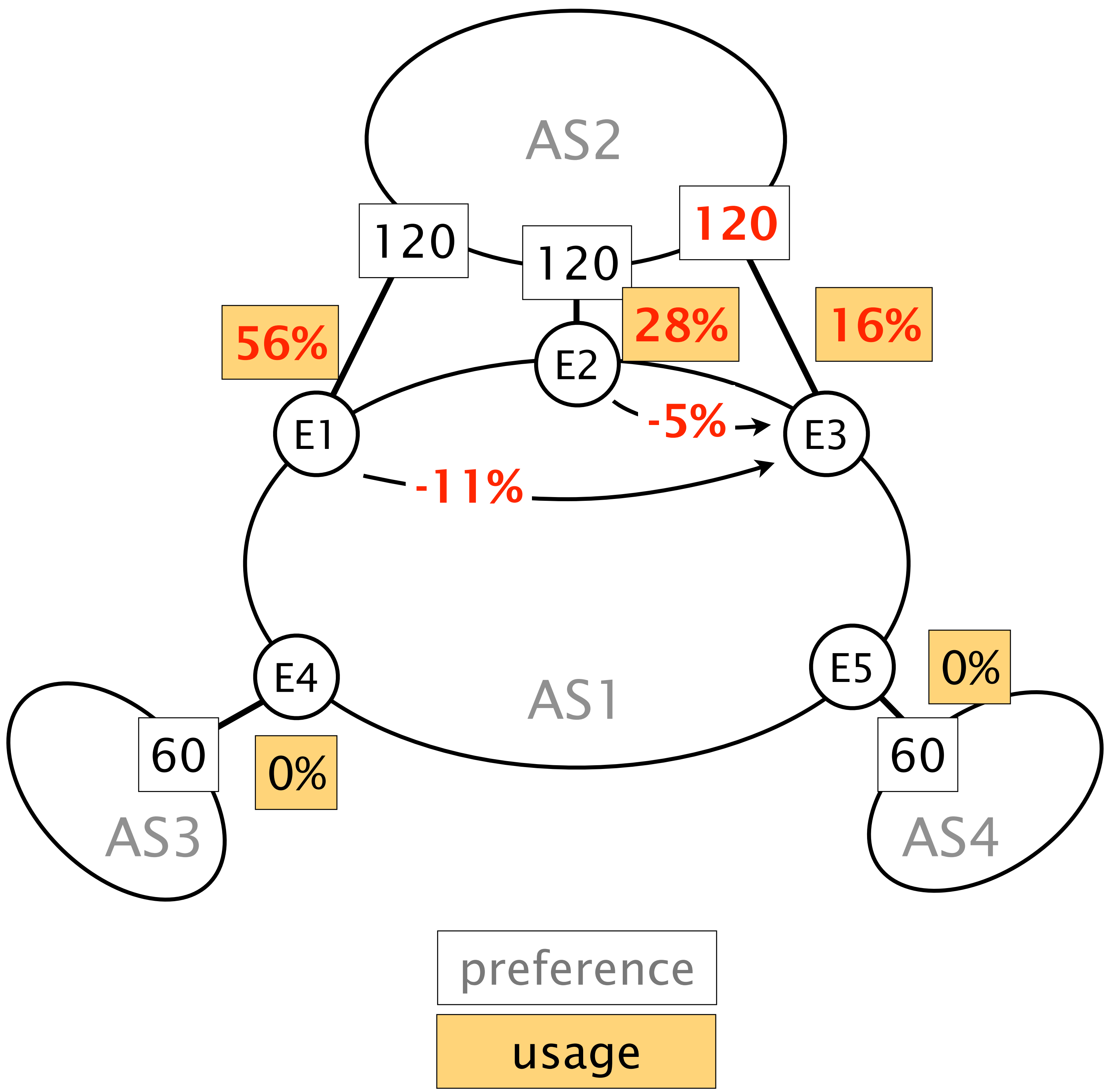


Let's say that AS2 becomes more preferred

60% of the traffic experience a traffic shift

33% of the traffic experience a traffic shift

16% of the traffic experience a traffic shift

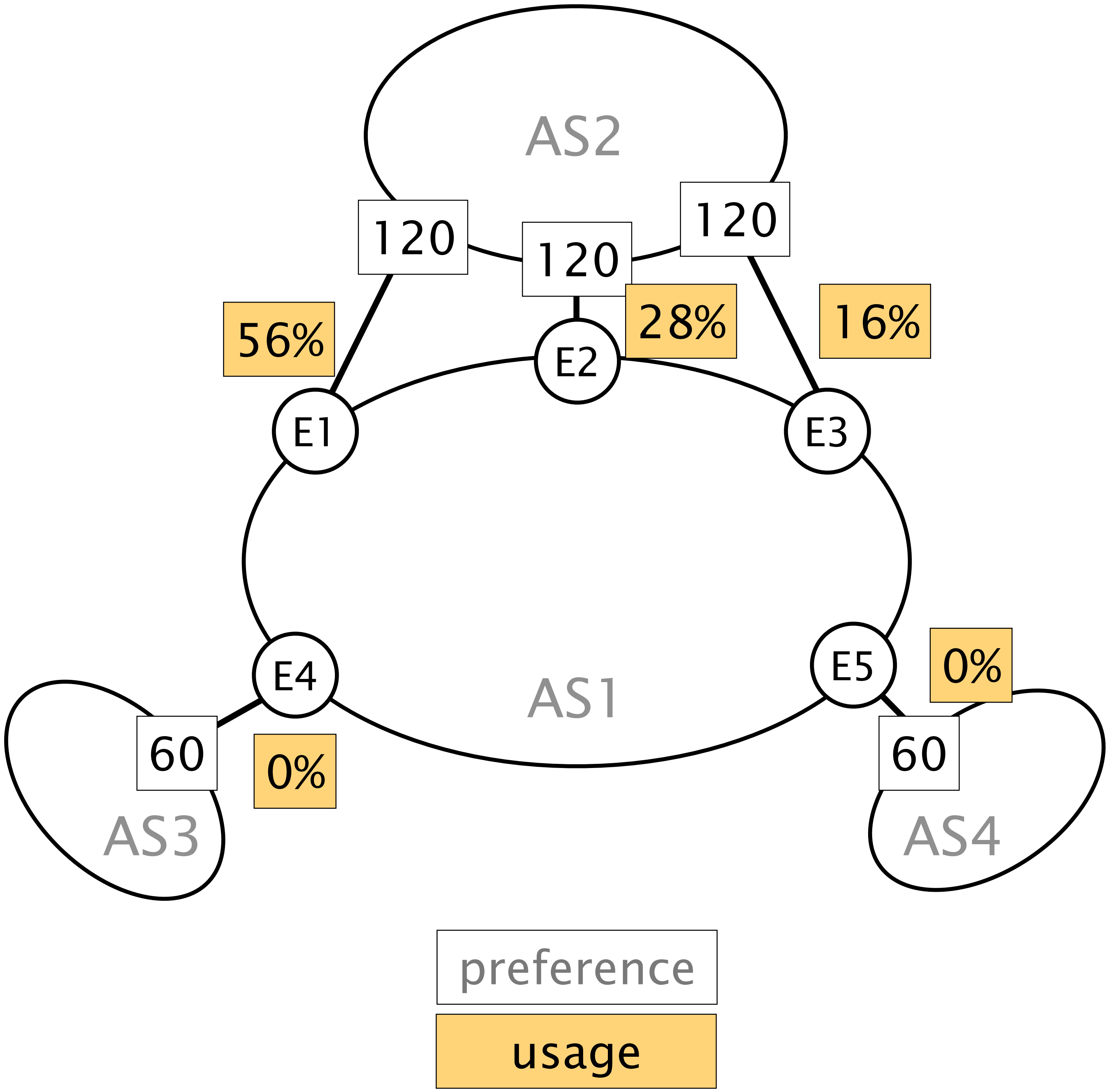


During the migration, 109% of the traffic has been shifted

60% of the traffic experience a traffic shift

33% of the traffic experience a traffic shift

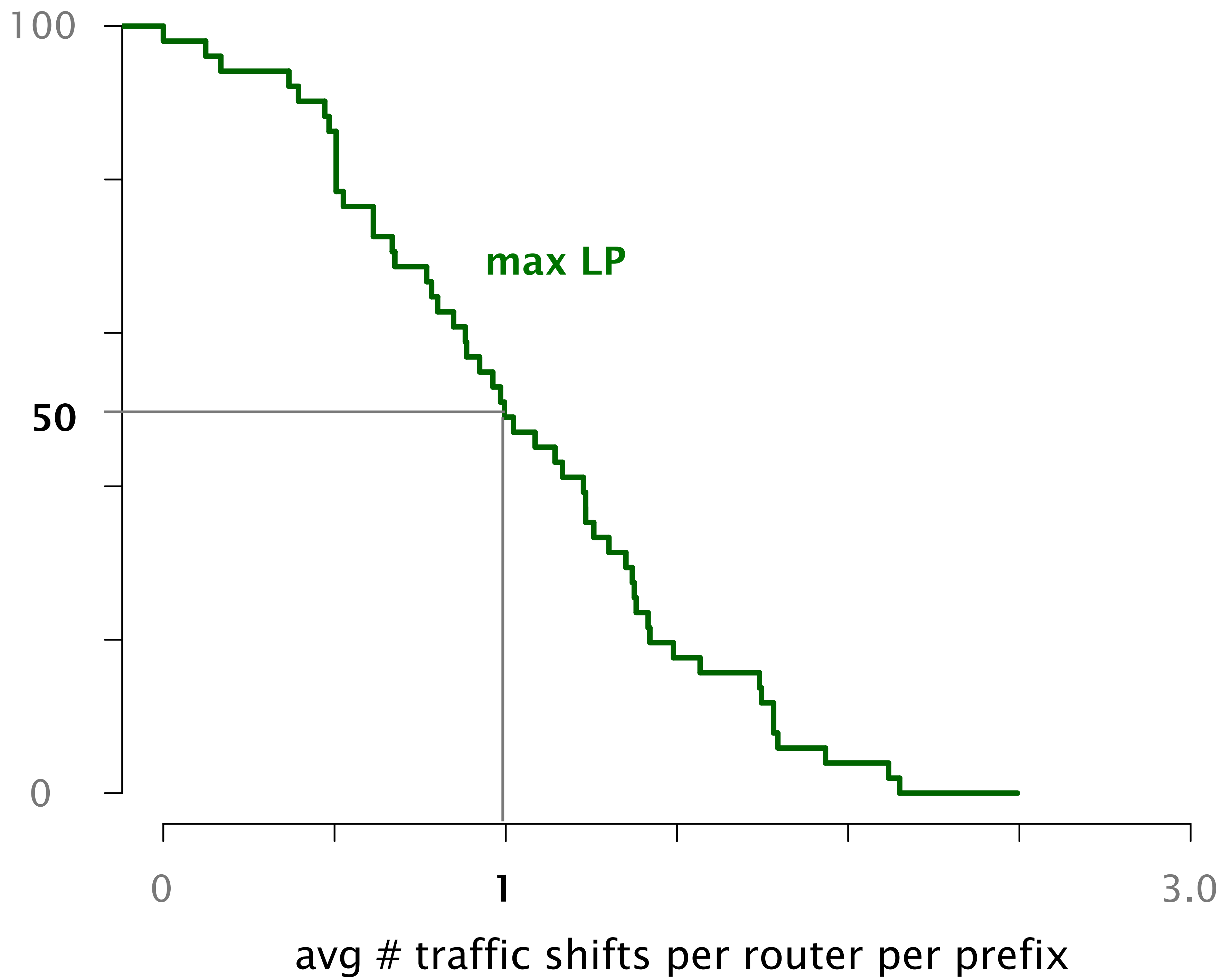
16% of the traffic experience a traffic shift



Tuning eBGP policies can create huge traffic shifts

Tier1 experiments
(cumul. frequency)

50% of the routers
experience > 1 TS
for each prefix



Improving network agility with seamless BGP reconfigurations

BGP reconfiguration

A crash course

2 Finding an ordering

Is it easy? Does it exist?

Reconfiguration framework

Overcome complexity

To avoid reconfiguration problems, a proper operational ordering must be enforced

Given an initial & final, anomaly-free, BGP configuration.

Find a sequence of configuration changes such that

- signaling anomalies
- dissemination anomalies
- forwarding anomalies

never occur, during any migration step

Find a sequence of configuration changes

Find a sequence of configuration changes

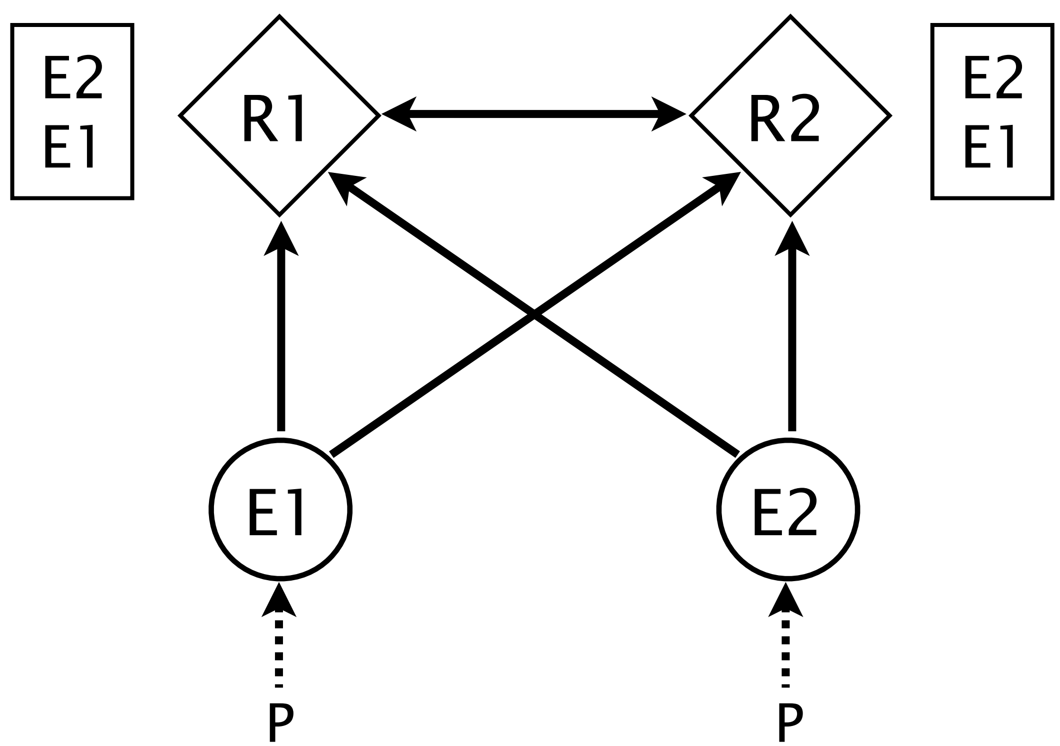
Does it always exist ?

Find a sequence of configuration changes

Does it always exist ?

Is it easy to compute ?

We model iBGP configurations by using extended Stable Path Problem instances



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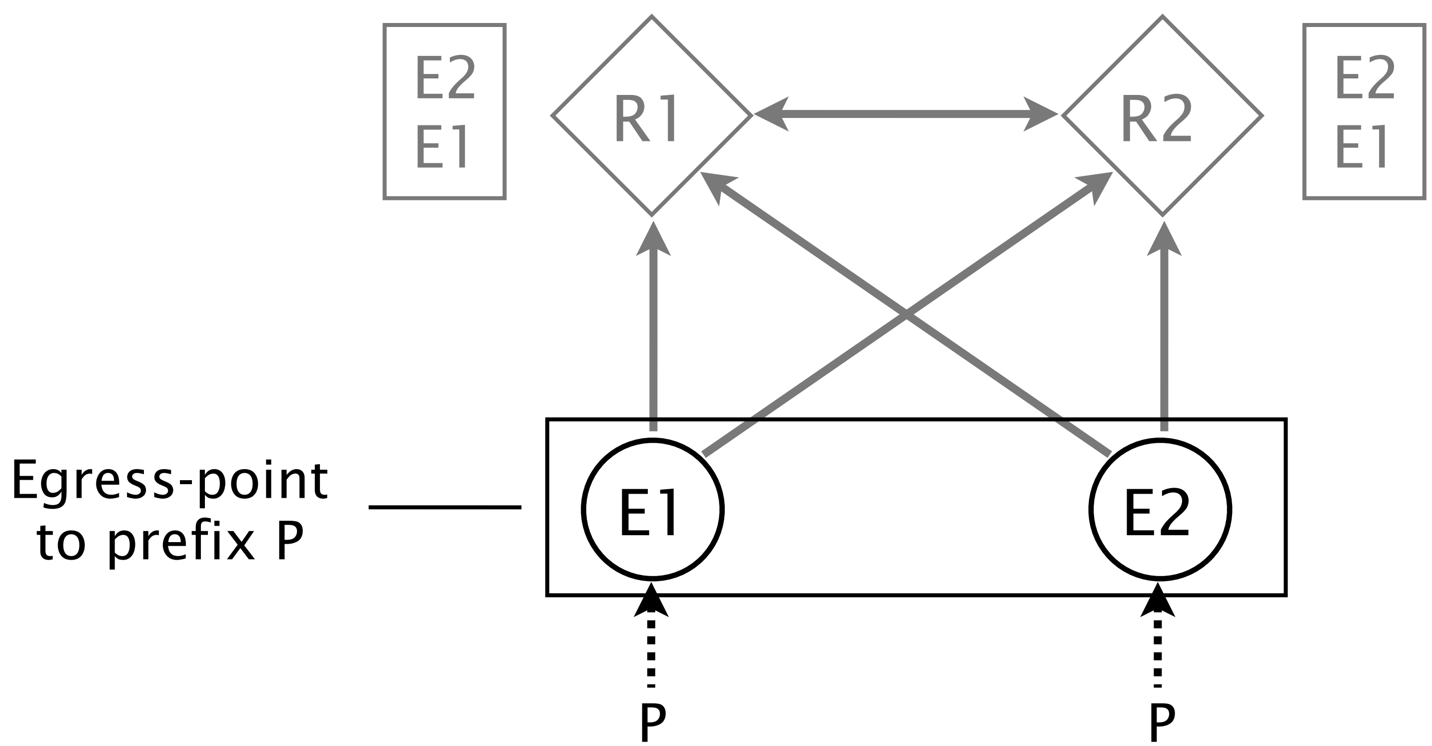

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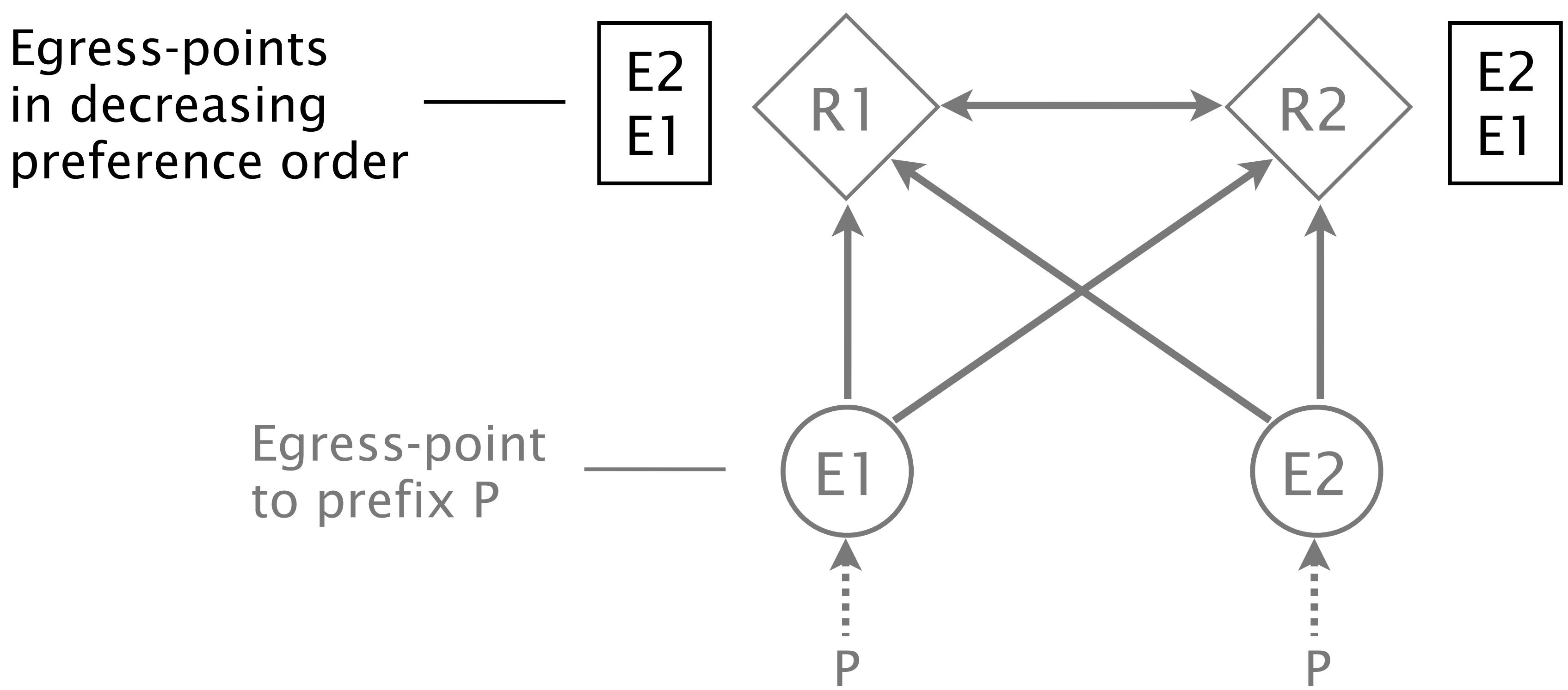

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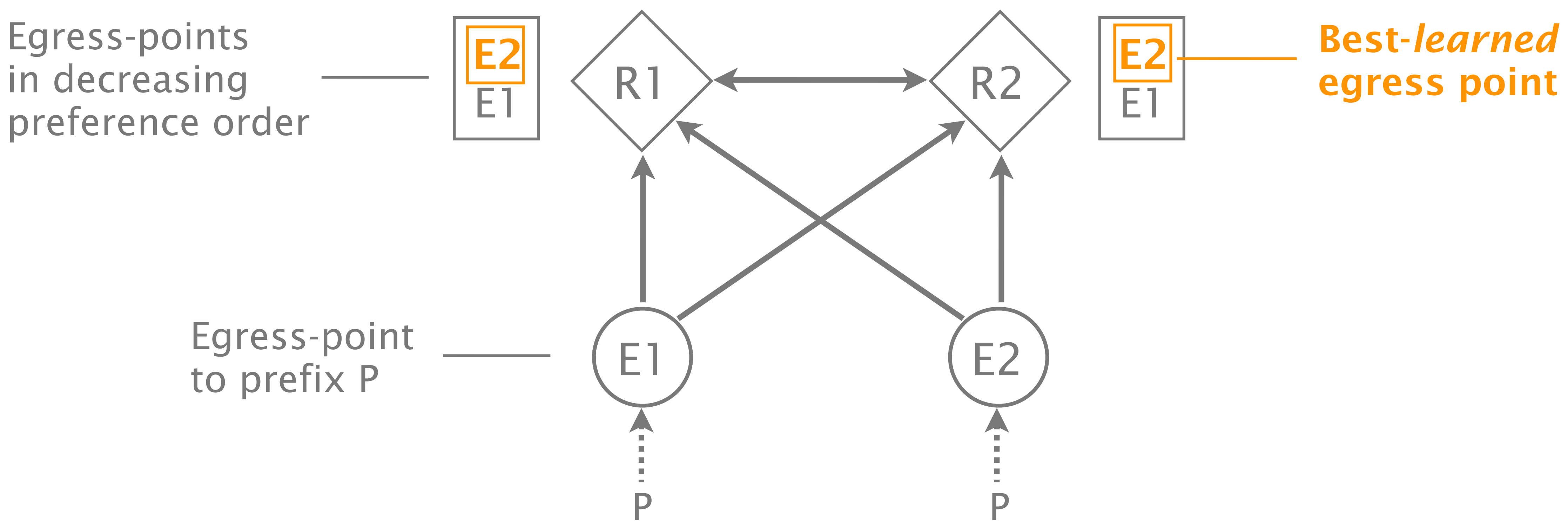
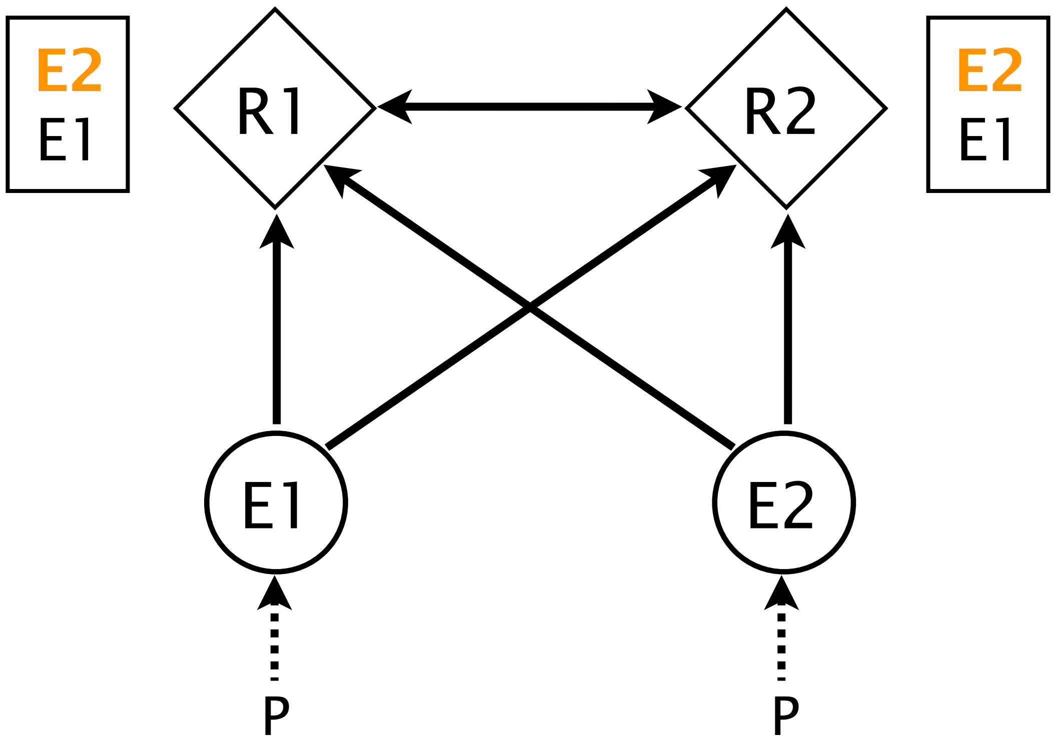
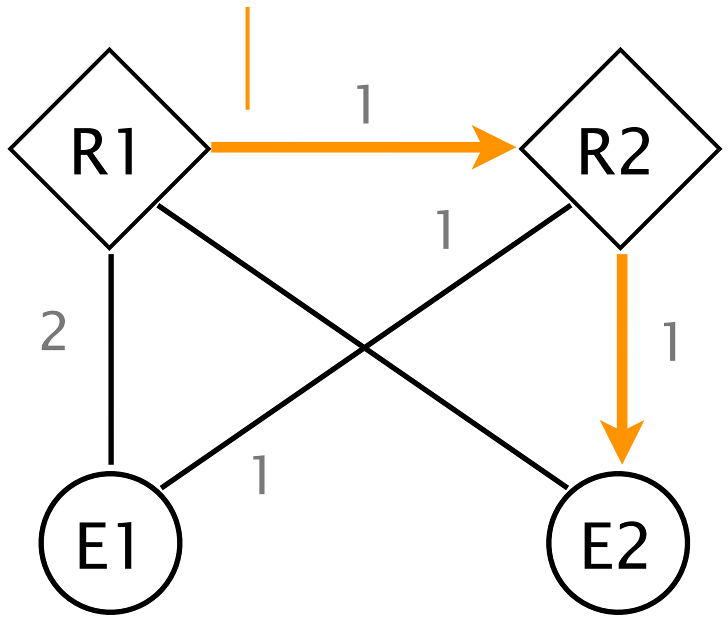


A stable BGP configuration determines the forwarding paths being used

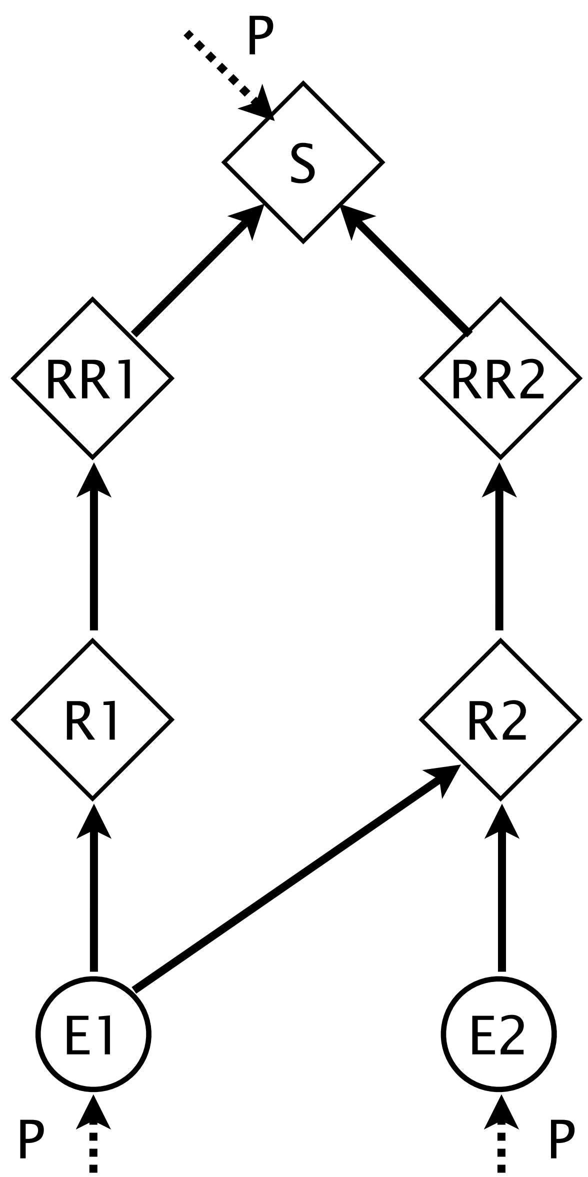


BGP configuration

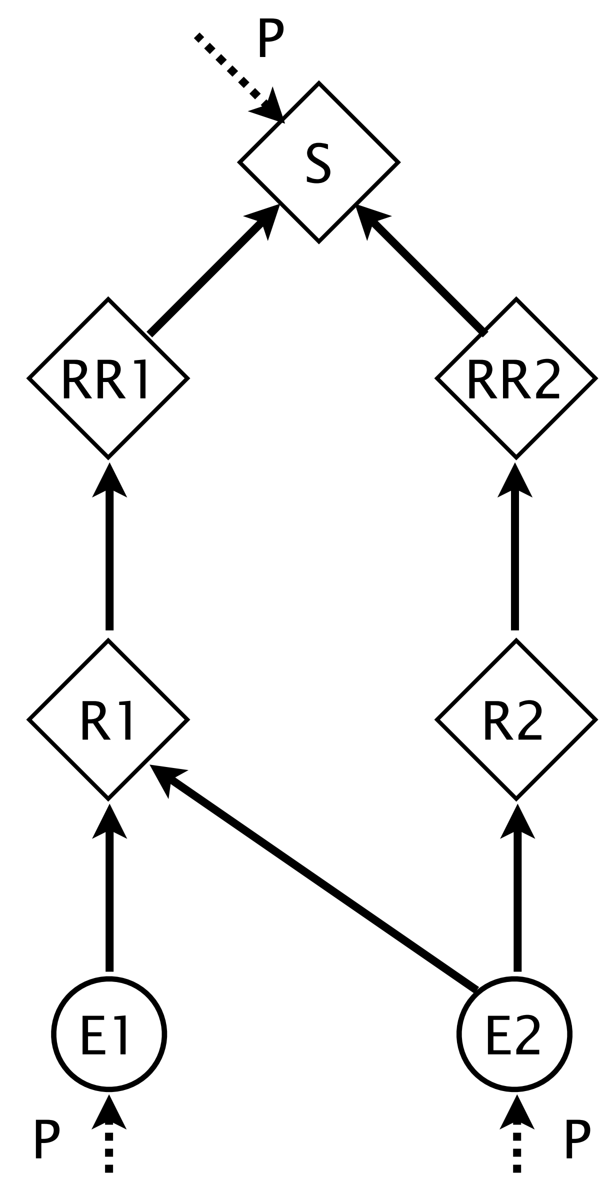


IGP configuration

A seamless migration ordering might not always exist

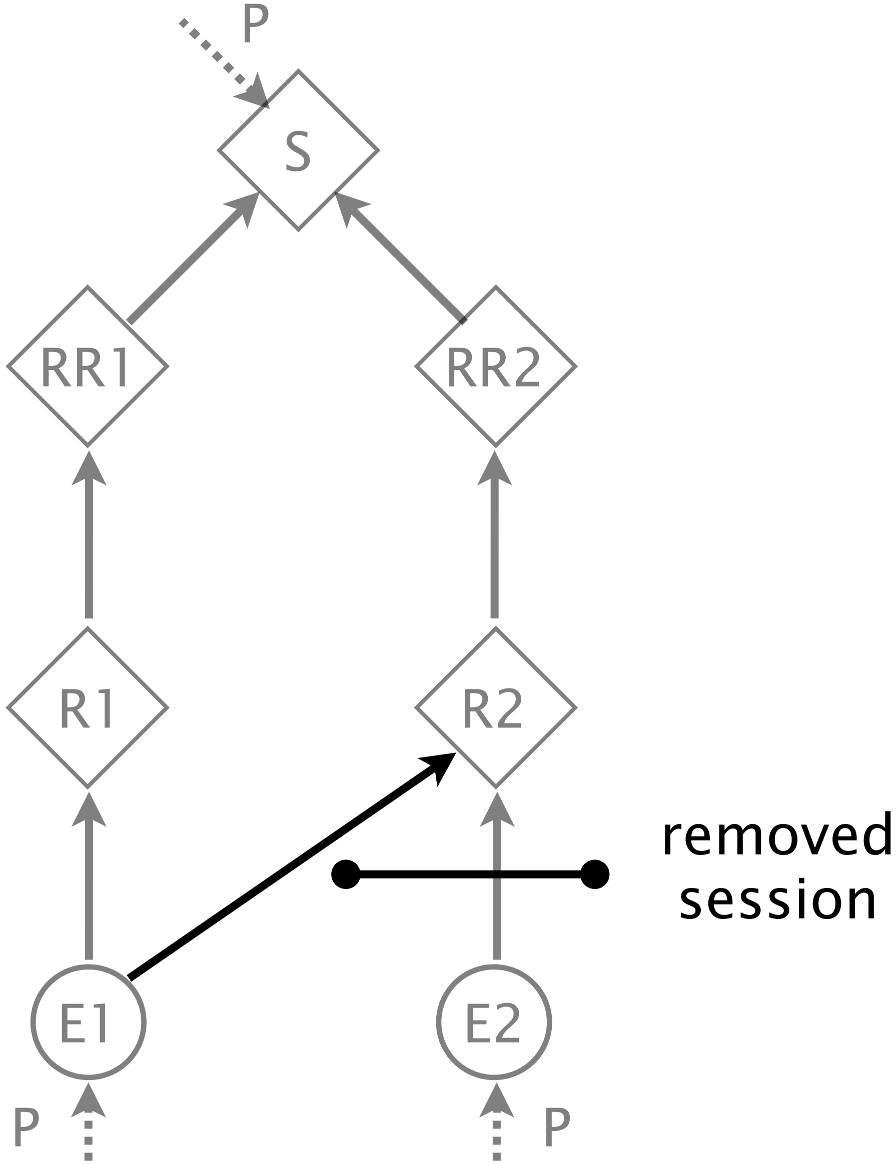


Initial BGP configuration

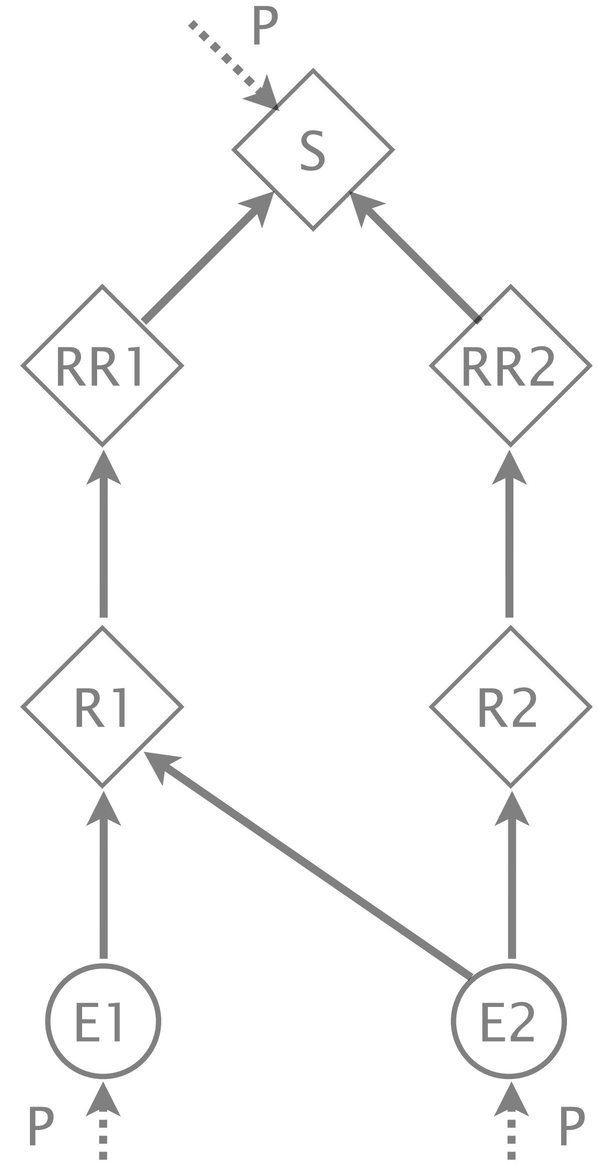


Final BGP configuration

A seamless migration ordering might not always exist



Initial BGP configuration



Final BGP configuration

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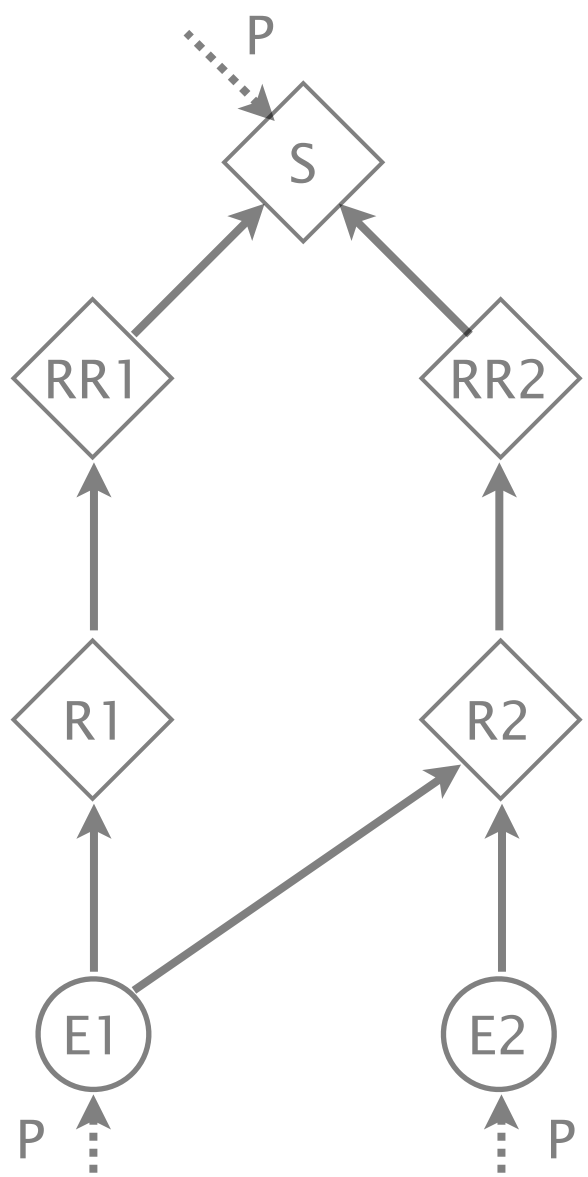

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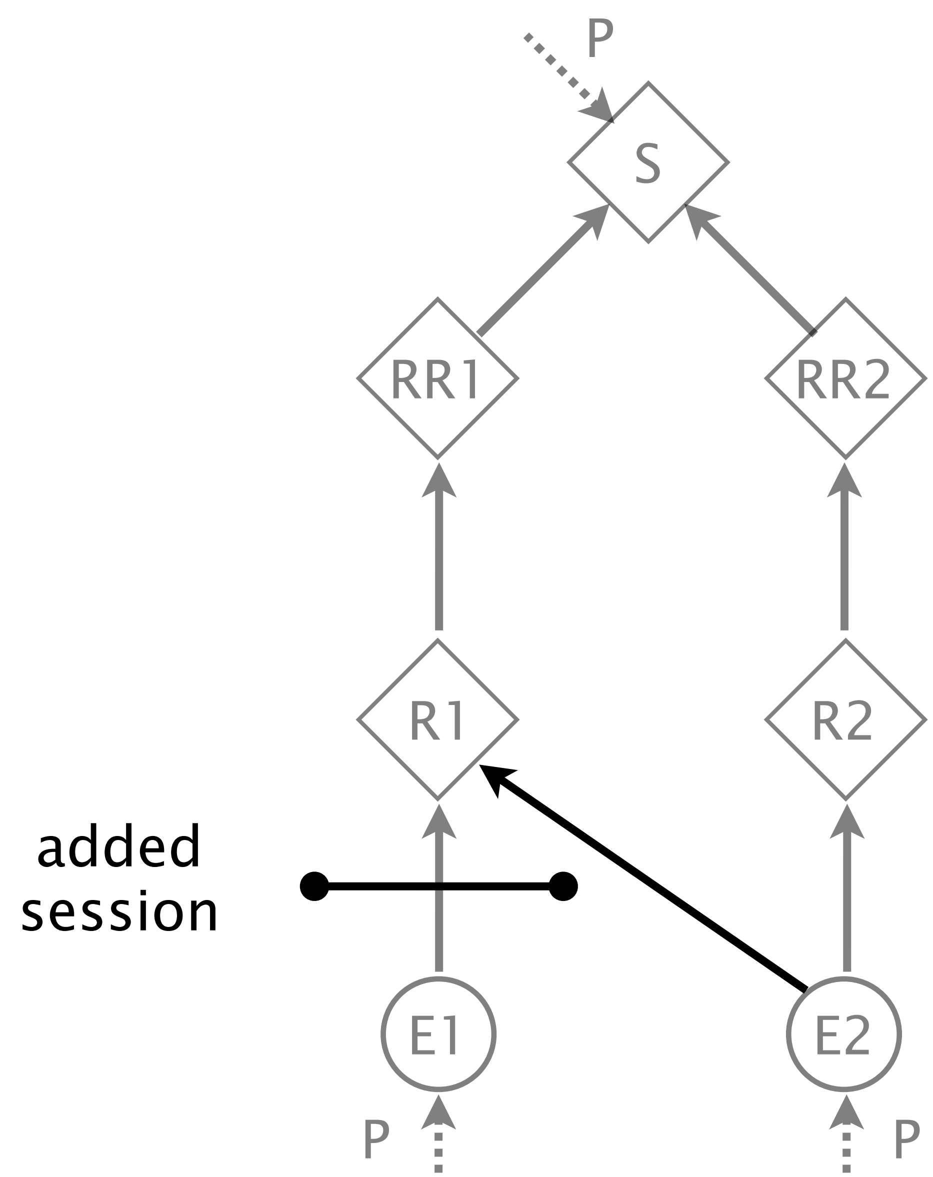
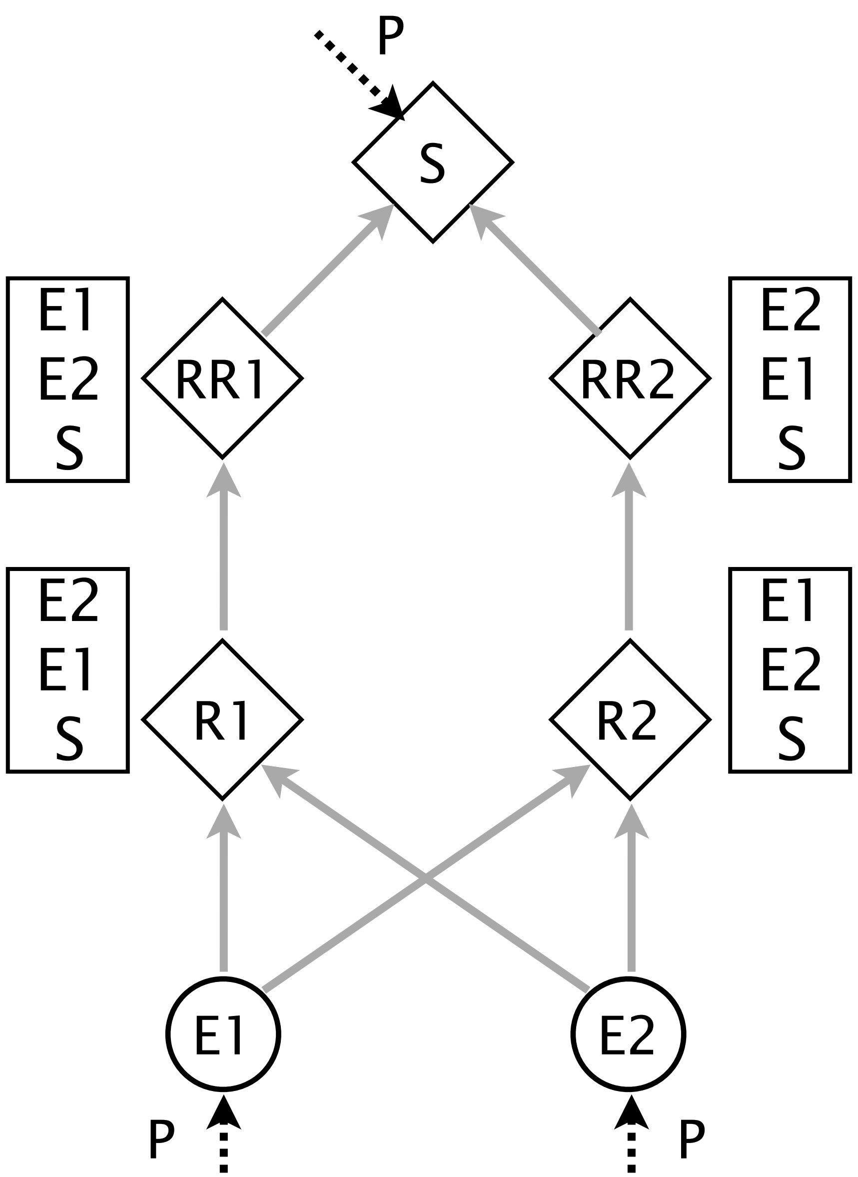
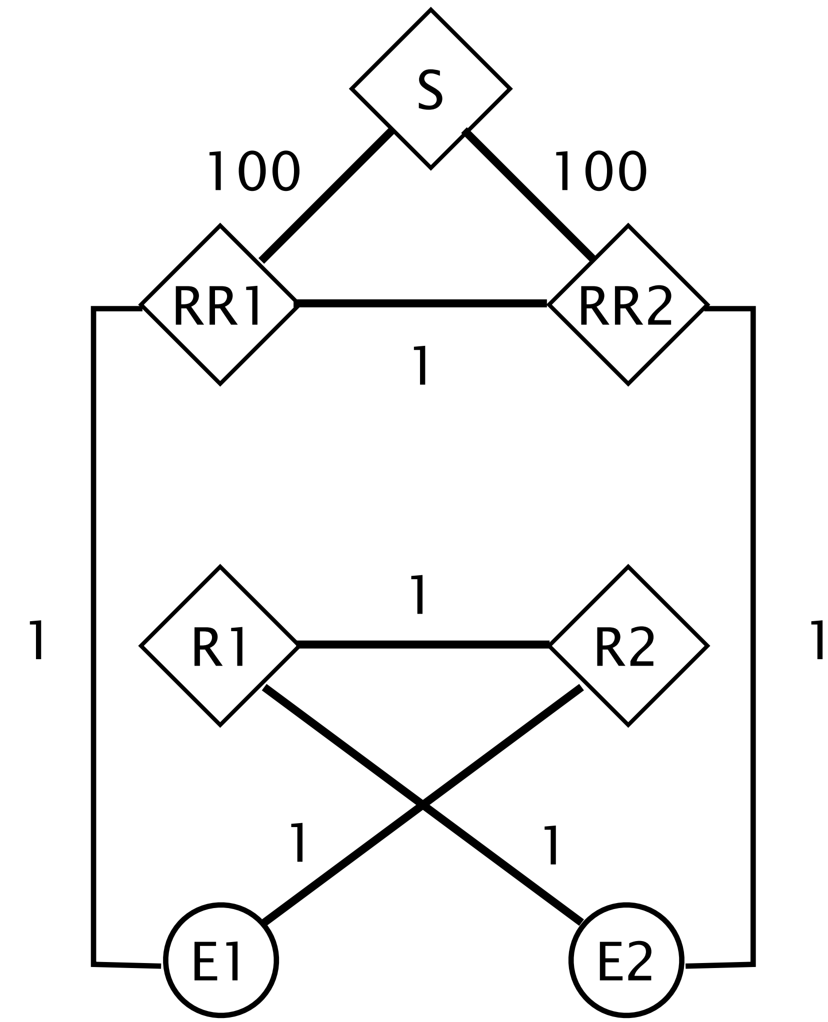


Final BGP configuration

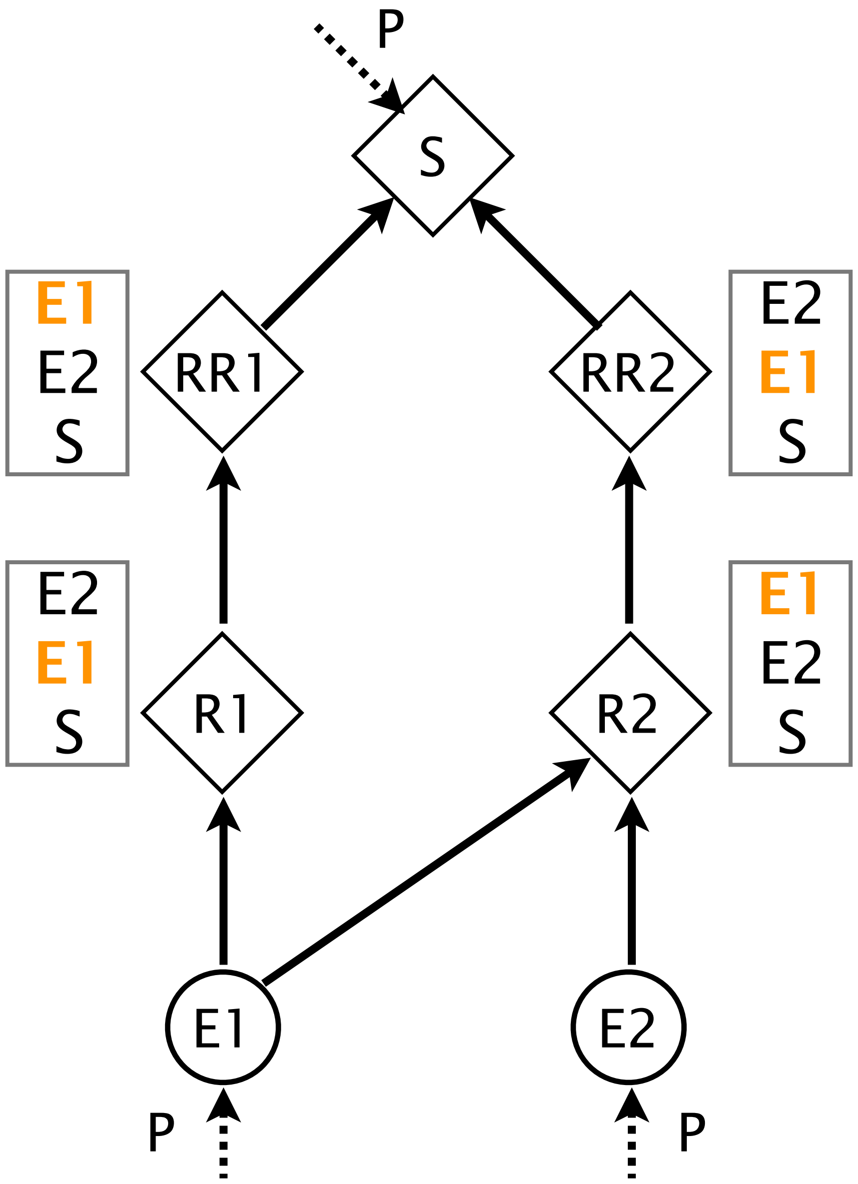


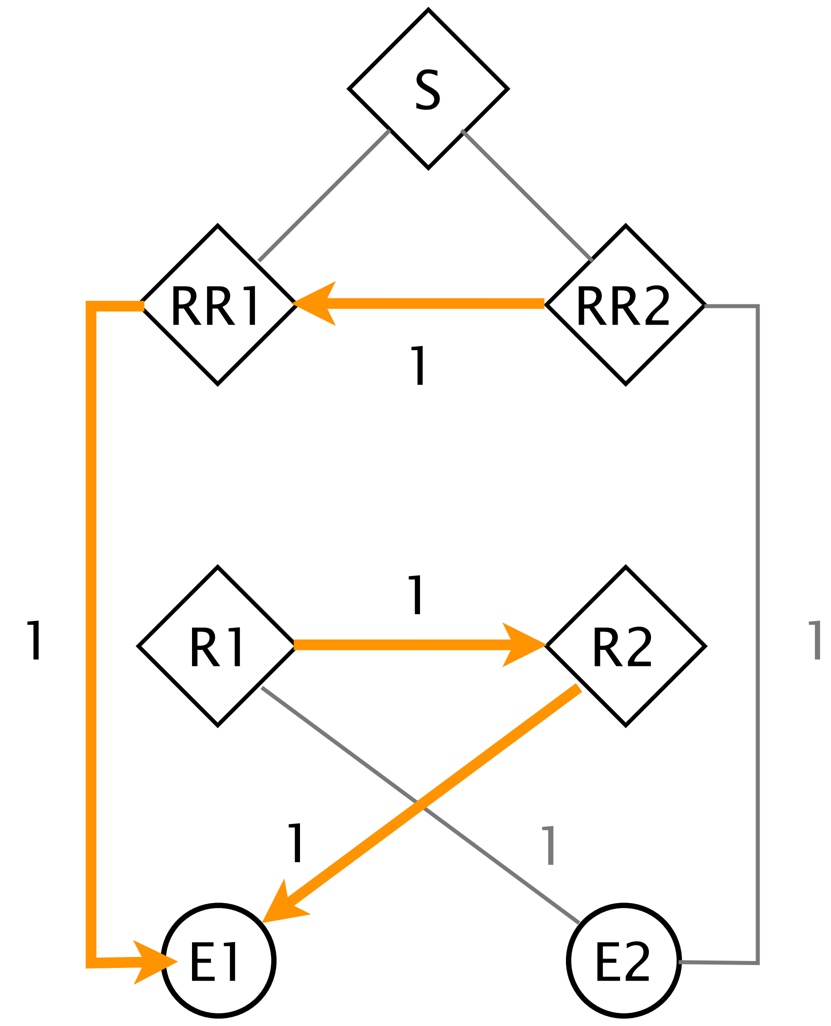
Path preferences



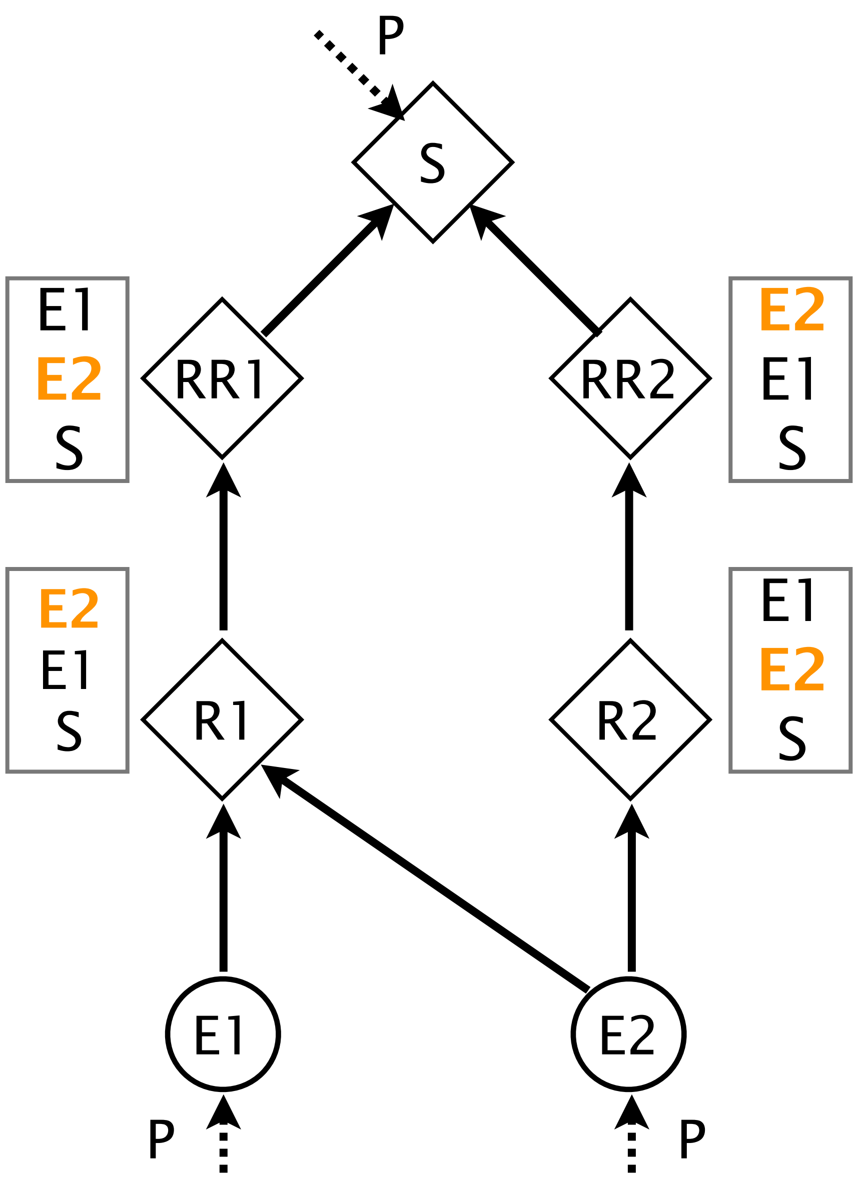
IGP configuration

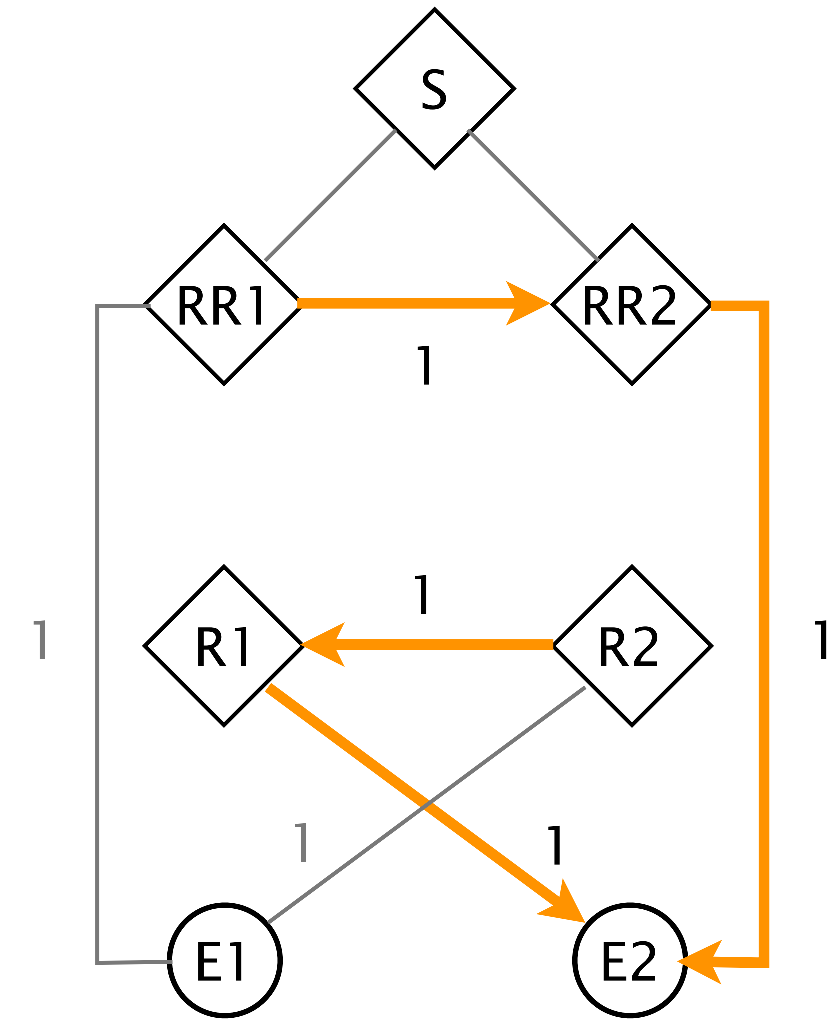
The initial configuration is anomaly-free



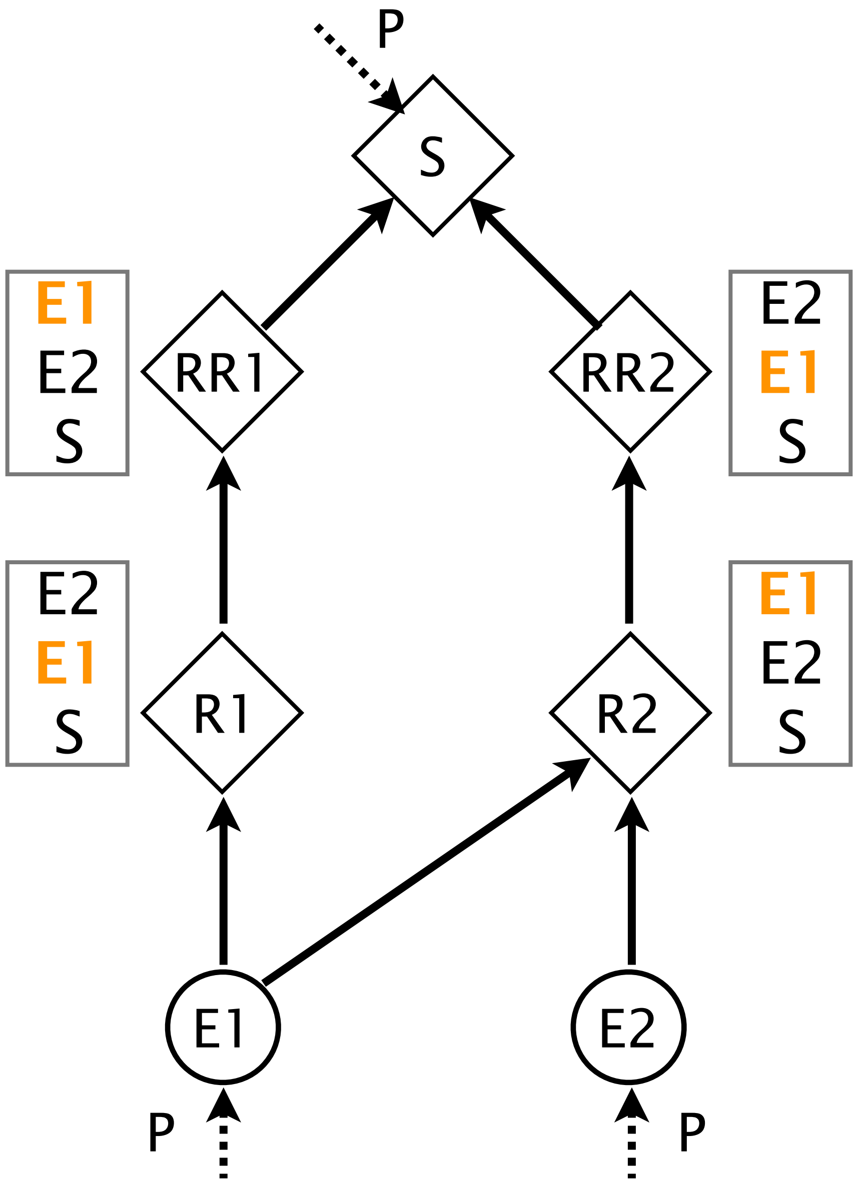


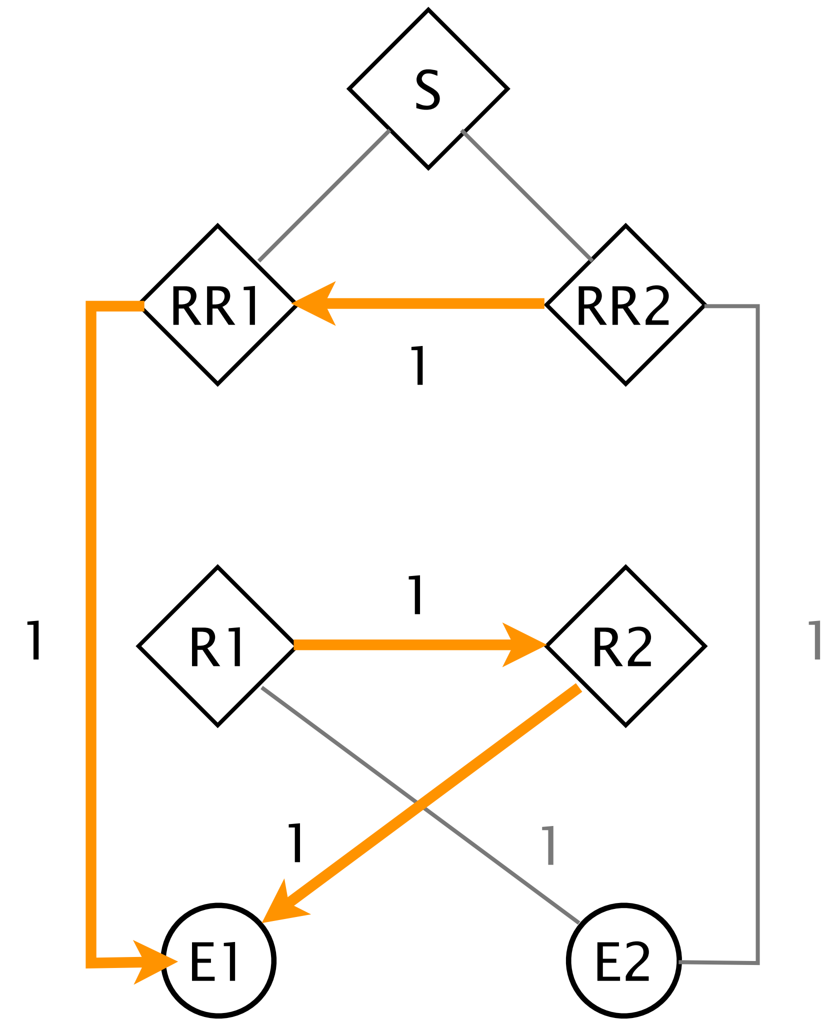
The final configuration is anomaly-free





Let's add the final session before removing the initial one





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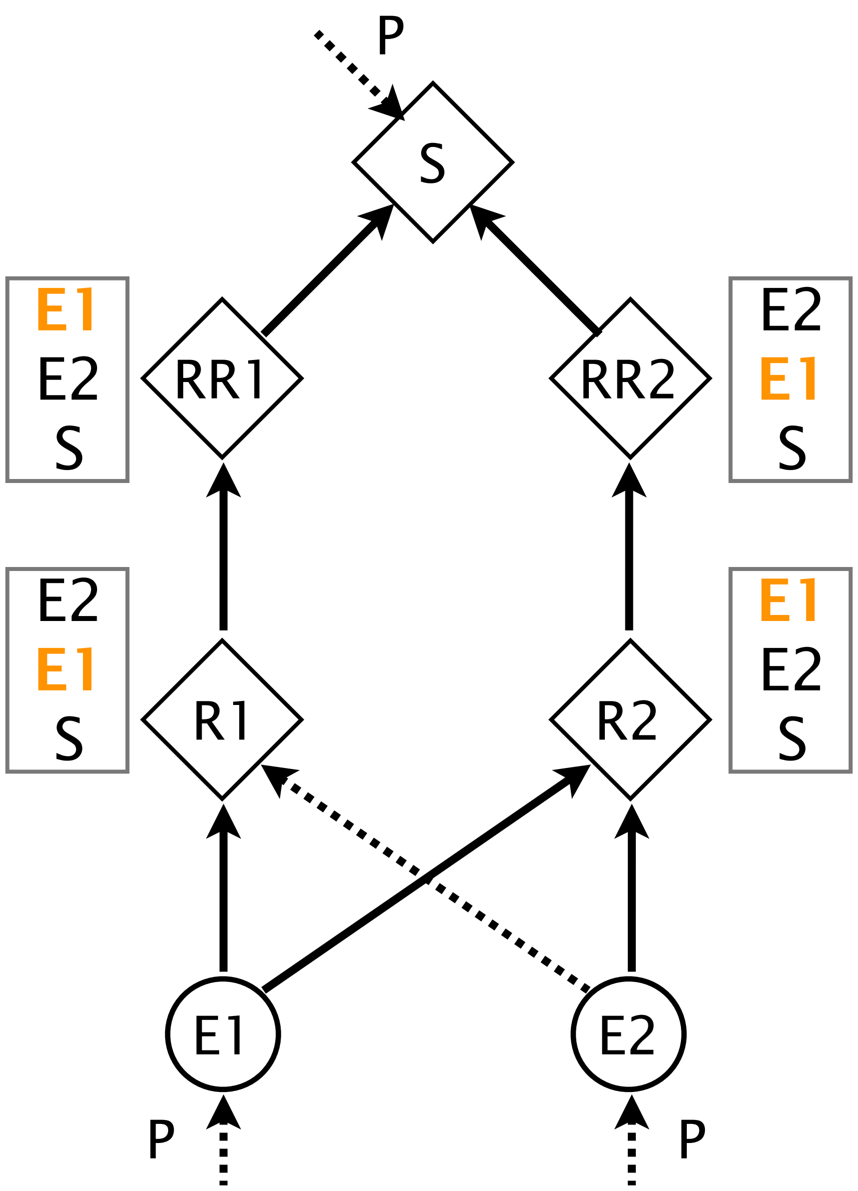
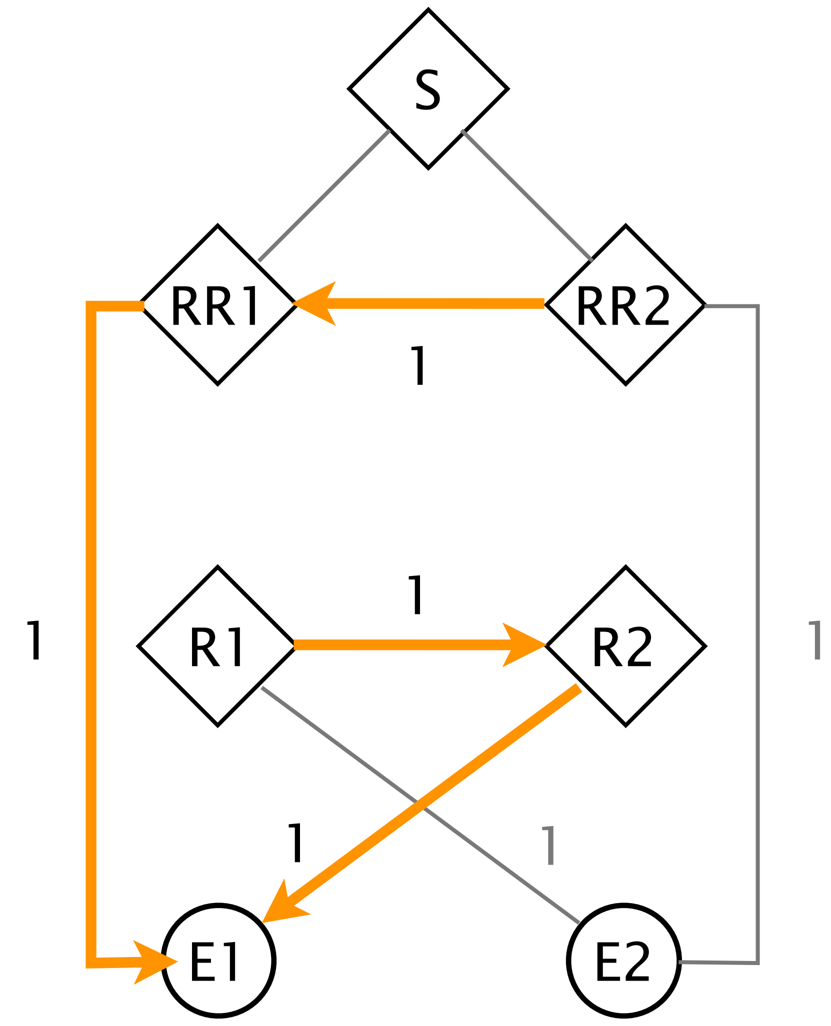
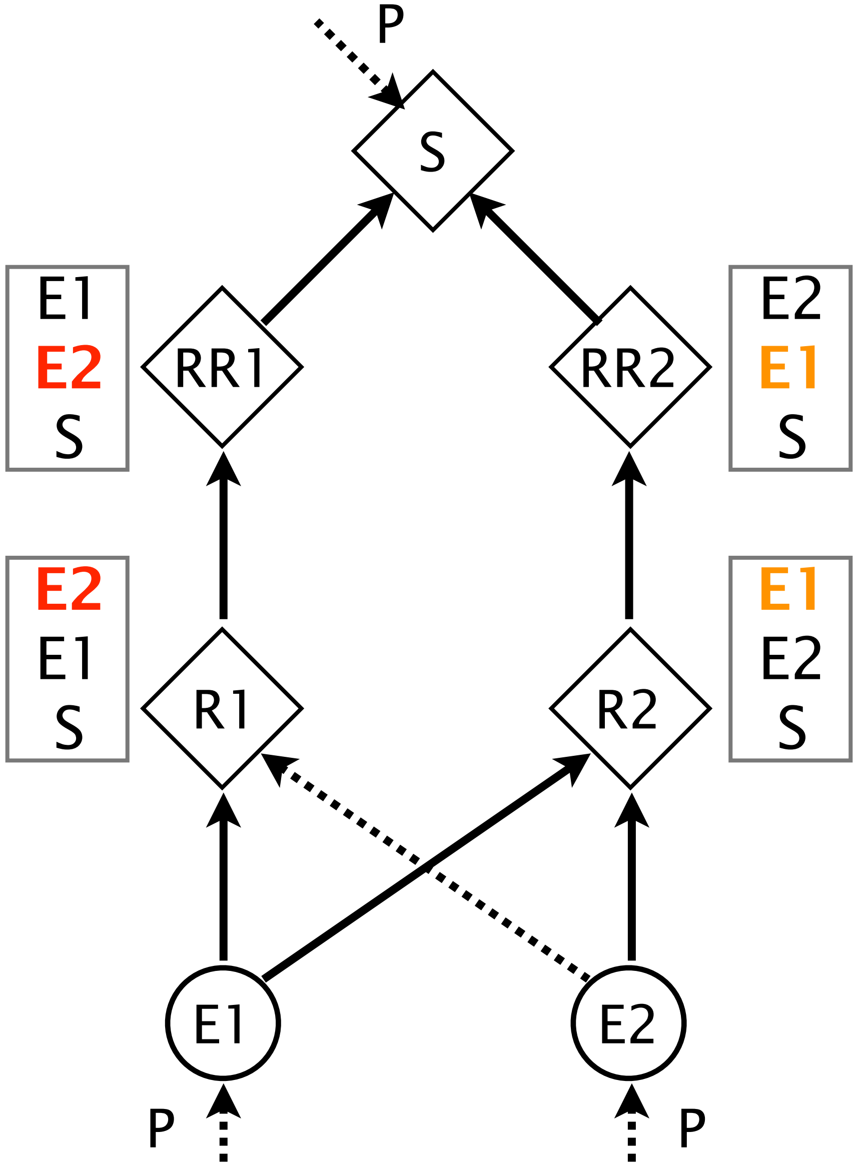
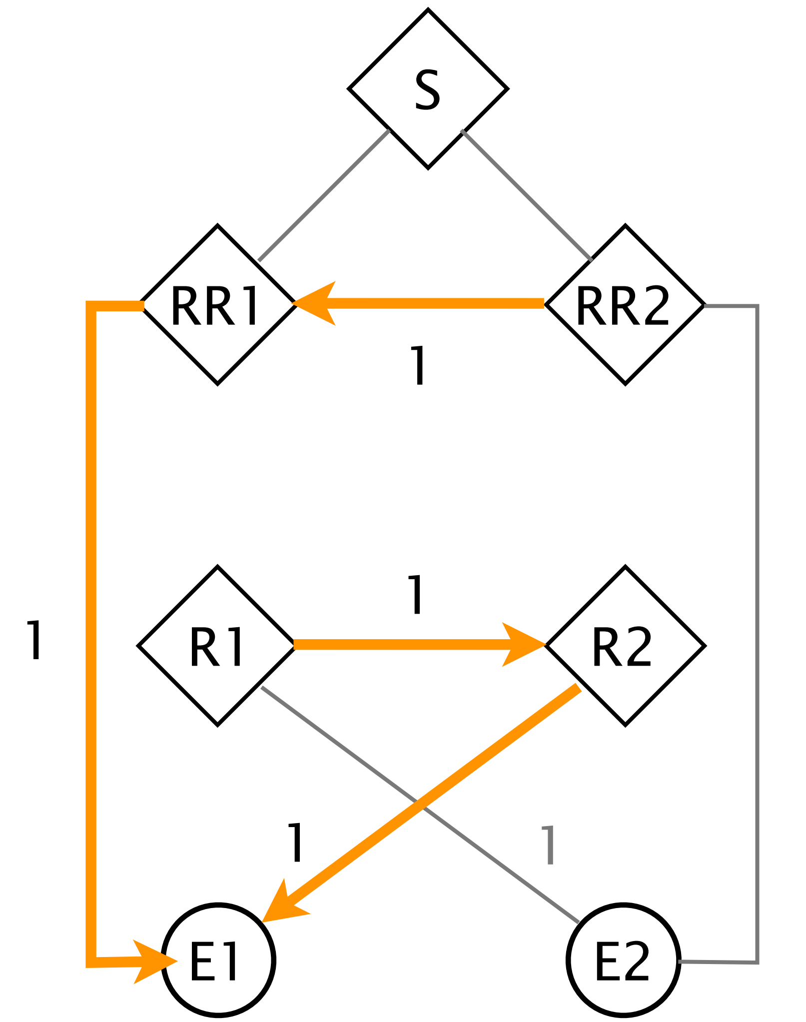


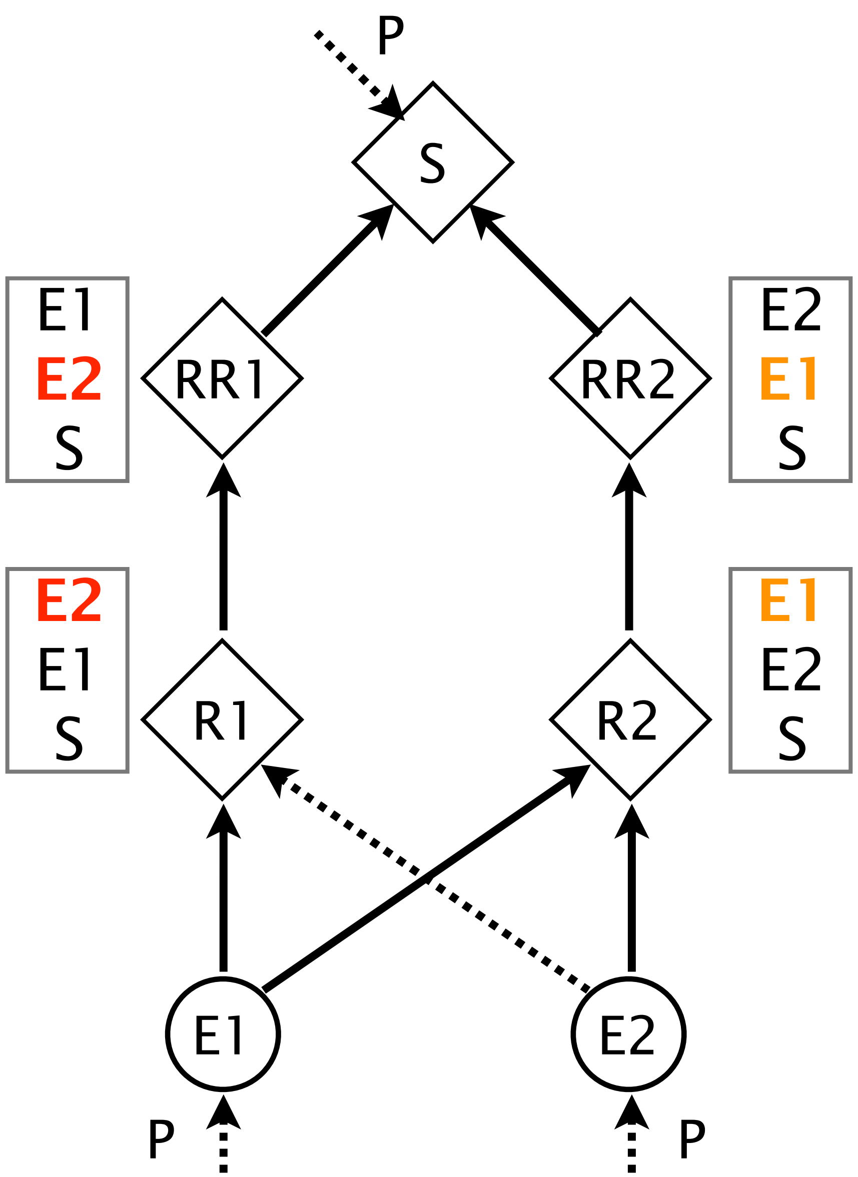


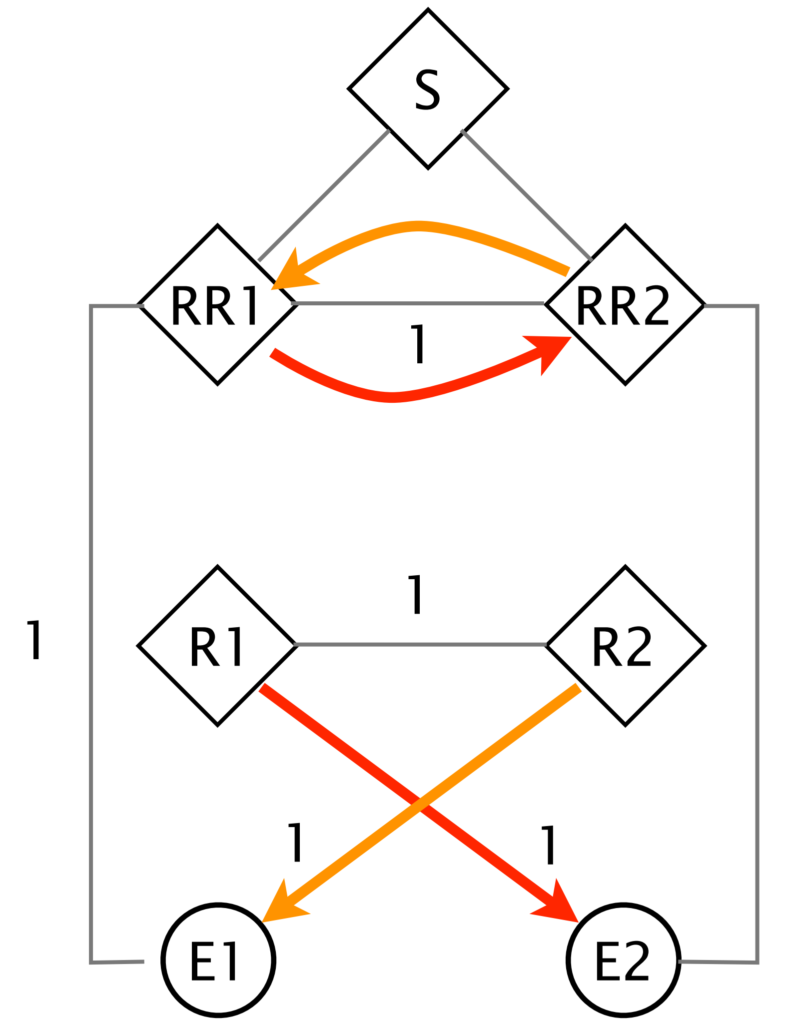
R1 now learns and selects E2, forcing RR1 to use E2 as well



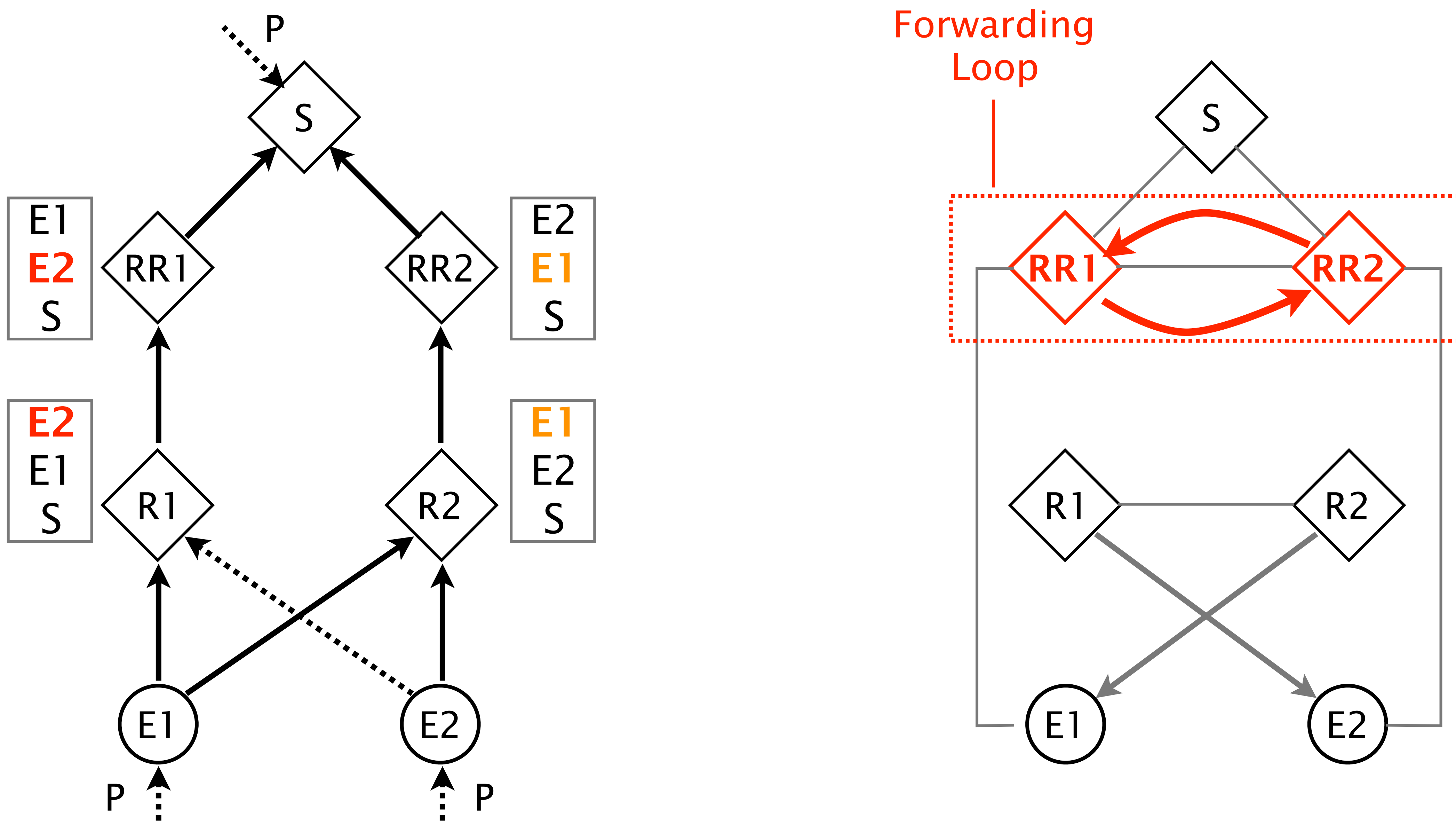


RR1 uses RR2 to reach E2, and
RR2 uses RR1 to reach E1 ...

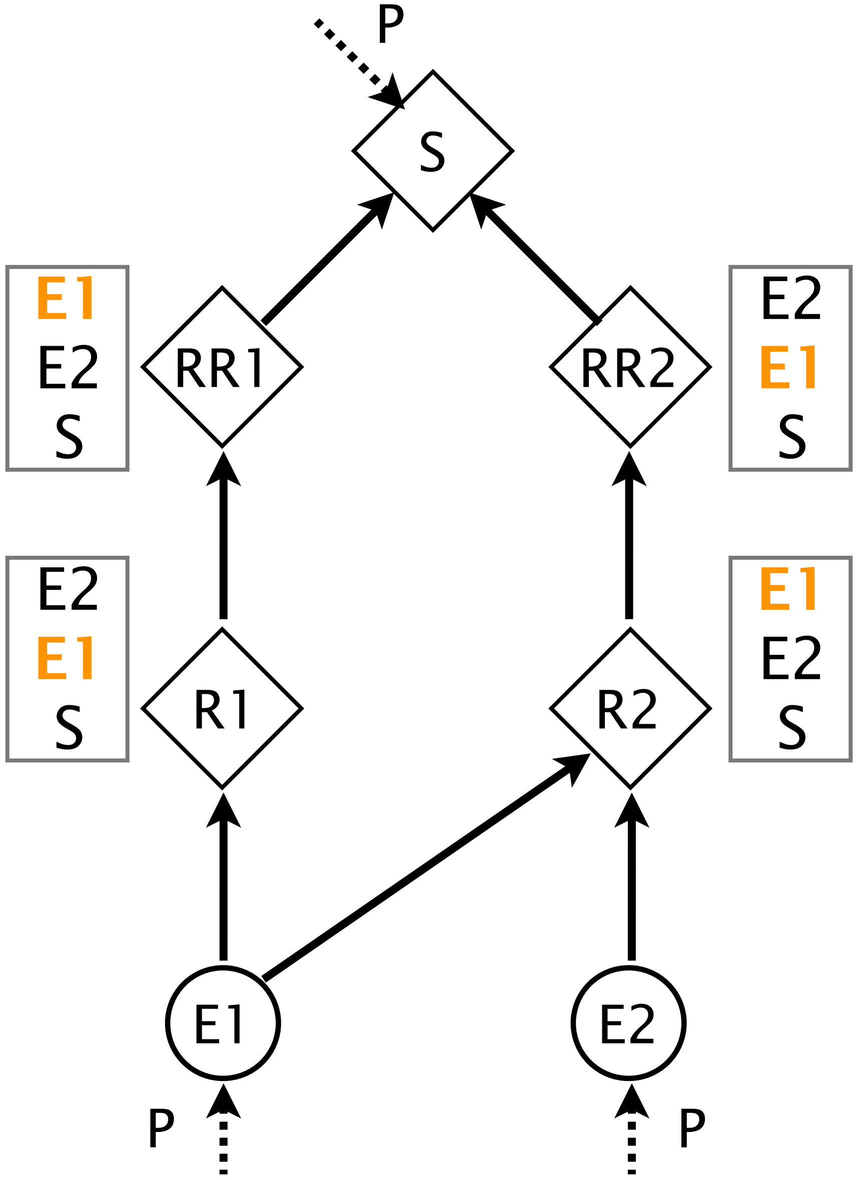


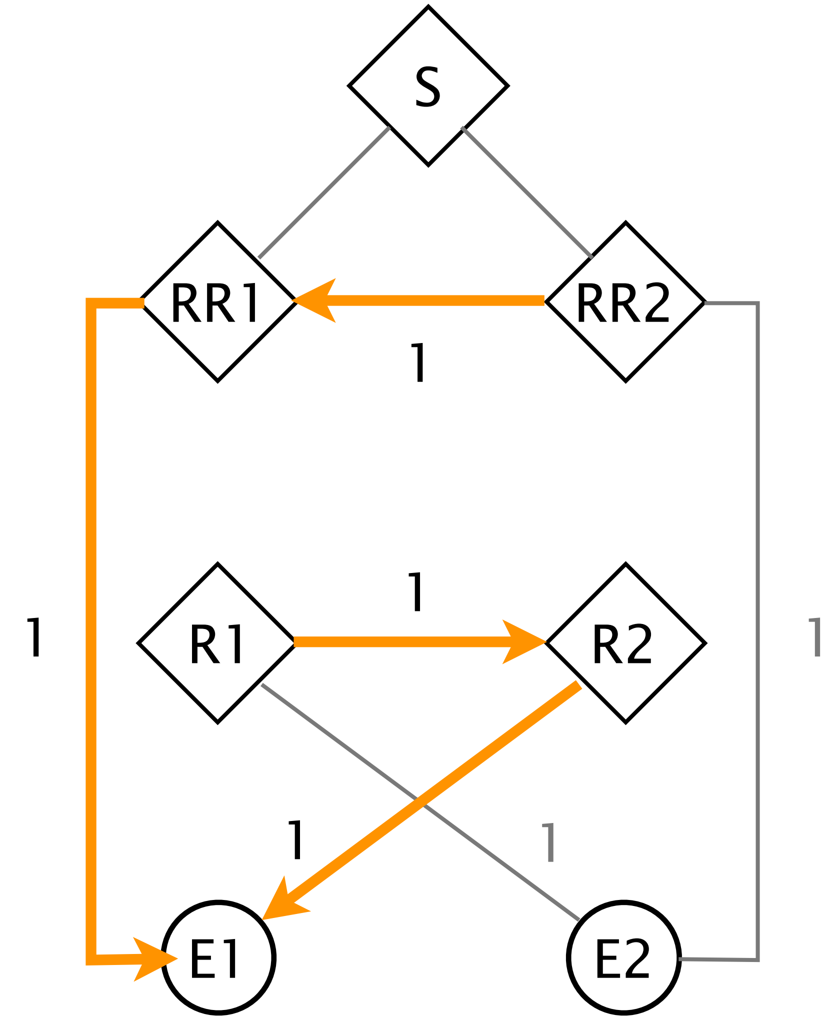


which creates a forwarding loops



Let's remove the initial session before adding the final one





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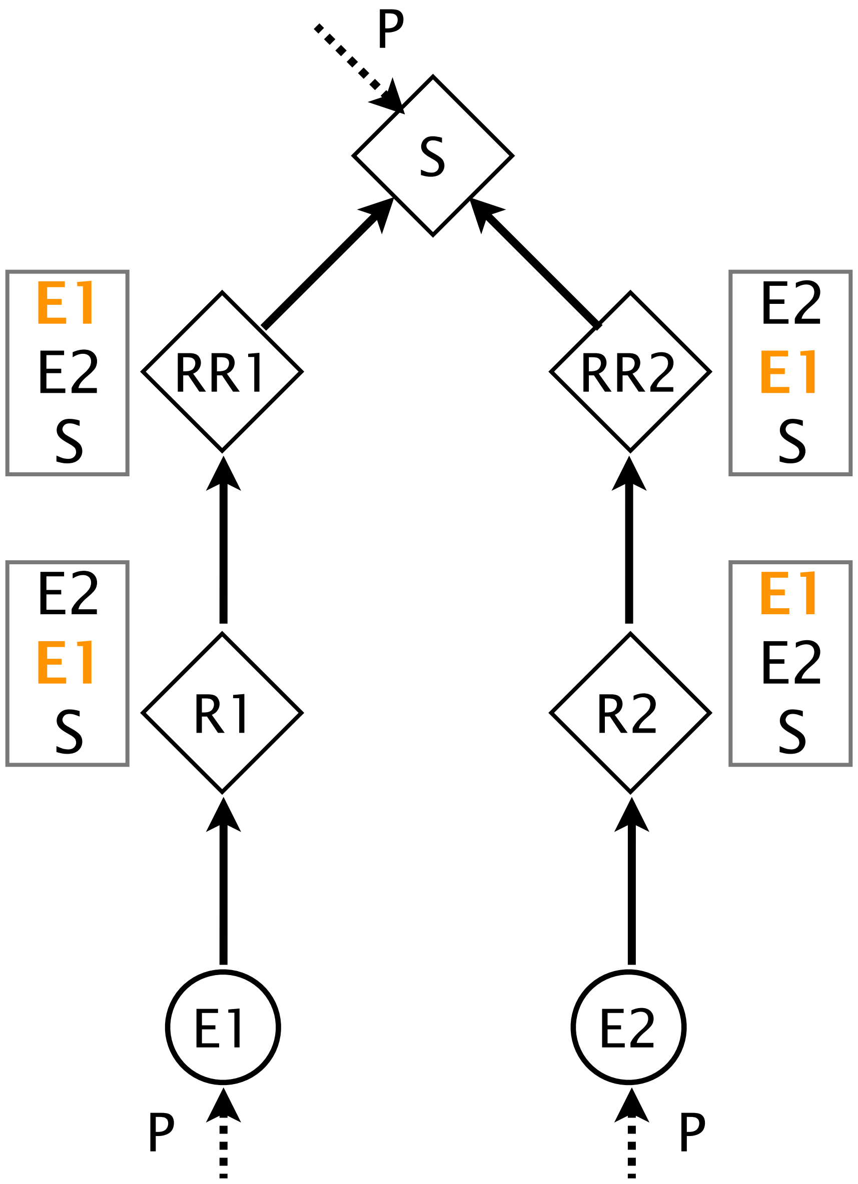
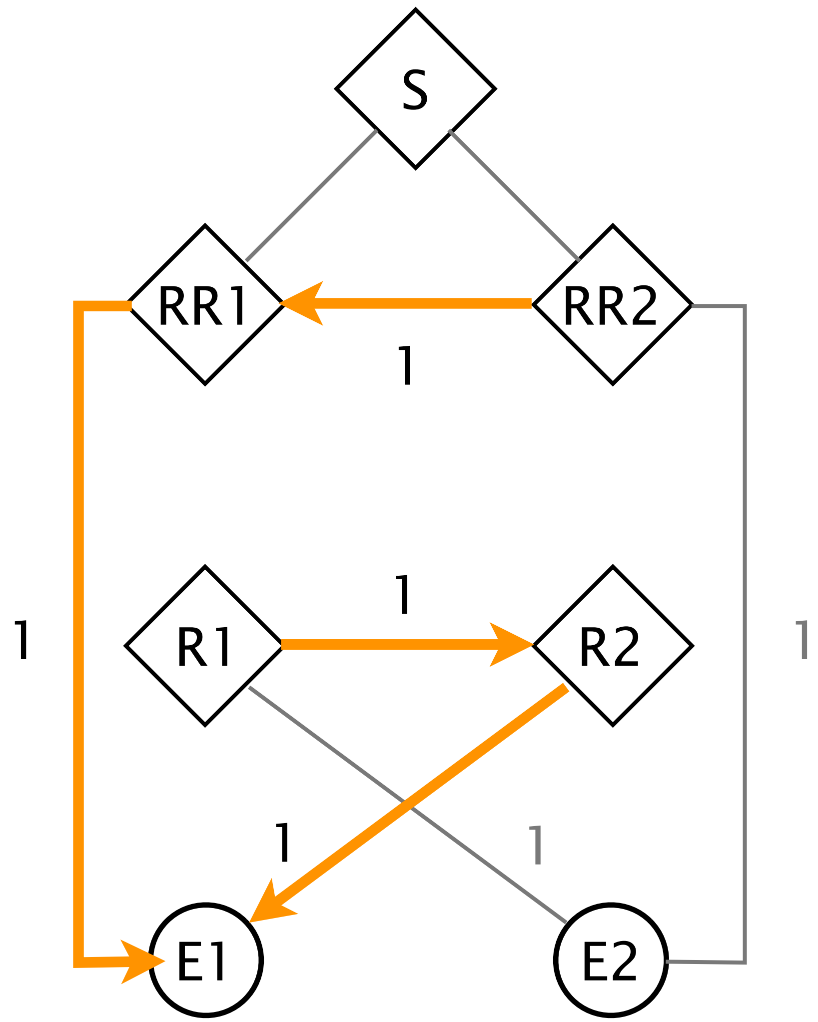
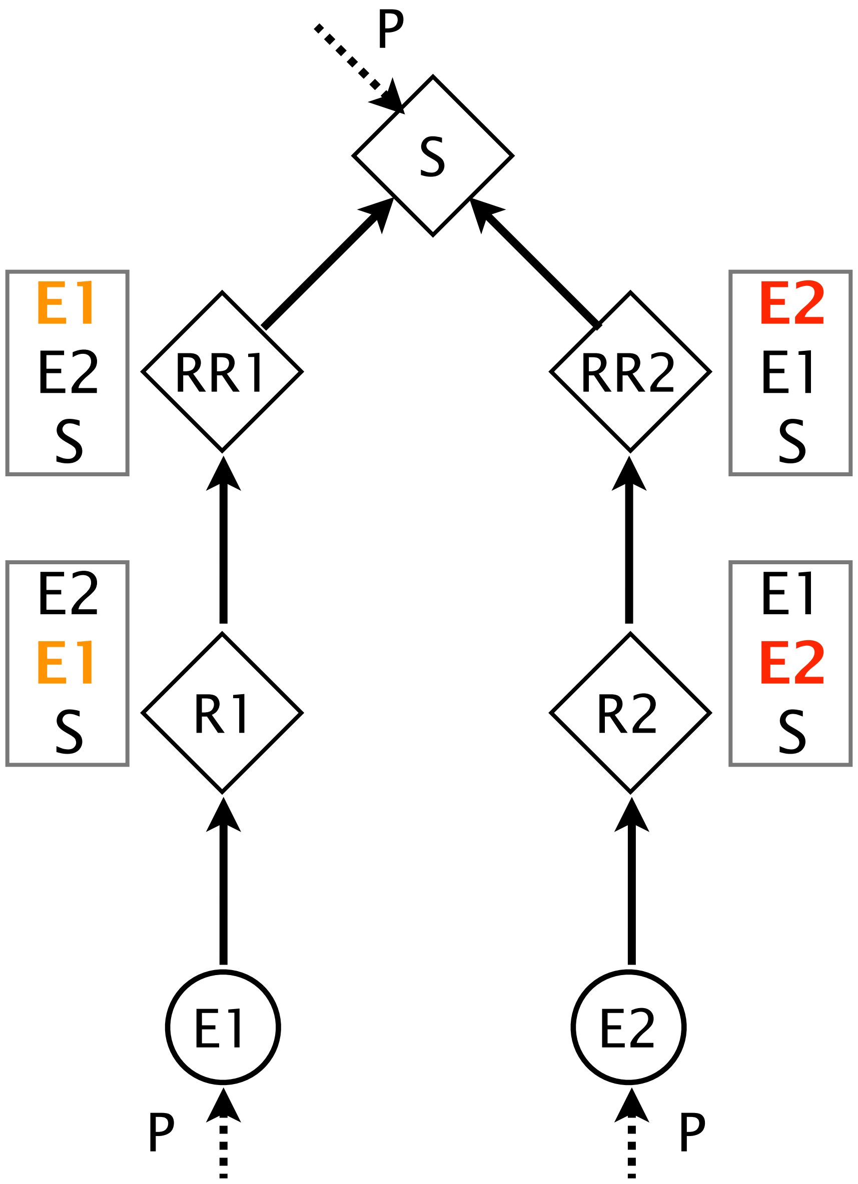
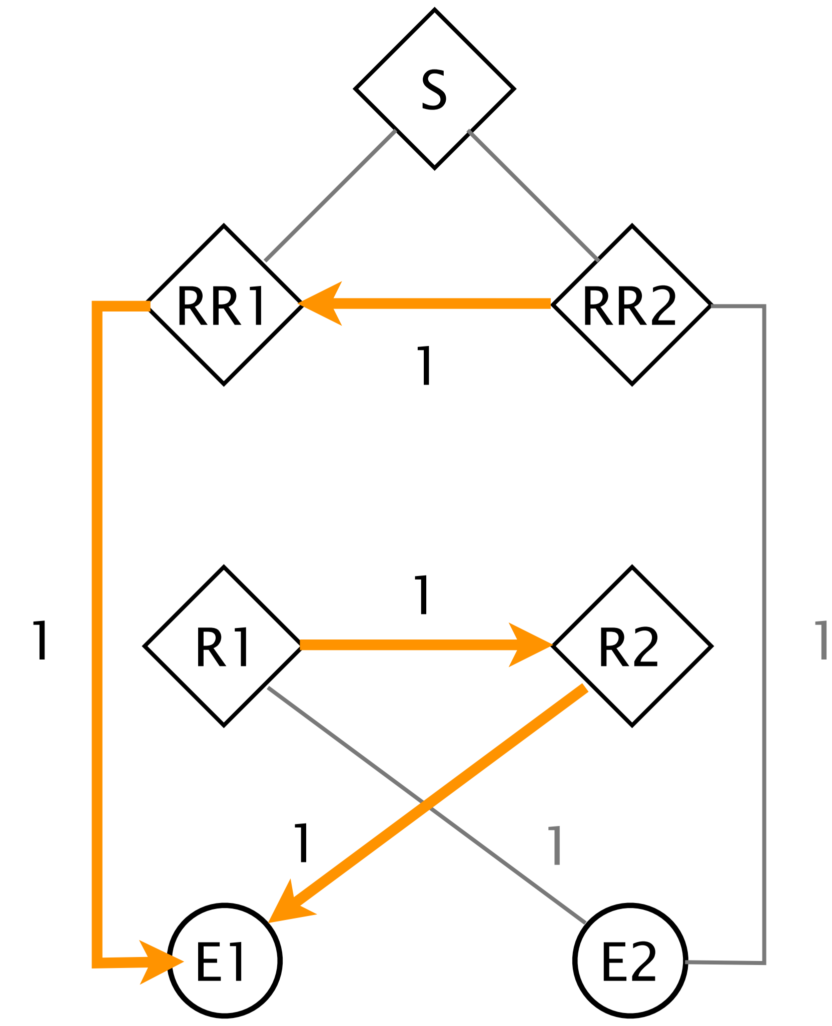


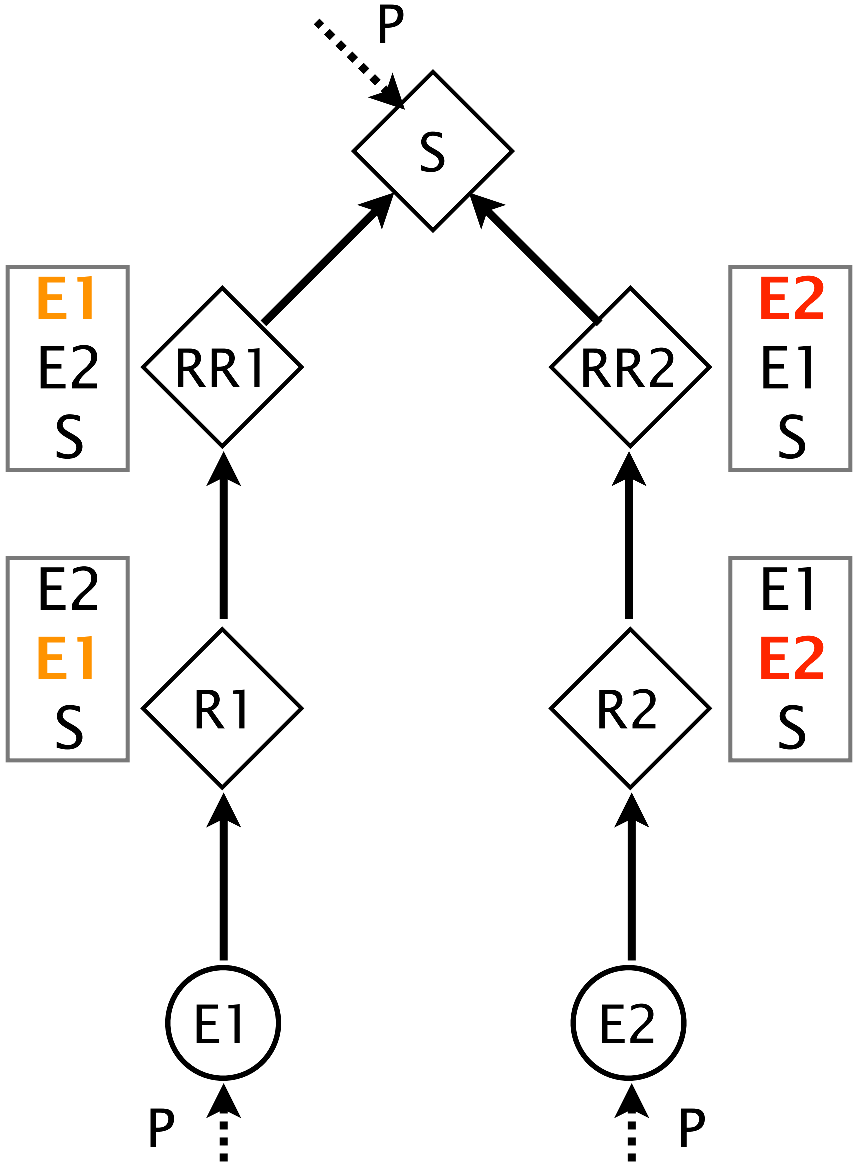


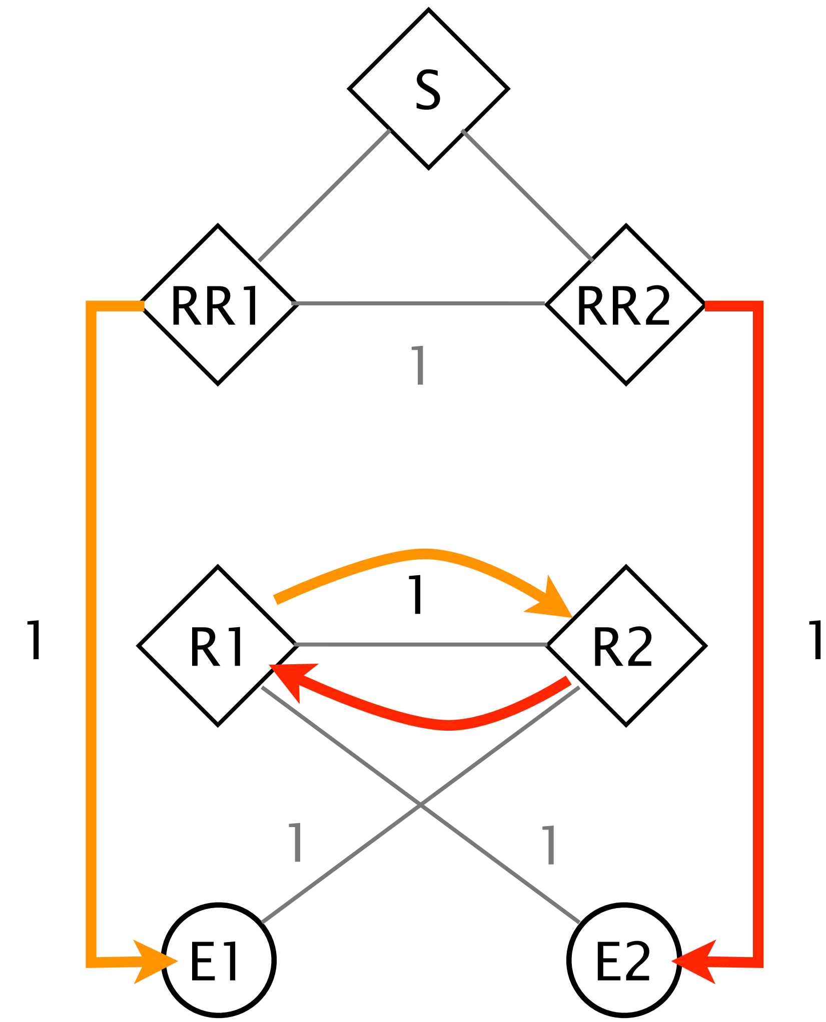
When we remove the session, R2 and RR2 stop learning E1 and switch to E2



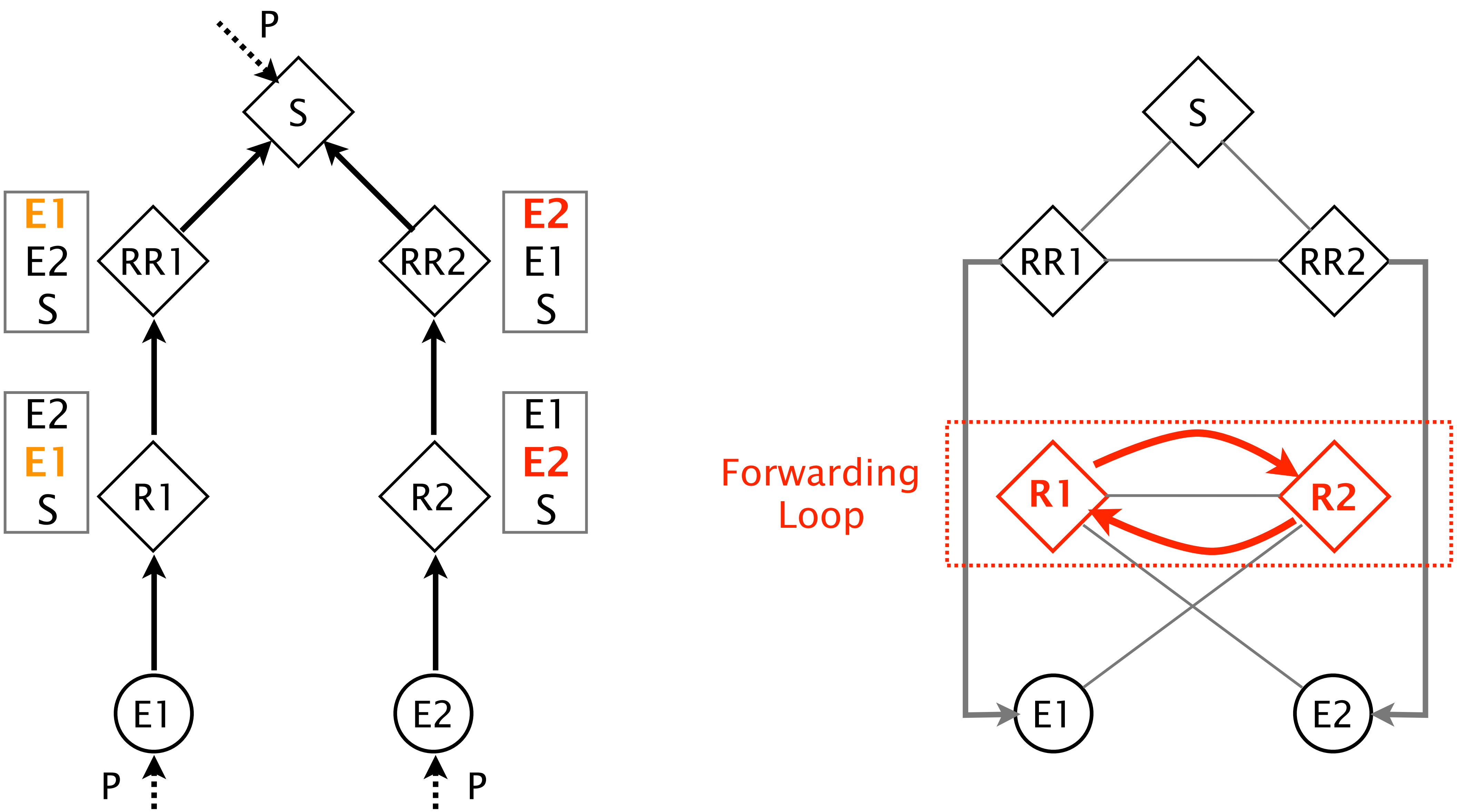


R1 uses R2 to reach E1, and
R2 uses R1 to reach E2





which creates a forwarding loop as well...



Find a sequence of configuration changes

Does it always exist ? **No.**

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Is it easy to compute ?

Finding a seamless migration ordering is computationally hard

Deciding if an ordering free from signaling anomalies exists is NP-hard

reduction in polynomial time from 3-SAT

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Deciding if an ordering free from signaling anomalies exists is NP-hard

reduction in polynomial time from 3-SAT

The same reduction applies for

- dissemination anomalies
- forwarding anomalies
- iBGP or eBGP reconfigurations

Find a sequence of configuration changes

Does it always exist ? **No.**

Is it easy to compute ? **No.**

Find a sequence of configuration changes

Does it always exist ? **No.**

Is it easy to compute ? **No.**

▶ **An algorithmic approach is not viable**

Improving network agility with seamless BGP reconfigurations

BGP reconfiguration

A crash course

Finding an ordering

Is it easy? Does it exist?

3 Reconfiguration framework

Overcome complexity

Why is BGP reconfiguration so complex ?

Local reconfiguration can have global impact

in an unpredictable manner

Why is BGP reconfiguration so complex ?

Local reconfiguration can have global impact
in an unpredictable manner

To avoid that, we could run each configuration
in an independent routing plane

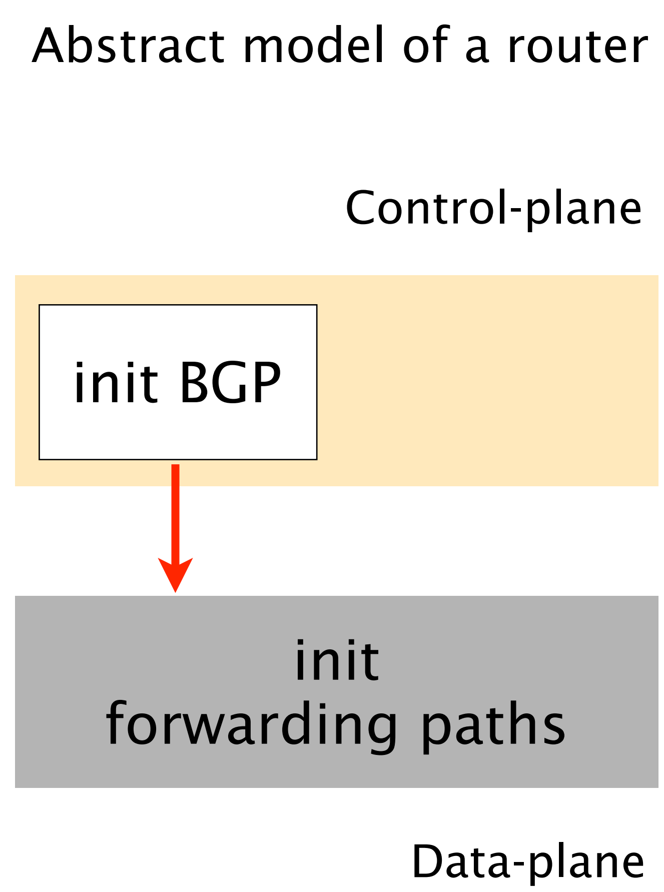
Similar to

- IGP reconfiguration [Vanbever, SIGCOMM11]
- Shadow configuration [Alimi, SIGCOMM08]

The reconfiguration framework leverages Ships-In-The-Night (SITN) migration for BGP

SITNs migrations consists in

1. running multiple BGP routing planes
2. waiting for each plane to converge
3. modifying the plane responsible for forwarding



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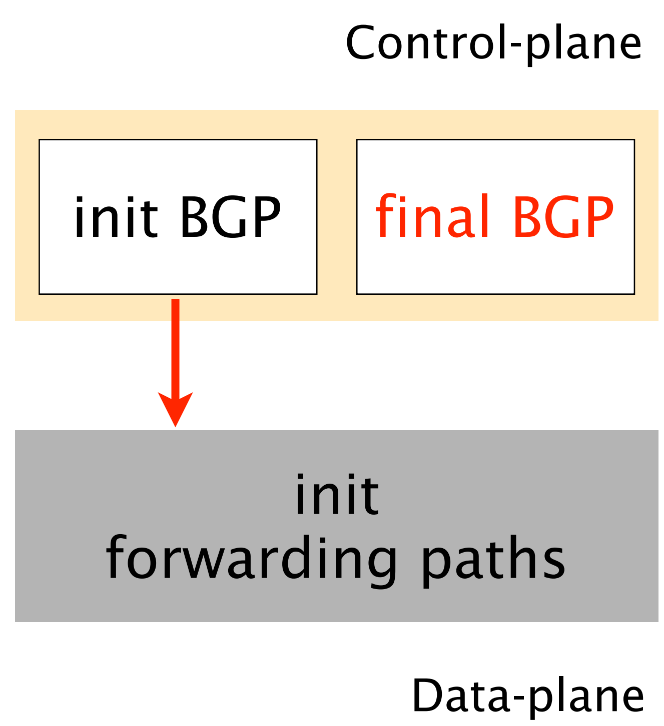
Abstract model of a router



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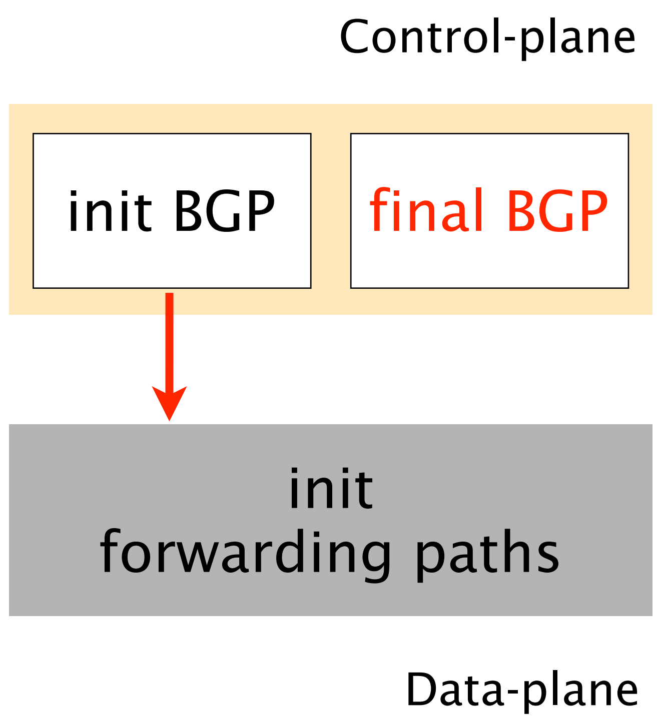

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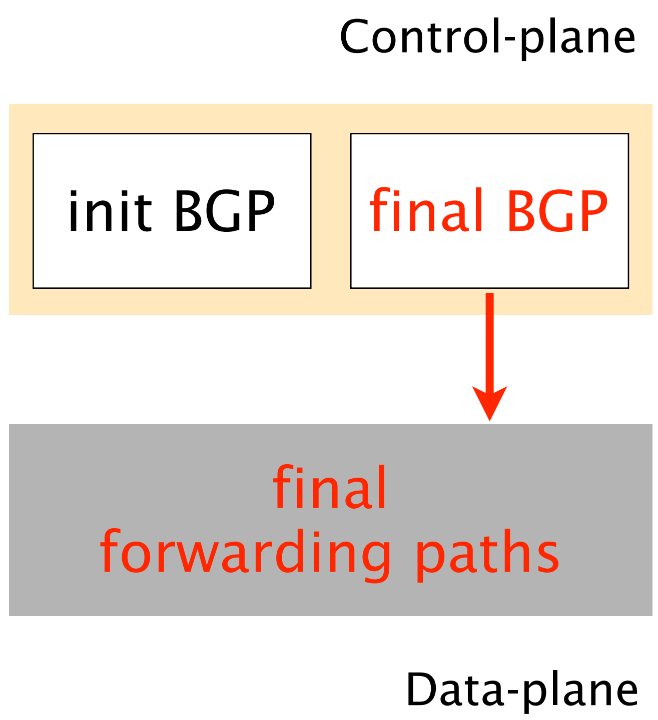

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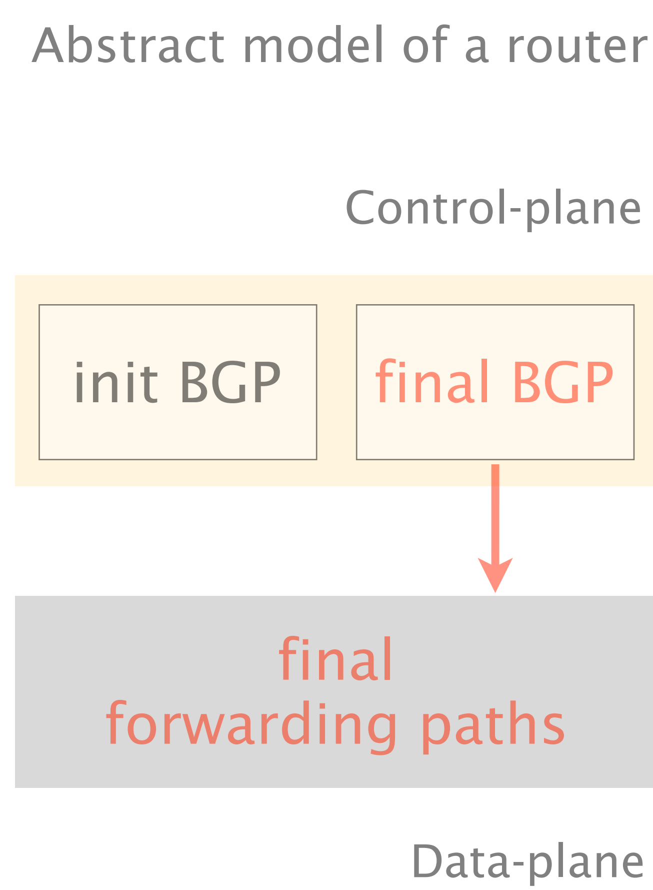
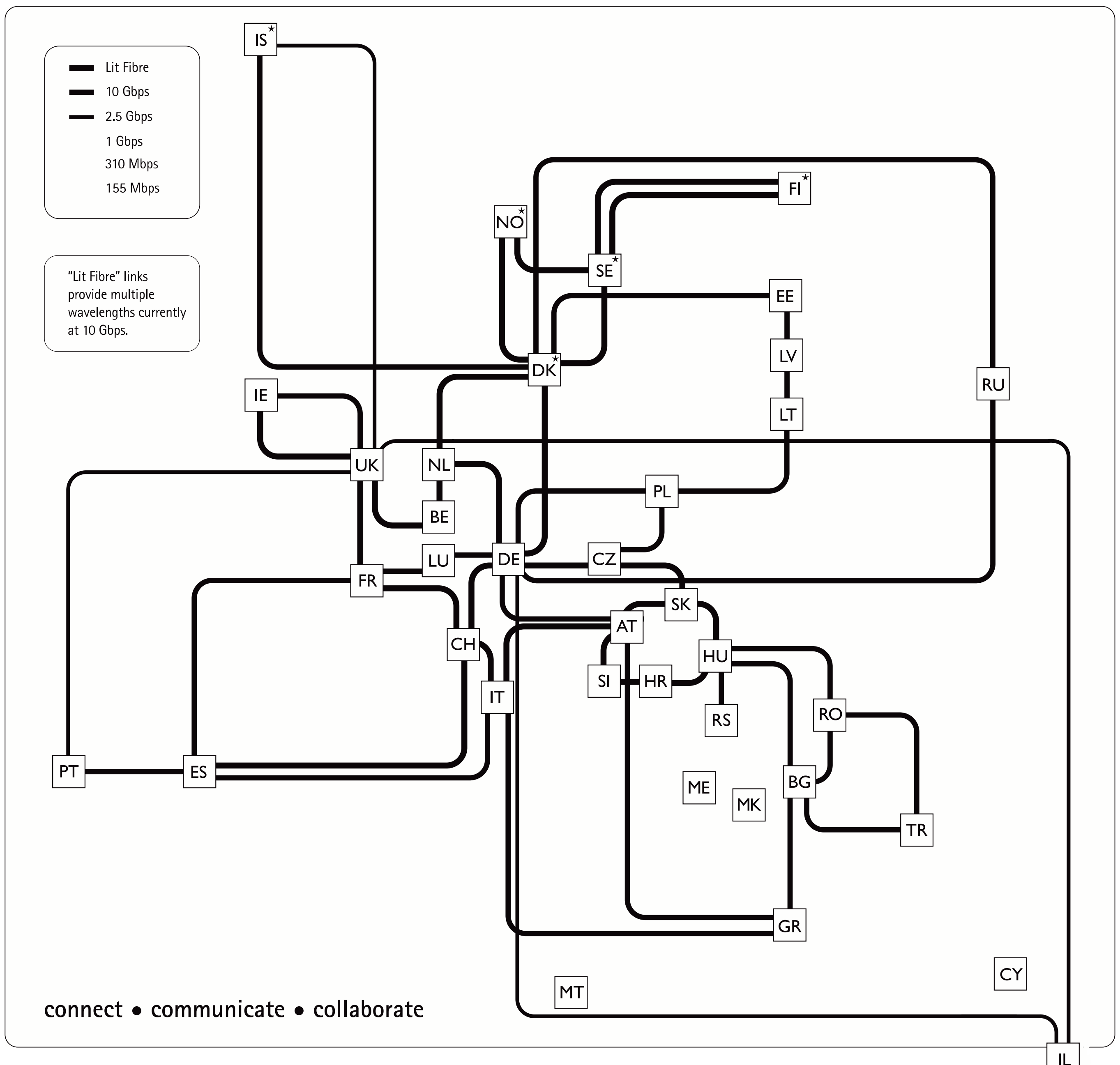


BGP SITN can be deployed on today's routers using BGP/MPLS VPNs technology

Let’s reconfigure a network from an iBGP full-mesh ...



Planned Backbone Topology by the end of 2010. GÉANT is operated by DANTE on behalf of Europe’s NRENs.

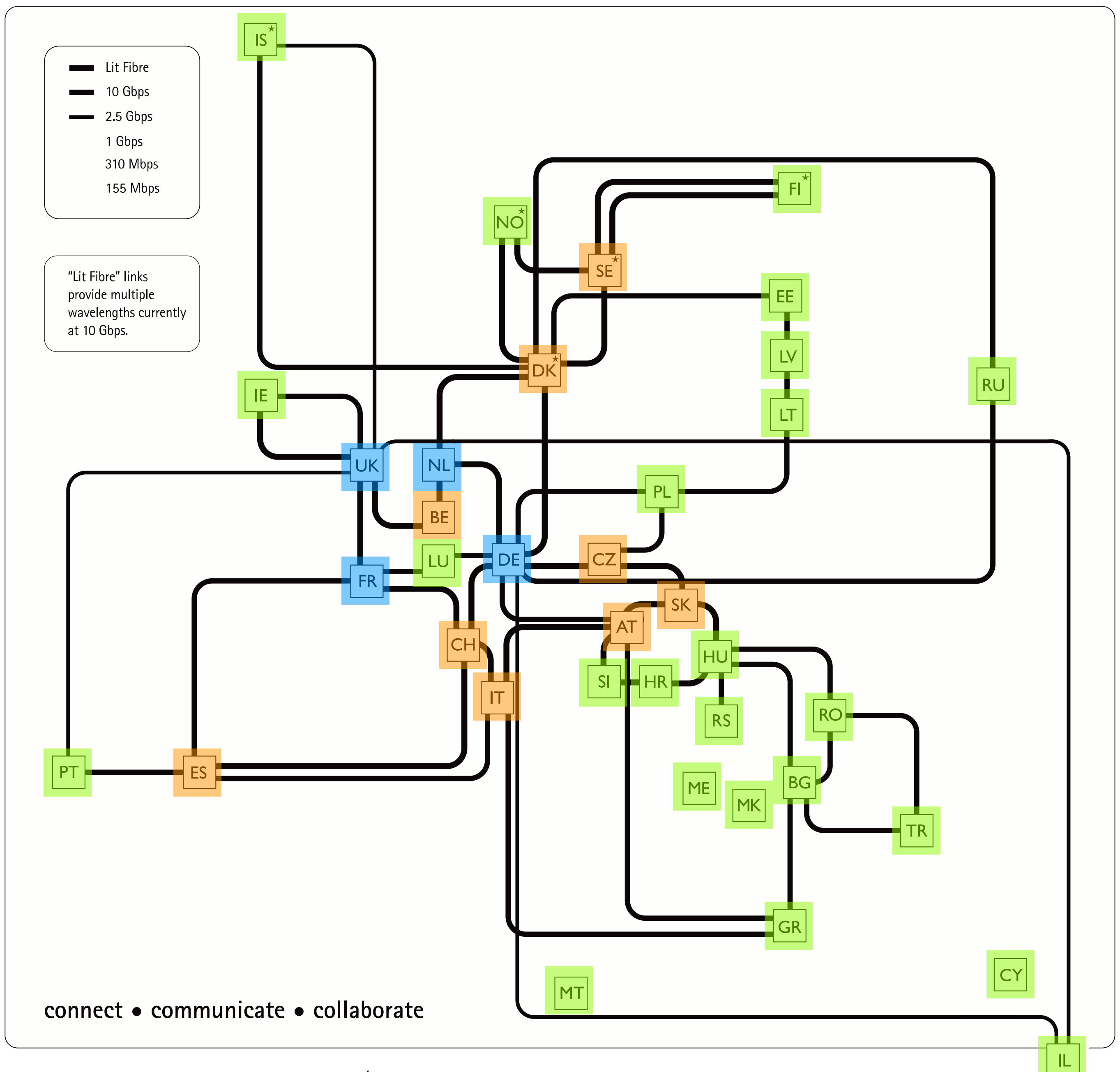
GEANT

European research network

36 routers (virtualized)

53 links

Let’s reconfigure a network from an iBGP full-mesh to an iBGP hierarchy



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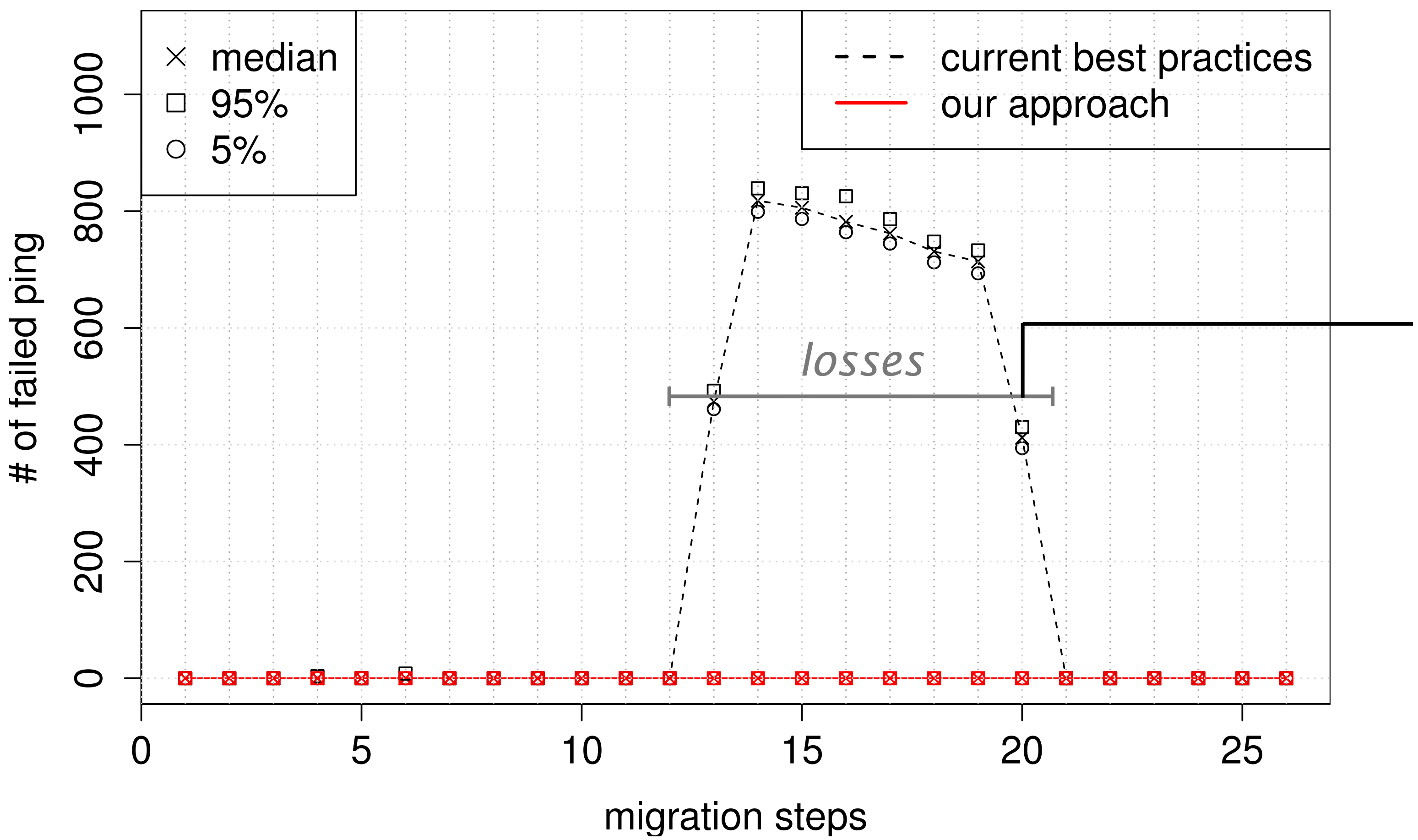
iBGP hierarchy

Top

Middle

Bottom

Following best practices, traffic was lost for *30% of the process*

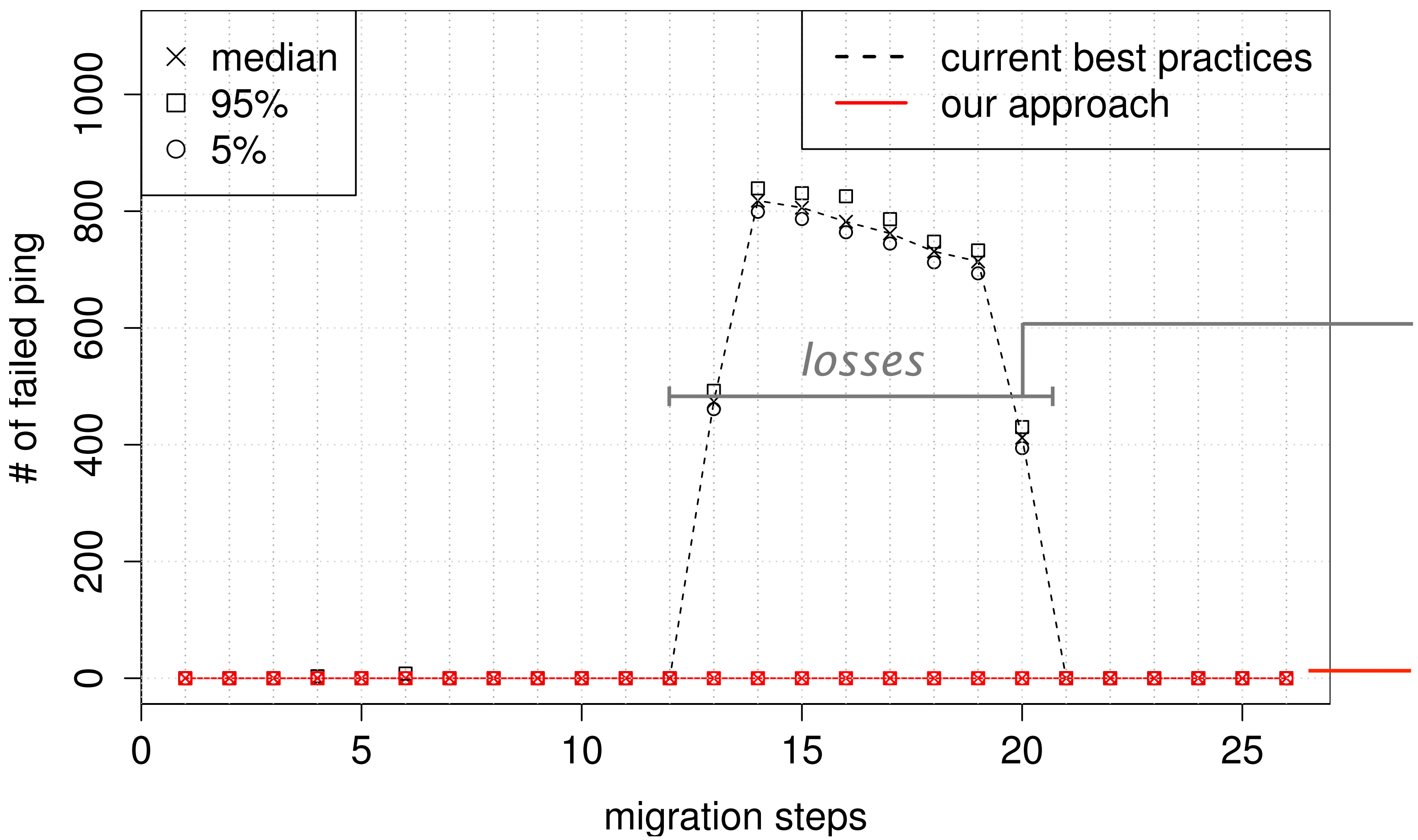


losses from 7 routers

60% of GEANT
routing table is impacted !

Average results (30 repetitions) computed on 120+ pings
per step from every router to 16 summary prefixes

Following our approach, lossless reconfiguration was achieved



losses from 7 routers

60% of GEANT
routing table is impacted !

No loss occurred
with our approach

Average results (30 repetitions) computed on 120+ pings
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Contributions

1 Study BGP reconfiguration, both practically and theoretically

2 Show that a (seamless) operational ordering

- might be needed
- might not exist
- is computationally hard to find

3 Implement and validate a BGP reconfiguration framework

Improving network agility with seamless BGP reconfigurations

Laurent Vanbever

http://vanbever.eu

IRTF Open Meeting, IETF87

July, 30 2013